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HELINA 2013

Proceedings of the 8th International Conference Health Informatics in Africa

Full and Short Papers

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Editorial to HELINA 2013 Proceedings

HELINA (**HE**a**L**th **IN**formatics in **A**frica) is a pan-African association that represents the Africa region of the International Medical Informatics Association (IMIA). It arose out of the First International Working Conference on Health Informatics in Africa, held in 1993. In the closing session of HELINA93, it was proposed that this successful conference should be periodically organised and along the same lines. So far, HELINA has been hosted as follows:

HELINA 93: Ile-Ife, Nigeria
HELINA 96: Midrand, Johannesburg, South Africa
HELINA 99: Harare, Zimbabwe
HELINA 2003: Sandton, Johannesburg, South Africa
HELINA 2007: Bamako, Mali
HELINA 2009: Grand-Bassam, Abidjan, Côte d'Ivoire
HELINA 2011: Yaoundé, Cameroon

HELINA aspires to get African countries to develop their National Health Informatics Societies so that they can qualify to join the world of Health Informatics by becoming a member of IMIA. This step will make them automatic members of HELINA.

The aims of HELINA are:

- Promoting the development of an African eHealth strategy as well as the development of eHealth policies in each African country;
- Showcasing best practices in Health Informatics and its application in Africa;
- Highlighting the role of Health Informatics applications for the millennium development goals in Africa;
- Translating research and innovations into improved healthcare delivery system;
- Fostering the creation of networks between African countries as well as e-health initiatives in Africa; and
- Fostering the development of Health Informatics research and education in Africa.

The 8th Health Informatics in Africa Conference – HELINA 2013 – took place in Eldoret, Kenya from 7 - 8 October 2013, hosted by the Kenyan Health Informatics Association (KeHIA). KeHIA is the national platform for health informatics activities in Kenya with membership drawn from corporate bodies, professionals and researchers involved in Health, Medical Informatics and Computer Science in Kenya from within and outside the country. The organization is a member of both HELINA and IMIA.

HELINA 2013 Conference Focus

HELINA 2013 solicited submission of original scientific research on all aspects of health informatics and e-health in Africa. The conference theme "Evidence Based Informatics for e-Health in Africa" encouraged submissions based on empirical evidence of the use of information management and information and communication technologies to provide better health care for people in Africa. Theoretical, methodological and practical papers within the following (non-exhaustive) list of sub-themes were solicited:

- National e-health strategies, policies and architectures
- Local, regional and national level of healthcare management
- Management within a health facility (hospital, health centre)
- Patient care in home, primary healthcare and hospital settings
- Health programmes and specialised care (maternal and child health, mental health, HIV/AIDS, etc.)
- Empowering communities, community health information systems, community participation

- Electronic and paper-based health records, information architectures, terminologies, data set standards
- Information systems analysis, development, implementation and assessment
- Software systems development, software architectures, interoperability and standards
- Health informatics education
- Research methods, research capacity development

HELINA 2013 Review Process

The decision on holding HELINA 2013 in Kenya was made in late May 2013 and the first announcement was published on 5 June 2013. The Chair and Co-Chair of the Scientific Programme Committee (SPC) were appointed by the General Conference Chair at the same time and they started to invite SPC members from a list of international experts with prior experience in Health Informatics in Africa. Altogether 40 experts were enrolled before the deadline for submissions.

The First Call for Papers and Abstracts was published on 16 June 2013 in English and French. The deadline for submissions was set at 31 July, to be able to complete the reviewing before 26 August and get the final revised submissions by 16 September. Because of several requests, the deadline for submissions was extended to 11 August.

Altogether 59 submissions to HELINA 2013 were received in time. All submissions underwent double-blind peer review by at least three reviewers. Anonymized submissions were allocated to SPC members according to their areas of expertise. Because of the unexpectedly high number of submissions despite the tight schedule, 4 more SPC members were invited from among the authors. Author submissions could be accepted (either as full research-based paper or research-in-progress / practical presentation), rejected, or invited to expand to a full paper and submit for re-review.

All full paper and abstract submissions that were accepted during the first round were revised by the authors and the final versions inspected by the SPC Chairs for meeting the technical criteria. The submissions expanded to a full paper were re-reviewed by at least two reviewers, and either accepted as a full paper or retained as a research-in-progress / practical presentation. If two reviewers did not agree, a third review was obtained.

The acceptance rate of the conference expressed as a percentage of total submissions (n=59) is:

- Full research-based papers: 25% (n=15)
- Practical cases or research-in-progress: 46% (n=27)
- Rejected or retracted: 29% (n=17)

Only papers presented in the conference were to be included in the proceedings. The Editorial Committee decided to make a few exceptions due to *force majeure* reasons: the non-issuance of visas to Malian citizens, the closure of the U.S. government, and a family funeral.

Observations on HELINA 2013 Scientific Programme

The most popular thematic areas arising from the accepted submissions can be grouped into (1) *Global, national and district-level health management*; (2) *Health care personnel and processes*, *Health records*, and *Diagnosis and treatment*; as well as (3) *Community health and m-Health*. While the first one has been a “hot topic” in all HELINA conferences, the second one (use of information in clinical settings) has been becoming more prominent over years, and the third one (use of health information outside of healthcare facilities and management) received significantly more attention than in previous HELINA conferences (cf. Korpela M. Two Decades of HELINA Conferences: A Historical Review of Health Informatics in Africa. *Yearb Med Inform* 2013:197-205).

Other submissions were grouped into the themes *Research capacity building*, *Education*, *Technology*, as well as *Strategies and policies*.

All in all, it can be concluded that the scientific contents of HELINA 2013 reflects well the current areas of the use of information and ICT in Africa, and focuses on key challenges. Compared with global conferences like MEDINFO, there is a greater emphasis on health management, community health, and mobile health in HELINA 2013.

At least the following African countries are represented by an author of a submission, according to their affiliations: Burundi, Cameroon, Democratic Republic of Cameroon, Egypt, Ghana, Kenya, Mali, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Zimbabwe (altogether 13 countries). Other countries represented by authors include Belgium, Finland, Israel, Netherlands, Norway, Spain, Switzerland, United Kingdom, United States of America (9 countries). Although the number of African countries did not yet reach that of the first HELINA (speakers from 17 countries), it is fairly representative. The number of Francophone African submissions was significantly lower, however, than in the three previous HELINA conferences.

HELINA 2013 is the first HELINA conference since HELINA 93 that produces a book of proceedings of full papers; only a book of abstracts has been available in other HELINA conferences, with a small number of full papers published afterwards in journals. This is a very significant step forward for the Health Informatics community in Africa. Even more, the proceedings is also the first issue of the *Journal of Health Informatics in Africa*. The conferences and the journal are emerging as the rallying forum for the scientific community.

HELINA 2013 Conference Programme

The HELINA 2013 conference programme was scheduled over two days from 7 to 8 October. The programme was expanded to include a number of pre-conference and parallel meetings and workshops:

Saturday 05 October 2013
Meeting/Workshop:
Standardization of health extraction indicators and interoperability of open- source/free health information systems used in Africa

Sunday 06 October 2013
HELINA Strategic Plan – Task force Workshop

Tuesday 08 – Friday 11 October 2013
Africa Build Consortium: Symposium on Capacity Building in Africa
Gathering experts, professionals, students and people interested in using Information and Communication Technologies to improve health research and learning in Africa

Sunday 06 – Friday 11 October 2013
Annual OpenMRS Implementers Meeting

We would like to thank all for their contributions in making the conference possible. We look forward to continuing discussions on health informatics in Africa at HELINA 2013, with old and new friends alike.

Mikko Korpela and Dalenca Pottas
Chair and Co-Chair, HELINA 2013 SPC

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Journal of Health Informatics in Africa

8th Health Informatics in Africa Conference (HELINA 2013)

Peer-reviewed and selected under the responsibility of the Scientific Programme Committee

Cloud Computing for Health Information in Africa? Comparing the Case of Ghana to Kenya

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Background and Purpose: A number of African countries have in recent years deployed online, web-based health information systems (HIS). We look at the opportunities and challenges of this new architecture by comparing recent HIS implementations in Ghana and Kenya.
Methods: This paper is based on several years of involvement by the authors in a large action research project (the Health Information Systems Programme) that focuses on developing and implementing health information systems. The project has a strong focus on active participation of the researchers in the research context, drawing on the Scandinavian tradition of participatory action research. All authors have been directly involved in the HIS implementations in Ghana and/or Kenya discussed in this paper.
Results: We show how the two countries studied in this paper, Ghana and Kenya, have rapidly transitioned from having an offline, decentralised HIS based on standalone software installations, to a new architecture that is online, web-based and centralised.
Conclusions: The cases of Ghana and Kenya demonstrate how a web-based, online architecture for HIS provides a number of advantages over the standalone, offline systems that have been the norm until recently. However, important aspects of such implementations, like developing skills and policies for system administration and ensuring system ownership need emphasis in order to ensure the long-term sustainability of these systems.

Keywords: Health Information Systems, Online Systems, Cloud Computing, Ghana, Kenya, Africa

1 Introduction

Ghana and Kenya are among a number of African countries that have driven an ambitious evolution of health information systems (HIS) from district-based standalone applications to national level web-based architectures. The difficulties of maintaining a decentralised HIS with hundreds of databases installed in district offices have become apparent, and several countries have therefore adopted an online, web-based HIS architecture in the last few years.

Establishing and sustaining an online HIS on a national scale requires a considerable mobilization of productive forces including network connectivity, data centre infrastructure and high-level skills. The resulting concentration of national data and functionality into a single system also raises questions of political significance about the physical location (particularly outside of the country), ownership and control of such infrastructure.

The objective of this paper is to examine the consequences of moving from an offline HIS to one based on an online, web-based architecture. We focus on the implications for end-users and system administrators, for management and hosting of the centralised HIS server, and for integration. What are the advantages and disadvantages of this new paradigm?

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The empirical setting that we use to place the issues in relief is the implementation of a national health information system by the Ghana Health Service with technical support from the University of Oslo. Each of the authors have been extensively involved at the various stages of the implementation of this system, from its inception and design in 2010 through to the live nationwide rollout in 2012 and subsequent settling into the maintenance and evolution cycle of the production system. We also draw on similar experiences from the implementation of a national HIS in Kenya. We believe that by reviewing and assessing the difficulties we have encountered to get a web-based system functional and active, we can expose crucial factors for the success of similar efforts elsewhere in Africa.

The paper is organized as follows. In the background section, we present a brief historical review of the implementation of health information systems in Africa through the Health Information Systems Programme (HISP) project. In doing so, we highlight particularly the significance of the move from standalone district-based systems to a centralized web-based architecture. We describe the current situation regarding ICT infrastructure in Africa, before presenting relevant literature on outsourcing and cloud computing. The proceeding section outlines our methodology, before we present our main cases of Ghana and Kenya in the results section. In the final section, we discuss our findings.

2 Background

2.1 HISP and Health Information Systems

The Health Information Systems Programme (HISP) is a loose collaborative network of research institutions, government and non-government organizations and individuals. From its origins in post-apartheid South Africa in the late 1990s, HISP has grown to a global network with nodes in Africa, South Asia, Latin America and Europe. The core initiative within HISP is the development of the District Health Information Software (DHIS2). DHIS2 is Free and Open Source Software (FOSS) based on web technologies that support collection, aggregation, analysis and presentation of health information. The development of DHIS2 is coordinated from the University of Oslo, Norway [1].

The goal for HISP is to improve healthcare delivery through better Health Information Systems (HIS). Having reliable and relevant information is important to allow managers in the health sector to make evidence-based decisions. The health sectors in many low and middle income countries have seen developments in the past three decades, especially with the advent of Millennium Development Goals (MDGs), which have increased the need for a strong HIS to support decision-making at different levels [2].

Despite their importance in the management of the health sector, HIS are often dysfunctional. The data being collected is of poor quality, data transmission is often delayed, and more data is collected than is needed for decision-making [2][3]. For health workers, the data collected is often of little relevance and they have little motivation to ensure it is of good quality [4]. Furthermore, use of information in decision-making has not been institutionalized in many countries [5]. Because the national HIS cannot reliably provide them with the necessary information, area-specific health programmes such as Disease Control, Family health, Malaria or HIV/AIDS often set up parallel vertical reporting systems [2]. As these parallel information systems emerge, the national HIS gradually becomes less relevant.

The computer systems that have been built to support HIS in Africa have typically been Microsoft Windows applications that were designed to function autonomously on desktop computers at the various administrative levels of the system. Maintaining integrity and compatibility of the data between the periphery and the centre has proved difficult, for example in Rwanda, Kenya, Liberia, The Gambia and Ghana. Furthermore, lack of availability of the software source code to the various ministries of health meant that as donor support for systems development gradually dried up it was not always possible to modify the software to respond to evolving information needs of the health programs. In each of these countries there was thus a strong motivation to (i) look at FOSS to avoid repeating the problem of dead-end systems and (ii) to embrace the centralizing logic of a national web-based system.

As we describe below, it is only in the last very few years that network connectivity within and between countries has developed sufficiently to support such architecture.

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2.2 Improved African ICT infrastructure

The expansion of network infrastructure within many African countries, driven largely by the expansion of coverage by mobile operators, has made national web-based systems increasingly viable (**Fig. 1**). The health management information systems deployed in for example Ghana and Kenya rely on health facility staff and district managers interacting with the system using nothing more than a web browser, with Internet connectivity mostly provided by the mobile networks.

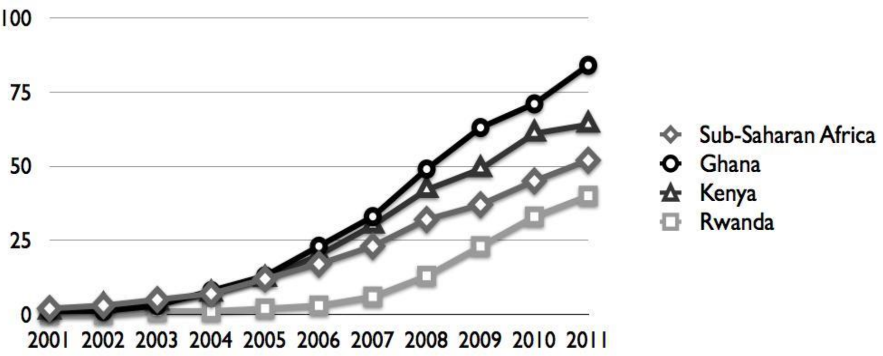

Fig. 1. Mobile subscribers per 100 people [6].

Improved connectivity within and between countries (see **Fig. 2**) makes possible the physical location of servers outside of the Ministries of Health, co-located within private data centres, within purpose-built national data centres, or making use of commercially hosted services offered by global providers. At the same time, this creates challenges with regards to legislation and policy and governance frameworks that are there to guide the procurement, maintenance and use of IT systems. Where such frameworks exist they typically have not foreseen the difficulties and opportunities raised, for example, by the availability of trans-national "cloud" services.

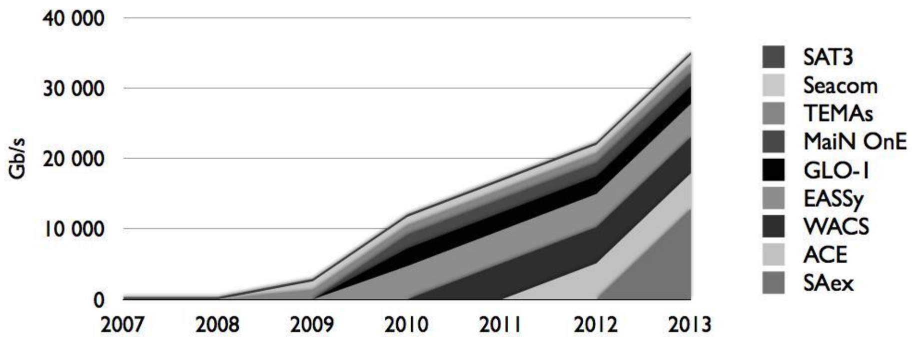

Fig. 2. Total bandwidth of communication cables to the African continent, showing how the African continent is rapidly becoming more connected to the rest of the world [7].

2.3 Outsourcing and Cloud Computing

Enabled by the improved ICT infrastructure discussed above, use of outsourcing and cloud computing is increasingly becoming a viable option in countries such as Ghana and Kenya. Avgerou has commented that whereas outsourcing has been extensively researched in IS (e.g. [8]), the literature is more sparse with respect to developing country clients of outsourcing arrangements [9]. In one such study, Silva describes an outsourcing arrangement where the client is the Guatemalan ministry of health, and he shows how a range of improvisations was made possible by the outsourcing arrangement [10].

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Putting a precise definition on “cloud” computing is difficult as might be expected of any new technology trend. Though there are a number of characteristics, which underlie most current uses of the term:

- Almost immediate access to large scale IT resources available over the public internet (usually, but not always, for a fee).
- Low cost of entry
- The possibility of “elastic” scaling of resources to meet demand

These characteristics have led a number of commentators to speculate that the cloud represents a unique opportunity for developing countries to leapfrog from a position characterized as “left behind” in the IT revolution - making available IT services which would not previously have been available [11][12]. Cloud computing can also be understood as just a current manifestation of the old outsourcing phenomenon [13]. And just as evaluation of the shared risks and rewards has been a central concern of the IT outsourcing literature from the outset [14], particularly risks associated with loss of control, these themes also dominate concerns relating to cloud computing [15]-[17].

3 Materials and methods

This paper is based on the continued involvement of the authors over several years in the HISP project in general, and in the implementation of DHIS2 in Ghana and Kenya in particular. From its inception, research within the HISP network has had a strong focus on active participation of the researchers in the research context, drawing on the Scandinavian tradition of participatory action research [18]. Action research is based on the premise that new knowledge can be generated by the researcher actively engaging to improve real-world situations, following a cycle of diagnosing problems, designing and implementing interventions and evaluating the outcome with the aim of developing new knowledge [19].

Building on this participatory action research tradition, the "Networks of Action" concept was developed by Braa et al. to describe the action research process within HISP [20]. The "Networks of Action" approach emphasizes the importance of sharing of knowledge across research sites in order to ensure sustainability of the research projects over time. Through our active involvement in the HIS implementations discussed here, the authors have gathered a large amount of primary data. Through our engagements with actors at various levels of the health system, we have discussed with, interviewed and observed a number of different stakeholders over time. In addition, we have as part of the larger HISP network a number of formal and informal data sources beyond our direct engagements in Ghana and Kenya.

4 Results

4.1 The case of Ghana

Ghana Health Service (GHS) is the implementing agency of the Ministry of Health (MOH) in Ghana, and is responsible for over 4000 health facilities spread across 220 health administrative districts. GHS has a history of computer-based HIS for routine data collection dating back to the early 2000s, when the development of a proprietary Microsoft Access-based HIS software began with financial assistance from the European Union (EU). The system was scaled up nationwide in 2008, but GHS soon faced many of the typical problems of running a proprietary, decentralized HIS system, as discussed in section 2.1 above: funding for further development and maintenance of the software was not available; maintaining and synchronising hundreds of standalone installations across the country proved difficult; and the area-specific programmes became dissatisfied with the situation and set up parallel vertical reporting systems. As a result of these challenges, GHS decided to adopt the open-source and web-based DHIS2 in 2010, which was seen as addressing many of the shortcomings of the previous system while still supporting the same district-centred information flow.

The processes of setting up DHIS2 and building local capacity on the system within GHS began in 2010, and are on-going even after the rollout in April 2012. These efforts were complemented both onsite and offsite by HISP and the University of Oslo. To ensure that the system was incorporated into the

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workflow in the districts, five persons from each of the then 170 districts across the country were trained, in addition to users at the regional and national level.

Experience from managing the previous system as a stand-alone system informed the deployment of DHIS2 as an online system. The internet infrastructure, primarily through the mobile networks, was seen as adequate to support a web-based system, and the first experiences from Kenya, where the system was being rolled out online at that time, were encouraging.

During the customization of DHIS2, the system was hosted on a virtual server procured by the HISP group at the University of Oslo. This made it possible to start the customization of the system immediately with technical support from the HISP team abroad. However, GHS wanted its server and data to be physically located in Ghana. They already had a physical server that had been procured for this project and physical location in Ghana was seen as a requirement stemming from public service information system policy. Consequently the server was hosted within a private data centre in Accra, and the system migrated there before the rollout.

Management of HIS with such complexities as DHIS2 poses a number challenges. At the time of national rollout the local team had developed the skills required to do most of the maintenance of the application. However, maintaining the server still required assistance from the HISP team at the University of Oslo. To address this human resource gap, several trainings have been held by the global HISP team for the local server managers. On the technical side, server tools have been developed to facilitate the management of DHIS2 on the server.

4.2 The case of Kenya

The implementation of an online system in Ghana was taking cues from a similar process going on in Kenya at the time Ghana was starting. In October 2010 the Ministry of Heath in Kenya started a project to customise the DHIS2 so that it could replace the Excel based system that they were using, which consisted of monthly transfer of Excel files from districts to the central level using FTP [21]. DHIS2 was implemented on a server rented by an international hosting company, Linode in London.

Testing of the system in late 2010 using modems on the mobile network to access the internet made it clear that an online ‘cloud’ based solution would be possible. The new sea cables had reached Mombasa and fibre cables were being laid out all over the country and the mobile network providers were already providing 3G to many parts of the country. During 2011, after a pilot phase in the Coast province, the system was rolled out to the entire country. This was the first fully online and web-based HIS deployment in Africa, something that was enabling the rapid rollout. While before, the term rollout of systems in Africa meant physically installing the software and ensuring technical support in hundreds of locations, now, in the case of Kenya, it meant training health workers to use the online system. On site technical support also became less critical than before, as any laptop or PC could be used to access the system.

The project in Kenya started by implementing the same reporting forms that were used by the previous system. Similar to the situation in many countries, however, there were many parallel reporting systems run by different health programs. The implementation of DHIS2 on a central server became an enabler for integration, as everybody could access and use the same system. The various health programs saw the benefit of being able to compare and use data across different health services and programs while at the same time reducing the burden of overlapping reporting for health workers.

Politically it was never really accepted to use an international cloud hosting service, as the government policy was to store data in-country. Consequently, the DHIS2 was moved to Safaricom, an in-country mobile network provider and hosting company. Their services are currently not of the same quality, however, as they are not able to provide the same capacity and response time as was available with the international hosting company. The longer term plan is to move to a new server in the MOH.

5 Discussion

The experiences from Ghana and Kenya demonstrate both the opportunities and challenges of a centralised, online deployment. **Table 1** summarizes advantages and disadvantages of an online HIS architecture.

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Table 1. Advantages and disadvantages of an online HIS architecture.

Aspect	Advantages	Disadvantages
End-users	• Improved information access, transparency and sharing. • No responsibility for system maintenance. • Continuous system improvements through software updates. • Supports an unlimited number of users at limited additional cost.	• Reduced control of data submission to higher levels. • No direct, low-level access to the data or database. • System can be changed (updated) without warning or training.
System administration	• Only one instance of the system needed to support the whole country. • Getting support from outside is easy, by giving access to the server.	• Requires highly specialised skills that might not be available in the implementing organisation or even in the country. • Can create reliance on outside support for long term maintenance.
Server hosting	• Flexibility in choice of hosting – room for improvisation. • All changes to the server hosting is transparent for end-users.	• Poor hosting environment can bring down the whole system – single point of failure. • Lack of policies and guidelines for secure hosting in many countries.
Integration	• A centralised database makes integration possible. • The potential for integration becomes apparent by showing data duplications.	• Integrating with existing software systems has proved difficult in practice.
System ownership	• Allows system owners to manage risks related to data loss, integrity etc. more verifiably/robustly/scalable than when the systems are dispersed throughout 100's of districts/computers	• Complexities relating to hosting large scale systems have resulted in increased dependency on external agencies such as service providers and development partners for infrastructural and technical support. Dependency = risk. New policy and procurement guidelines required managing new forms of risk.

5.1 End Users

The central concern of the DHIS2 artefact is to empower information users, the health managers in the districts in particular. A centralised web-based system implies some of shift of control from the district users to the national system administrators, for example of when data is revealed to the higher levels, access to the database, or updates to the software platform. However, while losing some control, end-users also enjoy many benefits. The central deployments of DHIS2 in Ghana, Kenya and other countries show that it is possible to satisfy the information requirements of the district health managers without

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having the software installed locally in the district offices, so that users no longer need to support and maintain their own system software and hardware.

With an online system, data is transparent and ownership shared among a larger group of users, potentially leading to increased use of information. In Ghana, there can now be 2000 unique users over a 30-day period, while the previous system was only installed on much smaller number of computers (likely in the low hundreds). Furthermore, those responsible for the standalone databases had a strong sense of ownership of the data, and were often reluctant to share it with colleagues. This is no longer a problem in a centralised system.

5.2 System administration

While the issue of how to host the server typically receives much attention among the agencies implementing DHIS2, less attention is given to how to manage the system running on the server. DHIS2 deployments are in most cases running on Linux servers, and DHIS2 requires a stack of software to be installed, configured and maintained. The freedom from having to maintain hundreds of standalone installations comes at the expense of the more complex, but centralized, task of maintaining a server infrastructure. While the requisite skills might be found within the ICT departments of the implementing organizations, they are harder to find in the data use departments that have been pushing the implementations in Ghana and Kenya.

Having a single, central national web-based system makes it easy to take advantage of external technical support and expertise. This possibility has been made use of both in Ghana and Kenya. In a sense, both countries can be seen as, for now, having outsourced the administration of the server to HISP, through the continuous technical assistance that has been provided. Relying on external support for a limited time is not necessarily a problem. However, there is a risk that it creates a longer lasting reliance on outside support and is damaging for the sense of ownership of the system. While the infrastructure for an online system can be changed quite easily, technical assistance can create dependencies that are difficult to remove. It is therefore important that a framework is in place to manage the security and access to the system, so that even while technical assistance is provided from abroad, control remains with the system owners.

5.3 Server hosting

A benefit of the web-based paradigm is that there is flexibility in the potential physical location of the server. Servers can be physically co-located in any data centre that can provide the environmental conditions and connectivity. These include mobile phone operators; internet service providers; and purpose built national data centres. Many of these private data centres are now also now offering virtual server rental, obviating the need for the MOH to invest in server hardware at all. Whereas such virtual infrastructure services are increasingly becoming available in country, economies of scale dictate that they will not be available at the same price as services being offered by large global providers such as Linode or Amazon.

Decisions around the physical location of the service also need not be permanent. We have seen how in both Ghana and Kenya, the service can be migrated from one location and mode of procurement to another without disruption to existing users. Ghana used an international cloud service provider during the customisation phase, before migrating to production server hardware owned by the GHS and hosted in the data centre of a local company. Kenya used an international cloud provider for the first years after the rollout, before recently moving to an in-country cloud provider. The opportunity to outsource the hosting of the HIS to the cloud brings us to Silva's argument that outsourcing has the potential to make room for improvisation [11]. There are a range of factors to consider related to cost, convenience and control that can determine the most appropriate hosting solution.

Our cases also demonstrate the political aspects of the issue of server hosting. In both countries, international hosting would be cheaper and at least as reliable as in-country hosting, yet none of the countries have chosen that option currently. Ghana had as a policy that the system should be hosted in country. Using an international virtual server provider was thus just a temporary measure to quickly get started on the customisation of the system. In Kenya, the plan was initially to host the system in the Ministry of Health, but poor infrastructure made this impossible. An international virtual server provider

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was therefore used, and this solution worked well. However, it later became a policy here as well that the data should be hosted in country, and consequently the system was migrated, this time to a national virtual server provider that have struggled with the quality of the service.

In any of the above scenarios, concern for information systems security plays an important part in assessing the suitability of the server hosting. It is our experience that a complex, large-scale system like DHIS2, which is relied upon by many people throughout the country, should be supported by a security management plan, regardless of whether it is hosted internally or externally. The need for clear information security policy, particularly in the context of outsourcing contracts, has been made clear in the literature (e.g. [22]-[24]). The security management plan should be informed by existing public service regulation and legislation and address issues of access control, risk management, service level agreements, non-disclosure agreements, disaster recovery and business continuity.

5.4 Integration

Fragmentation of HIS is a problem often caused by vertical reporting systems set up by area-specific health programmes or divisions within the Ministries. An online HIS architecture has the potential to promote integration and rationalisation of these vertical systems. Conversely, without a centralised and accessible database, integration is very difficult.

In Ghana, integration of the vertical health programme was always seen as critical. Data collection tools from the vertical programmes were included in the system, even though this meant that some of the same data was collected multiple times. Over time the stakeholders' confidence in the system has increased, and the realisation that data from different sources are available for all users has triggered a process of rationalisation of data collection instruments to reduce duplication of data collection.

Interoperating with other software systems has proven more difficult. Integration of data from different systems requires harmonisation of metadata, for example a way of identifying health facilities and data elements across systems. Managing the HIS as a national web based repository of such metadata has opened many interoperability possibilities by raising visibility, though in practice the number of information systems data sources which are actually in active use and are sufficiently stable and institutionalised in Ghana and Kenya has been small compared to the number of failed or incomplete system implementations. Despite these challenges, several medical records systems in Kenya have now been integrated with the HIS, and routinely transmit data that was previously keyed in by hand.

6 Concluding remarks

The cases of Ghana and Kenya demonstrate how a web-based, online architecture for HIS provides a number of advantages and some disadvantages over the standalone, offline systems that have been the norm until recently. We have tried to outline the implications of this new paradigm on several levels: from end-users to administrators, in terms of server hosting, and for HIS integration.

While we would argue that this new architecture brings with it a number of advantages for HIS in Africa, and probably for other categories of information systems, more attention needs to be paid to developing skills and policies for system and server management in the implementing agencies. Addressing these issues is essential in order to ensure the long-term sustainability of the systems.

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Evaluating the Impact of Hospital Information Systems on the Technical Efficiency of 8 Central African Hospitals Using Data Envelopment Analysis

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Objectives: this study evaluates the usability of Data Envelopment Analysis (DEA) for analyzing the technical efficiency before and after hospital information system (HIS) implementation for a set of 8 Central African hospitals (6 Rwandan, 2 Burundian; 6 public and 2 private).
Methods: DEA is a method that uses linear programming techniques to produce a relative efficiency score for organizational units where the presence of multiple inputs and outputs makes straightforward comparisons difficult. DEA is non-parametric, requiring no assumptions about the (most often unknown) functional relationship between inputs and outputs (in contrast to regression based models). The method directly compares health facilities against a combination of peers. In this study post-HIS implementation health facility productivity was also compared against results obtained before HIS implementation.
Results: the average technical efficiency increase of 5,04% after HIS implementation appeared not to be statistically significant in our small dataset.
Conclusions: despite the lack of statistical significance, the results still suggest that DEA may offer interesting opportunities for measuring productivity impact of large scale implementations of health information management methods and systems using data sets from heterogeneous collections of health facilities. Further research on an extended set of sub-Saharan health facilities has been programmed for that purpose.

Keywords: Data Envelopment Analysis, Sub-Saharan Africa, Technical efficiency, Hospital Information Systems

1 Introduction

An increasing number of hospital information management system (HIS) implementations have been reported in sub-Saharan Africa in the last few years [14]-[15]. Although lots of (potential) benefits of electronic health information management have been extensively documented in the literature, it remains difficult to measure the impact of HIS deployment on a health facility's output and productivity.

Productivity is a complex concept for which calculations are based on inputs (workforce, buildings, medical equipment, funding…) and outputs (case load, completed treatments, morbidity and mortality reduction…). No simple one-dimensional metrics (such as ratios) exist for expressing the complexity and richness of hospital productivity. As an alternative, a number of linear programming techniques, such as Data Envelopment Analysis (DEA), have gained popularity in the health domain for producing relative

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efficiency scores for organizational units where the presence of multiple inputs and outputs makes comparisons difficult. Most often, DEA and related techniques have been used for benchmarking health facilities against other facilities which operate in the same context (health centres, district hospitals etc.).

The objective of our study was to also explore the usability of a DEA-based method for measuring the impact of HIS implementation on hospital productivity in a set of low resource sub-Saharan health facilities.

2 Materials and methods

As shown in **Fig. 3**, many different efficiency and productivity measurement approaches exist: one- and multidimensional methods, frontier- and average-based methods, parametric and non-parametric methods and stochastic or deterministic approaches. Advantages and disadvantages of these methods have been evaluated prior to this study, resulting in Data Envelopment Analysis being chosen as the best adapted solution for our purpose.

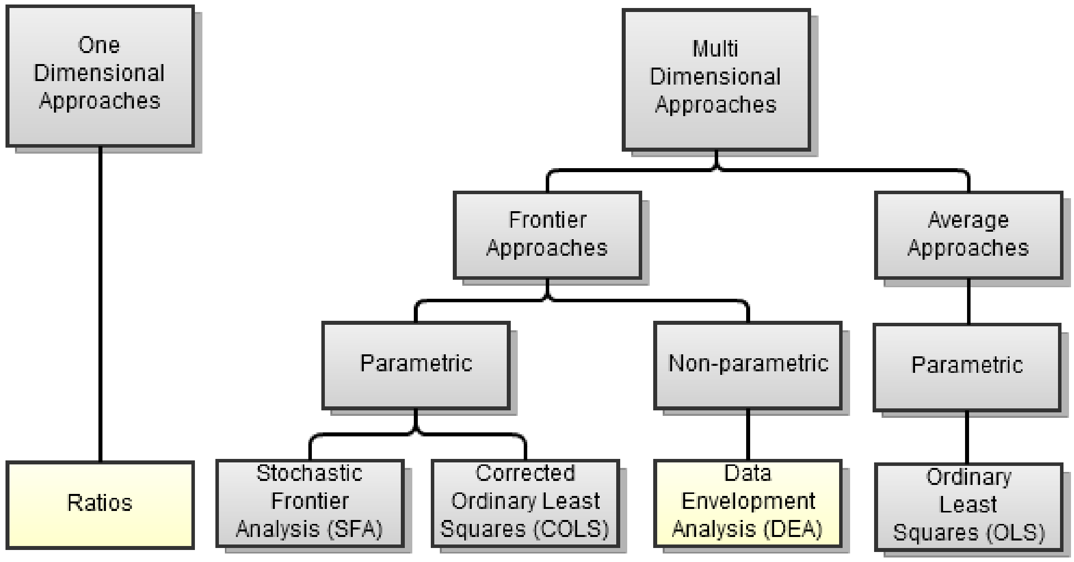

Fig. 3. Different evaluated productivity measurement techniques

2.1 Data Envelopment Analysis (DEA)

DEA is a method that uses linear programming techniques to produce a relative efficiency score for organizational units where the presence of multiple inputs and outputs makes comparisons difficult [1]-[4]. It is evident that health facilities are always using multiple inputs to produce multiple outputs, which makes a method such as DEA better adapted to our needs than the simple usage of ratios. DEA evaluates relative efficiency of each unit among a set of more or less homogeneous *decision*

making units (DMU), e.g. health centres or district hospitals. It draws a frontier of best possible productivity combining inputs and outputs from the best performing DMUs (health facilities in our case). Health facilities that compose this *best practice frontier* are assigned an efficiency score of 1 and are being considered technically efficient compared to other health facilities. Health facilities that are situated below the efficiency frontier will forcibly be inefficient. Their level of inefficiency is measured in terms of their distance from the frontier and is being expressed by a score between 0 and 1, larger scores expressing higher efficiencies.

As multiple inputs are being used to produce multiple outputs by health facilities, the technical efficiency of an individual health facility (Eff_j) can be expressed as the ratio of the *weighted sum of outputs* divided by the *weighted sum of inputs:*

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$$\mathrm{Eff}_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \dots}{V_1 x_{1j} + v_2 x_{2j} + \dots}$$

Where:

u_1 = the weight given to output 1
y_{1j} = amount of output 1 produced by health facility j
v_1 = the weight given to input 1
x_{1j} = amount of input 1 used by health facility j

Technically inefficient health facilities will then use more weighted inputs per weighted outputs or produce less weighted outputs per weighted inputs than their peers on the best practice frontier.

This measure of efficiency assumes that a common set of weights be applied to inputs and outputs across all DMUs. Such assumption will of course raise the problem of agreeing on a common set of weights. Different health facilities may choose to organize their care activities differently so that the relative values of their inputs and outputs may legitimately be different (e.g. one hospital might value the reduction in maternal mortality rate more than the number of admissions performed whilst another hospital might have the opposite approach).

The difficulty of finding a common set of weights had been recognized by Charnes, Cooper and Rhodes [5], accepting the legitimacy of the fact that DMUs might value inputs and outputs differently and therefore apply different weights. Therefore, they proposed that each DMU should have the opportunity of choosing the most favourable weights possible for comparing it to all other DMUs. In that case, the efficiency of a target DMU j0 can be calculated by finding the maximum possible efficiency of j0 using any combination of weight values whereby the efficiency of all DMUs remains <= 1. The solution will produce the weights most favourable to j0 and provide a resulting measure of efficiency. Algebraically, this can be represented as follows:

$$\mathrm{Eff}_{j0} = \mathrm{Max} \frac{\sum_r u_r y_{rj0}}{\sum_i v_i x_{ij0}}$$

stated that:

$$\frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij0}} \leq 1$$

$$u_r,\ v_i \geq \varepsilon\ ;\ \forall r,\ \forall i$$

Where:

u_r = the weight given to output r
y_{rj} = the amount of output r produced by health facility j
v_i = the weight given to input i
x_{ij} = the amount of input i used by health facility j
j_0 = the health facility being assessed

The variables u and v are constrained to be greater than the constant ε, which is a small positive quantity, in order to avoid that any input or output would be totally ignored in calculating the efficiency.

The above linear program is fractional and cannot be solved without converting it to a linear form. The individual values of the numerator and denominator in the above Effj0 equation are not important (they have no meaning after all): we are only interested in the ratio. Therefore it is acceptable to set the denominator equal to a constant (e.g. 1) resulting in the fact that we will remain with the numerator to be maximized. After such transformation, the linear program becomes as follows:

$$Eff_{j0} = \max_{u_r,\, v_i} \sum_r u_r y_{rj0}$$

stated that:

$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 1 \;;\; \forall j$$

$$\sum_i v_i x_{ij0} = 1$$

$$u_r,\ v_i \geq \varepsilon \;;\; \forall r,\ \forall i$$

Where:

u_r = the weight given to output r

y_{rj} = the amount of output r produced by health facility j

v_i = the weight given to input i

x_{ij} = the amount of input i used by health facility j

j_0 = the health facility being assessed

The resulting efficiency score of a health facility j0 will be a value between 0 and 1 indicating how much of the weighted inputs used by j0 would have been needed by an efficient health facility (score=1) to produce the same amount of weighted outputs as j0. Consequently, we may also be able to calculate the effort necessary for an inefficient health facility j0 to become efficient.

In order to illustrate this, let's create an example data set consisting of input & output data for a number of fictitious district hospitals over a period t: Every health facility produces 2 outputs (outpatient visits and in-patient admissions) from a single input being the number of employees working in the hospital. Output and input values for all health facilities are provided in **Table 2**:

Table 2. Sample inputs- and outputs for a set of 10 district hospitals

DMU name	Outpatient visits	Admissions	Staff	Outpatients/staff	Admissions/staff
Mulinga	42144	3112	188	224	17
Razonde	6055	984	47	129	21
Kipantu	254098	12108	767	331	16
Kusombo	108008	4366	311	347	14
Hinanji	86650	5113	277	313	18
Matabu	9806	1460	83	118	18
Timimbi	18120	1060	144	126	7
Rotungo	32077	1656	115	279	14
Fikipso	45050	804	76	593	11
Lamindo	32355	180	54	599	3

Using ratios such as out-patients/staff or admissions/staff, we can express the efficiency of a health facility in producing a single output based on the input. There we can clearly see that the Lamindo hospital is more efficient than Rotungo hospital in terms of out-patient visits performance. On the other hand, the Rotungo hospital is more efficient than Lamindo in terms of the number of hospital admissions per staff member. Depending on which of both would be valued most, both of the health facilities could rightfully state that they are more efficient than the other one. The example is trivial if we only consider these 2 hospitals, but things become more confusing when we start adding more health facilities to the evaluation.

Using the DEA approach, we will be able to combine efficiencies for multiple inputs and/or outputs by first identifying the health facilities that for any combination of input and/or output weights could rightfully state that they are more efficient than the others. In our data sample, such would be the case for the Razonde, Hinanji, Fikipso and Lamindo hospitals. The connecting lines between these efficient hospitals, as shown in **Fig. 4**, represent the efficiency frontier for our dataset. The frontier provides the boundaries of the best possible productivity that can be achieved based on data available and therefore can also be used as a threshold against which performance of other inefficient hospitals can be measured. Graphically, the efficiency frontier envelops the inefficient health facilities.

The efficiency score of a health facility (e.g. Mulinga) can be calculated as the ratio of its distance to the origin (black arrow) over the distance from the origin to the efficiency frontier (blue line). In the case of Mulinga, a score of 0,863 states that a hypothetic efficient hospital situated on the efficiency frontier (point A) would be able to produce the same outputs as Mulinga using only 86,3% of its inputs. In other words, in order to become efficient, Mulinga could reduce its inputs (staff employed) from 188 to 162 (input oriented approach) keeping the outputs at the same level. Another possibility would be to increase the outputs to 48817 out-patient consultations and 3605 admissions (output oriented approach) whilst keeping the input unchanged. And of course, combinations of both approaches (non-oriented approach) would also be possible.

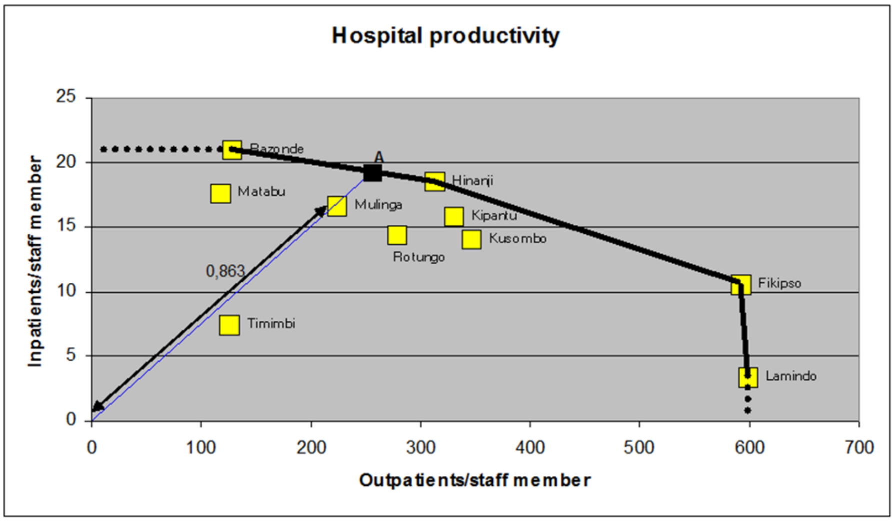

Fig. 4. Sample DEA analysis

2.2 Returns to Scale

The above projections of inputs and/or outputs needed by a non-efficient health facility to become efficient, do only make sense in cases where a change of all inputs by a proportion σ also leads to an increase of the outputs by the same proportion σ. Such case is called Constant Returns to Scale (CRS). In our example this would mean that increasing hospital staff by 10% would also automatically mean a 10% increase in out-patient consultations and a 10% increase in hospital admissions. Of course, such is rarely the case in real practice. A less than proportional increase of outputs would be called Decreasing Returns to Scale (DRS) and a more than proportionally increase of outputs becomes an Increasing Returns to Scale (IRS).

Health facilities that display CRS can be considered to be operating at their best productivity level. When DRS applies, the health facility should scale down and reduce inputs in order to reach its most

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productive size. In case of IRS, a health facility should increase its inputs in order to become scale efficient [6][7]. However, because hospital production processes are most often not linear, it seems appropriate to assume a default approach of Variable Returns to Scale (VRS) [8]. These can be calculated using DEA methods developed by Banker, Charnes and Cooper (BCC) in 1984, whereas the methods of the original Charnes, Cooper and Rhodes (CCR) model assumed CRS. Algebraically, the adapted model for VRS can be written as follows:

$$Eff_{j0} = \underset{u_r,\ v_i}{\text{Max}} \sum_r u_r y_{rj0} + u_0$$

stated that:

$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} + u_0 \leq 1 \ ; \ \forall j$$

$$\sum_i v_i x_{ij0} = 1$$

$$u_r,\ v_i \geq \varepsilon \ ; \ \forall r,\ \forall i$$

Where:

u_r	=	the weight given to output r
u_0	=	free in sign
y_{rj}	=	the amount of output r produced by health facility j
v_i	=	the weight given to input i
x_{ij}	=	the amount of input i used by health facility j
j_0	=	the health facility being assessed

2.3 DEA Strengths

DEA is multi factor, meaning that it can account for multiple inputs and outputs which is quite typical for health facilities. There are no requirements with regard to the units being used for inputs and outputs (they can be completely different). DEA is non-parametric, requiring no assumptions about the (most often unknown) functional relationship between inputs and outputs (in contrast to regression based models) [9][10]. The method directly compares health facilities against a combination of peers. Like ratios, DEA can be used to measure technical or productive efficiency. If cost data are available, differences in technical efficiency can be distinguished from differences in the costliness of the mix of productive inputs (e.g. the balance between physician and nursing labour). On the other hand, no cost-information related to inputs and outputs is required [11].

2.4 DEA Weaknesses

DEA does assume that all inputs and outputs are included in the analysis, meaning that the results may be unreliable if this assumption is not correct. DEA is typically "deterministic," that is, the method usually ignores random noise in inputs and outputs as a potential source of variation in efficiency scores. Any deviation from the best practice frontier is being attributed to inefficiency although part of it could be caused by statistical noise (measurement errors or temporary changes in the health care environment such as epidemics). The deterministic and non-parametric nature of DEA makes it difficult to perform statistical tests on the production function.

2.5 Data set

All hospitals (n=8; 6 Rwandan, 2 Burundian; 6 public and 2 private) in our study set had implemented an open source HIS (OpenClinic [12]) in the period between 2006 and 2012. For each hospital, an

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assessment was performed just before (baseline) and 1 year after HIS implementation taking into account a selection of input- and output metrics. Input metrics included labour inputs (physicians, nurses, ICT-staff and others) and capital inputs (operational beds). Output metrics included out-patient and in-patient case load and mortality rate.

The resulting data were merged in a table of 16 health facility states (8 pre-implementation and 8 post-implementation states). DEA analysis was performed comparing pre-implementation to post-implementation technical efficiency. DEA software used was MaxDEA version 5.2 [13].

3 Results

DEA was used to analyze the productivity of health facilities in terms of the generated volume of out-patient encounters and in-patient admissions related to hospital staffing, called case load total labour technical efficiency (MLTL). For analyzing MLTL, the model selected was revenue/cost based, non oriented and with constant returns to scale (CRS). Although in general, variable returns to scale (VRS) better matches the health sector reality, too many facilities in our limited data set would have been projected on the efficiency border. Taking into account the limitations of the chosen CRS model, the following inputs have been fed into DEA:

<u>Labour</u>
Physician personnel input (MD): average number of full-time equivalents of physiccians employed by the health facility
Nurse personnel input (NURS): average number of full-time equivalents of nurses
Other personnel input (OTH): the sum of all remaining personnel categories
ICT-personnel input (IT): average number of full-time equivalents of ICT staff

<u>Capital</u>
Operational admission beds (ICBE)

2 case load outputs have also been considered:
Out-patient case load (OACO)
In-patient case load (OACI)

Input unit costs being considerably different for Rwanda and Burundi, different unit prices have been used for MD, NURS, OTH and ICBE based on market averages which have all been converted to Rwandan francs (±620 Rwandan francs = 1 USD). Output unit prices were based on average user fees collected for out-patient encounters (OACO) and in-patient admissions (OACI). Output prices were also corrected for price indices calculated yearly for the period 2007-2012.

All parameters have been provided for every health facility prior to HIS implementation (PRE) and 1 year post-implementation (POST), resulting in **Table 3**.

As shown in **Table 4**, in the post-HIS implementation group, DEA identified the private Rwandan hospital La Croix du Sud (CDS) as being technically the most efficient health facility, meaning that they used the least inputs for producing outputs, independently from whichever weight one might give to any of the input and output variables. CDS therefore gets an MLTL technical efficiency score of 100%. The second most efficient health facility was the Military Hospital of Kamenge (HMK), with a technical efficiency score of 28,54%. The score means that a technically efficient health facility (CDS) would have been able to produce the same outputs using only 28,54% of the resources consumed by HMK. The HMK could then become technically efficient by reducing its inputs keeping its outputs constant (input oriented), by increasing its outputs keeping the inputs constant (output oriented) or by a combination of both (non-oriented). Necessary change in inputs and outputs to become technically efficient are provided for every health facility in **Table 4** in the slack movement columns.

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Table 3. input- and output metrics for the 16 health facility states

		Input					Outputs		Unit prices in Rwandan Francs					
DMU	TYP	IT	MD	NURS	OTH	ICBE	OACO	OACI	MD	NURS	OTH	ICBE	OACO	OACI
CHUK PRE	1	0	79	449	84	490	99.866	7.498	1M	350K	250K	25K	5.412	27.242
CHUK POST	1	1	88	515	201	513	128.077	14.186	1M	350K	250K	25K	7.059	82.744
CDS PRE	2	0	26	58	112	50	52.091	4.601	1M	350K	250K	25K	14.164	95.376
CDS POST	2	1	26	60	118	54	79.162	7.535	1M	350K	250K	25K	11.715	118.236
NYA PRE	3	0	13	78	53	167	30.412	6.612	1M	350K	250K	25K	3.906	16.756
NYA POST	3	1	10	85	67	170	27.913	6.538	1M	350K	250K	25K	5.231	37.908
GIH PRE	3	0	9	91	40	105	18.644	5.614	1M	350K	250K	25K	3.697	15.982
GIH POST	3	1	8	93	41	105	20.991	6.803	1M	350K	250K	25K	5.864	23.986
RWA PRE	3	0	12	93	80	207	22.011	8.864	1M	350K	250K	25K	2.451	12.038
RWA POST	3	1	14	99	75	290	23.329	10.404	1M	350K	250K	25K	4.264	22.346
NDE PRE	3	0	10	84	144	243	26.788	3.510	1M	350K	250K	25K	4.932	52.728
NDE POST	3	1	11	83	146	256	29.637	3.226	1M	350K	250K	25K	5.614	54.004
CMCK PRE	2	0	9	13	86	42	10.395	581	600K	275K	150K	15K	7.405	36.973
CMCK POST	2	1	9	13	86	45	10.299	756	600K	275K	150K	15K	8.036	35.284
HMK PRE	1	0	15	96	100	381	64.734	3.256	600K	275K	150K	15K	3.409	25.274
HMK POST	1	1	15	95	102	392	68.995	5.008	600K	275K	150K	15K	3.581	25.621

Table 4. DEA technical efficiency calculations for the 16 health facility states

			Slack movement					
DMU	MLTL	Improvement	MD	NUR	OTH	ICBE	OACO	OACI
CDS POST	100,00%	33,32%	0	0	0	0	0	0
CDS PRE	66,68%		-5	-10	-18	-7	0	2831
HMK POST	28,54%	5,43%	-3	-75	-50	-368	0	4255
HMK PRE	23,12%		0	-70	-32	-350	29429	8946
NYA POST	27,76%	10,73%	0	-62	-22	-149	40273	2501
NYA PRE	17,03%		-1	-51	0	-143	76218	17269
CHUK POST	26,85%	15,02%	-54	-436	-46	-442	45020	0
CHUK PRE	11,84%		-60	-406	0	-452	22117	15782
GIH POST	22,94%	10,24%	0	-75	-5	-88	27668	4626
GIH PRE	12,70%		0	-71	0	-87	66397	13283
CMCK POST	20,78%	2,05%	-2	0	-53	-30	9348	3542
CMCK PRE	18,73%		-2	0	-53	-27	10927	3521
RWA POST	19,04%	9,17%	0	-67	-11	-261	93778	11064
RWA PRE	9,87%		0	-65	-26	-182	152604	25293
NDE POST	17,58%	0,91%	0	-58	-96	-233	40257	3753
NDE PRE	16,67%		0	-61	-99	-222	45532	2989

Obviously, overall hospital efficiency does not exclusively depend on a limited set of input and output variables like the ones in our example. Therefore, slack movements suggested by DEA may sometimes appear very unrealistic. In our study, the Neuro-psychiatric hospital of Ndera showed to be the least technically efficient facility (17,58%). In order to become technically efficient, the hospital would have to reduce the 243 available beds by 233 units remaining with only 10 beds. Clearly, Ndera's efficiency results are being heavily compromised by the fact that the median length of stay is considerably longer for neuro-psychiatric patients (some patients may remain hospitalized for years). This clearly demonstrates the fact that DEA can only be used to technically compare decision making units (DMUs or health

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facilities in our case) that sufficiently share common context: district hospitals must not be mixed with health centres, private clinics should not be compared to public hospitals etc. Homogeneous grouping could not be done (and never was the purpose) for the limited sample of health facilities in our research. On the contrary, the sole purpose of DEA was to evaluate pre- and post-implementation change in technical efficiency for individual health facilities (the pre- and post-implementation operational contexts of the same health facility being considered comparable). From this point of view, for each of the 8 analyzed hospitals, we found that MLTL had improved after implementing the OpenClinic HIS, as is demonstrated in **Fig. 5**.

