

Bottom-up Architecting of National and Regional Health Information Systems in Malawi and West Africa

Edem Kwame Kossi



Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy (PhD)

The Department of Informatics,
Faculty of Mathematics and Natural Sciences,
University of Oslo
August 2016

Table of Contents

Chapter 1 - Introduction	1
1.1. Motivations.....	1
1.1.1. Theoretical motivations.....	1
1.1.1. Development and political motivations.....	2
1.2. Research problem and area.....	3
1.2.1. Fragmented HIS	3
1.2.2. Policies and guidelines	4
1.2.3. Generic open source software applications	5
1.2.4. Generic HIS architectures.....	5
1.3. Why HIS architecture is important?.....	6
1.4. Research questions	6
1.5. Theoretical perspective.....	6
1.6. Research approach.....	7
1.7. Contributions	8
1.8. Organisation of the thesis	8
Chapter 2 - Research Method.....	10
2.1. My background and its implication.....	11
2.2. My worldview	11
2.3. HISP AR.....	12
2.4. My own role	13
2.4.1. Sierra Leone, The Gambia, Malawi and Burkina Faso	14
2.4.2. West African Health Organization (WAHO).....	19
2.5. How data is collected and recorded.....	21
2.6. Data analysis.....	22
Chapter 3 - Related research.....	32
3.1. Architecture and architecting	33
3.1.1. Architecture and sense making.....	33
3.1.2. Approaches to architecture	34

3.1.2.1.	Top-down approach and architectural frameworks	34
3.1.2.2.	Bottom-up approach	37
3.1.3.	Architecture and evolution	38
3.1.4.	Architecture, flexibility and agility	43
3.1.5.	Architecting and Interoperability	45
3.1.6.	Architecting, Standardization & Standards	48
3.1.7.	Architecting and Integration.....	51
3.2.	Summary and proposed conceptual framework	54
Chapter 4 -	The cases	57
4.1.	Sierra Leone	57
4.2.	The Gambia	60
4.3.	Malawi.....	61
4.4.	Burkina Faso.....	63
4.5.	West African Health Organization (WAHO).....	64
Chapter 5 -	Summary of findings	67
5.1.	Integrating health information system in Sierra Leone	67
5.2.	Comparing strategies to integrate health information systems following a data warehouse approach in four countries	69
5.3.	Developing Integrated National Health Information Systems in Malawi: Oriented emergence of flexible architecture	71
5.4.	Networks of Networks – Collaborative efforts to develop health information systems across developing countries.....	73
5.5.	Developing decentralised health information systems in developing countries – cases from Sierra Leone and Kenya	75
5.6.	Summary of findings by research questions.....	76
Chapter 6 -	Contributions	78
6.1.	Implication for theory: Bottom-up architecting framework	78
6.2.	Implication for practitioners	93
6.3.	Implication for research method.....	95
6.3.1.	Following actions and actors surrounding them.....	96
6.3.2.	Following each site over multiple time frames	97

Chapter 7 - Conclusion.....	99
References	101
Appendices of publications	110

Figures

Figure 1: Map of Africa with the different settings.....	15
Figure 2: district HIS officers during one of the extensive training sessions in Freetown	18
Figure 3: 3-T Framework and the Four Characteristics of a “Pragmatic” Boundary Capability.	27
Figure 4: Trend line of data analysis	28
Figure 5: example of how data is coded from interviews, meeting notes, observations etc.	31
Figure 6: OpenHIE architecture (2013).....	39
Figure 7: Interoperability between DHIS2 and two transactional systems – OpenMRS and iHRIS – through SDMX-HD standard and integration between these two transactional systems.....	46
Figure 8: HMN architecture	57
Figure 9: an HIS officer using DHIS2 to manage data from various sources in Moyamba district.....	59
Figure 10: ECOWAS.....	64
Figure 11: comparing integration strategies in 4 countries	71
Figure 12: Interplay between networks involved, global soft standard and country HIS architecture..	92

Tables

Table 1: Country Fact Sheet 15

Table 2: summary of my involvement in the countries 20

Table 3: statistics on data collection..... 22

Table 4: four layers of interoperability by Kubicek and Cimander..... 47

Table 5: Research papers and their responses to research questions..... 77

Abbreviations and acronyms used

ANT: Actor-Network Theory

AR: Action Research

ARIS: Architecture of Integrated Information Systems

C4ISR: Computerized Command, Control, Communications, Intelligence, Surveillance and Reconnaissance

CEN: Comité Européen de Normalisation

CMED: Central Monitoring and Evaluation Division

CRIS: Country Response Information System

DHIS2: District Health Information Software version 2

EA: Enterprise Architecture

ESB: Enterprise Service Bus

FEAF: Federal Enterprise Architecture Framework

GIS: Geographic Information System

HIS: Health Information Systems

HISP: Health Information System Program

HMIS: Health Management Information System

HMN: Health Metrics Network

HSB: Human Service Bus

ICD: International Statistical Classification of Diseases and Related Health Problems

ICT: Information and Communication Technology

IHP+: International Health Partnership

iHRIS: Integrated Human Resource Information System

II: Information Infrastructure

IS: Information System

ISO: International Organization for Standardization

LIN: Luke International Norway

MDG: Millennium Development Goals

MoH: Ministries of Health

NTT: Nippon Telegraph and Telephone

OECD: European Commission and the Organisation for Economic Co-operation and Development

OpenHIE: Open Health Information Exchange

OpenMRS: Open Medical Record System

PARIS21: Partnership in Statistics for Development in the 21st Century

SDMX-HD: Statistical Data and Metadata Exchange for Health Domain

SOA: Service Oriented Architecture

TOGAF: The Open Group Architecture Framework

UiO: University of Oslo

UNAIDS: United Nations Programme on HIV and AIDS

USAID: United States Agency for International Development

WAHO: West African Health Organization

WHO: World Health Organization

WLAN: Wireless Local Area Network

ZF: Zachman Framework

Acknowledgement

First and foremost, I would like to express my sincere gratitude to my supervisors Jørn Braa and Ole Hanseth for their motivation, patience, insight and their thoughtful critiques and comments throughout this research study. I would like to extend gratitude to Sundeep Sahay and Eric Monteiro for their constructive comments and suggestions and for their continuous support.

I am very thankful to Kristin Braa for her support and motivation.

I extend my gratitude to the Information System research group and the faculty for giving me the opportunity to do this research in the incredible environment of University of Oslo. I would particularly like to single out my fellow PhD students for the stimulating discussions. It has been a period of intense learning for me, not only in the scientific arena, but also on a personal level.

This thesis would not have come true without the collaboration of all the people in the field in Sierra Leone, Gambia, Malawi, Burkina Faso and WAHO.

My sincere thanks also goes to the HISP network for all the fun we have had in the field and at IFI. I am very proud to belong to this network.

I am grateful for the Norwegian Government for providing the financial support this study. I also thank the administrative staff at IFI and at the International Students Office.

Finally, I would like to thank my family and friends for supporting me spiritually throughout writing this thesis and my life in general.

Abstract

The Health Information System (HIS) comprises of six components: resources, indicators, data sources, data management, information products, processes of dissemination and use. On the technological level, computerized systems span across these components. In practice, the software are provided by open source software developers and implemented by different organisations in the HIS environment. Additionally, statistical reporting systems are being implemented in a fragmented way and leading to the production of data that is not easy to use. This stresses the need for integration to avoid chaos and makes the design of interactions across these components a key challenge.

The call by global and national actors in the health domain, especially in developing countries, for integrated HIS, requiring better coordination of technical and institutional efforts and reliable information has made the debate on best approaches to building health information architecture more relevant than ever. While proposals for standard HIS architecture has reignited the dualistic arguments of top-down versus bottom-up approaches to HIS development and evolution, some researchers are now calling for a less polarised and more hybridized views that combine the best of both approaches, and contributes to successful architecture. However, knowledge about the process through which such hybrid forms of architecture can be designed and developed in the complex settings of developing countries, remains largely limited. This thesis explores these issues through the following research aim: .i) to better understand the process of architecting HIS in the setting of three West African countries (Sierra Leone, The Gambia and Burkina Faso), in Malawi and at regional level in West African Health Organization (WAHO), ii) to explore an alternative approach to addressing the challenge of fragmentation of HIS, and iii) to explore how to study a big phenomenon like national and international HIS.

In this thesis, I analyse the characteristics of the process of architecting which represents a two-way and mutual interaction through which the building of the architecture “blueprint” and its instantiation shape each other over time. More specifically, this thesis takes a socio-technical perspective to extend our understanding of the boundaries (and their interplays) of this interactional process and conceptualises conditions for the successful evolution of the architecture and its instantiation. The arguments in this study are developed through empirical analysis based on qualitative methods within an interpretive tradition conducted over five years (from 2008 to 2013) from three West African countries (Sierra Leone, the Gambia and

Burkina Faso), Malawi and the regional WAHO. I have been engaged in these settings in the processes of HIS strengthening that started in one country (Sierra Leone) and have gradually spread to the Gambia and Burkina Faso, and its subsequent adoption by WAHO. My empirical work has focused on working with HIS stakeholders at various levels in countries and the regional level to iteratively develop and implement integrated HIS adopting an action research framework. Theoretically, the concept of architecture and a collection of related concepts such as integration, interoperability and standards, and the integrative framework by Carlile (2004) were used as lenses, scaffolding devices and analytical tools to analyse the process of architecting

The key theoretical contribution of this thesis has been the development of a bottom-up based architecting conceptual framework which provides tools to analyse the process of architecting at its various boundaries as well as interplays - between and across the boundaries – through which architectures and their instantiations evolve over time. On the practical level, this research provides tools to understand and assess conditions for successful evolution of a given information system. It also contributes to the debate on strategies to study “big” phenomenon over a longer period of time. More specifically, it proposes strategies to carry out research in multiple sites and over a long term.

Chapter 1 - Introduction

This research is about exploring an alternative approach for developing and integrating Health Information Systems (HIS) internationally, and in individual countries as well as at the regional level in West Africa. The work began as an action research project for integrating parallel systems in some West African countries. However, after some iterations of action research cycles, it gradually emerged that integration is both a goal or vision (Ellingsen and Monteiro, 2008) and a process, and that what we have been doing represents a form of architecting – the process or instantiation of the vision – towards the broad goal of integration. The aim of this research has therefore shifted to exploring the ways architectures emerge over time from the tension between the need for good planning to avoid chaos, the need for flexibility to release local potentials and the need to harness resourceful top-down initiatives. The thesis seeks to think out of the compartmentalized boxes – bottom-up and top-down – in order to understand the characteristics of the process of making and instantiating HIS architecture.

The remainder of this introductory chapter is organised as follows. Section 1.1 presents the theoretical, development and political motivations. This is followed by the research problem in section 1.2 and importance of architectures in section 1.3. Sections 1.4, 1.5 and 1.6 present respectively the research questions, theoretical perspective and research approach. Section 1.7 presents the expected contributions and section 1.8 describes the remainder of the thesis.

1.1. Motivations

1.1.1. Theoretical motivations

Architecture is used as a plan to handle complexity, avoid chaos and set up the desired to-be situation. It supposes an intellectual mastery to address the complexity of the organisation in a blueprint. Two main approaches to architecture have been identified in the literature. The top-down perspective has developed frameworks such as Enterprise Architecture (EA) to be used by architects (Lankhorst, 2013; Ross et al., 2006; Zachman, 1987). These frameworks describe the architecture along many layers and aim to help the architect map the organisational imperatives down to the common lexicon and the technical system. The ultimate goal is to make sure that the to-be Information System (IS) is aligned with business strategies. This approach assumes the management view in the organisation is the source from which the underlying architectures are derived. The frameworks offer a detailed description of the organisation but desperately lack a rich account on the process through which organizational issues are dealt. The subsequent work on EA planning does not help in understanding such organizational issues (Spewak and Tiemann, 2006; Spewak, 1992). Additionally, the architecture tends to be static and too rigid (Ross et al., 2006) to enable the emergence of a working and innovative system resulting from the dynamics between user preferences, context and local potentials. When recent works on architecture call for flexibility and agility to adapt to emerging changes, they mean that the architecture should be stable but modular in order to confine the emerging changes in the modules (Bush et al., 2010).

On the other hand, the bottom-up approach does not have a formal model but recognises that the IS has at least technical and non-technical dimensions that shape each other. This approach focuses on the evolutionary development and implementation of IS and the need for the architecture to evolve over time (Aanestad and Jensen, 2011; Grisot et al., 2014). The bottom-up proponents argue that the IS emerges from dynamic interactions between the technical and non-technical dimensions and cannot be fully planned beforehand (Grisot et al., 2014). Adopting such an approach implies involving those who experience the problem in defining its solution because they know it better since they are part of the problem context.

While a top-down approach offers frameworks to fully develop the architecture and implement it, the main strategy in the bottom-up perspective is to work with users and gradually try new ideas. In other words, the main strategy is bricolage or improvisation. Improvisation, as mentioned in the IS literature, refers to dealing with unplanned situations (Ciborra, 1996; 1999; Elbanna, 2006). Improvisation perspective focuses on suddenness and supposes that the one who improvises reacts to a situation that is imposed upon him. Therefore, it does not address the possibility to influence or create conditions for a favourable future.

In summary, the top-down and bottom-up approaches lack a proper account of the characteristics of the processes through which architectures evolve from the tension between the need to avoid chaos and the need to develop a working system, which is in fact an empirical issue (Hanseth, 2001, p. 12).

1.1.1. Development and political motivations

As a student in medical school, I have been working since 1998 on applying IT for health in Mali. At that time, only a handful of students knew what the internet was and I was lucky enough to be accidentally part of this group. I wasn't a privileged student but I was fortunate to know someone in a telecommunications business who was aware of my passion for IT. Rapidly, we created a student IT club to popularise IT amongst all students on the campus because we believed IT was an unprecedented opportunity to leapfrog both the knowledge and resource gaps we faced. For us, IT allowed access to knowledge and content we did not have, and made it possible to better share the limited resources available. Ultimately, we believed naively that the digitization of book contents and easy access to information could enable us to compete equally in the e-world because, unlike industrialisation, initial investment was brain and computers, which are cheaper than factories. We thus trained thousands of students in IT since that time, and in 2000 we initiated a telemedicine project to offer continuous online training by experts in Europe and in a local university to health workers in remote areas. We believed that IT applied to health would improve health service delivery either by bringing expertise in health to remote areas via telemedicine or by implementing HIS for improved management. Later in 2004, we designed and successfully implemented a teleradiology project in Mali to bring the expertise of the only 12 available x-ray specialists in the country – 11 of them living in the capital – to all Malians by just sending x-ray pictures to these specialists and receiving the interpretation back as text. Many other projects were developed later but in an uncoordinated manner, leading to the duplication of efforts and fragmented systems. As time went by, I gradually noticed that the reality of IS was

not as simple as I had initially thought. Developing countries were not showing any signs of equal competition with western countries; there was no e-economy bubble in sight. Instead, history tended to be repeated; the gap was widening in knowledge and technology, as well as poverty. The growing number of IT projects that were failing after substantial investments was striking and was resulting in sleepless nights for the IT enthusiasts who believed IT would change the world. In fact, IT had changed the world, but not in the way they had anticipated. The only encouraging sign, in fact, has appeared more recently with some successful uses of mobile internet.

This gap between reality and our expectation has been the driving force of my move towards the IS field, and more particularly of my quest to explore architecting as an approach to overcome fragmentation and lack of coordination in this context.

1.2. Research problem and area

Malawi and West African countries are categorized as developing countries. These countries are often described as lacking financial resources, skills and infrastructure (road, power and water supply, internet ...). The HIS in the context of Malawi and West African countries is characterised by fragmentation and three types of dynamics: policies and guidelines, development of generic open source software and development of generic HIS architecture. These dynamics are meant to strengthen the HIS but contribute to the architecture challenge. The fragmentation and types of dynamics are presented in the following sub-sections.

1.2.1. Fragmented HIS

The common characteristics of HIS in Malawi and West African countries include the existence of numerous centralised program-based HISs that fail to provide accurate, timely, complete and coherent health information (Chilundo and Aanestad, 2004; Kimaro and Nhampossa, 2005). These parallel systems are organised around diseases such HIV/AIDS or malaria, while most of the key health challenges facing these countries are crosscutting. Therefore, the health ecosystem developed into several parallel systems that mutually reinforce existing inefficiencies. While the main challenges – like maternal and child health – facing these countries are crosscutting, relevant information required to address them is scattered in the various parallel HISs. For example, to address maternal health issues, a manager will need to manually collect data on antenatal care and deliveries from the reproductive health system, data on malaria in pregnancy from the malaria system, data on HIV in pregnancy from the HIV/AIDS system and data on tetanus prevention from the immunization system. In turn, because information produced from these parallel systems is hard to use and consequently not frequently used, the quality of this information remains poor (Feldman and March, 1981).

In the early 2000s, attempts, led by development partners and Ministries of Health (MoH), to address this fragmentation imposed a minimal dataset and indicator list on stakeholders. In other words, a limited number of raw data and indicators were supposed to accommodate the needs of all stakeholders despite their different interests and agendas. Furthermore, while the context and the needs have been constantly changing, the HIS leading forces lacked the capacity and resources to evolve the minimal dataset and indicator list accordingly.

Subsequently, the HIS stakeholders gradually went back to their own parallel reporting systems in order to satisfy their information needs.

1.2.2.Policies and guidelines

To overcome the mess and the lack of coordination in national HIS, some institutions and global stakeholders decided to develop some standards and guidelines for HIS best practices. PARIS21 (Partnership in Statistics for Development in the 21st Century) was important for its seminal work but the Health Metrics Network (2005) and the International Health Partnership (IHP+) were very critical in the shaping of HIS in low and middle-income countries.

PARIS21 was founded in 1998 by international organisations such as the UN, the European Commission and the Organisation for Economic Co-operation and Development (OECD). It is a network and forum of national, regional and international actors (statisticians, policy makers, development partners, users of statistics) aiming to address the data quality challenges faced by policy makers. Although it does not specifically target the health sector, it has the merit of underlining the problem of data quality and use. It proposes better coordination and evidence-based decision making if countries have to meet the Millennium Development Goals (MDG).

The Health Metrics Network (HMN) is a global partnership aiming to stimulate coordination and alignment around a harmonised national HIS in low and middle-income countries. It was established in 2005 and hosted by the World Health Organization (WHO). HMN developed a framework and standards for strengthening country-level HIS. The framework proposes a best practice in terms of HIS strengthening cycles ranging from assessment to strategies and their implementation. It emphasises the need of integrated HIS through consensus building among stakeholders, better coordination, technical integration, promotion of quality health information and information use. HMN believes the goal of HIS is “to produce relevant information that health system stakeholders can use for making transparent and evidence-based decisions for health system interventions” (HMN, 2008, p. 10). The framework was widely adopted in 85 countries (HMN, 2013). It comprises six components: resources, indicators, data sources, data management, information products, processes of dissemination and use. On the technological level, computerised systems span these components, making the design of interactions across these components a key challenge, and representing the problem of developing and instantiating the HIS architecture, which this research is about. See Figure 8: HMN architecture for the HMN architecture.

The International Health Partnership (IHP+) was launched in 2007 by developing countries, donors countries and international development agencies to accelerate the progress towards achievement of MDGs (IHP+). It aims to bring a country’s health stakeholders, including development partners, together to support a single country-led national health strategy and subsequently a single monitoring framework – in other words, integration. In addition, it promotes the needs for development partners to be flexible and let the country suggest its own strategy. It has been adopted by over fifty developing countries (IHP+).

1.2.3. Generic open source software applications

To address the fragmented HIS and propose a robust solution to efficiently strengthen country HISs on the technical level, global open source software development communities have emerged. The most influential in my context of study are District Health Information Software Version 2 (DHIS2), (integrated Human Resource Information System (iHRIS) and Open Medical Record System (OpenMRS).

DHiS2 is a generic open source and web based platform for integrating parallel reporting systems through a data warehouse approach (DHIS2). It is being continuously developed by the Health Information System Program (HISP) community coordinated by the University of Oslo (UiO). It is a distributed network for research, development and implementation of HIS (see www.hisp.uio.no).

iHRIS is a generic and web-based transactional system that manages data on health-related personnel (see www.ihris.org). It is an open source software developed by the CapacityPlus project funded by the US government aid agency (USAID). The project aims to provide the software tool for health human resources management in order to get the right health worker at the right place and at the right time (iHRIS).

OpenMRS is a generic open source and web-based medical record system developed by the eponymous community (OpenMRS). It is used for managing patients in health facilities, based on coded information with a minimum of free text so as to not slow the data entry process and to optimise data analysis (see <http://openmrs.org>).

1.2.4. Generic HIS architectures

In addition to guidelines and generic software applications, two main HIS architectures have been proposed by HMN and Open Health Information Exchange (OpenHIE) community. The first one is the HMN architecture. Although inspired from EA thinking (Stansfield et al., 2008), it is broad and is described in a functional but brief manner to enable HIS stakeholders' understanding. See Figure 8: HMN architecture. The second is the OpenHIE architecture developed by a community formed in 2013 (OpenHIE, 2013). It is inspired by Service Oriented Architecture thinking with interoperable software applications and registries linked together through an interoperability layer (see Figure 6: OpenHIE architecture (2013)).

These two architectural proposals are inspired from models used in strictly hierarchically organised business organisations with standardised processes. However, within the health sector – a multiplicity of autonomous organizations with different agendas, a core business part dominated by highly skilled professionals and ruled by standardisation of skills, and not a standardisation of processes (Berg, 2001, p. 150; Bolman and Deal, 2005; Mintzberg, 1979) – the distribution of health services, the multiplicity of data standards, and the different perspectives on health data – medical doctors, public health workers, and managers – typify the complexity of HIS. The challenge then is how to architect and develop an integrated HIS from this technically and politically complex context.

1.3. Why HIS architecture is important?

The HIS architecture has several subsystems. These sub-systems are often multiple, distributed, isolated and heterogeneous. For example, while each health facility can autonomously implement its own patient management system, there could be one national human resource system and many parallel statistical systems devoted to each major health challenge such as HIV/AIDS, malaria, reproductive health, etc. These systems are often not integrated and are uncoordinated, and pose the problem of data collection and use, as one must manually index their data if a comprehensive overview on a particular health challenge is needed.

The fragmentation of the HIS has made data collection and collation difficult and has led to the production of poor quality health information. Subsequently, because this information is not used, its quality remains poor. The problem of poor quality and lack of information use continues to undermine seriously the efforts of countries to provide better health services to the population. For example, the lack of quality or non-use of information may lead to an epidemic being discovered too late. A poor planning of the supply of essential drugs may endanger the lives of children or pregnant women.

Regarding the management of health information, although much of the information is produced in health facilities, it flows upward into parallel and uncoordinated systems.

Thus, the challenge is to develop and implement an HIS architecture that takes into account the technical and non-technical difficulties of organising such a complex system.

1.4. Research questions

1. To better understand the process of architecting HIS in the setting of three West African countries – Sierra Leone, The Gambia and Burkina Faso – and in Malawi:
 - a. What are the characteristics of architecting and what are their interplays?
 - b. What are the conditions for successful evolution of HIS
2. To explore an alternative approach to addressing the challenge of fragmentation of HIS.
3. To explore how to study a big phenomenon like national and international HIS.

1.5. Theoretical perspective

The standpoint of this thesis is not the understanding of the architecture as a stable blueprint, but rather that it emerges through complex dynamics and is not dissociable from its instantiation. Hanseth et al. (2014) describe architecture “as multi-level by nature. It links together individual users and developers with organisations, institutions representing industrial fields or sectors (like health care) and political institutions (ministries, governments and also supra-national institutions like the EU), and standardisation bodies at national and international levels” (ibid, p.38). Building on previous work on evolutionary development of IS (Hanseth, 2001; Hanseth and Lyytinen, 2004; 2010), I conceive this process – architecting

– as emergent and informed by practice, rather than decided or fully planned beforehand (Grisot et al., 2014). Architecture is dynamic and evolves over time (Hanseth et al., 2014) to adapt to changes in the context, in technology, in user needs, and patterns of use. While the IS literature overstates the dichotomy of top-down and bottom-up (evolutionary) approaches, the evolutionary approach alone seems insufficient and some elements of top-down might be useful. A good example to understand this perspective is to look at the development of standards. While evolutionary and trial-and-error problem solving ‘bottom-up’ approaches lead to selection of best practices which eventually get standardised (Braa et al., 2007a; Hanseth et al., 1996), the implementation and spread of such standards are typically ‘top-down’. It may therefore be better to use the verb “architecting” to stress its process dimension and that architecture is always in the making. Successfully designing and implementing large-scale or extra-large IT systems covering numerous and more or less autonomous organisations and facilities, such as in health, is beyond the control of a single designer – or stakeholder. There are several prerequisites needed in order for such a system to be in place and running, including the constituting organisations’ willingness to collaborate and to take part in the larger system, legal regulations, etc. The evolutionary approach to architecting could be compared to the bottom-up approach in languages, which starts by knowing which letters stand for which sound, then putting letters together to get words and words together to get a sentence and so forth (Gordon, 2007).

Although academics (Diefenbach, 2013; Marlow et al., 2012) denounce top-down approaches, I do believe that both top-down and bottom-up approaches are needed as both plans and local solutions are needed (Aanestad and Jensen, 2011; Easterly, 2006). Moreover, complex systems such as HIS are by nature ‘open’ (Hanseth and Lyytinen, 2010) and might be expanded over time to cover new geographical settings – even beyond a country – or new types of organisations or users. The evolution of such IT systems, however, is generally not planned, and is better understood as an improvisational process of gradually and iteratively aligning interests of networks of actions. Braa et al. (2004) have suggested the concept of networks of actions for HIS implementation in developing countries. They argued that one-site implementation projects tended to be too weak to scale and to be sustainable.

In summary, I hold that architectures are not static but evolve over time, and they cannot be dissociated from their instantiation. They are not a set of insentient boxes and they can be conceived as having technical, semantic and organizational boundaries that are not of hierarchical order. Applying the rational and top-down architecture approaches alone would be problematic in the very complex context of HIS. Rather, a combination of a bottom-up approach with the injection of some top-down elements would be better suited to address the problems of IS fragmentation in health domain.

1.6. Research approach

This research is based on an action research (AR) methodology with direct and multilevel involvement from 2007 to 2014 (Avison et al., 1999; Baskerville, 1999; Baskerville and Wood-Harper, 1996; Davison et al., 2004). It began in Sierra Leone in 2007 with the aim of working together with HIS stakeholders to solve the problems of HIS fragmentation.

However, it was gradually extended in 2009 to The Gambia, Malawi, and Burkina Faso, and in 2010 to the West African Region.

The research is part of a wider HISP on-going action research that started in 1994 in South Africa with the belief that technology can empower people in the workplace if they are actively involved in the design process and of implementation (Braa and Hedberg, 2000; Braa et al., 1997; Braa and Sahay, 2013; Kemmis and Wilkinson, 1998). Since then, HISP AR has extended to over fifty countries worldwide.

Both qualitative and quantitative data have been collected through my direct involvement and secondarily through my different co-authors. These data have been iteratively analysed through display techniques, reduction and interpretation by inductive reasoning.

1.7. Contributions

This thesis aims to contribute to theory, practice and methodology.