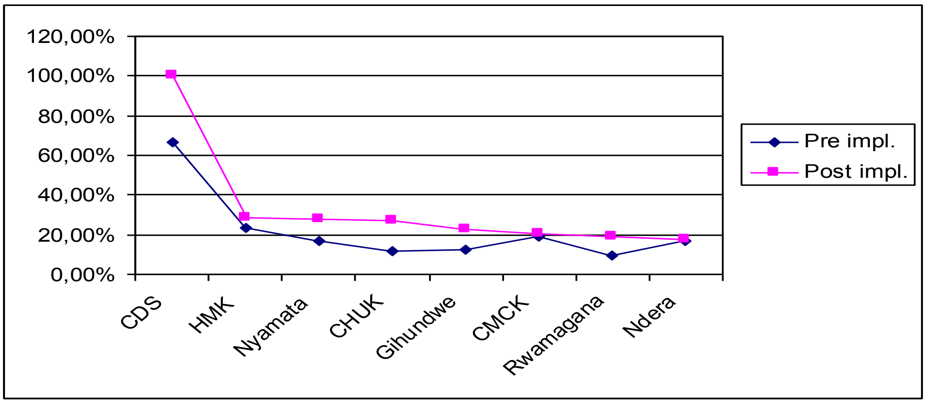

Fig. 5. Post-HIS implementation technical efficiency increase for 8 health facilities

Yet, the average increase of 5,04% appeared not to be statistically significant (single factor ANOVA test comparing pre- and post-implementation technical efficiency scores). Further research on an extended set of HIS-implementing health facilities will be needed in order to confirm or reject the obtained results and has already been planned for integration in a number of new implementation programs in Burundi, DRC, Mali, Congo-Brazzaville and Senegal.

4 Discussion

The proposed method for studying pre- and post HIS implementation change in technical efficiency looks promising when taking into account a number of important limitations. First of all, based on the preliminary results of the study, post-HIS implementation productivity improvements (based on multiple inputs and outputs) seem to be modest, requiring a sufficiently large number of study sites for demonstrating statistically significant changes. In case of different types/brands of information systems being used in the study sites, the number of required sites may further increase. Also, the study sites should preferably be located in different countries and technical efficiencies should be analyzed at different points in time in order to filter out location- or time related bias. Another problem is the fact that a more or less comprehensive set of input- and output metrics should be considered when performing DEA, which is only feasible in few low-resource hospitals in the pre-HIS implementation phase (data unavailable or unreliable, data collection to expensive etc.). Finally, DEA does not provide any information on causal relationships between input and output variables, making it hard to transform technical efficiency data into corrective actions.

For these reasons, the use of DEA for measuring HIS impact on productivity does not seem an appropraite method for evaluating progress made by individual health facilities. It may however still constitute a useful instrument for measuring global productivity impact of large scale implementations of specific health information management methods and/or systems: when performing statistical analysis solely on per-facility pre- and post HIS-implementation productivity progress, homogeneity of the health facilities in the study sample becomes irrelevant.

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Organisational Factors Associated with Electronic Health Information Management Systems Success in two Nigerian Teaching Hospitals

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Background and Purpose: Electronic Health Information Management Systems (EHIMS) are seen as crucial in public health institutions today, as they enhance quality care delivery. Efforts at implementing this system in public health institutions of developing countries have usually been fraught with failure, thus preventing it from delivering its intended benefits. One reason adduced to be responsible for failure is that more attention is given towards technological factors at the expense of organisational factors. Hence, this paper examined the relationship between organisational factors and EHIMS success in Nigerian Teaching Hospitals.
Methods: A correlational survey research design was adopted, while the study's population comprised 212 health information management (HIM) personnel in two south-western public teaching hospitals in Nigeria. Total enumeration technique was used to cover the 212 personnel who served as respondents. A self-developed instrument titled "EHIMS Success Organisational Factors" was used for data collection, while simple correlation analysis was used in analysing the collected data.
Results: It was revealed that a positive relationship exists between all the identified organisational factors and EHIMS success; organisational structure ($r = 0.443$, $p < 0.05$); top management support ($r = 0.613$, $p < 0.05$); leadership style ($r = 0.645$, $p < 0.05$); users' training ($r = 0.521$, $p < 0.05$); financial resources availability ($r = 0.331$, $p < 0.05$); and users' involvement in system design ($r = 0.633$, $p < 0.05$).
Conclusions: It was concluded that an understanding of the identified organisational factors are crucial in attaining successful implementation of EHIMS in Nigeria Teaching Hospitals.

Keywords: Electronic health information management system, Organisational factors, Information system success, Teaching hospitals, Nigeria

1 Introduction

Teaching Hospitals are tertiary level health care providers inherent in the Nigerian health care delivery referral system. They are known as sites of education and research, also providing qualitative and affordable tertiary health care to the nation's citizenry. Without an organised, effective and efficient health information management system in place, the functions expected of these hospitals become difficult to accomplish.

Over the years, the information required for evidence-based decision making in health care institutions has continued to increase, while its organisation and accessibility dwindles. This has led to inappropriate decisions and medical errors [1], thus calling for electronic health information management systems (EHIMS) to enhance accessibility and management of medical information [2].

The healthcare sector is no doubt an information intensive one, hence there's a need to have in place an organised information system to ensure quality of care delivery [3]-[5]. Also, as noted in the revised

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version of Nigeria's National Health Policy [6], "the availability of accurate, timely, reliable and relevant health information is the most fundamental step towards informed public health action (p.43)."

Investing in information technology as a means of delivering high quality care through rapid information retrieval and data management, have been recognised by health care organisations around the world. This, studies have shown that traditional paper-based health information system can be replaced with flexible electronic means which could lead to cost reduction and effectiveness in terms of timely delivery of health care services [7]-[10]. The application of information communication technology (ICT) for the management of health information in healthcare organisations in hospital is tagged Electronic Health Information Management System (EHIMS) in this paper.

EHIMS can be defined as a massive, integrated system that supports the comprehensive information requirement of hospitals; including patient, clinical, ancillary and even financial management. It is an instance of a holistic health information system which has been designed to store, manipulate, and retrieve clinical and administrative information [11]. Studies have shown that the use of EHIMS will bring about increased digitization which makes the management of comprehensive medical records easier; and has significant potential to improve patient safety, patient satisfaction and organizational efficiency, thereby improving health outcomes for patients [12]-[15]. Furthermore, an objective correlation between the degree of adoption of technologies in health care and reduction of complications and mortality in hospitals has also been shown [16][17].

As lofty as the introduction of EHIMS seems, attempts by developing countries governments in its introduction in public health institutions has usually been a difficult process of change, recording more failure instead of successes [18]-[20]. It is important however, that for public health institutions to benefit from their investment in EHIMS implementation, it must attain a state of success. A successful EHIMS in this paper is seen as that which is serving its intended purposes after implementation and subsequent use. The success of EHIMS can be measured along several themes of quality dimension (system quality, information quality, and service quality) [21]-[24]; which were adopted as means of measuring EHIMS success in this paper.

A number of factors have been identified as impeding EHIMS success in health institutions of developing countries. While efforts have usually been concentrated on technological factors, studies have shown that the successful implementation of EHIMS in hospitals is more of a human endeavour that technological sophistication. This is so, because according to Lorenzi in Aarts et al. [25], information systems implementation is subject to the vagaries of the human mind and the culture, politics and power that tie human groups together. While organisational factors in technology implementation especially in healthcare settings of developing countries are not receiving adequate research question, studies have shown that successes and otherwise failure of EHIMS are due to organisational factors and not just technological factors which always seem to be the focus of attention [25].

In a study conducted in Tanzania and Nigeria, proper planning, good managerial skills, top management commitment, leadership styles and end-user consideration were considered as organisational factors necessary to ensure EHIMS success [26]. Furthermore, many systems fail because of issues related to the organization itself. In developing countries, this means that issues like the national and organizational culture play a big role in EHIMS implementation. Kuhn and Giuse [27] allocate the success rate of a technology project as 80 percent dependent on the development of the social and political interaction skills of the developer and 20 percent or less on the implementation of the hardware and software technology. Also, a formative evaluation study of EHIMS conducted by Herbst, Littlejohns, Rawlinson, et al. [28] concluded that concentrating on technological issues (i.e. hardware and software) to the detriment of human ware is a risky strategy for implementing and sustaining EHIMS. However, there are challenges related to understanding and optimizing the complex interaction between people (healthcare professionals, patients and laypeople) and computer systems. While efforts have been made to implement EHIMS in the nation's health sector, there are issues challenging its continuous use and overall use. It is therefore crucial that this system is successfully implemented and continuously used over time if it is to bring about any of its intended benefit to healthcare delivery.

The objective of this study therefore is to ascertain the relationship between organisational factors and EHIMS Success in Nigeria Teaching Hospitals. It is believed that understanding these organisational factors could help to contribute to the discourse on factors affecting EHIMS Success in health institutions, especially in the context of developing countries. It is pertinent to state that this study surveyed the perceptions of EHIMS end-users, which in this study are health information management personnel. This

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is because the use of EHIMS is not in a steady state yet among other supposed users like physicians and nurses. Health information management personnel in Nigeria are professionals who have undergone a specialized training in the management of patients' data. However, for the purpose of this study, data entry personnel though not having been trained in health information management are also considered users. This study focused on two University Teaching Hospitals in South-West, Nigeria that have had experience implementing an EHIMS. The Hospitals are Lagos State University Teaching Hospital (LASUTH), Ikeja, Lagos State and University College Hospital (UCH), Ibadan. More importantly, this study focused on organisational factors such as organisational structure, top management support, leadership style, users' training, financial resources availability, and users' involvement in system design which were all derived from a review of existing literature.

2 Materials and methods

This paper is guided by the conceptual model below:

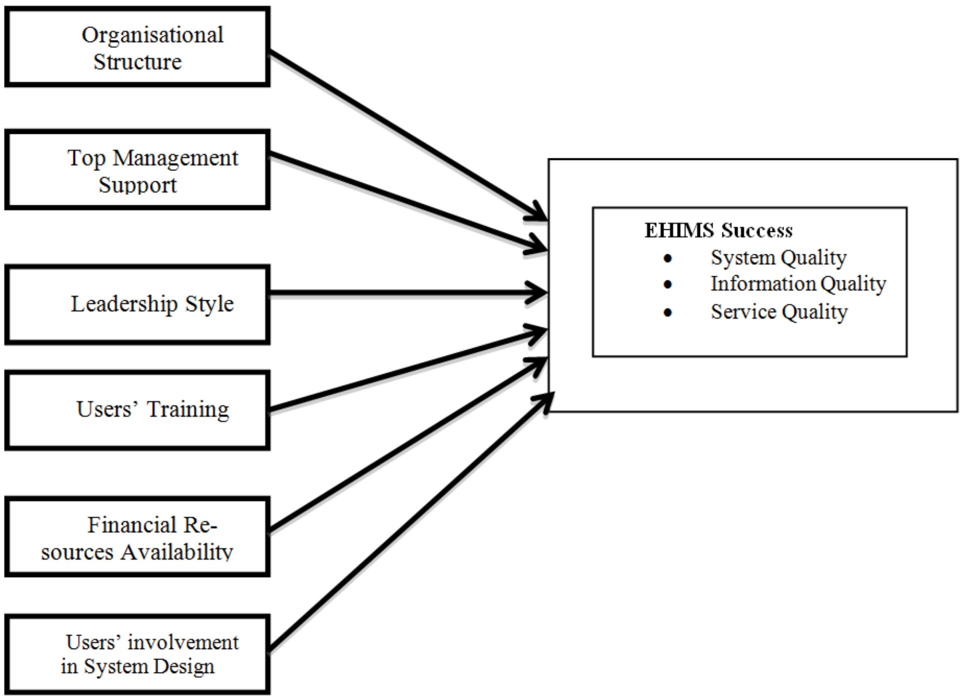

Fig. 1. Researcher's Conceptual Model

In line with the conceptual model (**Fig. 1**). The following null Research Hypotheses were formulated to guide the study:

1. There is no significant relationship between organisational structure and EHIMS success in Nigerian teaching hospitals.
2. There is no significant relationship between top management support and EHIMS success in Nigerian teaching hospitals.

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3. There is no significant relationship between leadership style and EHIMS success in Nigerian teaching hospitals.
4. There is no significant relationship between users' training and EHIMS success in Nigerian teaching hospitals.
5. There is no significant relationship between financial resources availability and EHIMS success in Nigerian teaching hospitals.
6. There is no significant relationship between Users' involvement in System Design and EHIMS success in Nigerian teaching hospitals.

A correlational survey design was used in this study, while responses were sought from health information management personnel who are the primary users of the system. Since this study was focused on two teaching hospitals (LASUTH and UCH), the study population therefore comprised of 212 health information management (HIM) personnel in the hospitals. Specifically, 110 and 102 HIM personnel from LASUTH and UCH respectively. A total enumeration technique was therefore employed to survey the responses of the 212 HIM personnel.

A researcher-developed measuring instrument tagged "EHIMS Success Organisational Factors" questionnaire was used for data collection in both hospitals. The questionnaire was subjected to reliability test using the Cronbach's alpha reliability technique. In line with the research hypotheses, a section by section reliability test yielded the following results: organisational structure – 0.87, top management support – 0.80, leadership style – 0.84, users' training – 0.71, financial resources availability – 0.63, users' involvement in system design – 0.76, and EHIMS success – 0.76.

212 copies of the questionnaire were thereafter administered to health information management personnel in the studied teaching hospitals by the researcher. A total of 205 copies of the questionnaire (representing a 96% response rate) were retrieved and found to be eligible for analysis. This was then analyzed using the simple correlation analysis. The analysis was done using the Statistical Package for Social Science (SPSS v 15).

3 Results

The results from the correlation analysis revealed a significant relationship between each constructs of organisational factors and EHIMS success. That is, there exists a positive relationship between organisational structure and EHIMS success ($r = 0.443$, $p < 0.05$); top management support and EHIMS success ($r = 0.613$, $p < 0.05$); leadership style and EHIMS success ($r = 0.645$, $p < 0.05$); users' training and EHIMS success ($r = 0.521$, $p < 0.05$); financial resources availability and EHIMS success ($r = 0.331$, $p < 0.05$); and users' involvement in system design and EHIMS success ($r = 0.633$, $p < 0.05$). This is summarised in **Table 1**.

Table 1. Correlation between Organisational Factors and EHIMS Success

		Organisational Structure	Top Management Support	Leadership Style	Users' Training	Financial Resources Availability	Users' involvement in system design
EHIMS Success	Pearson Correlation	.443**	.613**	.645**	.521**	.331**	.633**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	205	205	205	205	205	205

** Correlation is significant at the 0.01 level (2-tailed).

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4 Discussion

Results from the analysis shows a relationship between the identified constructs of organisational factors and EHIMS success. A number of studies have corroborated the findings from this study. Tsiknakis and Kouroubali [29] for example in a study of the Organizational factors affecting successful adoption of innovative eHealth services found that the two most influential factors for the success of ICT implementations were training and organizational support. The amount and type of training as well as the level of leadership and management were direct and/or indirect predictors of success. Ang et al. [30], also affirms that organizational factors such as organizational structure, organizational size, managerial IT knowledge, top management support, financial resources, goal alignment and budgeting method all influences IT usage. Biehl [31] as well, highlights top management support, well-understood work processes, the use of a cross-functional team, and maintaining cross-functional cooperation and communication as important organizational factors to be considered for successful information systems.

This result again supports the findings of Berg [32], who concludes that health information system implementation is a mutual process where both organization and technology influence each other. This should be supported by both management and future users. In the same light, Guy and Marie-Claude [33], found that a planned and rational implementation strategy centered on technological considerations, with a relative exclusion of wider organizational and human concerns, is most likely to lead to an EHIMS project failure.

This study was an attempt to understand the relationship between organisational factors such as organisational structure, top management support, leadership style, users' training, financial resources availability, users' involvement in system design; and EHIMS Success in Nigerian Teaching Hospitals. The healthcare sector is an information intensive one, as such requiring investment in EHIMS. While efforts have been made by governments, hospital managements and donor agencies alike to implement EHIMS in some of the nation's public health institutions – it has usually been fraught with failures. Hence, calling for an understanding of the factors responsible for EHIMS success, in order to prevent further failures.

While this study does not claim to be novel in this area, it contributes to the discourse on factors that could contribute to EHIMS success in public health institutions of developing countries. It also theoretically explains the organisational factors essential for EHIMS success, thus providing empirical evidence. The results of this study could help hospitals on the verge of implementing EHIMS understand organisational factors to be considered, consequently helping to prevent wastage of human and financial resources. Also, the call for an eHealth policy in most African countries is a legitimate one, the results of this study could contribute to the discourse on formulating and implementing such policies.

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Stakeholder Management in a Community mHealth Initiative in Malawi

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Background and Purpose: Varying interests and expectations of different stakeholders have implications on successful implementation of Information and Communication Technologies for Health (ICT4H) interventions. Research has shown that proper management of stakeholders' interests has a positive bearing on the effectiveness and sustainability of Information and Communication Technologies for Development (ICT4D) initiatives. However, there is a dearth of studies on stakeholder management in ICT4H research, especially the mobile for health (mHealth) domain. This could be due to the mHealth field still being in its infancy and many projects being implemented for a short period without being evaluated. This paper reports on management of stakeholders in an mHealth intervention from the community perspective. The study examined how management of stakeholders from the community affected the effectiveness and sustainability of the mHealth intervention.
Methods: The case of a Mobile System for Safe Motherhood intervention in maternal health in a developing country context was analysed. The study employed an interpretive approach using qualitative methods. Documentary review and semi-structured interviews were used to collect data, and the data was analysed using content analysis.
Results: Different expectations of mothers and other community agents were not given adequate voice and attention in reaching the common good towards achieving the main objectives of the intervention. Stakeholder management from the community perspective was inadequate due to: 1) less consultation of key community stakeholders in some stages of the project; 2) poor communication; 3) lack of formal procedures in operations; and 4) exclusion of tradition information systems.
Conclusions: Management procedures such as face to face meetings, training, effective communication using formal channels, and community empowerment would help in building winning coalitions that improve performance of interventions and enhance effectiveness and sustainability.

Keywords: mHealth, Community involvement, Stakeholder management

1 Introduction

Delivery of healthcare services in developing countries has been beset with a myriad of challenges such as limited resources, inadequate health personnel, lack of records, poor coordination among the health care providers and constraints in accessing health facilities [1][2]. Mobile technologies are perceived as antidote to some of the challenges [3][4]. Consequently, there is an increase in interventions that use mobile technologies such as mobile phones in health care services delivery and promotion of public health [5]. The services for mHealth include SMS, voice calls, voice messages, internet-based videos, and chat systems. mHealth interventions have the potential to support effective treatment of patients, tracking of patients, supply management of drugs, enhancing emergency services response times and providing information for clinical decision making [6][7].

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mHealth initiatives, like any other Information Communications Technology for Development (ICT4D) interventions, involve and affect different stakeholders. These may include healthcare providers, NGOs, private enterprises, development agents and beneficiaries. The stakeholders represent different interests and stakes. As a result, management of the stakeholders is a complex activity, but vital for the sustainability of an initiative [1][8]. Although the management of stakeholders is important in the ICT4D discourse, there is a dearth of studies on stakeholder management on mHealth. Previous studies on stakeholder management have focused on public ICT facilities [9][10], e-government [11], and local government [12].To our knowledge, studies on management of stakeholders in mHealth are lacking and there is limited understanding of stakeholder management in mHealth interventions.

Additionally, there are calls for bottom-up implementation strategies to be encouraged in mHealth projects so that communities may contribute toward the processes of realizing outcomes [6][13]. However, the phenomenon of community stakeholders management, especially in the context of rural areas of developing countries, has not been fully researched. This study aims at filling part of this knowledge gap. Therefore this study focused on the dynamics involved in the management of community stakeholders that can affect community's contribution towards the success of an intervention. The study was guided by the research question:

How does the management of stakeholders from the community affect the effectiveness and sustainability of mHealth interventions?

The study used an interpretive case study on a Mobile System for Safe Motherhood (MSSM) intervention in Malawi. The country was selected as a case because it has high maternal mortality and morbidity in sub-Saharan Africa, and a number of ICT innovations initiatives are implemented to improve maternal health care delivery and access. Stakeholders framework [10] was used as a theoretical lens to analyse the dynamics of stakeholders management from the community perspective. The rest of the paper is organised as follows. Section 2 presents the background to the study. Section 3 summarises the theoretical underpinnings of the study. Section 4 outlines the research methodology. Section 5 describes the context and case of the study. The findings and results are summarised in section 6. Section 7 presents the conclusions drawn from the study and implications for policy and practice.

2 Literature Review

2.1 Mobile Health

mHealth is described as the application of wireless technologies in delivery of health services [5]. Portable wireless devices such as tablet computers, laptops, Personal Data Assistants (PDA), RFDI devices and mobile phones may be used in mHealth [14]. The devices are characterised as being portable (anywhere), supporting immediacy (any time), convenience (easy to access), reasonable cost (relatively low unit cost) and pervasiveness (widely spread) [13]. With the rapid growth in number of mobile phone subscribers, mHealth is considered as an antidote to some of the challenges for health care services delivery in resource constrained areas such as developing countries [7][15]. mHealth services may include diagnostic and treatment support, remote patient monitoring, disease surveillance and data collection, health promotion, disaster crisis response, medication reminder and helpline systems [6][16].

Different stakeholders are involved in mHealth ecosystems and these may include NGOs, government departments, network operators, social welfare organisation, pharmaceutical companies, health insurance companies, software and hardware development companies, regulatory organisations, hospitals, law enforcement agents and beneficiaries [1]. **Table 1** summarises the stakeholders for mHealth and their interest in the projects.

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Table 1. Stakeholders in mHealth

Stakeholders	Interest in mHealth
Government	Effective health services delivery and effective government
Citizens and patients	Better access to health services and improved health outcomes
Hospitals and healthcare providers	Efficient delivery of health care service, reduced administrative costs
NGOs	Attracting funding and supporting socio-economic development
Hardware and software developer	Revenue generation and building a customer base
Network providers	Increase in revenue and mobile scribers base
International Development Organisation	Supporting socio-economic development
Regulatory organisations	Protecting the interests of citizens and supporting regulations and implementation of policies

2.2 Effectiveness and Sustainability of mHealth Initiatives

In ICT4D initiatives like any other projects, effectiveness and sustainability work hand in hand. The efficacy or effectiveness of an intervention lies in the technology meeting the needs of all relevant stakeholders, especially the beneficiaries [16][17]. Whereas sustainability refers to an intervention meeting the needs of present beneficiaries without affecting the prospects of future beneficiaries [8]. Sustainable mHealth interventions may be projects that are able to provide the services to the beneficiaries over a long period of time and empower the communities. Stakeholders are important for the effectiveness and sustainability of the mHealth projects. The role of stakeholders may be related to the categories of sustainability namely financial, social and cultural, political, technological and institutional sustainability[8][10][18]. The categories are summarised as follows:

- *Financial sustainability:* On-going use financial resources to support activities for the project or return on investment or achieving greater revenues than expenditure
- *Social and cultural sustainability:* support from communities on the impact of the intervention towards development and culture as part of sustainability to ensure that beneficiaries are empowered and that cultural issues have been taken into consideration.
- *Political sustainability:* Support for enabling environment of the intervention obtained through policies and regulatory frameworks.
- *Technological sustainability:* Support for technologies that can serve the needs of the beneficiaries over a long period of time and the capability adapt the changes in technology. For example consideration changes in hardware, software and supplies used in the intervention.
- *Institutional sustainability:* The capacity on prevailing processes and structures that support the intervention over a long period of time. For example sense of ownership, participation and engagement of stakeholders in the project.

3 Stakeholder Theory

Stakeholders have been described differently in different contexts. In this study stakeholders are described as “any group or individuals who can effect or is affected by achievement of organisation objectives” [19]. Stakeholders may be classified as primary and secondary depending on their influence on the organisation such as decision-making, power, interest, interrelations or networks and present and future positions [20]. Primary stakeholders are those with high influence on the organisation; if not managed well, the organisation may suffer serious consequences or even cease to survive [21]. On the other hand, secondary stakeholders’ interests directly affect the organisation; and they get to be affected by the organisation, but are not essential for its survival. In mHealth interventions it is vital to recognise the role and potential influence of stakeholders so that organisations actions and aims should be in-line with the interests of the stakeholders [21]. Stakeholders may be differentiated based on their importance and level of influence in the organization [22]. This importance versus influence method illustrates whose

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stakeholders' problems, needs, and interests are the priority of the intervention, and influence is how powerful the stakeholder is within the intervention [10].

Stakeholder management theory may also be described based on descriptive, instrumental and normative views[23][24]. Descriptive stakeholder theory view focuses on organisation behaviour, describing the organisations relations with its stakeholders. The normative stakeholder theory concentrates on the moral responsibility of the organisation to its stakeholders. Lastly, the Instrumental stakeholder theory view highlights the role of management to the organisation in achievement of success and competitive advantage. The different theory views present a holistic view of understanding the roles of stakeholders in an organisation; as such they do not work in separation, but are linked [25]. However, it is important to note that stakeholders change all the time and it is vital that they are managed well [10].

3.1 Management of stakeholders

Management of stakeholders involves addressing and balancing the interests of each stake in an organisation while maintaining the aims and objectives of the organisation [23]. This process may involve decision, understanding of behaviour of stakeholders, their interactions, their needs, assigning them responsibilities, informing and consulting them decision that affect their interest [19][20]. Management of stakeholders is a complex activity because of diverse interests among the stakeholders [10]. It is, therefore, necessary to ensure that claims for stakeholders are managed in an ethical way while balancing the interest of all stakeholders [23].

Stakeholder analysis may be applied in mHealth interventions to understand the involvement of stakeholders from different perspectives, their importance in the intervention and level of influence; and how they can affect intervention effectiveness and sustainability. Bailur (2006) suggested a stakeholder framework for development projects using the following steps:

1. Identifying stakeholders, understanding and explaining their behaviour and how they might work together
2. Stakeholder management strategies – who to inform, consult, offer partnership and control
3. Determining concessions if previous management strategies do not work

The framework has generic project life cycle stages which may be applicable to ICT4D initiatives. These are identification and analysis of stakeholders, planning, cost benefit analysis and resources allocation, implementation and monitoring and evaluation [10][26]. The steps are summarised as follows:

- *Identification and analysis:* Establish stakeholder for the intervention, their behaviour, needs and potential areas of conflicts
- *Planning:* Identify activities for the intervention
- *Cost benefit analysis and resources allocation:* Analysing the cost and benefits and allocation of resources such as human and financial assets to the intervention
- *Implementation:* Carrying out of activities using the resources
- *Monitoring and evaluation:* Checking the progress and assessing the results and outcomes of activities

In management of stakeholders in the project cycle, strategies used are categorised into four key variables namely informing, consulting, partnership and control. In informing, management provides information to the stakeholders. Management consult stakeholders to have their input on the decisions while in partnership there is collaboration in decisions and action for the intervention. In control there is sharing of power among the stakeholders to influence decisions [26]. This framework is for development projects applicable to ICT4D initiatives including mHealth interventions. This study will use the Bailur (2006) stakeholder perspective as conceptual lens to examine the case of MSSM intervention to analyse the effects of stakeholder management in community mHealth initiatives on efficacy and sustainability of the intervention.

4 Research methodology

The study was aimed at establishing in-depth understanding of management of stakeholders from the perspective of the community in their specific cultural and contextual setting. As such it adopted an

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interpretive paradigm using a qualitative approach [27][28]. The study used purposive and maximum variation samplings to identify participants with diverse demographics who would provide relevant information to the question being investigated [29]. Using the database for the mHealth initiative, a sample frame of about 100 intervention users, 50 community volunteers, and 40 Health Surveillance Assistants (HSAs) was randomly selected. This sample population was contacted using telephone to get their personal details and location. Further, maximum variation sampling was used based on participants' demographic information i.e. ages, marital status, and tribes to get participants of diverse characteristics. The sample frame for this study included twelve women using the intervention, four community volunteers, four HSAs, and four members of staff from the implementing agency of the mHealth initiative who were actively involved in the management of community stakeholders.

Data collection comprised of open ended questionnaires using using semi-structured, face-to-face interviews, annual reports, media reports and correspondences with members of management for the mHealth project through e-mail. The open ended questionnaires were piloted and necessary changes were made. Field notes and participant observation were also used for the data collection. All interviews were audio-recorded with the permission of the participants and transcribed. Data analysis employed content analysis [30][31], and the approach to data analysis was deductive where constructs from the conceptual model on stakeholders management were used [10][26]. The scope of the analysis focused on community stakeholders because most studies overlook community's contribution towards the effectiveness and sustainability of an intervention. Due to ethical reasons we will not disclose the names of the organisation and stakeholders for this study.

5 Case description

5.1 Context of the study

Malawi is located in the South East of South Africa and has a population approximate 15.3 million [32]. The country is ranked 153 out of 169 economies in the Human Development Index, and is categorised under the low human development economy [33]. Malawi is burdened with poverty and other challenges like limited levels of infrastructural development, low levels of literacy, poor healthcare systems, relatively high HIV prevalence, and ultimately high overall mortality rates. The impact of HIV/Aids has also affected the country. It is estimated that 10.6% of adults within the age between 15-49 years are living with the HIV virus. Delivery of maternal health care is also a challenge to the resource constrained government of Malawi. As of 2011, 82% of maternal healthcare consumers reported having at least one problem in accessing healthcare services including finances, long distance to health facilities, lack of resources (especially drugs) in health facilities and transportation to get them to a health facility in time for treatment [32]. In 2010, 95% of women received antenatal care from skilled attendants, thus from a health facility, but only 71% delivered from the health facilities. This contributes to high maternal mortality rates in Malawi.

Malawi, like many developing countries has also experienced an increase in number of mobile phone subscribers. It is estimated that there are 3.3 Million mobile phone subscribers [34]. The subscribers are shared among two mobile operators, Airtel and Telecom Networks Limited. The network coverage for mobile phones covers almost all the parts of the country including urban and rural areas. There is a belief that with such coverage, some of the public services may be provided using mobile phones [35].

5.2 MSSM Intervention

With 632 maternal deaths per 100 000 livebirths, Malawi has one of the highest maternal mortality rate (MMR) in sub-Saharan Africa [36]. The MSSM project is one of the initiatives implemented in the country to reduce the MMR in attempt to achieve millennium development goal number 5: To reduce three quarters of maternal mortality by 2015 [37]. A baseline study of perceptions and practices towards maternal health was conducted and the findings led a national wide competition of ideas to improving maternal health service delivery and utilization so as to reduce the high maternal morbidity and mortality in the country. Two ideas were successful in meeting the needs identified in the communities, and formed the foundation of the MSSM project: 1) the hotline for timely health information and advice; and 2) use

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of mobile phone technology for tips and reminders on maternal health issues, together with a booking system and databases at health facilities to improve documentation.

Since 90 % of the population in Malawi live in rural areas [32], the project was piloted in the rural areas of one small district. The main goal of the MSSM project was to maximize healthcare access and utilisation by remote mothers who were faced by so many challenges like walking long distances to access a health facility, resulting in delays in seeking care and unnecessary expenditures. The objectives of the project were:

1. Improve the quality of maternal health case management
2. Improve maternal health-seeking practices
3. Increase community confidence in the health system

MSSM is a toll free helpline and SMS Bulktool system running on one network operator out of three operators in Malawi. Remote women with mobile phones and on this one particular network could access the system for free, other networks needed to pay. The system/project had three main components:

(a) Toll-free case management hotline
(b) Tips and reminders
(c) Community outreach, education and mobilization on maternal health issues

Firstly, the toll-free case management hotline – this hotline was based at the district hospital being handled by qualified hotline workers who were trained in maternal health issues using the HSAs' (Community Health Workers) curriculum to serve the women better. Some nurses helped at the hotline on part-time basis. To register into the intervention women first used the hotline where their personal details were captured, and could enrol for tips and reminders. Upon registration women were told about their expected date of delivery and the current stage of pregnancy based on their last menstruation. In addition, they received protocol-based advice on pregnancy care, nutrition and sanitation. The hotline also provided health information to women who might have been out of reach of HSAs in the community or health centres; and health facility referrals to help prevent avoidable complication or emergencies.

Tips and reminders were a push service for automated tips and reminders for pregnant women through text or voice messages. The voice messages could be retrieved from the toll free line upon authentication using personal details while text messages were delivered straight to private phones. The tips were personalised to the stage of pregnancy, women were told what to expect (normal things) at a particular pregnancy stage and were also warned of danger signs not to be ignored. The reminders were for antennal appointments and also for prophylaxis medication and supplements taken during pregnancy i.e. Malaria drugs.

Lastly, the intervention also had community outreach, education and mobilization on maternal health issues component. The intervention recruited about 400 community volunteers in the four catchment areas of the pilot project. These are not Community Health Workers (CHW), but individuals in the community with basic literacy, already involved in health promotion and were willing to volunteer time to promote the MSSM intervention in their communities. Each village had at least one community volunteer. Due to poverty and low mobile phone penetration in Malawi [38], the project provided mobile phones to the volunteers in the villages as point of access and usage of the MSSM for women in the communities. The community volunteers' main role was to provide phone access and usage for the intervention, and to demonstrate how to use the system. They also promoted the intervention by educating leaders and community influencers about the intervention and persuaded them to encourage the community to use it. In addition, they were involved in community outreach, holding public meetings with the community. Community volunteers visited the women in their homes for registration and also follow-up on tips and reminders so that the women could listen to their messages.

During the time of data collection the intervention had recruited more than 3000 women from the four catchment areas, receiving between 450 and 600 calls every month. The calls ranged from advice seeking and minor ailments to major complication and emergencies. On average the women called the hotline three times during the whole pregnancy period, and they felt that MSSM gave them sufficient time to explain their problems in detail without being rushed as was the case at health centre due to overcrowding. This resulted in getting proper and accurate advice and medical help specific to their condition. The women received the tips and reminders every fortnight. This helped them to understand the changes going on in their bodies and also the development of the baby. This information prepared them for childbirth unlike before when they did not have ample knowledge of pregnancy and maternal care. The MSSM intervention proved to be convenient for the women as it provided timely medical advice at home, without requiring women to walk long distances to the clinic unnecessarily for any medical condition, even trivial ones.

6 Analysis of the case

6.1 Stakeholders for MSSM

The stakeholders for the MSSM intervention included international development agencies, telecommunication providers, Ministry of Health (MOH), hospitals, and health centres, health providers, implementing agency, other NGOs, the community and the beneficiaries. The international development organisations main stakes were supporting maternal and child health by providing financial assistance and technical expertise. One of the NGOs was responsible for designing the system and providing system support and maintenance; and the other one had interest in rigorous research to perceive what works or what not. Telecommunication providers supported the accessibility of the services at an agreeable cost. MOH had interest in supporting the intervention at the district hospital and the health centres. The implementing agency was responsible for the implementation and operations of the intervention. The stake for the beneficiaries was mainly in using the services to address their problems in the communities.

Our study focused on the stakeholders from the community in relation to the beneficiaries of the intervention, mothers. Management of the other stakeholders is out of scope of this paper. The identification process was iterative in an attempt to cover all relevant stakeholders from the community in the intervention [39]. Our initial identification process using the website and some project documents found that at community level only the community leaders such as village headmen and chiefs, community volunteers and pregnant women were the only stakeholders involved. The second round of the identification process, using the interviews and more project and media reports, revealed more categories of stakeholders as shown in **Table 2** which also summarises the stakeholders' interests and roles in the intervention as indicated in the data set.

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Table 2. Identification of Stakeholders

<table>
<tr><th>Community Stakeholders Identified</th><th>Roles</th><th>Interests</th></tr>
<tr><td>Community leaders</td><td>• Understand the benefits of the interventions and encourage their people to use it
• Draw policies that support and encourage the use of the intervention and improve health seeking behaviour
• Select reliable individuals in their village to be volunteers for the intervention (community volunteers)</td><td rowspan="4">• Positive change in health seeking behaviour of the community
• Improved health outcomes for the community
• Improved wellbeing of the community
• Interests in personal gain i.e. monetary incentives</td></tr>
<tr><td>Village health committee</td><td>• Promote the intervention
• Involved in the selection of community</td></tr>
<tr><td>Community volunteer</td><td>• Educate community leaders and other influencers about the intervention and encourage its use in the community
• Conduct community outreach events to promote the intervention
• Point of access and usage for the community mobile phones
• Visiting women of the child bearing age group in their homes to promote the intervention even to their influencers, for registration and also follow-up visits with mothers who were already registered to help them listen to their messages
• Record keeping for all intervention use in their village
• Attend regular meetings with implementing agency and health providers to discuss operations and new strategies</td></tr>
<tr><td>HSAs</td><td>• Promote the intervention in the communities</td></tr>
<tr><td>Mothers</td><td rowspan="2">• Register and use the intervention
• Act on the information given
• Promote the intervention</td><td rowspan="2">• Experiencing healthy pregnancy
• Giving birth to healthy babies
• Giving birth with the help of health personnel
• Raising up health children
• Empowerment</td></tr>
<tr><td>Women in the child bearing age group</td></tr>
<tr><td>Partners</td><td>• Give authorisation to the women to use the intervention
• Support the women in using the intervention and also in their action
• Promote the intervention</td><td>• Improved health outcomes</td></tr>
<tr><td>Elderly women</td><td>• Influence women decisions and actions
• Encourage/discourage the use of the intervention</td><td>• Imparting the local values of sexual and maternal care on young women
• Continuation of their local womanhood legacy</td></tr>
<tr><td>Babies under 1 year</td><td></td><td>• Improved health outcomes</td></tr>
<tr><td>Children 2-5 years old</td><td></td><td>• Improved health outcomes</td></tr>
</table>

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6.2 Stakeholders' Behaviour

According to the tenets of stakeholder management [19], the implementation agency was responsible for managing different interests of all the stakeholders involved; their activities and interactions to ensure unanimity towards achieving project objectives. The implementing agency approached the community leaders as an entry point into the community. When permission was granted, management gave the leaders control to choose reliable people in their villages who could be entrusted with a phone and act as a point of access and usage for community mobile phone, and also volunteer to promote the intervention in the village. The chiefs invited village health committees, and together selected a community volunteer from their village. HSAs become involved in the intervention by the virtue of being part of the village health committee and also due to their affiliation with the health centre as the lowest level of government health workers. These various stakeholders jointly promoted the intervention in the community by calling public meetings targeting women and their partners because they realised that culturally the women could be free to join and use the intervention only when their male partners allowed them to do so [40][41]. Some of the elderly women came to the meetings out of curiosity and many other were reached during house visit by community volunteers.

The initial target audience of the MSSM were pregnant women and babies under the age of one year as beneficiaries. Only these could register on the system to talk to the hotline workers (whom they usually referred to as 'doctors'), and received the tips and reminders on pregnancy and child development. Due to poor child health in Malawi, this strategy was later revised to accommodate children under the age of five years. This group was provided with health information and health facility referrals without registering them on the system.

It was found that the average age of the women using the intervention was 26 years. At that age a woman in the rural Malawi would have a number of children already. Management observed that the intervention was not capturing young women since women in rural areas start having children at the age of 15 years [32]. The findings confirmed that young women were not seeking information anywhere else but from the community [42]. Rarely would young women go to a health facility to seek advice on reproductive health, pregnancy and even family planning. Cultural norms such as the influence of elderly women emerged as the main factor hindering young women to seek health information and services, showing that the elderly women had interests and stakes as well in the MSSM intervention:

"I heard of MSSM from my friends when I was six months pregnant…my mother knew all about MSSM and even the community volunteer in our village but she never told me about it. So I said but mother why didn't you tell me about MSSM all this time. She said that 'I can tell you whatever you want to know about pregnancy'….later she gave me details about MSSM and I joined. And I have learnt much more than I could from home….But when time for delivery came, my mother took me to the nearby Traditional Birth attendant…mmmh…the person does not have enough equipment…" (Mother 1)

The behaviour of elderly women towards the intervention was that of resistance and negativity. This contributed to most women being sceptical and non-receptive about the intervention and maternal healthcare in general, since rural women in developing countries tend to listen and take advice from elderly women [41][43].

Prioritising the interests, needs and problems of stakeholders show how important they are in the intervention and the power they have to influence its operations and effectiveness [22]. However, the importance and influence assigned to a particular stakeholder changes at different stages of the project. **Fig 1** illustrates the importance of the community stakeholders and their level of influence in MSSM intervention as portrayed in the data set:

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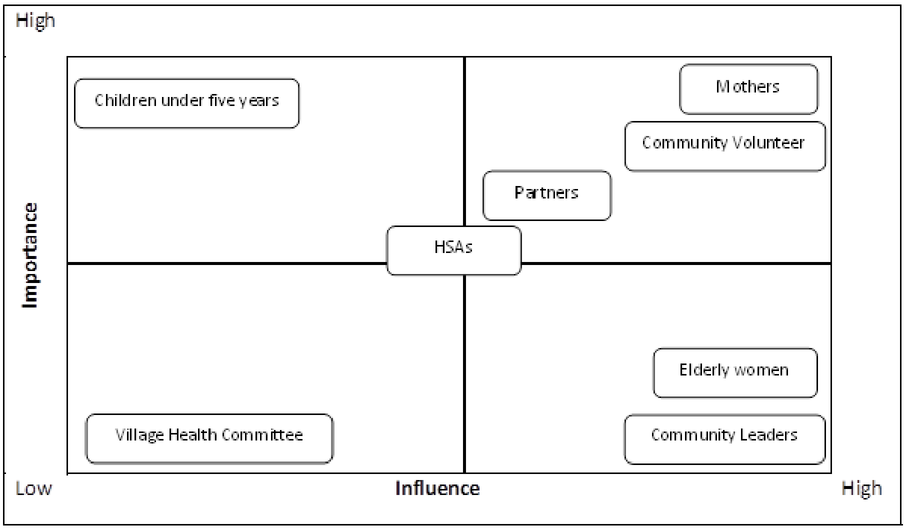

Fig. 1. Summary of management of community stakeholders

6.3 Concession and Bargain

The strategy to approach leaders as entry point into the community brought a sense of ownership to the leaders [17]. As a result, the leaders took it upon themselves to sensitise their people about the interventions and they put together polices to encourage the women to seek health services i.e. family paying a goat to the chief when a woman gives birth in the village or on the way to a health facility:

"Most women used to deliver their babies in the village…but this behaviour has decreased because all the chiefs in this area have set a rule that if a woman delivers in the village or on the way to the clinic then her family has to pay a goat to the chief…and people fear owing the chief a goat, as a result most women are now giving birth at a health facility" (Community volunteer 1)

There were no direct interactions between the implementing agency and the village health committee even though it was involved and had interests in the project. However, the committee was informed about the intervention activities and decisions through informal channels by HSAs and Community Volunteers since they were also managed by it in other projects. The role of HSAs in the intervention was not defined; they involved themselves in the MSSM intervention just like they would with any other intervention on community health in their area. However, it was found that some HSAs expected to receive mobile phones for the intervention like the community volunteers did. Another project implemented by the same implementing agency in another area had distributed mobile phones to all health workers including HSAs in all the health facilities of that area. When the HSAs heard that MSSM was going to be implemented in their area, they assumed that they would receive mobile phones together with all other staff i.e. nurses and clinical officers. When they had not received mobile phones, they became demotivated and not keen to work with MSSM.

Furthermore, other projects in the catchment areas of the MSSM, offered monetary incentives to HSAs, community volunteers and even the beneficiaries working with them. So even though the women had a good understanding of the intervention, how it worked and the benefits it offered, just like the HSAs and the community volunteers they also expected monetary incentives. The women did not have a chance to meet with the implementing agency initially and they got all the information from the community volunteers. As such, they suspected that the community volunteers had received money from the implementing agency and did not share with them. This affected the relationship between them and it also discouraged other women from joining the intervention. Overall, the community stakeholders of MSSM complained of not receiving monetary incentives, as a result some lost interest in the intervention. But they did not put in place procedures to voice out their concerns to the implementing agency, consequently the implementers were not aware of this; the people kept on hoping that things might change one day without doing anything about it. On the other hand, the HSAs and community volunteers involved in outreach events were paid a small amount of lunch allowance, and whenever the implementing agency was meeting with the community volunteers or the mothers, drinks and snacks were

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provided. Additionally, the community volunteers had received community phones and t-shirts to promote the intervention in the villages. This motivation strategy though not appreciated by the community stakeholders, since they were used to monetary incentives, worked in motivating the HSAs and CVs to do their jobs and the women to embrace the intervention.

The roles of the community volunteers were properly defined in the project documents. However, the community volunteers felt they were doing much more than what was agreed. The door to door visits to have women listening to the messages in their homes or looking for women to register was like going an extra mile from their assigned responsibilities and all the volunteers interviewed put it as if it was their own initiative not a requirement. The implementing agency trained the community volunteers once at the beginning of the program, and was visiting each facility once a month to meet with them and also address women at the ANC clinic, women who took the initiative to attend ANC on their own. Therefore, the community volunteers felt they did not have enough support from the implementing agency because the implementing agency had never visited the villages to promote the intervention, monitor the operations, or just see how the women were embracing the intervention. As a result, some women in the village did not believe that the community volunteers were working in conjunction with the any implementing agency; and according to the community volunteers this made the intervention lose its credibility [44]. As mitigation, the implementing agency introduced the outreach events with some entertainment activities and they would address the community themselves and assure them that the community volunteers were there to help/serve the community on their behalf. The outreach activities had a positive impact, the number of women registering and using the intervention increased.

The project was beset with technical problems and lack of proper technical support. By the end of first year of the project only 50% of the phones were working. The phones were basic and most of them had problems with key pads and batteries. Due to lack of action plan on mobile phone support and maintenance, the defected phones had to be repaired by individuals who had some skills in the villages. This led to a number of phones being redundant, so the strategy was changed to having the phones repaired at the district town. However, by then most villages had already been left without phones and this hindered on the operations of the intervention. This also demoralised the community volunteers from continuing to promote the intervention to those who could use personal phones.

Despite the fact that most of the community volunteers were dedicated to their jobs, some were rarely available for access and usage of the phones by the women and it affected the operations. It was observed that there were no channels for women to voice out such concerns and no proper procedures to monitor and verify whether the community volunteers were fulfilling their responsibilities or not in their assigned villages.

6.4 Management of stakeholders

The implementers involved the key stakeholders in the community through consultation, informing, partnership and some control [10][26]. Our findings show that there were no formal procedures and strategies for managing the community stakeholders. The implementing agency was responsible for whom to include or exclude at a particular stage of the project. **Table 3** illustrates the involvement and management of community stakeholders throughout the project cycle:

Table 3. Summary of community stakeholders' involvement

Project phase	Inform	Consult	Partnership	Control
Identification and analysis		Mothers Partners HSAs Elderly women		
Planning Cost benefit analysis and resources allocation				
Implementation	Mothers		Community leaders HSAs	Community volunteers
Monitoring and evaluation		Mothers Community Volunteers		

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The data showed that the community was consulted during the identification and analysis of stakeholders stage. This was done using a baseline study with the mothers together with their guardians (either partners or mothers), HSAs and the TBAs representing elderly women. The findings of the baseline assisted in understanding and taking into consideration the local realities of the rural area, and also determining the stakeholder to involve. In planning and cost benefit analysis and resources allocation stages the community stakeholders were not involved in any way. During the implementation stage, the community leaders were approached and offered partnership to work with the implementation agency. As such, the community leaders permitted the intervention into their communities and promoted it using their authority. The community volunteers were selected to work for the implementer as point of access and usage for the system, thus some power was shared with them to control the activities on the ground in the villages. Through partnership with the health facilities the HSAs were involved to promote the intervention in the communities.

In the implementation stage, the intervention was promoted to the mothers and there were given all relevant information to make an informed decision whether to join the intervention or not. Those who joined were kept in the loop for all the improvements that were being made to the system. The mothers were further consulted on the performance and effectiveness of the system during monitoring and evaluation, and so were the community volunteers as they were the facilitators and promoters of the intervention in the community.

7 Discussion and Conclusion

This paper examined the effects of stakeholders management on the efficacy and sustainability of community mHealth initiatives in maternal health. The paper analysed how the interests, relations and interactions of community stakeholders using the stakeholder theory [10]. The MSSM project like most other mHealth initiatives undertook both the bottom-up and top-down implementation strategies [13]. The findings show that to some extent the implementing agency consulted, informed, partnered and even shared control with diverse community stakeholders at different project life cycle, but more could have been done to steer the intervention in the right direction so as to enhance its effectiveness and sustainability. In the planning stage, management consulted the local people (community) in two ways:

(a) Involving them in a competition to ideas on the type of innovations that would improve maternal and child health in the context of Malawi
(b) Baseline study - the findings assisted in determining the potential stakeholders from the community perspective and also understanding the local realities from socio-cultural to economic dynamics.

This inclusive approach gives communities a strong sense of ownership that drives the development process and direction to the advantage of the initiative's success and sustainability [17].

The iterative process of stakeholder identification revealed some secondary stakeholders that the intervention did not take into account. These stakeholders had either high interests and low power or high power and low interests to influence the performance of the intervention as such they needed to be kept informed and satisfied [19]. The village health committee had interests and expectations for the performance of the intervention, if it was meeting the needs of their people. But the implementers had no interaction with the village health committees as a result the committee did not support the community volunteers selected which led to volunteers feeling they were on their own without the implementers and the village support. This affected the operations and sustainability of the intervention since community volunteers were not accountable to anyone in the village, in addition to not having a formal way of monitoring their jobs.

The implementers did a good job in acknowledging the local realities of the context but the local information ecology for maternal care was overlooked. Most ICT interventions fail because they undermine existing tradition information systems and they are viewed as a challenge to information brokerage role of existing community organisations [45]. The elderly women viewed the intervention as something that had come to eliminate their tradition. The elderly women had low interest in the intervention but high power to influence the decisions of the mothers on using the intervention because in

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rural areas the norm is that only elders should provide pregnancy information that guides the pregnant woman's action and conduct [42][43]. Leaving the elderly women out of the MSSM ecosystem was a setback to the intervention as it reduced the number of women registering and also discouraged those registered to seek medical attention, defeating the whole purpose of the intervention.

The role of the CVs and the mothers were defined in the project documents, mainly because they were the key stakeholders in the community. The undefined roles attributed to stakeholders having high expectations of the intervention which affected their behaviour toward the intervention. Failure to meet the stakeholders' expectations by the implementers led to conflict of interests and had a negative bearing on effectiveness and sustainability of the intervention, which flourishes with satisfying stakeholders' needs [46]. The study noted that the misunderstandings and conflicts in the stakeholders' expectations and interests were attributable to less consultation of key community stakeholders in some stages of the project, poor communication, lack of formal procedures in operations, exclusion of tradition information systems. The socio-cultural context of the rural communities where people rarely voice out their expectations and frustrations if their needs are not met exacerbated the conflict of interests, leaving most of the community stakeholders demotivated which affected the performance of the project.

For effective management of mHealth initiatives in rural communities, policy makers and implementers need to involve the communities at every stage of the project so that they do not miss some key stakeholders that can affect project performance even in the background. It would be important to respect and include tradition information systems, especially in sensitive domains like maternal care, so that communities do not feel threatened by the interventions, but a sense of inclusion and understanding that the innovation initiatives enhance and strengthen existing information systems. Stakeholder management using proper procedures such as face to face meetings, training, and effective communication strategies with formal channels build winning coalitions that improve the performance of the intervention leading to effectiveness and sustainability.

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The Consistency and Concurrency Between the Kenya HIV/AIDS Program Monitoring System (KePMs) and the National Reporting System (DHIS2), 2012

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Background and Purpose: Kenya implemented the use of District Health Information Software (DHIS2) countrywide in 2011. The successful roll out of DHIS as the national reporting system provided a strong foundation for the development of “One unified and integrated, country owned, country led, National Health Information System (NHIS).” In order to achieve this, there was need to transition all existing parallel reporting systems into the DHIS. The Kenya HIV/AIDS Program Monitoring System (KePMs) was one of the major parallel reporting systems that were targeted for integration. KePMs is a computerized database for the management and analysis of the President's Emergency Plan for AIDS Relief Care (PEPFAR), treatment and prevention indicators required by United States of America Government program managers. This paper examines the current status of the implementation of the DHIS2 for use as the national health information system in order to inform transition from KePMs to DHIS2. It examines the consistency and concurrency between the DHIS2 data and KePMs data using selected indicators.
Methods: In order to assess the concurrency of data between KePMs and DHIS2, data from sampled facilities and sampled indicators (in HIV Testing and Counselling (HTC), Prevention of Mother to Child Transmission (PMTCT) and Care and Treatment (CT)) were analysed by comparing datasets from the two databases (i.e. DHIS2 and KePMs).
Indicator selection was purposive as determined from an indicator matrix developed in previous meetings. The PEPFAR 2012 data set on KePMs was considered as the sampling frame for facilities in both the KePMs and DHIS2. The data for September 2012 were used. Data were received from one reporting tool (dataset); the MOH711. A convenient sample size of 141 facilities (comprising three facilities per county) was determined.
Descriptive data analysis was done using Microsoft Excel package. The analysis involved computing the concurrency and consistency between the data reported in DHIS2 and KePMs for the period of September 2012. During the analysis of these data, concurrency was only looking at the sites that had reported data while consistency checked through all the 134 health facilities sampled.
Results: On average, data in the selected indicators showed a consistency rate of 79.5% in both systems. The consistency rate was above 75% in all indicators except in the indicator; “Number of individual tested and received results through Provider Initiated Testing and Counselling (DTC/PITC)” which had 63%. The average concurency rate was 69%. Concurrency rates varied amongst the various indicators with DTC/PITC achieving the highest concurrency rate of 97%. The lowest concurency rate was for “couples testing for HIV” at 34%. In general 74% of data in both systems had no variance.
Conclusions: The main reason for developing parallel system was the absence of a reliable national system. The results show a very high consistency rate between the two systems. Minor differences in data were attributed to data entry and poor data validation rules. It is recommended that with minor improvements, the DHIS is in a position to provide the necessary data to cater for all stakeholders and hence become the National reporting system.

Keywords: Health Information Systems, District Health Information Software, Service delivery Indicators

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1 Introduction

Enhancement of Health information systems has become a top priority agenda globally, regionally and nationally. Reliable data is essential in identifying gaps for interventions to reduce mortality, improve quality of care, determine the extent of coverage and track progress of the various interventions. This creates an increased demand for better data to facilitate evidence based decision making at all levels of healthcare. Such data would be used to support the generation of policies as well as identification of priority areas for interventions. Recent years have witnessed significant commitments and investments towards the strengthening of health information systems. Efforts to improve health information systems in Africa often face various challenges including the emergence of fragmented systems propagated by the diverse international organizations supporting them, leading to the development of many uncoordinated donor initiatives that maintain parallel health information systems [1]. To counter the effects of many parallel systems, Kenya has embarked on a process of implementing "One unified and integrated, country owned, country led, National Health Information System (NHIS)." This calls for transitioning of all existing parallel reporting systems into the national reporting system. This paper compares data from the development partner supported reporting system with the national system.

1.1 The Implementation of District Health Information Software (DHIS2)

Kenya adopted the use of the District Health Information Software (DHIS 2) in 2010. This was hosted on a central server using cloud computing infrastructure [2]. DHIS is a tool for collection, validation, analysis, and presentation of aggregate statistical data, tailored to integrated health information management activities [3]. It was designed to allow data collection and use at the facility and district levels, encouraging data use for decision making at the lowest level. The software supports a full Web-API which gives access to all of the functions of the software through a web interface allowing data entry or reporting interfaces on mobile devices or desktops. It has a fantastic support from a worldwide network of users and developers [3].

1.2 The Kenya HIV/AIDS Program Monitoring System (KePMs)

The Kenya HIV/AIDS Program Monitoring System (KePMs) is one of the major parallel reporting systems in Kenya. KePMs is a computerized database for the management and analysis of the President's Emergency Plan for AIDS Relief Care (PEPFAR), Treatment and Prevention Indicators. It is a Microsoft Access based indicator monitoring database for use in the management, monitoring and evaluation of HIV/AIDS treatment and prevention programs supported by PEPFAR. The system was created approximately 6 years ago to plug the gap between the Government of Kenya reporting system and the PEPFAR reporting requirements. It is designed to operate at the level of in-country implementing partners who manage program specific data and forward it to national level where it is aggregated automatically by United States of America Government (USG) program managers. The KePMS also allows partners to monitor their own performance and make decisions informed by the data [4]. KePMS also collects and collates data from health facilities and is, therefore, largely seen to be duplicating the facility reporting functionality of DHIS2.

1.3 Transition of KePMs to DHIS

The completion of the rollout of DHIS2 in all districts in Kenya in the year 2011 and the completion of indicator harmonization process in most program areas within the Ministry of health (MOH) mean that the MOH has a strong foundation on which to integrate the service delivery data for use by all stakeholders in the health sector. The country is striving to eliminate the vertical Monitoring and evaluation (M&E) systems and developing an integrated health information system to serve as a repository for all health and health related data. It is against this background that the Ministry of Health selected, through consultative fora, the open source DHIS2 software as the framework for building the routine health information system as a first step towards integration. The objectives of the transition are:

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1. Ensure that all indicators in KePMs are captured and correctly generate results in DHIS2.
2. Ensure that DHIS supports both ad hoc and scheduled USG required reports.

In preparation for the transition, data from DHIS and KePMs were analysed to establish the consistency and concurrency. This paper examines the current status of the implementation and adoption of the web based DHIS2 software for use as the national health management system in order to inform transition from KePMs to DHIS2. It examines the consistency and concurrency between the DHIS2 data and KePMs data using a select set of indicators and data elements.

2 Materials and methods

2.1 Determination of Data Concurrency

In order to assess the concurrency of data between KePMs and DHIS2, data from sampled facilities and sampled indicators (in HIV Testing and Counselling (HTC), Prevention of Mother to Child Transmission (PMTCT) and Care and Treatment (CT)) were analysed by comparing datasets from the two databases (i.e. DHIS2 and KePMs).

Indicator selection was purposive as determined from an indicator matrix developed in previous M&E subcommittee meetings. The PEPFAR 2012 data set on KePMs was considered as the sampling frame for facilities in both the KePMs dataset and DHIS2 data set. The data for month September 2012 were used. Data were received from one reporting tool (dataset); the MOH711. A convenient sample size of 141 facilities (purposive) was considered in each of the 47 counties i.e. 3 sites per county. Sites that had reported on KePMs but not found on DHIS (16) were not substituted. The final sample was therefore 134 facilities.

2.2 Data Analysis

Descriptive data analysis was done using MS Excel. The analysis involved computing the concurrency and consistency between the data reported in DHIS2 and KePMs for the period of September 2012. During the analysis of these data, concurrency was only looking at the sites that had reported data while consistency checked through all the 134 health facilities sampled.

3 Results

The data reported in the two systems was obtained from MOH 711A which is the standard National Reporting Summary tool. Since the source of the data reported in both systems is the same for similar indicators it is expected that the data will be consistent. The section below presents results from the analysis of concurrency and consistency between data reported in KePMs and DHIS2 for the selected facilities.

Generally consistency of the data in 6 (75%) indicators out of the selected 8, performed better than the concurrency levels, as reflected in the **Fig. 1** below.

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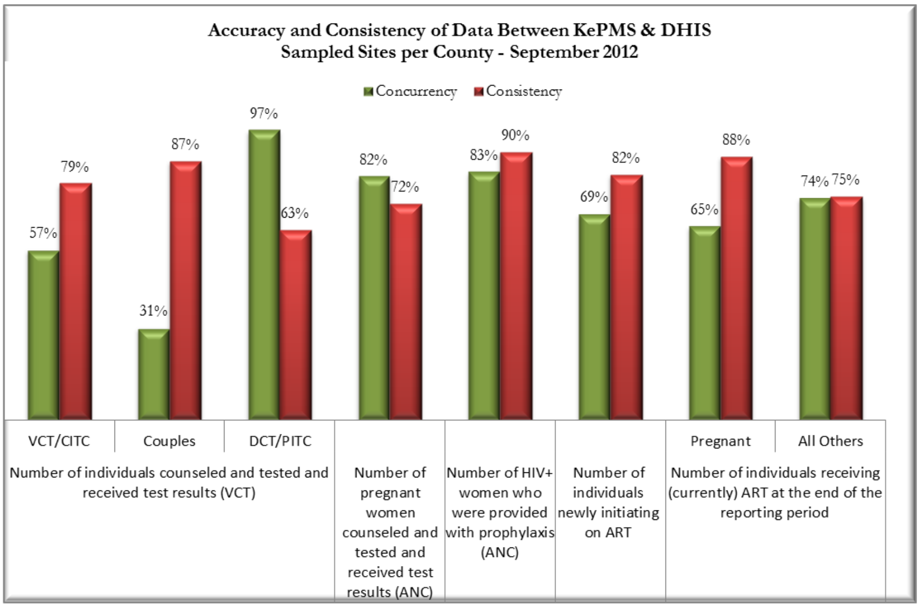

Fig. 1. Accuracy and consistency of Data between Kepms and DHIS, September 2012

Each indicator was analysed for consistency and concurrency. In general, the indicators displayed a very high rate of consistency of 79.5% in both systems. The average concurrence rates were however, lower at 69.7%. When both consistency and concurrence rates were analysed, the average accuracy rate for the data in both systems came at 74.5%. The following are the individual results for the indicators.

3.1 Number of individuals tested and received results through VCT (CITC)

For this particular indicator, the concurrency level was 57% in only 54 health facilities that had reported VCT services while consistency stood at 79% in all the 134 health facilities.

3.2 Number of couples tested and received through the VCT setting

Of the 45 health facilities assessed for concurrence, only 31% of them had similar numbers in the two softwares for Couples tested at the VCT setting. The consistency was at 87% for all the health facilities.

3.3 Number of individual tested and received results through Provider Initiated Testing and Counselling (PITC)

Out of the 107 health facilities that reported Diagnostic Testing and counselling/Provider Initiated Testing and counselling (DTC/PITC) data, the concurrency levels were at an all-time high of 97% while consistency was at 63% for all the health facilities.

3.4 Number of pregnant women tested for HIV in Ante Natal Care (ANC)

ANC services had the highest number of reporting sites i.e. 115 (86%) and concurrency was 82% while consistency was at 72% for all the health facilities.

3.5 Number of HIV pregnant women receiving Anti-Retroviral (ARV) prophylaxis

Out of the 47 health facilities that reported ANC prophylaxis, concurrency levels achieved was 83% while consistency was at 90% for all the health facilities.

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3.6 Number of individuals newly initiating on ARVs

Out of the 134 health facilities sampled, only 50 reported on the newly initiating clients on ART hence giving a concurrency level of 69% while consistency stood at 82% for all the health facilities.

3.7 Number of individuals currently on Anti-Retroviral Therapy (ART)

This indicator is a subset of the total clients currently on ARVs. Concurrency of data achieved was 65% for the 42 health facilities that reported pregnant mothers on ARVs while 88% of all the health facilities data was consistent.

3.8 Number of individuals currently on Anti-Retroviral Therapy (ART) (all others)

For all the clients currently on Anti-Retroviral (ARVs), only 65 health facilities reported on the indicator giving a concurrency level of 74% while consistency was at 75%.

4 Discussion

The DHIS is a recently adopted national system taking care of all the service delivery reports in the country. KePMs on the other hand monitors only HIV/AIDs data for the USG reporting requirements. The results show that consistency levels achieved were above 75% across all the indicators, hence a consistency level for the two systems had been attained. Minor differences in data could be attributed to data entry and poor data validation rules in both systems. Considering that both systems are well developed with highly trained personnel, it would be useful to find ways of enhancing their data quality and reducing duplication of data entry. For this to occur, each system would have to concentrate on different datasets to avoid duplication of efforts. One other possibility would be to address the accuracy rates in view of improving one system for use in the country. Since DHIS has a wider coverage, it is possible for it to be in a position to provide the platform for a national health information system.

In conclusion, the DHIS has proved that it is able to adequately serve the needs of HIV/AIDS reporting as required by the USG programs and has been recommended to take over the functions of KePMS.

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Statement on conflicts of interest

The authors will require further clearance from the Ministry of Health and USAID

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Automating Indicator Data Reporting from an EMR to Aggregate Data System Using OpenMRS and DHIS2

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Background and Purpose: Electronic HIS are considered essential for managing health information. However, due to challenges of implementing interoperability across HIS, often electronic data are manually printed and re-entered into aggregate data systems. In 2009, World Health Organization (WHO) developed Statistical Data and Metadata Exchange for Health Domain (SDMX-HD) to facilitate health indicator exchange. To date, no documented implementation has demonstrated a practical application of SDMX-HD in automating indicator data reporting. This study demonstrates the use of OpenMRS, to generate and transmit indicator data to DHIS2 using key principles of SDMX-HD.
Methods: We deployed OpenMRS and DHIS2 in a test environment at the US Centers for Disease Control and Prevention (CDC) Public Health Informatics Laboratory. OpenMRS was configured to send aggregate indicator data using DHIS reporting module and DHIS2 was prepared to receive them. The two applications were then linked and data exchange process was initiated in OpenMRS using demo data.
Results: Fourteen data elements with disaggregation were generated and transmitted to DHIS2 successfully. A report with the 14 data elements was accurately generated from DHIS2.
Discussions: Results indicate that indicator data can be sent automatically from OpenMRS to DHIS2, eliminating manual data entry. The success of this test will help evaluate the impact of implementing an automated generation of reporting indicators to reduce human resources needed to fulfill reporting requirements; and to improve data quality, completeness and timeliness. These impacts demonstrate that HIS scale-up can have a positive role in improving health service delivery, M&E, and public health planning.

Keywords: Health information systems, Electronic medical records, Data exchange, Indicators, Resource-constrained settings, Aggregate data

1 Introduction

Electronic health information systems (HIS) are increasingly being adopted for managing health information and evidence-based decision-making in many developing countries. This increase may be associated with the US President's Emergency Plan for AIDS Relief (PEPFAR) initiative to combat HIV/AIDS epidemic. PEPFAR supports implementation and use of patient and aggregate level HIS to track HIV/AIDS patient care, inform rapid scale up of antiretroviral therapy (ART), and for routine monitoring and evaluation (M&E) activities [1]. At health facilities, HIS enable management of patient information over time, and across health care settings and also support health workers to improve performance, compliance with clinical care guidelines and patient safety [2][3]. Policy makers and health

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system managers can utilize aggregate level systems for on-going monitoring of plans and programs, as well as for resource allocation purposes to improve health services [4].

Indicators are used to show the presence or state of a situation or condition. An indicator is defined as a quantitative metric that provides information to monitor performance, measure achievement and determine accountability [5]. In healthcare settings, indicators are used to measure results such as number of infections, reduction of new infections, level of coverage, quality, and outcomes of interventions and also for progress and situation reporting, health policy development and planning, and advocacy in country and globally. To better monitor the delivery of HIV care and treatment, including quality and outcome, and to report on program progress, the PEPFAR Next Generation Indicator (NGI) reference guide was released in 2009 [6]. These indicators were also developed to support harmonized planning and reporting processes. Currently, a strategy is being implemented to enhance host country ownership of HIV programs through alignment of PEPFAR reporting requirements and NGI with national reporting processes and M&E systems [7].

Even with the increased adoption of HIS, there are still challenges with data quality and timeliness for decision making due to multiple challenges of implementing interoperability across disparate HIS. Often indicator data from electronic medical records systems (EMR) are printed and manually re-entered into aggregate data systems. In resource-constrained settings, the consequences are: 1) increased burden to the already scarce human resources to support public health reporting from patient-level data; and 2) potential for reduced data quality from transcription errors; and 3) availability of information from delays caused by the additional step(s).

In 2009, World Health Organization (WHO) and its partners began to adopt the Statistical Data and Metadata Exchange (SDMX) standard to facilitate exchange of health indicator data from EMRs to aggregate data systems. SDMX is an initiative that fosters electronic standards to facilitate exchange of statistical information. SDMX version 2.1 standards were released in May 2011 and published as an “International Standard” (IS) 17369 on January 2013. Statistical Data and Metadata Exchange for Health Domain (SDMX-HD) was developed based on the SDMX version 1.0 standard[1] [8][9]. Since the SDMX-HD was developed, preliminary work has been done to implement it for indicator and other aggregate data reporting from EMRs to aggregate data systems, although with only limited success.

Recently, an Open Medical Records System (OpenMRS) module was developed by Health Information Systems Programmes (HISP)-India that implements some of the key principles of the SDMX-HD guidance document [8]. This module can support automatic indicator reporting to District Health Information System version 2 (DHIS2). The module triggers indicator data generation and transmission from OpenMRS to DHIS2. This indicator automation process can replace the need to print indicator data reports from an EMR and manually re-enter the data into an aggregate data system. As such, we wanted to test the data exchange functionality of the module to answer the following question: Is it feasible to automate indicator data reporting from an EMR to aggregate data systems? This paper reports on the test of automating indicator data reporting from one widely-deployed EMR, the OpenMRS, to DHIS2 with a subset of PEPFAR direct indicators. Using OpenMRS demo data[2], we examined whether it is feasible to send indicator data electronically from OpenMRS to DHIS2 without the need for manual data entry therefore automating the indicator reporting process.

2 Materials and Methods

2.1 PEPFAR NGI

The PEPFAR NGI reference guide released in 2013 classifies indicators in three ways [10]:

1. **Degree of importance/aggregation level** indicators are sub divided into three categories.

- Essential/Reported to PEPFAR headquarters (HQ) are considered to be of high importance and necessary to track the progress of HIV programs.

[1] SDMX version 1.0 standard is an International Organization for Standardization (ISO) published standard (ISO/TS 17369: 2005 SDMX)

[2] OpenMRS demo data used was accessed at https://wiki.openmrs.org/display/RES/Demo+Data

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- Essential/Not Reported to PEPFAR HQ are considered to be of high importance and necessary to track the progress of HIV programs, are reported to the PEPFAR country teams, and may vary by country.
- Recommended are indicators for partners and program managers who need additional information for program management.

2. **Reporting level** indicators are divided into PEPFAR direct and national indicators.

- PEPFAR direct indicators measure HIV targets or results of the PEPFAR program through its funded activities. These indicators are grouped in four technical areas namely prevention, care, treatment and health system strengthening.
- National indicators measure a country's HIV program targets and results.

3. **Standard M&E classification** indicators are divided into output, outcome and impact.

- Output indicators measure results of program activities,
- Outcome indicators measure the effect of program activities on target population
- Impact indicators measure long-term or cumulative effect of programs

2.2 Indicator selection

The indicator sample used was based on a subset of PEPFAR direct indicators. Based on preliminary work, we determined that indicators on care and treatment technical areas were appropriate for the test of indicator data reporting automation because data for these indicators are clinical and mainly stored in an EMR at the health facility. We excluded indicators whose data was not clinical, such as those measuring number of facilities offering a given service, and those that required facility and community based data. We included indicators whose data is collected on a routine basis.

2.3 Indicator data Exchange

We deployed OpenMRS and DHIS2 in a test environment at the US Centers for Disease Control and Prevention (CDC) public health informatics research laboratory (www.phiresearchlab.org). We prepared DHIS2 to receive indicator data by adding data elements for care and treatment indicators. Query statements to generate each data element from OpenMRS were created using an SQL editor. The query statements were embedded in an XML template generated from DHIS2 and the template uploaded to OpenMRS through the module. The two systems were then linked and the data exchange process initiated in OpenMRS to generate and transmit the data message to DHIS2. A report was generated in DHIS2 to confirm that data exchange was successful.

3 Results

3.1 Indicators tested

After excluding 3 indicators on nutrition whose data was not available in the demo data downloaded from the OpenMRS website, our sample included 13 indicators and 14 data elements (**Table 1**). Five indicators, C2.1D, T1.1D, T1.2, T1.3D and T1.4D, were disaggregated by age (less than 15 years and above 15 years) and gender (male and female) and one indicator, C2.2D, was disaggregated by age. Therefore the total number of data elements with disaggregation for the test was 30.

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Table 1. Care and treatment indicators selected for indicator data reporting test automation

	Indicator No	Indicator	Data Element	Disaggregation
Care Indicators				
1	C2.1D	***Number of HIV-positive adults and children receiving a minimum of one clinical service***	***Number of HIV-positive adults and children receiving a minimum of one clinical service***	***Age and Gender***
2	C2.2D	***Number of HIV-positive persons receiving cotrimoxazole prophylaxis***	***Number of HIV-positive persons receiving cotrimoxazole prophylaxis***	***Age***
3	C2.2N	Percentage of HIV-positive patients who are given cotrimoxazole preventive therapy	Calculated	
4	C2.4D	Percentage of HIV-positive patients who were screened for TB in HIV care or treatment settings	Number of HIV-positive patients who were screened for TB in HIV care or treatment settings	
5	C2.5D	Percentage of HIV-positive patients in care or treatment who started TB treatment	Number of HIV-positive patients in care or treatment who started TB treatment	
6	C2.6D	Number of eligible HIV positive patients starting Isoniazid preventive therapy (IPT)	Number of eligible HIV positive patients starting Isoniazid preventive therapy (IPT)	
7	C3.1D	Number of TB patients who had an HIV test result recorded in the TB register	Number of TB patients who had an HIV test result recorded in the TB register	
8	C4.1D	percentage of infants born to HIV positive women who received an HIV test within 12 months of birth	Number of infants born to HIV positive women who received an HIV test within 12 months of birth	
			Number of infants born to HIV positive women	
9	C4.2D	Percentage of infants born to HIV-positive women who are started on CTX prophylaxis within 2 months of birth	Number of infants born to HIV-positive women who are started on CTX prophylaxis within 2 months of birth	
Treatment indicators				
10	T1.1D	***Number of adults and children with advance HIV infection newly enrolled on ART***	***Number of adults and children with advance HIV infection newly enrolled on ART***	***Age and gender***
11	T1.2D	***Number of adults and children with advance HIV infection receiving ART***	***Number of adults and children with advance HIV infection receiving ART***	***Age and gender***
12	T1.3D	***Percentage of adults and children known to be alive and on treatment 12 months after initiation of antiretroviral therapy***	***Number of adults and children known to be alive and on treatment 12 months after initiation of antiretroviral therapy***	***Age and gender***
			Number of patients started on ART treatment in the last 12 months	
13	T1.4D	***Number of adults and children with advanced infection who ever started on ART***	***Number of adults and children with advanced infection who ever started on ART***	***Age and gender***

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3.3 Indicator data exchange

A total of 30 pieces of aggregate data for the 13 HIV care and treatment indicators were generated and transmitted to DHIS2 successfully (**Table 2**).

Table 2. Report results in OpenMRS after indicator data generation and transmission

Report result DataSet: HIV_CARE_TX OrgUnit: Eldoret Period: 200605	
Data Element: T1.4, Value: 66	Data Element: C2.2, Value: 136
Data Element: T1.4, Value: 124	Data Element: T1.4, Value: 12
Data Element: T1.4, Value: 8	Data Element: C2.1, Value: 1271
Data Element: T1.1, Value: 124	Data Element: C4.2, Value: 0
Data Element: C2.5, Value: 6	Data Element: C3.1, Value: 0
Data Element: T1.3, Value: 0	Data Element: C4.1DEN, Value: 168
Data Element: T1.3DEN, Value: 0	Data Element: T1.2, Value: 90
Data Element: T1.1, Value: 8	Data Element: C4.1, Value: 0
Data Element: C2.2, Value: 1455	Data Element: C2.1, Value: 2463
Data Element: T1.3, Value: 0	Data Element: T1.2, Value: 1760
Data Element: C2.1, Value: 116	Data Element: T1.1, Value: 12
Data Element: C2.4, Value: 6	Data Element: T1.2, Value: 896
Data Element: T1.3, Value: 0	Data Element: C2.1, Value: 232
Data Element: T1.3, Value: 0	Data Element: T1.2, Value: 162
Data Element: C2.6, Value: 61	Data Element: T1.1, Value: 66
Status; SUCCESS Description: Import process completed successfully DataValue count: [imports=30, updates=0, ignores=0]	

An HIV care and treatment report (**Table 3**) was created in DHIS2 with the 14 data elements sent from OpenMRS. The data in this report was identical to the report results transmitted from OpenMRS.

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Table 3. Report exported from DHIS2

HIV care and treatment Eldoret May 2006 (Generated: 2013-09-10)									
Data element name		**Disaggregation (gender and years)**							
		(15 +)	*(< 15)*	*(< 15, Female)*	*(< 15, Male)*	*Value*	*(Female, 15 +)*	*(Male, 15 +)*
C4.1DEN[3]	Infants born to HIV Positive women					168		
C4.2	Infants born to HIV positive women who are started on CTX prophylaxis within two months of birth					0		
C4.1	Infants born to HIV Positive women who receive an HIV test within 12 months of birth					0		
T1.3	Number of adults and children known to be alive and on treatment 12 months after initiation of ART			0	0		0	0
T1.1	Number of adults and children with advance HIV infection newly enrolled on ART			12	8		124	66
T1.2	Number of adults and children with advance HIV infection receiving ART			162	90		1760	896
T1.4	Number of adults and children with advanced infection who ever started on ART			12	8		124	66
C2.6	Number of eligible HIV positive patients starting Isoniazid preventive therapy (IPT)					61		
C2.1	Number of HIV-positive adults and children receiving a minimum of one clinical service			11	11		12	11
C2.5	Number of HIV-positive patients in care or treatment who started TB treatment					6		
C2.4	Number of HIV-positive patients screened for TB in HIV care or treatment settings					6		
C2.2	Number of HIV-positive persons receiving cotrimoxazole prophylaxis	1455	136					
T1.3DEN[3]	Number of patients started on ART treatment in the last 12 months					0		
C3.1	Number of TB patients who had an HIV test result recorded in the TB register					0		

4 Discussion

This test for automating reporting of indicator data demonstrates that this data can be sent electronically from OpenMRS to DHIS2 eliminating the need for manual data entry. The indicator data element report (**Table 3**) generated in DHIS2 was identical to the result report (**Table 2**) of indicator data generated and transmitted from OpenMRS signifying that data was exchanged between the two systems accurately. This indicator data was available in DHIS2 for use after transmission. This test show that automated data reporting has the potential to increase data availability and quality by reducing delays and transcription errors often introduced during manual data entry [11]. The ability to successfully automate indicator data reporting from EMRs to aggregate data systems will help evaluate the impact of these process improvements on both human resources needed to fulfill reporting requirements, and on data quality, timeliness and completeness, thus supporting HIS scale-up for health service delivery, M&E, and public health planning.

Feasibility for automating indicator data reporting from other EMRs used in resource-constrained settings to DHIS2 should be assessed, and conducted to map and document their automation process. This will help guide development of standardized indicator reporting from health facilities to the ministry of health and funders. The indicator data exchange feasibility is the first step in evaluating automation of indicator data reporting at a health facility. Future work should entail: 1) review of the PEPFAR indicators with monitoring and evaluation experts to identify appropriate indicators to exchange; and 2) configuration and automation of indicator data reporting for each indicator identified in a field test environment.

[3] DEN denotes denominator

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Disclaimer: The findings and statements in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Shaping the Evolution of the Health Information Infrastructure in Zimbabwe

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Background and Purpose: This paper describes the implementation process of an integrated health information system within the context of a developing nation. The Ministry of Health and Child Welfare (MOHCW) in Zimbabwe was engaged in migrating legacy paper and desktop based information systems to the District Health Information Software (DHIS2), a web enabled and open source technology. The aim of this paper is to contribute to the development of theory that can be adopted to improve outcomes in such endeavours.
Methods: The study is conducted using the Action Research (AR) approach whereby the authors were actively involved in shaping the implementation of the information system. It occurs within the broader context of the Health Information Systems Programme (HISP), where an AR approach, the Networks of Action, has been developed for sustainable interventions in developing nations. The work is also informed by the grounded theory methodology, whereby empirical data was the basis for making a theoretical contribution.
Results: An interorganisational network consisting of actors interacting at the administrative level of the public health system plays a central role in determining the trajectory of the health information infrastructure. Collaborative challenges at this level are demonstrated to lead to further fragmentation of the health system thereby increasing the inertia of the installed base. At the user level, numerous strategies to cope with the challenge of supporting the health information system are described. The development of capabilities at this level is shown to be key in increasing the adaptability of the installed base.

Keywords: Health Information Systems, Information Networks, Action Research, Developing Nations, Grounded Theory, Integrated Delivery Systems

1 Introduction

The health systems in Zimbabwe are constrained due to a shrunken infrastructure and increased information needs. The nation experienced major socio-economic and political vicissitudes in the period spanning 1998 to 2008. This eroded the significant gains that had been made in health information infrastructure strengthening which can be traced back to independence in 1980, with transformatory activities being recorded from as early as 1982 and computerisation in 1985 [1]-[3] (as referenced in [4]). However, the nation witnessed resurgence from 2009 to 2013, during a period when a unity government was in place. In this time frame, the Ministry of Health and Child Welfare (MOHCW), in partnership with stakeholders, started to migrate its information from decentralised, paper, and standalone software systems to an integrated, centralised, and web based system utilising the District Health Information Software (DHIS2).

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A rallying point for stakeholders within the discourse on HIS strengthening was, and continues to be, the prevalence of fragmented systems and the need for standardisation [5]. In order to direct scarce resources to critical and high impact areas, program specific systems flourished in many developing nations [5]. These were isolated from the broader health systems leading to their characterisation as vertical, siloed and fragmented [6]. Programs, such as those focusing on AIDS and TB, had their own information systems and funding arrangements, which contrasted with the poor condition of the surrounding infrastructure. The flow of information across the vertical organisational boundaries was therefore problematic. As information needs continued to increase, and resources decrease, many nations have chosen to develop 'shared' information infrastructures, thereby the call to integration of disparate systems [5][7].

Advances recorded in the internet infrastructure within many developing countries are lauded as an opportunity to achieve health system integration [8]. Projects aimed at replacing the paper-based and standalone systems with centralised internet based technologies continue in numerous nations, including Zimbabwe [5][9][10]. This network revolution within developing nations is also supported by the high proliferation rates of wireless internet access[11]. Health systems in developing nations seek to leverage these network infrastructural developments to achieve better healthcare for citizens and to improve the working conditions for public servants. Furthermore, as will be demonstrated in this study, health systems strengthening projects lead infrastructure development efforts within the domain. The domain consisting of a multiplicity of stakeholders such as policy makers, donor organisations, researchers, civil servants, developers and private interests [12]. The evolutionary path of health information systems is therefore determined by events that are not only specific to the implemented technologies but also originate in these organisational structures and the corresponding interactions [5]. The strengthening of the health information systems in developing nations is therefore considered as a complex socio-technical concern requiring systems thinking approaches to resolve [13]. The large scale nature of health systems development programs also entails their characterisation as information infrastructures [14]. This differentiates them from the smaller information systems projects that have fewer 'moving parts' and are limited in their temporal and spatial reach.

We will now continue by providing a review of information infrastructures literature for comparative purposes, paying attention to the different approaches that actors engage to resolve their concerns within the evolving socio-technical system. The methodological approach adopted in the study is given in the materials and methods section, after which we provide an analytical description of the evolution of the information infrastructure in the results section. Finally we conclude by discussing the practical and theoretical contribution from the study.

1.1 Information Infrastructure

An Information Infrastructure has been defined as "a shared, open, heterogeneous and evolving socio-technical system consisting of a set of IT capabilities and their user, operations and design communities" ([15]. P. 4). Typical information infrastructures are the internet (15), health information systems [14][16], public sector ICT architectures [7], and online collaborative environments [17]. These are to varying degrees, shared, open and contain numerous differentiated and interconnected parts and are therefore heterogeneous. Furthermore, they are constituted of IT capabilities distributed among their users, operations personnel and designers. A key to understanding the evolution of infrastructures is the installed base [7]. An installed base is the pre-existing and current state of a system and can be discovered and experienced as resistance or inertia during periods of change [15]. This shows that an information infrastructure is relational to the people and practices which it supports and it can not be known without them [18][19].

The evolutionary trajectory of an information infrastructure emerges from the resolution of the tension of whether a chosen path can initially accommodate the needs of an installed base on one hand, and whether it can be adapted to the needs of a growing user base on the other [15][16][20][21]. Tension arises due to the multiplicity of actors engaged in infrastructure development activities since what is often posited as the best design by others often falls short in the context of implementation, requiring innovation to appropriate to local contexts [22]. These issues are more pertinent in the "global village" where initiatives designed abroad find themselves in local settings, a process which has been called glocalisation [23]. The resolution of the tension between the local and the global is a key process for the

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emergence of infrastructure [19]. A tension has also been identified between the technical and social view of information infrastructures [19]. It is when these tensions are resolved that an information infrastructure emerges [12][19].

Shaping the Evolution of Information Infrastructures.

Of critical importance in the area of health systems development, is shaping the evolutionary trajectory of an information infrastructure [12][15][24]. This is important given that the evolution of infrastructures is intrinsically path dependent [15]. Once a decision is made to adopt specific systems and the installed base is developed, it becomes difficult to reverse the unintended side effects due to potential lock-ins [24]. An example that is often cited is that concerning the adoption of the QWERTY keyboard, which has become a de facto standard. Even if the Dvorak format of keyboard is espoused to be more efficient, it remains difficult to implement under current conditions due to the dominance of the QWERTY layout [25]. The paradox is that path dependence is also desirable due to the security of continuity it provides to organisational life [26]. Due to these seemingly conflicting attributes, an information infrastructure is therefore considered as a complex phenomenon. It grapples with intended goals and emergent unexpected consequences [26]. These shape its actual trajectory in practice and research suggests that the result is a high rate of unmet expectations [19][27]. To tackle this reality, studies on the suitable approaches that can be adopted to harness complex environments are widespread in the information systems discipline [12][28].

1.2 Macro Intervention Strategies

A primary approach for shaping public sector information infrastructures is standardisation. This entails bringing together stakeholders from government, the private sector, civil society, international agencies and research institutions to collaborate in the standardisation process [7]. These agencies have been recognised as prominent in shaping the evolution of ICT infrastructure in developing nations [12]. However, their engagement has also been recognised as problematic since the domain of their operation has a political character [29]. For instance in a study of health systems in Guatemala, Silva and Hirschheim [30] demonstrate how a health systems program was terminated as soon as one political party lost elections in the nation. The reason provided in this study (ibid) was that the health program had failed to alter the deep structures, that is the political culture that had become entrenched due to agreements made to end a civil war that had lasted for more than three decades. While such a case is unique, it remains that organisational networks are scenes where the negotiation of power occurs and infrastructural decisions are made [29].

1.3 Micro Intervention Strategies

While decision making is typically a concern for those in the realms of management, users and developers of systems adapt numerous strategies to cope with their corresponding challenges [22]. Concepts that have emerged in understanding how activities at this level shape infrastructure are bricolage, improvisation and articulation work [16][22]. Bricolage has been aptly defined as “the ways that individuals and groups borrow from existing cultural forms and meanings to create new uses, meanings and identities” [31]. Improvisation is a related concept that emphasises the momentary and timely aspects of reacting to emergent challenges [22]. Articulation work however, is differentiated from the concepts above in that it does not presume that that actors have “much control to stabilise the meanings and purposes of technologies” [31].

A characteristic which enables investigation of information infrastructure is that it is invisible except when undergoing design or has broken down [19]. When breakdown of infrastructure is imminent, articulation work ensues to cope. Articulation work has been defined as the work that enables other work [32]. Articulation work is therefore considered as infrastructure work [19]. There are different forms in which articulation work can be observed during breakdown such as ‘making do’, ‘workarounds’ and ‘institutional rearrangements’ [32]. The activities that ensue when infrastructure breaks down are occasions for innovation [16], and are seen by Ciborra [22] as important considerations in the formulation of strategies to develop information systems.

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2 Materials and methods

The study was primarily conducted within the action research approach which is the dominant method within the global Health Information Systems Programme (HISP). There are a number of action research approaches identified in IS literature [33] and the specific method chosen in this study is informed by the networks of action approach [21]. It emphasises the importance of collaborating with a diverse range of stakeholders in different organisations in order ensure the sustainability of an intervention [21]. The network of action approach does not prescribe procedures for data collection and analysis; hence a complementary method is appropriate to improve on the rigor of the study. To address this, the grounded theory method (GTM) was utilised. It is an inductive method which allows for the consideration of various data sources for the purpose of constructing substantive theory [34]. It offers a range of analytical procedures such as open coding, selective coding, theoretical coding and constant comparison [35]. The combination of the two methods to understand practice is not novel in the Information Systems discipline and this mixed approach has been named ‘grounded action research’ [34][36]. The procedures of open coding, selective coding and theoretical coding were utilised on the data collected during the action research.

The data utilised in the study was obtained from 8 qualitative interviews, 7 meetings with stakeholders, direct observation, project documents and by participating in conducting systems analysis. Field notes were the dominant method of capturing events. The participants included health information officers, information managers, program heads, donor agents and software developers. Constant comparative analysis was conducted on the data from 2 field work visits of 4-5 weeks each. Coding of data was conducted utilising nVivo software. The broad aim of the study was to discover the core concerns shaping the evolution of the information infrastructure understand how they are resolved by actors and develop theory on how they can be leveraged to improve outcomes. Categories generated through open coding were compared with other related codes and with concepts found in literature. Care was taken not to force concepts onto the data, and the principle of emergence of concepts from data was adhered to. Theoretical sensitivity was developed through a continuing literature review. The study is epistemologically critical and interpretive [37]. It is critical as it seeks to develop appropriate ideas to intervene to enable change and interpretive in that the authors acknowledge their involvement is implicated in the evolution of the information infrastructure.

3 Results

The MOHCW in Zimbabwe made significant progress in transforming its health information infrastructure enabled by a decision to change the decentralised paper and standalone software based information system to one that is centralised, integrated and web based. The health information system is organised into four levels, constituting the health facility, district, provincial and the national levels. The system had been based on a range of paper based registers implemented in all health facilities and collated on a monthly basis for reporting to the district level. At the district, the aggregate figures from the health facilities were recorded into a standalone ‘Microsoft Access’ based technology called DHIS 1.4. These were further aggregated upwards to the provincial and national levels through sending data files by email to the respective information officers. The entire process of sending data from the facility level up to the national level has been known to take up to a month, therefore affecting the timeliness of reporting. To circumvent this challenge, a weekly surveillance system was implemented using mobile technology, where all health facilities were provided with mobile devices as tools to report a limited amount of time critical health information. However, the MOHCW took a further step to implement a web based reporting system called DHIS2 in order to tackle the issue of fragmentation.

3.1 Sacrificing and Improvising

A key issue observed in Zimbabwe was the challenge of internet accessibility, from the level of district and below. Health workers from two rural hospitals and a district office visited within one district had been using wireless dongles which required that they performed data entry at midnight when internet access improved. This would be a form of articulation work, and one participant noted that this

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"sacrifice" was necessary. Another health worker also noted a challenge in obtaining a username and password to access the laptop for data entry into the system. This had occurred due to the fact that the health worker who had been trained for data entry into the system had since left the facility. Improvised in-house training had been arranged by nurses at the rural hospital to fill the gap. However, the laptop was lying idle due to a failure to obtain access privileges. With internet accessibility such a problem could have been resolved through remote desktop tools. This demonstrates the need to develop IT capabilities, so that such issues can be resolved locally. As noted by a manager: "*most of our personnel on the ground, that is the district health information officers ... their skills are limited in terms of what they actually know in IT*". This type of breakdown would require top management support and institutional rearrangement for sustainable repair.

3.2 Health System Development Network

The ministry was the key decision making body for the health information system intervention, which it implemented through an interorganisational network. A multiplicity of actors had been engaged in the development of the health information infrastructure by the MOHCW. At the institutional level, the network was composed of donor organisations, academic institutions, private companies, health programs and consultancies representing local, regional and international interests. These organisations are pivotal in shaping the trajectory of the evolution of the infrastructure by providing financing, technical competencies, and other material and non material resources.

The network is engaged with the ministry in their different capacities, and being part of the installed base contributes to its inertia. Inertia arises due to challenges in collaboration among actors due to a lack of clarity on procedure. As one participant noted: "*you can not jump certain steps ... we can only engage other people to get on board [when] the system is fully running ... inasmuch as technology is ready, policy is not ready so you still have to go back to policy and check what are the policies governing these people?* ". Challenges in collaboration can further fragment interventions on the ground, increasing the work of health workers to keep up with information needs. For instance reporting online can be requested from facilities that have not had access to internet infrastructure, impacting on data quality. In one instance, it was observed that electronic devices that were acquired for acquiring co-ordinates to enable tracking of individual cases of Malaria where highly proprietary and could not be easily programmed to address cross platform needs. Given that the acquisition process had been initiated, it was not possible to reconsider the alternatives. Such issues highlight the importance of improved collaboration among the stakeholders and how the outcomes of the decision making process can increase the inertia of the installed base.

3.3 Implementation Strategies

A key strategy used to intervene in the information systems of the MOHCW, is engagement with top management for support. Decision making is centralised in the health ministry, making such engagement crucial for success. A project manager noted that they had earlier tried a bottom up approach and faced challenges. This also suggests that an adaptive strategy is important for a successful intervention. To adhere to formal protocol meant early planning, as noted by a participant: "*getting an IP address took 6 months ... so we had to start early*". A multi-stakeholder meeting to discuss HIS support could not take place due to concerns raised about protocol. This also showed that power was an issue among implementation partners. There also existed a conflict of interest which increased inertia of the installed base. In an instance, a data manager in one organisation lamented as to how he was failing to get access to information on the latest health facility list, a problem that affected the organisations ability to meet internal reporting deadlines and had been ongoing for months. Access to information in the ministry is centralised, and the level of access by external stakeholders is related to ones positioning in the network. A project head noted the importance of attending to '*low hanging fruits*' as a strategy for success in this context. A manager also noted the importance of knowing "*where you are going*", while others lamented slow progress due to collaborative inertia. Information officers interviewed highlighted that, it was not only an issue of power that caused some interventions to flourish over others, it was how they assisted in alleviating concerns of the health worker. A key concern among health workers is the burden of balancing data entry in the numerous registers, and providing patient care on the other. Agencies that required

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increased data access and offered no direct incentives to reduce the workload of health workers faced a risk of failing to meet their objectives.

4 Discussion

In this study we find that while a bottom up approach to interventions is critical, engagement with the structures where power is negotiated is also important for success. The role of networks in shaping information systems projects in developing nations has been recognised in a study by Njihia and Merali [12] who studies the evolution of ICT provision in Kenya over a period of 42 years. They (ibid) develop a mechanism highlighting that certain changes to systems can lead to stasis or genesis. This supports the finding in this study that activities by actors in interorganisational networks can increase installed base inertia, particularly if they are fragmented, or reduce it through collaborative activity. It also confirms path dependence of information infrastructures, thereby demonstrating the network effects of decisions made by interorganisational network participants. The concept of donor dependence is of crucial importance here, since the activities they undertake can serve to entrench their interests in the installed base. One way that has been suggested to improve outcomes in information infrastructure projects has been to increase heterogeneity of actors in implementation networks, including those with diverse views into the process [15]. This should however be accompanied by the development of policy in order to reduce the advent of opportunistic behaviour [38].

Further work aims to develop the emerging conceptual model and to integrate the findings into the broader literature on information infrastructures. Issues that are of importance to further research include the development of strategies to improve collaboration in interorganisational networks, leveraging the installed base by paying attention to how implemented technology interacts with work practices, and institutionalising adaptive technology appropriation mechanisms. Specific consideration should also be given to the embeddedness of infrastructure in wider society, and the key issues that arise. Studies could do more to clearly demonstrate how the evolutionary trajectory of information infrastructure is located within the wider infrastructure of society. This would entail the development of substantive theories which are faithful to the contexts studied.

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Hospital Information Management Using Open Source Software: Results of the MIDA Project in 3 Hospitals in Rwanda

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Background and Purpose: The health sector in many developing countries, especially in sub-Saharan Africa, suffers since a long time from poor health information collection and analysis systems. This study evaluates the results of 3 projects financed by the Migration for Development in Africa-Great Lakes (MIDA GL) program in 3 Rwandan hospitals: Kigali University Teaching Hospital (CHUK), Neuro-psychiatric hospital Caraës-Ndera (NPH-CN) and Gihundwe district hospital (GDH). These projects aimed to empower hospital staff in collecting and analyzing hospital information by using OpenClinic, an open source hospital information management system.
Methods: The first analysis at CHUK used the results of a CAP (competence, ability, practice) survey addressed to healthcare staff in using OpenClinic, in 2010 and 2012. The second method analyzed results of NPH-CN and GDH in the OpenClinic software utilization between 1/1/2011 and 31/12/2012.
Results: Results showed that routine OpenClinic utilization increased by 20% (from 36.0% to 56.3%) at CHUK between 2010 and 2012 and skills levels increased significantly in admission (+9.2%) and laboratory (+10.0%) departments where the training programs were run. The results obtained from the hospitals of Gihundwe and Ndera showed that the 2 hospitals almost doubled their income one year after implementation and indicators like case load, encounter load and numbers of provided health care deliveries continue to increase linearly, demonstrating the continuity of OpenClinic utilization. Clinical modules however have not yet been well adopted in Ndera and Gihundwe: reason for encounter documentation and diagnostic coding are not being performed systematically.
Conclusion: The MIDA GL funding allowed 3 Rwandan hospitals to implement the OpenClinic tool easily and to improve its utilization by gathering and centralization of health information in real-time. The improvement of user skills level in OpenClinic enabled them to take ownership of the tool proving the need for regular staff training and evaluations in the OpenClinic utilization.

Keywords: MIDA, Empowering healthcare staff, OpenClinic utilization, Hospital information system, Rwanda

1 Introduction

The health sector in many developing countries, especially in sub-Saharan Africa, suffers since a long time from poor health information collection and analysis systems. Different causes can be identified: lack of financial resources, insufficient skills and bad performing tools for collecting and analyzing information.

First of all, the investment in health information in developing countries, particularly in Africa, remains too low. It is estimated that working health information systems require at least US$ 0.53 per

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capita in low-income countries and US$ 2.99 per capita in high-income countries [1]. Those figures may be on the low side. A study in Sierra Leone estimated the cost of running a complete system of health information at US$ 1 per capita per year [2].

Secondly, many developing countries suffer from shortage of staff with relevant training and skills in statistics, epidemiology, demography, public health and informatics: partly because too few people has been trained, and partly because of the inability of the public sector to retain qualified staff with low remuneration levels compared to the private sector. Another cause of the lack of skilled human resources in many parts of Africa is the mass exodus of leaders and university graduates. Political instability, armed conflicts, unemployment and poor governance are all incentives to emigrate to regions deemed more developed and stable. This brain drain is for many African countries a major obstacle to sustainable development, particularly for the health, education and rural development sectors [14].

Thirdly, paper-based systems continue to dominate in health information collection. According to the second Global Survey on eHealth conducted by WHO in 2009, nearly 90% of the responding countries reported relying on paper-based individual patient records at the health facility level, and less than 30% of countries reported using electronic records. At the subnational level, where aggregate patient information is essential for resource management, paper-based systems are prevalent in almost 60% of the responding countries, while slightly over 40% of countries report that their aggregate patient information is digitalized and can be transmitted electronically [3].

In Rwanda, the collection of information is most often done manually, at the end of the month by counting cases from registers. This work proves to be an important administrative burden because many instances require reports: ministries of health, vertical health programs, international organizations, etc. Also, the numbers of health indicators being collected is very high. The Rwandan Ministry of Health reports serve a range of donors with 890 separate health data items, 595 relating to HIV and malaria alone [4]. Since 2006, ICT-tools have been systematically introduced for organizing the Rwandan health information system. In 2008, a study has identified four types of systems for collecting and centralizing health information [5]:

1. Public Health Informatics, to evaluate population health, to monitor health trends, and to create a responsive surveillance system. Eventually, this becomes the National Health Information System (NHIS).
2. Electronic Health Records such as OpenMRS (Open Medical Records System) [15]
3. Mobile e-Health systems using mobile technology (SMS) to gather clinic level information on infectious diseases through mobile phones using Voxiva's TRACnet software.
4. Telemedicine – Information and communication technology used to deliver health and healthcare services, information and education to geographically separate parties

The major problem of these solutions is the lack of interoperability as each program has been developed in isolation from the others.

Meanwhile things have improved under impetus of the desire to create a national system for centralization of health indicators. Several systems currently exist within the health management information system (HMIS). Health facilities with internet connection use short messages (SMS) and Health information Systems (HIS) data stored remotely on a central server and others without internet connection fill electronic forms and put them on a stick. These files will subsequently download at the central server. If it appears that the electronic transfer of health information to the central level was a giant step forward towards more complete data gathering, the gains are however less spectacular when we look at the quality of the collected information. Data are mostly not collected in real-time but are manually compiled from several registers and then copied to electronic reports afterwards.

A new experience of real-time gathering and centralization of health information began in late 2007 at the Kigali University Teaching Hospital (CHUK), a national referral hospital in Rwanda. The information system that was implemented in this hospital has been completely tailored to local user requirements. The initially narrow-scoped set of ICT-tools has been progressively evolved to an integrated hospital management system under the name OpenClinic (OPEN system for Comprehensive heaLth facility INformation management in low Income Countries) [16]. Currently, the software runs in some 20 public and private hospitals in Africa, including 10 hospitals in Rwanda [6].

This open source software, which is focused on integrated patient record management, aims to generate predefined sets of indicators based on secondary use of routinely collected clinical data.

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Generated indicators relate to the hospital activities, user performance, health facility income, health insurance and reason for encounter- and diagnostic coding using international classifications such as ICD-10, ICPC-2, DSM4, LOINC etc… [6].

At the hospital level, information collected are important because they also allow to determine hospital performance indicators and hospital self-management that Government currently requires to public Rwandan hospitals in contracting policy using Performance Based Financing (PBF)-programs [7]. Today's hospital managers are being asked to derive performance indicators for their health facility, which are focused on the optimal use of hospital capacity, such as case load, admission load, length of stay, bed occupancy rate, cost effectiveness, disease costs etc. They are also called to report on the efficiency of the hospital, staff performance, procedure costs etc. [8] Part of a prospective global budget funding, a budget in balance becomes an important criterion for judging management quality. For private hospitals, profit may even be the primary performance criterion.

Therefore, it is crucial for the hospitals not only to report for the national health information, as required, but also to report on hospital performance, via solid measurements. Information collection that contributes to indicators and appropriate measurements requires skilled staff and computer tools for collecting, centralizing and analyzing health information indicators in real-time.

Concerning staff skills, Rwanda is a country that has experienced a significant loss in human lives and important brain drain due to the genocide and war in 1994. But if the brain drain is among many factors contributing to the underdevelopment of certain African regions, currently in Rwanda, the policy of the Ministry of Foreign Affairs and Cooperation through its Diaspora Directorate judge these movements as an opportunity to promote economic and social development using migrant intellectual potential acquired in the host countries [17].

This is why Rwanda benefits the projects from the Migration for Development in Africa (MIDA) program initiated by the International Organization for Migration (IOM) to develop synergies between Great-Lakes migrants' profiles and Rwandan country needs in the areas of health, education and rural development. Mida GL program aims to develop public and parastatal institution human capacity in knowledge and skills using migrant competences in Great Lakes countries (Rwanda, Burundi and RDC) [14]

Thus, in the health sector, the MIDA Great Lakes (MIDA GL) Phase IV (2009-2012) program supported 3 Rwandan hospital projects in health informatics capacity building. Those hospitals are:

- University Teaching Hospital of Kigali (CHUK), the greatest reference hospital (450beds) located in Kigali-city,
- Neuro-Psychiatric Hospital-Caraës Ndera (NPH-CN), 280 beds, a mental health reference hospital located in Kigali-City, 15 km from the center. It is a private facility runs by the Brothers of charity.
- Gihundwe District Hospital (GDH), 180 beds, located near the border with RDC at the most southern point of Lake Kivu, in Western province.

The CHUK project was to create a continuous training and research center in health informatics

The proposed project of NPH-CN was to develop an electronic dictionary coding diagnosis (Thesaurus) using International tri-classified (ICD-10, DSM-4 and ICPC-4) codification for disease cases encountered in mental health [18].

The project of GDH aimed to improve the management of patients and finances, including staff expenses.

The three hospitals currently implement the hospital management information system using OpenClinic software. CHUK was the first to use OpenClinc from early 2007. The last 2 hospitals have implemented the system in the framework of the MIDA GL phase IV program. GDH started in December 2010 and NPH-CN in August 2011

The implementation process of the hospital management tool was followed. This process includes the steps that have been implemented in other hospitals where OpenClinic runs [6] including a period of training and follow-up and a period of maintenance and assistance.

To implement the OpenClinic system, GDH has received funding for the administrative part of the system, which includes modules for patient identification (ID); admission, discharge and transfer (ADT), financial management and reasons for encounter (using ICD-10 and ICPC-2 codes). The NPH-CN received funding for the implementation of all modules including new developments thesaurus tri-classified diagnosis coding, ICD-10, DSM-2 and ICPC-4.

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MIDA GL program financed each project up to € 50,000. 60% of the funding was used to pay experts from Diaspora who came to support partner institutions, especially for human capacity development. 7 MIDA experts followed one another at the 3 hospitals to support them in the implementation of these projects. They made in total 24 missions of each 30-day average over 3 years MIDA GL program.

This research focuses on the results of the 3 projects in the field of empowering healthcare professionals in collecting and analyzing health information using the OpenClinic over a 3 year period, during which they were supported by the MIDA GL program.

The overall objective is to evaluate the results achieved in the implementation of the MIDA GL projects in 3 Rwandan hospitals, focusing on the empowerment of healthcare hospital staff in health informatics in order to allow them to improved collecting and analyzing hospital information by using the Openclinic tool. As specific objectives, the study:

- Analyzes healthcare staff competence, ability and practice (CAP) in using OpenClinic system at CHUK
- Analyzes efficiency in using OpenClinic at Ndera and Gihundwe hospitals.

According to the MIDA GL program schedule, the 3 projects have been implemented from 1/1/2010 to 31/12/2012. We will focus on the period when the project began in an each institution until 31/12/2012.