Contribution to theory:

- To conceptually characterise the process of architecting:
 - Further develop our understanding of the boundaries of architecting and their interplays
 - Conceptualise conditions for successful evolution of the architecture
 - Provide alternative strategy or levers that better supports the process of architecting in a complex multi-organisational context

Contribution to practice:

- Extend the knowledge of practitioners on how to conduct HIS strengthening efforts
- Provide alternative strategies and guidelines to conduct architecting and overcome fragmentation as well as assessing conditions for successful evolution of the architecture

Contribution to method:

- Suggest strategies to study a big and complex phenomenon like national and international HIS

1.8. Organisation of the thesis

This thesis has seven chapters including an introduction (Chapter 1). In Chapter 2, research method, the methodology is presented along with my background and its implication for this research, my worldview, the role I played, and how data is collected and analysed. Chapter 3 presents the research related to architecture in IS while Chapter 4 describes the cases used as empirical material to illustrate my arguments. The summary of findings from six journals and conference papers is presented in Chapter 5. Chapter 6 discusses the theoretical and practical

contributions and their implications. Chapter 7 summarises and concludes the thesis and, presents areas of possible research.

Chapter 2 - Research Method

This research is based on an action research methodology with direct involvement in assessment, identification of solutions, design and implementation of health information systems in 3 West African countries (Sierra Leone, The Gambia and Burkina Faso), Malawi and at the regional level in West African Health Organization (WAHO).

The approach of using several empirical settings was not an effort to combine qualitative and quantitative methods by being able to quantify categories of observations and compare countries in that way. Nor was it an attempt to increase the number of samples to better support the generalizability of my contributions. Even a single case could have been enough to generalize from case to theory (Lee and Baskerville, 2003). However, there is a clear connection between the settings as reflection on actions and outcomes in a given setting has informed actions locally but also in subsequent settings – and vice versa whenever possible. The relatively high number of sites in this research should not be seen as an effort to increase the sample to enhance generalizability but rather it should be seen as an opportunity to further develop our understanding of the phenomenon. Additionally, using multiple cases made it possible to compare how countries were using different strategies to pursue relatively similar goals of integrated HIS as shown in the paper about comparing strategies (Sæbø et al., 2011b)

Action Research (AR) is a form of participative research where the researchers take part in the problem solving process and actively try to improve the situation through a cyclic learning process (diagnostic, action planning, intervention, evaluation and reflection). Action research is a reflexive process of progressive problem solving methods through which the researcher, in collaboration with actors concerned with the problem, work together on determining what they deem an appropriate way to change a given situation. In this regard, “research offers its competence as a discussion partner but not as a superior authority”(Gustavsen, 1992).

My PhD research started officially in autumn 2008, as a longitudinal study starting in 2007 and extending through 2013 with multi-level engagement in problem solving in the field. In this regard, AR gave me the unique position and possibility to work together with stakeholders, be part of the process of diagnosing problems, identifying solutions, carrying out planned actions to produce desired change, learning from this process, reflecting upon lessons learnt and re-planning actions if necessary, and finally, contributing to the body of academic knowledge. However, my collaboration with those who live in the problem context – the users – has been inspired by participatory design approach (Simonsen and Robertson,

2012) with the belief that by involving and enabling users' active participation, I will learn from their expertise in the problem domain and they will learn from my expertise in IS. Furthermore, I have a strong belief that by giving voice to users of systems, we will be contributing to implementing democracy in the workplace and helping to develop a future system that will better support their work practices, therefore potentially bringing about innovation (Kyng, 2010; Simonsen and Robertson, 2012).

2.1. My background and its implication

As a medical doctor from Togo (another developing country in West Africa), I have been working in the health sector since 2002 in Mali, and I have gradually acquired IT skills since 1998. I have been working in developing and applying IT solutions to improve health service delivery in developing countries. Consequently, by the time I started this research project in 2007, I already had several years of experience and a good understanding and knowledge about the health domain.

Although my culture, background and experience in health in developing countries have undeniably been a great advantage in understanding people's viewpoints, and in increasing people's trust in me, my culture and background may also have made me blind to some issues that would appear quite obvious to a person with different background, culture and experience. For example, in 2002, I met a French nurse in Mali who had never been to Africa before. In our discussion, she said she was very surprised to note that all African new-borns have the same skin colour as European babies. Although African babies look pale, I have never thought that way.

2.2. My worldview

I define myself as a pragmatist because I belong now to two different academic communities both as medical doctor (with a quantitative tradition) and as an IS researcher within the interpretive tradition. I do believe "truth is what works at the time. It is not based in a duality between reality independent of the mind or within the mind"(Creswell, 2009, p. 11).

However, the belief that guides this research is that it is not possible to dissociate reality with our culture and our interpretations. Instead, reality is a social and historical construct. Reality – subjective meaning – is not simply imprinted on individuals but is also socially constructed through interaction with others, through cultural and historical norms. It is shaped by the context in which people live and work (Creswell, 2009, p. 8). My background, my culture,

and my experiences, therefore, influence how I interact with people, how I interpret and understand the phenomenon being studied in this research. I adhere to the belief that there is no pure universal truth and reality is not fixed or singular, but is instead multiple (Law, 2004).

2.3. HISP AR

My research is part of the overall Health Information System Programme (HISP) action research project. HISP is an action research collaborative network that involves countries in Africa, Asia, Latin America and Norway with the aim to:

- co-develop software that will help managing health care delivery from facility up to national levels,
- develop human capacity through graduate and non-graduate education,
- produce and share knowledge both in organisations in which research is taking place and with the academic community.

HISP began in 1997 in the newly post-apartheid South Africa as an effort to explore how disadvantaged communities, regions and countries could appropriate Information and Communication Technology (ICT) for their own empowerment. The project started as an effort to support decentralisation and local empowerment policy of the new government. The HISP team started developing HIS software that would support local communities or districts in managing their HIS instead of collecting and pushing data to upper levels. The software was thus developed through a participative and incremental approach focusing first on needs and what is available. After almost three years of intense development, the first version of the District Health Information Software (DHIS V1) was released as an open source application but based on Microsoft Office data, which was the de facto platform in the country's public sector. The application was piloted in selected districts and improved upon based on a series of feedback and feed-forward processes between users, developers and the mediators who served as a link between the users and developers. Through this process, a flexible product that accommodates the needs of users was developed. The success of this local experience attracted other provinces, which in turn adapted the application, gradually evolving it into a national standard for health data management. In addition to software development, a particular emphasis was put on developing both technical and non-technical skills, such as data analysis, information presentation and use.

Since then, HISP has reflected upon changes made in South Africa and the knowledge gleaned has gone through many cyclical processes both in terms of software, which has led to the development of DHIS2, and in terms of generating knowledge by extending action research to other countries. From 2003, DHIS 2 has been developed as fully open source web-based software and built upon lessons and principles learned from v1. So far, the HISP network has been expanded to more than 30 countries across Africa, Asia, Latin America and Europe. Accordingly, human capacity has been developed in these countries through many approaches. First, DHIS2 customisation and implementation usually takes place as a participatory process through which the local core team learns to master by doing, while HISP experts also learn from the problem domain. Second, the local team together with HISP members gradually train users and provide continuous support. Third, the advanced users are regularly invited to annual regional training sessions, called DHIS2 academies, where their challenges are addressed, feedback is received and updates on software development and experiences are shared. Fourth, HISP has also developed an initial Masters and PhD programme at the University of Oslo to develop country capacities that will form a basis for further graduate training in their home countries. Subsequently, after running these programs for several years in Oslo, many Masters programmes in health informatics are now running in Mozambique, Malawi, Tanzania, South Africa and Ethiopia. Moreover, these different learning processes and arenas are opportunities to gather feedback and develop functional requirements that are critical for the continuous evolution of DHIS2.

The HISP AR still continues. New countries and actors are joining in. The scope of DHIS2 is expanding. Many AR sub-projects, such as my PhD research, are initiated within the main HIS AR to improve HIS in the field and contribute to academic debates on IS concepts and theories like system implementation (Braa et al., 2007b; Lungo et al., 2007), sustainability (Braa et al., 2004), integration (Braa and Sahay, 2012; Sahay et al., 2007), etc.

2.4. My own role

As an AR researcher, and in order to understand the characteristics of bottom-up architecting, I committed to working with stakeholders in addressing HIS fragmentation in the field. In so doing, I was able to contribute to academic debates on architecting, as well as address salient challenges in health (in the settings of this research), such as gradually developing an integrated HIS architecture in compliance with international standards set by HMN. The empirical settings in this research were not selected randomly or actively. Instead they

voluntarily came to us as grounds for collaboration through which we can make change in their HIS and at the same time pursue our academic paths.

The initial plan was to study the phenomenon in Sierra Leone with a comparative input from The Gambia. However, it gradually emerged that what has started in Sierra Leone and then in The Gambia, is now translating into a regional dynamic. Many countries in the region have been implementing the same system. So I just followed the trend from one country to another and from individual countries to the West Africa regional level. Subsequently, the empirical settings should rather be seen as West Africa – with a focus on specific countries – and WAHO with a comparative input from Malawi. However, the fact that the research was moving from one setting to another in a sequential order gave us two opportunities. First, each setting has had its own AR cycles with its own objectives and specificities. In this regards, although the general aim in all setting is similar, the approach adopted and actions taken were different. Second, because the broad aim in all the settings is similar, each setting represented an opportunity to reflect on lessons learned from the previous setting and further develop our understanding and knowledge. Thus lessons, experience – and materials developed – in Sierra Leone have informed actions in Gambia and further to Malawi, Burkina Faso and WAHO.

During this AR project, I went into the field with some knowledge and concepts such as sensitizing devices (e.g., user participation, socio-technical complexity, flexibility, situatedness, bricolage, network of action, etc.) and I actively participated in planning HIS strengthening efforts in individual countries as well as at the regional level in West Africa. I have also contributed to discussions at the global level on the evolution of DHIS2 and on collaboration with other global actors in the Health and eHealth domains, such as the WHO, HMN, CapacityPlus, etc.

2.4.1. Sierra Leone, The Gambia, Malawi and Burkina Faso

In what will follow, I will first present the country fact sheet comparing the countries and then present only in detail my role in Sierra Leone, since I have played more or less the same role in other settings, as shown in the summary of my involvement in **Table 2**.



Legend: Countries in red are the selected countries in West Africa whereas those in green are the other West African countries. Malawi is in Yellow and in southern Africa

Figure 1: Map of Africa with the different settings

Table 1: Country Fact Sheet

Indicators	Countries	Sierra Leone	The Gambia	Malawi	Burkina Faso
Total population		5,868,000	1,728,000	15,906,000	16,469,000
Gross national income per capita (PPP international \$)		840	1,750	870	1,250
Life expectancy at birth m/f (years)		46/47	57/60	57/58	54/57
Probability of dying under five (per 1 000 live births)		185	101	71	146
Probability of dying between 15 and 60 years m/f (per 1 000 population)		459/438	295/237	384/347	298/236
Total expenditure on health per capita (Intl \$, 2011)		165	94	77	93 (2010)
Total expenditure on health as % of GDP (2011)		18.8	4.4	8.4	6.7 (2010)
Human Development Index rank in 2009 (over 182)		180 th	168 th	160 th	177 th

Since the launch of HMN in 2005 as a global partnership to facilitate better HIS at the country, regional and global levels, and the development of an HMN framework as a harmonised framework for country-level HIS development, the previously neglected issue of poor HIS performance has been brought into the spotlight.

In Sierra Leone – one of the HMN pilot countries – after the development of a strategic plan, a HISP team of three, including me, was contracted by the joint United Nations Programme on HIV and AIDS (UNAIDS) and MoH to integrate a software package named Country

Response Information System (CRIS) with DHIS2 to address information needs of both MoH and HIV/AIDS programs. Additionally, the project would draw on the strengths of existing applications while leveraging the existing human, technical and financial capacities. The project started with our 12-day visit to the country from June 25th 2007. Although a self-assessment was already carried out with technical assistance from HMN, the purpose of this first visit was to conduct another assessment ourselves in order to have a better understanding of the context, the problems and identify their causes. The HISP team was joined by staff from HMN, UNAIDS (global and local), MoH and a local M&E consultancy company. The assessment involved gathering data through observation and consultations with health authorities and users and providers of information at the central level in Freetown (Western Area) and district and facility levels (Moyamba and Kono districts). The result of the assessment was presented in a validation workshop where all stakeholders and representatives of the facilities visited were present. The findings were discussed and validated. A project plan with activities was also presented, as well as a prototype developed in order to help participants understand what could be an Integrated Data Warehouse and what its potentials are. From July to December 2007, I took part in remote discussions on the project and attended meetings at the global level in Oslo and Geneva. One meeting held in Geneva in October 24th was of particular interest since it yielded an HIS top-down architecture for Sierra Leone. The meeting gathered major health open source actors such as HISP and Open MRS, in addition to well-known global health institutions such as the WHO and HMN. HISP and Open MRS demonstrated their respective software. The WHO demonstrated their sponsored and to-be finalised Open Health application, which has great features for data analysis and presentation. The participants decided to work toward an integrated architecture for health, or a health open-source suite that will integrate open MRS as the patient record system feeding DHIS2 as the statistical system. That would in turn be feeding Open Health, which would include analytical and presentation tools such as Geographic Information System (GIS) and web pivot table. The architecture would thus provide a framework for both vertical integrations ranging from patient management up to statistical decision support systems at the central level, as well as horizontal integration encompassing reporting systems from health programs. However, things did not go at all that way.

In February 2008, the customisation process of DHIS2 started with the training of the national technical core team followed by iterations of participatory design activities, testing, demonstrations, feedback and feedforward. From March to July, I made two visits devoted to

the customization and deployment of DHIS2 in four districts – Kono, Makeni, Moyamba and the Western Area – and at national levels in MoH. In each district, we set up the DHIS2 on a low-power computer running an Ubuntu server, as well as a Wireless Local Area Network (WLAN). In this initial deployment, the focus was on getting things started with data entry and basic data analysis. Accordingly, a short two-page training manual with screenshots was developed to support the basic training conducted in each district. During the deployment and afterwards, we got a lot of feedback from pilot sites and we improved the system accordingly. We continued the development of the system and regularly upgraded it in the districts and further trained the users on additional and new features. From the user's side, their expectations started growing and they became very demanding, especially in terms of more features for data analysis. Therefore, while waiting for the alleged forthcoming Open Health, which would have web pivot table tools and allow thematic analysis using maps, we had to rethink the approach and offered a nicely customised Excel pivot table in which M&E officers can automatically get their raw data and indicators from different levels. In May and June, we conducted extensive two-week training sessions in Freetown for two representatives of each DHMT and health program. Meanwhile, we also trained the technical team on how to support districts with technical issues. From August to December 2008, I remotely contributed to the preparation of review meetings, preparation of harmonisation of reporting tools, and support in technical issues. The excerpt email below from the HIS advisor typifies this remote support:

“... many times when we test things in Freetown they work fine only to find out that it's not working when we get to the field. What is the reason for this I cannot explain, but you will agree with me that it has been the case on many occasions. I also tested the script and it worked in Pujehun ... but failed in Bo during the same visit... I was also able to update the system in Bombali following the same instructions. So I don't know why it failed in Bo and Moyamba. My suggestion is to send the script again with readme file so I can try it the remaining districts. As regards the log files, I did not look at them in all occasions, so it will be difficult to get them. I have just received a report from Bo that their system has suffered the same problem it had the last time... you can send the instructions or I will work with you online as they urgently need their system back online.”

In January 2009, I went back for a one-month visit devoted to the rollout to the six remaining districts – Kailahun, Bo, Port Loko, Bonthe, Koinadugu and Tonkolili – and the harmonisation of reporting tools.



Figure 2: district HIS officers during one of the extensive training sessions in Freetown

The same year, a new DHIS2 built-in GIS module was developed, since the DHIS2-OpenHealth integration had failed and the OpenHealth project was abandoned due to organisational challenges consisting of delayed delivery of a stable system and the discontinuation of funding from the WHO. Additionally, the integration between the DHIS2 and OpenMRS through a gateway seemed more challenging than had been foreseen, and so it was gradually abandoned. Ironically, from the strategic alignment of the health suite plan, only the DHIS2 has emerged.

In June 2009, we went back to readapt the system according to the newly harmonised reporting tools encompassing all programs.

The same year, a report from HMN eulogised the project as a success story and was widely spread throughout the world and particularly in Africa. Moreover, representatives from the country have been sharing their experience of the HISP approach in regional HIS meetings organised by WAHO.

From August 2009 to the end of April 2012, my involvement continued as remote support on technical issues, discussion through email on how to improve things, and training in DHIS2 regional academies where representatives from different countries are trained in DHIS2.

In The Gambia, Malawi and Burkina Faso, my roles were similar to the one in Sierra Leone, except for some peculiarities like my full involvement in strategic planning in Malawi and Burkina Faso. Table 2 summarises my involvement in these countries as well as at the WAHO level.

2.4.2. West African Health Organization (WAHO)

My first formal contact with WAHO was in June 2010, when we started the preparation of the Accra workshop on Statistical Data and Metadata Exchange for Health Domain (SDMX-HD) and interoperability. After the workshop, we met in Dakar in November 2010 with other regional and global actors in HIS. In Dakar, the regional forum of HIS partners was created with the aim of coordinating interventions in the relevant countries, strengthening country-level HIS and consequently regional availability of quality information.

HISP (including me), as a representative of the University of Oslo (UiO), was part of the forum as an academic member that can do research and disseminate knowledge about HIS strengthening in the sub-region. In April 2011, the forum met in Accra and decided to develop a regional HIS. Meanwhile, WAHO started its collaboration with HISP in some countries like Guinea Bissau and Togo. While this concrete collaboration started at the country level, WAHO has selected HISP/UiO to develop the regional HIS policy. We conducted a regional situational analysis, including WAHO headquarters in December 2011 and in seven countries – Burkina Faso, Niger, Guinea, Ghana, Liberia, Guinea Bissau and Cape Verde – from December 2011 to February 2012.

I conducted the situational analysis in Burkina, Niger, Guinea and Liberia, where I was joined by other two HISP members. The remaining countries were taken care of by other HISP members. Health facilities both in urban and rural areas, hospitals, districts and regional health offices, programs and department within MoH were visited and people interviewed and observed. Documents were also collected and pictures taken. In each country, at the end of our visit, our findings were presented and discussed with health authorities and the people we met. The findings were discussed in a workshop with countries' representatives as well as regional actors. Priorities, objectives and strategies were set. In April, we presented the policy document in a regional workshop for discussion and adoption. The policy document was validated by country HIS representatives as well as the regional HIS committee and endorsed by the Assembly of Health ministers a few weeks later. From June, we began the drafting the policy implementation plan with the regional committee.

One of the recommendations of the policy was to develop a data warehouse that will improve data management across WAHO programs, departments at WAHO headquarters, and also between WAHO and the countries involved. On this topic, WAHO asked us to propose a plan for both developing a regional data warehouse that will manage data of different types and sources coming from the various countries and from WAHO headquarters. HISP (including me) has started this process since June 2013 with a limited number of countries – The Gambia, Sierra Leone, Nigeria, Ghana and Burkina Faso – and gradually added the remaining ones.

Table 2 summarises my involvement in these countries as well as at the WAHO level.

Table 2: summary of my involvement in the countries

Time	Sierra Leone	Gambia	Malawi	Burkina Faso	WAHO
Assessment	+++	++	++	++	+++
Strategic planning			+++	+++	+++
Project plan	+++	+++	++	+++	+++
Prototype	+++	+++	+++	+++	+++
Customization	+++	+++	+++	+++	+
Training	+++	+++	+++	+++	+
Testing	+++	+++	+++	+++	+
Deployment	+++	+		+++	
Negotiation with local actors	+++	+	++	++	+++
Remote support	+++	+++	+	+++	+
Revision of forms and indicators	+++			+	+++
Time frame	2007 – 2012	2009 – 2013	2009 – 2013	2009 – 2013	2011 -
Estimated number of months spent in country/settings	5	1.5	2.7	5	3
Discussion at global level	Discussion at regional and global level regarding HIS architectures				

The number of “+” indicate the degree of involvement from full (++++) to little (+)

2.5. How data is collected and recorded

Both primary and secondary, and also quantitative and qualitative data has been collected over the years of my engagement.

Primary data have been collected through my direct participation in assessments of HISs, planning workshops, design and development activities, training sessions, formal and informal meetings, supportive visits, policy development activities, interviews, email archiving, the cyclic development of integrated HIS and the revision of indicators and data collection tools processes. During my fieldwork, notes on my observations and my interaction with people during meetings, discussions, workshop and daily works were written in my notebooks. Notes were also taken during interviews and documents that interviewees referred to were also collected. More generally, any documents that could provide relevant information were collected. In addition, my fieldwork reports, emails exchanged with local and global or international actors were archived electronically. As far as interviews were concerned, most of them were conducted during assessment phases and were organised as group interviews including people from different levels in a given office or organisation. For example, an interview in a health facility will include the manager, the data manager, health workers (one or more depending on the size of the facility), a representative from the administration team, etc.

This primary data collection has taken place at three different levels: country, regional and global. Firstly, at the country level, data has been collected in the context of national implementation of HIS. At the regional level, it has taken place in the context of collaboration with WAHO, the involved countries and other partners at the regional level to address HIS issues, as well as in the context of regional HIS policy and regional HIS implementation. At the global level, data has been collected through my participation in meetings with global actors such as the WHO, HMN, CapacityPlus, OpenMRS, UNAIDS, other global HISP members, etc. From country to regional levels, data has been collected from interactions with people from all levels – low, middle and top levels. At the global level, my interactions were mainly through workshops and meetings, and were limited to low and middle-level officers with the ability to decide on issues at stake (see Table 3 for details). I have also collected data from published and unpublished resources such as strategic planning documents, policy documents, web pages, reviews, newsletters, bulletins, surveys, annual reports, project documents, etc.

Secondary data has been used in this research and has been collected from my co-authors through their direct involvement in other research projects. All data related to Botswana, Kenya, Mozambique, South Africa and Zanzibar are of secondary nature. In addition, assessment reports have been collected and used as secondary data.

Table 3: statistics on data collection

	Sierra Leone	Gambia	Malawi	Burkina Faso	WAHO	Global	Total
Workshop	36	3	8	12	20	6	85
Meetings	83	24	25	37	68	4	241
Direct observations	68	19	5	10	18	0	120
Emails							1500
Interviews	18	18	0	18	57	0	111
Web	4	3	3		2		12
Reports and documents	21	31	10	65	25	0	152
Bulletin	6		0	3	3		12
Newsletters	1	0	0		1		2

2.6. Data analysis

Data collected has been analysed through inductive reasoning by making inferences from data to knowledge. The analysis has been inspired by the theme of this research, i.e., the bottom-up architecting. Data collected has been analysed by identifying and following the dynamics and processes contributing to or aiming at the realization of an integrated architecture. The analysis has been iteratively carried out in three steps. First, data display techniques were used, such as tabular display showing processes over time or figures representing architectures). Second, data was reduced to emergent patterns and concepts identified. Third, these patterns and concepts were interpreted and discussed in light of current theory. These three steps have been gone through iteratively. For instance, the data and displays have been shared at a research method workshop where I received feedback from my peer PhD students as well as the facilitators. My analysis has been also discussed with my supervisors as well as with representatives from other networks of actions during some WAHO HIS partners' forums. This kind of discussion has even sparked a joint paper on networks of networks. Additionally, I have been guided by the principles for interpretive field research developed by Klein and Myers (1999) including hermeneutic circle, contextualization, interaction between researchers and the subjects, abstraction and generalization, dialogical reasoning, multiple interpretations, and suspicion.

By iteratively following the AR cycles of evaluation, planning, action and reflection, it became apparent that the emerging architecture is shaped by events and interplays that are not controlled by the team. This has sparked first the need to investigate the discrepancy between the planned integrated HIS architecture and the emerging one. Subsequently, the different top-down initiatives have been analysed in contrast to the gradual emergent architectures from the field and dictated by the actual circumstances. Second, the focus of this research has shifted from integration to architecting as our understanding of the phenomenon at hand has iteratively evolved through AR cycles. It was then clear that what I was investigating is architectures that are always evolving towards the goal of integration. Thus, if integration is both a goal and a continuous process, architecting in this research represents its process dimension towards the goal of an integrated HIS.

Subsequently, the process through which HIS emerging architectures are being built up, from Sierra Leone to WAHO via The Gambia, Burkina Faso and eight other West African countries, has been investigated. These architectures which are always in the making have been analysed both at country and regional levels, and the interplay between them has been examined as well.

Finally, I used network of actions and the knowledge of integration framework (see Figure 3) by Carlile (2004) as scaffolding devices in my effort to develop knowledge from this research.

Networks of action

Research over the years, especially within the HISP network, points to strategies of “flexible standards” (Braa et al., 2007a), “networks of action”, and the “hierarchy of standard” principle (Braa and Hedberg, 2002a) as some of the approaches to developing and implementing sustainable and integrated HIS. Drawing on works by Latour (1986) on Actor-Network Theory (ANT) and by Castells (1996; 2000) on network society, Braa et al. (2004) developed the concept of networks of action to “capture the dynamics of translating, aligning heterogeneous networks of routines, technology, and learning within politically contested terrains of opposing projects and ideologies in an effort to promote sustainable, replicable changes” (ibid). They argue that networks of action consist of “(1) abandoning singular, one-site action research projects in favour of a network of sites, (2) generating local, self-sufficient learning processes together with working mechanisms for the distribution of appropriately formatted experiences across sites in the form of vertical and horizontal flows, (3) nurturing a robust, heterogeneous collection of actors likely to pursue distinct, yet sufficiently similar

agendas, and (4) aligning interventions with the surrounding configurations of existing institutions, competing projects, and efforts as well as everyday practices.”

This emphasises a horizontal and bottom-up approach inspired by local and emergent translations and contrasts with a top-down approach of architecture which views architecture as plans or blueprints predicting what to do at a given time under given circumstances, outlining what resources are to be used and how. Elbanna (2006, p. 173) corroborates this view in the context of ERP implementation and argues that implementation methodologies are not determined beforehand, and instead involve an improvisation pattern of rebuilding networks and aligning actors.

In sum, individual or single-site projects are not sustainable because scalability is a prerequisite for sustainability. Thus, the networks surrounding such projects might seek synergistic alliances to learn to work together, scale and become stronger because “establishing networks creates opportunities for sharing of experience, knowledge, technology, and value between the various nodes of the experience” (ibid).

Carlile’s Integrative framework

I brought and adapted a knowledge integration framework (see Figure 3) by Carlile (2004) to systematically disentangle the boundaries or dimensions – syntactic, semantic and pragmatic – of architecting/integration, their characteristics and corresponding processes – transfer, translation and transformation – at each boundary as well as the interplay between the boundaries. This framework has emerged as I was discussing with my supervisor and colleagues involved in the research in Sierra Leone, the dimensions of integration and architecture. While analysing our data, we noticed there were three emerging patterns or perspectives: integration in relation to technical issues, integration in relation to data to be shared over subsystems and integration in relation to organizational issues such vision, willingness to collaborate, and aligning interests. Attempts to use the three-domain model of integration (Wainright and Waring, 2004) or Information Infrastructure (II) as scaffolding devices (Walsham, 1995) were unsatisfactory. The first lacked explanation on semantic issues. The latter also lacked semantic issues and was not able to satisfactorily explain the relationship between these three domains, nor the complex dynamics taking place within the organisational domain (see Figure 3). Therefore, we decided to explore other models in the literature and ended up with Carlile’s model. In fact, as mentioned in the introduction, at that time the focus of this research was on HIS integration. The relevance of this framework was

again assessed when the focus of this research shifted to architecting. Other alternatives such as architecture frameworks (Zachman's framework (1997) or TOGAF (2013)) have been considered. These frameworks were found unsatisfactory for three reasons. Firstly, they mainly focus on the sequential and logical development of architectures starting from the business level. Their underlying principle is that everything should derive from the business architecture, which captures the business strategies and goals. Therefore, they do not account for emerging patterns. Second, the interplay between the layers are in one direction and hierarchical. Lastly, architectural frameworks, although they account for semantic issues in their information system architecture, do not provide a due account for dynamics at the business layer or explain how lower layers also shape others.

The integrative framework proposed by Carlile was developed for sharing knowledge across boundaries in an organisation, involving progressively complex processes – transfer, translation and transformation.

At the syntactic boundary, differences and dependencies between actors are known, and a common lexicon is developed to sufficiently share knowledge at a boundary. The corresponding process is transfer. Syntactic capacities, taxonomies, storage and retrieval technologies are required.

The semantic boundary: its corresponding process is translation. Novelty that arises at the syntactic level generates differences and dependencies that are unclear and leads to multiple interpretations. Therefore, a common meaning needs to be developed to address differences in interpretation. However, developing a common meaning is a political process of negotiation and defining common interests. When only the semantic boundary is faced, the actors involved just need to agree on common meanings, but it is not necessary for them to transform their specific domain knowledge.

The pragmatic boundary: transformation is its corresponding process. The transition from semantic to pragmatic boundary arises when the novelty results in different interests among actors and needs to be addressed. The novelty at this boundary may require transformation of both the levels of common- as well as domain-specific knowledge. And because knowledge is invested in practice, such novelty might also impact current practice. Boundary objects such as drawing, prototype and trade-off methodologies have proved effective in representing different functional interests as well as facilitating their negotiations. However negotiating and transforming domain-specific knowledge is a trial-and-error problem-solving process.

The fourth dimension of the framework is iteration in addressing novelty at the pragmatic boundary. Carlile argues that multiple iterations are needed to successfully negotiate different interests and transform domain-specific knowledge. By participating in iterations, actors get better at identifying which differences and dependencies are of consequence, better at collectively developing a more adequate common lexicon and meanings and better at aligning their interests.

Although this framework seems linear, it is instead a kind of cumulative capability framework. In other words, for example, when novelty arises at the pragmatic boundary both the semantic and the syntactic capabilities are required to successfully align stakeholders' interests. And novelty and change can arise at any boundary or span many boundaries. The framework helps analyse and describes the mismatch that can occur when novelty arises at a given boundary and the type of capacity mobilised as well as the process used, such as when a syntactic boundary is faced and a costly translation and transformation processes are developed. The framework also explains how knowledge, especially common knowledge, moves dynamically towards the bottom as differences and dependencies become known over time.

Although the demarcation of boundaries looks clear in the inverted triangle of the framework, the transition from one boundary to another is not easily identifiable for actors involved.

To summarise, the syntactic, semantic and pragmatic boundaries are linked to information processing, and interpretive and political perspectives, while iteration is needed through trial-and-error problem solving to align interests at the pragmatic boundary.

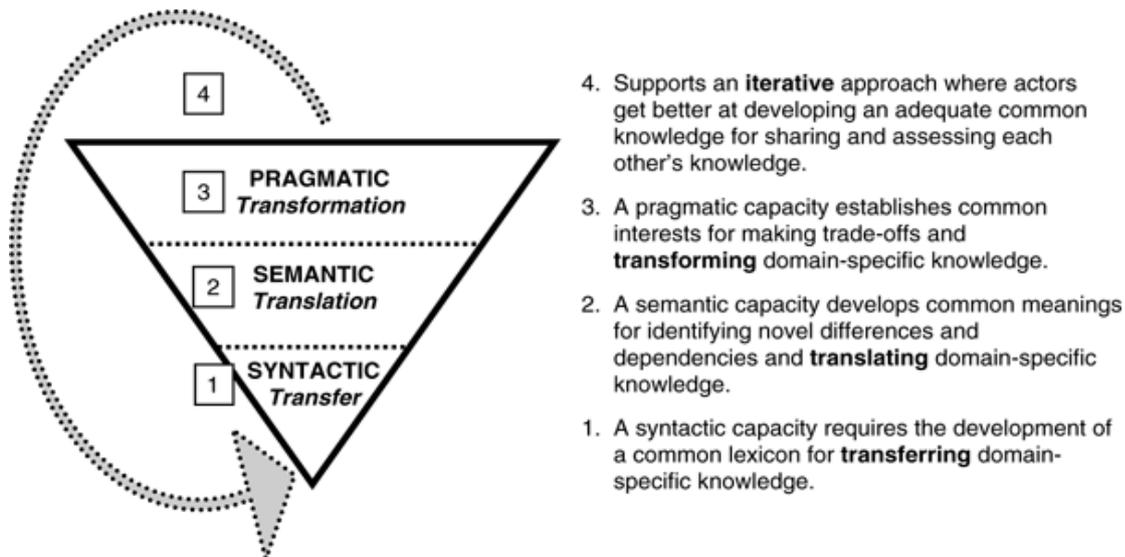


Figure 3: 3-T Framework and the Four Characteristics of a “Pragmatic” Boundary Capability.

Although this framework has been developed for sharing knowledge across boundaries in organisations, I brought it to the IS field as a framework to describe different boundaries faced by different processes and understand how a dynamic triggered by constant changes propagates across boundaries, as well as to determine the appropriateness of processes proposed to address these changes.

This framework is of particular relevance when describing processes of architecting such as routine and non-routine changes. Routine information or data sharing across systems or organisations occurs at syntactic boundaries. However, for this to successfully work, common lexicons as well as organisational procedures need to be defined and agreed on. For instance, a routine transfer of “number of midwives” in a given facility between a human resource system and a data warehouse requires a technical standard, the same understanding of what a midwife is, and a shared reference of that facility. So when novelty or change arises at a syntactic boundary, a semantic boundary is faced if the novelty is related to semantics. For example, a new actor or a new system could request data such as “number of children who slept under mosquito net the day before they came for their third Pentavalent immunization”. This data will be searched for in the metadata document or registry. If it already exists, but with a different name, or if existing data could not be combined to generate the new data required. But if the existing data cannot be translated to generate the new requirement, a communication problem that goes beyond the semantic boundary is created and the pragmatic boundary should be faced. Nevertheless, all the four characteristics of this boundary are mobilised to address the change and align interests of involved actors by transforming the

architecture. This transformation could result in new practices, a new metadata registry – a new common lexicon – and new tools. In this case, a survey can be designed and conducted in order to get this information, but if it is required in the routine system, then a new health service ledger and reporting forms must also be defined and health care providers will be required to ask mothers if their children slept under the mosquito net when given their third Pentavalent doses. And the data management software needs to be updated accordingly. But when an inappropriate boundary is faced, the response to the change will be unsatisfactory and resources will be misused.

While outputs of processes at semantic and pragmatic boundaries shape what is possible at the syntactic boundary, possibilities or outputs at both syntactic and semantic boundaries also shape the transformation process at the pragmatic boundary.

The adoption of this framework has gradually emerged as part of the inductive inference of empirical materials to knowledge throughout the different iterations of AR cycles within and between the settings. The way the use of this framework has improved from one paper to another and to this thesis clearly indicates how my understanding of the phenomenon I have been studying has evolved over time. Thus, the use of the framework is an output of the analysis but also an input for further analysis (see Figure 4 and Figure 5: example of how data is coded from interviews, meeting notes, observations etc.).

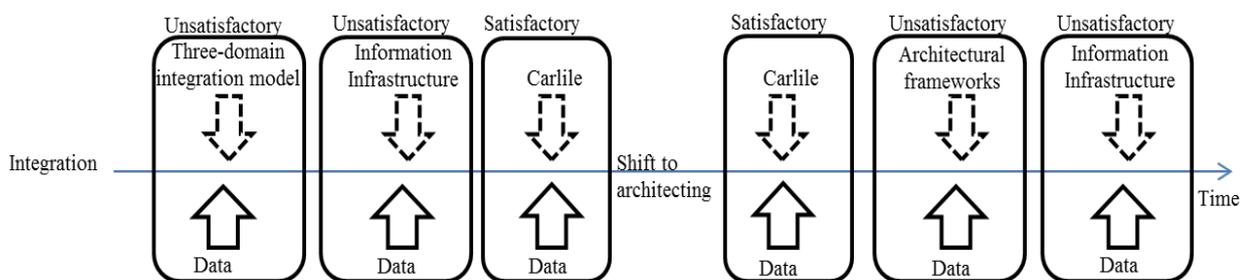


Figure 4: Trend line of data analysis

I will summarise this chapter by using some of the principles for interpretive field research developed by Klein and Myers (1999):

The principle of the hermeneutic circle is a kind of a meta principle including the other principles. It indicates that human understanding is developed through iterations between the whole and the parts of the problem in question. My preconceptions about integration has been challenged by what emerged from the field and through several AR cycles (or hermeneutic

iteration) in the various settings, the focus of the research as well as my understanding have gradually evolved to the process that lead to integrated HIS. For example, the deeper understanding of what it takes to achieve integration of health programs and standardisation of data sets between health programs is developed through iterations between different parts of the problem area and the 'whole'. While the 'parts' may be seen as the different data sets, health programs, particular dichotomies between stakeholders and concrete efforts undertaken to bring stakeholders together, the 'whole' may be seen as the overall group of health programs and stakeholders and the stages in which the agreement and standards were developing – or not. The case of Sierra Leone included many such iterations; in the beginning there were no collaboration, no standards and generally no agreement. A main reason was that the individual stakeholder did not see that it was possible to overcome the problems due to technological and organisational challenges. Through several iterations of, first, demonstrating the poor state of data quality and overall information system, then several steps of populating the data warehouse with their own data while at the same time solving the data conflicts (e.g. overlaps) between the health programs, gradually, a 'trust' in the new shared system was developed.

Principle of contextualization: in the subsection about my role, I provided the historical background of the settings but also how the dynamics of architecting unfolded from one setting to another and what are the driving forces. In the different settings, the historical background had to be a major component of the research. For example in Sierra Leone, the terrible civil war (1991-2002) made up the important context for most discussions and observations; health facilities were destroyed, health workers were killed and the scars of the war could be seen everywhere. All this in stark contrast to the situation in for example Malawi, a country with a peaceful past, but as a dictatorship under the president Banda, who was the only African leader allied with South Africa. In our case of building 'new' information systems, it might be argued that the phase of reconstruction and unity after the war in Sierra Leone made up a more conducive context for change than the more 'normal' situation in Malawi.

Principle of interaction between the researchers and the subjects: my understanding of architecting as a process towards integration and interoperability has gradually widened through the iteration of my AR cycles but also through my interaction with people dealing with HIS at different levels in my settings. The way the integrative framework has been used in my papers is an example of how the understanding has evolved. For example, my

interaction with software and architecture development stakeholders, policy development arenas as well as users in field in countries and at WAHO level have exposed me to different logics of ordering. In Sierra Leone, despite the achievement of technical interoperability between DHIS2, OpenMRS and iHRIS, users haven't enjoyed interoperability in practice.

Principle of abstraction and generalization: Figure 5 provides an example of a step of how data has been coded and organised in light of the boundaries of the integrative framework adopted. This allowed me later to further analyse the process of architecting at these boundaries as well as the interactions between them.

Principle of dialogical reasoning: my fading faith and enthusiasm in technology and in the merit of interoperability (as described in the introduction) have gradually worsened because of the “ugly facts” that emerged from the fields. Instead, I realised that what matters is a working solution and appropriate – in the good sense – technology. Additionally, as coming from the so called developing world my view on development has evolved through tensions with the views of other development actors in the field. For example, it is was hard for me to understand that development partners only view/measure “poverty” as numbers or statistics and ignore how many people in these statistics cope with their conditions and environment without necessarily feeling poor or unhappy. I also realized that people in developing countries and in development partners' community share the same flaws regarding perception of HIS. For example a senior officer at WHO told us during one of our discussions on HIS strengthening in African countries:

*“You know what? Even people in this house believe you can
bypass HIS and get everything from surveys”*

Principle of multiple interpretations: during this research, I have been aware of and have had opportunities to deal on many occasions with multiple interpretations. For example, at the diagnostic phases of my AR in the settings, when people are asked to illustrate the information flow in their countries, those in charge of the HIS tend to present a neat map whereas other stakeholders depict chaotic flows. In one country, we ended up not agreeing on a visualization of the information flows. This also applies in general to the assessment of the performance of the HIS and poses the problem of distinction between presentational and operational data (Van Maanen, 1979, p. 542).

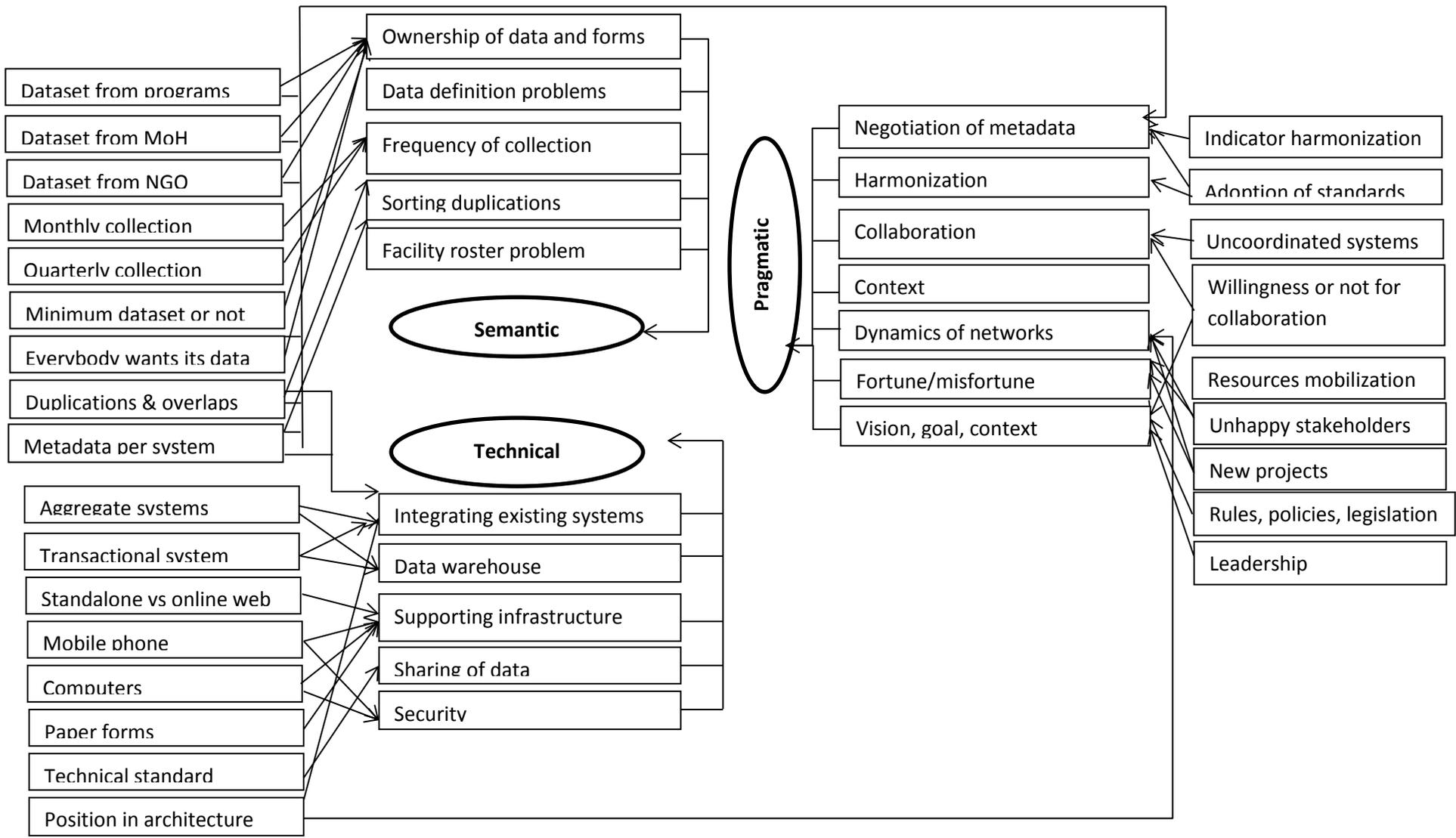


Figure 5: example of how data is coded from interviews, meeting notes, observations etc.

Chapter 3 - Related research

Developing and successfully evolving IS across organisations to seamlessly produce information for management or deliver expected services is one of the key issues in IS literature (Aanestad and Jensen, 2011; Braa and Sahay, 2012; Chen et al., 2008; Chilundo and Aanestad, 2004; Hanseth, 2007; Janssen, 2012; Kubicek and Cimander, 2009; Pardo and Burke, 2008; Pardo et al., 2012; Puri, 2007; Scholl and Klischewski, 2007). Though IT systems tend to grow out of the control of a single designer or stakeholder, there is an increasing need for organising them to avoid chaos. Architecture, a metaphor borrowed from the construction field, has been suggested as a way to organise such systems or to represent the future state of the IT system to be developed (Zachman, 1987). Despite its wide use in the IS literature, the concept is still elusive. Many definitions of the term have been proposed in the literature (ISO, 2011; Jonkers et al., 2006; Smolander, 2002). It is the “fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution” (ISO, 2011). This definition of architecture has been made more explicit by Kruchten (2000, p. 84), who takes into account the usage, functionality, performance, reuse, resilience, comprehensibility and aesthetics, economic and technological constraints and trade-offs.

Research on architecture in IS has focused on different facets of architecture such as its components and their linkages, e.g., modules, standards and gateways (Hanseth, 2001), the role it plays in the evolution of the IT system (Grisot et al., 2014; Hanseth and Henningson, 2013; Henfridsson and Bygstad, 2013), the role of stakeholders in its making (Hanseth et al., 2006; 2007), the flexibility required to adapt to constant changes in context and use (Braa et al., 2007a; Braa et al., 2005; Bush et al., 2010; Hanseth and Nielsen, 2007; Tiwana and Konsynski, 2010) and how to develop it (Hanseth et al., 2014; Hanseth and Lyytinen, 2004; Lankhorst, 2013).

In the rest of this chapter, I will discuss meanings associated with architecture, and approaches to developing architecture. I will also relate the concept to some key concepts such as evolution, flexibility and agility, interoperability, integration, standards and standardisation.

3.1. Architecture and architecting

According to IEEE, architecting is the “process of conceiving, defining, expressing, documenting, communicating, certifying proper implementation of, maintaining and improving an architecture throughout a system’s life cycle ... Architecting takes place in the context of an organization (“person or a group of people and facilities with an arrangement of responsibilities, authorities and relationships” (ISO, 2011)) and/or a project (“endeavor with defined start and finish criteria undertaken to create a product or service in accordance with specified resources and requirements” (ibid)). This description explicitly or implicitly pinpoints some key aspects related to architecture such as people, context, institutions, standards and interoperability.

3.1.1. Architecture and sense making

The word architecture has been inconsistently used in IT (Corneliussen, 2008; Lankhorst, 2012; Smolander, 2002; Vassilakopoulou and Grisot, 2013; Zachman, 1987). The word’s meaning lies in the eyes of the beholder, however. It can refer to the internal structure of a microprocessor, the internal structure of machines, networks, software (Rozanski and Woods, 2011), or a larger IS including its organisational and technical aspects (Zachman, 1987). In the process of architecture making, stakeholders often have different perspectives on the architecture at stake (Corneliussen, 2008; Zachman, 1987). Smolander (2002) has identified four general metaphors of architecture based on certain emerging properties of architecture description and design activity:

- “Architecture as blueprint: architecture is the structure of the system to be implemented.
- Architecture as literature: architecture resides at the documentation and reference architectures for future readers.
- Architecture as language: architecture is the language for achieving a common conception about the system.
- Architecture as decision: architecture is the decision and basis for decisions about the system to be implemented.”

He has summarised architecture as a plastic concept that is robust enough to maintain its identity and integrate work amongst different stakeholders. However, in his conceptualisation of IT architecting, Corneliussen (2008) has identified two streams of architecture in IS research. He has defined software architecture as tools for describing and documenting the

high-level implementation of the application without regard to its context, while business architecture does take the application's context into account and is less occupied with the structuration of the application itself.

In sum, architecture is a multidimensional concept, which can mean different things at different boundaries.

3.1.2. Approaches to architecture

Recent studies on approaches or strategies to IS architecture have focused on two main streams: top-down and bottom-up. I now present each of the two approaches.

3.1.2.1. Top-down approach and architectural frameworks

The top-down approach is (and derives from) the traditional specification-driven approach to software development (Lankhorst, 2013; Peristeras and Tarabanis, 2000; Segars and Grover, 1994). It focuses on developing fully detailed specifications and requirements of the architecture and thus developing the technical solution based on them. Furthermore, it assumes that work processes can be broken down into well-defined objects with logical relations, which can be programmed into algorithms and inscribed into the IT systems to automate work processes. An underlying aim of such an approach is to increase control over work processes, to enhance time and cost efficiencies (Simonsen and Robertson, 2012). Several architecture types have thus been suggested to help in developing such architectures. The most popular of these types is Enterprise Architecture (EA) which comes in a variety of frameworks such as The Open Group Architecture Framework (TOGAF), Zachman Framework (ZF) (Jonkers et al., 2006; McGovern et al., 2004; Pereira and Sousa, 2004; Zachman, 1997), Architecture of Integrated Information Systems (ARIS), Federal Enterprise Architecture Framework (FEAF) (Winter and Schelp, 2008). Besides EA, there is also a popular architectural style to integrate software applications called Service Oriented Architecture (SOA) (Arsanjani, 2004; Papazoglou, 2003; Perrey and Lycett, 2003).

EA has been defined as “a coherent whole of principles, methods, and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems, and infrastructure” (Lankhorst, 2013, p. 3). It is a master plan which links together aspects of business planning, aspects of business operations, aspects of business automation and the enabling infrastructure of the business (Schekkerman, 2004). EA analyses hierarchically the business, processes, information, application and technology strategies and their impact on business functions. Each of these levels (business, processes, information,

application and technology) has its own architecture and the different architectures relate to each other in a hierarchical way. For example, the requirement and specification of business strategies are the basis for the underlying process architecture. Development of a complete architecture framework, then, goes recursively from business down to technology architecture. The overall EA is thus the set of these architectures and their relationships (Lankhorst, 2013; Pereira and Sousa, 2004; Ross et al., 2006). Furthermore, this view assumes the framework can help depict both the as-is architecture, and the to-be architecture, and carefully plan the steps toward the latter.

While EA is now hailed as the efficient way to comprehensively address different views in organisations and ensure enterprise-wide architecture that is effectively aligned with business strategies and processes and provides agility to adapt to changes (Hoogervorst, 2004; Jonkers et al., 2006), some scholars downplay its benefits (Fallmyr and Bygstad, 2011) and call for caution in its use (McGovern et al., 2004). For Fallmyr and Bygstad (2011) and McGovern et al. (2004), EA can lead to a documentation-heavy approach. It could lead also to process-heavy approach of developing definitions of collections of rigorous processes to support or maintain traceability among the artefacts in a framework such as the ZF (see Pereira and Sousa (2004) or Zachman (1997) for details about ZF)(McGovern et al., 2004). Furthermore, it is argued that although EA is widely adopted in the architects' community, it is not yet accepted within the software development community, which is still offering software and not architecture (Fallmyr and Bygstad, 2011; McGovern et al., 2004). To address such critics, Winter and Fischer (2006) argue that the critical success factor in using EA is to distinguish between the broad but aggregate EA on the one hand, and the detailed and specialised architectures on the other hand. The architecture layers, the argument goes, should be broad and leave details to sub-architectures, which have appropriate tools to handle them. For example, the business architecture should not go further than sub-processes because detailed descriptions, which include activities, are out of scope in EA and should be managed by using process-modelling tools. In fact, dropping details in EA does not mean giving up the top-down approach to specifying these details. It is instead using other types of top-down tools for such.

To integrate software applications in an enterprise, the SOA has been proposed as an architectural style which aims at loosely coupling software applications devoted to a complete and meaningful business function (Arsanjani, 2004; Papazoglou, 2003; Perrey and Lycett, 2003). It helps bridge the gap between business processes and underlying applications

(Assmann and Engels, 2008). For Bieberstein et al. (2005), “SOA facilitates aligning existing IT infrastructure and systems to achieve end-to-end enterprise connectivity by removing redundancies, generating unified collaboration tools, and streamlining IT processes.” In SOA, a business function implemented in a software application is called service. The services are intended to be used and reused at the level of the enterprise either as primary service or part of composite services. Each service has a documented interface which provides information about available operations for its clients, while its internal logic is hidden from outside. The services are listed in service registry so that a client can search for a service and then bind to it. Services can serve as both providers and clients. All available services are loosely-integrated through an Enterprise Service Bus (ESB) which is an enabling infrastructure over which services interact, aggregate and coordinate (Papazoglou, 2003). The ESB is thus both a loosely coupling and management infrastructure which deals with common attributes of services such as quality of service, security, routing, error handling, mapping of service instances, *et cetera* (Papazoglou, 2003; Schmidt et al., 2005). In so doing, SOA aims at allowing for dynamic recombination of services to support new business processes or strategy, harnessing legacy systems together with new technologies and applications to form a robust and enterprise-wide architecture and create a net value in the architecture for other services to be plugged (Bygstad and Gronli, 2011; Schmidt et al., 2005).

Taking the idea of SOA further, Bieberstein et al. (2005) suggest complementing or streamlining the IT transformation with organisational and cultural changes to realise the true value of SOA. They suggest mimicking the organisation structure with SOA. In other words, to develop service teams (services) specialised in delivering particular activities or tasks. Several service teams can, then, be combined to execute high level tasks. The teams and their core competences, as well as policies on how to interoperate with them, are published (service registry). A Human Service Bus (HSB) – ESB – is needed to orchestrate, monitor and manage the new organizational structure.

Despite the appeal and benefits of SOA, it has been argued that the picture seems too good to be true. Its opponents argue that SOA is based on messaging between services and one application could be sending millions of messages, and as the number of services grows the complexity in handling messages could escalate (Xiaoye et al., 2013). Additionally, critics suggest that the reuse of services is often low and their increasing number fostered by service variant results in more complexity than in the legacy systems (Schelp and Aier, 2009).