2 Materials and Methods

Based on the elaboration of the 3 projects we have developed 2 types of analysis:

- The first analysis uses the results of a CAP (competence, ability, practice) survey addressed to healthcare staff in using OpenClinic software at CHUK between 2010 and 2012.
- The second was to analyze the results of NPH-CN and GDH in the OpenClinic software utilization between 1/1/2011 and 31/12/2012.

Under the MIDA GL program in its 4th phase, several activities were carried out in hospitals CHUK, NPH-CN and GDH to support these 3 hospitals to build their healthcare staff capacity in health informatics. These activities sum up to:

- Purchase and install computers
- Install and configure the local network
- Install and configure a hospital management system (OpenClinic software)
- Train in health informatics: epidemiology, statistics, general computer and OpenClinic software utilization;

The vast majority of the hospital staff (specifically the staff from hospitalization and lab departments for the CHUK) has been included in the MIDA GL project. They have been, primarily, trained in OpenClinic utilization.

We focused our analysis to the impact of the OpenClinic software utilization. To do this, we used the results of the CAP survey in CHUK and the results achieved by GDH and NPH-CN in OpenClinic implementation. The results of those indicators were derived from the statistics module of OpenClinic and from the Global Health Barometer (GHB) centralized indicators [19]. The GHB performs fully automatic health & performance indicator extraction from local databases and merging of the resulting data into a single central database.

The CAP surveys were conducted in the CHUK in August 2010 and August 2012. A sample respectively of 69 and 96 healthcare staff (OpenClinic users) responded to the questionnaire. Epi Info 3.5 was used to enter and analyze the survey data. This survey allowed us to measure several indicators:

- The software utilization level expressed in terms of OpenClinic daily utilization by the healthcare staff
- The satisfaction level of healthcare staff in OpenClinic utilization
- The general skills level of healthcare staff in OpenClinic software utilization, expressed by grouping variables related to the utilization, perception and satisfaction, and by departments

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To measure the efficiency in OpenClinic utilization as a health information system in the hospital management, we used statistics obtained from OpenClinic systems installed at NPH-CN and GDH sites and from the statistical indicators centralizing in the GHB. The following measures were used:

- Comparison of incomes by healthcare delivery groups during 2 years of OpenClinic project implementation.
- Evolution of the number of a representative sample of recorded data to assess the extent and quality of data collected.

3 Results

3.1 CAP survey results

The MIDA GL project trained more than 300 people in the utilization of computer applications, in particular the OpenClinic system, which has become a tool for daily work at the 3 hospitals.

According to the GHB, in 2012, 791 OpenClinic users are configured at the CHUK, 147 at NPH-CN and 81 at GDH. Among CHUK users, 69.2% were female and 30.8% male.

According to the CAP surveys conducted in 2010 and 2012 at CHUK, the sample was represented respectively by 69 and 96 OpenClinic users. Hospitalization and laboratory department's staff represent respectively 52% and 20% of all potential OpenClinic users staff.

The survey also showed that in 2010, 26.1% of respondents were male against 72.5% female. And in 2012, 28.6% of respondents were male and 71.4% female.

On the level of utilization the percentage of daily users of the system increased between 2010 and 2012, from 36.0% to 56.3%.

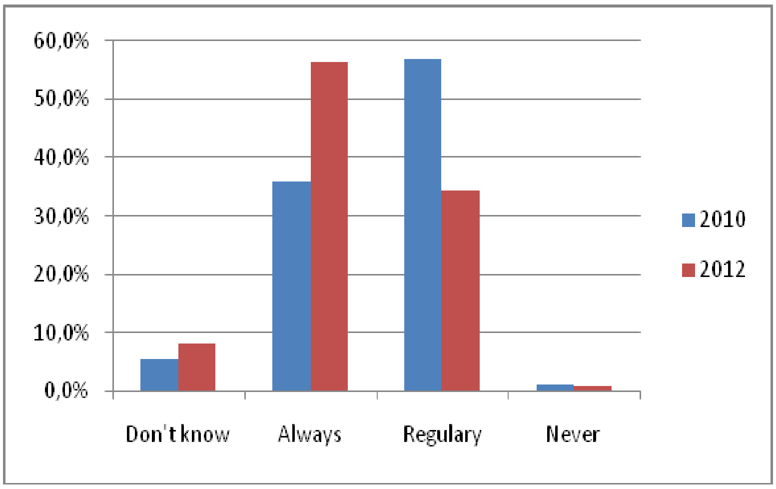

Fig. 1. OpenClinic daily utilization level at CHUK in 2010 and 2012

We also noticed looking in the CHUK OpenClinic database that the number of OpenClinic users increased between 2010 and 2012. It went from 600 to 790 between December 2010 and December 2012. The majority of news users are those who work in the hospitalization and lab departments.

The survey showed that while in 2010, 34.8% of users estimated that the system helped them to fulfill their tasks; this has increased to 45.3% in 2012.

Regarding the degree of satisfaction in the OpenClinic system, in 2010, 84.1% of respondents were satisfied (17.4% very satisfied) against 5.8% who are not happy. In 2012, 84.4% of respondents were satisfied (21.9% very satisfied) against 3.1% who are not happy.

To determine staff skills in OpenClinic, we combined variables related to the utilization, perception and satisfaction in OpenClinic. The graph below summarizes the level of general OpenClinic skills level by CHUK departments in 2010 and 2012.

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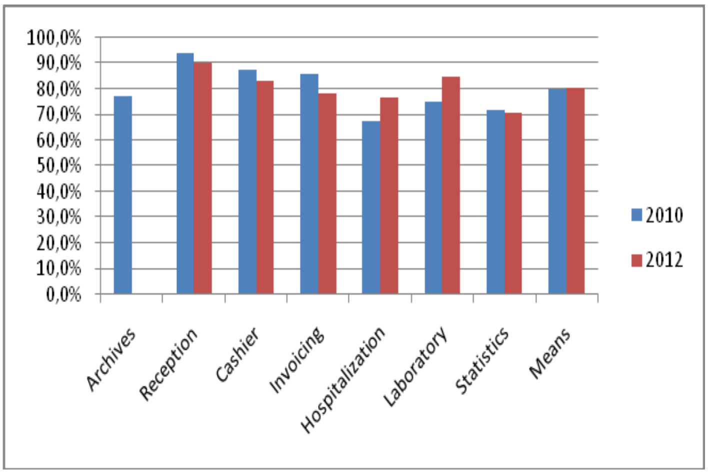

Fig. 2. OpenClinic skills level at CHUK departments in 2010 and 2012

The general OpenClinic skills level average is 80% (SD = 9.2%) in 2010 and 81% (SD = 8.3%) in 2012.

The level of skills in OpenClinic utilization have greatly increased in hospitalization and lab departments between 2010 and 2012, respectively, from 67.5 to 76.7% and from 75.0 to 85.0%. This is justified by the profile of the staff who attended the training provided within the framework of the MIDA GL project at CHUK.

3.2 Efficiency of the system

The efficiency in the system is based on the revenue gain recorded and the volume of information stored in the Openclinic system at NPH-CN and GDH.

Hospital incomes recorded in OpenClinic consist in payments of the patient and the insurer, under the health insurance policy. In Rwanda, the costs of patient care are covered by the patient himself, his insurer and sometimes an additional insurer.

As our 2 hospitals have begun to improve by using OpenClinic billing software from the 2nd (at GDH) and 3rd (at NPH-CN) quarter in 2011, we decided to compare the incomes recorded for the 4th quarters of 2011 and 2012.

We noted that the income for the quarter nearly doubled from 133 million to 206 million between Q4 2011 and Q4 2012 at NPH-CN. We noted the same trend at the GDH. Looking also the income generated by the 2 hospitals in 2011 and 2012, we noted a significant increase in revenues. If we take the GDH, we noted that within the 4 last years, its revenues tripled!

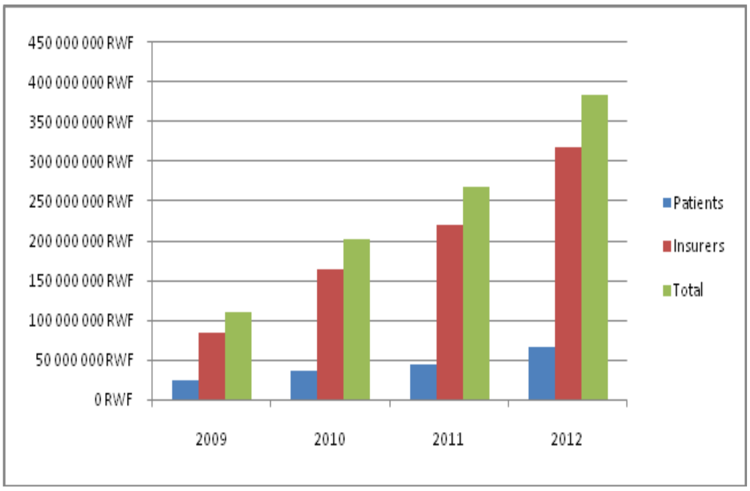

Fig. 3. GDH incomes evolution from 2009 to 2012

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GDH revenues increased compared to 2009: +83% in 2010, +141% in 2011 and +246% in 2012. The computerization of patient records might explain increases in the last 2 years.

We analyzed the evolution of the indicators from their systems regarding the number of patients and the number of encounters.

At GDH, between 2011 and 2012, the number of patients in the database was 53,261 of which 66.9% are female and 33.1% male. The distribution by gender is statistically different ($p<0.00$). The GHB showed that the children less than 5 years represented 9.3% of the patients at the end of fin 2012.

At NPH-CN, the data base contained late 2012, 50,599 of which 50.4% are female and 49.6% are male. The proportion of women was not statistically different than the proportion of men ($p=0.45$). The GHB showed that the children less than 5 years represented 5.4% of the patients at the end of fin 2012.

The number of the encounters increased in a constant way at the 2 hospitals. It exceeded the 55.000 at HDG and 50.000 at HNP-CN at the end of 2012.

The “in-depth” analysis of encounters is summarized in **Table 1**. The table shows the number of consultations and hospitalizations per year registered in Gihundwe and Ndera hospitals for 2011 and 2012.

Table 1. Patient encounters at HDG and HNP-CN in 2011 and 2012

	HDG			HNP-CN		
	2011	**2012**	**Total**	**2011**	**2012**	**Total**
Number of new admissions	6 023	6 616	12 639	1 915	3 321	5 236
Median of number of admissions days	6	8	6	11	10	10
Number of consultations	19 762	20 735	40 497	11 101	34 271	45 372
Number of outpatient	12 621	13 022	25 643	4 269	8 517	12 786
Encounter by patient	1.6	1.6	1.6	2.6	4.0	3.5
Total of encounters	**25 785**	**27 351**	**53 136**	**13 016**	**37 592**	**50 608**

The median of admission distribution days is 6 at GDH and 10 at NPH-CN. On average, the patient performs 1.6 encounter in consultation at GDH and 3.5 in NPH-CN for the two years.

The GDH meets a problem of encounter management of encounter. The staff of hospitalization department let the patients in the OpenClinic hospitalization contact, after their effective discharge. That gives aberrant bed occupancy rate.

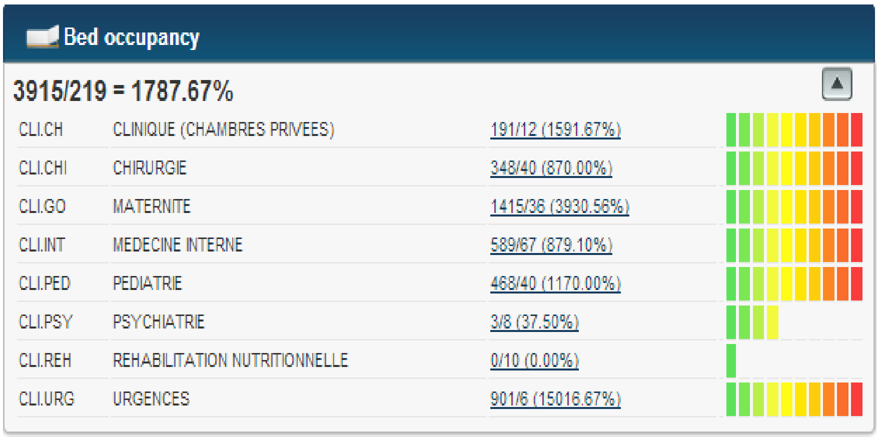

Fig. 4. Bed occupancy at GDH on 31/12/2012

And on the level of medical results, stages still remain to be crossed by the 2 hospitals because the (amongst others) encoding of reasons of encounter using international codification (ICD10, ICPC2 or DSM4) is not regular at GDH and had not started yet at NPH-CN at the end of 2012.

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4 Discussion and Conclusion

After these case study results on utilization of the OpenClinic system as a hospital management system in CHUK, NPH-CN and GDH, we observe the important role of users when they are well trained in the utilization of IT tools. Indeed, these IT systems become daily work tools and the empowering of users leads to the quality of results.

From the experience of CHUK OpenClinic users, we evaluated the capacity, ability and practice of those healthcare staff and found that users are adapted to the tool by the training they received. Thanks to the MIDA GL program, the level of OpenClinic utilization increased from 36.0% to 56.3% for daily users at CHUK. We found that the majority of new users came from the hospitalization and laboratory departments. Indeed the OpenClinic system is implemented in phases. The “boom” in utilization is achieved when the majority of hospital staff is involved. At CHUK, targeting hospitalization and laboratory’s staff in OpenClinic training allows to increase significantly the number of empowered users.

The level of user satisfaction has also increased from 17% in 2010 to 22% in 2012 for the very satisfied users. It has been shown that low levels of user satisfaction in the context of the implementation of such a project should always be considered as cause of failure [9].

The level of skills in the OpenClinic implementation brought together the utilization, perception and satisfaction of users. At CHUK, we noted that, although the average skill level has remained stable (around 80%) between 2010 and 2012, it at least increased in hospitalization (+9.2%) and laboratory (+10.0%) departments to respectively 76.7% and 85.0% in 2012. The increase of user skills level in an ICT tool allows them to take ownership of the tool [9].

After the analysis of users empowering in OpenClinic utilization, we demonstrated the effectiveness of OpenClinic using in Ndera and Gihundwe hospitals. To do this, 2 key performance indicators were measured between 2011 and 2012:

- The evolution of incomes
- The evolution of certain indicators such the number of patients and the number of contacts.

We used some measurements of endogenous performances of hospital activities without taking account of the "outcome measures" related to the health of the patient. These measurements can be tools for permanent evaluation of the users, incomes and internal activities [11]. The evaluated activities are performance and output indicators concerning particularly curative services drawn from the quarterly data of the hospitals of districts [12].

Some indicators, particularly financial, show improved performance management in the 2 hospitals through the utilization of OpenClinic as hospital management system.

On the revenue side, we found that incomes of the 2 hospitals have significantly increased during the past 2 years. Comparing the 4th quarter of 2011 and 2012 for the two hospitals, we found that incomes doubled to NPH-CN and increased 50% to GDH. One might think that this increase is directly related to increased encounters (visits and admissions) in the same period. The proportion increasing of encounters was 41% at HDG and 4% at HNP-CN between Q4 2011 and 2012. This increasing cannot alone explain the increase in incomes recorded which almost doubled. Here, we have evidence of the real impact of the OpenClinic utilization. The "OpenClinic" effect in the increasing of revenue has also been shown to CHUK where the hospital has doubled its revenue one year after the implementation of OpenClinic [10].

The trend indicators between 2011 and 2012 as the number of patients, the number of contacts and the number of registered services, etc. show continual activity in using OpenClinic at GDH and NPH-CN. This is in line with observations made in other hospitals where the system is implemented.

The management of the encounters in admissions and the utilization of the OpenClinic medical module are the 2 objectives which could not be fully reached within the framework of project MIDA implemented in the 2 hospitals, Gihundwe and Ndera. The reasons are related to the lack of time for physicians to use the system but are also due to patients' records which are not being available in time to the staff working in computerized medical record department. Another reason for this is the doctors’ writings are not easily readable to complete the medical records [13].

This research has shown that with the MIDA GL program, Rwandan hospitals, CHUK, GDH and NPH-CN were able to implement the OpenClinic software, hospital management information system.

The CHUK was the first hospital to implement this system early 2007. The CAP surveys 2010 and 2012 have shown the need for users training in OpenClinic utilization. The hospital staff becomes more empowered through training and Openclinic utilization. A user training and user ICT-assistant must be a continuous process that doesn't stop after a few years of OpenClinic implementation if the hospital management information system should become a continuously staff evolving application.

This research also showed that using OpenClinic as a hospital information management tool allowed GDH and NPH-CN to increase their performances and has quantified the resulting increases. This has been proven by the ability of the hospital to follow its health indicators day by day and its financial situation improved as the incomes have doubled one year after OpenClinic implementation.

The funding by MIDA GL allowed 3 Rwandan hospitals to implement the OpenClinic tool easily and to improve its utilization. Challenges still remain in terms of the implementation of the patient's medical record starting with the proper management of discharged patients admitted in the system and the systematic record of the reasons for encounter and diagnostics after hospitalization.

We cannot say that the MIDA GL projects in the 3 hospitals have been 100% successful, but this approach of training and capacity building using the migrant skills allowed participating hospitals to improve their management system.

There are indeed elements that lead us to advocate for sustained and continuous training in medical informatics and in particularly, OpenClinic utilization. OpenClinic software gradually becomes a tool for hospital management in several African countries, especially in Rwanda where the number of hospital users, both public and private, increases. Currently, 12 hospitals and clinics use this system in Rwanda [9].

Compared to the major project of the Ministry of Health in Rwanda to collect, centralize and analyze health information, the contribution of the MIDA GL program was useful in 3 hospitals in Rwanda but it is a drop in the ocean, taking into consideration the immense needs in these area. What is safe and interesting is that the technique of collection and centralization of health information in real-time at the hospital level has already proven in the 3 hospitals funded by MIDA GL and other twenty hospitals in the region.

Analysis and implementation of different systems of health information gathering currently existing in Rwanda for their integration would be very useful to join the energies developed all sides and thus regulate the field of e-Health in Rwanda.

Acknowledgments

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FOSS HIS in Public Health Domain: Case of Design-Reality Gap and Local Improvisation in Global South

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Background and Purpose: Health Information Systems (HIS) are an integral in health reform agendas even in developing countries, although technological and financial limitations found to be the major barriers. Hence, free and open source software (FOSS) plays an enabling role in global south. FOSS HIS are developed based on generalized domain requirements and, FOSS implementations faces challenges of discrepancy between global design and local requirements. This is known as design-reality gap. The disagreement between abstract requirements and local actuality was found to be crucial for the sustainability of HIS, and design and actuality improvisations were coined as remedial measures.
Methods: This comparative case study encompassing empirical experience of introducing FOSS HIS to Sri Lankan public health sector, expects to discuss health managers' awareness of possible design-reality gaps in embarking on FOSS HIS implementation decisions. It also tries to explore to what extent health managers are ready to accept a design-reality gap and to change the business actuality of health organization to accommodate functional restrictions of FOSS HIS. A series of semi-structured interviews and focus group discussions with health programme managers and public health experts were major source of data for this discussion.
Results: It was revealed that the health programme managers were aware of possible design-reality gap in considering FOSS artefact as a HIS implementation candidate. Also, in Sri Lankan context, health managers preferred design improvisation over actuality improvisation with a conservative view towards business process revision.
Conclusions: Abstract functionalities of FOSS HIS required to be extended to suit the business contexts of health programmes. The specific business routines demanded FOSS artefact to be further customized and the level of customization required ranged up to the source code level. Ability to reach consensus over design improvisation was successful than proposing for business process revision.

Keywords: Health Information Systems, Open Source, Requirement Abstraction, Design-Reality Gap, Local Improvisation

1 Introduction

With the current advancements in Information and Communication Technology (ICT), health Information Systems (HIS) has become an integral part of health reform agendas of most of the countries. ICT considers a key enabler in improving healthcare process and achieving health for all [1]. As a result, healthcare organizations around the globe are investing in health information infrastructure despite the validity of the above assertion. However, technological and financial limitations found to be among the major obstacles in introducing health information systems to national health services in developing countries. In this context, free and open source (FOSS) health information systems play an enabling role in global south, providing not only software solutions with no licensing costs, but also contributing to

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local knowledge and technological advancement by ensuring free access to software source code [2]. Open source design and development [3] is seen as empowering strategy in developing country context for coordinating global and local design process [4][5][6].

Due to the wider socio-political motivation of open source software, the design of the FOSS architecture is based on a generalized and abstract end user requirement specifications and global standards [7]. Also, with regards to open source software development, end user requirements are constantly being evolved and elaborated, and as a result the product is never in a finalized state [8]. FOSS artefacts are designed and developed for general use in the sense that the software features can be modified while being used by a wider community. So, the open source developer communities tend to make FOSS HIS non-specific through the process of generification by identifying those universal aspects of the system when addressing diverse user requirements is extremely difficult. Generification is defined as design strategy software developers adhere to when developing a single artefact that fits into the needs of multiple customers [9]. Rather than based on interactions with the user organizations for programme specific requirements, developer tends to design and code applications based on the basic understanding of the user group on abstract understanding of the user organization in general [10]. For this reason, a FOSS HIS software artefact may not fit in to all user requirements of a health programme during the current software release cycle. The possible disagreement with user requirements is a remarkable challenge health manager and administrators have to face in adopting FOSS HIS artefacts compared to bespoke development of HIS according to the requirements of healthcare organizations. This makes it necessary, either the FOSS HIS to be further customized to the specific need of the healthcare organization or to accommodate business process re-engineering to the health programme operations for it to align with the capabilities of the FOSS HIS considered to be implemented.

However, it was argued that the success of a information system implementation is depend on the alignment of the functionality of the information system (IS) and the organizational work routines and business context. Many information system implementations in developing countries have been reported as total or partial failures and reason for failure were attributed to the gap between IS design and the organizational context [11][12]. Health Information Systems are also among the victims of information system failures due to the design – reality mismatch [13]. Failure of understanding the complexity of the clinical work routines and managerial process of health sector in requirement elicitation is a major reason for this design – reality incongruity. Similarly, fragmented donor policies may also aggravate HIS design – reality gap by ignoring organizational context in introducing health information systems [14]. Donor funding is an essential source of support in strengthening national health information architecture, although there could be institutional, technological, economic and political factors operational in externally funded information technology transfer initiatives [15].

Theoretically based on the argument of HIS design-reality gap and possibility of local improvisation [12][13], this paper analyses the empirical findings of three selected cases of HIS implementation attempts in Sri Lankan context. The open source HIS, District Health Information System (DHIS2) [16] was the focus of these HIS implementation attempted in two vertical health programmes and the empirical findings believed to help in understanding health programme managers' perception of the design – reality gap in FOSS HIS implementations and to identify their preference of different local improvisation options and approaches.

2 Materials and methods

2.1 Theoretical Underpinning

Free and open source software promotes local technological development by having access to the source code of the software artefact. FOSS helps in developing country perspective by helping to set up an information economy, advancing knowledge more quickly and avoiding being hostage to propitiatory software [2]. Similar benefits of FOSS available to the healthcare domain as well. Specially, vendor independence through the availability of source code provides reduced total cost of ownership, reduced cost of maintenance and competitive cost for software adaptation and customization. Also, FOSS HIS provides flexibility in end user training and reduction of the risk of losing legacy data when migrating to a new software version or new solution [17]. The distributed development of FOSS enables more user participation and it has been identified as an important development in FOSS HIS to absorb domain

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concepts successfully. Generification and abstraction are common practices in open source development process [9]. In the DHIS2 developer community as well, generification and abstraction was the strategy for absorbing local innovation to the global design through participation and network of action [18][19].

HIS implementation attempts sometimes ends up in a failure and the success or failure of a HIS adoption is theorised as not merely a technical matter. The HIS success has been described as the synergy between the information system, the primary (patient or community care) work process as well as the secondary (management and support) work process [20]. Social and professional culture of healthcare organization, complexity of routine care and managerial process and dissonance between the expectations of the HIS commissioner, the FOSS developer or the supplier and the user of the system have been described as major reasons for HIS acceptance or rejection by a healthcare organization [21]. Various attempts have been taken to theorize reasons for HIS failures and, design-reality gap is a well-accepted among those [22].

Design – reality gap consists of six major dimensions of incongruity between IS design and domain context. It portrayed as the temporal and systemic contingency between the current system (political actuality) and the expected future system (rational design) through organizational changes induced by the adopted information system [13]. The actuality and the design has been described under, information; technology; process; objectives and values; staffing and skills, management systems and structures; and other processes. As summarised in **Table 1**, it was attempted to highlight incompatibilities between the rational design and political actuality [12].

Table 1. The difference between the rational design and political actuality

Dimension	Rational Design	Political Actuality
Information	Standardized, formal, quantitative information	Contingent, informal, qualitative information
Technology	Simple enabling mechanism	Complex, value-laden entity
Process	Stable, straight forward and formal	Flexible, complex, constrained and often informal
Objectives and values	Formal and organizational	Multiple, informal, personal
Staffing and skills	Staff viewed as rational beings	Staff viewed as political beings
Management systems and **S**tructures	Emphasis on formal, objective processes and structures	Emphasis on informal, subjective processes and structures
Other resources	Used to achieve organizational objectives	Used to achieve personal objectives

In the context of healthcare domain and health information systems, the rationality has a medical component as well The medical rationality has been described as "When medical information is seen to play a central role in HIS, those information systems are therefore themselves likely to be conceived according to an objective and rational model" [13]. The design – reality gap has been debated in the context of FOSS HIS as well and there, the controversies between the sponsor and the FOSS developer; the global developer and the local developer; and local developer and local user has been identified with regards to various FOSS HIS implementations [23].

It is easy to embed rational design in software development, but it is nearly impossible to embed political rationality to an IS design with the requirement abstraction. Based on the developers' understanding of the medical domain, generification and abstraction of user requirements and local user expectations and programme objectives, the design - reality gap could be identified with regards to DHIS2 design and implementations as well [24]. The design – reality gap may increase during implementation and operations. The local improvisation is coined as a remedial measure to this phenomenon [12]. Local improvisations are situated actions affected by and affecting the context of their execution. There are two broader categories of local improvisation as follows.

- Actuality improvisation – changing the local actuality (business process and context) to make it closer to IS design.
- Design improvisation – changing the IS design to make it closer to domain concepts and user actuality.

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2.2 Research Design

FOSS HISs are results of distributed development based on generification and abstraction of functional requirements. It was argued that the most important role of the IS in the organization is only discovered during the implementation process, hence there is a possibility of an incompatibility between global design and local reality (actuality) in the implementation phase of a FOSS HIS. The ITPOSMO framework [12] suggests design improvisation or actuality improvisation as means to reduce the design-reality gap and to improve the success and acceptance of HIS. The improvisation approach has been practised in many HIS implementations throughout the world [25]. However, authors' empirical experience suggested that in a well-established national level healthcare programs, persuading health managers for actuality improvisation is not a successful strategy in introducing FOSS HIS to health sector.

With the aim of contributing to the academic discourse of HIS design – reality gap, following research questions were formulated.

- Whether health managers are aware of possible design – reality gap in embarking on FOSS HIS implementation decisions?
- To what extent health managers are ready to accept a design – reality gap and to change the business actuality of health organization to accommodate functional limitations of FOSS HIS (actuality improvisation over design improvisation)?

To investigate the above research questions a comparative case study covering two vertical health programmes in Sri Lanka was designed. The three selected cases were based on the empirical findings of attempting to implement FOSS public health information system, District Health Information System (DHIS2). The cases were carefully sleeted to cover a successful attempt, a partially successful attempt and an unsuccessful attempt in introducing DHIS2 to national health system.

In the data collection process, multi-method approach [26] was adopted employing with several data collection methods. Participant observation, semi-structured interviews and focus group discussions with FOSS implementers, health programme managers, public health experts and other technical partners were conducted and data from informal meetings and relevant document analysis were also gathered during the study process. The two vertical health programmes studied was Family Health Bureau (FHB) and National Programme of Tuberculosis Control and Chest Diseases (NPTCCD) in Sri Lanka [27]. Two HIS implementation attempts were considered in FHB scope, for *National Maternal and Child Health Information System* and *National Foeto-Infant Mortality Surveillance System*. Within the NPTCCD, DHIS2 was attempted for *Integrated Electronic Disease Registry for Tuberculosis and Chest Diseases*.

Case 1 - National Maternal and Child Health Information System: The National Maternal and Child Health Information System was the computerization attempt of existing paper based National Maternal and Child Health records [30] which collect data from Medical Officer of Health (MOH) areas. Data collection is being done by Public Health Midwives (PHM) attached to each MOH are using PHM's Monthly Record and will be aggregated to Maternal and Child Health Return and Quarterly MCH Clinical Return under the supervision of Medical Officer of Health. The date will then be sent to the FHB for further analysis. The HIS implementation attempt was spanned from October 2011 to April 2012. After piloting in few MOH areas, FHB requested to halted DHIS2 implementation until institutional decision is made to implement a national HIS to cover all public health data managed under the FHB.

Case 2 - Integrated Electronic Disease Registry for Tuberculosis and Chest Diseases: Integrated electronic registry for Tuberculosis, Asthma and Chronic Obstructive Pulmonary Disease (COPD) was a long felt need of The National Programme of Tuberculosis Control and Chest Diseases (NPTCCD) of Sri Lanka. DHIS2 tracker was identified as a potential tool for computerising the respiratory diseases registries and aggregated patient information. With the success of piloting in early 2013, NPTCCD decided to implement the system to collect data from selected peripheral chest clinics throughout the island and to customize and evaluate DHIS2 to replace existing HIS for Tuberculosis registry.

Case 3 - National Foeto-Infant Mortality Surveillance System: National Foeto-Infant Morality Surveillance system was suggested to strengthen the foetal and infant death investigation process of the

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FHB. The data related to foetal and infant deaths were supposed to gather from hospitals through heads of the institution and from MOH areas through Medical Officers of Health. HIS supposed to generate summaries of foetal and infant deaths to monthly perinatal meetings headed by the Medical Officer – Maternal and Child Health of the region. DHIS2 was suggested to customise for this purpose and evaluated in early 2013. Unfortunately it was decided that DHIS2 was not capable to fulfil the needs of the Foeto-Infant Morality Surveillance programme.

The semi-structured interviews and focus groups were selected for gathering the qualitative data that will provide insight into the health managers' perception of the end user requirements and the existing functionalities of the DHIS2 software release. The structure of these interviews was mainly based on the software requirement specifications (SRS) prepared for each pilot project. Unit of observation of the study was the organization and this posed a challenge of identifying key-respondents while collecting organizational level data. It was assumed that the perception of health management in vertical health programmes reflect the collective perspective of the health programme and as a result, the views of top managers could be held as reliable source of organizational-level data [28]. So, the opinion of top level administrators those who are able to recognize and assess the strategy within the organization boundaries weighted more in describing the data extracted from interviews, focus group discussions and other communications. A qualitative data analysis was performed with post data collection reduction [29].

3 Results

The health managers apprehended the deviations of current DHIS2 features from the software requirement specification prepared for each HIS implementations to variable degrees based on the business context and operational needs of the health programmes considered. However, they were not dejected by the mere fact of the presence of a design-reality gap in FOSS HIS. However, in general they were hesitant to revise the business process, data elements or indicators for it to be more favourable for the existing capabilities of the HIS.

The specific findings with regards to the comparison of end user requirements and business process of each health programme and the functionalities of DHIS2 were as follows.

Case 1 - National Maternal and Child Health Information System: The main objectives of introducing HIS in the Maternal and Child Health programme was to improve data quality and timeliness of reporting and the based on PHM's Monthly Record, Maternal and Child Health Return and Quarterly MCH Clinical Return. DHIS2 was equipped with the data quality checks and speed up the aggregation and piping data from periphery to central level. DHIS2 was appreciated for its ability for assisting aggregation of data at PHM level. However, the very same feature was seen as voiding the immediate supervision by Medical Officers of Health form the FHB perspective. By the time DHIS2 was piloted in FHB scope, the role based authentication was not strong in DHIS2. Former was affected in long term acceptance of DHIS2 by FHB, even though the direct supervision of PHMs was not an explicit requirement documented during the requirement analysis phase. DHIS2's ability to conform to national language regulations was also questioned. However, limitations of DHIS2 graphical user interface, DHIS2 branding and usability of report generation was particularly criticised.

Case 2 - Integrated Electronic Disease Registry for Tuberculosis and Chest Diseases: In information management related to the activities of NPTCCD, it was vital for HIS to be able to handle patient centric records as well as information required for monitoring, evaluation and planning. In general, DHIS2 with its Tracker module found to be capable in delivering necessary functionalities. Since DHIS2 Tracker was storing individually identifiable patient data, security and confidentiality of the clinical records were among priority needs. However, the data security provided by the DHIS2 was considered satisfactory by the NPTCCD. DHIS2's ability to capture individual patient records by clinic visits and tracking visits and treatment defaulters were aligned with the programme needs. In NPTCCD as well, graphical user interface and limitations of the usability of report generation was noted. Major drawback highlighted during the piloting was DHIS2's inability to seamlessly integrate aggregate and individual patient records between DHIS2 core and the DHIS2 Tracker module. However, health managers agreed to use manual aggregation of individual records while the necessity of this feature was stressed to the DHIS2 developer

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community. Almost all data elements in NPTCCD clinic books were able to capture using DHIS2, except for a diagram used to record findings of pulmonary auscultations. As a temporary measure, programme decided to use text based record for chest auscultations.

Case 3 - National Foeto-Infant Mortality Surveillance System: The most unique requirement of the HIS in national foeto-infant surveillance programme was the ability to side-by-side comparison of foetal and infant death investigation records sent by hospital and MOH office for a death of a particular baby. The proposed system shall be able to compare multiple records of death reports and alert for possible duplicates records. This feature was not among the functionalities of DHIS2. Further, DHIS2 based web forms were not be able to capture data using continuous scales, check boxes etc. and to handle questionnaire specific functionalities, like skip logic and piping. After considering all these facts, health managers decided not to consider DHIS2 as a candidate HIS for proposed national foeto-infant mortality surveillance system.

4 Discussion

The empirical setting Sri Lanka, has a centralized healthcare system with a well-established and time tested paper based record system with a better health indices. Hence the health system is generally conservative in business process revisions and computerizations tend to be seen as a business risk. In general, it was noted that health managers are sensitive to the conflict between generified requirements which is used to design FOSS HIS and the programme specify functional and non-functional requirements of national health system. It was also noted that health managers engaged in FOSS customizations with the pre-occupied understanding of bespoke software development.

During the study, it was observed that health programme administers prefer design improvisation (highly customization of HIS, including software code level changes) than actuality improvisation (revising the business process). The graphical user interface changes were very suggestive design improvisation in Sri Lankan context to imply the ownership of the HIS by the particular health programme. Possibility for local improvisation (e.g. locally available software coding support) minimized the tension over design – reality gap in vertical public health programmes considered. Also, design improvisation was more successful approach than actuality improvisation, with the exception of NPTCCD seemed to agree for minor actuality improvisations.

Actuality improvisation was acceptable to health managers to a certain extent. This was evident in the behaviours of NPTCCD in accommodating certain changes in web forms, which is different to paper based forms to overcome the limitation of image manipulation abilities of DHIS2. Also, NPTCCD was more flexible to tolerateDHIS2's inability to integrate aggregate and individual patient records. However, this was not the case in national foeto-infant surveillance project where, still the side-by-side comparison could be performed manually while accommodating certain changes in business process to tolerate limitations of DHIS2 functionalities. It was evident that the health managers are willing to sacrifice optional functional requirements if the mandatory functional requirements are satisfied.

So, in concluding the discussion, it is safe to assume that health managers are willing to accept existing functionalities of FOSS HIS in the presence of a design - reality gap in HIS implementations if the majority of functional requirements are satisfied. It is also necessary for health managers to apprehend the difference of FOSS and bespoke software development principles. Accommodating all data elements in the HIS customization, graphical user interface modification to convey the ownership of the system, facility for role based authentication and role based data visibility and high end data analysis found to be having high priority among the functional requirements. It was safe to assume that to a certain extent, health managers are willing for actuality improvisation, even though they are more comfortable and demanding for design improvisation. So, it was advisable for local FOSS HIS implementation teams to equip with the necessary skills and resources for code level customizations in FOSS HIS piloting projects to improve the acceptance by national health programmes.

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An Assessment of Health Information Management Infrastructures for Communication in the Matabeleland South Region Border-line Health Institutions in Zimbabwe

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Background and Purpose: Developing countries face the challenge of providing quality healthcare to rapidly increasing populations without adequate infrastructure. Health information management infrastructures are important for the smooth flow of important health information required for efficient service delivery. They form the essential physical, logical and intellectual link that facilitates the provision of health care services for a country. This study was carried out to assess the health information management infrastructures for communication in the Matabeleland South Province of Zimbabwe, particularly focusing on border line health facilities that stretch from Southern boarders with Mozambique, South Africa and Botswana.
Methods: The researchers employed an exploratory survey research strategy through the use of observation and structured interviews. Elements from the eHealth Architecture Model (eHAM) developed by the International Organisation for Standardisation (ISO TR 14639) [1] as a roadmap tool for capacity based eHealth architecture were used as guiding principles.
Results: The researchers identified that there is a wide spread lack of health communication technology, particularly computers and related technology. Health staff capacity to process information and communication is low and information management infrastructures are dilapidated.
Conclusions: Health information management infrastructures for communication in the area studied are inadequate, and underserviced. This is coupled by a low quality in data and service delivery mainly due to lowly qualified staff and dilapidated information management infrastructure. Current researchers recommend the use of computers, related technology and improvement of communication connectivity solutions, staff capacity and servicing of information management infrastructure to improve health communication efficiency.

Keywords: Health information management infrastructures, Health communication infrastructures, Remote health centres

1 Introduction

Health information management infrastructures for communication are important in forming the essential physical and intellectual link between and within institutions and their related service providers and clients as they transact in health service delivery. These include but are not limited to:

(a) Computers hardware and software;
(b) Computer networks (Internet) / connectivity solutions
(c) Staff capacity (ICT Professionals and technical support)
(d) Emergency radio communication systems
(e) Telecommunication systems
(f) Mobile phone communication systems
(g) Data and records (information) management services

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The services requiring such infrastructures for communication in health institutions include: community-based services; primary care services; hospital/clinic/institutional services; public and health disease surveillance; emergency response; diagnostic services; healthcare supply chain; and health records and information management.

1.1 Focus and Area of the Study

This study focused on assessing Health information management infrastructures for communication in the Matabeleland South Province of Zimbabwe. The Province is divided into seven districts namely: Beitbridge, Bulilima, Mangwe, Gwanda, Matobo, Umzingwane and Insiza. Most of the health institutions in this area are in border line communities; remote and largely rural health centres are prevalent. They strive to serve larger communities because most of them are widely spaced.

Matabeleland South Province is situated in the South-Western part of Zimbabwe sharing boundaries with Botswana on the west, South Africa on the south, Masvingo Province on the South east, Midlands on the north and Matabeleland North on the North West. The Province is divided into seven districts namely: Beitbridge, Bulilima, Mangwe, Gwanda, Matobo, Umzingwane and Insiza. Of these urban councils are in the main towns: Beitbridge, Gwanda and Plumtree while the other 5 are rural district councils (See **Fig. 1**). The Province covers an area of 54 172km^2 with a population of 679 571 at an annual growth rate of 1, 1% based on the results of the Census of 2012 [2].

1.2 Theoretical Underpinning

From a theoretical concept point, this study was guided by the eHealth architecture model presented by ISO TR 14639 (A roadmap for capacity based eHealth architecture). The eHealth Architecture Model (eHAM) shown in **Fig. 1** provides a model structure for an effective health care service delivery system. It outlines the elements and structure of a model ideal healthcare service. Key to this study are elements on health information infrastructures for communication which are at the base as ICTs Foundation Infrastructure. These are: local access to equipment and facilities; electronic communications infrastructure; ICT processing and storage services; and ICT professional and technical support. Interestingly the model indicates that these should be bound by standards, guidelines and methods within the health facility as well as its policy sphere. It further stipulates that the elements need to be constantly financed and maintained.

1.3 Health Information and Communication Infrastructures

Most health care specialists, researchers and planners for health facilities [3]-[6] report in literature that information exchange is crucial to the delivery of care on all levels of the health care delivery system the patient, the care team, the health care organization, and the encompassing political-economic environment [3]. For instance, one researcher [4] indicates that, to diagnose and treat individual patients effectively, individual care providers and care teams must have access to at least three major types of clinical information—the patient's health record, the rapidly changing medical-evidence base, and provider orders guiding the process of patient care.

In a related paper [4] discusses from findings of his study that to integrate these critical information streams, there is a need for health staff capacity building through training/education, decision-support, information-management, and communications tools. Further points are given [4] that at the organisational level, hospitals and clinics “need to have free flowing” clinical, financial, and administrative data/information to measure, assess, control, and improve the quality and productivity of their operations. Similarly [5] adds that at the socio-environmental level, state funding and regulatory agencies and research institutions need information on the health status of populations and the quality and productivity/performance of care providers and organisations to execute regulatory oversight, protect and advance the public health (surveillance/monitoring), evaluate new forms of care, accelerate research, and disseminate new medical knowledge/evidence. As such health communication infrastructures for information management are the backbone of health care service delivery.

However, studies [6] have shown that most health care-related information/communications technologies investments to date have been concentrated on the administrative side of the business, rather

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than on clinical care. On the subject of health communication infrastructure, there are reports [6] that there has been a prolonged underinvestment and little overall progress toward meeting the information needs of patients, providers, hospitals, clinics, and the broad regulatory, financial, and research environment in which they operate. Reporting specifically from an empirical study in the US [7] significantly indicates that a number of localised efforts have been made to develop and implement electronic patient records and other clinical applications of information/communications technologies since the 1960s, but little progress has been made in closing the gap.

Many factors have contributed to the information/ communications technology deficit. One scholar [7] reports the following five reasons:

(a) the atomistic structure of the industry (the prevalence of relatively undercapitalized small businesses/provider groups);
(b) payment/reimbursement regimes and the lack of transparency in the market for health care services, both of which have discouraged private-sector investment in information/communications systems;
(c) historical weaknesses in the managerial culture for health care;
(d) cultural and organizational barriers related to the hierarchical nature and rigid division of labor in health professions; and
(e) the relative technical/functional immaturity (until very recently) of available commercial clinical information/communications systems.

However, in this paper, researchers propose that a seemingly overlooked reason is a lack of information by national health planners about the current state and capacities of health institutions in terms of health information management infrastructures for communication. We argue that the gravity of the situation can only be understood if empirical data is amassed and clearly presented to indicate all aspects of the nature of the deficit in particular places rather than a national generalisation. As such, we conduct an exploratory study reported in this paper with the notion to take it up further.

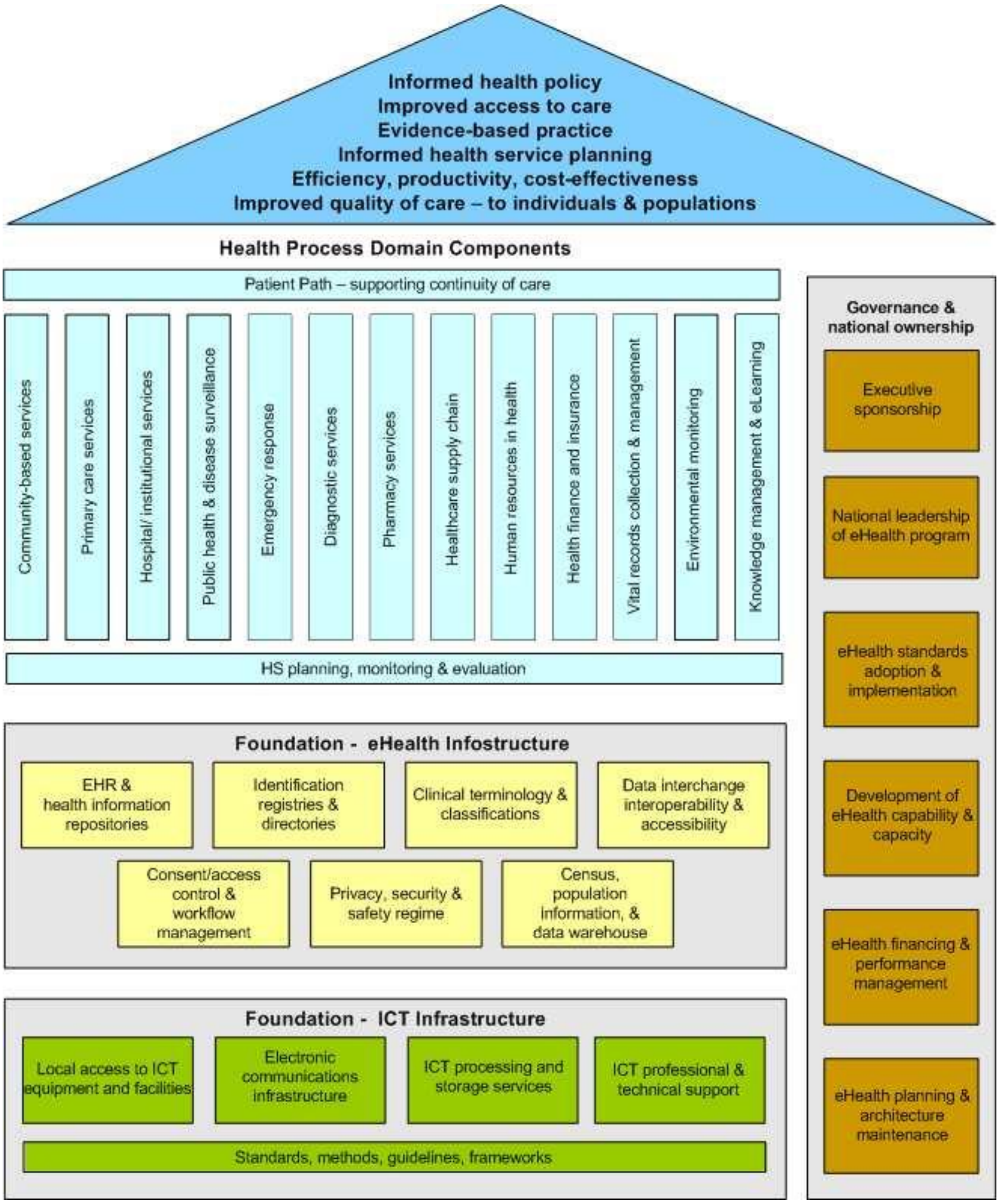

Fig. 1. eHealth Architecture Model (eHAM) according to ISO TR 14639 - Capacity Based eHealth Architecture Roadmap - Part 1

2 Materials and methods

Research Design

This study was a survey research of health institutions in the seven districts of Matabeleland South, most of which are in the border line areas.

Research Instruments and Techniques

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Observation and structured interviews were used to collect data from health institutions about the status of their health information management infrastructure for communication.

Study Population and Sampling
The population of the study comprised of all health centres and clinics in the Matabeleland South Province of Zimbabwe. These are structured according to districts as shown (**Table 1**).

Table 1. Study population: health centres and clinics in Matabeleland South Province. Data Source: Multiple Indicator Monitoring Survey [2]

District	Government	Council	Mission	Total
Beitbridge	1	6*	2	**9**
Gwanda	2	6*	2	**10**
Bulilima	2	5	0	**7**
Mangwe	1	5	0	**6**
Umzingwane	1	3	1	**5**
Matobo	1	3	0	**4**
Insiza	1	3	1	**5**
Total	**9**	**31**	**6**	**46**

A census survey of these health facilities was made and only three health facilities (in Beitbridge and Gwanda as indicated by a *) could not be visited as they were under refurbishment.

3 Results

3.1 Computer and Related Technology

The general overview of the results is that the province has an inadequate health communication infrastructure. Radio systems though installed are all not working. The researchers identified that there is a wide spread lack of communication infrastructure, particularly computers which could be used for electronic health information processing thus quickening decisions made on health information.

The use of computers and connectivity solutions which would improve communication efficiency through the use of electronic e-mail and online communication systems is very low with only two health institutions of the 41 visited recording the presence of computers. In these two cases, health personnel report that transmission technologies have been so unreliable that they have resorted to transporting data on memory sticks which costs heavily on their work efficiency. At one of the two health facilities with computers, they further report of intermittent interconnectivity affected constantly by lack of technology enhancers such as outers, connection hubs and power surge adapters. This has meant insufficient power and connectivity outlets meaning that users cannot connect and power up 3 to 4 computers simultaneously.

Related to this is a widespread poor network coverage by local communication firms such as Econet®, NetOne®, and Telecel®. This has meant that these boarder line health facilities rely on foreign networks filtering in from neighboring countries such as Orange® and MTN® from South Africa. Health workers, nurses and doctors indicate that these are however, unreliable and expensive and buying air time would require them to cross the border to South Africa or Botswana at are sporadic occasions. Of the 41 health facilities studied, a response rate was used to come up with the frequency of the availability of usable communication systems at health institutions (**Fig. 2**).

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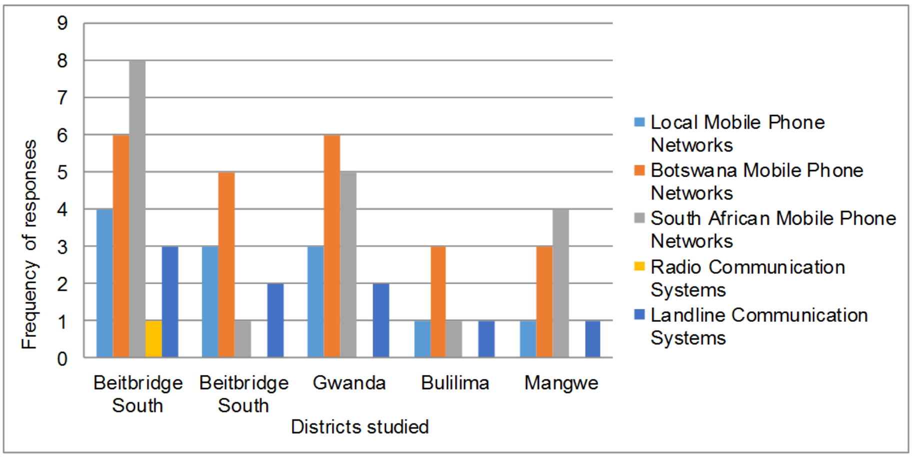

Fig. 2. Prevalence of communication infrastructure: available connectivity solutions

3.2 Radio Communication Systems

Of the 41 health facilities visited, only 1 government clinic in Beitbridge had a working radio system for emergency services whilst the rest (approx. 97.5%) were not working. This has also impacted on communication system of the health facilities. One respondent importantly indicated the predicament in the following words:

"it is difficult, sometimes we face critical emergencies, where we need to call nearby Health Technicians, ambulance services, or send urgent messages,…we have community health workers who were allocated with radios, but the radio systems have not been working for long now…we barely communicate"

3.3 Physical Transport Communication Problems

Apart from a poor logical link through Internet, radio and wireless communication, poor road networks also delay the physical link through road transport. Bridges are damaged and in rainfall season this they become practically impossible to cross, thus sealing off physical communication links with some remote places where urgent health issues may need to be addressed.

3.4 Computer Literacy Skills by Health Information Officers

In all the 41 visits made, it was only at two health facilities that the researchers identified computer systems for health services in client management and medical record-keeping. This was at a Mission and a Government Hospital. At these stations, the researchers carried out interviews with Health Information Officers to gather information about their computer literacy skills. The data indicates low staff capacity in terms of skills and knowledge to utilise computer resources for health information processing and communication (See **Table 2**).

3.5 Quality of Data and Service Delivery

Data quality and service delivery were also investigated thorough observation and interviews. From an observation point, physical files that feed into institutional health information are not properly maintained. A simple walkthrough observation in all rural health centres recorded overcrowding and accumulation of patient records, case notes and related medical records in a haphazard manner. The following elements were investigated and recorded as shown in **Table 3**.

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Table 2. Staff capacity in utilising health communication technologies and computers

Item	Response
Health Information Management Training, Education or Relevant Experiential Appreciation	Did not attend any training Does not have any Health informatics or ICT qualification
Use of Office package (Word processing; Spread sheet Processing; Presentation Processing; Databases and E-mail)	Has working knowledge for word processing and spreadsheet only
Knowledge and use of any health informatics software	No knowledge
Knowledge and use of any health informatics hardware gadgets	No knowledge

Table 3. Records, data and information services at the health institutions

Elements Observed and investigated through interviews	Number of institutions		Researchers' Comments
	YES	NO	
Presence of a clear records classification and coding system	**12**	**29**	A generally unclear maintenance systems (not guided by any manual or classification system) was observed. This has a high implication of retrieval and usability of data and information stored in records which feeds directly into the health information system.
Utilisation of the stipulated Register and Tally System [8]	**39**	**2**	There is a notable high utilisation of the tally system for patient registration and tracking as well as disease surveillance which is commendable. However, the registers in which the data is recorded maintained within crumbling registry storage facilities, sometimes irretrievable. In all the 41 institutions visited there was no use of electronic registry systems for patient registration, tracking and disease surveillance which entails that data analysis is tedious.
Presence of fully utilised file cabinet systems	**5**	**36**	File cabinet systems for paper records are largely inadequate and prioritised for drug storage rather than medical and health records. This has resulted in paper files and records being strewn everywhere in a haphazard fashion such that the risk of information loss is real.
Effective retrieval time (Health information officers were asked to retrieve specific data of 2005. The standard used was 5 minutes)	**4**	**37**	A generally ineffective retrieval time ratio was noted. This is significantly caused by an unmonitored accumulation of paper files and documents. It also spells out the need for automation though this is a subject of contestation considering the background of ailing record-keeping systems.