3.1.2.2. Bottom-up approach

The second stream, representing the bottom-up approach, argues that experimental and gradual development of flexible and simple solutions offer a better chance for the evolution of a system (Grisot et al., 2014). It criticises the traditional approach for being top-down and ignoring the social, embodied and contingent nature of everyday work practices (Greenbaum and Kyng, 1991; Shapiro, 2005; Simonsen and Robertson, 2012). For Greenbaum and Kyng (1991, p. 4), work is fundamentally social and work practices are composed of situated actions and this means that workplace life is not easily describable. Furthermore, it has been argued that attempts to control often bite back with more complexity, more rigidity and more uncertainty (Hanseth and Ciborra, 2007). Top-down approaches, the critics say, ignore the emergent nature of IT systems (Ciborra, 2000b) and their situatedness (Suchman, 2007). They argue that routine work in organisation is based largely on tacit knowledge (Orlikowski, 2002) and trade-offs that top-down approaches fail to account for. Therefore, it has been proposed that an evolutionary and participatory approach in which the participants typically undertake the two principal roles of users and designers is more suited to developing architecture (Braa and Hedberg, 2002b; Grisot et al., 2014; Grisot et al., 2013; Hanseth et al., 2014; Hanseth and Lyytinen, 2004; Puri, 2007; Simonsen and Robertson, 2012). For Simonsen and Robertson (2012), designers strive to learn the realities of the users' situation while users strive to articulate their desired aims and learn appropriate technological means to obtain them" (ibid, p.2). These two roles translate into two fundamental principles: i) enable users of the future technology to have a voice in its design without speaking the language of the professional technology design. This can be achieved through interactions with prototypes, mock-ups and other tools that can represent the system to be developed and future practices. ii) People who are not professional technology designers may not be able to define what they want from a design process without knowing what is possible (ibid). However, while acknowledging the critical role of users' active participation, recent literature argues that it is not possible to involve all stakeholders because aligning different interests is a hard task (Braa and Sahay, 2012). Instead, the project team should be relatively small to lessen political issues and enable quick decision and actions (Braa and Sahay, 2012; Hanseth et al., 2014).

Hanseth and Lyytinen (2004), in their theorising of Information Infrastructure (II), have compared the approaches and have concluded that the evolutionary approach allows organisations to quickly implement a solution and gradually improve on it, by learning from

experience and by adapting it to changes in users' needs. So trying to gather full specifications of the overall system and planning everything beforehand are time consuming and do not allow quickly taking ideas to the field, selecting what works through trial and error and moving forward.

In sum, from the literature on approaches to architecture, two main streams emerge. The first one is the top-down approach that tries to describe full specifications and requirements and carefully plan all steps of its instantiation. This might have proved efficient for software architecture but is definitely challenging in the context of complex IT systems that can span across organisations. The second stream is the bottom-up approach, which emphasises user participation and stepwise development through trial and error, as designing is a situated action and usually problems are weakly formulated in the beginning.

3.1.3. Architecture and evolution

A big concern in IS research has been how to get the IT system to successfully evolve. DeLone and McLean (1992) have suggested a model to measure IS success. The model has six interrelated and interdependent categories – system quality, information quality, use, user satisfaction, individual impact and organisational impact. Since its formulation, the model has been widely used in IS (DeLone and McLean, 2003). However, in their recent work, Henfridsson and Bygstad (2013) argue that although such a model fits well with traditional in-house IS, it cannot be applied to information infrastructures which evolve over time, are interconnected, open and have heterogeneous stakeholders who interpret success differently. Therefore, they suggest success should instead be related to the role of the infrastructure in and fit with the environment it inhabits (ibid). For them, infrastructure success is “an outcome realised when (a) the infrastructure survives in a business ecosystem by filling a relevant role over time, and (b) the infrastructure's affordances cannot be escaped endogenously but is only vulnerable to exogenous shocks” (ibid, p.14).

The top-down strand argues that the successful evolution of the architecture is rather linked to better orchestration (Lankhorst, 2013; Nadler et al., 1997; Peltz, 2003) than local optimisation. The evolution of IS, the argument goes, depends on the ability of architects to logically and coherently derive and model business from strategies and to develop a flexible system that will be aligned to an organisation's strategies and that is able to adapt to expected and unexpected changes in the organisation. The ingredients for successful evolution are the control over the process by top management and the balance between the stability of the

architecture and its capability to adapt to changes that may arise over time (Bush et al., 2010; Engelsman et al., 2010; Hoogervorst, 2004; Jonkers et al., 2006; Lankhorst, 2013; McGovern et al., 2004; Ross et al., 2006; Tiwana and Konsynski, 2010).

For the bottom-up strand, a flexible and loosely coupled architecture that is operationable and allows gradual development, scaling and growth has more potential for success (Aanestad and Jensen, 2011; Grisot et al., 2014; Hanseth et al., 2014; Hanseth and Lyytinen, 2004) than a tightly coupled one. Hanseth et al. (2014) argue that the architecture must be designed in such a way that it can be developed by a single organisation because the initial bootstrap of an infrastructure is best supported by a centralised architecture that is developed by a single and small organisation. In addition, they argue that architectures need to change over time because the one that may make an information infrastructure bootstrap may be different if not opposed to the one that makes it continue to grow (ibid).

In light of the above arguments, the OpenHIE (2013) proposal could be seen as a counter example of a gradual and operationable architecture. The OpenHIE architecture model requires all registries (clients, health workers, facilities), the shared health records, the terminology service, and at least a patient records system in all health facilities to be in place before being able to use the system and query the shared health records to generate health information at district or national level.

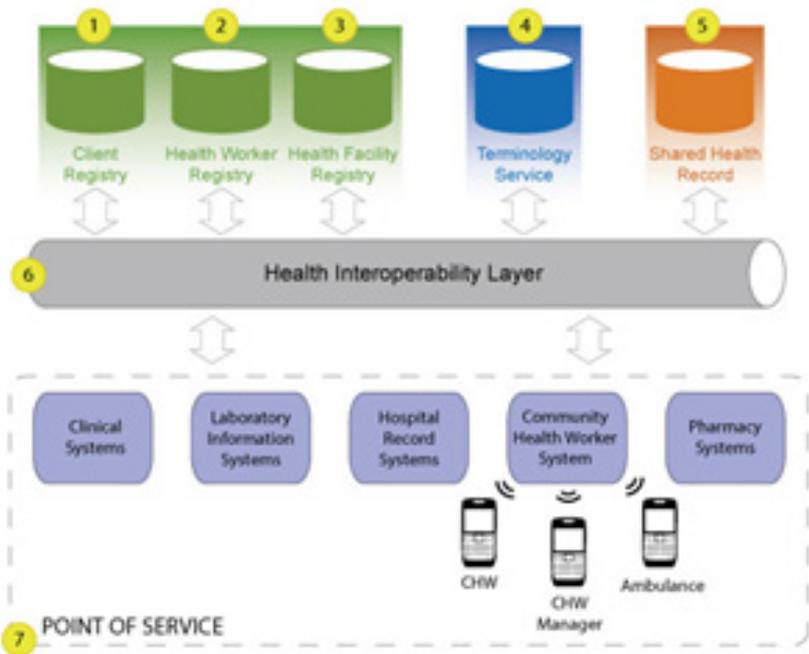


Figure 6: OpenHIE architecture (2013)

Henfridsson and Bygstad (2013) have questioned the relationships between an infrastructure's success and its architecture's loose-coupledness and control mechanism. They argue a case survey of 41 cases of infrastructure evolution in literature has revealed success in both tightly and loosely coupled architecture.

In their design principles, Hanseth and Lyytinen (2004) argue a system has to extend from an existing one and be designed in a way that offers lower adoption cost for the users. It should focus on the current needs if it wants to get momentum.

Some researchers have suggested that planning, streamlining work processes and standardising are central to business life and that such order-making could never be complete in one go. Instead, they suggest that IS evolution is a succession of planning, development, implementation, emerging misfits in use and workarounds, which at some point may lead to planning another development phase to solve these emerging misfits (McGann and Lyytinen, 2008; Rolland and Monteiro, 2002). Thus, there is need to follow a "reflexive design process" (Rolland and Monteiro, 2002). Nevertheless, this sounds like tinkering through improvisation a system that is developed in a top-down manner when confronted with reality in use. The word improvisation has been defined as a "situated performance where thinking and action seem to occur simultaneously and on the spur of the moment. It is purposeful human behaviour which seems to be ruled at the same time by chance, intuition, competence and outright design." (Ciborra, 1996, p. 369). It is a reaction to address a situation (unexpected or not) without having beforehand all required resources (including plan for actions). It is a central theme in the bottom-up approach as the designers or architects explore, know by doing, hold that design and implementation are not separable and evolve iteratively (Nerur and Balijepally, 2007).

In the literature on generativity and innovation in relation to architecture, Henfridsson and Bygstad (2013) have identified three fundamental mechanisms that contribute to IS success: innovation, adoption and scaling. Architectures that allow for a self-re-enforcing process of all these three mechanisms or at least adoption and scaling mechanisms will succeed.

Generativity has been defined by Zittrain (2006, p. 1980) as "the essential quality animating the trajectory of information technology innovation. Generativity denotes a technology's overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences..." and "...a function of a technology's capacity for leverage across a range of

tasks, adaptability to a range of different tasks, ease of mastery, and accessibility.” Thus, generativity can be understood as the sum of end-to-end architecture and programmability of terminals in the fringes (Hanseth and Nielsen, 2007). Expanding on the concept of generativity, Hanseth et al. (2014) have suggested the notion of generative architecture, which, in addition to capacities in Zittrain’s definition, emphasises the ability to bootstrap. It has been therefore suggested that there is a need to democratise governance and distribute control in the architecture to increase potentials for successful evolution (Hanseth and Henningson, 2013; Hanseth and Nielsen, 2007; Nielsen and Hanseth, 2010; von Hippel, 2005). In the context of digital platform, the issue of control over the IS has been source of tension between the lead creator and the application developer and it has been suggested the use of boundary resources (software tools, programming interface and regulation) to keep control (architectural control) while providing access to core resources of the system (Ghazawneh and Henfridsson, 2013). As far as innovation is concerned, four dimensions have been identified by Hertog (2000): service concept, client interface, service delivery system and technology. In practice, many service innovations imply a combination of some of the dimensions. A new service might require a new client interface and a new service delivery system that itself may rely on a new technology. However, innovation could be as simple as recombining the modules in new ways without changing the whole architecture – architectural innovation – (Henderson and Clark, 1990). Therefore, modules in the architecture should be generic in order for them to be reused and recombined in different ways (Grisot et al., 2014).

In their work on service innovation Lusch and Nambisan (2015) have adopted a broadened view on service to conceptualize service innovation. First, a service is the application of knowledge and skill through processes, performance and institutional arrangement for the benefit of another or self. In this process, the key resources are knowledge and skill to process or use other resources which are mainly information which can be separated from physical materials and transport independently of people (liquefaction). Subsequently, all the resources (knowledge, skills and information) as well as processes, performances and institutional arrangement can be split pieces and rebundled to create new resources that are beneficial (innovation). The services are exchanged in an environment or service ecosystem (a community of interacting entities) that is relatively self-contained and shaped by the actors. However, for their viability actors exchanging service will seek for more resources for increased density and will turn to service platform which can liquefy more knowledge,

information and technology. A platform is defined as “service platform as a modular structure that comprises tangible and intangible components (resources) and facilitates the interaction of actors and resources (or resource bundles)” (ibid). The structural flexibility of the ecosystem will enable easy reconfiguration (spontaneously or through intermediary) of actors to create more opportunity for innovation (ibid). In their exploration of what made google a innovation machine Iyer and Davenport (2008) identify some key characteristics: architectural control on the ecosystem, innovation built into job descriptions, cultivated taste for failure and chaos, and using data to vet inspiration. The architectural control provides Google a strong position to access transaction data from users, third party developers and advertisers and therefore get continuous awareness of changing conditions. In the job description of Google’s employees, there is a time allocation for innovation meaning that they a certain percentage of their time to work on what they want. In so doing employees are motivated and new products are been developed. The management encourages initiatives from employees, praises failure as opportunity to learn and view innovation and failure as going hand in hand. Additionally, the company does take seriously extensive use of data for rigorous decision making. However, the fact that the company is not in urgent need for resources has helped it adopt a strategic patience to its development and innovation.

Another perspective on architecture and evolution is the evolution of the architecture itself. Some researchers have criticised the belief that architectures are static and stable and have argued instead that architectures evolve over time (Foote and Yoder, 1997; Hanseth et al., 2014), and sometimes in a way that was not foreseen. The architecture might change over time because there is a change in technology (for example, from standalone systems to cloud computing), a change in the context (new regulations forbidding transfer of data from one organisation to another) or a change in business (Scholl and Klischewski, 2007).

A recent work by Nielsen and Sæbø (2016) has shown how the components of an architecture and subsequently the overall architecture evolves over time. They have identified three strategies for functional architecting: charting, encroaching and connecting. They define charting as an opportunistic move of a component in the architecture to address unmet needs outside its traditional functional domain. Encroaching is a strategy based developing new functionalities that are already offered by another component in the architecture. The last strategy, connecting is a strategy to connect one component to another in a different domain for complementarity. This could be a unilateral move or an agreement between the components. Both charting and encroaching can be rightly or wrongly seen as a threatening

move while connecting denotes synergy. However, the argument goes, the strategy – that leads such evolution of the component and the overall architecture – evolves itself over time and shift from one to each of the other two depending on the context and opportunities that arise. Therefore, the stance of other components in the architecture towards the evolving component will also change overtime (Scholl, 2005). See 3.1.5 (Architecting and Interoperability) for work on how collaborating or interoperating entities' stances towards each other can change overtime.

In sum, from the bottom-up perspective, architectures are not stable or static. Instead, they are dynamic and need to evolve over time. For architecture to be adopted and to keep growing, it should be modular and rapidly actionable so that a subset can be developed and implemented quickly while gradually developing new modules. In addition, making architecture modular might create possibilities for innovations such as architectural innovations.

However, both approaches lack explanation of the process or mechanisms through which architectures evolve. The top-down EA model does not offer a rich account of the dynamics at the organisational level and has proved challenging for managers as they don't speak the language of EA (Fallmyr and Bygstad, 2011). Additionally, the EA model assumes changes should be confined in modules (Jonkers et al., 2006). The lack of account on critical issues such as leadership, culture and sense-making limits EA's ability to explain satisfactorily complex dynamics that lead to alignment of stakeholders in a multi-organisational context. On the contrary, the bottom-up approach does not have a model, but does offer some design principles (Aanestad and Jensen, 2011; Grisot et al., 2013; Hanseth and Lyytinen, 2004). As far as the architecture evolution is concerned, when it is evoked in bottom-up literature, all merits are given to the evolutionary strategy, the flexibility of the technical solution, user participation and/or the decentralised control mechanism of the architecture without offering a framework to better understand the complex dynamics – between the technical solution, the meanings and the organisational issues, including the context – through which the architecture evolves.

3.1.4. Architecture, flexibility and agility

It has been argued that because IT systems are embedded in contexts that change over time, flexibility and even agility (the capacity to rapidly adapt to unexpected changes (Sharifi and Zhang, 1999)) are required to help in aligning IT with business strategies or to solve the emergent misfit between IT and organisational imperatives (Braa et al., 2007a; Braa et al.,

2005; Bush et al., 2010; Hirschheim and Klein, 2003; Tiwana and Konsynski, 2010).

Adopting a modular architecture with generic modules and standardised interfaces is therefore a good strategic choice if one wants the system to be flexible and agile enough to fix emerging misfits between IT and continuously changing organisational imperatives (Sabherwal et al., 2003; Tiwana and Konsynski, 2010). Nevertheless, it has been argued that modularity alone is not enough and has to be complemented by decentralised governance (Hanseth and Henningson, 2013; Janssen, 2012; Tiwana and Konsynski, 2010).

Architecture modularity has been defined as “the degree of decomposition of an organization’s IT portfolio into loosely coupled systems that communicate through standardized interfaces” (Tiwana and Konsynski, 2010, p. 290). While modularity is a “continuum describing the degree to which a system’s components can be separated and recombined, and it refers to both the tightness of coupling between components and the degree to which the “rule” of architecture enables (or prohibits) the mixing and matching of components and the degree to which the “rule” of architecture enables (or prohibits) the mixing and matching of components” (Schilling, 2000, p. 312). It has been argued that breaking systems into modules that are linked through standardised interfaces (or standards, see 3.1.6 below) will increase the flexibility of the system since it will allow making changes in one module without disturbing other modules or the entire systems (Hanseth and Lyytinen, 2004; Sanchez and Mahoney, 2002; Tiwana and Konsynski, 2010). It has been also suggested that there is need to black-box modules and only look at their standardised interfaces and visible behaviour (Hanseth et al., 1996), while Janssen (2012) has suggested opening the black boxes. Thus architecting is at least as much about what is in the black boxes as what is between them.

Having a modular architecture alone is not good enough and there is a need to complement modularity with IT governance decentralisation to enhance agility (Hanseth and Henningson, 2013; Tiwana and Konsynski, 2010). In their recent work, Hanseth and Henningson (2013) have even suggested process strategy (bottom-up or top-down, evolution or revolution), governance regime and the architecture itself as tools to manage the evolution of information infrastructure.

In sum, organisations evolve in an ever-changing context. Therefore, there is need for flexibility and agility of the architecture in order to adapt to emerging misfits. Ingredients pertaining to such flexibility and agility are modularity and interoperability, which need to be

complemented by decentralised governance. In addition, flexibility in terms of project management is also important as a small team with limited users can easily make decisions on trying new ideas.

3.1.5. Architecting and Interoperability

According to ISO/IEC 2382-01, interoperability is the “capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units” (ISO/IEC, 1993).

Interoperability has also been defined as the ability for two systems to understand one another and to use the functionality of one another (Pardo et al., 2012; Scholl, 2005). However, for such inter-operation to concretely happen, the systems must exist in the first place and be supported by quality infrastructure (Lanzara, 2013, p. 14).

Consequently, standards are needed to enable interoperability between various systems. However, recent IS research admits interoperability is more than merely technical and providing a standard is not enough to attain interoperability (Chen et al., 2008; Chen et al., 2007; Gottschalk, 2009; Janssen, 2012; Kubicek and Cimander, 2009; Mulley and Nelson, 1999; Papastergiou et al., 2007; Pardo et al., 2012; Scholl, 2005; Scholl and Klischewski, 2007; Sheth, 1999; Veltman, 2001).

For Chen et al. (2008), interoperability “has the meaning of coexistence, autonomy and federated environment, whereas integration refers more to the concepts of coordination, coherence and uniformization.” For example, for Braa and Sahay (2012) in the architecture in Figure 7 below, DHIS2 is interoperable with iHRIS through SDMX-HD standard. DHIS2, which is the statistical and decision support system, can send metadata definitions to the human resource system – iHRIS – that in turn will send aggregated human resource data to DHIS2 according to the metadata definition. While HISP and CapacityPlus – respective networks of actions around DHIS2 and iHRIS – collaborated towards the development of SDMX-HD to make their systems interoperable, as organisations they are still not interoperable. However, the result of this collaboration – SDMX-HD – is instrumental for instantiating interoperability between human resource and HIS department running respectively iHRIS and DHIS2. Without a mutual agreement at the organisational level, the technical solution – technical standard along with DHIS2 and iHRIS – will not make interoperability a reality.

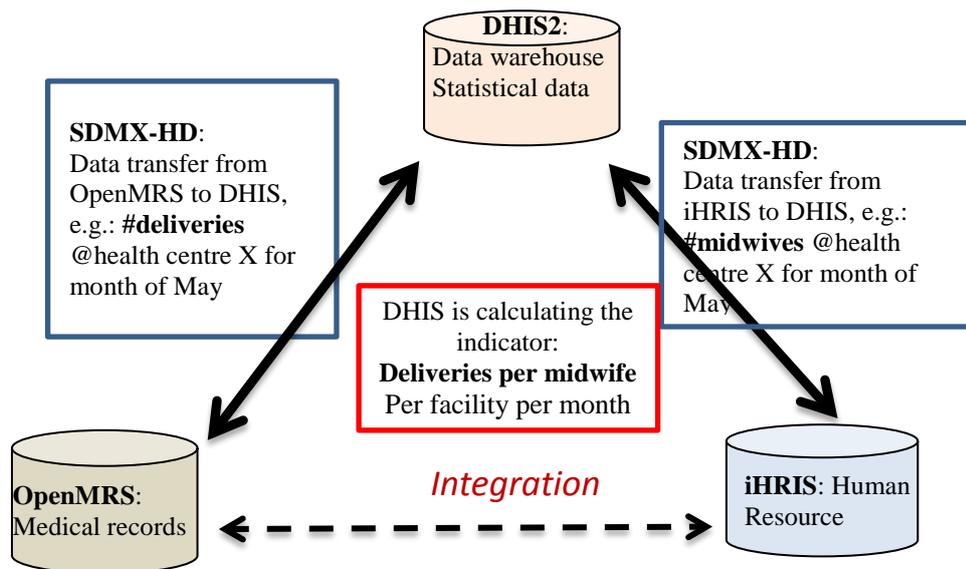


Figure 7: Interoperability between DHIS2 and two transactional systems – OpenMRS and iHRIS – through SDMX-HD standard and integration between these two transactional systems

Many IS researchers have described interoperability as having several levels ranging from purely technical to organisational. Some examples of such modelling are:

- The LISI (level of Information System Interoperability) model is a matrix of four levels (isolated, connected, functional, domain and enterprise) and four attributes (procedures, applications, infrastructure and data). See Computerized Command, Control, Communications, Intelligence, Surveillance and Reconnaissance (C4ISR) architecture framework (1997) for details.
- E-health interoperability framework with three levels: technical, informational and organisational
- The interoperability maturity model proposed by Gottschalk (2009). This model has five levels: computer, process, knowledge, value and goal.
- The European Interoperability framework (2010) with four levels: legal, organisational, semantic and technical, in addition to a cross-cutting political context. Others have conceptualised interoperability as having several dimensions.
- Interoperability framework by Kubicek and Cimander (2009) consisting of technical, syntactic, semantic, and organizational levels.

Table 4: four layers of interoperability by Kubicek and Cimander

Layer of IOP	Aim	Objects	Solutions	State of Knowledge
Technical IOP	Technically secure data transfer	Signals	Protocols of data transfer	Fully developed
Syntactic IOP	Processing of received data	Data	Standardised data exchange formats, e.g., XML	Fully developed
Semantic IOP	Processing and interpretation of received data	Information	Common directories, data keys, ontologies	Theoretically developed, but practical implementation problems
Organizational IOP	Automatic linkage of processes among different systems	Processes (workflow)	Architectural models, standardised process elements (e.g. SOA with WSDL, BPML)	Conceptual clarity still lacking, vague concepts with large scope of interpretation

Regardless of the models, for interoperability to be materialised, it has to be addressed at different boundaries: syntactic, semantic and pragmatic.

Despite the enthusiasm about interoperability, there are rising concerns about unexpected effects as “too much interoperability at a specific level and at a specific time yields undesired consequences at a different level or at later time” (Lanzara, 2013, p. 13). Furthermore, in situations where power is not evenly distributed, collaboration may lead to moves whereby less powerful stakeholders who collaborate are co-opted whereas those who do not are excluded (Hardy and Phillips, 1998). Consequently, involved actors may have different stances toward interoperability – supportive, threatening and both. And these stances evolve over time as the project unfolds (Scholl, 2005). Therefore, technical interoperability is subordinate to organisational interoperability.

In sum, from the different works on interoperability, it emerges that the concept has several layers or boundaries ranging from technical to organisational. These layers too, as for architecture, could be summarised in three boundaries following Carlile’s framework (Carlile, 2004): syntactic, semantic and pragmatic. To collaborate or interoperate, stakeholders should first share that goal, agreeing on what one needs from the other, and how to share information. If interoperability is hailed by recent architecture models such as SOA, there are also some rising concerns about its side effects. First, if it is not complemented with decentralised

governance, there are risks for some less powerful actors to be marginalised. Second, too much interoperability may lead to increased complexity at a different time or at a different level.

3.1.6. Architecting, Standardization & Standards

The word “standard” used as an adjective refers to something that is commonly used, widely accepted or something that conforms to a rule or is appropriate or regular. But what is a standard? A technical standard is an established norm or requirement. It is usually a formal document that establishes criteria to be fulfilled by a product, process or service (ISO/IEC, 2004). Based on the process to which standards are made, three kinds of standards can be distinguished: *de facto*, *de jure* and formal standardisation (Schmidt and Werle, 1998). A *de jure* standard is a standard that has a law-like status and is made by authorised institutions. A formal standard is the one set by a standardisation body such as the International Organization for Standardization (ISO) and the Comité Européen de Normalisation (CEN), to name a few. Finally, *de facto* standard is a standard that is not issued by any of the above standardisers and is imposed by the market, that is, it is widely adopted by the majority of actors and therefore new actors have to adopt it if they want to benefit from services available in the large existing network of adopters. Furthermore, Brunsson and Jacobsson (2002) have defined standards as “...rules about what those who adopt them should do, even if this only involves saying something or designating something in a particular way” (ibid p4). These rules set by a standardiser aim to facilitate necessary co-ordination and co-operation (Brunsson et al., 2012). Brunsson et al. have identified three types of standards: standards about being something, standards for what we do and standards for what we have. Standards about being something classify things in a standardised way. Examples: ICD-10 (2010), the International Statistical Classification of Diseases and Related Health Problems, says what a single spontaneous delivery is in scientific classification. This type of standard also includes measuring such as the metric system. Standards for what we do refers to how individuals or organisations should behave, processes within an organisation, procedures and presentation. The HMN framework for strengthening HIS in developing countries is an example of such. Standards for what we have refers to what people or organisations have or should have. For instance, a modern state should have a constitution. Furthermore, Brunsson and Jacobsson (2002) have identified those who set standards, namely standardisers. Different kinds of actors can create a standard: formal standardisation bodies (ISO), individual (experts, scientist), large corporations, international NGOs and so on. The standardisers, however, do not have hierarchical authority.

Nevertheless, states can issue a standard in a form of law with many optional elements. Regardless of the type of standards and who made them, what is at stake is how these standards are adopted and what their impacts are. The standards are supposed to be voluntary and those who set them have no means or resign to impose them to the adopters. But when by any means a standard becomes widely adopted, it is internalised by adopters and taken for granted. In other words, it becomes a norm and is institutionalised (Brunsson and Jacobsson, 2002, p. 8). However, spreading a standard or getting it widely adopted is costly, so the standard makers often form alliances with more powerful actors to do the job for them.

While standards can be seen as mere rules passively waiting for volunteer adopters, they are instead powerful tools for shaping organisations and altering institutionalised behaviour (Brunsson et al., 2012) (especially standards that have arisen from social movements). HMN frameworks, IHP+ and Paris21 have played and are still playing a role in changing the behaviour of development partners as well as in bringing HIS stakeholders together for improved coordination and collaboration.

A key debate with respect to standards in public health information systems is on how to develop uniformity in an environment that is inherently uneven. Data standards – the shared metadata registry or ontology – in the architecture is seen as a means of enabling aggregation and comparability across geographical entities and actors as data will have the same meaning and will be measuring the same phenomenon evenly. Towards this, the concept of flexible standards is very relevant. A given information infrastructure is comprised of many interdependent standards and the lock-in state of one individual standard may impede the evolution of the whole system (Braa et al., 2007a). Additionally, a given standard may not meet local requirements at different places (Hanseth and Monteiro, 1997c).

The process of standard making - Standardisation

A technical standardisation is good example of the top-down approach that tries to fully detail the specifications. This process of standard making or standardisation, appears “to be anything but technical” (Brunsson and Jacobsson, 2002, p. 9). It is rather the alignment of interests, preferences and trajectories of involved human or non-human actors in the network (Timmermans and Berg, 1997). Standardisation is a heavily political process through which actors involved try to get or assure a strong position or to be a gatekeeper instead of seeking out the best technical solution (Hanseth and Monteiro, 1997a). Standardisation is also a matter of strategy (Funk, 1998; Funk and Methe, 2001) because the one who manages to have his

homemade solution as the standard or whose knowledge will be favoured in the standard will have greater chance to lead in the market and have a sizeable share. Additionally, how the process is conducted also matters. In analysing the GSM standard compared to DoCoMo's standard for mobile phones, Funk (1998) argues that the openness of the process – that is, the possibility of other actors to attend and contribute to the standard making – is critical. For him, the openness of the GSM standard in which most of the key actors in mobile phones telecommunication were involved assured a better diffusion of the GSM standard compared to the closeness of Nippon Telegraph and Telephone (NTT) DoCoMo's standardisation.

The debate on openness of standard setting (technical or non-technical standard) has been taken further by ICT For Development (ICT4D) researchers. They argue that the openness of standard setting or planning implies better participation from stakeholders – foremost users – and a shift from passive consumer view about users to active contributors (Heeks, 2008; Smith et al., 2011). This view is in line with criticism of the normative perspective on ICT which tends to replicate and maintain the status quo of Western domination on the developing world through ICT (Thompson, 2003). Furthermore, it is assumed that openness in ICT4D programming and open access to information is leading to changes in approaches to development. Therefore, the participation of users and beneficiaries and the need for decentralized approach require flexibility, critical thinking and situational awareness to respond to emergent issues (Smith et al., 2011). An interesting 'open development' process, to apply the term coined by Smith et al (2011), is currently being carried out by WHO and partners within the framework of the Health Data Collaborative (<http://www.healthdatacollaborative.org>). Here the aim is to develop open data standards and software based templates for their dissemination by applying the DHIS2 open source software. Data sets and indicators and templates for data use for Disease Surveillance, TB, Malaria and HIV/AIDS are examples of areas being addressed by this global initiative. This development indicates that Open Source Software, Open Standards and eventually Open Data and Open Governance are converging around an Open Development (ibid.) platform. Of course, Open Data, Open Access and Open Governance are not yet a reality, but an interesting area of future research would be to study to what extent open data standards and open source software could become an enabler for open access to public data and transparent open governance of the health sector in particular (as it is our context) and an open government more generally.

Standards and soft regulation

From the organisational perspective, the formally voluntary character of standards has favoured them as the appropriate means for soft regulation (Ahrne and Brunsson, 2005). Because hard laws are subject to resistance, costly and difficult to implement in complex environments, soft regulation through standards is appropriate because they are voluntary, and provide leeway to the follower. “Standard-setting can be described as only ‘half’ a decision, as part of the decision to act in accordance with the rule is postponed and left to prospective rule followers” (Ahrne and Brunsson, 2005, p. 186). Ahrne and Brunsson have defined soft regulation as a situation in which all fundamental characteristics of organisations are not fully used to support organisational rules. The fundamental characteristics refer to organisational membership, management’s right to information, management’s right to issue sanctions and its monopoly at issuing rules, the organisation’s ability to accumulate resources and its structure. Thus, standards are a means for soft regulation that leaves the decision for the prospective follower to adhere to the proposed means for co-ordination and co-operation.

However, standards should not be seen as passive artefacts, waiting for prospective adopters. They do influence and interact with organisations through different mechanisms (Brunsson et al., 2012). First, professionalisation can exert a normative pressure toward the standard. Second, organisations can model themselves on others through mimetic pressure to get legitimacy. They can also adopt a standard for network externalities (Katz and Shapiro, 1986). In both cases, such dynamics can lead to changing or altering institutionalised behaviour (Brunsson et al., 2012). Third, when the adoption of the standard proves difficult, organisations can decouple their talk and action by continuing their old practices and saying they comply with the standard. Fourth, a third party may exert pressure for the adoption of the standard. In sum, standards are a way of organising.

3.1.7. Architecting and Integration

If the word integration nowadays refers to a utilitarian goal of greater efficiency, effectiveness and competitiveness in organisation, the term could mean all things to all people (Wainright and Waring, 2004, p. 329). Nevertheless, in the IS literature, the concept of integration has evolved over time from the narrowly technical perspective to a complex socio-technical one. The desire to integrate different systems in order to have better information and thus better control has often resulted in greater risks and less control. Following the theory of Beck Reflexive modernisation, Hanseth et al. (2006) have shown through the process of integration of information systems in hospitals in Norway that integration may lead to more

fragmentation and less control than expected. From the original intention of having a single large integrated system, where paper would disappear completely, the project has gradually drifted, for several reasons that the founders did not necessarily control, to a portal that included a new system in addition to other existing systems and more use of paper. Through this case, they have showed that the more one seeks to strengthen control by integrating, the more they risk ending up with less control. For them integration produces effects whose consequences cannot be predetermined and that “side effects” may have great consequence and disrupt the entire system or only have limited consequences. Ciborra (2000a) in “A critical review of the literature on the management of corporate information infrastructure” has argued that technology, especially information infrastructures, tend to fail in the sense that they do not provide the desired control and that their use or the final product is often far from what was planned.

The developing countries are no exception to this general trend. Although integration cases are reported in the public sector, they largely follow the trend to failure (Avgerou, 2008).

What is integration?

From the technical perspective, integration was a matter of exchanging information between two systems that were initially not compatible. Thus, integration can be performed through gateways that will allow the communication between the non-compatible systems. It provides potential for solving duplication, non-consistency and improving efficiency and quality (Davenport, 1998). This integration can be achieved either by allowing multiple systems to interact through a gateway or setting up an integrated data repository which will contain data extracted and transformed from different systems. However, the number of failed IS integration projects has challenged that view and led to the strategic approach, where integration is considered a matter of strategic alignment of business, organisational and ICT strategies. Proponents of the strategic view to integration prescribe strategic alignment from top level to implement information infrastructure, in general, and to integrate different subsystems across different units or departments of the organisation. Such an approach is contested because it ignores the natural failure tendency of an information infrastructure (Hanseth and Ciborra, 2007) and the complexity at the micro level of the organisation.

Integration has been described by some researchers (Davenport, 1998; Wainright and Waring, 2004) as belonging to various domains or levels, ranging from the technical to the organisational. Wainright and Waring (2004), in the attempts to give a more complete model

for implementing integrated IS, have identified three domains of integration: i) technical with focus on data, communications, automation, operation, workflow and business process. This domain involves ICT user communities and ICT professional communities. ii) Strategic domain focusing on integration within and across organisations and involving industry leaders, executive management and consultants. iii) Organisational domain with focus on social and political issues and involving organisational actors. They have stressed the importance of adding the organisational domain which is seldom acknowledged by researchers or when they do, it is only considered retrospectively and not proactively.

Without denying the technical dimension of integration, Sahay et al. (2007) have presented integration as a strategy – more precisely a detour strategy. For the authors, IS integration should rather be named “coalition making, building alliances, achieving alignment of interests or mobilization of support”. The authors have used the case studies of HISP implementation in two Indian states (Gujarat and Andhra Pradesh) to emphasise the non-technical aspect of integration, especially the political side of IS integration. For the authors, in the ecology of HIS of the state, DHIS can play different roles but has to position itself as a competitor or collaborator. They argued that both political and technical alliances are necessary for integrating systems. In Gujarat, HISP positioned DHIS as front-end, feeding a GIS system. This legitimised the presence of HISP in the system as it added value to strongly established system. Whereas in Andhra Pradesh, HISP positioned DHIS as back-end, serving like analysis tools. In conclusion, the authors summarise the HISP strategy like a “detour strategy” where HISP presented the integration solution not only as its own solution to its own problem but one that simultaneously solves its competitors’ problems as well. For Sahay et al.(2007), the prerequisite of integration in stark political asymmetries context is flexibility. The small players have to be flexible to stay in the network and compensate its political weakness.

From all these works on integration, I do view it as a vision or goal (Ellingsen and Monteiro, 2008) to seamlessly deliver information or expected services across systems or organisations and as a continuous process of instantiating such vision – that is architecting or having architecture as always being in the making.

Integration, gateway and standard

According to Vernadat (2007) “application integration has often been promised, but so far never satisfactorily achieved. However, IT application interoperability is becoming a reality thanks to recent advances in technology and standards” (Ibid. p137). He argues that tight

application-to-application interfaces have resulted in a monolithic system and are now more and more abandoned. Hanseth et al. (1996, p. 410) corroborate that it is not cost-effective, nor even possible, to use only gateways when a large collection of subsystems are at stake. Standards must be used mostly and combined sometimes with gateways.

3.2. Summary and proposed conceptual framework

The architecture debate has focused on approaches (top-down, bottom-up), models or frameworks, the concept of the architecture (its meanings and sense making), its evolution and needs for flexibility and agility, strategies, the planning of the process of architecture design, types of functional architectures and how architecture evolve over time. In terms of approach, first, the top-down models proposed offer a hierarchical and sequential development as well as careful planning perspective on architecture. Second, the bottom-up approach does oppose such hierarchical view and suggests a pragmatic perspective based on what works. Third, there is an emerging third way which assumes that there have been successful IS from both approaches and therefore factors of successful evolution are rather innovation, adoption and scaling. However, what is lacking is a conceptualization of the characteristics of the processes or mechanisms through which a given architecture gradually evolves successfully in a complex situation where different and autonomous organisations and stakeholders at various levels are in interplay.

While I do fully agree with the bottom-up stance, I also admit that a strictly bottom-up focus may not always lead to successful development of architecture. Therefore, ingenious injections of some top-down elements might increase the potential to succeed.

To offer a better understanding of the dynamic and complex interactions that take place in the process of making architectures and instantiating them in a complex environment, I suggest a bottom-up architecting framework. This framework firstly uses a verb – architecting – instead of a noun to emphasise the architecture in the making – the process – and the two-way interaction between the plan and the reality. This choice also echoes a general trend in the literature to emphasise the process and emergent nature of a phenomenon. The verb contexting (Asdal and Moser, 2012) has been used to refer to the performative nature of a context and not as a passive reality. Braa and Sahay (2012) have also used the verb designing instead of design to stress the process dimension and its emergent and situated nature (Gero, 1998). In addition, the verb architecting forefronts the issues of process, multiplicity, emergence and drift in contrast to other alternative such as Information Infrastructure, which

is seen maybe mistakenly as a physical infrastructure. Secondly, it is developed from a network of concepts such as architecture, bottom-up and top-down, standards and interoperability. In developing the framework I propose, Carlile's integrative framework (Carlile, 2004) and networks of action (Braa et al., 2004) have been used as scaffolding devices (Walsham, 1995).

Herein, the term bottom-up tries to emphasise the evolutionary approach with user participation, without excluding backing or initiatives from the top. While a bottom-up approach is advisable to successfully develop and implement a system in one place, a top-down approach might be helpful to get it to scale in geography. The only requirement for the intermittent top-down phases is to be broad enough to release local potentials. For example, a bottom-up approach would be required to successfully develop a pilot in one district. However a top-down approach might be needed to shift from one district to countrywide adoption and implementation or from one country to another. Therefore, architecting is a bottom-up zebra with top-down stripes. This process can start with any of the approaches.

In bottom-up architecting, a single stakeholder does not control it. By nature, architecting is connecting boxes with arrows, except the fact is that in this context, the boxes are not passive or neutral objects to drag and connect at will. Instead, they are complex systems or even networks of actions with their interests and paths. Thus, architecting requires a continuous effort to hold components together and grow the collection. A key player influencing the dynamics of the boxes in bottom-up architecting are standards and soft regulations. Be it technical or not, a standard is not merely a passive object waiting for adoption. It directly and indirectly shapes the way networks of actions are aligned in the architecture.

I adopt Carlile's integrative framework (see 2.6 Data analysis) to unpack the boundaries of architecting as well as their corresponding processes. I use this framework to conceptualise architecting as a continuous multidimensional process which has three boundaries – syntactic, semantic and pragmatic – and three corresponding processes – transfer, translation and transformation. At the syntactic boundary, there are technical issues such as network architecture, hardware, security protocols, technical standards, software, data, etc. At the semantic boundary, a common lexicon is agreed upon to enable data sharing at the syntactic boundary. At the pragmatic boundary, there are organisational issues such as politics, governance, vision, leadership, alignment of interest, etc. The pragmatic boundary is a cumulative capability boundary where syntactic, semantic and pragmatic capabilities are

required to successfully align interests of stakeholders to keep the architecture growing. This alignment could not be achieved in one try. Iterations, trial-and-error, might be required. Through these iterations, stakeholders get better in working with others and improve their ability to negotiate. This capability further translates into more capacity for further alignment. Thus, the evolution of the architecture is not only by design. However, the dynamics across and the interplays between the boundaries that shape architecting remain unanswered questions to investigate further in my fieldwork.

Chapter 4 - The cases

The empirical context of this research comprises 3 West African countries – Sierra Leone, Burkina Faso and The Gambia – as well as Malawi, where I have been involved in the process of architecting their HIS. Additionally, I focus on WAHO (West African Health Organization), a regional health organisation for West African countries. In all the cases, with the exception of WAHO, the HMN framework – including HMN HIS architecture – has been adopted and DHIS2 has been used as a data warehouse throughout the evolution of the HIS architecture, from statistical domain to transactional applications. Figure 8 shows the HIS architecture proposed in HMN frameworks adopted by countries.

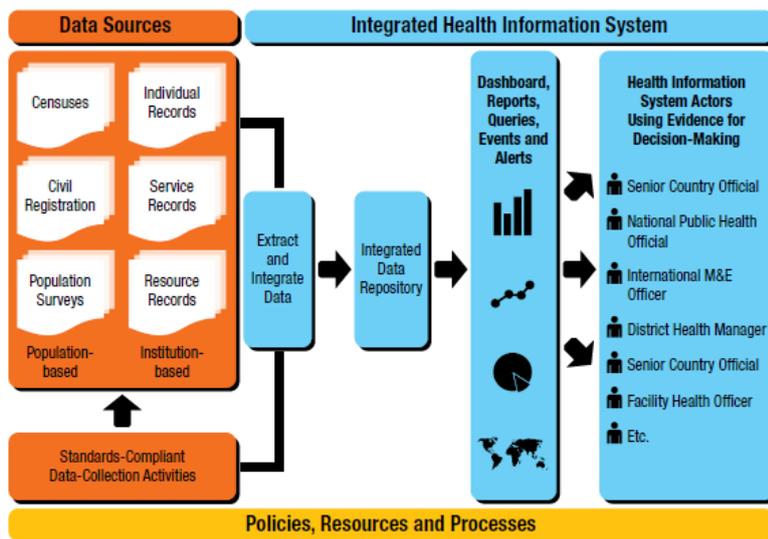


Figure 8: HMN architecture

This chapter presents the cases in chronological order as things took place from one country to another and from the country level to the regional level, in West Africa. The chapter closes with a summary of the cases.

4.1. Sierra Leone

Iterative integration of parallel HISs

When the process started in 2007 in Sierra Leone, the stakeholders were sceptical if not reluctant about integration because previous attempts at integration had imposed a minimalist indicator dataset on them. This minimalist approach only considers a small set of indicators that are far from covering the information needs of all stakeholders. Subsequently, the stakeholders became very protective and attached to their data reporting forms. The initial aim was to merely demonstrate a technical integration between two systems. However, after

consulting the MoH and other stakeholders in the field, a decision was made to turn the concern other way around. Instead of focusing on the integration between two applications and merely focusing on HIV/AIDS data, we decided to start from the needs of quality health information for decision making and extend this integration project to the whole HIS framework to leverage government and donor's efforts. This decision prompted the following reaction from the officer in charge of the project at global level:

“Unfortunately there do seem to be some misunderstandings about what was proposed. Our primary interest was showing aggregated clinical data from facilities imported into CRIS. Since CRIS is present in all 14 Districts in Sierra Leone, we hoped to demonstrate seamless flow of data from the facility to national and international levels, perhaps writing it up for publication. We also have a similar collaboration starting with the WHO OpenMRS and hope to show this type of integration working soon.”

The project technical team, composed of HISP members and representative of the HIS unit of MoH, decided to start working on the technical integration of reporting forms into a DHIS2 data warehouse. Duplication and overlaps of data were only solved at the database level, while keeping the forms as they were in the field. The solution was not perfect, but it had the merit of putting together all data in a better way. The system was implemented countrywide as distributed standalone instances by late 2008, after a pilot phase in six districts.

In 2009, after documenting problems related to uncoordinated and overlapping reporting forms, stakeholders agreed to adopt harmonised metadata documents and forms. This process yielded a set of modular and coherent forms to solve the problem of plethoric, overlapping and sometime duplicated reporting forms. All the data needs of stakeholders were addressed in the new forms, which were later implemented in DHIS2. Gradually, the few stakeholders who were initially sceptical joined the system. Later that year, HMN proclaimed the project and the architecting approach as a successful case and disseminated it in its large network of countries and development partners.



Figure 9: an HIS officer using DHIS2 to manage data from various sources in Moyamba district.

In the two iterations of the architecting process, the architecture always had the following characteristics. At the syntactic boundary, there were numerous reporting forms (first iteration) and coherent modular forms (second iteration). At the semantic boundary and in the first iteration, stakeholders' metadata were just put together and some elements were translated in the data warehouse to avoid duplication. In the second iteration, a modular and coordinated metadata documents were developed. At the pragmatic boundary, in the two iterations, there were autonomous and heterogeneous stakeholders cooperating, but with different information needs.

Downward evolution of the HIS architecture driven by concrete needs and opportunities

The downward evolution of the architecture in the country, that is, the expansion of the architecture to transactional system, was driven by a series of opportunities in 2010.

The first opportunity was the announcement of free maternal health care. In 2010, the government decided to launch free maternal health service for all in the country, to address maternal deaths, as well as one of the key achievements to mention while celebrating the 50 years of independence in 2011. Obviously, the government wanted to monitor the implementation of such a policy, which increased the demand for information. However, one of the unintended effects of such a good policy was the strike of health workers who suddenly wanted better salaries. Due to low salaries in government, health professionals did not like working for the government, and those working in public facilities improved their income by

illegally charging patients extra fees. These employees were therefore very worried about the free service policy, since it meant reducing their possibility to charge patients. Eventually, the government doubled health professionals' salaries. Subsequently, a need for a human resource system to effectively manage these health workers emerged.

The second opportunity was the development, in that same year, by WAHO and CapacityPlus of a regional project to implement the integrated Human Resource Information System (iHRIS) in West African countries, where Sierra Leone was selected as a pilot country.

The third opportunity was the development of the SDMX-HD standard initiated by the WHO. HISP joined the process as well as OpenMRS and CapacityPlus. Because the implementation of DHIS2 was seen as a success, it was not difficult to convince the SDMX-HD team to use it as a use case. For CapacityPlus and OpenMRS, expanding the HIS architecture with their systems provided network externalities not only in Sierra Leone but also elsewhere.

OpenMRS and iHRIS were therefore later deployed in Sierra Leone as pilot in order to test the standard. The release of the standard a few months later allowed the country to have an interoperable architecture in which transactional systems such OpenMRS and iHRIS were able to electronically exchange data and provide better quality information to DHIS2, as a decision support system.

This expanded architecture exhibits heterogeneity at the pragmatic boundary and distributed semantics with a shared core at the semantic boundary. At the syntactic boundary, there were heterogeneous and autonomous software applications, yet interoperable.

4.2. The Gambia

Iterative Integration of parallel HISs

The first iteration started in 2008 with negotiations among stakeholders, to harmonise the HIS at the pragmatic boundary. The negotiations translated into a monolithic and minimal indicator list and a monolithic reporting form. Many stakeholders' data needs were left out of the system. These tools were later managed in Excel sheets. However, after the echo of DHIS2 in the neighbouring Sierra Leone, The Gambia decided to adopt DHIS2 and invited HISP for its implementation. The harmonised tools were developed in DHIS2 and the system was deployed in a distributed manner similarly to Sierra Leone because of the lack of internet connectivity. The resulting architecture was characterised by autonomy and heterogeneity at

the pragmatic boundary, by monolithic and minimal metadata at the semantic boundary, and by a monolithic reporting tool integrated in DHIS2. The inherent problem with such an approach is that it requires a heavy process of negotiating the minimum list and often a strong political backing to impose them.

Second iteration: as the new needs emerged, the HIS unit was unable to regularly conduct new rounds of negotiations and develop new tools accordingly. Developing new tools entails printing new forms and most importantly training health workers in all health facilities across the country on how to fill them. Subsequently, the stakeholders used this as a pretext to develop their own additional tools with their own parallel software. By 2012, it became clear to the HIS unit that their approach had failed and they decided to change their strategies. They started to integrate unilaterally all the forms used by stakeholders and deployed DHIS2 online because internet connectivity had substantially improved in the country. The duplications and overlaps were solved only in the database. These efforts have been convincing, as stakeholders have adhered to the new system with the assurance that they will have direct access and some administrative rights on their own data. The change at the syntactic boundary mediated the alignment at the pragmatic boundary, and by 2013, nearly all stakeholders were using the integrated HIS. The new architecture has autonomy and heterogeneity at the pragmatic, semantic and syntactic boundaries. Nevertheless, there is still some reluctances as shown in this note from a meeting with a program management team:

EPI prefers getting hard copies of national standard form at its headquarter for data input and management in their own system named DVD MT while the overwhelmed regional HMIS staff is also entering the same data into DHIS2...

For them this parallel reporting is motivated by the need to report on time to WHO and partners. We suggested they use their resources to do data entry in DHIS2 for the benefit of the entire system while at the same time they will also get their report on time. But they were not open to this idea and argued they cannot shift from their systems to DHIS2 without WHO approval.

4.3. Malawi

Iterative integration of parallel HISs

In 2002, Malawi had implemented a monolithic and minimalistic reporting tool in DHIS1.3, as had been implemented in The Gambia. However, this gradually proved ineffective as changes in requirements were arising. In addition, the Central Monitoring and Evaluation Division (CMED) of the MoH, which has oversight of the national HIS, lacked the capacity to

negotiate the tension between changes in requirements and the need for this minimal dataset. The HIS became gradually fragmented.

In 2009, Malawi adopted HMN framework and DHIS2. This time, the country adopted the approach that had been used in Sierra Leone and let the programs autonomous while trying to bring them together around a DHIS2 data warehouse. However, we had to spend time convincing stakeholder and providing answers to their concerns.

“We can’t go to pilot when funds for national roll-out have not been identified... I don’t believe in piloting and stopping... The on the fly validation feature needs to be implemented because it is critical and its absence could lead to very poor data quality and it may take a lot more time to clean and validate data... We will have to run the two systems in parallel since DHIS2 cannot meet these requirements on data validation” A stakeholder during one of our meetings.

After a stepwise development and testing, DHIS2 was finally implemented in Lilongwe district for piloting by the end of 2010. In 2012, it was deployed countrywide as an online web-based system. The resulting architecture then exhibited the same characteristics at syntactic, semantic and pragmatic boundaries as in Sierra Leone. Nevertheless, despite this coherence, internet connectivity issues are still hampering the use of the system.

The overall HIS architecture

In the overall architecture, beside DHIS2, there are two main Electronic Medical Records systems providers: Baobab and Luke International Norway (LIN), who have been working in Malawi since 2002.

To achieve HMN integration vision, CMED and other stakeholders took the lead in 2008 to establish a national data standards group, which is a collaborative framework to engage stakeholders in on-going planning and implementation of the health information infrastructure. The national data standards group aims to build consensus on HIS policies, integrated HIS, appropriate standards, interoperability and promotion of innovative and scalable solutions. In sum, the data standards group is responsible for developing a more coherent, effective HIS architecture. Although the data standards group has never issued any

technical standards or architecture, it acts as an arena to revive the vision of integration, negotiation and putting pressure on systems to integrate. By the time SDMX-HD was released in 2010, there was already a readiness at the organisational boundary (or pragmatic boundary) for interoperability. Subsequently, Baobab and LIN have undertaken efforts to integrate their systems with DHIS2 and decided to collaborate in implementing SDMX-HD. Because the data standards group has levelled the field for integration, the department of human resource contacted the HIS unit for collaboration and integration when it decided to implement iHRIS.

4.4. Burkina Faso

Integration of parallel HISs

The integration process started as in The Gambia with a harmonisation process at the pragmatic boundary. This process yielded monolithic and maximalist reporting forms and metadata documents. In fact, the Health Management Information System (HMIS) unit wanted to develop a monolithic tool that would encompass all stakeholders' needs. All stakeholders were invited and took part in the development of such all-encompassing reporting tools. Unfortunately, despite their involvement, the stakeholders kept using their own reporting tools. The monolithic reporting forms were implemented in DHIS2 from 2011 to 2012. In 2013, DHIS2 was deployed as a centralised online server. At the syntactic and semantic boundaries, all stakeholders' needs were covered through maximalist and monolithic reporting forms and metadata documents, whereas at the pragmatic boundary, there was heterogeneity and autonomy.

After deployment, the HIS unit realised that the health programs were unwilling to join its supposedly integrated HIS.

“The use of the new reporting tools developed on DHIS2 will be problematic as the programmes are not willing to abandon their own reporting forms in favour of the new ones” said one district health officer

The HIS unit then changed its strategy and wanted to demonstrate first that it is possible to pursue its own path while working together with others. Therefore, it started to collaborate with NGOs and small health programs to integrate their reporting tools in addition to the all-encompassing tools.

As far as the overall HIS is concerned, when the head of directorate of information systems of the Ministry of Health was asked about the future plan for iHRIS after the demonstration of SDMX-HD, he replied:

“Right now the hot potato we have at hand is DHIS2. Let get it up and running first and later on we can talk about iHRIS”.

And the country has so far not implemented iHRIS nor OpenMRS.

4.5. West African Health Organization (WAHO)



Figure 10: ECOWAS

WAHO is a specialised health agency for the Economic Community of West African States (ECOWAS). See WAHO (2009) for details.

WAHO has a political mandate, which means its decisions are binding on the member countries of ECOWAS. WAHO can make regional health policies and provide technical support to their implementation, including support related to HIS. WAHO has its own regional HIS based on an in-house package. This system focuses primarily on communicable diseases, maternal and child health, hospitals and human resources. The system was intended to be integrated and used by the West African countries, but unfortunately it adopted a classic top-down approach that ended in failure. At WAHO, the designers opted for a minimalist approach of key indicators and left the various professionals' information needs unsatisfied. These professionals have therefore maintained their traditional reporting systems. Vis-à-vis countries, the process was not participatory and the regional HIS came as an additional tool that required both additional learning and data collection efforts. In addition, some countries have found the information requested by WAHO as ambiguous at times. Consequently, few reports, with often less than 50% of the required data, reached WAHO. This hampers the aim

of WAHO to provide health information for all in the sub-region. As said one officer at WAHO during an interview in December 2011:

“The security of the personnel is part of my responsibility including risk of epidemics. But to get epidemiological information about a country, I have to contact early warning system in Abuja or through informal contacts.”

In 2010, WAHO undertook to provide technical support to countries to implement an Integrated Human Resource Information System (iHRIS) in collaboration with CapacityPlus – the developer of iHRIS. They selected Sierra Leone and four other West African countries as pilot sites. Later on, WAHO, CapacityPlus and HISP decided to work together in various domains. On the one hand, CapacityPlus joined HISP and others in the SDMX-HD development efforts led by WHO. On the other hand, HISP joined WAHO’s official partners circle.

Having seen the progress made by HISP in national HISs, WAHO decided to develop a regional HIS policy to promote interoperable HIS architecture and provide a framework for HIS strengthening activities in the region. This mission was entrusted to HISP, who developed the policy in collaboration with stakeholders (country and regional stakeholders).