4 Discussion

The way forward from the indicated results appears to be a comprehensive health information and communication infrastructure analysis in all health institutions. Following the eHAM model, this will generate specific data that can be used by health planners and policy makers as they budget to cater for the glaring deficit in computers, networks and related communication infrastructure critical for transmitting health information. Importantly, the current researchers recommend a follow up on this

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research and the employment of the Six Sigma method for process improvement to work together with the e-HAM model as a theoretical framework.

This was an exploratory survey, and its results on the health information management infrastructures for communication in the Matabeleland South Province of Zimbabwe indicate gaps, under servicing and poor coverage. The researchers expect that a more detailed investigation will decipher more intricate results. From the current results, the backbone of health information infrastructures for communication appear to be shaken by inadequate technologies compounded by low staff capacity and subsequent poor records, data and information service.

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Aeetes: An App Generator for Sustainable and Secure Health Data Collection

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Background and Purpose: Aeetes represents an approach to patient data collection in LMIC that is intended to be scalable, sustainable and secure.
Methods: Existing approaches to data collection are typically either personal-computer-based or enterprise-based. Aeetes occupies a third space, that of peer-to-peer devices. It is intended to occupy a spot between the PC-based and enterprise-based approaches, addressing issues that make these approaches a poor match with some deployment scenarios.
Results: The Aeetes approach is characterized by a compiler-based approach to data collection app generation: A new data collection app is generated from an input specification of the data to be collected and the user interface for data collection. The benefit of this is greater software reliability, since the data model is made explicit in the code, and eventually greater security through analysis of the code for information flows. Aeetes also takes measures to protect patient confidentiality against loss of devices.
Conclusions: Aeetes represents an approach to moving away from PC-based approaches to data collection with poor security characteristics, to an approach that is more reliable and secure, while also being sustainable. It is hoped that some of the approach taken by Aeetes may eventually influence other systems such as OpenMRS.

Keywords: Health Impact Assessment, Public Health Informatics, Health Information Management, Software Design, Computer Security, Database Management Systems

1 Introduction

In general, healthcare information technology is regarded as essential to providing efficient and effective healthcare delivery. In countries ravaged by pandemics such as HIV/AIDS, healthcare data collection plays an important role in healthcare analysis and planning, revealing where resources need to be allocated and what treatments are efficacious. Any deployment of healthcare IT in LMIC must meet the goals of being scalable, sustainable and secure. *Scalability* refers to the ability of the technology to scale up from small field trials to large numbers of patients in production deployment. *Sustainability* refers to the ability of any such deployment to eventually become self-sufficient, once an initial deployment support framework is withdrawn. Finally, *security* refers to the protection of the confidentiality of patient data in such systems. Failure to protect confidentiality can undermine patient trust in the patient-doctor relationship, and in some cases expose patients to discrimination, blackmail and even death.

As part of developing data collection tools for epidemiological studies in several LMICs, we considered all three of these criteria, and evaluated several alternative approaches based on their fit with the conditions for IT deployment in the member countries. Our approach was designed to address what

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were seen as deficiencies in some of the alternative approaches already in use. Those deficiencies were in respect of sustainability and security: For some of the alternative systems, it was not clear that they would be appropriate to the deployment situations that were envisaged, while for other systems security and confidentiality were serious concerns.

2 Materials and methods

In surveying the existing systems for patient data collection, we categorized these systems into a few broad categories.

The first category consists of *personal computer-based systems* that store patient data on desktop or laptop computers. Such systems are typically based on Microsoft Windows and the Access database management system. An example of such a system is the EPI-INFO system [1] provided by the Centers for Disease Control (CDC) , currently in use for example in clinics in Democratic Republic of Congo. SQLite is a standard database management system used for the Android and iOS platforms that in some ways is similar is Access, so a system similar to EPI-INFO could be developed for mobile devices.

The second category consists of *enterprise-based systems*, that adopt a client-server distributed system approach to patient data management. We refer to these systems as “enterprise” because they are typically built on an enterprise software stack. For example, the IQCare system [2] is built on SQL Server and the Microsoft .NET software platform. The popular OpenMRS open source system [3] is built on the Spring and Hibernate Java frameworks for building Web-based enterprise applications. Clients of an OpenMRS system typically execute as AJAX applications in a client Web browser, although it is also possible for client applications to execute on mobile devices (e.g. Sana Mobile and Open Data Kit [4]-[6]).

There is a third category of systems, that is in some ways still in a nascent state: That of *devices organized into a peer-to-peer local network*. They are distinguished from personal computer systems by the use of a network to coordinate the data on the devices, and they are distinguished from client-server systems by the absence of a central server. Our approach fits in this third category, and we argue that this is an important architecture to be considered for future IT development for healthcare delivery in LMIC.

In our view, personal computer systems for patient data management have the following issues. In one country where we collect data, informed consent is required of patients that are involved in the study. This informed consent is collected electronically, and data collection should prevent the entry of data for patients without such consent. But informed consent and data entry are performed by different personnel, on different devices. Second, most such systems are, as noted, based on Windows and Access. The benefit of this approach is that these systems are broadly familiar to clinic workers, and it is for example feasible for relatively technically unsophisticated staff to use form-based tools to formulate ad-hoc database queries. However there is a fundamental security flaw in such systems: the very ability of users to manage these systems introduces the possibility of social engineering attacks, where users install software apps that include malware such as Trojan horses. The unfettered ability of users to self-manage these systems is a legacy of business decisions made early in the history of personal computers, and the use of techniques such as virtualization and UAC to rectify this situation has met with limited success.

Our main concern with enterprise approaches is sustainability (ironically, a strong point with personal computer systems). An enterprise system composed of a Web server, application container, a persistence framework and a database server is a fairly sophisticated system to manage. For example, Tierney et al [7] report on the deployment of OpenMRS systems in three African countries. While the experience with OpenMRS was positive, deployments struggled once funding for clinic IT staff was withdrawn. With a national commitment to OpenMRS, as in Rwanda, it is possible to train a pool of professionals who can support OpenMRS deployments, and the relatively small size of the country enables a support strategy based on sending centralized IT staff to fix local problems. In a larger country, this strategy will not work for small rural clinics that may be many hours of travel away from where IT staff is located.

Our concerns with secure device management led us to consider the Android platform. Mobility was not an issue in this decision, and in fact mobile phones are a poor choice for data entry and were not a consideration. The attraction of Android is that it provides facilities for restricting user device management and enabling remote device management. There is already third-party commercial off-the-shelf (COTS) software, exploiting hooks provided by the Android kernel that can be used to restrict the applications that users can install on Android phones. Restricting the applications that can be installed by the user on the device is a key factor in protecting the device against malware. For this reason, it was

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decided early on that Web browsers (including embedded Web browsers using Webviews) should be discouraged on a device, because of the potential attack vector provided by mobile Javascript code. In addition, the ability to remotely manage such devices has been convincingly demonstrated, for example by Google removing malware-containing apps from consumer phones. This ability to manage devices “by remote control” was a key reason for our decision to deploy on Android devices.

There are several different hardware platforms to choose from in our deployment. Our current deployment is based on the ASUS Transformer Prime tablet, accommodating a docking station that includes a keyboard and trackpad. Android laptops are also available, such as the Go Note laptop from the UK. In future, we will be able to use desktop devices such as the HP Slate, that provides a 21” display on an Android device that connects to external peripherals such as a keyboard and mouse. Non-display devices such as the CompuLabs Utilite personal computer provide an ARM-based PC that can run either Ubuntu or Android, and includes WIFI, Bluetooth, Gigabit Ethernet and USB connections. Such devices may be useful for example as local backup devices. We can expect other forms of embedded devices, such as “smart glasses” as evidenced by Google Glass, to join this increasingly rich ecology of devices that our approach is based on.

Our concerns with sustainability have led us to adopt a peer-to-peer architecture for devices within a clinic, rather than the client-server architecture favoured by enterprise approaches. Our motivation is that IT deployment in a clinic without professional IT support should be as simple as installing consumer electronic devices in a residential household. Effectively users should be able to switch on a device and immediately see it working[1]. “Underneath the hood,” the new device may for example use a discovery protocol, for example using WIFI broadcast, to find peers to communicate with. But the device is capable of continuing to function in standalone mode if no peers are discovered. In our architecture, data is replicated across devices in a clinic, and devices communicate peer-to-peer to share data, transparently to the users of these devices. Security is clearly a critical issue in this architecture, particularly since devices may be relatively portable.

3 Results

In this section, we give a detailed overview of the Aeetes approach to generating and supporting data collection tools.

3.1 User Interface

Our initial prototype of a data collection tool was based on Open Data Kit. ODK records questionnaires as XForms documents, constructed off the device using a form builder such as ODK Build. An Android app, ODK Collect, allows these forms to be displayed and filled in on an Android device, typically a smartphone. A Web service backend in the app then uploads these filled-in forms to a Web application. We adapted a version of ODK Collect, off the main development branch, that has a particularly rich user interface for tablets, developed for the New York City Department of Health. Although clients’ first impressions of the app were favourable, more experience with the user interface was less satisfactory. The UI reflects the origins of ODK as a data collection system for cell phones. The user experience with this interface was inferior to systems such as Access, that allow flexible navigation around the form.

Our second version therefore developed a native (hand-written) Android interface, with the interface designed to mimic as much as possible the user experience with paper-based forms. The user experience

[1] Similar consideration lay behind the Jini system [8], developed by Sun Microsystems for network appliances.

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with this interface was more satisfactory. The issues with this version were with the development, and with the backend handling of data. Because of the amount of data being collected, the development was extremely repetitive and tedious, which in turn increased the possibility of programmer errors, as well as making maintenance and routine form changes more difficult than they should be. This mitigated against a sustainable approach to data collection. Another issue, shared with the original ODK app, is that data collection is essentially “untyped.” The app itself has no knowledge of the data model for the data being collected. One of our eventual objectives with this research is to be able to analyse code that handles sensitive patient data, to ensure that potentially third-party code does nothing to leak sensitive information or violate patient confidentiality. A first step towards this goal is to make explicit the structure of the data being collected, and then make sure that each data item is handled (by software) in an appropriate manner.

The Aeetes approach built on these early prototypes, to take a new approach to developing data collection tools. As with the second prototype, the user interface is a native Android interface, with the potential for questionnaire designers to provide an arbitrarily rich user experience, using all the power of the Android GUI. However, rather than developing this interface by hand, it is instead generated by the Aeetes compiler, which is at the heart of the approach. The Aeetes markup language is used to describe both the user interface and the data model for an application. The markup language is based on the language for describing Android user interfaces, including views and view groups. It augments this with elements for specifying forms, such as sections and questions. At the heart of the markup language is a `<select>` element for specifying structured data collections, including drop-down lists, radio-button lists, check-box lists and tables.

From this input specification of the user interface, both an Android user interface, and an HTML preview, are generated. The Android UI includes a static description of the user interface for forms (in the Android markup language), a string resource file (one for each of the languages of the study), and Java classes for the user interface for each form. The HTML preview uses HTML5 elements to provide a preview of the forms that can be viewed through a Web browser. This is intended to allow data analysts, whose input is used to design the forms, to view and critique the forms without requiring access to an Android device. Currently the markup specification for a form is done using an XML editor, through a dialogue between data analysts and someone conversant with the markup language for forms. An interfactive form builder, based on the HTML preview, is under development, to allow data analysts to design forms directly. However to realize the full power of the Android UI, we expect that manual customization of the form markup specification will always be necessary.

The reason for form-specific classes in the output of the compiler is that the Aeetes compiler supports “typed” data collection, based on generating a model of the patient data being collected, and generating user interface code that is specialized to that model. Each form has a corresponding activity class, indexed by the patient data model, while each section of the form has a corresponding fragment class for managing the screen for that form section, indexed in turn by the corresponding submodel for that section of the form. Each input control is in turn indexed by the model for the data item being collected by that control. The intention is to eventually leverage this arrangement to augment the data model with security information, ensuring for example that only someone with proper authorization can view or edit a particular field in a form.

A data collection study typically consists of several forms, such as an enrolment form, a follow-up form and a lost-to-follow-up (LTFU) form. There is typically a high degree of overlap between these forms. For example, a form may specify laboratory test results, drug regimens, adherence to treatments, etc. The language for these forms must be carefully chosen to be consistent across multi-lingual studies (One of the countries we work with has at least two different languages, across different regions), and the skip logic must also be consistent between the forms. A markup document therefore describes all of the forms in a study, with sections and questions annotated to specify in which forms they appear, in the study. The main reason for describing forms this way, instead of separating the forms into separate specifications, is that it enables an overall data model for the study to be generated from the input specification, and each form related to the parts of this model for which it is designed to gather data.

3.2 Data Model

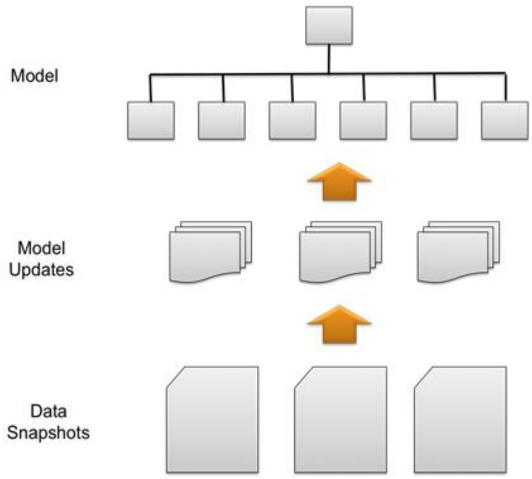
A major distinction between the Aeetes approach, and that of tools such as ODK and frameworks such as OpenMRS, is that we support typed data collection. The Aeetes compiler builds an explicit model of the patient data being collected, and statically ensures that the application gathering data is doing so in a type-safe manner, i.e., data is being handled in a manner consistent with the format of the data storage on the computer. As already noted, the motivation for taking this approach is to eventually support static code analysis to ensure that patient data is being handled by software in a secure fashion. For example, sensitive information should not be output to storage unencrypted, and should not be displayed on the screen for users without sufficient authorization to view the data.

By extracting the data model from the description of the data collection, we are able to relate each form generated from that description to the part of the patient data that it is responsible for collecting. The default choice is to extract the data model directly from the description of the questionnaire, since the two are usually closely related. For example, each section corresponds to a class for a persistent data object in the model. However where necessary, it may be useful to specify the model separate from the questions in that section, and a mapping used to describe where input data in the questionnaire is stored in the data model.

The default mapping from question type to data type is straightforward. Drop-down lists and radio-button lists are compiled to enumeration types, with the common special case of Boolean data recognized by the compiler. Checkbox lists, and tables with nullable rows, are compiled to lists. Where the rows in a checkbox list or table may have structured content, we may generate a class to box that content. In the case where different rows in a list have different types associated with them, we generate an abstract base class for the overall type, and concrete subclasses for each row in the list. Parts of a model, generated from a form specification, are also affected by the role of the form in the study. If a question is only asked in one form, and that form only administered once (e.g. in an enrolment form), then the data collected by that question comprises a field in the model. If the question is asked in multiple forms, or in a form that is administered several times (e.g. in a follow-up form), then the data model specifies a list of values, each one with an associated encounter date.

3.3 Data Handling

There are several levels at which the data being collected may be viewed:



Ultimately the objective is to build a patient data model, based on observations collected from various sources. In a data collection tool, these sources are forms filled in by clinicians as a result of patient encounters. However there is an intermediate stage between the data collection and its recording as part of the data model. Consider for example drug treatment regimens that a patient is currently undertaking. Data collection based on paper forms will record for each visit the dosage and frequency of

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administration for each of the drug treatments that a patient is receiving. Data models such as OpenMRS and HIV Cohorts Data Exchange Protocol (HICDEP) model treatment in terms of starting date, ending date, dosage and frequency. Data collection must therefore infer, based on differences between treatments from one encounter to the next, changes that have occurred in the treatment regimens. This is reflected by the intermediate stage above, between data collection and recording the data in the model.

An alternative approach is, rather than inferring changes in treatment from the data collected, to directly record the updates themselves. To do so requires a technically small, but conceptually large, change to the app. Rather than simply entering forms and uploading this data to a date warehouse, as with ODK, we may retain at least some part of the data in a database on the device. Data entry then consists not simply of filling in parts of a form that is initially empty, but also in some cases consists of updating parts of the database (in this case, to change drug treatments). This can avoid inference errors from data collection, and also serve as a useful data quality check at the clinic level. There are also other considerations. Providing even a simple EMR may enhance acceptance of the data collection tools in a clinic, since users will experience a tangible benefit from the use of the tools in their workflows.

There are other reasons for working at the level of data updates rather than data snapshots. In the peer-to-peer setting for this app, devices share data using “gossip protocols.” Periodically a device selects a peer and exchanges its data with that peer. There are two broad approaches to performing this sharing. One approach is to exchange the parts of a database that have been modified on one device but not the other. Another approach is for each device to keep an operation log, recording the update operations that have been performed on the data. A device then exchanges its data with another device by sending the operations not yet seen on the peer device. Once received at the peer device, the update operations are replayed there to bring the peer device up to the same state as the source device. The advantage of this update-based approach is that there are protocols that substantially reduce the amount of metadata that must be exchanged for the peer devices to identify the information that must be exchanged, while there are issues with extending these protocols to synchronization based on exchanging parts of the database [9].

To support the update-based approach, parts of the patient data model may be cached on the device. A new form may then be populated with the cached contents of the previous instance of this form for the patient, to allow direct updating of the date. These updates, along with updates for filling in other parts of the forms, are exchanged peer-to-peer with other devices, and eventually uploaded to the data warehouse for data analysis. Conceptually this uploading could be performed on a continuous basis, providing the data warehouse with an “almost-real-time” view of the clinic data. Practically, there are good reasons to batch the updates for uploading.

3.4 Security

Security of the data being collected is obviously paramount. This is particularly true when sensitive patient data is being stored on relatively small devices that may be lost or stolen. One of the challenges with deploying our approach has been to convince our collaborators not to adopt desktop computers for their clinic IT systems. Their understandable motivation has been that it is more difficult for a desktop computer to be stolen than a laptop or tablet. Nevertheless, the days of the desktop personal computer are numbered, and we have prevailed upon them to accept the future. The challenge remains then to make sure that patient data is properly protected.

It might be considered that, as long as no identifying patient information is kept on the device, data loss is no worse than publishing anonymized patient data. For example, for the purposes of epidemiological studies, patients can be identified by a study identifier rather than their medical record number. There are several objections to this. First, there are variables in the data, such as date of birth, that are considered quasi-identifiers, but which epidemiologists wish to collect for analysis. There are now well-known de-anonymizing attacks, such as the Netflix attack, that can be used to expose the identity of parties in a dataset from which identifying information has supposedly been removed. These attacks are based on correlating information in the dataset with another dataset that still retains identifying information. Second, there are scenarios where it may in fact be necessary to store the patient record number on the device. For example, much of the data useful for studies is stored in register books of various kinds, as mandated by government regulations, with patients identified in registers by their medical record number. Requiring a data entry person to look up a patient’s study identifier for every line

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in a register book is infeasible. This mapping must be performed by the app itself, even though the medical record number should never be part of the data that is uploaded to the data warehouse.

Our threat model assumes that any attacker who has access to a device can eventually bypass any access restrictions on the device, be they in the app or in the underlying Android/Linux operating system, and access any data stored on the device. Our strategy for protecting the data on a device is to keep the data encrypted in storage, and require an attacker to have three things in order to be able to compromise the data. Although Android supports encryption of the file system, we do not make use of this for several reasons. File system encryption is based on password-based encryption, and this does not provide a sufficient level of security. Furthermore, there is a problem if the user forgets their (Android) password. We instead implement our own encryption of patient data, and provide escrow for information that is required to access the data.

The data for a device is encrypted using an AES secret key. This provides a much higher level of security than a user password. Clearly storing this password on the device itself is insufficient, given our threat model. We instead store the secret encryption key off the device, as a QR code on a card. A user who logs in to access patient data is required to present the QR code. The app takes a picture using the device's camera, decodes the encryption key stored in the QR code, and can then use this key to decrypt data stored on the device. Obviously if both a device and its QR code are stolen, or if the QR code is photographed and the device stolen, this scheme will be subverted. Our recommended practice is that the QR code stays under the supervision of the administrator at all times, stored in a locked cabinet that only the administrator has access to. A user logging in will need to physically go to the administrator to obtain the QR code. A device that has been inactive for a period may require a user to authenticate with their password, while the device remembers the QR code. After a longer period, such as a lunch break, the device should forget the QR code and require another visit to the administrator to obtain the code. The ultimate goal is to ensure that an attacker who steals a device does not have access to the QR code anywhere on the device, and therefore cannot compromise the confidentiality of the data.

We still plan for the worst-case scenario, where a QR code is compromised in some way. We pair each device with its own private encryption key. We do this using a master password, unique for each device, and used as an authentication key for the encryption key. The key stored as a QR code is the encryption key, encrypted in turn using the master password. Both the encryption key and the master password are created in advance, with the QR code, by central IT administration. As part of installing the app on a device, the administrator enters the master password and presents the QR code to the camera. The app initialization decodes the password-encrypted encryption key in the QR code, decrypts and authenticates the encryption key using the master password, and then encrypts the master password using the administrator password and stores it in a record for the administrator in the user database on the device. Every time the administrator creates a new user account, the master password is encrypted using that user's password and stored with their record in the user database. Therefore every user, once they have authenticated with their user password, has access to the master password in their use of the app. To log in, a user must present both the QR code and their user password. Once the user is authenticated, their password is used to decrypt the master password, and the master password is in turn used to decrypt and authenticate the encryption key provided in the QR code.

An attacker wishing to access the data on the device must therefore have the physical device itself, a copy of the QR code that is specific to that device itself, and the password of a user on that device. Clearly all of these can be obtained via an insider attack, unless we have procedures such as described above for preventing theft of the QR code. The user password provides a line of defence against the scenario where for example a thief breaks in and steals both a device and a QR code. The last line of defence is a "kill switch" for the device, administered in both a push-based way (using Google Cloud Messaging) and in a pull-based way (if the app attempts its normal background processing by contacting the data warehouse in the cloud).

Peer-to-peer data sharing is complicated by the use of per-device encryption keys, since we cannot assume a single shared encryption key for sharing all data across devices. Instead we require every device to have its own RSA public-private key pair, generated as part of installing the app on the device. Devices share their public encryption keys as part of discovery, and a source device sharing updates with a sink device must first generate an AES session key for the duration of the synchronization, encrypt the session key using the sink device's public key, encrypt updates to be sent to the sink device using the session key,

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and then send the encrypted session key and updates to the sink device. A very similar protocol is used for pushing updates to the data warehouse.

4 Discussion

Aeetes is not intended necessarily to replace existing PC-based and enterprise-based approaches to data collection. Rather it fills a gap that we have perceived in such tools, between simple Access-based approaches and more sophisticated approaches such as OpenMRS. We believe (or least hope) that the days of Access-based approaches are numbered. Our reason for hoping this is true is due to the security issues with Windows-based, Access-based approaches to data collection and storage. Today the private records of hundreds of thousands of HIV/AIDS patients reside unencrypted on Windows devices potentially infected by malware. The Aeetes approach suggests a possible migration path away from Access to more sophisticated and more secure approaches.

There is much that we would still like to accomplish, to make Aeetes a viable long-term alternative to Access systems. Our point of comparison for Access-based approaches is the EPI-INFO system supported by CDC. The two advantages cited for EPI-INFO are: (a) the ability to automatically generate a database schema from a user interface, and (b) the ability to program extensions, particularly for data analyses. The Aeetes compiler provides the former ability, and our next task is to develop a framework for supporting the latter. One issue here is that the Android platform has a difficult programming model, using asynchrony and callbacks ubiquitously to keep long-running computations off the main UI thread, and with an application life cycle model that is more complicated than that for more conventional operating systems that simply swap processes in and out transparently to application programmers. We are developing a domain-specific programming language for Aeetes extensions with the intention that programmers of extensions will be able to avoid the use of callbacks entirely. The kinds of extensions that we are focused on are on-device analyses of patient data, based on the experience with EPI-INFO.

We have not said anything about databases, because for now we have found it unnecessary to use databases. The app contains several content providers (for users, forms, form instances, etc), implemented using SQLite, but mostly these are simple tables. The implementation of role-based access control is the only place where we found it necessary to model relationships in the database schema. The relationships in patient data are one-to-one or one-to-many, represented in our schemas as lists. So a document-oriented NoSQL database such as Couchbase would suffice to store patient data. For now, we are storing patient data in files because of the need to store the data encrypted. It also keeps the runtime of a non-standard database management system outside our trusted computing base. We expect to revisit this at some point in the future, since some form of map-reduce-based parallel processing may be necessary to support efficient data analyses.

OpenMRS has demonstrated the value of having an extensible component framework for building EMRs in an open source community. Although designed initially as a data collection system, Aertes could become the foundation for an EMR, less ambitious and simpler than OpenMRS, but perhaps more appropriate to some situations where IT support is lacking. It is therefore intended to occupy a different market niche from OpenMRS. We have some hope that some of Aertes approach, in particular the use of a compiler to generate concept schemas, may eventually make its way into the OpenMRS community, since it can support more reliable and eventually more secure data handling.

Other systems have also explored the space of peer-to-peer architectures for data collection. AndroidOpenMRS combines an interface implemented using ODK with an implementation of the OpenMRS concept dictionary in SQLite, and includes peer-to-peer data replication. The focus in Aeetes has been on an improved user interface, by compiling from input specifications to native Android user interfaces, explicitly modelling the data being collected for reliability and security, protecting the confidentiality of patient data against attacks such as device theft.

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Adequacy and Quality of Immunization Data in a Comprehensive Electronic Health Record System

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Background and Purpose: Timely, simultaneous and combined vaccination is important to protect children from common infectious diseases. In a large health care delivery system in Western Kenya, we examined the adequacy and quality of data within the electronic health record (EHR) to assess the feasibility of developing a clinical decision support system to improve childhood vaccination uptake and coverage.

Methods: The study evaluated vaccination information collected and stored in an EHR between 2006 and 2012 involving 23,270 children. Encounters for 10,299 children lacked immunization information and were excluded.

Results: Documentation of vaccination coverage and timeliness is rendered in Kaplan–Meier time-to-event plots. Vaccination coverage at the end of one year ranges from 60% to 90% for all vaccines assessed individually that are part of the Kenya Expanded Program on Immunization (KEPI). Timely documentation of vaccination is low, with 52.8 weeks (95% CI: 52.1, 53.5) for measles vaccine and 29.2 weeks (95% CI: 28.5, 29.8) for the Bacillus Calmette–Guérin (BCG) vaccine. Complete vaccine observations were recorded in 16% of the encounters. Combination and simultaneous vaccine administration had high congruence and consistency.

Conclusion: A clinical decision support system that generates reminders to clinicians and caretakers of children would optimize vaccination uptake and improve overall immunization coverage. To achieve this, immunization data in the EHR must be timely, complete and consistent. Assessed vaccination timeliness is low, despite high coverage. Vaccine observations are often incomplete. There is need to improve the data collection process to achieve data quality levels that can adequately support a clinical decision support system.

Keywords: Vaccination, Electronic health records, Developing countries, Data quality

1 Introduction

Throughout the world, the use of vaccines has helped to save many lives. The Expanded Program on Immunization, created in 1974, is considered one of the world's most successful public health initiatives of the 20th century [1]. The Global Alliance for Vaccines and Immunization, which supports vaccination programs in developing countries, estimates that by 2010 its work supporting vaccination helped avert approximately 5 million pediatric deaths worldwide [2]. Vaccination programs have proven to be highly cost effective, and are important in achieving Millennium Development Goal 4, which calls for reduction by two-thirds of under-5 mortality by 2015[3]. In developing countries, vaccination programs also form a fundamental part of the healthcare systems. This is because vaccination sessions provide additional opportunities to deliver other health care services that might otherwise be missed, including treatment for malnutrition, malaria, intestinal worms, growth monitoring, breast feeding education, among others [4].

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Beyond individual benefits of vaccination, herd immunity can also be achieved when adequate numbers of children are immunized for the particular condition.

In developing countries, immunization information is often collected along with other clinical information as part of routine clinical care for the child. In these cases, the immunization information becomes part of the child's longitudinal record. Well-functioning immunization programs need reliable record systems to assist providers in offering timely and high quality immunization care. These records should include details about a child's prior vaccinations, immunizations administered on a particular visit, and the administration dates for all vaccinations [5]. The same individual immunization data can be aggregated and used by administrators and Ministries of Health in health services planning and to inform healthcare policies. With increasing adoption of Electronic Health Records (EHRs) in developing countries, immunization data is increasingly being stored in an electronic format as part of a longitudinal electronic record [6]. When available electronically, immunization information can potentially be leveraged to deliver automatic reminders and alerts for upcoming or missed immunizations. The immunization information stored can also be aggregated in various ways to best serve the needs of decision-makers at multiple levels.

To best serve the clinical purpose, immunization records need to be part and parcel of the patient's comprehensive record and available to clinicians when needed. As such, cases of isolated immunization databases, often seen as part of some immunization campaigns, rarely reflect the reality of the child's comprehensive clinical record.

EHRs are oftentimes touted as leading to more accurate, timely and readily available data than traditional paper systems [7]. However, almost no research exists to inform on the adequacy with which immunization information collected as part of routine care within EHRs in developing countries actually meet the needs for high quality immunization care [8]. In this study, we critically evaluate the quality and usefulness of child immunization data collected as part of routine clinical visits in a large comprehensive care program in Western Kenya. We particularly focus on how well this data reflects the real picture of immunization services provided, and whether the data passes 'fitness for use' test to inform decisions at individual and systemic levels.

2 Methods

2.1 Study setting

This study was conducted in a large care program formed by the partnership between United States Agency for International Development (USAID) and the Academic Model Providing Access to Healthcare (AMPATH) in Western Kenya [9]. Established in 2001, the AMPATH program is one of the largest comprehensive care programs in sub-Saharan Africa, serving a catchment area of over 2 million individuals through 30 parent and 49 satellite clinical sites. The program offers a broad range of services from antenatal care, pediatric and adult primary care services, HIV care and chronic disease management programs.

At AMPATH clinics, childhood immunizations are offered as per the Kenya Expanded Programme on Immunization (KEPI) schedule, with each child completing routine immunizations in five encounters [10]. The immunizations administered as part of the KEPI schedule are as follows: At Birth - Bacillus Calmette-Guerin (BCG) and Oral Polio (Polio 0); At 6, 10 and 14 weeks of age the children receive Oral Polio, Pentavalent, and Pneumococcal Conjugate vaccines at each of these visits. Measles vaccine is administered last at the age of 9 months. Pentavalent vaccine is a combination vaccine comprised of Diptheria, Pertusis,Tetanus (DPT), Hemophilus influenza Type B (HIB) and Hepatitis B (Hep B) vaccines.

2.2 Immunization Records

Since 2004, AMPATH clinics have used the AMPATH Medical Record System (AMRS) to store comprehensive, longitudinal electronic patient records for all enrolled patients [11]. AMRS is the original implementation of OpenMRS, an open-source electronic health record system deployed widely in the developing world [12]. Clinicians caring for AMPATH patients do not enter data directly into AMRS but rather complete paper encounter forms that contain clinical parameters and categorical observations

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previously defined and encoded into the AMRS concept dictionary (see Appendix A for pediatric encounter form). Where necessary, clinicians can write down diagnoses, test results, and other observations as free-text if these are not included in checklists on the encounter form. Clerks with basic computer skills and minimal medical knowledge enter data from the encounter forms into the AMRS. The encounter forms are then placed in the patient's paper clinic chart, which is available to the clinician during patient care.

At AMPATH, immunization information is collected within pediatric encounter forms by clinicians at every visit (Appendix A & **Fig. 1**). Immunization information collected include all previous immunizations (**Fig. 1** – Item 32a), whether the child is on schedule with immunizations or not (**Fig. 1** – Item 32b), and the exact immunizations administered during the visit (**Fig. 1** – Item 51e).

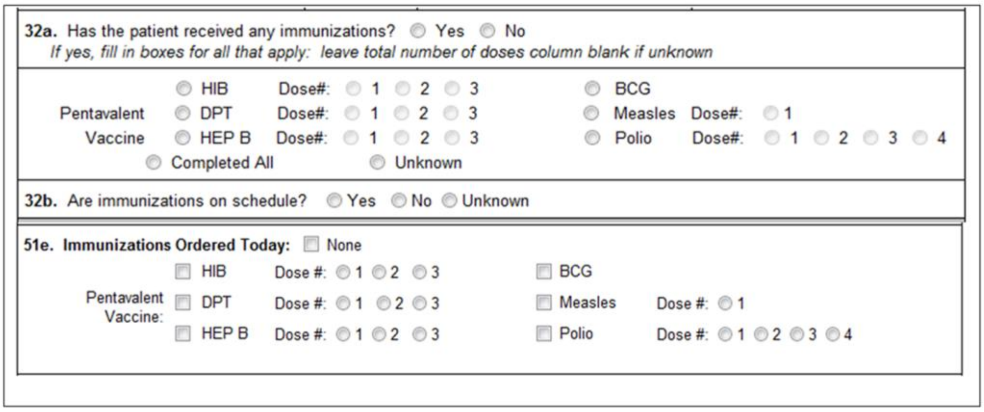
32a. Has the patient received any immunizations? Yes No
If yes, fill in boxes for all that apply: leave total number of doses column blank if unknown
Pentavalent Vaccine: HIB Dose#: 1 2 3; DPT Dose#: 1 2 3; HEP B Dose#: 1 2 3
BCG
Measles Dose#: 1
Polio Dose#: 1 2 3 4
Completed All Unknown
32b. Are immunizations on schedule? Yes No Unknown
51e. Immunizations Ordered Today: None
Pentavalent Vaccine: HIB Dose #: 1 2 3; DPT Dose #: 1 2 3; HEP B Dose #: 1 2 3
BCG
Measles Dose #: 1
Polio Dose #: 1 2 3 4

Fig. 1. Sections of routine clinical encounter form that capture immunization information for a child

2.3 Study Population

This study involved evaluation of immunization data collected for all children enrolled in the AMPATH program clinics and born between January 2006 and December 2010 as represented on **Fig. 2**.

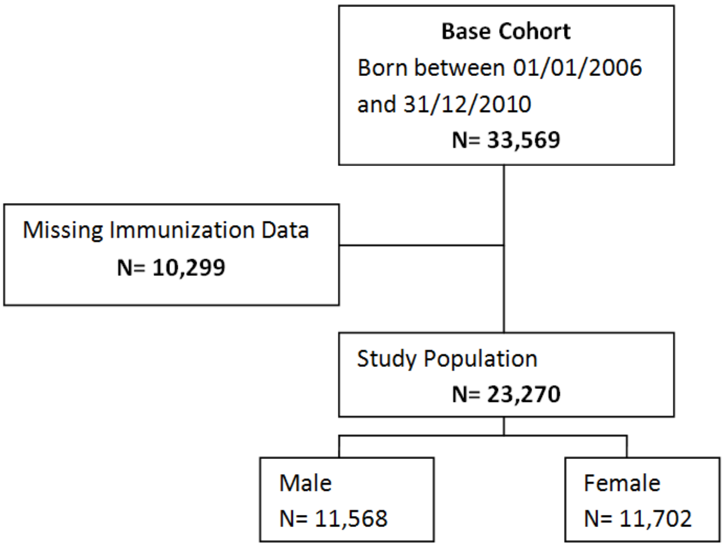

Fig. 2. Study population

2.4 Data Collection

All immunization information for the cohort of children in the study was collected in the paper encounter forms, and the data entered into the AMRS EHR. We used data in the EHR from January 1, 2006 to 31

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March 2012. These dates were chosen because the oldest children in the cohort were born in January 2006, whereas the youngest were born in December 2010. By looking at data until March 2012, we felt comfortable that the youngest children in the study cohort would be expected to have completed the required immunization as per the schedule. For each of the study participants, we extracted demographic information and for each clinical encounter, we extracted historical immunization information, and the vaccine types and value of dose administered.

IRB approval was obtained from the Institutional Research and Ethics Committee at Moi University School of Medicine, Eldoret, Kenya, and Indiana University's Institutional Review Board in Indianapolis, Indiana. All data was de-identified before analysis.

2.5 Outcome measures

The goal of this study was to assess the data quality and adequacy of immunization data collected within the EHR to satisfy the needs of a clinical decision support system aimed at improving immunization in the relevant population. Data quality dimensions that are generally accepted as depicting the real world scenarios are accuracy, timeliness, completeness, precision and consistency [13]-[17]. As pertains to immunization data quality, these dimensions have been refined in the General Recommendation on Immunization [18]. Since these redefined dimensions are better at ascertaining the accuracy and adequacy of immunization data, we chose to apply these in our analysis. These are:

1. Timeliness. Age appropriate administration of vaccines as recommended based on demonstrated efficacy and safety for specific age groups at risk of experiencing the disease. Timely vaccinations induce adequate immunity.
2. Spacing of the multiple sources of the same antigen. Optimal immune response is achieved when doses of the same vaccine are administered at recommended intervals.
3. Simultaneous administration. Administering more than one vaccine on the same clinic day, at different anatomic sites, and not combined in the same syringe. There is adequate scientific basis for simultaneously administering all vaccines for which a child is eligible at the time of a visit and this increases the probability of age appropriate compliance.
4. Combination vaccines. Combination vaccines merge equivalent component vaccines into single products to prevent more than one disease or to protect against multiple strains of infectious agents causing the same disease. This also reduces the number of injections patients receive and alleviates concerns associated with the number of injections.

2.6 Data analysis

MYSQL was used to extract the data from AMRS and analysis was done in SPSS version 19.The analyses were confined to 23,270 children aged 15 – 75 months (born between 1 January 2006 and 31 December 2010) excluding 10,299 children due to missing vaccination information. A reference date of 31 March 2012 was set for age calculations and vaccination observations made after this date were excluded.

Age appropriate vaccination uptake (timeliness) was estimated by the Kaplan-Meier method with age in weeks as the timescale [19][20]. Vaccination coverage at age t was estimated by 1 - SKM (t), the Kaplan-Meier survival function; 1 - SKM (t) is the cumulative probability of being vaccinated by age t. Comparison of survival distribution from cohort to cohort was carried out using Log Rank and Tarone-Ware techniques [21].

3 Results

A total of 23,270 eligible children (49.3% male, 50.7% female), aged 15 - 75 months in a total of 272,926 encounters and 1,258,348 immunization observations comprising 5 birth cohorts were included in the study period from 1 January 2006 to 31 March 2012. 10,299 children did not have any immunization data collected during this period. The mean age for the study subjects was 42 months (SD 17.4). The distribution of children in the cohorts is 3,125 in 2006; 3,848 in 2007; 4,095 in 2008; 5,359 in 2009 and 6,843 in 2010 cohorts.

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Kaplan-Meier estimates show an overall systematic reduction in the mean time of recording of the first immunization observation over time towards the recommended age of vaccine administration. This trend is best demonstrated by measles observations with a mean time of 38.240 (95% CI: 37.728, 38.751) weeks against the recommended age of 36 weeks in the last cohort (2010), however the overall mean time throughout the 5 cohorts is slightly higher, 52.804 (95% CI: 52.147,53.462). The first vaccine in the schedule, BCG, takes longer to be administered or recorded in the system with a mean overall time of 29.162 (95% CI: 28.482, 29.841) weeks, but this interval reduces over time through the cohorts (**Fig. 3** and **Fig. 4**).

The time course of completion of BCG and DPT series vaccinations is described graphically in **Fig. 3**.It is evident that for both BCG and DPT the series completion of primary vaccination is achieved by only about 10% of the children by the recommended time of 14 weeks at most, and it takes another 300 weeks for all children to have the vaccine observations recorded.

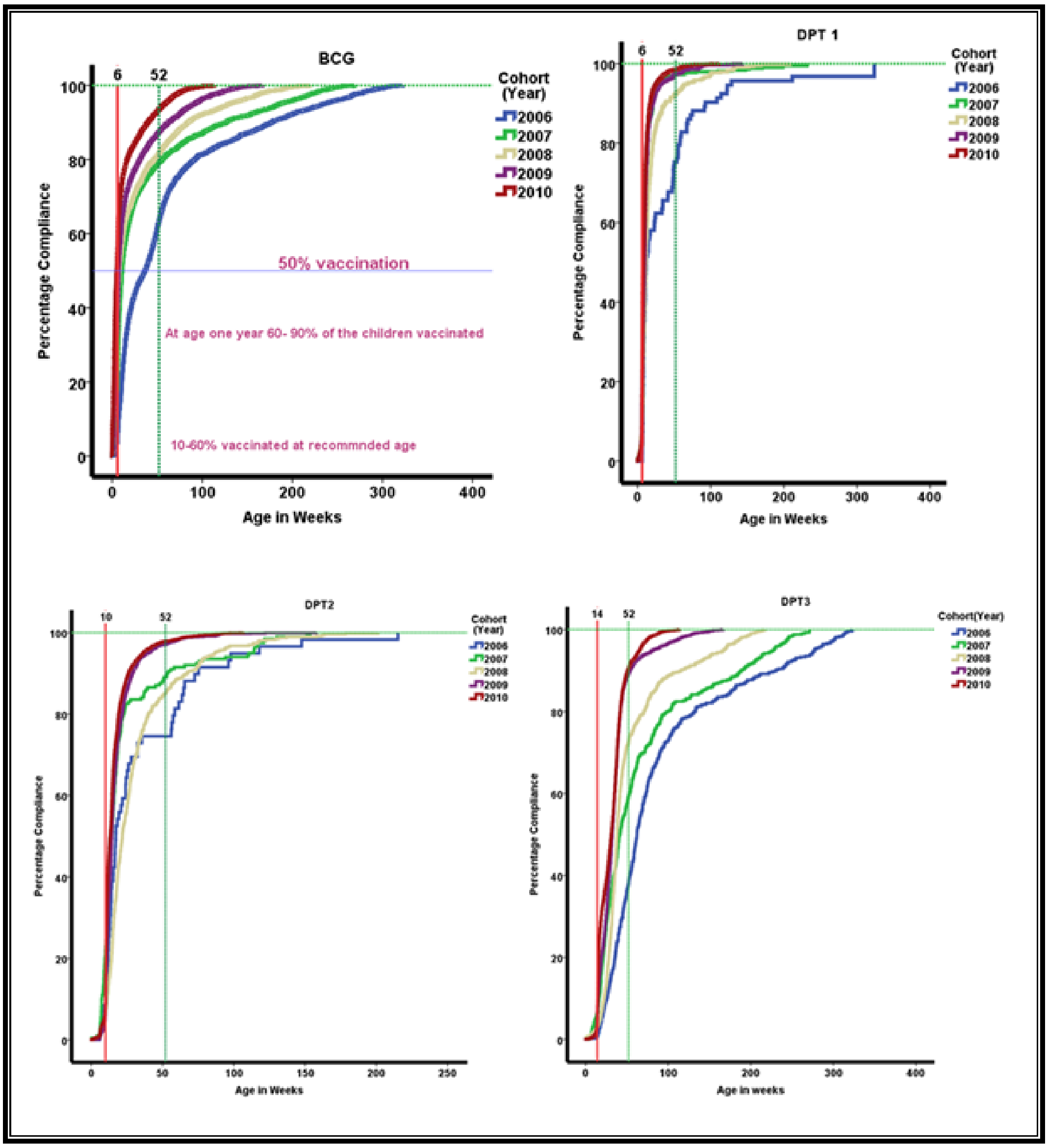

Fig. 3. Age at recording of vaccine observations presented in Kaplan–Meier plots (inverse and cumulative) for BCG and DPT. The X-axis is the age in weeks (used in KEPI schedule) and the Y-axis is the proportion of vaccine observations at each time point. The red vertical lines indicate the recommended age for vaccination. Age of one year is indicated as a scaling (green vertical dotted line), and is the age when all the vaccines are required to have been completed.

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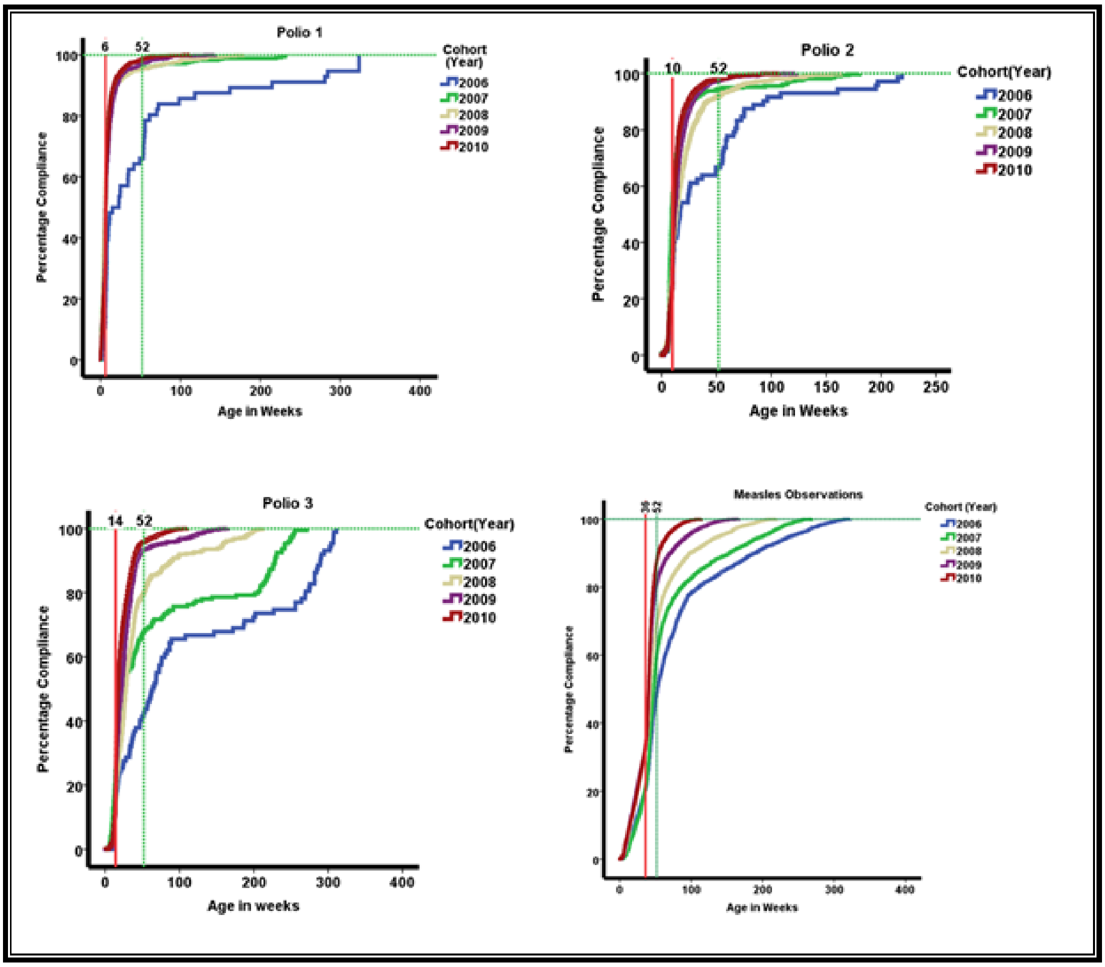

Fig. 4. Age at recording of vaccine observations presented in Kaplan–Meier plots (inverse and cumulative) for Oral Polio and Measles

Up to 80% of all children have their observations recorded by their first birthdays, demonstrated by steeper survival curves. After the first year, the curves generally plateau off and it takes much longer for the remaining children to have their vaccine observations administered or recorded. This also explains why most vaccine coverage estimations in the region are found to be about 80%; since age one year is usually taken as the benchmark for a fully immunized child, against a global recommendation of 90% [22]. This commonly used approach is disadvantageous since vaccination coverage can only be determined for the preset age groups and it is not possible to establish the age at which the defined coverage levels are achieved [20]. The multiple dose vaccines such as DPT and Polio reach the 80% mark within the recommended age of 6 weeks for the first doses in both vaccines. The subsequent doses show less steep curves and reach 80 % after longer time intervals.

Test of equality of survival distributions for the different vaccine and different birth cohorts using Log Rank (Mantel-Cox) and Breslow (Generalized Wilcoxon) methods found significant differences between cohort pairs and overall comparisons. This means that the timeliness of vaccine administration and observation changes over the years; with a systematic improvement from 2006 to 2010 as demonstrated by differences in gradients of the graphs.

In the year 2011, the total number of pentavalent component vaccine observations (DPT,Hep B and HIB) were the highest throughout the study period. During this time, this combination vaccine had a concurrence of 97.4% for the 3 vaccine components. This is expected since these vaccines are administered from the same vial. There was no significant difference between the individual vaccine observations (**Fig. 5**).

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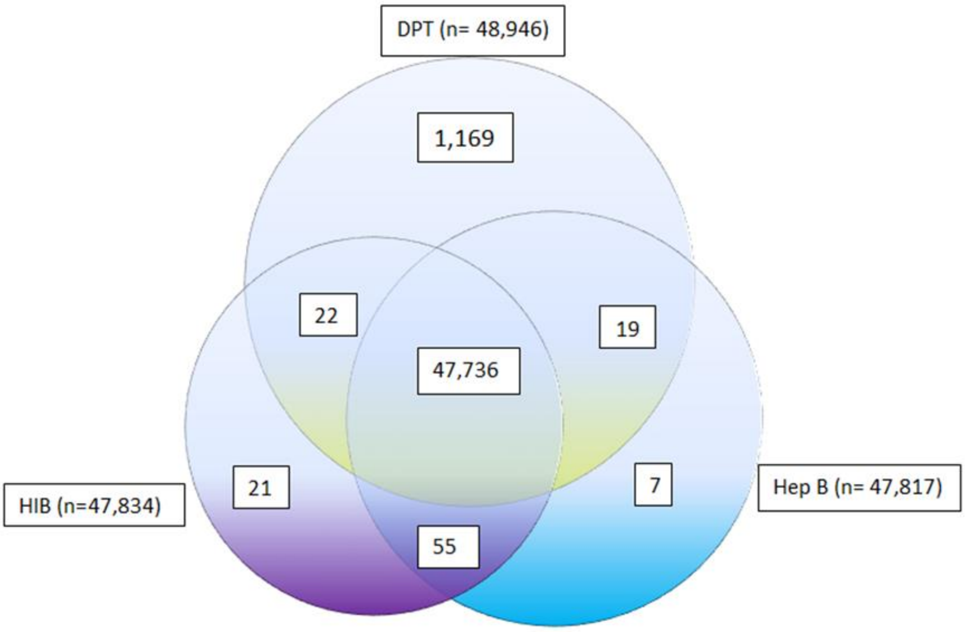

Fig. 5. Relationship of combination vaccine components for immunization observations in 2011.

Based on the recommendation that all age-appropriate doses of vaccines be administered simultaneously to children for whom no specific contraindications exist at the time of the visit, **Fig. 6** depicts the relationship between Polio and DPT observations through the 5 cohorts [18]. The proportions of DPT observations range from 48.1% to 50.0% while Polio observations range from 50.0% to 51.9% through the 5 cohorts. There are no significant differences between these proportions at alpha 0.05 levels as demonstrated by the overlapping 95% CI bars in the first two cohorts. Polio 0, administered at birth for children born in health facilities, estimated at 40% of all deliveries, contributes to the slightly higher polio observations in the last 3 cohorts, since DPT is not administered at this time [23]. In these 3 cohorts, the 95% CI do not overlap and thus the differences are significant.

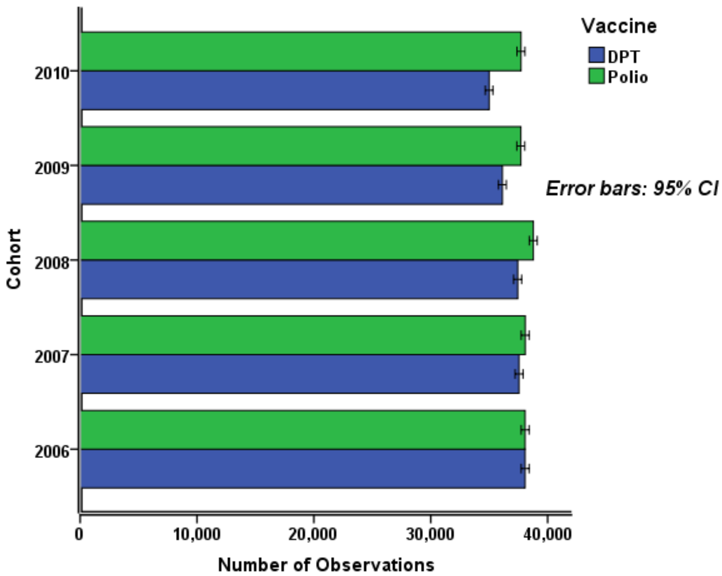

Fig. 6. DPT/Polio Observations showing simultaneous administration

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Fig. 7 shows an output from the EHR. Each vaccine represented is incomplete and it is not possible to know how far the child is in the vaccination schedule. This is a direct consequence of having 2 checkboxes for each vaccine as clinicians often tick one of the two required places. When they tick only the checkbox with the vaccine type, the system will store that vaccine type without the dosage, and when they only tick the checkbox with dosage, the system stores a value without a corresponding vaccine type. This is a very common phenomenon and

Table 1 shows exactly how this applies to other vaccines for the study duration. Most vaccines have doses 1-3 and polio has 0-4.