On the technical side, WAHO felt it could build a regional system on top of the autonomous national HISs as there were an increasing number of countries using the same DHIS2 platform. In fact, DHIS2 became a de facto platform for statistical health data management in the region (at that time, eight countries out of 15 had already adopted DHIS2 and four others were about to adopt it). Subsequently, WAHO adopted DHIS2 in 2013 as a regional data warehouse for managing health data coming from the involved countries, as well as across its different health programs and departments. A minimal list of indicators was defined and implemented in the regional system along with other health programs’ data. Six countries – Ghana, Guinea Bissau, The Gambia, Liberia, Nigeria and Burkina Faso – were selected to be part of the pilot phase before gradually expanding the process to other countries. WAHO believes that since these countries are already using DHIS2, it would be technically easier to implement a regional dataset into a country database and export electronically required data to the regional database without any additional effort, as was the case with the previous system. However, in 2013, with the start of a regional project to strengthen epidemic-prone disease reporting, HISP convinced WAHO that it is better to focus on already-established epidemic

reporting to show immediate usefulness while gradually establishing the reporting for the key indicator list. When the Ebola outbreak was declared in early 2014, the regional HIS was ready and has been used for monitoring it. This new architecture exhibits heterogeneity and autonomy at the pragmatic and the syntactic boundaries. However, at the semantic boundary, there are still some challenges, especially with regard to metadata and the definition of epidemic thresholds. In fact, the countries have different thresholds for the same epidemic-prone disease. Subsequently, the same number of cases or the same incidence rate of a given disease in two neighbouring districts from different countries may be regarded as an epidemic situation in one, but not the other. There are also challenges regarding what to do with data pulled from country databases, where the data has not yet been approved by a country.

Chapter 5 - Summary of findings

This research started in Sierra Leone with the focus on integrating parallel systems. However, as the project unfolds and by iteratively reflecting on our actions, I noticed that integration is both a goal – or an end – and a process. And architecting is the process dimension of integration. What we have been doing is organising a system of systems to achieve integration. Thus our strategy toward achievement of integration is bottom-up architecting. Subsequently, the focus in my papers has shifted from integration to architecting, which is in fact our journey to integration in this research.

In the following subsections, I provide a summary of the accepted conference and journal papers I have written in the context of this thesis and which are included in this theses.

5.1. Integrating health information system in Sierra Leone

This paper is about the first steps of the project in Sierra Leone. It focuses on the dynamics in the participatory and evolutionary development of an integrated health information system in the country, in contrast with previous top-down and static integration approaches that had led to more fragmentation. After a long civil war, most public services and infrastructures – power grid, internet, and roads – were ravaged and the challenges were many. Supporting infrastructure for the HIS, software, equipment, tools, and qualified human capacity as well as financial resources, all critical for the success of the project, were all lacking. Different health programs each had their own reporting systems and health programs were persuaded to keep the plethora of data they had been collecting despite the fact that the reporting forms contained overlapping information and most data collected remained unused. Previous attempts to integrate the HIS were not satisfactory and unable to cope with the constantly changing environment of HIS. Subsequently, the purported integrated system turned out to be one of the many fragmented systems because the various programs kept their own systems.

This paper firstly presents how different alliances were made with different networks such as Inveneo for low power hardware expertise, MoH for its legitimacy as well as domain and context expertise, HMN for its expertise in HIS, a regional IT company, IDC, for its closeness and expertise in HIS and Open source, and HISP for its expertise in HIS and software development. While Inveneo dealt with deploying low power hardware to cope with lack of power supplies and installing an open source OS on these computers (to avoid damages related to viruses or local “Microsoft experts” for whom the only solution for any problems is

to format), MoH, HISP, the WHO and IDC had been addressing remaining issues such as designing the system, piloting it and building capacity.

As far as the system is concerned, the HISP team adopted a participatory and evolutionary development approach. A prototype was developed first to enable users' understanding and active participation. After demonstrating the prototype, many of the reluctant programs understood they could benefit from the proposed system while pursuing their own path. However, they were not ready to accept changes in their reporting forms. To avoid a backbreaking, lengthy and heavy political process of harmonisation of reporting tools of programs, the project team instead focused on sorting the mess behind the scene by identifying and removing duplication in the database while keeping the forms as they were. With this approach, programs were happy because their tools were not changed, and the HIS officers doing data entry were happy because there was no longer any need to enter the same data several times into different forms, as it would automatically appear once the information is entered via another form.

The active participation of both users and stakeholders helped the implementation team through several loops of feedback and feed forward to gradually develop the system as they want it. Emerging needs and specific requirements – although they sometimes clashed with the generic and customisable solution philosophy of the DHIS2 development team – have helped improved DHIS2 as global software by providing a rich insight to the use case. The flexibility of DHIS2, both in terms of use (distributed implementation because of lack of internet) and change (to adapt to new data requirement such as future harmonized tools) was presented as instrumental.

Without mentioning the Carlile integrative framework, the paper discusses how an initial step addressing a technical problem was able to bring together different actors with different interests who mediated the move to the next step: harmonisation of reporting tools. The technical problem solving, although not the ideal solution, was good enough to satisfy stakeholders and bring them together to share the same HIS as a platform. By bringing all reporting systems together without restriction, it became gradually easier for stakeholders to see any gaps and weaknesses of the system and acknowledge the need for revision and harmonisation of tools.

5.2. Comparing strategies to integrate health information systems following a data warehouse approach in four countries

This paper is about comparing integration strategies following a data warehouse approach to integrating vertical health systems in four developing countries: South Africa, Botswana, Zanzibar and Sierra Leone. The different facets of integration – political, organisational and technical – and their interplay are explored through the four longitudinal case studies in which different versions of DHIS have been used.

In South Africa in 1996, DHIS was developed as a technical solution to solve a problem at hand in the Western Cape province. The instant success of DHIS attracted other provinces and it gradually became a national data management system around which actors later agreed to implement minimum datasets with the hierarchy of standards policy allowing each level in the system to add their own data as long as data required by upper levels were kept. In Botswana, due to the lack of political support and ability to negotiate, each actor wanted to keep their overlapping and duplicated data in the data warehouse. This led to the computerisation of the mess with same data elements having different figures. Subsequently, although this technical solution permitted the kick-off of the project, it was not useful enough to trigger further steps toward integration. In 2005 in Zanzibar, thanks to strong political and financial backing, the integration process started first with harmonisation of reporting tools and later on, the harmonised forms were implemented in DHIS. However, actors meet every year to revise the forms and changes are reflected in DHIS. In 2007 in Sierra Leone, the approach to integration was a stepwise process starting from just addressing duplications and overlaps in the database while keeping the forms as they are. In so doing, the project showed that integration through data warehouse was possible and has convincingly documented problems with the current reporting tools. This learning process has sparked interests in working together and revising the tools.

The four cases were analysed following an integrative framework by Carlile – knowledge integration framework – and consisted of three boundaries with three corresponding and increasingly complex processes: transfer process at the syntactic boundary, translation at the semantic boundary and transformation at the pragmatic boundary. A fourth dimension – iteration – has been added to the framework. In Sierra Leone, for instance, the integration process started at the technical level or the syntactic boundary with a technical solution that served as boundary object to enabled communication, sharing and agreement across the

boundaries. The process started at the syntactic boundary with the adoption of a technical solution for managing and sharing data (transfer), followed by defining common lexicon and sorting inconsistencies behind the scene in database (translation). After one year, the actors eventually agreed to revise and harmonise the reporting tools (transformation). They also agreed to meet regularly to revise reporting forms according to emerging needs (iteration). In Zanzibar, the strong political backing allows them to start at the pragmatic boundary with the harmonisation of reporting tools before successfully moving down to simpler boundaries – semantic and syntactic – and the iteration of revision of forms. In Botswana, however, the same technical solution DHIS has failed to translate into a useful system that will facilitate further processes at further boundaries and has led to the failure of the integration process.

The main finding of this paper is that integration has technical and non-technical dimensions that shape the system. The technical solution should be deeply rooted in the organisational and institutional context and also serve as a boundary object to mediate further steps of integration. At the same time, the context also shapes from the outset the technical solution that will be designed and implemented. In addition, the paper shows how one flexible tool – DHIS2 in Sierra Leone and DHIS 1 in the remaining cases – served as attractor to align different health programs and how changes at global and country levels – setting of MDG, establishment of HMN to build legitimacy for integration approach and better information, PARIS21 for better statistics, IHP+ to harmonise aid agencies and align them with national systems – can interplay with the attractor to increase the resulting attracting force.

The relevant aspect with regard to architecting is that the four countries – all pursuing the same vision of integration or an architecture that integrates all vertical health systems, and all using the same data warehouse approach – have all experienced different strategies and fates.

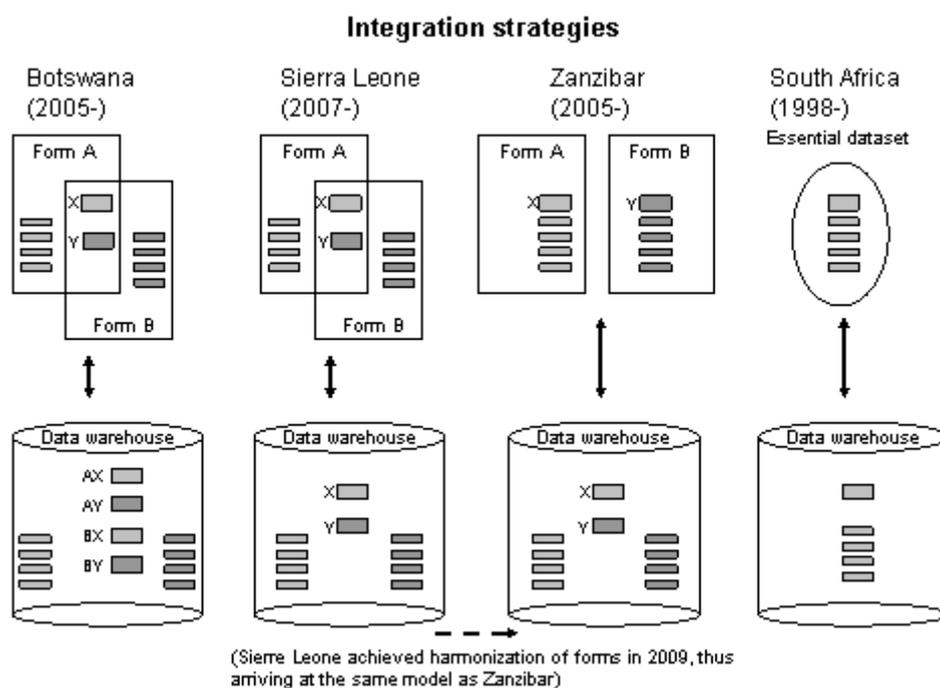


Figure 11: comparing integration strategies in 4 countries

5.3. Developing Integrated National Health Information Systems in Malawi: Oriented emergence of flexible architecture

This article explores how political will and conjectures contribute to the emergence of an integrated HIS architecture in a context characterised by heterogeneous, strong and autonomous subsystems, lack of resources for technical standardisation and steadily evolving needs. It focuses on two processes with regards to HIS architecture in Malawi: a) incremental integration of vertical health systems into one data warehouse, and b) the interoperability of the data warehouse with transactional systems.

In 2009 in Malawi, and in response to the failure of the integration of vertical systems following the minimum dataset approach, the Data Standard Group (DSG) decided to adopt the HMN framework and implement an integrated HIS following the data warehouse approach. DSG is a group of HIS stakeholders in the country with the aim of overseeing HIS strengthening efforts and promoting integrated architecture. It is also the arena for high level negotiation and consensus building regarding HIS. A piecemeal approach to integrating vertical health systems was adopted and the process started with the Health Management Information System, the HIV/AIDS reporting system and the EPI reporting system.

As far as the overall HIS is concerned, it is composed of transactional systems such as patient record systems, human resource management systems, logistic management systems, Census and surveys at the National Statistics Office, etc. For the patient record systems, there are two main competing actors well established in the country – the Baobab system and Luke International Norway (LIN) – and the DSG did not want to favour any of them. In order to integrate these subsystems, the DSG only had a broad picture of the integrated architecture with the transactional system exchanging data with the backbone system – DHIS2 – and all vertical statistical reporting systems directly integrated in the data warehouse. However, the DSG lacks skills and resource to define a technical standard, but has utterly made clear its will for open standards to ensure interoperability. While the DSG was longing for an open standard, each of the patient records actors was developing a gateway to exchange data with the DHIS2 without being stopped by the DSG. Eventually in 2010, the successful testing and launch of Statistical Data and Metadata Exchange for Health Domain (SDMX-HD) filled in the missing link in the overall architecture.

The main findings of this paper are twofold. First integration is a rather dynamic process, and a “one size fits all” approach combined with a static process of integration could not work. Integrating several vertical routine systems is a stepwise process with iterative negotiation and entails both technical and non-technical issues. Second, architecting the overall HIS requires political will and resources. And in this case, the DSG is the arena for negotiation and has a strong will to achieve integrated HIS architecture despite the lack of resources to set standards for interoperability between transactional systems and DHIS2. However, the strong and openly stated will for open standard and interoperability has created awareness and has influenced the emergence of the overall HIS architecture for which the development of SDMX-HD was a good conjuncture.

Another aspect of the paper relevant to architecting is that IS is emergent, and instead of looking for a perfect system promised by the top-down approach, it is better to just try to positively influence the architecture and get a working system that represents a trade-off between the ideal system and local constraints.

5.4. Networks of Networks – Collaborative efforts to develop health information systems across developing countries

Drawing on concepts of networks of action and attractor, this paper presents, through HIS strengthening dynamics in West Africa, how networks are aligned around an attractor or to create it and the synergistic effects when networks are aligned in a network.

In Sierra Leone, HMN, a network comprising organisations, countries and individuals, is a global actor with legitimacy in HIS-strengthening policies. It wanted generic and flexible open source software to implement as data warehouse and in 2007, contracted HISP, the second network. HISP/DHIS2 is a network for HIS research and open source software development and implementation. In 2009, DHIS2 implementation in Sierra Leone was declared a success story by HMN. By making visible the success in Sierra Leone, HISP/DHIS2 became more attractive to other countries in the region which started to implement DHIS2. In late 2009, the WHO initiated the development of the Standard for Data and Metadata Exchange for Health Domain (SDMX-HD). HMN and HISP decided to push this forward and successfully implement the standard in software applications planned in Sierra Leone HIS architecture, namely DHIS2 and OpenMRS – a medical record system which was installed in one hospital to track Anti-Retroviral Therapy (ART) clients. Open MRS was thus able to export aggregate data from patients' records to DHIS2 for management and planning purposes at facility, district and national levels. A third network, CapacityPlus, a partner of HISP and HMN, comprises open source software developers and implementers, human resource professional, organisations and countries implementing their integrated Human Resource Information System (iHRIS). By 2010, CapacityPlus was implementing SDMX-HD and was collaborating with the West African Health Organization (WAHO) to implement iHRIS in several countries. CapacityPlus has its legitimacy in Human Resources for Health. In May 2010, CapacityPlus has mediated the linking of HISP, HMN and the WAHO as Sierra Leone HIS architecture was being expanded to encompass iHRIS. Following this linking, the WAHO (another network, comprises West African countries, HIS units in countries and individuals.) invited HMN to discuss the expansion of Sierra Leone architecture. In September 2010, in a joint conference organised by these networks, SDMX-HD was launched and interoperability has been demonstrated between DHIS2, OpenMRS, iHRIS and the WHO Indicator Measurement Registry (IMR) in the presence of country HIS leadership. The architecture became very attractive and the involved countries started

requesting support from HISP and CapacityPlus for the implementation of their respective systems.

The main findings of this paper are threefold. First, aligning networks in a network is a win-win process in which the emerging added value is greater than the sum of values of individual networks. Implementing sustainable systems required backing for users in the bottom, but also buy-ins from national and even regional and global levels. HMN and the WHO's backing opened the door for HISP in Sierra Leone through national backing. HISP's work on the ground helped create local legitimacy through success, which in turn benefited individual networks. Second, an attractor is crucial in aligning networks and networks that align to the attractor or to form it, gain in strength and legitimacy. The showcasing of the success in Sierra Leone was a political attractor which reinforced HMN legitimacy to raise more funds and made DHIS2 a technical attractor for other countries. The development of SDMX-HD and its testing in the setting of Sierra Leone using DHIS2 has contributed to creating another technical attractor which has come as a force to hold subsystems around the data repository as recommended in the HMN standard framework for HIS. From the alignment of networks of the WHO, HMN, the WAHO, HISP/DHIS2, CapacityPlus and OpenMRS around SDMX-HD, a stronger attractor and network was created. SDMX-HD has changed HIS architecture to a flexible network of networks in which a network can be plugged or unplugged. Third, the successful alignment of these networks was not by design or documented plan but rather a directional improvisation strategy based on doing bricolage to achieve a vision. To achieve this, HISP has developed the principle of AAA: Awake, Alert and Agile. Awake refers to being present in situations in which opportunities might arise. Alert encompasses being alive to different possibilities that exist given the conditions and use experience and understanding to make choices. Agile means being able to act quickly and decisively. The last element of this strategy is the understanding of architecture or architecting as a networking process in which not only technical artefacts are connected, but also networks with resulting synergies.

5.5. Developing decentralised health information systems in developing countries – cases from Sierra Leone and Kenya

This paper looks at strategies to develop and nurture a decentralised and bottom-up HIS and the role of communities in in this processes in developing countries.

Sierra Leone was selected in 2007 along with four other countries as HMN pilot countries for HIS strengthening efforts because it had the highest maternal death rate in the world. In order to design and implement the HIS following an integrated data warehouse approach and enable stakeholder participation, a prototype based on DHIS2 and encompassing immunisation, population and human resource data was developed. The stakeholders thus quickly understood the potential of the system and agreed to set up a national technical team comprising representatives from different health programs and the like and from different levels: facility, district and national. During the development, district representatives drew attention to the focus on information use so that non-health administrative units such as chiefdoms and local councils would be taken into account. Although DHIS2 is a web-based system, it was decided that it should be deployed as a replicated system in each district because of the lack of internet connectivity. After the piloting and countrywide roll out of the system, the project team decided to develop and regularly publish a HIS quarterly bulletin to be disseminated to all stakeholders. In addition, a district league table was established to rank districts transparently on selected key indicators that represent major issues such as maternal death, immunisation and reporting rate. The combination of these two initiatives has sparked actions from districts down to communities. The Western area district (the capital) was ranked very low in the first district league and its district health team has decided to both foster reporting from private facilities and make maternal health services free in the district. Subsequently, delivery rates at facilities grew steadily in the following month. The league principle has been adopted in many other districts to compare chiefdoms' performances. These leagues tables are shared in district review meetings where paramount chiefs and communities are represented. By knowing their rank and health service performance compared with others, community leaders were able, for instance, to take measures to stop home delivery and create better conditions for facility delivery.

In Kenya, the same distributed implementation of DHIS2 was planned, but the project team inadvertently discovered in one remote district that mobile internet in the country was good enough to remotely access dhis2 online.

The key findings are that a) there are dynamics at different boundaries of the architecture and the IS has emerged gradually and through iterations, and is shaped by the local context. Both in Sierra Leone and Kenya, integration was the goal and the design was centred on use of information and users. In so doing, local potentials were released and an innovative system has emerged. Lack of internet availability has imposed a distributed deployment of DHIS2 in Sierra Leone, making communities rely on the district health office to get information while the availability of mobile internet made it possible to host DHIS2 in the cloud and get communities to feel empowered because they can now have access to their data regardless of where they are. In addition, constraints related to internet connectivity combined with a new HTML5 standard have contributed to the development of an offline data entry feature in DHIS2. b) ISs are like organs on their own and once seeded, need to be nurtured in order to grow. By initiating league tables and bulletins, the project team sparked cascade actions, which were instrumental in getting momentum for the use of the system and subsequently improving the quality of information, which in turn better informs action taken to tackle local issues. In so doing, local communities have developed a sense of ownership toward the system. c) HIS that only focuses on one community is not good enough. Each community needs to be part of a bigger entity, including peers, because in the context where information about how things should be is sparse, comparing one's own data with that of peers could be helpful.

5.6. Summary of findings by research questions

RQ1: To better understand the process of architecting HIS in the setting of West African countries and in Malawi

- a. what are the characteristics of architecting and what are their interplays?
- b. What are the conditions for a successful evolution of HIS

RQ2: To explore an alternative approach to address the challenge of the fragmentation of HIS.

RQ3: To explore how to study a big phenomenon like national and international HIS.

Table 5: Research papers and their responses to research questions

	RQ1	RQ2
Paper 1	<p>Bottom-up architecting is an improvised and iterative alignment of networks of action ranging from different levels and driven by users' needs.</p> <p>Alignment with HMN network as well as users networks in the field has shaped DHIS2 which was gradually enriched with new features</p>	<p>Users' needs-centred approach is preferred to the top-down and narrowly technical approaches to architecting.</p> <p>Continuously align networks to leverage other efforts.</p>
Paper 2	<p>Architecting occurs within three boundaries – syntactic, semantic and pragmatic – with three corresponding and progressively complex processes – transfer, translation and transformation. Iterations are needed to successfully align the networks. Enabling users' participation through prototype is important. Architecting is a continuous process which has technical and non-technical dimensions.</p> <p>Changes at the global level – release of standards of soft standard such as the HMN framework, IHP+ – can increase interest of networks of action towards the emerging architecture.</p> <p>By working together with other networks, individual networks learn from others and are subsequently shaped through accumulation of experience and knowledge.</p>	<p>Continuous and iterative and gradual alignment of networks through negotiation is required.</p> <p>Local context shapes the emerging HIS because same vision, same technical solution and same approach can lead to different strategies and outcomes.</p>
Paper 3	<p>Architecting is a dynamic and stepwise process with iterative negotiations. When aligning networks within a political arena, it is good to set broad goals, avoid chaos and level the field for a flexible and integrated HIS. Architecting is about role and prestige devolution and legitimacy building.</p>	<p>A dynamic and iterative stepwise approach is preferable to a static "one size fits all". A combination of preparedness and seizing opportunity is key in influencing the emergence of the HIS</p>
Paper 4	<p>Architecting is an accumulation of prestige and legitimacies through alliance. Architecting is a networking process through which a network can be plugged and unplugged. Architecting is a serendipitous process of aligning networks towards a vision or a broad goal.</p> <p>A technical standard – be it soft or formal – is an enabler or a barrier for aligning networks of action of technical order.</p> <p>Networks are keen to align with successful networks or networks that have legitimacies they can benefit from.</p>	<p>Synergistic alignment is needed to scale and be sustainable. Subsystems that are already interoperable and with strong legitimacy are preferable in order to avoid the headache of defining technical standard at local level.</p>
Paper 5	<p>Action or dynamics at one boundary can propagate across all boundaries. The league table has been instrumental to developing further local ownership and nurturing the use of the system.</p> <p>Architecting is releasing local potentials to innovate</p> <p>The centralised web-based architecture in Kenya combined with the potentials of new HTML5 standards have led to the development of an offline data entry feature.</p>	<p>Backing for users in the bottom but also buy-ins at national and even regional and global levels are important.</p>

Chapter 6 - Contributions

6.1. Implication for theory: Bottom-up architecting framework

Architecture is key to efficient and effective healthcare provision and the appropriate approach to designing, developing and implementing it has been central to the IS debate. My study contributes to this debate through conceptualising the process of bottom-up architecting as a multidimensional and evolutionary process that is led by serendipity as strategy and influenced by accumulation of legitimacies. The framework has the following key characteristics:

- *Multidimensional* process: this process consists of three progressively complex boundaries (syntactic, semantic and pragmatic) with three corresponding and progressively complex processes (transfer, translation and transformation). The boundaries shape each other.
- *Evolutionary* process: this process emphasises a bottom-up approach with some injections of top-down approach. It is led by serendipity as strategy.
- *Serendipity* as strategy: the idea of serendipity indicates that architectures are emergent and represent a network of networks of actions that have their own paths. Any single actor does not control them. Thus aligning these networks of actions is a serendipitous reconfiguration that orients the emergence of the architecture over time.
- *Legitimacies* accumulation process across contexts and domains: in this process, the perceived legitimacies and the way they are accumulated, plus the way they span contexts and domains, play an important role in a self-reinforcing process of adoption and evolution.

These concepts are described in further detail below.

6.1.1. Bottom-up architecting as multidimensional process

The bottom-up architecting framework characterises architecting or architecture at three highly dependent boundaries: syntactic, semantic, and, pragmatic (Kossi et al., 2011; Sæbø et al., 2011b). The models proposed here are neither merely a summary nor a simplification of architecture layers as described in Zachman (1987) framework.

First, unlike the top-down architectural framework, the three-boundary model offers a richer account for organisational issues and recognises the need of iteratively aligning interests as

stakeholders are often autonomous and the architecture is not controlled by any single actor (Hanseth, 2013; Hanseth et al., 2014; Hanseth and Lyytinen, 2010) .

Second, the increase in complexity from syntactic to pragmatic in this model does not suggest a hierarchical or a sequential order as proposed in the top-down architectural frameworks (Lankhorst, 2004; 2013; McGovern et al., 2004; Pereira and Sousa, 2004; Schekkerman, 2004; Zachman, 1997). It instead suggests starting at the boundary (or boundaries) where action is quickly possible and iterations might be required. Additionally, while the term “level” suggests hierarchy and clear-cut delimitation, the term “boundary” suggests the organisation combined with its context is addressed within the three boundaries, making it difficult to disentangle the organisational, semantic and technical issues. While some issues could be purely technical or semantic, others may require pragmatic, semantic and technical capabilities to address them.

Third, this model aims to offer a framework for understanding and guiding the bottom-up approach to architecture. While the bottom-up approach mainly emphasises improvisation, iteration and stepwise evolution, this framework offers explanation of how each step works, how a change or novelty can propagate across boundaries and their interplay. These interplays are twofold:

- **Between boundaries:** legal regulation, strategies, organisational policy, values and leadership – pragmatic boundary – shape the overall HIS architecture in terms of what could be exchanged, with whom, what component is part of the architecture and what are its linkages. Thus, what happens at the pragmatic boundary shapes the two other boundaries. Translations at the syntactic boundary mediate alignment at the pragmatic boundary but they are also a prerequisite for data transfer at the syntactic boundary. Dynamics at the syntactic boundary also shape the pragmatic boundary as they can help stakeholders develop a good understanding of the technical solution and influence their decision making in subsequent iterations of negotiation. In Sierra Leone, for example, the position (backend or frontend) of CRIS and DHIS2 in the blueprint – which can be seen as technical issues – led to the transformation at the organisational level as UNAIDS, a key initiator, felt unhappy and left the project (Sæbø et al., 2009). A change in technology can also shape the alignment process at the pragmatic boundary. For instance, the move to an online web-based system in Gambia helped to successfully align the interests of the health programs that saw the opportunity to get full control over their data without the burden of

maintaining the technical system and without having to wait for the HIS unit to get their data. Subsequently, this situation shifted the HIS unit role from processing and disseminating data to stakeholders, to maintaining the technical system and producing information for significantly fewer stakeholders.

- **Need for coherence or congruence across the boundaries:** to evolve successfully, the architecture should be congruent across the three boundaries. In other words, the architecture, such as that at the syntactic and semantic boundaries, should reflect the one at the pragmatic boundary. A disagreement at the pragmatic boundary should be reflected at the semantic and syntactic boundaries. A growing attention is being given to semantic issues in IS (Chen et al., 2007; Hunter, 2003; Lopez and Blobel, 2009; Obrst, 2003; Sheth, 1999), including challenges related to metadata documents or registries. A metadata document is the common lexicon that defines what is being collected and how, as well as how this data is combined into indicators to provide health information. In Sierra Leone where the project has got momentum and continues to align stakeholders, both the reporting forms and the metadata document reflect the heterogeneity and autonomy at the pragmatic boundary. The metadata document did not leave out any data or indicators deemed necessary for any stakeholders, and the harmonised forms were rather modular and coordinated across stakeholders. In Gambia, Burkina Faso, Malawi and WAHO, where stakeholders acknowledged difficulties and later changed strategy, they first went for a monolithic metadata and reporting forms, which did not reflect heterogeneity and autonomy at the pragmatic boundary. Subsequently, they had to change their approach towards developing a coherent architecture across the boundaries.

In Sierra Leone, Gambia, Burkina Faso, and Malawi, the first step to improve technically the HIS was to use DHIS as a generic application to integrate parallel reporting systems following a data warehouse approach. In all cases, a small team that had the ability to try new solutions managed the project. However, they did not all experience the same outcomes until they changed their respective approaches. This indicates that having a small team at the beginning of the infrastructure, as suggested by Hanseth et al. (2014), or developing an architecture that mirrors the structure of the organisation developing it might not be enough. Instead, what is important is to ensure the architecture is congruent across the three boundaries, in addition to having a small technical team. If there is disagreement at the pragmatic or semantic boundary, the technical solution at the syntactic boundary should reflect such disagreement.

Nevertheless, because, in the context of inter-organisational IS in the public sector, the pragmatic boundary is characterised by autonomy and to some extent coordination, a flexible

and modular architecture is more likely to meet the congruence requirement across the three boundaries. Though the question one may ask is, “When do we know the boundaries are congruent?” While this notion of congruence sounds intuitively correct, it is hard to clearly answer it. I have only partially provided its characterisation and given some obvious examples.

In their work, Hanseth and Ciborra (2007); Hanseth et al. (2006) and Urry (2004) account for how attempts to create order can bite back with “side effects” or “unintended effects” which propagate and lead (surprisingly or otherwise) to more complexity. These findings contribute to understanding how decisions to create order at one boundary can lead to unintended effects that propagate across the other boundaries, often contributing to more disorder. The model proposed here goes beyond such a view and suggests that actions or changes at any boundary could possibly lead to unexpected effects (positive or not) and that through iterative and evolutionary problem solving, the negative side effects can potentially be addressed while positive ones can be fostered. This was the case in Sierra Leone with the creation of the district league table that propagated across all the boundaries and contributed to strengthening the HIS (Kossi et al., 2012).

The traditional top-down perspective sees architectures as blueprints based on rational drawings of boxes and their linkages. The proposed model suggests that the boxes are not passive and their position in the blueprint matters at the pragmatic boundary. The position in the blueprint that could be seen as merely a technical issue (at the syntactic boundary) could have important impacts at the pragmatic boundary. Thus, the drawing is not just a passive technical artefact but is a powerful tool. You do not exist if you are not in the drawing. This supports findings in previous research (Rodon and Hanseth; Sahay et al., 2007) that suggest that the position of the boxes in the architecture influences stakeholders’ stance towards it. Furthermore, an existing network could enjoy a prestigious position and any architecting attempt that negatively alters such a position may lead to resistance and unsuccessful alignment.

6.1.2. *Bottom-up architecting as evolutionary process*

In bottom-up architecting, “bottom-up” refers to the evolutionary process through which an integrated HIS architecture emerges and evolves over time. Because designing is a situated action (Greenbaum and Kyng, 1992; Suchman, 2007), it is not possible to know everything beforehand as regards what will work in a particular context. Therefore, designers together

with a small group of users gradually develop the IS by iteratively trying new solutions through trial and error processes (Kossi et al., 2011). The team managing the development should thus focus on solving one problem at a time before moving to the next and so on. In addition, resources for implementing all constituting systems are often not available and countries have to rely on development partners who have their own agendas. It is therefore important for the architecture to be modular and quickly actionable to enable it to evolve or to opportunistically solve concrete problems. However, a pure bottom-up approach might not necessarily lead to a successful evolution and some injections of top-down elements might be required at some stages of the evolution. While a bottom-up approach at one site could lead to a selection of a best practice (Braa et al., 2007a; Hanseth et al., 1996), its scaling countrywide and to other countries might require a top-down approach. Nevertheless, such top-down approaches should be broad enough to release local potentials.

The empirical world of this research has identified that a completed HMN architecture has not been achieved in any site yet. The architecting process began in Sierra Leone by gradually integrating parallel statistical HISs followed by extension to transactional systems and the development of SDMX-HD standards to link them. At the outset, the demand for integration of parallel HISs was high and resources were only available for a subset of the architecture. However, as users started getting better information the needs for interoperation with other data sources such as human resources also emerged gradually. In order to attain such integration, however, each of these systems needed to be implemented and running.

A rational way of implementing such an architecture would have been to start from the different transactional systems with the assumption that once these systems were up and running, they would automatically send quality data to the data warehouse, which should be implemented later. However, this approach would have taken many years to implement, and would still not quickly address the needs for statistical information for decision makers, nor the lack of resources which would have hampered the overall implementation.

This evolutionary characteristic supports previous works that argue that the best approach to developing a working system is through a stepwise development and evolution of the architecture (Aanestad and Jensen, 2011; Grisot et al., 2014; Hanseth and Lyytinen, 2004). While the bottom-up approach in Sierra Leone led to the selection of a best practice (Braa et al., 2007a; Hanseth et al., 1996), its spread countrywide and to Gambia, Malawi and Burkina Faso needed a top-down approach. Both top-down and bottom-up approaches were necessary.

It should be noted, however, as suggested by Rolland and Monteiro (2002), that the top-down initiatives should always be flexible enough to strike a balance through an evolutionary adjustment between organisational imperatives and users' needs. Only such flexibility could release local potentials and, in so doing, help innovate or enhance the usefulness, and fit within the environment the system inhabits – success (Henfridsson and Bygstad, 2013).

In their work, McGann and Lyytinen (2008) have proposed an IS evolution model that consists of a series of improvisations and planned actions along organisational and IT dimensions. However, unlike the evolutionary process with some injections of top-down elements proposed in bottom-up architecting, their model emphasises improvisations from the users' side (both in process and IT use) that will eventually become known by the management and be adopted through change planning. The approach proposed in bottom-up architecting is primarily a continuous effort to involve users in progressively trying new ideas and assessing them. Acknowledging some emerging misfits as well as subsequent workarounds and then planning change (be it process or IT) (McGann and Lyytinen, 2008) overestimates the role of management and might not work in the context of multiple organisations where there are several centres of power.

In our cases, the HMN architecture (see Figure 8) could be seen as a top-down architectural approach and a version of EA. It was helpful because it contributed to creating awareness about the health sector-wide integration and architectural approach instead of a software-oriented HIS. In addition, it was broad and flexible enough – almost without any specification – to allow different interpretations and facilitate an evolutionary approach to development. For example, when one of the resource records (iHRIS) was available, as well as a technical standard (SDMX-HD), it was possible to extend this architecture to cover a new domain – human resource management – adding a new box to the architecture. The HMN architecture is not patient centred and recognises patient management will still be paper-based for a while and would require significant donor funding to computerise it. Therefore, a gradual approach was definitely needed. To the contrary, an openHIE architecture (see Figure 6) is very rigid and focuses more on transactional systems. For this architecture to be usable, all registry services should be in place, internet connection should be available and patient record systems should be implemented in health facilities. This scenario is far from realistic for the time being in most developing countries.

However, while the current architecture (in countries) focuses on exchanging statistical data and metadata from different systems (because the health system itself emphasises infectious diseases), it might also change in the future, as the focus shifts to patient centred following the epidemiological transition (from infections and communicable diseases to non-communicable diseases)(Omran, 1998). For this reason, an architecture could be seen as set of modular sub-architectures, and strategies required to develop each of them should be adapted to their specific challenges.

6.1.3. Bottom-up architecting as serendipitous alignment of networks of action

Architecture creation is not just drawing and connecting boxes and arrows at will. It is instead about aligning networks of actions into a stronger network of networks of actions (Sæbø et al., 2011a). Networks of actions have been defined as a concept for aligning small projects in IS implementation to get stronger and grow. Linking this concept with the improvisational alignment, I see bottom-up architecting as a serendipitous synergistic alignment of interests (Timmermans and Berg, 1997) of involved networks of actions. Rather than merely improvising, aligning these networks of actions into a stronger entity requires foremost preparedness and the sagacity to seize opportunity or to transform fortune or misfortune into opportunity or innovation that will drive further alignments. Serendipity goes beyond the notions of improvisation and bricolage that only account for doing with what is at hand in a given circumstance. Serendipity emphasises how the architecture team can work to create favourable circumstances – or to reinterpret favourably the circumstances – to be better prepared for improvisation (Kossi et al., 2011; Sæbø et al., 2011a).

Horace Walpole, cited in de Ron & Morley (2010), wrote in 1754:

“... One fine day, so goes the tale, three princes from Serendip (Ceylon, or modern-day Sri Lanka) were sent by their father on a prolonged journey to acquire empirical experience as part of their training. Misfortune befell the princes when happening upon a camel driver, who enquired of them about a camel he had lost. Though the princes had not seen the animal, they were nonetheless able to accurately describe it: it was blind in one eye, lacking a tooth, and lame. Furthermore, the camel was carrying butter on one side and honey on the other, and was being ridden by a pregnant woman. Their description was so accurate, in fact that the camel owner accused the princes of having stolen his camel, and formally

charged them in the emperor's court. However, in the presence of Emperor Behram, it became clear that the princes were entirely innocent, having merely pieced together various events. They explained that they thought the camel blind in the right eye because the grass had been cropped only on the left side of the road. They inferred that it was missing a tooth from the bits of chewed grass scattered across the road. Its footprints seemed to suggest that the animal was lame and dragging one foot. Also, finding ants on one side of the road and flies on the other, they concluded that the camel must have been carrying butter on the ants' side, and honey on the other. Finally, as of the presence of a pregnant woman, a combination of carnal desires on the part of the princes and imprints of hands on the ground sufficed to bring about this final conclusion”.

While the word serendipity nowadays means different things ranging from discovery by luck or “meaningful coincidence” (Green, 2004, p. 14) to information-searching techniques (Makri and Blandford, 2012), for Leakey (2010) and from this story, the combination of preparedness and readiness to seize unexpected opportunity or to connect *a priori* unrelated facts is central to serendipity. He rejects the idea of discovery by pure luck because it is not enough to be in the right place at the right time to make a discovery by luck. Many men floated in the water before Archimedes and many apples have fallen since the time of the Garden of Eden. Serendipitous events or discoveries very often are attributable to a single “moment”, but at the same time are entirely dependent upon the relationship between the right circumstances and the potential to respond to them in an advantageous way; the meeting of fortune and the preparation to identify and react to that fortune. To summarise, serendipity does not play its role in a particular observation, but rather it is the response to this observation, the readiness, the knowledge and the expertise of the observer which lets innovations, discoveries or inventions emerge from unexpected situations or *a priori* ordinary facts.

As far as architecting is concerned, there are various external dependencies and no one entity controls it. Therefore, the small management team or driving forces behind the architecture must be prepared, learn from experiences, and be awake, alert and agile (Sæbø et al., 2011a). The team needs to be present in situations in which opportunities might arise. It should be alive to different possibilities that exist given the conditions and use experience and understanding to make choices. It should be able to act quickly and decisively. In other words,

the team needs to have the sagacity to sense where there could be actions and turn fortune or misfortune into possibilities that further develop the architecture and that they can reflect on.

A bottom-up approach implies that the IS emerges from an interaction between design efforts with users and the context, and fundamentally involves improvisation (Ciborra, 1996; 1999; Hanseth et al., 2014; Hanseth and Lyytinen, 2010; Heeks, 2002; Orlikowski, 1996).

Improvisation is ruled by intuition, experience, competence, design and chance (Ciborra, 1999, p. 78). A lack of a reliable internet connection can force one to improvise a workaround just as a speaker can decide to improvise a speech while addressing an audience. Serendipity is improvisation, prepared improvisation and beyond. In serendipity, attention (Weick and Sutcliffe, 2006), knowledge, intuition and competence are used to sense where action could be taken and where opportunity may arise, to create or influence conditions favourable for desirable future state and to improvise quickly and decisively. Serendipity not only plays its role in a situation where all required resources are unavailable (as for improvisation) but also when taking advantage of *a priori* ordinary facts. There is, therefore, a need of preparedness and sagacity to interpret the current situation and sense possible future actions. Attention must be paid to routine processes or events to detect any misfit or opportunity to improve the system. Such improvement could be in terms of use, technology, coordination and information quality. This is in line with the work by Weick and Sutcliffe (2006) on mindfulness. The authors argue that, on the one hand, less-mindful practice in an organisation is about converting uncertainties and anomalies into acceptable risks or simply ignoring them. On the other hand, they state that “mindfulness captures unique particulars, i.e., differences, nuances, discrepancies, and outliers that slow the speed with which details are normalized. These visible anomalies foreshadow potential problems and opportunities, and preclude incubation until events become unmanageable” (Weick and Sutcliffe, 2006, p. 518).

6.1.4. Dynamics of legitimacies

In their work, Henfridsson and Bygstad (2013) suggest that three mechanisms – adoption, innovation and scaling – are in interplay in the successful evolution of architecture, and at least Adoption and Scaling mechanisms are fundamentally required for such an evolution. However, they do not explain what drives such mechanisms. By adopting the legitimacy perspective, I argue that perceived legitimacies and institutions can drive or can play a critical role in the adoption and scaling of IS by organisations. This role is even more important when there are “legitimacy crises” (Nelson et al., 2004, p. 642), that is, when existing legitimacy is questioned or when existing practices are delegitimised.

Institutional theory has discussed legitimacy as important in the process of acquiring resources for survival (Lyytinen and King, 2004; Palazzo and Scherer, 2006; Suchman, 1995). Although I have not addressed the literature on legitimacy in relation to institutions, because my aim is not to contribute to that debate, I found it important to illustrate how it plays a critical role in the adoption and scaling of IS within and across organisations.

For Suchman (1995, p. 576), institutionalisation and legitimacy are “virtually synonymous”. He identifies three types of legitimacies – pragmatic, moral and cognitive – and argues cognitive legitimacy (which implies taken-for-grantedness) is a strong (if not the strongest) form of legitimacy. He defines legitimacy as “a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions.” (Suchman, 1995, p. 574).

To justify their existence and secure resources for their own survival, it has been argued that organisations need to acquire legitimacy. This legitimacy is acquired by proving they are reliable and predictable, they address issues that are politically salient, they conform to norms, standards or policies set by institutions, or they adopt widely used and accepted practices (Elsbach, 1994; King, 2006; Powell and DiMaggio, 1991; Ritti and Silver, 1986; Suchman, 1995). In their work, King et al. (1994) stress the role of institutions (states, regulatory bodies, international agencies, research oriented institutions, labour organizations, religious institutions, etc.) in creating conditions that could constrain or enhance innovation, its adoption and its diffusion. Taking these arguments further, I argue that when an organisation with its product/practice accumulates legitimacies from its constituencies or given institutions that are complementary (but important in the potential adopters’ population), it produces two mutually reinforcing processes that translate into a self-reinforcing process of adoption and diffusion (Sæbø et al., 2011a). First, it becomes gradually unquestionable (and taken for granted) and this subsequently lessens barriers for its adoption. Second, organisations in the potential adopters’ population will tend to adopt that solution for two reasons: i) they will legitimise themselves by adopting a legitimised solution/practice (Elsbach, 1994; Powell and DiMaggio, 1991), and ii) the adoption of this solution by other organisations will increase a mimetic pressure on them. These two mutually reinforcing processes will lead to a self-reinforcing process of adoption and diffusion as the more a solution accumulates legitimacies, the more it is gradually taken for granted and greater is the need to adopt it for self-legitimation (and thus easy adoption). In turn, the more it is adopted, the higher is the mimetic pressure. Additionally, other actors could align with the legitimised solution being adopted for

network externalities or for “influence legitimacy” (Suchman, 1995, p. 589) by co-opting actors that are credible in their potential adopters (Sæbø et al., 2011a). Furthermore, this effect is exacerbated when a given institution issues new policies and when there is a lack of competitive solutions that have been anointed by institutions. The institution itself needs to demonstrate that the policies are applicable (DiMaggio, 1988) and prove its social salience (King and Lyytinen, 2006). This opens the door evenly for early actors (with legitimacy or not) willing to implement the new policies, to collaborate with the institution and gain respect (Suchman, 1995).

Legitimacies, the way they complement each other as well as the creation and strengthening of myths (Ritti and Silver, 1986) contributing to their achievement, are therefore critical in a successful alignment of actors engaged in architecting (Sæbø et al., 2011a). However, if the creation of myths contributes to gaining legitimacy, gatherings such as workshops are good opportunities for strengthening both of them. First, gatherings provide opportunities to spread the myths. Second, they create arenas in which to talk, shape the stance towards and enact legitimacy, and exacerbate the mimetic pressure on actors or organisations to model themselves on others’ practices that are hailed as best practice by legitimated actors. Furthermore, this effect is exacerbated when there is lack of competitive solutions that have been anointed by institutions. My arguments here are in line with Henfridsson and Bygstad (2013), who find that successful evolution of architecture is associated with self-reinforcing mechanisms of adoption and scaling, and not to loosely or tightly coupledness or to centralisation or decentralisation as suggested previously (Aanestad and Jensen, 2011). However, flexibility has the potential to contribute to the adoption process by increasing its use in different contexts without being a *sine qua non* condition for success.

From my empirical material, it emerged that HMN wanted to legitimate its new framework and was looking for a credible partner to prove that it is actionable. It partnered with HISP to conduct the implementation of the frameworks using DHIS2 (HISP’s technical solution). In so doing, it created a coupling between HMN frameworks (as a guideline) and DHIS2 as a technical solution recognised by HMN as appropriate solution. Subsequently, countries needed to adopt the fully coupled HMN framework-DHIS2 for self-legitimation vis-à-vis HMN (read WHO) and increasing number of peer countries who have been implementing them.

In my empirical analysis, it emerged that the different actors involved have perceived their legitimacy as an asset and understood that by aligning with other legitimate actors, there will be network externalities (Sæbø et al., 2011a). Five processes of legitimacies accumulation have been identified as a response to the legitimacy crises (Nelson et al., 2004): global-country, country-country-global, global-global, regional-global and regional-country.

Global-country legitimacies accumulation: in this project, HISP has come with a legitimacy built over two decades of HIS implementations in developing countries that have been seen to be successful. HMN, by setting a new way of managing HIS in countries, has ruled out previous uncoordinated management and forefront integration and information use. Despite inheriting legitimacy from the WHO, HMN needed then to demonstrate that its framework was actionable and further accumulate legitimacies in order to get more resources (Ritti and Silver, 1986). For HISP, collaborating with HMN was seen as a kind of recognition. This created a win-win collaboration context for HISP and HMN. The combination of their legitimacies opened the door for them in Sierra Leone. However, once in the country, HISP worked closely with users. In so doing, it got the recognition from users who have the legitimacy of their context and needs. So when users, the country, HMN and HISP said the project was successful, this meant it was successful for each of them. It also meant the others have approved and recognised their approach and efforts in the project and therefore they have each accumulated more legitimacies and created a new myth (Ritti and Silver, 1986).

The newly accumulated legitimacies made the DHIS2 and HISP approach more attractive for other countries in West Africa, as anointed by Sierra Leone (local stakeholders) for being successful in their context, by HMN as compliant with its standards and by academics as being scientifically appropriate. Subsequently, The Gambia, which had already adopted HMN standards, saw the DHIS2 and HISP approach as a good candidate, as it was certified by HMN and by a peer country that has also adopted the HMN standards. For HMN, working with HISP and countries was an opportunity to implement and offer use cases for their HIS framework. HMN and HISP have consequently reinforced the social salience and trustworthiness of issues they address (King and Lyytinen, 2004).

Country-country-global legitimacies accumulation: The mimetic pressures (Brunsson et al., 2012, p. 618; DiMaggio and Powell, 1983; Suchman, 1995) exerted by the HMN framework led nearly all West African countries to adopt it while the DHIS2 and HISP approach was perceived as HMN certified and compatible. The countries wanted to comply

with the framework because they saw it as legitimated by the WHO, and in so doing, they will legitimatise themselves vis-à-vis peer countries and the HMN/WHO. This supports what King (2006, p. 14) describes as the need to look similar to legitimatise oneself, and the need to conform to rules and requirements to receive legitimacy (Lamb et al., 2003). Along the way, the countries also adopted DHIS2, which became a *de facto* technical solution compatible with the HMN framework. However, some countries interpreted things differently for political reasons and adopted the HMN framework without implementing DHIS2. Subsequently, some tensions emerged in these countries between stakeholders who wanted DHIS2 and those who did not.

Global-global legitimacies accumulation: the spread of the HMN framework and DHIS2 in Western African countries attracted other global actors such as OpenMRS, OpenHealth and CapacityPlus, who wanted to accumulate legitimacies by aligning with HISP and the HMN/WHO, and leverage on network externalities. This has led to efforts to offer better solutions such as making DHIS2, iHRIS and OpenMRS interoperable through the SDMX-HD standard branded as a WHO standard. Here too, the idea was to build the legitimacy of SDMX-HD on existing legitimacies from the WHO, and other collaborating global actors.

Regional-global legitimacies accumulation: the WAHO has been granted legitimacy from member countries since its creation. The WAHO has been watching closely the HIS-strengthening trend in the sub-region and realised it would be profitable for itself and for the countries involved if it aligned itself with the salient actors. Such alignment eventually took place in 2010 and together with HIS partners in West Africa, the WAHO decided to develop the regional HIS policy, which, to some extent, selected the architectural approach and solution in Sierra Leone as best practice (to be adopted in other countries). In addition, the WAHO wanted to leverage country HIS-strengthening efforts by developing a regional HIS to be fed by the integrated national HISs.

Regional-country legitimacies accumulation: the adoption of the regional HIS policy created another loop of legitimacies accumulation. Nevertheless, this is not in reaction to a legitimacy crisis. Instead, it is a fostering and weakening stance of those who respectively complied or did not comply with HMN-DHIS2. This subsequently contributed to stabilising the HMN-DHIS2 couple as well as an interoperable architecture (including other networks such as CapacityPlus) in the region. In so doing, the mimetic pressure, combined with the biding nature of the policy, has translated into the spread to many other countries. Eventually,

by the time of the finalisation of this thesis, all West African countries except Cape Verde, will have implemented or are in the process of implementing DHIS2.

While the accumulation of legitimacies has played an important role in the spread of the HMN framework and DHIS2 in the involved countries, it is important to stress that in each country or context, there is a need to prove social saliency to users in order to gain their anointment. The acquired legitimacy is just a potential and as such could only open doors at different levels but does not make systems institutionalised. However, the selection of one successful solution as a best practice by legitimate actors could, through need for legitimation and mimetic pressures, contribute to organisations (or countries) complying with the selected best practice.

The second critical factor of HIS institutionalisation is the roles of workshops, which play two utility roles. First, they contribute to the creation of conditions of success (by developing local capacities), which if realised will contribute to the creation or strengthening of legitimacy. In turn, the success achieved contributes to the creation of a myth that conveys an unquestionable belief (Ritti and Silver, 1986). Second, they serve as an arena for evolving the myth and its acceptance. The regular regional gatherings, such as DHIS2 academies, have created the feeling of a rather international trend and provide opportunities for countries to convincingly talk to each other about their experience both formally and informally, as well as the chance to provide feedback on their requirements for the HISP team.

Another way of looking at the dynamics of legitimacies is through the lens of soft regulations and their interplay. Policies, guidelines and standards set by institutions continuously shape and reshape the architecture and stakeholders' stance toward it. Following the definition of soft regulation by Ahrne and Brunsson (2005), the HMN framework and the WAHO HIS policy could be seen as means of creating soft regulation for HIS coordination, architecture as well as information.

These soft standards have had an impact on HIS architecture in the salient countries and at the WAHO level. They have been widely adopted in developing countries and are actively promoted within the development partners' community. The soft standards set guidelines and recommendations for improving health information quality through better coordination and development of an integrated HIS architecture. Most importantly, these guidelines were neither contradicting each other nor competing. Instead, they complementarily address issues at the three boundaries of architecting. They also created awareness in the community of

development partners (including software developers such HISP), as well as in the local HIS environment, about the urgent need for integration, coordination and active participation of stakeholders at all levels. In so doing, they exerted a pressure on development partners who are now changing their approach and valuing HIS as central to their development agenda and are stressing the importance of information for evidence based decision making and for accountability.. This in line with the description of standards (Brunsson et al., 2012, p. 620) as “a powerful tool for challenging and altering institutionalized behaviour and identities” because a certain behaviour is inscribed in them (Hanseth and Monteiro, 1997b). It also supports the work by Smith et al. (2011) on the potential for change or transformation, directly and indirectly, provided by the ‘openness’, as in open standards, but also as in open data, open source and open development.

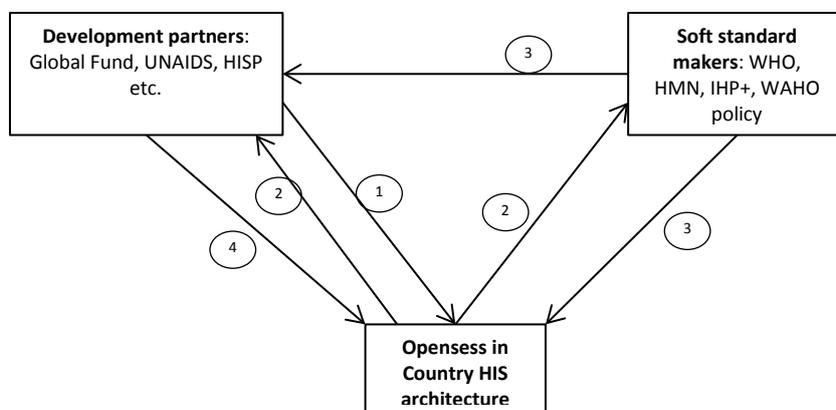


Figure 12: Interplay between networks involved, global soft standard and country HIS architecture

Legend:

- 1: Traditional top-down approach of development partner has led to fragmentation in countries.
- 2: This fragmentation has been documented and shared.
- 3: Elaboration and dissemination of soft standards or best practices for health HIS. These soft standards are now shaping both development partners and countries.
- 4: Some development partners are now shaping their approach in countries toward integrated HIS architecture.

In sum, this research has contributed theoretically to the following debate:

- Understanding of the boundaries of architecture and how they shape the evolution of architectures

- Assessing the conditions of successful evolution of architecture through the notion of congruence across the boundaries
- Strategies and/or levers to action alignment of stakeholders in the architecting process: serendipity and accumulation of legitimacies

6.2. Implication for practitioners

6.2.1. Need for congruence of the HIS architecture across the three boundaries

Usually, the first thing practitioners think about when it comes to HIS strengthening is the harmonisation of metadata and the creation of minimal datasets or indicator lists. This research has indicated that successful evolution is linked to the congruence of the architecture across the pragmatic, semantic and syntactic boundaries. This means metadata documents, data collection forms and technical solutions to be implemented should reflect the heterogeneity and autonomy observed at the organisational level. Therefore, if stakeholders disagree at the pragmatic boundary, for instance, the metadata document or registry, as well as reporting forms should reflect that disagreement. Subsequently, the restrictive minimal dataset approach with one reporting form is not congruent with heterogeneity and autonomy at the organisational level. Maximalist metadata approaches with a monolithic single reporting form might also fail for the same reason.