9.

IMMUNIZATION HISTORY	
PREVIOUS IMMUNIZATIONS ADMINISTERED	NUMBER OF DOSES RECEIVED BEFORE ENROLLMENT
	4.0
	1.0
BACILLE CAMILE-GUERIN VACCINATION	
	3.0

Fig. 7. Sample output from AMPATH Medical Record System.

Table 1. Completeness of immunization data for multiple dose vaccines

			VACCINE TYPE								
			DPT	Hep B	Polio	HIB	Pneumovax	Penta	PCV 10	Missing	Total
Dose value	0	Count	N/A	N/A	798	N/A	N/A	N/A	N/A	935	1,794
		%			0.4%					2.7%	0.2%
	1	Count	5,391	3,593	5,534	3,623	10	1	19	8,318	26,428
		%	2.9%	2.0%	2.9%	2.0%	3.8%	0.5%	9.7%	24.3%	3.5%
	2	Count	5,252	3,445	5,556	3,445	9	4	41	5,407	23,159
		%	2.9%	1.9%	2.9%	1.9%	3.4%	2.1%	20.9%	15.8%	3.0%
	3	Count	13,111	11,087	5,850	11,099	211	171	128	17,060	58,717
		%	7.1%	6.2%	3.1%	6.2%	79.6%	90.0%	65.3%	49.9%	7.7%
	4	Count	N/A	N/A	8,975	N/A	N/A	N/A	N/A	2,495	11,470
		%			4.7%					7.3%	1.5%
	Missing	Count	160,422	159,609	163,630	159,761	35	14	8		643,479
		%	87.1%	89.8%	86.0%	89.8%	13.2%	7.4%	4.1%		84.1%
Total		Count	184,176	177,734	190,343	177,928	265	190	196	34,215	765,047

4 Discussion

A fully immunized child is one who has received all the recommended immunizations within the first one year of life as per the KEPI schedule. This commonly used measure of the proportion of children with specific immunization types at defined ages (`up-to-date') lacks the flexibility of measuring immunization compliance over time and often gives lower compliance figures. EHRs allow visualization of

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immunization compliance over time. Kaplan-Meier survival plots enable graphic visualization of vaccination at any chosen time interval [20].

Measuring immunization compliance at specific ages recommended for particular vaccine administration and at the age of 1 year showed significantly low rates compared to the overall rates achieved at the end of the study period. This could be explained in two ways; delays in vaccine administration and information system time lag between vaccine administration and recording [24]. Actual delays in vaccine administration are common in the setting where this study was carried out and there are many shortfalls in the healthcare system and personal factors that result in this. Identified characteristics of a well-functioning vaccination systems that promote timely vaccination include availability of health services at all times, short distances and waiting times, media promotion and campaigns [24]. The time intervals between vaccine administration and recording into the EHR vary, and could affect calculation of compliance rates when these intervals are large because vaccine observations are recorded on the date of encounter and not the date of administration.

In the 5 cohorts, there is a general trend of improvement in compliance rates at the age appropriate intervals as time progresses. Whereas the compliance rate of BCG in 2006 is about 60% at the age of one year, it is over 90% in 2010 at the same age. The EHR was relatively new in 2006 and clinicians and other users were still getting used to use it. This phase of learning involves not only getting used to the new encounter forms and workflows, but also disrupts routine tasks and interrupts existing workflows in the healthcare processes with record keeping and data quality falling behind the previous schedules [25]. By 2010, extensive use of the encounter forms and full integration into the workflows resulted in marked improvements in timeliness and therefore, compliance rates. This is important because timely vaccination aside from good coverage, offers better protection from diseases such as Pertussis, Measles and Haemophilus Influenzae type B [26]-[28]. However, we do not know for sure whether the changes in timeliness are due to changes in the recording process or healthcare administrative processes because the system records vaccine observations as per encounter dates and not administration dates. To adequately address this phenomenon, we will carry out another analysis after redesigning the encounter form to take into consideration human and system factors that affect vaccine data quality.

Other studies have found similar differences between up-to date and age-appropriate vaccination [20] [29]. However, in this study care must be taken when evaluating compliance across time because data delay and ongoing processes yield incomplete data and comparison at face value may not be fully valid. In addition, there are logistical challenges such as failure to store sufficient vaccine stocks at all times, poor cold chain system maintenance, and inadequate staffing at health facilities that further reduce compliance rates [30].

Simultaneous and combined vaccine administrations were found to have high consistencies and concurrence among the various affected vaccine observations. This is associated not only with reduced number of injections, but also improves the main target of vaccination programs: timely and complete protection [31].

Findings from this study are mostly consistent with other reports on analysis of EHRs. While EHRs provide a versatile means of information storage and access, there are associated deficiencies in clinical and managerial applications [25]. There are many reasons for this, ranging from people dynamics to electronic tools. In relatively new systems, like the AMRS, the learning process is still taking place. The data collection forms and processes are initially still being refined and the personnel are getting used to the new system. Completeness was found to have the lowest data quality across all data variables (

Table 1). We found that providers often did not complete the immunization fields as required in the forms. They would check the vaccine type and leave out the dose and vice versa. This made it difficult to calculate the spacing between different doses of the same antigen, as this requires vaccine type and dosage values to be present.

Decision support tools are important in promoting structured data entry and other determinants of data quality [16]. Since data entry is a tedious process and consumes a considerable amount of clinicians' and data entry clerks' time, it would be efficient to collect only new and relevant data during every encounter. The design of the encounter forms plays a significant role in data quality. 10,299 (30.1%) of the children had missing immunization observations attributable to the encounter type used in this group. The Rural Health Centre Encounter form does not have the section on 'previous immunizations' and only collects 'ordered' (given today) immunization observations (See appendix 2), which directly contributes to significant missing data.

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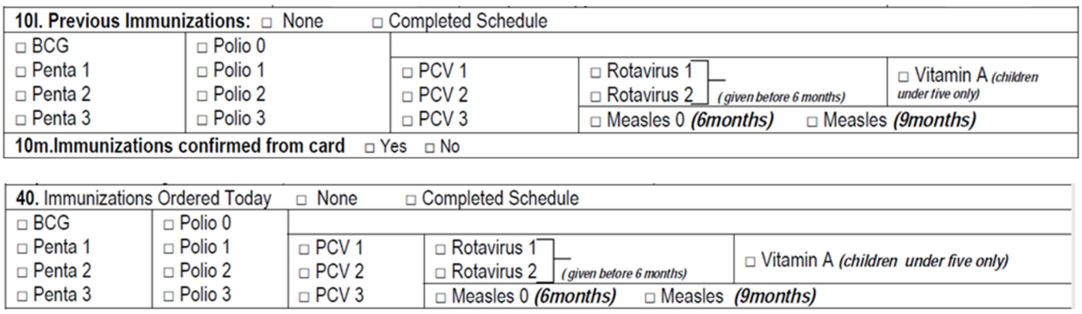
As a result of this evaluation, the encounter form has been significantly improved to take into consideration human factors that affect data quality and effective data collection processes. The immunization sections on the redesigned encounter forms are depicted on **Fig. 8**. In this design, the separation of vaccines and dosages has been eliminated and these now appear as one combined tickable checkbox for each vaccine given. Combined vaccine Pentavalent is now represented as one vaccine instead of individual components. The arrangement also corresponds to the KEPI schedule and it is convenient for clinicians to check all vaccines in a row that are given at the same time.



10l. Previous Immunizations: □ None □ Completed Schedule
□ BCG □ Polio 0
□ Penta 1 □ Polio 1 □ PCV 1 □ Rotavirus 1 □ Vitamin A *(children under five only)*
□ Penta 2 □ Polio 2 □ PCV 2 □ Rotavirus 2 *(given before 6 months)*
□ Penta 3 □ Polio 3 □ PCV 3 □ Measles 0 ***(6months)*** □ Measles ***(9months)***
10m.Immunizations confirmed from card □ Yes □ No

40. Immunizations Ordered Today □ None □ Completed Schedule
□ BCG □ Polio 0
□ Penta 1 □ Polio 1 □ PCV 1 □ Rotavirus 1 □ Vitamin A ***(children under five only)***
□ Penta 2 □ Polio 2 □ PCV 2 □ Rotavirus 2 *(given before 6 months)*
□ Penta 3 □ Polio 3 □ PCV 3 □ Measles 0 ***(6months)*** □ Measles ***(9months)***

Fig. 8. Immunization section on redesigned AMPATH pediatric encounter form

4.1 Limitations

Generalizability of these findings is limited to settings with similar characteristics. The study uses vaccine observation times rather than administration times.

In some cases, it may be justified to postpone vaccination temporarily when children are moderately or severely ill. Vaccination is then recommended to be given soon after recovery. This was not assessed nor analyzed.

5 Conclusion

Data quality is affected by many factors involving data collection, storage and retrieval. Development of a clinical decision support system that generates reminders directed at clinicians and parents with immunization eligible children would optimize vaccination uptake and improve overall immunization coverage. This study found low age-appropriate vaccination status and high overall vaccination coverage which implies that vaccine administration and recording into the EHR are not timely. Many children were unprotected by vaccination for several months despite being vaccinated at the end of follow-up. The data collection through ticking of checkboxes on paper encounter forms contributes to incomplete data when clinicians fail to tick all the required checkboxes. To achieve data quality levels adequate for a clinical decision support, data collection processes need to be improved through form redesign and clinician sensitization.

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Appendix A: AMPATH Pediatric Clinical Encounter Form

USAID | AMPATH PARTNERSHIP

PAEDIATRIC RETURN VISIT FORM

Date: / /

1.Name: **AMPATH ID:** **Previous ID:**

Mother's AMPATH ID

2. DOB: / / **Age:** ____ **Yrs.** ____ **Mos.**

3. Mother Deceased: □Yes □No □Unknown
Father deceased: □Yes □No □Unknown

4. □ Scheduled □ Unscheduled Early □ Unscheduled Late

5. Clinic Location:
MTRH Module: □1 □2 □3 □4 Chulaimbo □1 □2 Busia □1 □2
□ Amukura □ Burnt Forest □ Iten □ Kabarnet □ Kapenguria □ Turbo
□ Khunyangu □ Kitale □ Mosoriot □ Mt. Elgon □ Naitiri □ Port Victoria □ Teso
□ UG District Hospital □ Webuye □ Moi's Bridge □ Moi University □ Soy
□ Nambale □ Mukhobola □ Bumala A
□ Satellite: ____ □ Other: ____

6. Category:
□ Pilot □MTCT Plus
□NASCOP □Self Pay
□ Awaiting Assignment
□Research □Other:

7. Person Bringing Patient:
□ Mother □ Father □ Sibling
□ Grandparent □ P □ M
□ Auntie □ P □ M
□ Uncle □ P □ M
□ Children's home □ Other ____

8. Current Feeding: *tick all that apply*
□ Breast □ Formula □ Cow's/Animal milk
□ Expressed Breast milk □ Other liquids
□ Water □ Solid Food

9. Previous Immunizations: □BCG
□HIB Dose#: □1 □2 □3 □Measles Dose#: □1
□HEP B Dose#: □1 □2 □3 □Polio Dose#: □1 □2 □3 □4
□DTP Dose#: □1 □2 □3 □Completed all □Unknown

10. If breastfeeding, is mother on ARVs?
□Yes □No □Unknown

11. Are there Siblings < 18 months? □Yes □No
If yes, are they registered in Pediatric HIV clinic? □Yes □No □Unknown
If yes AMPATH ID's: 1.____ 2.____

12. Child's Current HIV Status: □HIV exposed, status indeterminate □HIV infected □HIV Negative

13. Has patient been hospitalized since last visit? □ Yes □ No Reason:

14. Does Child have a disability? □ Yes □ No If yes, Specify:

15. Current Medications:

15a. ARVs: □ Yes □ No Is this the patient's Primary Regimen? □Yes □No Reason for ARV's: □pMTCT □Clinical disease
□ 3TC (4mg/kg): □ Syrup ____ mg ____ml □Tabs ____ mg □Kaletra (0.125ml/kg): □Syrup ____ mg ____ml □Tabs ____ mg
□ d4T (1mg/kg): □ Tabs □15 □20 □30 mg □ ABC (8mg/kg): □Syrup ____ mg ____ml □Tabs ____ mg
□ AZT: (180mg/m2): □ Syrup ____ mg ____ml □Tabs ____ mg □ DDI (100mg/m2): □Syrup ____ mg ____ml □Tabs ____ mg
□ NVP: □ Syrup ____ mg ____ml □Tabs ____ mg □ Nelfinavir: □ Powder ____ mg □Tabs ____ mg
□ EFV: □ Syrup ____ mg ____ml □Tabs ____mg □ Other: □Syrup ____ ml □Tabs ____mg

15b. PCP Prophylaxis: □ None □ Septrin □ Dapsone
15c. TB Prophylaxis: □ None □ INH

15d. TB Treatment: □ None □ Completed (Date: / /) □ Rifater □ Rifinah (Rifampin/INH)
□ Rifampicin □ INH □ Pyrazinamide □ Ethambutol □ Streptomycin **Start Date of TB treatment:** _/__/___

15e.Cryptococcus Tx: □None □Diflucan
15f.Other Drugs:

16. Adherence:

16a. Who has been giving the medicine to the patient? (Please tick all that apply):
□Mother □Father □Sibling □Grandparent □Auntie □Uncle □Self □Children's Home □Other (Specify):

16b. During the last month has the patient missed any medications? □ Yes □ No
□ ARVS □ PCP Prophylaxis □ TB Prophylaxis □ Anti-TB Medication
Drug(s) Missed: Reason:

16c. During the last seven days how many of his/her pills did the patient take?
□ ARVS: □ None □ Few □ Half □ Most □ All Drug(s) missed____
□ PCP Prophylaxis: □ None □ Few □ Half □ Most □ All Drug(s) missed____
□ TB Prophylaxis: □ None □ Few □ Half □ Most □ All Drug(s) missed____
□ Anti-TB Medication: □ None □ Few □ Half □ Most □ All Drug(s) missed____
Reasons for missing pills in the last 7 days:

17. Does the patient have any interval complaints? □ Yes □ No

□ Diarrhea: □ days □ weeks □ Months □ continuous	□ Vomiting: □ days □ weeks □ Months □ Continuous
□ Abdominal pain: □ days □ weeks □ Months □ Continuous	□ Cough: □ days □ weeks □ Months □ Continuous
□ Difficulty breathing: □ days □ weeks □ Months □ Continuous	□ Fever: □ days □ weeks □ Months □ Continuous
□ Sore throat: □ days □ weeks □ Months □ Continuous	□ Ear discharge: □ days □ weeks □ Months □ Continuous
□ Skin rash: □ days □ weeks □ Months □ Continuous	□ Swelling(specify)____ □ days □ weeks
□ Other (specify) ____ □ days □ weeks	□ Other (specify) ____ □ days □ weeks

Comments:

18. Physical Exam:

Vitals: RR: P: Temp: Weight: Height: Head Circ: (if < 2 yrs) BSA: SaO₂:

General: □ Jaundice □ Pale □ Adenopathy □ Edema □ Thrush □ Kaposi □ Rash □ Parotid enlargement

RS: □ Normal □ Abnormal	**CNS:** □ Normal □ Abnormal	**CVS:** □ Normal □ Abnormal
MS: □ Normal □ Abnormal	**PA:** □ Normal □ Abnormal	**HEENT:** □ Normal □ Abnormal

Exam Notes:

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19. Test Results: (Please record date test was drawn, rather than date test was run)

Test	Result	Test Date	Test	Result	Test Date
WBC/mm^3			CD4		
Hgb g/dL			CD8		
MCV			CD4%		
Platelets/ mm^3			HIV Long Elisa		
ALC/ mm^3			HIV DNA PCR		
SGPT			Viral Load		
Creat mmol/L			Other:		
CXR: Code:			Codes: 0=normal 1=Pl Effusion 2=Infiltrate 3=Miliary 4=Diffuse abn/non-miliary 5=Cavity 6=Cardiomegaly 7=Other abnormality		

20. Current Pediatric Staging:

CDC Class: □ N □ A □ B □ C Criteria ____________ New Stage □Yes □ No

WHO Stage: □ 1 □ 2 □ 3 □ 4 Criteria ____________ New Stage □Yes □ No

Not-applicable: □ HIV negative □ HIV Exposed, status indeterminate

Tuberculosis:

21a. Household member diagnosed with TB? □Yes □ No

21b. Has the patient been diagnosed with TB since the last visit □ Yes □ No

21c. Have you diagnosed this child with TB today? □ Yes □ No □ Already on anti-TB

21d. If diagnosed, TB Diagnosis was done on basis of:
□ Household contact □ Chronic cough (> 2 weeks)
□ FTT/weight loss □ Persistent fever
□ Suggestive CXR □ AAFB positive
□ TST positive *□ Keith Jones score_____ □Other (specify):____
*□ Edward Keith score_____ *□ (Refer to the manual)

22. ARV Side-effects/Toxicity: Any side-effects attributable to ARV since the last visit? □ **Yes** □ **No**
If yes, tick all that apply: □ Rash □ Anemia □ Lipo-dystrophy □ Hepatitis □ Neuropathy □ IRIS □ Steven-Johnson syndrome □ Lactic Acidosis □ Diarrhoea □ Persistent Vomiting □Other (specify):

23. Diagnosis: New Diagnosis (* *Tick "Add" to add to summary sheet. Tick "Remove" to delete to from summary sheet*)

Diagnosis	New	Ongoing	Resolved	Diagnosis	New	Ongoing	Resolved
1.	□	□	□	3.	□	□	□
2.	□	□	□	4.	□	□	□

24. Plan:

24a. ARVs: □None □Start ARVs □Continue Regimen □Change Formulation □Change Regimen □Re-dose □Stop All
Reason for stop/change/re-dose: □Failure □Toxicity (Specify) ________ □Weight Change □Other________
If start or change or re-dose, tick new regimen:
□ 3TC (4mg/kg): □ Syrup ____ mg ____ml □Tabs ____ mg □ Kaletra (0.125ml/kg): □Syrup ____ mg ____ml □Tabs ____ mg
□ d4T (1mg/kg): : □ Tabs □15 □20 □30 mg □ ABC (8mg/kg): □Syrup ____ mg ____ml □Tabs ____ mg
□ AZT: (180mg/m2): □ Syrup ____ mg ____ml □Tabs ____ mg □ DDI (100mg/m2): □Syrup ____ mg ____ml □Tabs ____ mg
□ NVP: □ Syrup ____ mg ____ml □Tabs ____ mg □ Nelfinavir: □ Powder ____ mg □Tabs ____ mg
□ EFV: □ Syrup ____ mg ____ml □Tabs ____ mg □ Other:

24b. PCP Prophylaxis: □ None □ Start □ Continue Regimen □ Change Regimen □ Re-dose □ Stop
Reason for stop/change/re-dose: □Toxicity (Specify) ________ □ Weight Change □ Other________
New Drugs: □ Septrin ____tabs/day or ____ml/day □ Dapsone ____mg/day

24c. TB Prophylaxis: □ None □ Start INH □ Continue INH □ Re-dose □ Stop INH
Reason for stop/change/re-dose: □ Completed □ Toxicity(Specify) ________ □ Active TB
□ Weight Change □ Other____________ Drug Dose: □ INH ____mg/day

24d. TB Treatment: □ None □ Start Induction □ Change to Continuation □ Continue Regimen □ Re-dose □ Stop
Reason for stop/change/re-dose: □ Completed □ Toxicity (Specify) ________ □ Weight Change □ Other________
New Drugs: □ Rifater____tabs/day □ Rifinah____tabs/day □ Rifafour____tabs/day □ Ethambutol____mg/day
□ Streptomycin____mg □ Rifampicin____mg □ INH____mg □ Pyrazinamide ____mg

24e. Immunizations Ordered Today: □ None
Pentavalent Vaccine { □ HIB Dose#: □ 1 □ 2 □ 3; □ DPT Dose#: □ 1 □ 2 □ 3; □ HEP B Dose#: □ 1 □ 2 □ 3 }
□ BCG
□ Measles Dose#: □ 1
□ Polio Dose#: □ 1 □ 2 □ 3 □ 4

24f. Feeding plan: □ Breast □ Expressed Breast milk □ Formula □ Cow's/Animal milk
□Other liquids (Uji, tea, soup, juice) □ Solid food (ugali, potatoes, bananas)
If this is a change, reason for change: □ Age □ Affordability □ Intolerance □ Other(Specify):

24g. Other Drugs Started or Re-dosed at this Visit:

Drug	Dose	Freq & Duration	New	Dose∆
1.			□	□
2.			□	□
3.			□	□

25. Tests Ordered:
□ Full Haemogram □ Hgb □ SGPT □ CD4 Panel □ Viral Load
□ HIV Elisa □ HIV DNA PCR □ Creatinine □ CXR □ Other (Specify):

26. Referrals:
□ None □ TB treatment/DOT program □ Adherence Counseling □ Nutritional support □ Mental Health Services
□ Psychosocial counseling □Social Support Services □ Disclosure Counseling □ OVC □ Express care
□ Inpatient care/Hospitalization: (□ MTRH □ Health Center □Other ____________) □ Other referral (specify):

Additional Comments:________________
Return to Clinic: Weeks______ Months______ Date__________ CO/Physician:______________ Provider #: ____

□ HIV Negative, Discontinue from Clinic Nurse:______________ Provider #:______
□ Transfer care to other centre:
□ AMPATH □ non-AMPATH TO: ____________

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Appendix B: AMPATH Rural Health Centre Pediatric Clinical Encounter Form

Mosoriot Health Centre Primary Care Encounter Form **Today's Date:** / / (dd/mm/yyyy)

1. Name (3 names – given, middle, family): **2. AMRS ID:** **3. Old MMRS ID:** **4. HCT ID:**

5. Age: Yrs ________ Mo_________ Days ______ 6. Sex: ☐ M ☐ F 7. Marital Status: ☐S ☐M ☐D ☐W ☐Se

8. Next of Kin: 9. Phone #: 10. Occupation:

11. Clinic	Child< 5	Child 5+	Adult	FamPlan	STI	Chest/TB	Dental	ENT	Eye	PhysT	Occ T	Plaster	Psych	Other
New														
Return														

12. Main Problem (today): ______________________________ Duration of illness (days)_________
☐ None (preventive care, follow-up, etc.)

Prior Care for this Problem: ☐None ☐Self-medicated ☐Traditional healer ☐Private Pharmacy ☐CHW

13. Vital Signs:
BP:____/______ Pulse:________ Weight:_____kg Height:_____cm Temp:_______°C Head circ _______cm

Visual Acuity: R___/_____ L: ___/_____

Notes:

14. Counseled on HIV today?: ☐ Yes ☐ No ☐N/A 15. Tested for HIV today?: ☐ Yes ☐ No ☐N/A (If Yes, record Test result in test section)

Family Planning Clinic Data **FP #:** ______________

16. Contraception (check all that apply):☐ condoms ☐ IUD ☐ sterilization ☐ natural FP ☐ diaphragm ☐ DepoProvera ☐ pills
☐ Other:________________ **Notes:**

Paediatric Clinic Data

17. Underweight? ☐ Yes ☐ No 18. Issued with ITN today? ☐ Yes ☐ No

19. Danger Signs this visit? ☐ Yes ☐ No
If Yes: ☐ Unable to drink or breastfeed ☐ Vomiting everything ☐ Has had convulsions ☐ Lethargic ☐ Unconscious
☐ Other urgent sign demanding immediate attention: ☐ Cough or difficulty breathing ☐ Diarrhoea ☐ Fever
☐ Ear Problem ☐ Other:______________________________

Additional Comments:

20. Immunizations Given Today:

Pentavalent (DTP-HepB-Hib)		1	2	3	BCG	0	Revacc
Polio	0	1	2	3	Measles	1	2
Yellow Fever		1			Hepatitis A	1	2

Other:______________________________

Immunizations Complete? ☐ Yes ☐ No BCG Scar Present? ☐ Yes ☐ No

21. Vitamin A:	6-11 mo	12-17 mo	18-23 mo	24-29 mo	30-35 mo	36-41 mo	42-47 mo	48-53 mo	54-59 mo	60+ mo

22. Ancillary Services

☐ Medical Exam ☐Medical Report ☐Plaster of Paris ☐ Dressing ☐ Other:

23. Dental Clinic

☐ tooth filling (# filled:____) ☐ tooth extraction (# extracted:____) ☐ other procedures (list):

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24. Test Results:

VDRL: ____________________

Malaria smear: ____________________

Pregnancy Test: ____________________

Widal Test: ____________________

Blood sugar: __________ ☐ Below normal ☐ Normal ☐ Above normal

Hgb: ____________________

Blood Group: ____________________

Other: ____________________

HVS: ☐NAD
☐Pus cells ☐Yeast ☐GNRs ☐GNCs
☐GPCs ☐GPRs

Urinalysis: ☐NAD

☐Pus cells:	☐+	☐++	☐+++
☐Red cells:	☐+	☐++	☐+++
☐Protein:	☐+	☐++	☐+++
☐Sugar Present:	☐+	☐++	☐+++

Brucella Test: : Aborteus__________ Mellitiues:__________

Sputum for AFB: New Test 1st _____ 2nd _____ 3rd _____

Follow-up test:______________

HIV Rapid Test: BIOLINE:______________ UNIGOLD:__________

Stool Exam: ________________

Other ( ): ____________________________________

Other:____________________________

X- Ray 1: ____

Ultrasound: ____

25. Diagnoses This Visit:	**New**	**Continue**	**Resolved**
1.	☐	☐	☐
2.	☐	☐	☐
3.	☐	☐	☐
4.	☐	☐	☐

26. Drugs Given This Visit	**Dose**	**Frequency**	**Duration**	**Picked up**
1.				☐
2.				☐
3.				☐
4.				☐
5.				☐
6.				☐
7.				☐

27. Financial Office Signature:______________________

Item:	**Ksh:**	Exempt	Waiver	**Item:**	**Ksh:**	Exempt	Waiver

28. Referrals

Referrals: ☐ None ☐ MTRH ☐ Kapsabet District Hospital ☐ Nandi Hills District Hospital
☐ Admit to Mosoriot Inpatient Unit ☐ Other: ______________

Reason for Referral: ________________

Followup Needed?: ☐ Yes ☐ No Type of Followup:________________

Return to Clinic: Days: ____Weeks:_____ Months:_____ Date:___/____/_____

CO/Physician: ______________

Provider #: ______________

Nurse:______________

Provider #:______________

Registration Fields: Date of Birth: ______________ Father's Full Name: : ______________________

Mother's Full Name: : ______________________Guardian's Full Name: ______________________

Other person bringing patient: ______________________Next of Kin: ______________________

Location: ______________ Sublocation: ______________ Village:______________ Estate: ______________

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Information Systems for Monitoring the Burden of Chronic Diseases in Public Reference Health Facilities in Central Africa

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Background and purpose: Chronic diseases are an increasingly important cause of death in sub-Saharan Africa. Diseases such as cancer, diabetes and arterial hypertension remained for years in the background, in the shadow of pandemics such as malaria, HIV / AIDS and tuberculosis. Chronic disease incidence in the Central African region however, is poorly documented. This study explores to what extent secondary use of clinical information stored in hospital information systems can help to provide evidence related to the burden of diabetes, cancer and hypertension in DR Congo, Rwanda and Burundi.
Methods: In the past 6 years, 4 reference hospitals of Kisangani, Bukavu, Kigali and Bujumbura implemented open source hospital information management tools integrating international classification systems such as ICD-10 and ICPC-2. Clinical and financial data from chronic disease treatments in the period 2006-2012 were merged into Diagnosis Related Groups (DRGs) for further analysis. Metrics related to case load, mortality load and financial burden have been calculated for diabetes, cancer and hypertension DRGs.
Results: 89,765 out-patient visits and 59,434 admissions have been analyzed in this study. The results show a worrying growth of the 3 chronic diseases in the region. Costs related to the studied diseases are expected to increase by 10% (diabetes) to 70% (cancer & hypertension) between 2011 and 2015 in the studied reference hospitals.
Conclusion: the study demonstrates that the problem of chronic diseases also grows rapidly in the Great Lakes region and therefore urgent steps must be taken, both by governments (Rwanda, DRC and Burundi), by the international donor community and by local hospital boards.

Keywords : Information systems, Diagnosis-Related Groups, Chronic Disease, Sub-Saharan Africa, Neoplasms, Hypertension, Diabetes

1 Introduction

Chronic conditions are estimated to cause more than 60% of all deaths worldwide. More than 80% of these deaths occur in the developing world [6]. The number of deaths from chronic diseases is higher in sub-Saharan Africa than in other regions of the world, yet far too little attention is paid to the problem [2]. To prevent future epidemics of diabetes, cardiovascular disease, stroke and cancer among Africans, policies and programs are needed for encouraging healthy lifestyles, adoption of policies aimed at

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controlling access to, and consumption of, food and drinks high in refined sugar and fat, and promotion of sports and exercise programs. The chronic disease problem is also expected to have serious implications on the African health workforce [5][8], which is already going through a serious crisis [7].

Because chronic conditions require ongoing management over a period of years or a lifetime, health systems must also plan for increasing burden and complexity of care. According to a World Bank report [8], within a few decades, chronic non-communicable diseases will dominate health care needs in most low- and middle-income countries as a result of the epidemiological transition and aging.

Since 2006, a series of hospital information management system (HIMS) implementation projects have been conducted in some 25 public and private hospitals in Rwanda, Burundi and the Democratic Republic of the Congo. Using open source HIMS software called OpenClinic [9], many of these health facilities have started systematic ICD-10, ICPC-2 and DSM-4 based coding of out-patient encounters and in-patient admissions, which was integrated in routine data registration procedures [10]. Based on international classifications, the University Teaching Hospital of Kigali developed in 2009 KPGS [11], a set of Diagnosis Related Group codes (DRGs) adapted to the sub-Saharan health care setting, enabling more efficient evaluation of clinical activities. In the light of what has been explained earlier, routinely registered KPGS-based out- and in-patient diagnoses have been collected from 4 different third line reference hospitals in Rwanda, Burundi and the Democratic Republic of the Congo for studying the regional evolution of incidence and financial burden of a number of chronic non-communicable diseases, more specifically cancer, diabetes and hypertension.

Study concept. This is a comparative retrospective study in which disease related information is studied including case load, mortality load, cost of provided health services and diagnostic coding using ICD-10, ICPC-2 and KPGS classifications.

2 Materials and methods

In 2006, the University Teaching Hospital of Kigali started systematic coding of all its discharge diagnoses using international ICD-10 and ICPC-2 classifications. This was done through the use of 3BT [13], a middleware clinical thesaurus which simultaneously linked a large set of keywords via clinical concepts to ICD-10 and ICPC-2 classification codes. This approach enabled the hospital to produce systematic clinical coding, which was performed by paramedical staff after a short training program [12]. In 2007, with the support of the Belgian Technical Cooperation (BTC), 3BT was also integrated in the hospital's new HIMS and diagnostic coding was extended to out-patient visits.

In 2010, two other reference hospitals in the same region (Eastern DRC) also implemented the same HIMS: implementations were provided to the University Teaching Hospital of Kisangani and the Provincial Reference Hospital of Bukavu through the EU funded eb@le-santé project.

Finally, the Military Hospital of Kamenge, situated in Bujumbura, Burundi, joined the group in 2011. This military health facility is open to the general public and also fulfils the role of a national reference hospital.

Diagnostic and financial data from the 4 hospital HIMS databases were merged, providing DRGs and financial transaction information on 84,713 in-patient admissions (period covered: January 2006 – August 2012) and 485,367 out-patient visits (period covered: August 2008 – August 2012). Diabetes was identified in the KPGS classification by DRG 04B, hypertension by DRG 09C and malignancy has been defined as the grouping of 3 complementary DRGs:

02A	MALIGNANT NEOPLASMS, STATED OR PRESUMED TO BE PRIMARY, OF SPECIFIED SITES, EXCEPT OF LYMPHOID, HAEMATOPOIETIC AND RELATED TISSUE
02B	MALIGNANT NEOPLASMS OF ILL-DEFINED, SECONDARY AND UNSPECIFIED SITES + MALIGNANT NEOPLASMS OF INDEPENDENT (PRIMARY) MULTIPLE SITES
02C	MALIGNANT NEOPLASMS, STATED OR PRESUMED TO BE PRIMARY, OF LYMPHOID, HAEMATOPOIETIC AND RELATED TISSUE

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For each of the chronic disease groups (cancer, diabetes and arterial hypertension), we have then calculated the following metrics (separately for in- and out-patients):

- **Absolute monthly DRG case load (AMCL)**: the number of encounters associated to a specific DRG
- **Relative monthly DRG case load (RMCL)**: the percentage of the total monthly hospital's case load associated to the DRG
- **Absolute monthly DRG mortality load (AMML)**: the number of deaths associated to a specific DRG
- **Relative monthly DRG related hospital mortality load (RMML)**: the percentage of the total monthly hospital's mortality load that was associated to the DRG
- **Relative monthly DRG specific mortality load (SMML)**: the percentage of DRG related admissions for which the patient died

3 Results

After performing necessary data quality and completeness verifications on the available dataset, 89,765 out-patient visits and 59,434 admissions remained available for our analysis, meaning that 80% of the outpatient encounters and 30% of hospital admissions were discarded, mainly because DRG codes were missing. Manual à-posteriori DRG coding on a random subset of 1.314 outpatient encounters and 432 hospital admissions from the discarded data showed no significant differences in chronic disease DRG distribution.

3.1 Cancer

A total of 1,193 out-patient visits representing 1.3% of the out-patient case load in the study period and 2,489 admissions representing 4,19% of the total in-patient case load have been collected. Out-patient cancer related AMCL significantly increased from 6 cases/month in 2008 to 29 cases/month in 2012 (linear regression: R=0,50, p-value of F-Test=0.0003) while in-patient AMCL grew from 9 to 42 monthly cases between 2006 and 2012 (R=0,75, p-value of F-Test <0.0001) as shown on the following charts:

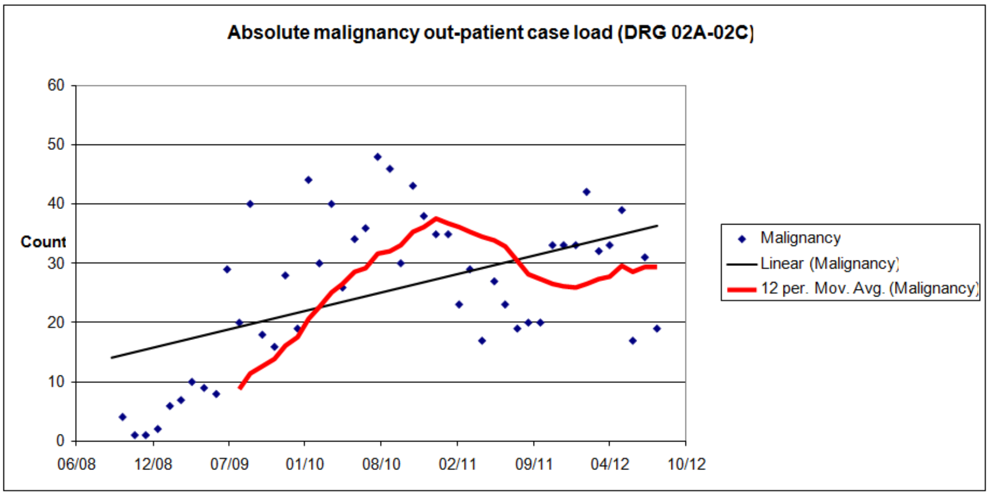

Fig. 1. Rise in malignancy related out-patient case load between 2008 and 2012

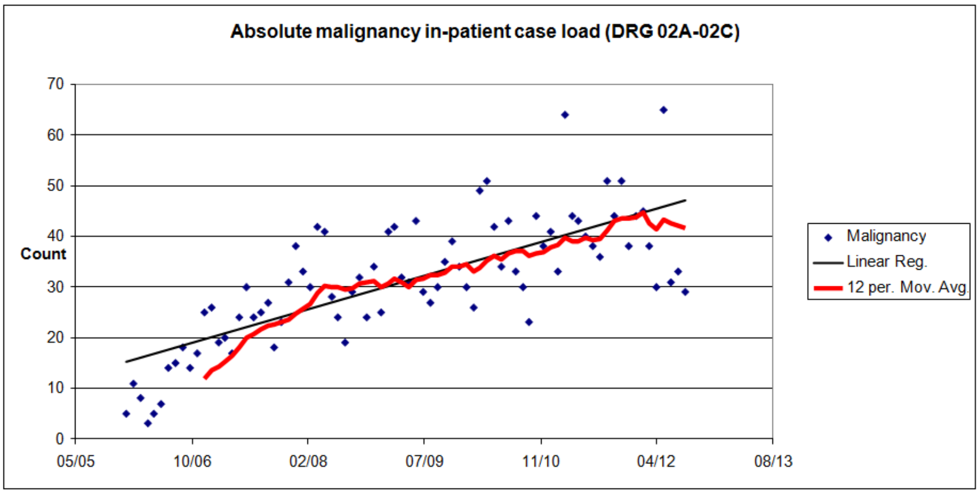

Fig. 2. Rise in malignancy related in-patient case load between 2006 and 2012

Relative in-patient mortality (RMML) due to cancer also more than doubled in the same period from 4.9% to 10.1% (R=0,41, p-value of F-test=0.0002).

The relative in-patient malignancy case load (RMCL) increased from 1.5% in 2006 to 5.5% in 2012, showing that in-patient neoplasm treatment had gained a lot of attention in the group of 4 central African reference hospitals. However, the opposite was true for out-patient visits: relative case load dropped from 4.0% to 1.1% between 2008 and 2012, showing that despite the growing number of cancer-related consultations taking place, a number of other diseases had generated an even more important increase in out-patient activity. In this case, this was due to the opening of a new gynaecology-obstetrics (GO) department at the University Teaching Hospital of Kigali in 2008, causing an important relative case load drop for non-GO DRGs in the first year, after which out-patient non-GO AMCL values stabilized.

After splitting up cancer DRGs into subtypes based on underlying ICD-10 codes, we obtained a cancer subtype distribution pattern that was somehow different from averages that had been reported for Africa by the World Bank in 2006 [16]. The relative importance of stomach-, oesophagus-, prostate- and cervix cancer showed to be lower in our study whilst non-Hodgkin lymphoma and the group other cancers had higher incidences.

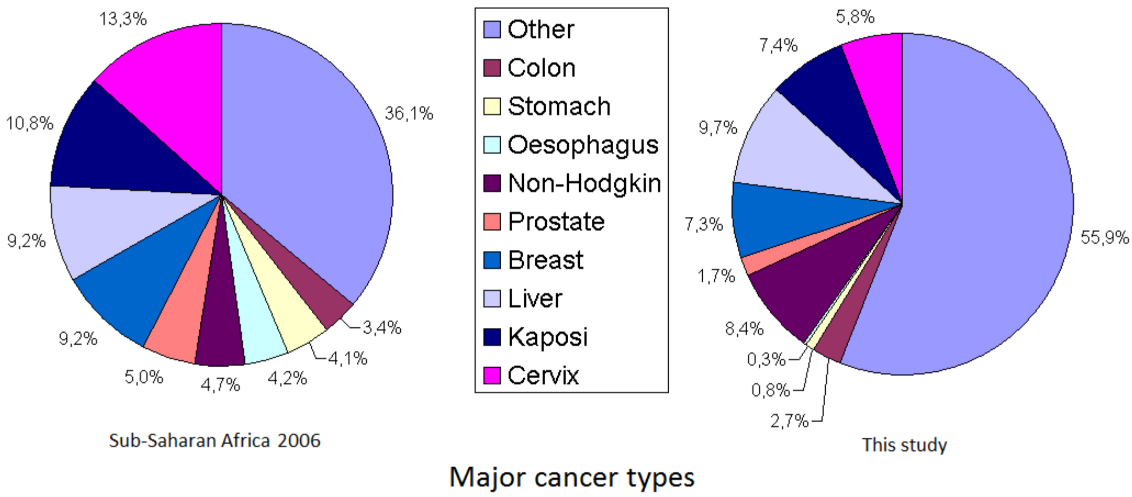

Fig. 3. Differences between African average and study distribution in cancer subtypes

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3.2 Diabetes

After the publication of a number of papers on the worrying growing burden of diabetes in sub-Saharan Africa [2][14][15], also emphasizing the high rate of undiagnosed diabetes in most countries of the continent, different diabetes awareness campaigns have been set up in our study region. Obviously, these campaigns had a clear and measurable effect on the numbers of diabetes related out-patient visits, which suddenly grew from 4 to almost 120 a month (n=3,288). Yet, this effect only lasted for some 18 months, after which diabetes out-patient incidence levels dropped again to a much lower level of about 62 consultations a month, which however still constituted an important rise compared to 2008.

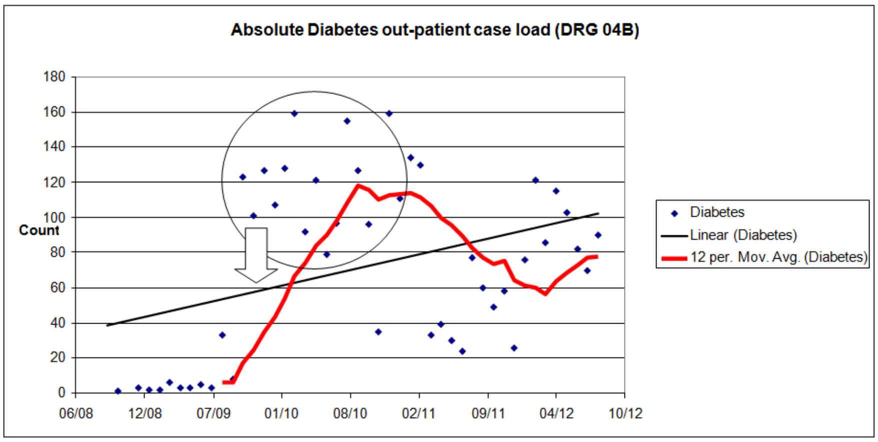

Fig. 4. rise in diabetes related out-patient case load between 2006 and 2012. The white arrow indicates start of diabetes awareness campaigns

Interesting enough, similar effects could not be demonstrated on the in-patients sample, although a significant growth from 6 to 15 diabetes related admissions a month has been seen between 2006 and 2012 (n=885). Relative diabetes related in-patient mortality (RMML) at the same time increased from 0.9% to 2.4%.

Diabetes AMCL results showed a remarkable seasonal variation, with lowest incidences seen in June and the highest between October and March. Seasonal diabetes incidence variations had already been described for other sub-Saharan countries [1][16], but no data could be found in literature for the Great Lakes region where our study sites are situated. Results from our research seem to rather well match the ones obtained by McLarty [1] from a study in Tanzania. Vitamin D (diabetes type 1) and seasonal fluctuations of virus infections (diabetes type 1 & 2) have been forwarded by some authors as possible pathways for explaining this phenomenon.

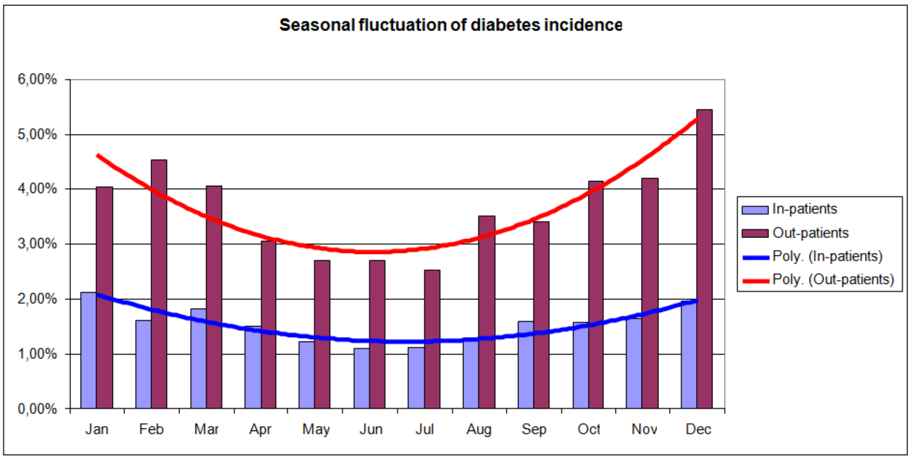

Fig. 5. Seasonal fluctuation of diabetes incidence (Polynomial regression)

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3.3 Arterial hypertension

In the 4 years period between August 2008 and August 2012, out-patient case load for arterial hypertension showed an evolution which more or less followed the pattern seen in diabetes: awareness campaigns had of course also identified many hypertensive patients amongst diabetics. After an initial steep increase during 18 months, hypertension incidence levels also dropped to a lower level, still showing a significant increase from 3 to 53 cases a month. No significant difference was found between incidence data from hypertensive diabetes patients and hypertensive patients without diabetes.

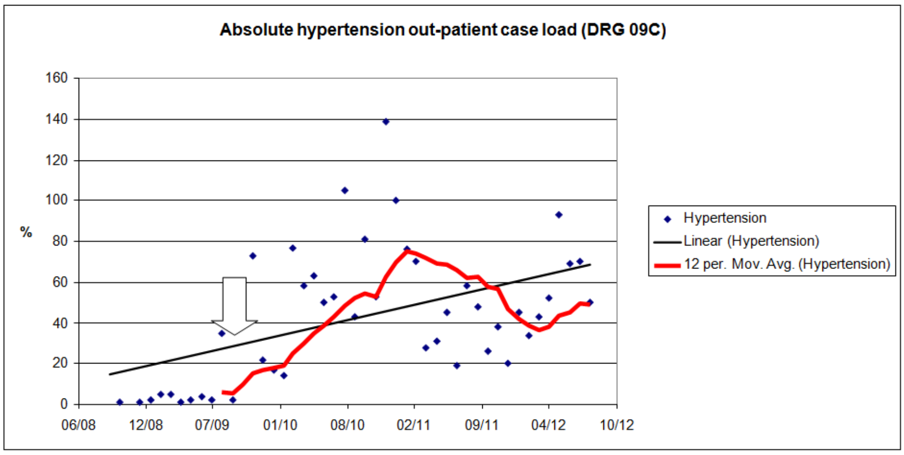

Fig. 6. Rise in hypertension related out-patient case load between 2008 and 2012

In-patient hypertension related case load analysis showed a more constant growth from a mere 3 cases a month in 2006 to 9 cases a month in 2012. The number of patients which were admitted for hypertension related problems and died from it (SMML), did not change significantly in this period and remained at a high level of 10,57%.

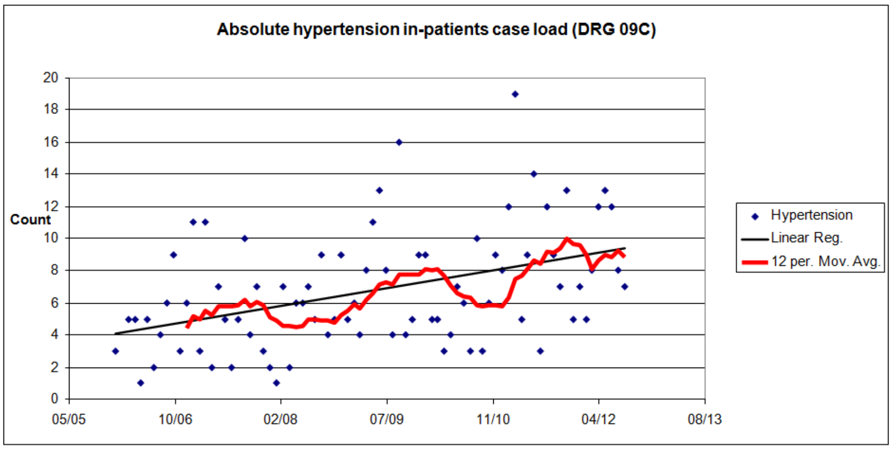

Fig. 7. Rise in hypertension related in-patient case load between 2008 and 2012

3.4 Cost of care

Calculating the exact costs associated to the treatment of the chronic diseases we studied, was not feasible in our research setting. Therefore, we have chosen to use an available proxy metric in the form of direct payments. Direct payment for medicines and health services at the time of need [18] is one of the most common forms of health sector payment in the world. In spite of the willingness of a number of African leaders to take strong action to remove financial barriers for vulnerable groups [19], direct payment

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remains a universal practice in sub-Saharan hospitals, even for government owned facilities. According to WHO, from a health care perspective, systems requiring direct payment at the time people need care, prevent millions from accessing services and result in impoverishment of millions more [18] and should as such definitely not be encouraged. Although direct payments are not restricted to low-income countries, their impact on the individual budget is a lot more important for poor than for rich people: even if the prevalence of direct payment procedures seems to be universal, they still account for a much higher percentage of total health expenditure in low-income countries. That being said, from an impact analysis perspective, the demonized but prevalent user fees constitute an interesting input measure for estimating the impact of chronic disease incidence change in our study.

In 2010, we developed at the CHUK a simple prototype method for calculating financial impact and comorbidity of clinical conditions treated in the sub-Saharan hospital context (CALCO method) [11]. An essential element of that study was to link a cost-related burden of disease index to each KPGS (DRG) code so that the KPGS instrument could later be used for cost and resource allocation purposes in health facilities. In contrast to original DRG logic however, the focus has not been on the development of a tool for reimbursement purposes, which would have assumed a high level of cost-related homogeneity of all diseases and clinical conditions mapping on a same grouping code (which obviously is not the case for KPGS). The goal of KPGS must rather be seen in the context of productivity analysis logic [20][21], where we wanted to deliver an instrument for making comparisons between groups of diseases in terms of resource consumption (called inputs).

Applying the CALCO method to our study sample, we were only able to calculate median direct payments allocated to malignancy, diabetes and hypertension related to in-patient admissions for the University Teaching Hospital of Kigali (too few financial data were available from the other hospitals). The results (expressed in US dollars) are shown in **Table 1** (amounts represent the median of total direct patient- and insurer payments made per admission):

Table 1. Median chronic disease related direct payments per admission between 2009 and 2011

	Malignancy	Diabetes	Hypertension
2009	$ 118	$ 179	$ 39
2010	$ 145	$ 181	$ 57
2011	$ 148	$ 175	$ 70

In-patient malignancy treatment became 30$ (25%) more expensive in 2 years' time while hypertension related costs increased by 31$ (79%). The cost of diabetes showed to remain somewhat stable, although from the start this was already at a level which is hardly accessible for a major portion of the population being served by the CHUK.

Combining direct payment data with case load information learns that the financial impact of the 3 studied chronic diseases can be expected to be very important in the next couple of years:

Table 2. expected growth of financial chronic disease costs between 2012 and 2015 at CHUK. Total growth = (1 + cost growth) x (1 + incidence growth) - 1

	Malignancy	Diabetes	Hypertension
Expected cost growth 2015	37,50%	-1,44%	39,50%
Expected incidence growth 2015	25%	11,73%	22,00%
Total growth	**71,88%**	**10,12%**	**70,19%**

By August 2015, cancer and hypertension related in-patient costs are expected to increase by more than 70% whereas the already expensive diabetes related admissions will become 10% more expensive. Monetary evolution and inflation of course have to be added to these estimates.

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4 Discussion

This study demonstrates the feasibility and usefulness of implementing ICT-based tools for international classifications based registration of diagnostic information, even in the sometimes technologically difficult settings of the reference hospitals of Kisangani, Bukavu, Kigali and Bujumbura. On all sites, structured diagnostic registration was part of routine data entry procedures and did not require any study-specific developments.

The results of this research clearly demonstrate the growing importance of chronic non-communicable diseases in the Great Lakes region. The global burden of chronic diseases can be expected to heavily weigh on available resources in third level health facilities in the next 5 to 10 years. Health care staff which have been adequately trained in chronic disease management are not available in sufficient numbers in the studied hospitals to cope with this problem.

Although communicable and non-chronic diseases still account for the bulk of hospital activity today, politicians, health administrations and health facility managers should prepare for the worrying progress of chronic health problems in the sub-Saharan region.

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Critical Success Factors for Adopting Enterprise Architecture Metamodels in the Health Sector: Literature Review

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Background and Purpose: Metamodels can be used as templates for describing models. In the context of the government enterprise architecture (GEA), the metamodels or metamodel-based reference models are primarily used to execute national strategic objectives in information systems. For example, if a National Health Insurance (NHI) service is to be delivered to approximately 400 government hospitals and 4000 clinics in South Africa, reference models (e.g. Business Information Reference Model for Health) will have to be seriously considered. This approach will require the proper definition of metamodels or metamodel-based reference models. The main purpose of this paper is to report the critical success factors (CSFs) for adopting enterprise architecture (EA) metamodels in the health sector.
Methods: The latest scientific literature based on the adoption of EA metamodels in the health sector was reviewed. The guidelines of the systematic literature review were partly adapted to organize the search.
Results: Queries made from the abstracts of eight digital libraries in September 2013 produced 31 hits. No papers were found on critical success factors for adopting EA metamodel in the health sector.
Conclusions: Governments are adopting EA for implementing their strategies and for improving production of services, especially in the health sector. However, there is little or no scientific research done on the adaptions of EA metamodels in the health sector.

Keywords: Enterprise Architecture (EA), Metamodel

1 Introduction

Within government services, healthcare has surfaced as the most critical services that need attention. The World Health Organisation (WHO) has recommended the expenditure of 5% of a country’s gross domestic product (GDP) in health [1]. However, the United States, for example, is spending over 16% of GDP in health, and for South Africa the figure is 8.5% [2]. No wonder that healthcare is the biggest item of expenditure in governments around the world.

“To improve the health of populations and reduce the per capita cost of healthcare, all nations will need to go beyond improvements in the performance of their healthcare delivery systems to embrace the broader determinants of health” [3]. Therefore, governments are adopting EA for implementing their strategies and for improving production of services, especially in the health sector. This has been made possible because of EA’s robustness in developing solutions that are holistic, coherent, and responsive to the need [4].

One precondition of holistic solutions is EA artifacts which are “tangible work products” [5]. It is important to understand how the solutions affect the EA artifacts (e.g. single models and model elements), discovering possible inconsistencies [6]. Another precondition is EA deliverables which “pre-

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define typical or recommended content in the form of work products that would be packaged for delivery" [5]. At the governmental level, it is important that the solutions take into consideration the EA deliverables (e.g. reference models) which usually contain constraints about interoperability.

We assume that there are one or more EA metamodels (the other forms of writing are meta-models or meta models) behind the GEA development. Therefore, we want to make the literature review of scientific researches around the adoptions of the EA metamodels (especially the GEA metamodels). We are familiar with the Government Wide Enterprise Architecture (GWEA) Framework — "the first [South African] public sector entity to formally adopt and adapt TOGAF® 9 for Enterprise Architecture (EA)" [7]. GWEA contains several artifacts and deliverables. The influence of the TOGAF content metamodel [8] is in the GWEA artifacts which are mainly entities of the TOGAF content metamodel. Furthermore, we are familiar with the Finnish governmental semantic assets repository (yhteentoimivuus.fi) [9]. In Finland, the EA development framework is called JHS 179 and is based on TOGAF [10]. However, the entities of the TOGAF content metamodel are implicitly mapped on the JHS 179 artifacts.

2 Materials and methods

A systematic literature review (SLR) is used as the method for identifying, assessing, and analysing published studies. Kitchenham & Charters [11] and later Okoli & Schabram [12] have suggested a well-defined protocol to undertake a SLR study. Kitchenham & Charters [11] view the SLR study method as an effective way of summarising the existing evidence, identifying gaps in the current literature, and providing the framework or background to position the new research. Okoli & Schabram [12] further suggest that the SLR process is more suitable for investigating information systems because of its nature to incorporate social sciences, business and computer science.

We did not perform systematic literature review as "a form of secondary study that uses a well-defined methodology to identify, and interpret all available evidence related to a specific research question in a way that is unbiased and (to a degree) repeatable" [11]. Rather, we adapted SLR to explain the procedure explicitly and to collect evidence to establish the latest scientific research around the adoption of EA metamodels in GEA. Thus we set out to provide "a theoretical background for subsequent research", to learn "the breadth of research on a topic of interest", and to answer "practical questions by understanding what existing research has to say on the matter" [12]. Our review process had the following steps:

1. Specifying the search terms
2. Selecting the databases
3. Searching for the papers
4. Appraising the hits and selecting the papers
5. Citing the statements from the papers

3 Results

We appraised (

Table 1) the papers containing the terms "enterprise architecture" and metamodel (or meta-model or "meta model") in the abstracts. As a further requirement, the appraised papers had to be written in English and be peer-reviewed (i.e. proceedings or journal papers). Finally, the appraised papers must be available in full versions from the digital libraries (i.e. without request permissions). When we added "health" to refine the search we did not find any papers which satisfied the search requirements.

Alternative suggestion: Our study was limited to peer-reviewed (i.e. from proceedings or journals) papers written in English, and which must be available from the digital libraries without request permissions. Within these criteria we then extracted for appraisal (

Table 1) those papers containing the terms "enterprise architecture" and (metamodel or meta-model or "meta model") in their abstracts. When we added "health" to refine the search we did not find any papers which satisfied the search requirements.

Table 1. Appraised hits

Digital library	Search query	Hits	Available full paper	Exclusions	Inclusions
ACM [13]	Abstract:"enterprise architecture" AND (Abstract:metamodel OR Abstract:"meta model")	21	2	2	-
IEEE [14]	"Abstract":"enterprise architecture" AND ("Abstract":metamodel OR "Abstract":"meta model") AND "Abstract":health	2	2	2	-
PubMed [15]	enterprise architecture"[Title/Abstract]) AND "meta"[Title/Abstract]	0	-	-	-
Wiley [16]	"enterprise architecture" in Abstract AND "meta" in Abstract.	1	0	-	-
EBSCO [17]	AB "enterprise architecture" AND AB "metadata"	1	0	-	-
Scorpus [18]	ABS("enterprise architecture" AND (metadata OR meta-data OR "meta data"))	6	0	-	-
ScienceDirect [19]	ABSTRACT("enterprise architecture" AND health) and ABSTRACT(metamodel OR meta-model OR "meta model")	0	-	-	-
Sage [20]	"enterprise architecture" and health in Abstract and meta in Abstract	0	-	-	-

Two papers from the ACM were excluded — one was presented in a workshop and the other was an invited talk. The net result is that, from eight digital libraries, the selection and extraction process yielded no papers that qualify for further analysis.

However, we did make the following observations:

- Some papers were extensions or modifications of the ArchiMate metamodel.
- Some papers were about analyzing or modeling the IT Impact on organizational structure.
- More than 10 papers discussed meta-database, metadata registry, intefaces, or interchange
- Metamodels are usually adapted for a smaller context than the (G)EA framework as, follows:
  - for automated enterprise architecture model maintenance
  - to make cost predictions and do risk analysis
  - to support service management in an enterprise context and to allow for service classification (an enterprise architecture metamodel for service-oriented architectures consisting of 39 entities)
  - for analyzing impacts of goal and requirement changes in EA goal models
  - a structure for the comprehensive capability meta-model
  - for the domain modelling of information systems
  - to propose Enterprise Architecture-based SBITA (Strategic Business and IT Alignment) assessment metamodels which have a limited set of 74 artifacts that can be modelled through 71 questions
  - to support enterprise system quality analysis
  - to support decision making on IT organization change scenarios
  - for enterprise service interoperability analysis
  - supporting organizational performance analysis
  - to propose a meta-model for Zachman Frameworks
  - to provide a suite or repository of various transformation elements made up of people, processes, and deliverables

Although we did not get any papers fulfilling our inclusion criteria, we did highlight some statements at the citing phase. These are quoted in the form of sentence snippets, where excluded parts are represented by three dots (...).

- How metamodels are important in the EA context:
  - "whether explicit or implicit in architecture frameworks, meta models play an important role in all EA efforts by providing a common language for the enterprise **...** Meta models are a core concept of EA, describing the fundamental artifacts of business and IT **...** the permissible entities and their connections are prescribed by the meta model, so that all models based upon it are coherent **...** the meta model enforces semantic rigor among the models subsequently created in its image. Such rigor is a precondition for successful communication and documentation **...** Analogously to the case of entity relations, a meta model can prescribe attribute relations." [21]

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- "IS Strategic Planning and Enterprise Architecture are two major disciplines in IT Architecture and Governance **...** The main concept underlying both the process and the taxonomy is the metamodel to describe architecture elements and to produce architecture deliverables **...** it is necessary to define a rich and structured metamodel covering both architecture elements (processes, applications, data..) and transformation elements (programs, projects, budgets) **...** The metamodel is the backbone of architecture description and methodology. The metamodel guarantees the exhaustiveness of overall architecture work and the coherence and alignment of architecture layers **...** Many metamodels have been defined explicitly or implicitly by EA frameworks. They are of different natures and focus depending on their intent. Some of them are poor in term of business or IS content" [22]

— GEA metamodels define required information and their relationships [23]:

- "A meta-modeling approach is used to design GEA database and to communicate with agencies regarding how they should manage agency-level EA information **...** the KGEA {Korean GEA} Meta-model is a set of standard EA deliverables required by agencies to create and report for the sake of the government-wide EA success. It is a backbone model used to construct an agency's EA, by defining required architectural information and their relationships. Agencies can develop their own EA by defining architecture models or meta-models aligned with the agency's EA objectives, however, agencies' models must include the information required by the KGEA Meta-model."

— There are different kinds of metamodels [24]:

- "Metamodels are generally used in specifications or frameworks to describe models. For example, TOGAF 9 uses a metamodel in its Content Metamodel description to inform the generation of enterprise architecture content **...** the OMG (Object Management Group) uses metamodels in specifications such as SPEM (Software Process Engineering Metamodel) **...** and HL7 (Health Level Seven, Inc. - the global authority on standards for interoperability of health information technology) specified the HL7 RIM (Reference Information Model) as part of HL7 Version 3 **...** HL7 RIM specifies the grammar of HL7 V3 messages and specifically, the basic building blocks of the language (nouns, verbs etc.), their permitted relationships and data types."

— Probably, several metamodels and frameworks have to adopted in the health sector [25]:

- "The Generic Component Model (GCM) is used as a framework for modelling any system to evaluate and harmonize state of the art architecture development approaches and standards for health information systems as well as to derive a coherent architecture development framework for sustainable, semantically interoperable HIS {health information system} and their components. The proposed methodology is based on the Rational Unified Process (RUP), taking advantage of its flexibility to be configured for integrating other architectural approaches such as Service-Oriented Architecture (SOA), Model-Driven Architecture (MDA), ISO 10746, and HL7 Development Framework (HDF) **...** tailoring the RUP best practice for large projects in order to provide a process configuration that supports the development of architectures for health information systems **...** the HL7 Message Development Framework (MDF), and offers models and artifacts for information modeling in healthcare."

4 Discussion

Is it an only critical success factor if the government formally adopts and adapts a certain EA framework, especially formally adopts and adapts a certain EA metamodel (e.g. TOGAF Content metamodel)? We know that there are difficulties in understanding the elements of the metamodels — i.e. entities, their attributes, and relationships between entities. Furthermore, some EA frameworks do not explain their elements explicitly. However, instances of the elements (e.g. actors, data, processes, and services) are mainly enterprise-specific. Therefore, GEA provides guidelines to collect those instances, and it usually suggests the set of allowable frameworks (standards, for example) and other constraints, like the implementations of the strategies (**Fig. 1**). We assume that it is difficult to discover or formulate special CSFs for adopting the EA metamodel in the health sector. However, it is a crucial part of our study and it will point out subjects for further research.

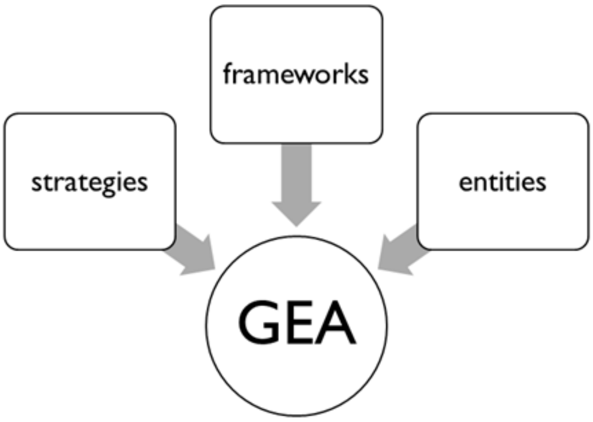

Fig. 1. GEA makes effects of the entities, frameworks and strategies transparent

In future, it might be reasonable to talk about concrete (critical) activities [26] instead of CSFs. For example, we can ask what activities have to be done if a service like a National Health Insurance (NHI) is going to be delivered to approximately 400 government hospitals and 4000 clinics in South African. It will not be enough to reply that the reference models (e.g. Business Information Reference Model for Health) have to be taken into consideration. We must control activities by setting performance indicators. Critical activities (critical success factors) drive the strategies forward and indicators enable the measurement of strategic performance (**Fig. 2**).

Fig. 2. GEA includes goals which are achieved by critical activities (CSFs) and key performance indicators (KPIs)

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ICTs and Public Healthcare Service Delivery in a Developing Country Context: Critical Factors towards Addressing the Health Divide

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Background and Purpose: Global references continue to suggest that, Information and Communication Technologies (ICTs) in healthcare service delivery has brought with it great advancements. In developing countries, various ICTs and healthcare initiatives/ policies have been put in place to address challenges of providing equitable health care and improving the quality of health care services in a cost efficient manner. Although in Africa the advent of e-health has offered an exciting opportunity to reduce or control the growing healthcare inequity, a lot still needs to be done in drawing up the appropriate strategies to narrow the disparities in the access to healthcare delivery information. South Africa has implemented initiatives addressing such disparities however; all has not been well with most of these initiatives as they have failed to achieve their anticipated objectives. This therefore, calls for effective e-health strategies to ensure the full exploitation of the benefits it brings towards narrowing of the health divide. This paper aims to identify those factors or variables imperative to drawing up strategies for narrowing the health divide using ICTs within the public healthcare sector in a developing country context, in this case South Africa

Methods: Data was gathered using literature analysis, key informant interviews and government websites on health. Data analysis methods used on survey data includes, descriptive statistics, and factor analysis. Data was drawn from two case sites making up the dichotomous (First and Second Economy) landscape of the South African demography

Results: Exhausting all the variables towards narrowing the health divide is very complex. Finding suggest that, the failure of the public sector to keep pace with the private sector technologically; poor funding towards effective health information access awareness programmes; lack of policy makers, poor infrastructure; and unskilled personnel amongst many other issues continue to be the crucial issues hampering the narrowing of the health divide

Conclusions: Proper planning for ICT deployment with the fundamental inclusion of healthcare stakeholders can bear tremendous results in narrowing the health divide. There is need to engage a diverse group of health professionals, policy makers and the public in the drafting of roadmaps for narrowing the health divide.

Keywords: E-Health, Health divide, Health Information, Information and Communication Technologies

1 Introduction

The health sector is currently the prime growth sector of most economies. Advancement of Information and Communication Technologies (ICTs) and demand for health information to inform policies, research, resource allocation, monitoring and evaluation of healthcare programmes has brought huge advantages within the health sector in most developing countries [1][2]. Global references suggest that new ICTs and information systems have commanded a powerful potential to improve the operational activities of most healthcare organisations [3]-[9]. This has led to the emergence of the term 'ehealth' which according to

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[10], refers to health services and information being delivered or enhanced through the Internet and related technologies.

It is however imperative to note that despite the hype and embracing of such technologies, a lot still needs to be done in addressing health inequalities still hampering development in most developing countries [11][12]. This continued rise in inequalities within healthcare service delivery has undermined the development of a healthy society in developing countries. Logic prevailing, this entails that employing ICTs in healthcare delivery at a distance would be important in addressing some of the inequalities in developing countries.

In Africa the advent of e-health has offered an exciting opportunity to reduce or control the growing healthcare inequalities; however a lot still needs to be done in drawing up the appropriate strategies to narrow the disparities in the access to healthcare delivery information [13]-[15]. These disparities have led to the coinage of the term "health divide", meaning the gap existing in the access to healthcare information using ICTs between those who have access to healthcare and those who do not have" [16]. This paper therefore outlines the research question as: What are those factors critical to narrowing the health divide in developing countries? This paper aims to identify those factors instrumental to drawing up or formulating strategies for narrowing the health divide in a developing country context. The context of interest in this paper is South Africa.

1.1 Demography and Healthcare in South Africa

The South African demography is characterized by two distinct economies, namely, the first and the second economies. The first economy is characterised by a well-structured environment catering for the affluent segment of the population, while the second economy is characterised by underdevelopment, operating in the midst of poverty.

The country's population stands at 50 586 757, of which 26 071 721 (52%) were female and 24 515 036 (48%) were male. Africans are in the majority at 40.2-million, making up 79.5% of the total population. The white population and the coloured population are both estimated at 4.5-million (9.0%) and the Indian/Asian population at 1.3-million (2.5%) [17].

Of note is that, key challenges include health issues; with a high prevalence of HIV/Aids and TB infections and other drug related deaths in most of the poorest communities of blacks and coloureds [18]. With the population of South Africa having increased significantly it still exerts pressure on the health budget for the country [19][20]. About 80% of South Africans live in the rural areas and the rest in urban areas.

1.2 Healthcare System in South Africa

South Africa presents a dichotomous healthcare system from the most basic primary health care, offered free by the state, to highly specialised, hi-tech health services available in the both the public and private sector.

However, the public sector is strained and under-resourced. Whilst the state contributes about 40% of all expenditure on health, the public health sector is under pressure to deliver services to about 80% of the population [21]. The private sector, on the other hand, is run largely on commercial lines and caters for the working class who tend to be members of medical schemes. It attracts most of the country's health professionals [22]. Such a system is deemed inequitable and inaccessible to a large portion of South Africans as institutions in the public sector have for long been faced with perennial challenges like poor management, underfunding, deteriorating infrastructure also compounded the burden of diseases such as HIV and tuberculosis (TB), and a shortage of key skilled medical personnel. While access has improved, the quality of health care has been on an all-time low.

1.3 Health Care Expenditure in South Africa

The bulk of health-sector funding comes from the South Africa's National Treasury. The health budget for 2012/13 was R121-billion, which was aimed at improving hospitals and strengthening public health ahead of the National Health Insurance scheme. In 2011, total spend on health was R248.6-billion – or around 8.3% of GDP, way above the 5% recommended by the World Health Organisation [20]. Despite this high

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expenditure, health outcomes remain poor when compared to similar middle-income countries. The health system is still struggling to cope with the collision of four excessive health burdens, that is; communicable disease (especially HIV/AIDS), non-communicable disease, maternal, neonatal and child deaths, and deaths from injury and violence [23]. South Africa spends more on healthcare than many other countries but patient care continues to decline [11]. This can largely be attributed to the inequities between the public and private sector.

2 Method

This study employed an interpretive approach to case study for the research presented [24][25]. The interpretive approach has proven to be a suitable methodology to study IS as social systems, where the aim is to investigate the complexities of social and technical aspects of IS development [26].

A comparative study from respondents representing both the First and the Second economy of South Africa was conducted in the Western Cape City of Cape Town. A total of two randomly selected healthcare centres and 180 respondents participated in the survey. Healthcare centres where the research surveys were conducted wanted to remain anonymous. The healthcare centres represented the first and second economy and were from the suburbs of Tableview and Gugulethu respectively. The study design was oriented to both the qualitative and quantitative paradigms validity and reliability.

2.1 Data Collection

Ethical Clearance
Ethical clearance was obtained from the Ministry of Health and the University Ethical Clearance (Cape Peninsula University of Technology) committee. Letters of consent were also issued to participants to confirm the confidentiality and purpose of the study.

Selecting the Study Cases
The study was conducted in the City of Cape Town, which falls under the Metropolitan Province of Western Cape. The City of Cape Town as one of South Africa’s five metropolitan municipalities has a relatively simple legislative structure and is classified as a category A municipality. Focus on the research area of study was given to two suburbs (Table View and Gugulethu) representing the two economies in the City, that is, the first economy (characterised by a well-structured environment catering for the affluent segment of the population) and the second economy (characterised by underdevelopment, operating in the midst of poverty).

2.2 Research Findings and Data Analysis

Empirical results of the findings and the analysis of data that was collected from surveys conducted in the Tableview Area and Gugulethu Area both representing the first and the second economy respectively. This study was limited to descriptive statistics, correlation analysis and factor analysis. Correlation analysis section was used to determine the relationship between socio-economic issues (Gender, Age, Education, Employment and Income) and perceptions on ICT adoption in the selected economies. The statistical analysis package SPSS complemented by Microsoft Excel was used for the most part of data analysis in this study. From the study, information gathered pertained to the general demography of the two economies, user ICT access perceptions and attitudes, ICT access, general ICT awareness and general perception and attitudes towards ICT utilization. Key informants in the form of managerial and supervisory staff at Clinics from the areas of study provided crucial and complementary information through interviews for the research study.

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3 Results

3.1 ICTs User Access: Perceptions and Attitudes

This section provides analysed data on general information and communicating technologies that are being used by respondents in the first and second economies. Information is most notably multi-response data as respondents were found to be using more than one technology in communication.

Table 1. General ICTs used in communicating information in the first and second economies

		Economy			
		First Economy		Second Economy	
		Count	Column Responses %	Count	Column Responses %
Which ICT have you used in communicating information?	PCs - Communicate Information	78	17.9%	0	.0%
	Mobile Phones - Communicate Information	90	20.6%	93	33.3%
	Telephones/ Faxes - Communicate Information	86	19.7%	93	33.3%
	Internet - Communicate Information	89	20.4%	0	.0%
	Radio/TV - Communicate Information	93	21.3%	93	33.3%

3.2 ICTs used in communicating information

Table 1 shows data on ICTs used in communicating general information. The majority of respondents in the first economy use all of the ICTs at hand (that is PCs, mobile phones, telephones, Internet, Radio/TVs all at rates of 17.9%, 20.6%, 19.7%, 20.4 and 21.3% respectively) whilst a majority of respondents in the second economy use mobile phones, telephones and radio/televisions (all at 33.3% column responses that is, 100% response rate) in communicating information.

3.3 ICTs used in communicating health information

Results gathered show that respondents in the first economy use all general ICTs to communicate health information whilst in the second economy they use only radios/televisions to communicate health information. The reason for all this is that radios/televisions are affordable and simple to use for respondents in the second economy. In the first economy they use all the ICTs from PCs to radios/televisions because they can afford most of them and also because they understand how to use them. Use of PCs and the Internet in this economy is high as the health institution they visit which also uses these ICTs in communicating health information complements it. This is unlike in the second economy where the health institution still uses the traditional ways (that is, paper charts and community gathering) of communicating information to its patients. Radios/televisions are still the only medium of communicating health related information in these communities. **Fig. 1** shows the responses to general ICTs used in communicating health information from both the first and the second economies.

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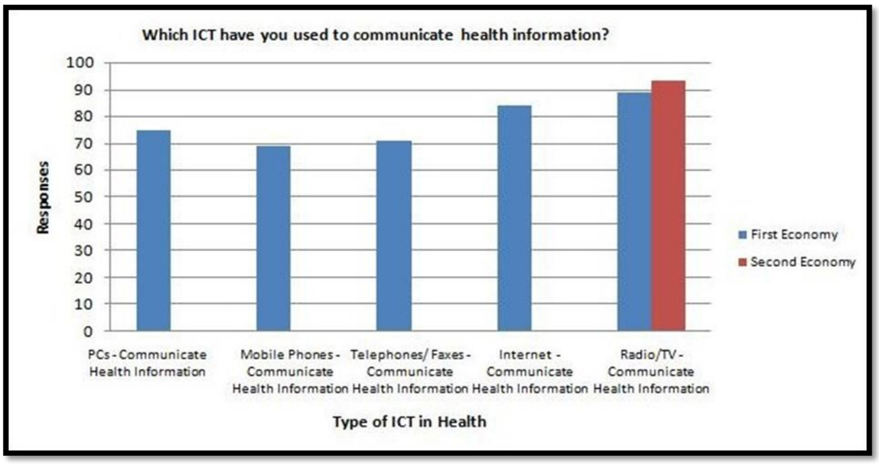

Fig. 1. Graphical representation of general ICTs used in communicating health information in the first and second economies

3.4 Frequency of ICTs used in communicating both general and health information

The frequency of use of ICTs in the two economies depended on the accessibility of the ICTs by the respondents. From the findings, respondents in the first economy used a varied type of ICTs as compared to the second economy with respondents using only, mobile phones, telephone and radios for communication. The use of mobile phones, radios/televisions and telephones in the second economy can be attributed to the affordability, simplicity and easy availability for purchase to the majority of these respondents [27]. **Fig. 2** shows graphically represented data on these frequencies.

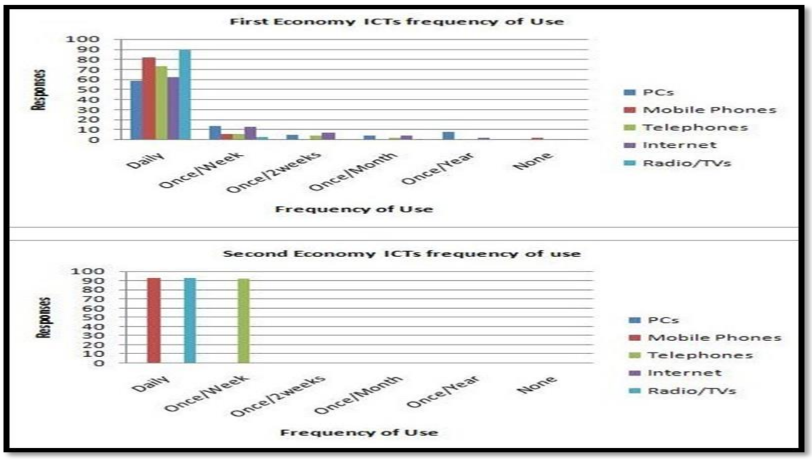

Fig. 2. Graphical representation on first and second economies ICTs frequencies of use

3.5 Special purpose ICTs in communicating health information

Special purposes ICTs in communicating health information are prevalent in the first economy whilst in the second economy they do not use any special purpose ICTs. Whilst the second economy has a column response rate of 0% in all categories, the first economy sees its respondents using telemedicine, e-prescription, webcasting facilities, online health awareness applications and consumer health interactive websites (all at the rates of 30.6%, 7.3%, 14.5%, 35.8% and 11.9% respectively) as their modes of communication for most health related information. Table 3 shows the first and second economies' special ICTs responses.

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Table 2. First and second economy special purpose ICTs responses

	Type of Special ICTs	Economy			
		First Economy		Second Economy	
		Responses	Column Responses %	Responses	Column Responses %
Which Special ICT have you used in e-health?	Health Information Systems(DSS/ES)	0	.0%	0	.0%
	Telemedicine	59	30.6%	0	.0%
	E-prescription	14	7.3%	0	.0%
	Clinical Support Systems	0	.0%	0	.0%
	Web Casting /Video conferencing facilities	28	14.5%	0	.0%
	Online health awareness applications	69	35.8%	0	.0%
	Consumer health interactive websites	23	11.9%	0	.0%

3.6 ICTs meeting information needs

In the first economy ICTs such as PCs, mobile phones, telephones, radios, and Internet are viewed as meeting the information needs of most users whilst in the second economy it was only mobile phones, telephones and radios/televisions which are viewed as meeting most of the users' information needs. The degree of these technologies meeting the users' information needs in these two economies depends on accessibility, availability, affordability and ease of use of these technologies. Because respondents in the second economy use mobile phones and radios/televisions most they however find these technologies as meeting their everyday information needs. This was also the same scenario with users in the first economy.

3.7 Legislative and regulatory issues complementing ICTs utilization in healthcare

Legislative and regulatory issues in e-health are of concern especially in developing countries. Key points from interviews highlighted the need for government laws and policies upholding ICTs in healthcare. Positive responses from both the first and the second economies in support of a national awareness policy to promote ICTs diffusion and adoption in healthcare were noted. In the second economy 93 responses support this initiative and in the second economy 92 responses support this issue. This was also complemented by the key informants' responses in support of a strong framework contributing to ICTs diffusion and adoption in the healthcare sector.

3.8 Correlations

Several correlation analyses at 0.5% significance test level were performed. In summary, there was some complementarity in the relationship between, education, employment, income and the rate of ICTs use in the two economies. Thus education, employment and income impact positively on the use of ICT. Research complementing this finding suggests that, the most successful efforts to incorporate information and communication technologies have occurred in countries with determined government and academic institutions committed to invest in education [28]. Other correlations included the following:

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- There is no relationship between income and special purpose ICTs, thus the use of special purpose ICTs depends on the knowledge on operation of these ICTs and not affordability
- There is a relationship between income and the ICTs access points. It can be deduced that as individual have access to more income, the ability to access ICTs increases due to higher spending power

It is also important to note that there were quite a number of correlation tests that were carried but had invalid or inconclusive results due to lots of missing values from both the first and second economies responses.

3.9 Factor Analysis

Factor analysis was carried based on the survey data computed by SPSS and the results were inconclusive. The reason for this despite having survey information of up to 186 respondents was that, there were a number of missing values especially from the second economy respondents. This caused the results to be invalid as they surpassed the 0.5% significance test levels.

4 Conclusions, Recommendations and Limitations

It can be concluded that citizens residing in well up areas (first economy) of South Africa have better access to healthcare information as compared to those in the disadvantaged areas (second economy). There are several variables that need to be addressed so that those citizens in the underserved areas have better access like those citizens in the well-served areas. Such variables include the following:

- Government taking embracing the ICTs in healthcare roll-out model used in the private sector to strengthen the way public sector healthcare services.
- Creating of healthcare information awareness through the use of cellphone applications, which are mostly affordable to the poor, for example, Whats app, Mixit and many other applications.
- Full completion and implementation of the District Health Information System can play a role in the provision of relevant health information to the public.
- An intensive human resource capacity framework needs to be drafted to ensure the empowerment of public healthcare workers with the necessary ICTs skills as we are now in a dynamic information age. Investment within the public healthcare sector needs not only focus on the technology aspect but also the users and manipulators of such technology.
- The curriculum structure for healthcare students need to emphasise on instilling ICTs skills so that all healthcare sectors (private and public) are even in providing better healthcare services.
- The public needs to be constantly educated and made aware of the benefits of e-health so that they will more receptive to e-health initiatives. If they are aware of the benefits they can also push policy makers to invest in e-health.

Given the aforementioned challenges, contributions and recommendations, the following questions should therefore be addressed in the future: What technologies are most suitable for e-health adoption in developing countries? Which of the available ICTs in the developing country context would best promote health information access in order to narrow the health divide?

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Short Papers

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Extraction Automatique d'Indicateurs de Santé de Systèmes d'Informations de Soins: le Projet du Global Health Barometer

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Contexte et objectifs: Dans la grande majorité des pays à faibles ressources, la collecte d'indicateurs de santé et l'organisation d'un rapportage fiable sur les activités des structures sanitaires restent aujourd'hui un important problème. Pourtant, de nombreux acteurs comme les ministères de la santé, les projets de financement basé sur la performance, les programmes d'assurance maladie et bien d'autres dépendent en grande partie d'informations complètes et correctes sur les systèmes de santé.

A ce jour, l'enregistrement et la centralisation des indicateurs se réalise dans la plupart des pays principalement à l'aide de procédures d'enregistrement parallèles et redondantes (systèmes nationaux d'informations sanitaires, DHIS2, programmes verticaux comme le VIH, TB et autres), avec des registres qui sont souvent spécifiques pour chaque destinataire. Dépendant du nombre de partenaires impliqués, certains centres de santés en région sub-saharienne doivent remplir périodiquement plus de 30 registres différents. Ce travail représentant une charge médico-administrative supplémentaire excessive, la qualité des informations fournies est très souvent contestable. Parfois même, des données totalement fictives (copies légèrement modifiées d'anciens rapports) sont envoyées par des centres qui manquent de temps et de personnel pour correctement réaliser cette activité.

Suite à ces constats, en 2010 le projet du Global Health Barometer (GHB) a été mis sur pied, avec comme objectif de fournir un rapportage alternatif d'indicateurs de santé basé sur l'extraction automatique d'informations des systèmes d'informations de soins (SIS) présents dans les structures sanitaires sub-sahariennes.

Il faut noter que beaucoup de solutions open sources de système d'informations de soins ont été déployées dans les pays concernés par ce projet, s'agissant de MediBoard (CINZ@N) pour le Mali (tous les hôpitaux publiques et les centres de santé de référence dans le cadre de la mise en œuvre de l'assurance maladie obligatoire) et d'OpenMRS pour le Rwanda et le Burundi, aucune de ces solutions n'intègre encore l'extraction automatique des données. Ce qui fait l'originalité de la présente étude préliminaire.

Méthodes: Le projet a été conçu autour de la création d'un data-warehouse de santé (DWS), pouvant accueillir un grand nombre de différents types de données sanitaires (administratives, financières, pharmaceutiques, laboratoires, cliniques, statistiques etc.). Le DWS devrait être accessible à travers une interface web et une série d'interfaces informatiques devraient être définies pour permettre aux SIS d'envoyer des informations à cette base de données centrale. Les interfaces spécifient aussi bien la syntaxe des messages que la sémantique de leur contenu, tout étant basée au maximum sur des classifications internationales comme la CIM-10, la CISP-2 ou LOINC.

Il est à noter que les technologies ouvertes web sont les standards utilisé dans le développement des outils du Global Health Barometter qui sont les mêmes que ceux du logiciel de système d'information de soins « OpenClinic ». Ces technologies sont le système de gestion de base de données MySQL/Postgre

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SQL, le serveur TOMCAT, le tout interfacé avec les langages de programmation Java et Javascript, dans une architecture globale client-serveur léger.

Une implémentation pilote devrait ensuite être mise en place sur base d'une sélection de SIS existants, dans lesquels un nombre de modules d'extraction spécifiques pour le GHB devraient être intégrés.

Résultats: Le DWS a été développé en 2010 et est accessible via le web sur un URL public : http://www.globalhealthbarometer.net. Une implémentation pilote a été réalisée sur base d'un SIS à sources libres (OpenClinic) qui était déjà déployé en 2010 dans une vingtaine de sites au Rwanda, au Burundi, en Belgique et en RDC. Au cours des 3 années de l'étude, d'autres hôpitaux situés au Mali et au Congo-Brazzaville ont encore été ajoutés. En 2013, 35 sites sont interconnectés dans un VPN dédié au projet et envoient chaque nuit sans aucune intervention utilisateur un nombre important d'indicateurs structurés au DWS. Il s'agit d'indicateurs démographiques, financiers, diagnostiques, laboratoires, des chiffres de mortalité et même des indicateurs informatiques (espace disque libre, mémoire utilisée etc.) informant la cellule centrale sur l'état des différents serveurs. Le volume de données récoltées est vaste : en août 2013 plus de 2 millions de dossiers patients, 300.000 hospitalisations, plus de 2 millions de consultations et plus de 13 millions de prestations ont été documentés dans l'implémentation pilote du DWS pour 35 hôpitaux.

A travers l'interface web, ces données peuvent être interrogées à tout moment par les utilisateurs disposant d'un code de sécurité qui leur donne accès à un nombre de sites correspondant à leurs responsabilités. Le site web n'offre non seulement la possibilité de tirer des statistiques ou de générer des graphiques, mais permet également d'automatiser un nombre d'opérations comme l'impression centralisée de cartes d'identification ou le transfert de données de couverture maladie et de facturation entre prestataires de soins et assureurs.

Conclusions: Sur base des résultats obtenus au cours des 3 années de cette étude pilote, l'utilisation secondaire des données de soins moyennant des procédures d'extraction automatiques s'avère une alternative potentiellement attractive pour un nombre de procédures existantes de collecte d'indicateurs de santé. Les extraits étant basés sur des données de soins réels et aucun travail supplémentaire n'étant nécessaire pour la production des indicateurs, on pourrait espérer obtenir des rapports plus complets qui correspondent mieux à la réalité du terrain.

Les expériences dans le cadre de ce projet avec la transmission de données d'assurance maladie entre prestataires de soins et assureurs confirment que, moyennant un nombre de développements supplémentaires, des systèmes comme le GHB pourront en plus jouer un rôle de passerelle de données dans le futur. Pensons aux possibilités de rapportage central (plus besoin d'envoyer des rapports par les structures sanitaires), l'implémentation de la couverture maladie universelle, la surveillance épidémiologique, les programmes de financement basé sur les performances et bien-sûr la retransmission de données aux différents programmes verticaux de santé. Dans ce cadre, une intégration avec le DHIS2 est actuellement en développement.

Mot clés: Indicateurs de santé, Afrique sub-saharienne, Systèmes d'informations de santé, Classifications internationales

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Laboratory Informatics and AIDS Indicator Surveys

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Background and Purpose: National AIDS indicator surveys generate large volumes of specimens and associated data, necessitating the preparedness of systems and processes in the reference laboratory. Specimen management is often more routine while management of data becomes secondary. However, complete and accurate laboratory results are essential to ensure data quality. Robust laboratory informatics solutions for managing data are needed to increase data accuracy and reduce turnaround time.

Methods: During the 2012 Kenya AIDS Indicator Survey (KAIS), 62,435 samples were collected from respondent households and transferred to the National HIV Reference Laboratory (NHRL) for testing. The Association of Public Health Laboratories (APHL) collaborated with the Kenya Ministry of Health in laboratory process improvement, laboratory information system design and governance focusing on preparing the laboratory to manage the large volume of samples and associated data.

This task included developing detailed work flow and data flow diagrams for the entire process, from field specimen and data collection, to receipt, testing and storage. These diagrams were used for training and for reference during the survey process. They were also used to define KAIS 2012 requirements for the existing laboratory information management system (LIMS). Laboratory processes were documented and matched up with the configurations developed in the LIMS. The team also designed specimen tracking and receiving forms based on KAIS 2012 protocol and LIMS requirements. They matched these forms with data elements in the LIMS for data harmonization.

The KAIS survey team developed contingency plans for every KAIS 2012 laboratory activity to ensure NHRL implemented uniform procedures when normal operations did not occur. These plans focused on the management and standardization of human resources as appropriate personnel and associated procedures are integral to optimal information system performance. The team defined staff roles and responsibilities and developed procedures for managing forms, specimens and electronic data, including quality and use aligned with survey protocols. During the project, the KAIS team provided knowledge transfer to NHRL to ensure the development of local capacity and long-term sustainability.

Results: Due to the informatics processes in place, NHRL was able to share laboratory test results from KAIS with other stakeholders within a day of being received. NHRL was also able to immediately access data on storage locations of all samples that were previously managed using paper systems – a significant challenge before the project.

Visualization, mapping and contingency planning for each step of the process ensured that laboratory support to KAIS 2012 was timely, and of high quality, regardless of digressions from standard operating procedures caused by unexpected circumstances. While contingency plans are not routine, they can be critical to the success of the survey.

Conclusions: Preparedness is key. Finalization of the survey protocol three months before the pilot, training and piloting all aspects of laboratory services a month prior to the survey ensured informatics solutions are appropriate and robust. Engaging all stakeholders -- particularly survey, laboratory and LIMS staff -- in laboratory informatics solutions planning, implementation, monitoring is critical to

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developing the most efficient systems and processes for a large national sero survey. During execution, constant and ongoing communication is essential to adapt to the evolving needs of the survey and its participants.

Keywords: LIMS/LIS, Informatics, survey

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Activity Theory Model in Information Systems Research in Practice: Theoretical Framework for Information Communication during Management of Intrapartum

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Background and Purpose: Intrapartum period is defined as the period from the diagnosis of labour to one hour after the delivery of the placenta, also known as fourth stage of labour. Information communication during intrapartum management is vital for the continuation of care. This paper focuses on how the Activity Analysis and Development (ActAD) framework and the Activity-Driven Information Systems Development (AD-ISD) model can be practically used in the analysis of the information communication processes. The practical application for work-oriented information communication research in practice is discussed. The dimensions, levels and phases of the AD-ISD model are elaborated on their application in analysis as a theoretical framework, for information communication by skilled birth attendants during the intrapartum period of pregnancy.

Method: The ActAD framework views work activities as an integration of systems with its elements and activity networks forming information communication. Within these levels there are barriers of communication and enablers which require identification in order to enhance work activities.

The AD-ISD model then provides methods and techniques for 1) understanding the present state of an activity; 2) describing the goal state of the activity; and 3) planning for the transformation to the goal state through planned changes.

Results: We provide an ActAD analysis of the current state of activities during the intrapartum period in a case Maternal and Obstetrics Unit (MOU) in Cape Town, South Africa, focusing particularly on the information communication within the MOU and between the MOU and its referral hospital. We then describe the goal state of the intrapartum activities by applying AD-ISD. The plans of change and the practical application of the model will be elaborated on after the completion of the research data collection.

Conclusion: The current engagement results and pilot study experiences have been very reassuring on the applicability of the ActAD framework and the AD-ISD model to analysing the current state and drafting the goal state of information communication in healthcare activities in an African context.

Keywords: Activity Theory, Information systems, Intrapartum period, Meaning

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The Changing Landscape of HIS in SA

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Background and Purpose: South Africa, with support from the University of Oslo, developed the District Health Information Software, version 1.3 between 1996 and 2006, and together with support from the National Department of Health, rolled the system out across the whole country. Between 2006 and 2010, DHISv14 was implemented in the country, and a significant number of data sets were developed to support the national health information system (HIS). South Africa is now preparing for the transition to DHIS2, which is seen as a key component of the information systems that will be required to support the development of the national health insurance system in South Africa. The transition to DHIS2 is different in South Africa because of the long-standing investment in the DHIS14 system, and the multitude of different data sets that have developed to support the National HIS. This paper describes the preparations that are taking place, at organisational level (both within the public sector at national, provincial, district and sub-district levels, as well as amongst NGOs) to develop capacity to support the use of the DHIS2, as well as technical level to ensure an appropriate transition.

Methods: The research is set within the multi-country HISP-network action research project. The authors have been involved in the development of the national health information system since 1992, both as public sector employees and as employees to HISP South Africa. The paper draws on the interpretive research tradition for the data analysis, and reflects on processes that have unfolded in the last two years, as part of a larger action research project in which HISP is engaged. Data sources are personal diaries, meeting notes, official documentation and workshop reports. Additional sources of information included in-depth interviews with key informants, informal discussions, as well as field visits and observations. Direct observation of staff at work was a major source of information as authors worked with the country team.

Results: The authors use the HMN framework for HIS strengthening to analyse the HIS developments over a 20 year period, and use this to reflect on how the approach that is being adopted to introduce DHIS2 in South Africa will influence previous approaches. The presentation highlights the strategies that are used to overcome technical, organisational and behavioural barriers, and how these relate to the current policy environment in SA. In particular, we reflect on the skills sets that are needed to support DHIS2, and efforts to ensure that these skills are available in a sustainable manner. In response to the technical requirements of the DHIS2, organisational capacity needs to be adjusted, within the public sector as well as within NGOs that support the NDoH. The anticipated improvements to the national health information system are discussed, and the implications of the experiences are highlighted for other countries.

Conclusions: Over 20 countries in Sub-Saharan Africa are using the DHIS. In many of these countries, the information systems are still fairly simple, or in the process of being established. In comparison, South Africa has a fairly advanced National HIS, with many facets that can now be managed in a more integrated manner. This paper describes the processes that are being planned to ensure a smooth transition from the distributed access databases used in DHISv14 to the centralised and integrated system represented in DHIS2.

Keywords: Information Systems Development, Skills sets for information systems support, Data warehousing, Business intelligence

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AFRICA BUILD: Creating Web 2.0 Communities of Biomedical Researchers

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Background and Purpose: Health researchers need access to continuing education and specialized advice to improve the quality, efficiency and accessibility of health systems. The creation of communities of researchers can provide the information necessary for their daily work in addition to strengthening the links between researchers. In this context, Web 2.0 technologies can facilitate the establishment of these communities.

The AFRICA BUILD project aims to promote health research through the creation of virtual communities of health researchers, educators and practitioners, and the use of Information and Communication Technologies. This paper highlights the main findings and challenges found in the development of these communities.

Methods: We have developed a social platform, the AFRICA BUILD Portal (ABP), which integrates health research related didactic contents and resources, as well as tools that facilitate collaboration. This portal has been developed following three principles: (i) use of free and open source tools, (ii) adaptation of these tools to low bandwidth connections, and (iii) creation of a Euro-African community of developers for the sustainability of the ABP.

Results: Several communities of users were initiated within the ABP, mainly structured in three types according to: the organization or country to which they belong, the specific area they are working in, and researchers from two pilots courses on HIV/AIDS and Reproductive Health Research.

Conclusions: Project partners and associates, who form several communities of users, currently use the ABP. The main challenges faced in the creation of these communities are: the language, a need for facilitators for the discussions and interactions, and the motivation of some members to actively participate and contribute in exchanges. In future steps, we plan to develop new functionalities within the ABP and disseminate the platform to the biomedical scientific community in Africa, fostering the creation of African communities of biomedical researchers.

Keywords: Community Networks, Health Research, Social Media

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The Mobility of Researchers and Professionals of Health in Africa: the AFRICA BUILD Project Case Study

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Background and Purpose: AFRICA BUILD is a coordination action funded by the EU involving 4 African institutions, 3 European and one international. It is designed to promote education and research in the field of health using Information and Communication Technologies (ICT). One of the main objectives of the project is the development of centers of excellence in health and the development of services and mechanisms for mobility. The present work is designed to report the status of the implementation of this mobility.

Methods: To achieve mobility, policy and strategy have been defined as a first step. These strategies include defining the scope, duration, criteria and mechanism of mobility. A survey was then conducted to list applications and mobility offerings among the AFRICA BUILD Consortium. Finally, a computer information system has been developed and integrated with the AFRICA BUILD Portal [1] to deliver applications and requests. This work concerns only the mobility of the staff of the institutions of the Consortium. The system can be used by any health professional connected to the AFRICA BUILD Portal. For the financing of mobility of students and researchers from institutional partners of AFRICA BUILD, it is fully ensured by the applicant institution through its budget allocated within the framework of the project.

Results: Three mechanisms or types of mobility have been identified: South-South mobility (i.e. between African partners) which is more encouraged, the North-South (i.e. European experts go to African institutions) and the South-North (i.e. African researchers go to European institutions). So far, 203 demands and 31 mobility offers are listed on the AFRICA BUILD Portal. These requests are related initial and continuous training in public health, medical informatics and clinical specialties. The first initiatives are already underway with 5 already completed.

Conclusions: In light of the current results, we can say that there are real needs of mobility for researchers and professionals of health in Africa. Considering the important requests made by researchers and professionals outside of the Consortium, it will be very useful to explore the possibility of including a list with possible sponsors willing to fund mobility on the AFRICA BUILD Portal.

Keywords: Mobility, E-Health, AFRICA BUILD

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State of the Art of IT-enabled Tools for Strengthening Health Research Capacity in Africa: Comprehensive Analysis

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Background and Purpose: eHealth in Africa is considered as a National Socio-economic Development Strategy according to the New Partnership for Africa's Development (NEPAD) Council "5Is" Perspective for Sustainability (Innovation, Individual, Investment, Infrastructure, and Industry).

The AFRICA BUILD project (www.africabuild.eu) uses Information and Communication Technology (ICT) and know-how; e-learning and knowledge-sharing via web-enabled virtual communities to promote health research; education and healthcare practice in Africa by creating virtual centres of excellence. So, a fundamental step to achieve these goals is to analyze the state of the art of utilizing IT-enabled tools in health research and education in Africa.

Methods: 271 literatures that used in this study were obtained by searching scientific portals, scientific journals and portals of international organizations. The search was limited to literature that was published within the past 10 years and written in English. Initially, an index of the collected literature was created. Then, the synthesis matrix methodology was used to build a matrix containing the resources against the topics and subtopics covered by the literature. Finally, an analysis of each topic was conducted through comparing different perspectives and making relations between different aspects and ideas. Furthermore, a needs assessment study collected primary data (surveys and mind-maps) to deeply analyze the requirements of the African partners of AFRICA.

Results: The main outputs of this study are the following:

- State of the art in eHealth in Africa: highlighting the importance of adopting eHealth in Africa and its adoption level. This section includes capacity building programs, eHealth challenges and opportunities, lessons learned from different activities (studies and implemented projects) and future outlook.
- Training assessment and needs: covering the minimum contents of a training plan in health research, analysis of requirements in Africa and training requirements and needs.
- Research and innovation systems for health and development: new aspects of utilizing research and innovation for health and development and the current activities carried out in this emerging discipline.

Conclusion: African countries share similar challenges (e.g. urban and rural population density), strengths and opportunities to improve the entire health systems and research through ICT. Most of the African countries implemented various projects and initiatives tackling these challenges with ICT support. Furthermore, the health capacities in these countries are aware about the potential ICT to improve health. On one hand, there is a great potential in Africa to build the required "Science, Technology and Innovation (STI)" capacities in the health sector, developing synergies between successfully implemented projects, and utilizing the recent initiatives and toolkits provided by international organizations for developing robust national health research systems along with national eHealth strategies.

On the other hand, African countries still face some common challenges in deploying ICT to greater extent in the health sector, including: poor infrastructure in many African countries, lack or low adoption

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of common legal and regulatory standards for eHealth, strong need to the qualified workforce, and lack of political will and strong commitments of all involved stakeholders.

Keywords: Biomedical and Health Informatics, eHealth, Information and Communications Technology, Health Education and Research

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Building Capacity Through a Social Network for African Researchers: Piloting two eLearning Courses on Evidence Based Medicine and Research within the AFRICA BUILD Project

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Background and Purpose: Practicing Evidence-Based Medicine (EBM) means integrating the best available external clinical evidence from research into clinical care and new research. Certain skills, often involving Information Technology, such as searching scientific literature databases, appraising or grading evidence, are essential to apply the latest evidence for a health care intervention or to identify gaps in clinical research. The target population for learning these skills, health care workers willing to do clinical research or deciding on policies, often lack time to enrol in full time face-to-face training in EBM and clinical research. Therefore part-time, flexible and modular distance-learning courses have a larger potential to learn EBM and research techniques.

As part of the AFRICA BUILD project, a Coordination Action to improve capacity in health research and education through ICT, we designed a pilot course on EBM and clinical research, which was offered through an on-line educational platform, embedding several features similar to a social network, to African researchers. The objective of this pilot course was to identify factors contributing to success and/or failure of an on-line education programme through such social network.

Methods: Different lecturers from partner institutions in Mali, Cameroon and Belgium recorded short presentations using DUDAL software (developed by the RAFT Network, University of Geneva) on the topics of EBM and clinical research. Theory from those sessions could then be applied in on-line assignments and in a group exercise. Experts from Mali and Cameroon facilitated those group exercises and discussions between participants. Seminars, exercises, group discussions and a virtual community were integrated in the eLearning platform designed for this purpose, allowing participants to connect with experts and fellow students.

The pilot course was evaluated using both quantitative and qualitative methods, such as: attendance statistics from Google Analytics, results of pre- and post-course tests, users' satisfaction surveys and participants' focus group discussions.

Results: 33 out of 38 participants starting the course completed a final test and the course evaluation. For 24 out of those 33 (73%), the Internet connectivity remained the main barrier for attending the course. Although the on-line webinars required limited bandwidth, only 23% of participants has not had any problem when watching on-line sessions. Despite these problems, hardly any participants would have preferred to be approached by a different learning method. 82% valued applying theory in a group exercise as essential component of this on-line course. The application of the main principles of EBM and research were tested through a few practical examples before and after the course. Participants would be most eager to continue taking on-line courses if these covered statistical analysis within clinical research and methods on how to write scientific papers. They named a lacking "research culture" and difficult

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access to scientific journals as main barriers to start mastering research. Their main motivation to engage in research was a possible future academic career, i.e. teaching at the Faculty of Medicine.

Conclusions: A potential to let many students successfully complete a course in EBM and clinical research is there, but it requires engaging participants in an active exchange with fellow participants and experts involved in the on-line course development or at the Faculty. The impact and benefits of linking even more peers and experts in the field should be investigated in a second pilot phase of this EBM and clinical research course.

Keywords: Education, Distance, Research ,Evidence-Based Medicine

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Are the Terms and Conditions Offered by Cloud-Servers Safe for Personal Health Record-Keeping?

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Purpose: This exploratory paper investigates the terms and conditions offered by cloud service providers, questioning whether these are a safe environment for personal health record-keeping with regards to privacy, security and intellectual property control among other factors. We focus on evaluating the extent to which the privacy of sensitive information is protected in these systems as well as the extent to which terms provided comply with relevant regulations. Whilst many people may be excited about the introduction of cloud solutions to managing their personal health information, there are questions that we urge the public to ask before entrusting their sensitive health records to any cloud-service system.

Methods: This is an exploratory research based on Internet resources about terms and conditions offered by common cloud service providers used by many people. The researcher explores terms and conditions of four common cloud-servers, namely: Dropbox, Google Drive, Microsoft Health Vault and Microsoft's SkyDrive. To further augment the study, the researcher conducted a randomized, questionnaire-based survey at a local university in Zimbabwe, and engaged 100 users to provide responses regarding their use of these cloud-servers as processing and storage centres for their personal health records.

Results: The study establishes that users rarely read the terms and conditions; very few are concerned with finding out about the privacy, confidentiality and intellectual property issues pertain to their information stored in the cloud; yet, there is a potential loss of valuable information, or at least un-monitored transfer of property rights that may need careful scrutiny to decipher.

Conclusions: Several recommendations are made, among which include education of users to understand the meaning of terms and conditions offered, a call for the simplification of the terms and conditions and probable use of local 'home-grown' solutions.

Keywords: Cloud Server Solutions, Personal Health Records, Privacy and confidentiality

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Electronic Data Capture in a Rural African Setting: Evaluating Experiences with Different Systems

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Background and Purpose: Electronic data collection (EDC) has been used in Africa for more than 10 years. There are many potential benefits of EDC e.g. in-questionnaire data validation. However challenges such as data protection issues and lack of mobile network coverage in some areas remain. As hardware such as smart phones become cheaper and more widely available, it is a realistic option to use them as field research tools. We aimed to evaluate the pros and cons of four systems being used simultaneously in rural Malawi: two platform applications for Android systems (CommCare and ODK Collect) and one for PALM and Windows OS (Pendragon) and a custom-built application for Android (MIVA).

Methods: We evaluated the four EDC systems in terms of: ease of development, ease of use for end-users, technical support, features available, ease of data transfer and access, and cost. Data was assimilated from project managers, local tool developers and field staff, using structured questions.

Results: Development of the stand-alone 'app' required specialist skills; however development of tools using the remaining three systems was possible by non-specialists. ODK Collect and CommCare both have user-friendly web-interfaces, with CommCare providing excellent technical support. In both instances more complex logic and displays require the use of Xform programming. Pendragon requires all logic properties to be programmed using Xform, although question entry uses a simple user-interface.

For all systems, two to three days training was found to be sufficient for the end-user to competently capture data in the field. One of the main features we deemed important to evaluate the suitability was how data could be assimilated following collection and data security. CommCare relies on an Internet connection or phone network, something that could cause issues but so far has been successful in rural Malawi. The data stored on the phone is encrypted and the app password protected, therefore CommCare provides several in-built security features. ODK Collect also uses this system as the default although you can transfer data though a USB connection to a computer. Data from Pendragon is also downloaded using a USB connection, however if multiple PDAs are used it is necessary to manually combine the data post-transfer. Finally, data from the stand-alone app could be texted, a system with cost and network coverage implications, manually downloaded by USB connection or uploaded wirelessly.

Features of note in the different systems included the "case" feature in CommCare, which allows data to be locally stored for use in subsequent interviews, a useful feature in studies with follow-up interviews. The standalone app has the ability to process and analyse data, as well as being tailored specifically for the data collection at hand and is thus standardized.

The only system which is truly 'free' is ODK Collect, an open source software. CommCare has a nominal user-fee if you have more than 20 users, therefore at scale there are budgetary implications. Pendragon requires a user license fee and building an app can incur skilled labour costs.

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Conclusions: EDC offers many opportunities for efficient data collection, but brings some issues requiring consideration when designing a study; the decision of which hardware and software to use should be informed by the aim of data collection, budget and local circumstances.

Keywords: Electronic Data Capture, Application, Africa

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Architecture for Health Information Systems Interoperability in Africa

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Background and Purpose: Africa has seen a steady increase in the Information and Communication Technology (ICT) systems deployed in health care institutions. This uncoordinated mass migration to electronic health information systems in Africa has created an heterogeneous and complex computing environment where most of the deployed systems have technologies that are local, proprietary and insular. Furthermore, the infrastructure in Africa to facilitate the electronic exchange of information has a number of constraints. The infrastructure connectivity on which applications run is still segmented. Most parts of Africa lack the availability of a reliable connectivity infrastructure. In some cases, there is no connectivity at all. The realities of interoperability and re-usability problems have started to become more prominent in Africa as more systems are developed and deployed. It is not practical to either discard the existing systems or have only one system in place to solve this problem.

The standards development work of the ISO TC 215 will have a major impact on the applications deployed across the continent once completed. Some African countries sit on these committees and it is important that the developers of architectures that will be deployed in Africa keep an eye on the work being done by the working groups of the TC 215. Another important aspect particular to an African environment is the connectivity issue. One has to be aware of the fact that the connections between the different systems are unreliable and subject to high segmentation levels. Architectures deployed need to be able to operate in a disconnected environment. Thirdly, technologies, particularly programming languages used to develop systems, need to be based on what the teaching industry, colleges and universities is providing to students in Africa.

The core purpose of this work is interoperability of various IT assets in and outside a health institution and the connectivity of IT systems in the face of unreliable connectivity infrastructure in Africa. The goal of this research was to produce an outcome that can be generalised and applied to other cases in Africa.

Methods: To solve the problem described above required the building of an artefact using specific software engineering methods. What systems that are in use today need, in additional to other standards issues, is an upgrade in order to expose them as web services and make them part of a Service Oriented Architecture (SOA), based on web services.

Results: The three main theoretical contributions are a SOA Driven Disconnected Architecture (SOA-DDA), Runtime Dynamic Routing (RDR), and a methodology to enhance an application for future interoperability. The key practical contribution is an Application Programming Interface (API) design based on the Health Level 7 Reference Information Model (HL7 RIM) that is able to not only deal with the mediation or interoperability issues, but also operate in an unreliable connectivity environment and adjust to the ever changing and evolving health care standards. The API exposes REST based web services to the consumers of the services. It can be used to build systems from the ground up. It was constructed using rigorous documented processes to produce constructs, models, methods and an instantiation.

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Conclusions: The framework developed takes care of all the issues that need to be addressed in order to build a workable system.

Keywords: Architecture, Interoperability, Distributed Computing, Web Services, Health Information Systems

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Developing a Novel, Open Source EMR-Integrated Appointment Scheduling System for the Developing World

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Background and Purpose: Electronic medical record (EMR) systems streamline access to medical information and are important for strengthening continuity of care. EMRs do not, however, typically manage workflow associated with scheduling and monitoring patient visits. Integrating existing stand-alone scheduling systems with information stored in EMRs is error-prone and inefficient. Furthermore, functional criteria important to developing world health centers may not be addressed by systems designed for use in the developed world. An integrated system tailored to the needs of developing world health centers is necessary to efficiently use medical and clerical resources, improve quality of care, and decrease the burden of seeking healthcare for patients. This abstract discusses how these design requirements were developed into an appointment scheduling module for OpenMRS, an open source EMR. Software implementation at the Refugee Clinic in Tel Aviv is used as case study to demonstrate the module's value. The Refugee Clinic is staffed by volunteers and provides care to immigrants from Eritrea and Sudan; it can be considered a special case of a developing world health center.

Methods: Design requirements of an appointment scheduling module were established by a multidisciplinary, international team of health center staff, OpenMRS implementers, and computer programmers. An iterative development process that incorporated feedback was employed to be sure design criteria were met and that the final product was appropriate for use in health centers worldwide. The module was installed at the Tel Aviv Refugee Clinic. Three months after implementation, a user study was undertaken to assess staff understanding of the module and solicit feedback for improvement.

Results: An appointment scheduling module was developed and is available as an open source add-on to OpenMRS at modules.openmrs.org. Key software features include: scheduling patient appointments based on provider availability; operating a block or sequential scheduling system; "squeezing" a patient into a full timeslot; converting a patient appointment into a patient visit; managing a patient queue; gathering statistical data; and maintaining confidentiality. A user study revealed that the module was well understood, easy to use, and had a large and positive impact on resource utilization and efficiency. Concerns about error recovery and missing features were identified and addressed by subsequent software modifications. The module is being actively used, with 4,296 appointments scheduled at the Refugee Clinic in eight months. In the 90 days after public release, the software was downloaded 150 times, and positive feedback has been received from implementation sites in five countries.

Conclusions: We have developed a novel, open source appointment scheduling system that is fully integrated with OpenMRS. Our module links a patient's medical history with past and future appointments for improved follow-up. The scheduling algorithm developed is especially applicable to the workflows of the developing world, as validated during eight months of use at the Tel Aviv Refugee Clinic. There, a user study and feedback indicate that the module has improved resource utilization,

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efficiency, and scheduling frustration amongst patients and staff. Additionally, previously unknown statistics, such as average appointment duration, are being generated and used to inform decision-making.

Keywords: Appointments and Schedules, Waiting Lists, Medical Records Systems, Computerized

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An Assessment of the Records Keeping Status in Some Selected Health Institutions of Matabeleland South Province, Zimbabwe

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Background and Purpose: Records keeping is important for a functional health delivery system in the management of important information. It forms the indispensable informational and logical link between the different levels of health care both in terms of the referral of patients, supervision, outreach services, the supply of health commodities and disease management. It is an important component of the health care delivery system. The purpose of the study was to find out the range and types of records kept by the health centres, clinics and hospitals; to find out if there are electronic records keeping systems used by the health institutions; to determine the records management and records keeping systems used by the health centres, clinics and hospitals and comparing them to internationally recommended standards; to find out the skills and experience of staff who manage records at different levels; and to suggest ways of improving records management systems in the health institutions province.

Methods: The quantitative research approach was used through a descriptive exploratory survey used to gather data from a sampled population from health facilities in Matabeleland South boarder line area covering four districts in Zimbabwe.

Results: The insufficiencies in health delivery and disease management can be partly attributed to poor records management practices in health institutions due to lack of training of nurses, poorly maintained infrastructure and a multiplicity of other factors discussed in this paper.

Conclusions: If promoted, Records Keeping Systems (RKSs)* which often generate several information-based solutions can be used to complement and partially fill the gaps left by the endeavours of medical and research-based solutions in improving health systems service delivery and disease management in remote, rural communities.

***Notes:**

A "Records Keeping System" is a manual or automated system that collects, organizes, and categorizes records, facilitating their preservation, retrieval, use, and disposition. Elements of a records keeping system are:

- Records - information resources, in any format, that are:
  - created in the course of business,
  - received for action, or
  - needed to document institutional activities.
- People - the records management personnel such as records clerks, classification specialists, and information officers
- Processes - procedures on how to manage records throughout their lifecycle or continuum which are stipulated in standing orders, procedure manuals and policies as well as programmed software.
- Tools - equipment and software used to capture, organise, store, track, transmit/communicate and retrieve the records.

Keywords: Records Keeping Systems (RKSs), Health Care Delivery Systems, Health Records Management , Marginal communities

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Implementation of Electronic Patient Records in two Rural District Hospitals and one Urban University Hospital in Cameroon

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Background and objectives: The health system in Cameroon has to deal with several health problems which increasingly affect the economically active population (e.g. AIDS, Multidrug-resistant tuberculosis, increasing rate of diabetes, nephrology, cardiovascular and other chronic diseases). It is globally recognized that care processes of these health problems can be efficiently and effectively managed in care facilities with electronic patient records. In addition, the work of research organizations and strategic institutions such as the Ministry of Health and research or international institutions rely partly on the quality of data and the reports of locally operating facilities. Experience gathered on AIDS and tuberculosis in other developing countries has proven that innovative locally appropriate implementation of cost-effective electronic patient records (EPR) can lead to considerable improvement. For this reason, we implemented and evaluated an already validated innovative eHealth-based solution with EPR [1] in two rural district hospitals and one urban university hospital of Cameroon, in order to contribute to the improvement of the situation presented here, compare and evaluate implementation challenges (difference between rural and urban facilities), measure the impact on the local care process, and identify success and sustainability factors for future projects.

Methods: A review of the relevant research literature and project report has been performed. A Stakeholder analysis was conducted using qualitative methods. Process and infrastructure analysis were performed and key requirements identified. Based on these, an implementation plan and evaluation indicators were formulated. Agile methods (SCRUM and KANBAN) and quality management based on continuous improvement processes were applied for the project management (including software customization and change management).

Result and discussion: The 22 indicators evaluated indicated that 5 activities were realized within the planed timeslot, 14 activities have been partially realized with an average delay of about 7 months, and some activities were postponed for the second phase of the project. The qualitative evaluation conducted at the end of the first phase of this research project showed a clear satisfaction of the stakeholders with the achieved results and specially the agile methods approach. This enhanced the local ownership which is a key requirement for the project sustainability. The agile methods and the availability for unpaid experts however led often to an extension of the activities deadlines.

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Keywords: Electronic patient record, electronic health record, clinical information system, electronic medical records, eHealth, agile methods.

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Health Care in Sub-Saharan Africa: An Explorative Study of Photography as a Healing Art

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Background and Purpose: Therapeutic art plays an important role in patient recovery in hospitals. Art therapy in prescribed terms captures the use of arts and words to express ones feelings. Unlike many developed parts of the world, art rarely plays a significant role in the healing processes at hospitals in sub-Saharan Africa. While waiting to see medical officers or during admissions in the hospital, patients often find themselves either staring at blank walls or looking at health informational images — two extremes of the imagery spectrum. This may psychologically have a positive or negative impact on the health of the patient.

However, research shows the importance of art in the healing process as well as in comfort and the perceived level of care. Research conducted on patients who have undergone surgery indicates that patients who had photographs mounted in their wards recovered faster than their counterparts. Similarly, researchers have also found that digital storytelling is one of the viable ways to facilitate self-healing. With the availability of Information and Communication Technologies (ICTs), there is a possibility of improving healing, facilitated within this form of cognitive-behavioural and psychodynamic process of therapy.

This on-going case study, explores the use of digital photography in facilitating healing process in a hospital. It explores the use of ICT-enabled therapeutic art installation in the medical wards to aid in clinical care and practice.

Methods: A qualitative approach is employed to gain deeper insight and understanding of ICTs in therapeutic art. The study focuses on maternal and child healthcare (MCH). The research is being conducted in a private-general hospital in Ghana where most of the patients are middle-income earners. Through participatory processes, images created from the input of patients and health workers were installed in the female wards and waiting areas. Interviews and observations were used to obtain impressions from patients and hospital staff about the installation in the clinic. Twenty key informants comprising doctors, nurses and patients conveyed their views.

Results: Preliminary results show that, patients prefer hospital environments with therapeutic art. It relieves them of boredom and makes them feel more comfortable and relaxed. Subsequently, artistic intervention takes their mind of their ailment. It may be realised that the use of ICT- enabled therapeutic art installation has potential in facilitating healing.

Conclusions: The preliminary results suggest that through simple photos created from ICTs, patients and health workers mood could be improved in the hospital. This form of phototherapy also makes patient's appreciate art. Further research could be conducted in other private and public hospitals in cities and rural areas in other sub-Saharan African countries to validate the study.

Keywords: healing; ICT; maternal healthcare; photography; sub-Saharan Africa; therapeutic art

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Factors Associated with HIV Prognosis in Rural Uganda: Sequence-Mining the Medical Record

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Background and Purpose: With the increased adoption of the electronic health record, data mining emerges as an important technique for the empirical discovery of new knowledge from health data. Itemset sequence mining is a technique that enables the discovery of temporal (ordered) associations between entities in a database. The purpose of this study is to demonstrate the use of itemset sequence mining to discover factors associated with good and poor HIV prognosis amongst a cohort of HIV patients in rural Uganda.

Methods: We obtained a de-identified and date-shifted OpenMRS-based medical dataset from the Millennium Villages Project site in Ruhiira Uganda. The dataset contained the records of 129,080 patients with 5,825,579 observations made in 335,000 encounters between 2008 and 2011. We extracted relevant demographic and clinical variables for all HIV positive patients in the dataset. The extracted cohort was stratified into good and poor prognosis groups. The good prognosis group comprised patients whose modal stages over the duration of follow-up were either WHO stage I or II. The poor prognosis group comprised patients whose modal stages were either WHO stage III or IV. We applied the Sequential Pattern Discovery Equivalence classes (SPADE) algorithm via the arulesSequences package in R (programming language) to discover frequent sequence rules in each group. Pruning strategies were used to filter out sequence rules that were insignificant. Internal validation was done using 10-fold repeated random sub-sampling and only sequence rules common to all folds were assumed to be representative findings. External evaluation was done by two independent researchers who assessed the relevance of the generated sequence rules.

Results: A total of 3,353 records pertaining to HIV positive patients were extracted from the dataset. The good and poor prognosis groups contained of 1,441 patients and475 patients respectively. 18 sequence rules in the good prognosis group and 14 sequence rules in the poor prognosis group were obtained. The external evaluation of these sequence rules was conflicted, with an inter-rater agreement by Cohen's Kappa being 32% (poor) for the good prognosis rules and 57.1% for the poor prognosis rules. The good prognosis group was associated with having a normal body mass index, being single or married, being diagnosed with urinary tract infections, and having signs and symptoms of fever and headache. The patients in this group were more likely to be newly diagnosed and less likely to be on antiretroviral therapy. The poor prognosis group was associated with being underweight, being widowed or divorced, and being diagnosed with respiratory tract infections. The patients in this group were more likely to be in the WHO stage III and reported the HIV status of their partners as either positive or unknown.

Conclusions: Our study suggests that sequence mining may indeed substantiate known associations as well as generate useful hypotheses concerning HIV prognosis. Further investigations using larger and more diverse datasets are warranted.

Keywords: HIV Prognosis, Sequence Mining, Rural Uganda

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A Review of Ghana's E-health Strategy

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Background and Purpose: Ghana has been faced with weak health systems leading to preponderance of communicable diseases, under-nutrition, and poor reproductive health resulting in difficulties in meeting some of the targets of the MDGs. There are also increasing incidence of non-communicable and chronic diseases, and severe inequities in access to health services resulting in large disparities in health outcomes across the country. In light of these, the Ministry of Health and Ghana Health Service in 2007 developed a National Health Policy which has three broad objectives. These are:

(a) To ensure that people live long, healthy and productive lives and reproduce without an increased risk of death.
(b) To reduce the excessive risk and burden of morbidity, mortality and disability, especially in the poor and marginalized groups
(c) To reduce inequalities in access to health, reproduction and nutrition services.

However, achieving these objectives require a change in the way health business is run and that the health sector must find new and innovative ways of reaching more people with information and resources to help them make informed decisions. Under these circumstances the Ministry of Health and its agencies have identified e-health as the best means to achieve the above objectives and hence formulation of Ghana's e-health strategy in 2010. The research seeks to: give an overview of the 2010 Ghana e-health strategies as a driving force in achieving the health sector goals; enumerate success chalked from implementation of e-health strategies; identify the barriers to the implementation of e-health strategies in Ghana.

Methods: Ghana's e-health policies and strategies since 2003 have been reviewed. Situational analysis approach was used in this review. Several stakeholders such as the Ministry of health, Ghana health service, Development partners, National Information Technology Agency, Academia, Telcos etc were consulted and they made very valuable contributions to this review.

Results: Within 10 years Ghana has seen the development of five documents on e-health policies and strategies: ICT for Accelerated Development (ICT4AD) Policy; Proposals for Ghana eHealth Strategy; Health Sector's ICT Policy and Strategy; ehealth plan: 2007-2011 and Ghana E-health strategy 2010. Ghana's 2010 e-health strategy seeks to: streamline the regulatory framework for health data and information management; build sector capacity for wider application of e-health solutions in the health sector; increase access and bridging equity gap in the health sector through the use of ICT and develop strategies towards paperless records and reporting systems. Ghana has chalked some success since the implementation of e-health strategies which are categorised as (1) Capacity building – Msc in Health Informatics**;** **C**ertificate and Diploma in Health Informatics; e-learning project in all Health training institution. (2) mHealth initiatives - Sene smart phone project, MoTeCH, MVP Project – telemedicine, SMS for life, EWS, Fio-GHS and RDT smart reader. (3) Health Management Information Systems – LMIS, HIS, iHost (GHS), NHIA – eClaims, eRegister and DHIMS2.

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Conclusions: Full execution of this strategy is expected to lead to developing a robust ICT system to capture, store, exchange health information thereby improve patient care services throughout the country and facilitating the achievement of the health sector goals.

Keywords: E-health strategy, National Health Policy, Ministry of Health, Ghana Health Service

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Design and Implementation of a Web-based Application for Patient Management and Decision Support Using Mobile Phones and Geographic Information System

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Background and Purpose: HIV affects a significant proportion of the population in many developing countries. One major problem with HIV treatment is to make patients pursue their treatment, including medication and medical check-ups until completion. While there may be many reasons for the lack of endurance, there may be ways to improve completion of treatment programs by maintaining better contact between doctors and patients. Mobile phone text messaging is well suited for supporting self-management and improving patients' self-efficacy skills through, for instance, medication reminders and supportive messages. But there is also a need for interactive program management by reacting promptly and effectively to deviations from program plans. This may include operational decisions for short term management of patient retention at individual care centres, tactical decisions such as re-configuring the messaging based on performance, and strategic decisions e.g. if and when trends are discovered which can be attributed to some factor(s), like geographical, social, economic, or other conditions, call for large-scale systematic action. Despite the growing body of literature reporting positive outcomes of e.g. SMS based communication with patients, there is yet very little research about the integration of communication technologies and spatial decision support systems. This paper seeks to address this gap in the literature by investigating the design issues that need to be addressed regarding both content and form, addressing patient end-users as well as decision makers at different levels, as well as system requirements, protocol decisions in relation to the development of an integrated wed-based tool designed to support patients' self-management of disease and health workers' decision-making based on a system designed and implemented in Mozambique.

Method: A case study involving three healthcare sites in Mozambique as a basis for discussing general design issues for this kind of system. A messaging system implemented in all sites feeds data into a central data repository which can be used for analysis of operations and decision support. Interviews with healthcare workers and decision-makers were undertaken to define user requirements and to inform content development as well as system design. Prototyping was used for usability tests and questionnaires for user acceptance.

Results: The developed system automatically, based on the treatment schedule, sends SMS appointment reminders, medication reminders, and supportive messages to patients enrolled in antiretroviral treatment. The system also maps patients' movements within their residential area so as to understand their mobility patterns. We found six crucial design considerations that need to be addressed for success: (i) availability of data; (ii) text message content; (iii) remote care; (iv) systems features; (v) cost, and (vi) connectivity. By integrating statistical functions the project ensured that data analysts and decision-makers can analyse and monitor patients' treatment outcomes. While prototyping allowed to perform several improvements mainly for issues (ii), (iii) and (iv), questionnaires indicated a general positive acceptance of the web-based platform used as a decision support system.

Conclusions: The integrated system provides support for increasing patients' knowledge, skill, and confidence in managing their health problems. Moreover, it provides a representation of patients'

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treatment regarding both outputs – e.g. medication and visit patterns – and outcomes – result of treatment - which can inform decision-making during the treatment process as well as after. The project showed that there are several design considerations which must be taken into account, and which may require different solutions in different contexts so as to achieve the intended benefits.

Keywords: web-based system, reminder system, GIS, decision support, patient management

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Mobile Technology-Enabled Healthcare Service Delivery Systems for Community Health Workers in Kenya: A Technology-to-Performance Chain Perspective

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Background and Purpose: Community Health Worker's (CHW's) are often the only link to healthcare for millions of people in the developing world. These health workers represent the most immediate and cost effective way to save lives and improve healthcare in their respective communities. They contribute to delivery of quality primary care by inter-alia conducting monitoring and evaluation exercises, disease surveillance, and point-of-care diagnostic support. There is consequently growing interest in supporting CHWs at the point-of-care through the application of mobile-health (mHealth) technologies. Unfortunately, these mHealth initiatives are often unsustainable pilot projects that fail to 'scale-up' meaningfully and there is a lack of substantive evidence of the impacts of these mHealth tools on healthcare service delivery outcomes. Moreover, extant literature on mHealth largely comprises studies that are non-replicable, and do not have large sample sizes.

Consequently, we lack answers to fundamental questions: To what extent can mHealth platforms enhance the performance of CHW's, and how can their workflows be improved through the utilization of mHealth tools? Without such answers we cannot provide rigorous evidence-based solutions for the enhancement of community-based healthcare service delivery systems, the empowerment of CHW's in the delivery of healthcare services, and the proper and successful scale up of mHealth projects.

The purpose of this study is to address these questions. More specifically, this study aims to examine (1) the fit (from multiple fit perspectives) between healthcare tasks and mHealth tools used by CHW's (2) the factors influencing CHW perceptions of the fit of mHealth tools to their work tasks, (3) the extent of mHealth tool utilization amongst CHWs, (4) the precursors to utilization, and (5) the perceived effects of mHealth tool utilization on the performance of CHW's.

To address these objectives, the study draws on theories of task-technology fit and utilization, to develop an extended, replicable Technology-to-Performance Chain (TPC) model. This model not only hypothesizes the effects of selected technology and task characteristics on task-technology fit perceptions of CHWs, but also subsequent implications for the utilization of mHealth tools and CHW performance. This study conceptualizes task-technology fit by drawing on four of Venkatraman's (1989) fit perspectives: (1) Fit as Matching, (2) Fit as Moderation, (3) Fit as Mediation, and (4) Fit as Covariation. This model is appropriate because despite efforts to study mHealth deployment and CHW performance in the developing world, there is a lack of consensus on how to assess their effectiveness, efficiency, and quality of care, coupled with poor methodological study designs. Whilst prior research has made important advances, there still remains a gap in our understanding of (1) the determinants of utilization of mHealth tools for healthcare service delivery in the developing world, (2) the impacts of mHealth tool utilization on CHW performance, and (3), whether the mHealth tools are adequately designed to fit with their intended healthcare service delivery purposes, thereby enhancing the workflow efficiencies of CHW's. Such gaps in mHealth research can be overcome by (1) having more replicable study designs, with adequate sample sizes for purposes of generalizability and (2) comparison studies to study the effectiveness of technology for healthcare intervention in developing countries, across varying healthcare service delivery tool usage settings.

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Methods: The empirical context for this study is Kenya. Kenya is amongst Africa's developing countries becoming synonymous with the rapid diffusion of mobile technologies, and has one of the highest mobile penetration rates in the developing world. Moreover, it is one of the leading developing countries in the deployment of mHealth initiatives. Due to the need to identify and operationalize the concepts of fit, utilization, and performance, formulate hypotheses of relationships amongst them, and subsequently use multivariate data analysis techniques – this study lends itself to a hypothetico-deductive approach, consistent with empirical positivism.

To test the proposed model, a cross-sectional survey instrument – which helps ensure generalizability and replicability, will be used to collect data from CHW's with access to mobile-technology enabled tools in the areas of Kibera, Nakuru, and Kajiado. A survey instrument will also be administered to CHW's operating within a manual (paper-based tool) setting. Their results along various performance metrics will be compared to data collected from the CHW's in mHealth technology settings – so as to demonstrate the expected impacts of mHealth tool use. A total sample size of 700 CHW's in the three areas will be targeted, via proportional stratified sampling techniques.

Expected Results: It is expected that results of this study will be used to determine which perspective of fit offers the best explanation for observed variations in mHealth tool utilization and CHW performance. Since the four fit perspectives examined in this study are theoretically and methodologically distinct, an empirical comparison would have implications for the design and implementation of mHealth tools for healthcare service delivery - if one perspective of fit better explains CHW utilization and performance than another. It is also expected that this study will provide evidence-based solutions for the enhancement of community-based healthcare service delivery systems, and the empowerment of CHW's in their delivery of healthcare services – thus informing the improved scalability of current and future mHealth deployments.

Conclusions: This study makes a number of contributions. First, a theoretical contribution is made as a result of the development of a TPC model, drawn from theories of fit and utilization, to test perceptions of task-technology fit, utilization, and performance impacts amongst CHW's in Kenya. In addition, this study will contribute to growing knowledge repositories in the sub-disciplines of Information and Communication Technologies for Development (ICT4D), Information and Communications Technologies for Community Health Workers (ICT4CHW), Mobile Informatics, and Health Informatics. Second, a contextual contribution is made by examining the concepts of task-technology fit, utilization, and performance within the context of community-based healthcare service delivery systems in Kenya, and thereby providing much needed empirical evidence into the use and impacts of mHealth in developing country settings. Third, a methodological contribution is made by conceptualizing, developing, and validating scales to measure task-technology fit, utilization, and performance. Advanced data analysis techniques such as Partial Least Squares (PLS) path modelling will be used to test the context-specific TPC developed. Fourth, a practical contribution is made by informing policymakers, funders, and implementers charged with the responsibility of deploying mHealth initiatives in the developing world.

Keywords: Public Health Informatics, Healthcare Service Delivery, Community Health Workers, Kenya, Task-Technology Fit, Technology-to-Performance Chain

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An Information Systems Approach to Addressing Health Care Provision Challenges in Socially Marginalized Communities: Case of Grabouw Settlement in the Western Cape, South Africa

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Background and Purpose: This paper is part of wider collaborative research activities aimed at finding information technology-based solutions to socially marginalized communities in the area of health provision. This particular study is empirically scoped around Grabouw, a settlement in the Western Cape in South Africa. It is one of thousands of such settlements in South Africa which are alienated without equal access to education, health, transport, housing, jobs and a general descent livelihood. The fragmentation of South Africa's economy is largely attributed to its apartheid history where black Africans have been alienated from the mainstream economy.

The purpose of the study is to apply one of the analysis tools, LACASA, which were developed within the ISD4D research group in order to understand the context of Grabouw community. The results will inform stakeholders of quick design approaches to reach usable, sustainable and useful solutions which address healthcare information needs of the community.

Methods: The paper follows the ISD4D's "Daisy" approach to locate the study within the group's wider research context. The LACASA analysis tool (Tiihonen, 2011), is then applied in order to understand the healthcare challenges and needs of the Grabouw community. Interviews with healthcare workers, the local government and individual community members were undertaken to define the Grabouw general context and healthcare landscape in particular. This contextual analysis will lead to the design and development of solutions in the next phase of the ISD4D research for this particular community.

Results: Preliminary observations are that Grabouw is an over-populated community with minimal healthcare facilities. There is very high unemployment and rampant crime. There are too many migrants from other African countries and also internally from far provinces of South Africa. The LACASA tool, adopted within the ISD4D research group, has been selected on the basis of its robustness to depict a rich contextual picture of a situation, thereby increasing shared understanding for information systems development.

Conclusion: The paper provides a comprehensive contextual situation of the Grabouw community. The overall aim is to develop information systems that act as a quick solution to current information provision problems around healthcare. The paper also provides a methodological contribution to systems design and development activities as the LACASA tool depicts an overall understanding of information needs.

Keywords: *ISD4D, LACASA, Contextual Analysis*

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Identifying the Need for m-health: A Community Capability Approach

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Background and Purpose: Mobile-Health, or m-health, is regarded as an enabler for rural communities to access medical services through mobile devices. Research points to the fact that many of these initiatives fail in rural communities, not only to meet the expectations of the communities, but also to bring about any development. The traditional view of development utilizes tangible indicators such as the gross domestic product of a region to assess development. Within the African context, however, for an initiative to be deemed successful, it must provide the answer to a very fundamental question: "Have our need(s) been met?" A positive response to an intervention in this respect can lead to development.

We propose an approach to identify m-health needs within a rural community based on an amendment of Sen's Capability Approach (CA) paradigm to include *community* capabilities, as communities as entities play such an important role within the African landscape. Sen defines development as human development and capabilities as being what people are effectively able to do and to be. Sen argues that the assessment of capabilities should focus on what people are able to do and be by removing obstacles from their lives. We applied our approach within a rural South African community.

Methods: Our proposed framework views community health-needs as *capability-deprivation* that can be expressed as either a lack of an opportunity itself or a lack of the means to take advantage of an opportunity.

The developed framework requires the investigation of both "the community" and "m-health" as two entities that together define the community health-capability. The community entity consists of *current health-capabilities and health-goals*; what the prevalent *technology within the community* delineated to health is; and finally the community's *potential health-capabilities*. Potential capabilities can be defined as the projected outcomes in terms of capability development that the introduction of the relevant intervention could produce. The community entity elements are influenced by external factors (not explained here for purposes of brevity).

The m-health entity on the other hand comprises of what *outcomes* m-health can enable; what affordable, familiar technology is *prevalent* as a delivery mechanism for m-health; as well as what intended and unintended *potential capability development* a particular m-health intervention can have. Predetermined characteristics and the identified pitfalls of m-health influence the subsequent elements respectively.

Results: The community identified very little current health-capabilities. This capability deprivation stems not only from the lack of access to health related services in the area, but also from the inability to make use of these services when they are available due to transport-deprivation. The community, in terms of its capability set, can make use of- and has access to mobile phone technology.

One potential capability was identified as "being healthier"; a result of regular access to health-related services. M-health has the ability to address some of the identified health-needs such as regular access to certain health-information, health-guidance or streaming video consultations. The smart-phone was

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identified as the affordable technology that fulfils the predetermined characteristics of an m-health delivery mechanism.

Conclusions: The proposed framework addresses community health-needs analysis with regard to m-health from a community-capabilities perspective. This first iteration of the framework performed adequately and showed promise as a reliable working part of a larger Community Capability Approach (CCA) framework to attain human development as a result of an m-health intervention.

Keywords: M-Health, Capability Approach, Needs Analysis, Community Capabilit ies, Human Development

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Le Projet @mkoullel : Déplacer l'Information des Centres de Santé vers les Familles

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Contexte et objectif: Le système de santé du Mali est pyramidale avec à sa base les Centres de Santé Communautaire (CSCOM) dirigés par des Associations de Santé Communautaire (ASACO). Il s'agit de centres issus d'initiatives communautaires, et œuvrant suivant un Paquet Minimum d'Activités (PMA) établi par le gouvernement. Sur les 6 points que composent le PMA, 4 ont attrait aux activités de promotion de la santé c'est à dire aux activités de prévention, d'Information d'Education et de Communication (IEC). Cette activité de promotion de la santé se repose essentiellement sur les 13 Pratiques Familiales Essentielles. L'activité de promotion de la santé se passe presque uniquement dans les CSCOM au moment des CPN ou les séances de vaccination donc juste pour les femmes. Hors d'une part les hommes sont plus décisionnaires sur bien de questions de santé, et d'autre part il n'ya pas que les femmes qui viennent dans les Centres en dehors donc des CPN et les jours de vaccination, et tout le monde dans les communautés rurales ne vont pas dans un centre de santé. Aussi, les CSCOM ont du mal à effectuer correctement cette tâche qui normalement est l'essence même de leur création, à cause d'un manque de personnel et ressources financières pour assurer certains types d'IEC comme les démonstrations culinaires promouvant une alimentation saine et équilibrée et valorisant les produits locaux.

Afin de contribuer à diminuer le poids du manque de personnel, afin de soutenir la viabilité des CSCOM, afin de porter l'information de santé dans les foyers, faire du porte en porte avec l'information, le Projet @mkoullel fût crée. Il s'agit d'un projet utilisant les outils multimédia pour l'Information, la Communication et d'Education. Un projet pour créer un pont entre les producteurs et les consommateurs d'informations de santé. Un projet pour accentuer l'impact des IEC sur les communautés à travers des images et vidéos proches d'elles, adaptées à leur contexte, à leur environnement, des images et vidéos qu'elles pourront prendre part à leur production. @mkoullel, vient d'une langue locale peulh signifiant le Petit Conteur. En effet jadis, Ces petits conteurs monades se déplaçaient de communauté en communauté pour transmettre à travers des contes les bons savoirs faire, les bonnes pratiques. Ces jeunes conteurs de part leur jeunesse avait la particularité de puiser leurs exemples dans leur entourage, dans leur environnement. Aujourd'hui encore les IEC dans les centres de santé sont une transmission de bonnes pratiques basées sur une étude des pratiques actuelles, une étude de l'environnement …. d'où ce projet @mkoullel. Le petit conteur de l'ère numérique. Le projet est conjointement mis en œuvre par la Fédération Nationale de Santé Communautaire (FENASCOM) et le Centre d'Expertise et de Recherche en Télémédecine et E-Santé CERTES) comme partenaire technique. Le Projet est soutenu financièrement par l'Institut International pour la Communication et le Developement (iicd.org).

Méthodes: Les centres ont été sélectionnés sur la base de leur taille, de l'affluence dans les centres, du nombre et de la composition du personnel de santé et enfin de l'engagement de l'ASACO à utiliser une autre méthode pour réaliser les IEC. Dans chaque centre un médecin, une sage-femme et ou un infirmier ont été sélectionnés pour rendre opérationnel leur centre. Dans certains centres des Agents de Santé Communautaires et des Animateurs Communautaires ont été impliqués. Les thèmes à traiter au cours des séances étaient choisis dans la liste des 13 pratiques familiales essentielles de façon consensuelle par tous

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les centres d'une part et d'autre part chaque centre peut traiter d'un thème particulier en fonction des réalités de sa communauté. Les IEC montées avec les outils multimédia sont diffusés dans les centres (IEC Intracentre) deux fois par mois et une fois par mois en dehors des centres au sein même des communautés (IEC Extracentre). Les IEC extracentre sont sur programmation ou demande des groupes d'individus comme les groupements de femmes, les associations communautaires, les aides ménagères...Il faut noter que des centres peuvent faire plus que le nombre de séances d'IEC. Les séances d'IEC passent par plusieurs de méthodes de communication via les vidéos et images avec le public, les tests de connaissances, des tests de niveau d'informations, des questions-réponses, des jeux de rôle, des jeux d'attention

Avant de commencer l'animation des séances d'IEC version @mkoullel, il est était nécessaire de faire un renforcement de capacité du personnel de santé devant produire les ressources d'IEC. Ce renforcement de capacité était de deux types. Le premier concernait une formation méthodologique sur les aspects conceptuels de recherche et d'analyse de contenus sur une ressource multimédia pour les IEC et le deuxième type était basé sur le montage technique des vidéos et des images et l'utilisation et conditionnement du matériel multimédia. Le logiciel utilisé pour le montage vidéo est Nero 12. Le Kit @mkloullel était composé d'un vidéoprojecteur (Optoma ES521) ou d'un pico projecteur (Optoma Pico PK301+ avec une microSD 32 Go) selon les localités, d'un écran de projection (Procolor STAR Square Format), d'un trépied(Hama), d'un appareil photonumérique (Fujifilm FinePix S1500), d'une caméra numérique (Handycam HDR-CX160E), d'une plaque solaire portable(Oyama Oy340) pour la recharge du matériel en zone rurale, d'un haut-parleur (Logitech Z 323 et XMI-X-Mini II) et d'un ordinateur portable(Toshiba Satellite C660-22V). Le personnel de santé a été formé au montage durant 7jours puis, chaque centre est assisté durant les premiers montages ainsi que les premières diffusions pendant les séances d'IEC durant 8semaines. Le projet a démarré en janvier 2012 et doit se dérouler sur 4ans avec une première évaluation prévue à la fin de la deuxième année. Cet article axé sur des résultats quantitatifs, ne prend pas donc en compte les questions d'impacts qui seront traitées lors de l'évaluation.

Résultats: Deux types de kits @mkoullel ont été fournis. Les centres urbains ont reçu chacun un vidéoprojecteur, un ordinateur portable, un écran de projection et un haut-parleur. Le kit pour les zones rurales était composé d'un pico projecteur doté d'une carte mémoire de 32Go, un haut-parleur, une caméra numérique, un appareil photonumérique, et une plaque solaire pouvant recharger l'ensemble du matériel du kit rural.

La formation des agents de santé a duré 7jours et a concerné l'initiation à l'informatique et internet, les aspects conceptuels, déontologiques, de recherche et de traitement des images. La formation a aussi concerné le montage des images et des vidéos dans Nero vision. L'assistance des centres a duré 8 semaines pour une bonne maitrise des outils multimédia. Les agents formés étaient 4 médecins, 4 sages-femmes, 8 infirmiers, 8 Animateurs communautaires et 3 agents de santé communautaires.

En 18mois, 13 CSCOM ont été enrôlés dans le projet. Ils ont effectué 871 séances d'IEC animées en intracentre pour 35.730 participants et 295 séances d'IEC animées en extracentre pour 18.589 participants soit un total 1.166 séances d'IEC pour 54.319 participants. Cela donne des moyennes de 67 et 22,69 séances par CSCOM, 3,72 et 1,26 séances par mois et par CSCOM, 41,02 et 63,01 participants par séance, respectivement en séance intracentre et extracentre. Deux Thèmes communs sur la malnutrition et la contraception ont été montés par tous les centres, 10 thèmes individuels ont été montés et 5 séances de démonstrations culinaires ont été animées. Un thème a été réalisé avec la participation des membres d'une communauté, le but était de leur faire participer dans la production de l'information devant servir à la sensibilisation des autres membres de la communauté. 11 Associations villageoises ou communautaires, 3 écoles communautaires, 17groupements de femmes ont invité ou ont été impliquées dans l'organisation ou la mise en œuvre des certaines IEC extracentre. 5 ONG nationales ont commandité à des CSCOM des thèmes à traiter, axés sur l'excision, le VIH et les maladies sexuellement transmissibles.

Des difficultés de collaboration avec certaines ASACO avaient ralentie l'évolution du projet dans certains CSCOM, le niveau bas en informatique du personnel de santé rendant plus longue la période d'assistance qui est allée de 8 à 15 semaines dans certains CSCOM. La mutation de certains agents dans certains centres a poussé à faire des formations relais dans les centres afin de garantir la pérennité des connaissances acquises. Aucun incident majeur n'a été enregistré sur le matériel pouvant entraver le bon fonctionnement du projet.

En termes de pérénnisation l'investissement initial reste le facteur réel à soutenir, les frais pour réalisation des IEC intra ou extracentre sont déjà dans les budgets opérationnels des ASACO. Ainsi la pérennisation des projets n'a pas été une question difficile à discuter puisque @mkoullel s'aligne simplement sur le fonctionnement normal des ASACO donc n'engendre aucun frais additionnel.

Une évaluation d'impacts est prévue en décembre 2013. Cette évaluation sera axée sur la fréquence de survenue de certaines pathologies dans les CSCOM concernés, les impacts sur les connaissances de membres choisis au hasard dans les communautés, les impacts sur la fréquentation des CSCOM par la population, les impacts sur le travail du personnel des CSCOM, les impacts sur la gestion et la responsabilité des ASACO dans la promotion de la santé.

Conclusions: L'implication communautaire dans la bonne marche du projet dénote leur intérêt réel pour cette méthode de mener les IEC. Une étude d'impacts devra être réalisée au cours d'une évaluation afin de prouver son efficacité et son efficience dans la prévention et le changement de comportement des communautés.

Mot clés: IEC, @mkoullel, Mali

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Depicting the Healthcare Landscape Around a Community for a m-health Intervention: A Look into Maternal Health in KaTembe, Mozambique

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Background and Purpose: This work-in-progress is part of a larger project that aims at developing methods for information systems developers to support local communities in Africa to develop their life situations in the way they decide. The focus is on maternal and newborn health – how can the maternal and newborn healthcare services available to communities be improved by means of appropriate information and communication processes, particularly using mobile phone technology and computer-based information systems. To that end, information technology (IT) analysts and developers must first learn about the communities in question and the setting around them. The purpose of this study is to test and further develop an existing method for analysing the "healthcare landscape" around a given geographic community. The results of the analysis should be useful as a basis for the community, their healthcare providers, local authorities, and IT analysts to identify relevant stakeholders for a collaborative needs analysis and solutions development project. The main focus is on maternal health and mobile technology but within a holistic view.

Methods: The "community" in case is the rural KaTembe district in Maputo, the capital city of Mozambique. The landscape depicting method of Korpela et al. (2008) was used as the starting point. The research was partly based on public sources of information, partly on interviews with local government and healthcare personnel as well as with individual community members, mainly pregnant women and mothers of new-borns. We sought opportunities for technology mediated approaches to problems identified by interviewees.

Results: The first observation: instead of "the community" there are many, partly overlapping communities based on geography, means of livelihood, ethnicity, and so forth. The method used must be expanded to guide the analysis in such a situation: what are the essential pieces of information that should be presented about a community? How can they be obtained? How to describe such a complex setup with sufficient detail in view of the project aims?

The second observation: public healthcare services and political-administrative structures are relatively easy to depict, if we start from what is officially assumed as the official "standard" of infrastructures, resources and services to be provided. However, the actual layout and performance vary tremendously, as providers tend to construct scenarios based on what they perceive as adequate. Example 1: although clinics should start at 7:30AM, clients at the largest facility informed that nurses would start effectively seeing clients or delivering health education at 8:30 or 9:00AM. This was justified by the nurses has a necessary measure to ensure the concentration of a significant number of clients - they had assumed that most clients were peasants who had to tend to their fields before coming to the clinic.

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The third observation: traditional providers of care needed to be identified as powerful opinion leaders and respected members across distinct communities, as they may derail or endorse technology mediated approaches, particularly in sensitive areas like maternal/reproductive health.

The fourth observation: the effects of development challenges, such as the case of a new road being built as well as other major construction (a deep water harbour, a cement company) within and around KaTembe required extensive preparation of the researcher in order to pinpoint and assess undocumented and obscure impacts on the existing livelihoods and ways of doing things by KaTembe residents.

Conclusions: When the aim is to empower people with health information systems development, it is crucial to have a holistic view of their communities and the landscape around them. This view has to be continuously updated and not be taken as static in time, given that geographic, economic and social challenges induce considerable changes in the communities. We provide methodological suggestions for creating such an overall view in a given case. We also identify areas for deeper analysis by other methods.

Keywords: Research methods, Community, Healthcare system, Maternal health, Mozambique

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Africa Build Educational Widget for Capacity Building in Health Education and Research

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Background and Purpose: Many Sub-Saharan African countries are unable to take full advantage of the rapidly growing Information and Communication Technology (ICT) revolution to improve human health and health delivery. This is partly due to inadequate human resource capacity, weak infrastructure, underinvestment in research and lack of information on existing health training institutions in Africa. The challenge of inadequate health education information compels health professionals seeking advancement in knowledge and research to study outside Africa which is expensive and majority do not return back to their countries. The question therefore is which institutions in Africa are offering such programmes? What is the scope of the programmes they offer and at what cost? In line with the larger objective of the EU-funded *AFRICA BUILD Project* to implement an ICT-enabled, open and collaborative infrastructure for health research and education through the provision of informatics tools, collaborative training infrastructure were developed which include Educational widget and database to provide access to information on all health educational programmes and institutions in Africa which is currently difficult to obtain.

Methods: The widget was built with a social-media orientation using an open source platform ELGG which provides the basic functionality to run a social network and MySQL database, both of which will help to achieve sustainability of the portal. The widget was designed with a backend database of information such as name of institution, country, programmes offered, level, duration etc. Data was obtained through phone calls, email surveys and online searches which are technology driven and making responses more reliable cheaper and faster as compared to traditional postal questionnaire surveys.

Some of the limitations include lack of online presence of some institutions and programmes, non response, language barrier and lack of cooperation from some institutions.

Results: A functional educational programmes widget has been developed and currently running on the e-laboratory page of the AFRICA BUILD Portal. About 970 universities were identified in Africa out of which 213 have been contacted and 86 have responded. Analysis of the database information showed the following:(i) there were a total of 506 programmes offered by 38 different institutions; (ii) Bachelor's Degree programmes constituted the largest, 186 (36.8%), followed by Master's programmes, 136 (26.9); (iii) Of the different categories, Biomedical Research was the commonest, 340 (67.2%) followed by Public Health Research,151 (29.8%); (iv) detailed descriptions of the various programmes were only available in 193 (38.1%) cases; (v) offline/classroom mode of teaching was used in 282 (55.7%) of the programmes; (vi) programmes with English as a medium of instruction were 246 (48.6%) and those in Afrikaans were 178 (35.2%); and (vii) the majority of the programmes are offered in South Africa, 228 (45.1%) and Nigeria, 124 (24.5%). Information gathering for populating the database is still ongoing.

Conclusions: A functional widget has been developed and tested. This widget will provide information about the existing health educational programmes in Africa on lunch of the Africa Build Portal.

Keywords: AFRICA BUILD, Educational Programme, *Widget, Ghana,UG-SPH*

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Health Informatics and Education: An Example of Multilateral e-learning Program for Post Graduate Trainees

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Background and Purpose: Health Information is one of the major factors contributing to better management of patient, insure patient safety and improve the quality of research. Cameroon as African Countries in general who intend to fill the gap in the field of Health education and research, demonstrates through using IT tools, improvement in the field of health education among the community of medical lecturers and trainees.

Methods: Over a period of two years (2012-2013), we conducted an observational study in the teaching hospitals and the Faculty of Medicine of the University of Yaounde 1. We analyzed e-learning program.

Results: Several e-courses of post graduate training have been developed since the creation of medical and surgical subspecialties at the faculty of medicine of Yaounde in 2010. (55 post graduate courses are available on the Dudal plate form). Many lecturers of the faculty of medicine have shown positive implication to online courses and the pedagogic orientation of the faculty is currently directed to the use of IT as the main tool in the training program of medical students and post graduate trainees. A structured post graduate e-learning program has been defined with six fields: Neuroscience, Ophthalmology, Pediatrics, Obstetrics and Gynecology, General surgery and Internal Medicine. This e-learning program was supported by collaboration of African countries (Cameroon, Mali, Senegal, Madagascar) and European countries (Switzerland, France). Also, special virtual communities have been created to strengthen the training and collaboration in several fields with the contribution of Africa Build project.

Conclusions: Collaborative multilateral e-learning program for post graduate trainees seems to be helpful in our setting.

Keywords: e-learning, Education, Post graduate

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The Collaborative Design of a Health Informatics Fundamentals Curriculum for the South African Context

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Background and Purpose: Information and communication technology (ICT) has the potential to strengthen healthcare service provision, communication, information processing, and management. In developing contexts, great improvements were made towards utilising ICT in healthcare. However, the same factors influencing the provision of healthcare services also make the utilisation of ICT more problematic. In addition to the limited resources in designing, developing and maintaining appropriate healthcare innovations, there seems to be limited understanding of the 'situated design considerations' for ICT interventions. There is a need, ultimately, for professionals and practitioners who understand the nuanced aspects of healthcare services and informatics. In this regard, there is a further need to develop courses for scholars and innovators looking to incorporate ICT in the healthcare domain.

This paper describes the collaborative design of a health informatics fundamentals (HIF) curriculum. This endeavour formed part of an internationally funded project to develop capacity for relevant healthcare courses and teachers for African partner universities. The main research question for this paper is: "What are the collaborative design considerations for a health informatics fundamentals curriculum for African universities?"

Methods: A constructive alignment process was used to design a basic curriculum for a health informatics fundamentals course as a basis participating universities. A series of joint workshops were hosted by the participating partners. Asynchronous participation took place via an online platform. During the joint workshops, participants focused on situational analysis, statements of intent and programme building (content). One of the African partner universities then offered the fundamentals course based on the work done at the joint workshops, and by adding instructional strategies and assessments. The results of the course evaluation (curriculum design and implementation) were shared with the partner universities during a final joint workshop.

The analysis of the curriculum design process is done using the recommendation of Biggs for constructive alignment. The outcomes of the curriculated course are linked to the conceptual framework used in the project.

Results: The certificate course was offered as an elective 4th year subject in the degree of BTech: Information Technology during the second semester of 2012. The subject name was Health Informatics Fundamentals, and comprised 12 SAQA credits (South African Qualifications Authority), which translates into 3 ECTS credits. The course was implemented in 120 notional hours, which required 1.5 – 2 hours per week contact time over a period of 14 weeks. The course was attended by 35 students in total.

The course assessment was both formative and summative and aligned to the assessment criteria on the level of study with an emphasis on application. 77% of enrolled students passed the course with an average final mark of 56%. Content contained local and contextual examples and exposed students to real-life health scenarios. Students cited great interest in the field of health informatics and some of them opted to continue with their studies in this domain. The main criticism from the students and trainee teachers was that the topics were slightly fragmented. This was due to a high variety of topics and

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extensive input from multiple disciplines. The general consensus was that the offering was a success and that it provides a good foundation for further courses in health informatics.

In terms of creating staff member groups with appropriate capacities, the project employed a core project team responsible for coordinating the HIF efforts. This consisted of a project leader (or expert), a project officer, and two project administrators. These persons' administrative capacities were developed to the point of managing and coordinating a complex international venture.

Conclusions: The project can be regarded as a success with sufficient materials for designing health informatics qualifications for the African context. The involvement of experts from participating universities has provided a richer and more comprehensive view of the needs for ICT innovations in healthcare. There is now an increased capacity of persons equipped to teach health informatics fundamentals topics and there is a repository with relevant content and assessments. The collaboration with experts from both the domains of healthcare and ICT resulted in the incorporation of both views in an integrated manner. The designed curriculum therefore is sufficiently integrated in its outcomes, content, assessment and offering.

Keywords: Health informatics, Curriculum design, Healthcare services, Information and communication technology

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Capacity Building for Rural Health Care Providers in Cameroon using a Blended Learning approach – Experience of Koegni-eHealth

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Background and objectives: The health system in Cameroon has to deal with a drastic shortage of well trained and specialized professionals in rural areas. This is an obstacle to a good and adequate health care delivery in these areas. Accordingly, the few clinicians who are available, the patients (and their relations) and other active players need support throughout the care process. For this reason, we developed capacity building programs that prepare rural health care providers to efficiently deal with the increasingly number of new (for African countries) health challenges.

Methods: A review of the relevant research literature and project report has been performed. A Stakeholder analysis was conducted using unstructured interviews methods. Profiles and infrastructure analysis were conducted and key requirements identified. Based on these, German certification Curricula were adapted and implemented using the virtual environment of Koegni-eHealth, the expertise of the African Diaspora and German physicians colleagues, and a mixture of e-learning and face-to-face theoretical and practical courses. An implementation plan and evaluation indicators were formulated. Agile methods and quality management processes were applied for the project management (including change management)

Results and discussion: The stakeholder analysis led to a first focus in the area of neurology and gastritis. Six face to face theoretical and practical courses were conducted, 4 lectures online, and virtual classes were created. Trainees and Trainers have continued to work online between two face to face meetings. The qualitative evaluation conducted at the end of the first stage showed an improved quality of care delivery in neurology and gastritis in the pilot facilities. It was also observed that standardized care procedures were applied and the number of neurology-patients increased. A big challenge however remains the internet connectivity and computer literacy.

Keywords: Capacity building, eHealth Africa, eLearning, Blended Learning.

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