This congruence principle indicates that in the architecture aiming at integration, the metadata document or registry has to cover all data requirements of all stakeholders while at the same time avoiding duplications. The metadata document should allow the reuse of data elements into different indicators. Secondly, the reporting forms derived from such metadata should be modular and not a single monolithic reporting form that would be hard to change because of the costs of printing and dissemination to health workers, as well as the necessity for all stakeholders to come together to negotiate any change. However, if the reporting form is modular – as is the pragmatic boundary – then any change is likely confined to a single module. This would then eliminate the need to bring all stakeholders together to negotiate such a change. Usually, health programs that have resources for such processes are those who often introduce such change, which would mean that the only role the HIS unit would need to play is that of coordinator and ensuring that the change is still compatible with the overall data structure. Thirdly, the technical system should also reflect the heterogeneity and autonomy of the stakeholders. Each stakeholder should have access to its data in an autonomous and coordinated manner enabling self-management.

To summarise, by making the metadata and paper forms modular, the system gets flexible and evolves without requiring heavy political negotiation. When change arises, the boundaries faced should be identified and appropriate processes triggered. The minimal indicator list or minimal dataset should not aim to replace all the data stakeholders need. Instead, it should only serve as a summary or highlight information generated from what the different stakeholders need.

6.2.2. Backing from top is important but information needs and usage perspective is critical

In this project, a first top-down and narrow initiative of technically integrating DHIS2 and CRIS through IXF gateway was seized as an opportunity to go to Sierra Leone and work with stakeholders and together develop the best solutions for the context. Once in the country, HISP worked with stakeholders in the limit of our agreement to propose a suitable solution for stakeholders. Although one of the initiators did not much appreciate the suggested solution and later dropped out of the project, other stakeholders took the lead and provided financial and political backing. This backing from the top was also instrumental in moving from a pilot program to a nationwide implementation of DHIS2 in the involved countries.

Furthermore, the different attempts to develop a health suite or interoperable HIS architectures, despite being top-down and clumsy, were finally translated into the development of the SDMX-HD standard, which, in the context of these countries, was a big jump towards the achievement of an integrated HIS architecture. Thanks to this standard, at the country level, stakeholders can now decide to adopt it to link any compliant system with their DHIS2 data warehouse.

Finally, using resourceful top-down initiatives to work in the field to gradually develop solutions that address users' needs is key. This requires a certain level of flexibility in top-down initiatives.

6.2.3. Appropriate response to change or problem at each boundary: continuous alignment

While addressing fragmentation or changes in the process of architecting the HIS, it is critical to properly analyse the boundaries that are faced and trigger adequate processes. It has been argued (Braa and Sahay, 2012, p. 29; Hanseth and Lyytinen, 2004) that it is preferable to start with what is achievable and quickly address the problem at hand. For this reason, systems designers and implementers should firstly identify at which boundary – technical, semantic or

pragmatic – action can be taken to quickly give at least a first response to the problem at hand. If the problem is only at the syntactic boundary, provide technical response. If it is of semantic order, the responses are with the translation process and so forth. If a pragmatic boundary is faced and transfer is triggered, the response might not successfully address the issue. If the syntactic boundary is faced and transformation is triggered, resources will be wasted in a heavily political alignment for an uncertain result whereas a simple transfer would have been good enough. This is usually the cause of duplications when a new actor joins the system and wants to introduce its own forms while the system already has required data to generate the information he needs. However, a single problem can span the boundaries. In this case, if sufficient conditions are not met to act on all three boundaries, then the response should be phased in steps starting from the boundary where action is quickly possible and the first result can mediate further steps. Iterations might be needed before successfully addressing the problem (Sæbø et al., 2011b). Many integration attempts have failed in West African countries because there are usually no continuous and iterative attempts to align stakeholders' interests at the pragmatic boundary. Instead, the integration process tends to be static and unable to align interests over time; thus leading stakeholders to set apart and develop their own systems.

Regular meetings and metadata revision workshops are the arena where stakeholders' interests are aligned in order to keep the existing collaborative entities together, but also to enrol new actors.

6.3. Implication for research method

Studying a “big” phenomenon, e.g., activities like those I have studied distributed across multiple sites/regions, as well as over extended periods of time, pose immediate challenges to research methods (Ribes, 2014). Williams and Pollock (2012) suggest, for instance, that researchers tend to leave too soon after IS implementation and therefore fail to learn from long-term outcomes. I reflect on the strategies I have pursued in studying what undoubtedly is a big phenomenon, the evolving and expanding network of HISP across about 40 countries in the south. My study began in Sierra Leone as a one-(country)-site project of implementing the DHIS2 application. However, the branding of such efforts as successful by the country and influential third parties such as HMN legitimised the approach – and the software – which in turn attracted more countries. Two main strategies have been used in order to study this still emerging and evolving phenomenon in West Africa: following the actions and the actors

(immediate and not) surrounding them (moving to multiple sites) and following each site over multiple time frames.

6.3.1. Following actions and actors surrounding them

By following the actions and surrounding actors, we were able to study what was going on in each site as well as studying the actors involved in these actions. The actors are of different types and at different levels—some at the local level, others at regional and global levels. Thus, one local actor's immediate contribution to action might be limited to the local level while others at upper levels might be able to pursue the action or influence its continuation at other sites.

However, if the move from one pilot site to a full country rollout could be planned, its diffusion and appropriation in other countries would be a serendipitous alignment led by our preparedness to sense and be where actions may arise and seize available opportunities. So, although the initial resources and plans of this research were limited to Sierra Leone, we were eventually able to continue action and follow the emergence of the HIA architecture from one country to another and ultimately at the regional level.

On the one hand, by following actions we were able to pinpoint how implementation in a previous site influences adoption and diffusion in other sites and how the overall process of implementation in multiple sites or country/countries translates into other processes at regional, international and global levels. For example, the emergence of countrywide implementation has translated into regional HIS, which is now being adopted in East Africa.

On the other hand, following actors (immediate or not) that surround actions allowed us to understand the complex relationship (between actions and actors) through which action is enabled at a local place, how it is spread to other places in the country, to other countries, and to regional levels. In so doing, we are able to pinpoint, for example, how the interplay between users, system implementers, system designers, policy makers, and so on, are shaping and reshaping the HIS architecture at country and regional levels.

The fact that we worked as a stable team moving from one country to another helped us in having multiple eyes on different facets of the same object (Ribes, 2014, p. 161) and in conveniently covering multiple sites.

However, moving from country to country was not enough and we needed to interact with those concerned by regional or global perspectives on HIS architecture. We also followed the

action upward as the global and regional actors are always in interplays that shape the emergence of country and regional (international) HIS. In this regard, DHIS2 academies and different meetings at regional and global levels were opportunities to scale up our research. As rightly described by Ribes (2014) in his work about scaling up research, “knowing and managing the size of the enterprise is a concern for the actors” (ibid p161). Thus, meetings (regardless of the venue) with the actors who are concerned with handling HIS at the regional level, for instance, are enough to investigate it at that level. Additionally, in this research, discussions during meetings or workshops, minutes, the regional indicator list, HIS policy and database, and the HMN frameworks, etc., were used as “scalar devices” to scale up our research to regional and global levels. However, in our case, in addition to meetings we were also able to work closely with actors to solve their problems at country and regional levels in their premises.

This strategy is in line with the call of Williams and Pollock (2012) for multiple-sites study, and for what Marcus (1995) called “Follow the thing” but actually differs from these concepts by suggesting a serendipitous approach to scale up the research instead of planning all the sites in advance. Resources for all sites might not be available beforehand and it might be difficult to know *a priori* which site or country may adopt a given technology. Nevertheless, it is important to notice a particular role played by the HMN and some HISP members – including myself – in mediating the diffusion of DHIS2 and in influencing HIS best practices despite our tight link to DHIS2. While at the outset, HMN was instrumental in the proclamation of the project in Sierra Leone as successful, in the later stage (after the shift in HMN focus) many stakeholders (at all levels) found us trustworthy enough to provide them with information on implementations in other countries and to provide advices on state-of-the-art HIS. This usually took the form of academic papers, HIS policies and strategic planning. This supports findings by Williams and Pollock (2012) about the role played by some particular actors in the diffusion of technology and in the shaping of the organisational technology but differs from it by the fact that HISP is not an independent third party. A plausible explanation could be the fact that we were seen as an academic institution and not a commercial organisation, and we actively tried to be as transparent and objective as possible. Or maybe HISP was trusted because of a lack of legitimate alternative.

6.3.2. Following each site over multiple time frames

The second strategy of our approach is to follow each site over multiple time frames so as to go beyond short-term outcomes of the research. By studying sites over multiple time frames,

we were able to pinpoint how the syntactic, semantic and pragmatic boundaries are shaping each other over time and how the architecture is emerging from such interplays. In The Gambia, for instance, the early result of the process showed that the newly implemented technology did not change the local practice of waiting for HMIS unit to get data. However, four years later, after the shift to online servers, and after seeing how other countries were using DHIS2, users started asking for more rights to access their own data and even rights to manage their own data in the shared data warehouse. In so doing, a new practice that relegates the HMIS unit to mere maintenance of the system has emerged. This supports findings by Williams and Pollock (2012) suggesting that short-term outcomes of implementation research may differ from medium- and long-term ones.

This strategy was made possible because the research was part of a bigger on-going HISP project which had many IS research activities in the same country over many years.

I am not suggesting that all IS implementation research should be integrated into a bigger project. Rather, that there are often opportunities for those doing action research in HIS to go back to implementation sites after several years, either because there is a revision of the metadata or because there is a need for new cycles of actions.

Chapter 7 - Conclusion

This thesis has addressed the challenges of fragmented HIS, and has proposed bottom-up architecting as an alternative to overcome these challenges.

The bottom-up architecting framework suggests a bottom-up approach with some injections of top-down approaches in the development and implementation of IS that spans organisations. Metaphorically, bottom-up architecting can be described as bottom-up zebra with top-down stripes. It suggests the HIS architecture is shaped by the interplays between and across its three intrinsic boundaries – pragmatic, semantic and syntactic. The interplay between the boundaries describes how the boundaries shape each other while the interplay across the boundaries denotes the need for the architecture to be congruent across the boundaries, that is, the HIS architecture at the semantic and syntactic boundaries should reflect the pragmatic boundary. However, as architectures evolve in a dynamic and complex environment (users, IT, policies, legitimacies, funding, beliefs, etc.), their development cannot be fully planned beforehand. Therefore, the framework offers two main levers that one could apply in architecting: serendipity as strategy and accumulation of legitimacies.

The role of development partners in prescribing and implementing some solutions may arguably push to state that the contribution of this thesis is specific to the context of developing countries. However, I believe that this framework is equally relevant for inter-organizational IS development, not only in most developing countries but also in developed ones, although I clearly have not had a chance to demonstrate that myself. The literature I cite (cf. section 2), however, strongly supports the relevance of my framework of bottom-up architecting also in developed countries.

Given that developing countries will probably progress towards an HIS architecture that focuses on patient-centred systems (what I call downward development of the architecture), adopting such perspectives will help avoid most of the traps and difficulties currently facing developed countries in terms of HIS architecture.

This research has also provided strategies to study a big phenomenon like information infrastructure development at national and regional levels. It suggests an emerging and serendipitous approach to scale up the research by following the actions and actors surrounding them.

Nevertheless, it is important to point out some limitations of this research. Although the idea of congruence sounds intuitively correct, the question one may ask is, “What are the very characteristics of congruence between these boundaries?” I have only partially defined it and have provided some obvious examples of congruence and non-congruence without giving tools to assess when boundaries are congruent or not. I haven’t even said if there is a continuum from congruence to non-congruence. This opens up a possibility of research about models or more taxonomy of congruence of the three boundaries in a complete way.

The second area of possible research is concerned with the upward HIS architecting and especially the emergence of the regional HIS. This development brings to mind more complexities in term of country-level HISs’ peculiarities, three languages (French, English and Portuguese), uncoordinated organisational units hierarchies and different country policies and culture regarding information sharing.. Investigating such processes may further enhance the proposed bottom-up architecting perspective.

References

- (AWG), C. I. A. W. G. 1997. "C4ISR Architecture Framework version 2.0."
- Aanestad, M., and Jensen, T. B. 2011. "Building nation-wide information infrastructures in healthcare through modular implementation strategies," *The Journal of Strategic Information Systems* (20:2) 6//, pp 161-176.
- Ahrne, G., and Brunsson, N. 2005. *Soft Regulation from an Organizational Perspective*, (Sociologiska institutionen, Univ.
- Arsanjani, A. 2004. "Service-oriented modeling and architecture," *IBM developer works*), pp 1-15.
- Asdal, K., and Moser, I. 2012. "Experiments in Context and Contexting," *Science, Technology & Human Values* (37:4) July 1, 2012, pp 291-306.
- Assmann, M., and Engels, G. 2008. "Transition to service-oriented enterprise architecture," in *Software architecture*, Springer, pp. 346-349.
- Avgerou, C. 2008. "Information systems in developing countries: a critical research review," *Journal of Information Technology* (23:3), pp 133-146.
- Avison, D., Lau, F., Myers, M. D., and Nielsen, P. A. 1999. "Action Research," *Communications of the ACM* (42:1), pp 94-97.
- Baskerville, R. L. 1999. "Investigating Information Systems with Action Research," in *Communications of the Association for Information Systems*.
- Baskerville, R. L., and Wood-Harper, A. T. 1996. "A Critical Perspective on Action Research as a Method for Information Systems Research," in *Journal of Information Technology*, pp. 235-246.
- Berg, M. 2001. "Implementing information systems in health care organizations: myths and challenges," *International Journal of Medical Informatics* (64:2-3) 12//, pp 143-156.
- Bieberstein, N., Bose, S., Walker, L., and Lynch, A. 2005. "Impact of service-oriented architecture on enterprise systems, organizational structures, and individuals," *IBM systems journal* (44:4), pp 691-708.
- Bolman, L. G., and Deal, T. E. 2005. *Reframing organizations: Artistry, choice, and leadership*, (Recording for the Blind & Dyslexic.
- Braa, J., Hanseth, O., and Heywood, A. 2007a. "Developing health information system in developing countries: the flexible standards strategy," *MIS Quarterly* (31:Special Issue August 2007).
- Braa, J., Hanseth, O., Heywood, A., and Mohammed, W. Year. "Flexible standards," Standardization and Innovation in Information Technology, 2005. The 4th Conference on, IEEE2005, pp. 37-49.
- Braa, J., and Hedberg, C. Year. "Developing district-based health care information systems: the South African experience," 2000.
- Braa, J., and Hedberg, C. 2002a. "The struggle for developing District health information systems in South Africa," *The Information Society* (18:3).
- Braa, J., and Hedberg, C. 2002b. "The struggle for district-based health information systems in South Africa," in *The Information Society*, pp. 113-127.
- Braa, J., Heywood, A., and Shung King, M. 1997. "District level information systems: Two cases from South Africa," in *Methods of Information in Medicine*, pp. 115-121.
- Braa, J., Igira, F. T., Titlestad, O. H., Lungo, J. H., Sheikh, Y. H., Mahundi, M., Shaw, V. P., Khamis, M., and Makungu, A. 2007b. "Designing and Implementing Hospital Management Information Systems: Experiences from Zanzibar,").
- Braa, J., Monteiro, E., and Sahay, S. 2004. "Networks of Action: Sustainable Health Information Systems Across Developing Countries," *MIS Quarterly* (28:3) September 2004, pp 337-362.
- Braa, J., and Sahay, S. 2012. *Integrated Health Information Architecture : Power to the Users : Design, Development and Use*, (Matrix publishers: New Delhi.
- Braa, J., and Sahay, S. 2013. "Participatory Design within the HISP network," *Routledge International Handbook of Participatory Design*), p 235.

- Brunsson, N., and Jacobsson, B. 2002. *A World of Standards*, (Oxford University Press, Incorporated.
- Brunsson, N., Rasche, A., and Seidl, D. 2012. "The dynamics of standardization: Three perspectives on standards in organization studies," *Organization Studies* (33:5-6), pp 613-632.
- Bush, A. A., Tiwana, A., and Arun, R. 2010. "Complementarities Between Product Design Modularity and IT Infrastructure Flexibility in IT-Enabled Supply Chains," *Engineering Management, IEEE Transactions on* (57:2), pp 240-254.
- Bygstad, B., and Gronli, T. M. Year. "Service Oriented Architecture and Business Innovation," System Sciences (HICSS), 2011 44th Hawaii International Conference on 2011, pp. 1-10.
- Carlile, P. R. 2004. "Transferring, translating, and transforming: an integrative framework for managing knowledge across boundaries," in *Organization Science*, pp. 555-568.
- Castells, M. 1996. "The rise of the network society. Vol. 1 of The information age: Economy, society and culture," *Massachusetts and Oxford: Blackwell*).
- Castells, M. 2000. "Globalization in the Network Society," in *Prometheus Journal*, pp. 109-123.
- CEN "Comité Européen de Normalisation."
- Chen, D., Doumeingts, G., and Vernadat, F. 2008. "Architectures for enterprise integration and interoperability: Past, present and future," *Computers in Industry* (59:7) 9//, pp 647-659.
- Chen, Z., Gangopadhyay, A., Holden, S. H., Karabatis, G., and McGuire, M. P. 2007. "Semantic integration of government data for water quality management," *Government Information Quarterly* (24:4), pp 716-735.
- Chilundo, B., and Aanestad, M. 2004. "Negotiating multiple rationalities in the process of integrating the information systems of disease-specific health programmes," *Electronic Journal of Information Systems in Developing Countries* (20:2), pp 1-28.
- Ciborra, C. U. 1996. "Improvisation and information technology in organizations," *ICIS 1996 proceedings*, p 26.
- Ciborra, C. U. 1999. "Notes on improvisation and time in organizations," *Accounting, Management and Information Technologies* (9:2) 4//, pp 77-94.
- Ciborra, C. U. 2000a. "A Critical Review of the Literature on the Management of Corporate Information Infrastructure," in *From Control to Drift: The Dynamics of Corporate Information Infrastructures*, Oxford University Press.
- Ciborra, C. U. 2000b. *From Control to Drift: The Dynamics of Corporate Information Infrastructures*, (Oxford University Press.
- Commission, E. 2010. "European Interoperability Framework (EIF) for European public services."
- Corneliusson, M. S. Year. "IT ARCHITECTURING—RECONCEPTUALIZING CURRENT NOTIONS OF ARCHITECTURE IN IS RESEARCH," 15th European Conference on Information Systems 2008.
- Creswell, J. W. 2009. *Research Design: Qualitative, Quantitative, and Mixed Methodes Approaches*, (3rd edition ed.) Sage.
- Davenport, T. H. 1998. "Putting the Enterprise into the Enterprise System," in *Harvard Business Review*, pp. 121-131.
- Davison, R. M., Martinsons, M. G., and Kock, N. 2004. "Principles of canonical action research," in *Information Systems Journal*, pp. 65-82.
- DeLone, W. H., and McLean, E. R. 1992. "Information Systems Success: The Quest for the Dependent Variable," in *Information Systems Research*, pp. 60-95.
- DeLone, W. H., and McLean, E. R. 2003. "The DeLone and Mclean model of information systems success: a ten-year update," in *Journal of Management Information Systems*, pp. 9-30.
- DHIS2 "DHIS2 overview."
- Diefenbach, T. 2013. *Hierarchy in Organization*, (Taylor & Francis.
- DiMaggio, P. J. 1988. "Interest and Agency in Institutional Theory," in *Institutional Patterns and Organizations* L. G. Zucker (ed.), Ballinger: Cambridge, MA, pp. 3-22.
- DiMaggio, P. J., and Powell, W. W. 1983. "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields," *American Sociological Review* (48:2), pp 147-160.

- Easterly, W. 2006. *The White Man's Burden: Why the West's Efforts to Aid the Rest Have Done So Much Ill and So Little Good*, (Penguin Group (USA) Incorporated.
- Elbanna, A. R. 2006. "The validity of the improvisation argument in the implementation of rigid technology: the case of ERP systems," *Journal of Information Technology* (21:3), pp 165-175.
- Ellingsen, G., and Monteiro, E. 2008. "The organizing vision of integrated health information systems," *Health Informatics Journal* (14:3) September 1, 2008, pp 223-236.
- Elsbach, K. D. 1994. "Managing Organizational Legitimacy in the California Cattle Industry: The Construction and Effectiveness of Verbal Accounts," *Administrative Science Quarterly* (39:1), pp 57-88.
- Engelsman, W., Quartel, D., Jonkers, H., and van Sinderen, M. 2010. "Extending enterprise architecture modelling with business goals and requirements," *Enterprise Information Systems* (5:1) 2011/02/01, pp 9-36.
- Fallmyr, T., and Bygstad, B. 2011. "Enterprise Architecture to Enhance Organizational Agility? An Exploratory Study," *NOKOBIT* (2011).
- Feldman, M. S., and March, J. G. 1981. "Information in Organizations as Signal and Symbol," *Administrative Science Quarterly* (26:2), pp 171-186.
- Foote, B., and Yoder, J. Year. "Big Ball of Mud," Fourth Conference on Patterns Languages of Programs (PLoP '97/EuroPLoP '97), Monticello, Illinois, 1997.
- Funk, J. L. 1998. "Competition between Regional Standards and the Success and Failure of Firms in the World-Wide Mobile Communication Market," *Telecommunications Policy* (22:4-5), pp 419-441.
- Funk, J. L., and Methe, D. T. 2001. "Market- and Committee-Based Mechanisms in the Creation and Diffusion of Global Industry Standards: the Case of Mobile Communication," *Research Policy* (30:4), pp 589-610.
- Gero, J. 1998. "Conceptual designing as a sequence of situated acts," in *Artificial Intelligence in Structural Engineering*, I. Smith (ed.), Springer Berlin Heidelberg, pp. 165-177.
- Ghazawneh, A., and Henfridsson, O. 2013. "Balancing platform control and external contribution in third-party development: the boundary resources model," *Information Systems Journal* (23:2), pp 173-192.
- Gordon, T. 2007. *Teaching Young Children a Second Language*, (Praeger Publishers.
- Gottschalk, P. 2009. "Maturity levels for interoperability in digital government," *Government Information Quarterly* (26:1), pp 75-81.
- Green, D. G. 2004. *Serendipity Machine: A Voyage of Discovery Through the Unexpected World of Computers*, (Allen & Unwin Australia.
- Greenbaum, J., and Kyng, M. 1992. "Introduction: situated design," in *Design at work*, L. Erlbaum Associates Inc., pp. 1-24.
- Greenbaum, J. M., and Kyng, M. 1991. *Design at work: Cooperative design of computer systems*, (Routledge.
- Grisot, M., Hanseth, O., and Thorseng, A. A. 2014. "Innovation Of, In, On Infrastructures: Articulating the Role of Architecture in Information Infrastructure Evolution," *Journal of the Association for Information Systems* (15:4), pp 197-219.
- Grisot, M., Thorseng, A., and Hanseth, O. 2013. "Staying Under The Radar: Innovation Strategy In Information Infrastructures For Health,").
- Gustavsen, B. 1992. *Dialogue and development*, (Van Gorcum.
- Hanseth, O. 2001. "Gateways--Just as Important as Standards. How the Internet won the "religious war" about standards in Scandinavia," in *Knowledge, Technology and Policy*, pp. 71-89.
- Hanseth, O. 2007. "Introduction: integration-complexity-risk - the making of information systems out-of-control," O. Hanseth and C. Ciborra (eds.), Edward Elgar Publishing.
- Hanseth, O. 2013. "Developing Pan-European e-Government Solutions: From interoperability to Installed Base Cultivation," in *The Circulation of Agency in E-Justice: Interoperability and Infrastructures for European Transborder Judicial Proceedings*, F. Contini and G. F. Lanzara (eds.), Springer Netherlands.

- Hanseth, O., Bygstad, B., and Johannesen, L. K. 2014. "Towards a Theory of Generative Architectures. A Longitudinal Study of eHealth Infrastructures in Norway."
- Hanseth, O., and Ciborra, C. U. 2007. *Risk, Complexity and ICT*, (Edward Elgar Publishing.
- Hanseth, O., and Henningson, S. 2013. "Towards Information Infrastructure Theory: How process strategy, architecture and governance regime in interaction shape the evolution of information infrastructures.."
- Hanseth, O., Jacucci, E., Grisot, M., and Aanestad, M. 2006. "Reflexive Standardization: Side Effects and Complexity in Standard Making," *Mis Quarterly* (30:Special Issue on Standard Making), pp 563-581.
- Hanseth, O., Jacucci, E., Grisot, M., and Aanestad, M. 2007. "Reflexive integration in the development and implementation of an Electronic Patient Record system,")
- Hanseth, O., and Lyytinen, K. 2004. "Theorizing about the Design of Information Infrastructures: Design Kernel Theories and Principles," *Case Western Reserve University, USA . Sprouts: Working Papers on Information Systems* (4:12).
- Hanseth, O., and Lyytinen, K. 2010. "Design theory for dynamic complexity in information infrastructures: the case of building internet," *Journal of Information Technology* (25:1), pp 1-19.
- Hanseth, O., and Monteiro, E. 1997a. "Inscribing behaviour in information infrastructure," in *Accounting, Management and Information Technologies*, pp. 183-211.
- Hanseth, O., and Monteiro, E. 1997b. "Inscribing behaviour in information infrastructure standards," *Accounting, management and information technologies* (7:4), pp 183-211.
- Hanseth, O., and Monteiro, E. 1997c. "Inscribing behaviour in information infrastructure standards," *Accounting management and information technologies* (7:4).
- Hanseth, O., Monteiro, E., and Hatling, M. 1996. "Developing Information Infrastructure: The Tension between Standardisation and Flexibility," in *Science, Technology & Human Values*, pp. 407-426.
- Hanseth, O., and Nielsen, P. 2007. "Infrastructural Innovation. Flexibility, Generativity and the Mobile Internet," *Book Infrastructural Innovation. Flexibility, Generativity and the Mobile Internet*).
- Hardy, C., and Phillips, N. 1998. "Strategies of engagement: Lessons from the critical examination of collaboration and conflict in an interorganizational domain," *Organization science* (9:2), pp 217-230.
- Harrison, R. 2013. *TOGAF® 9 Foundation Study Guide - 3rd Edition*, (van Haren Publishing.
- Heeks, R. 2002. "Information Systems and Developing Countries: Failure, Success, and Local Improvisations," *The Information Society* (18), pp 101-112.
- Heeks, R. 2008. "ICT4D 2.0: The Next Phase of Applying ICT for International Development," *Computer* (41:6), pp 26-33.
- Henderson, R. M., and Clark, K. B. 1990. "Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms," in *Administrative Science Quarterly*, pp. 9-30.
- Henfridsson, O., and Bygstad, B. 2013. "THE GENERATIVE MECHANISMS OF DIGITAL INFRASTRUCTURE EVOLUTION," *Mis Quarterly* (37:3).
- Hertog, P. D. 2000. "Knowledge-intensive business services as co-producers of innovation," *International Journal of Innovation Management* (04:04), pp 491-528.
- Hirschheim, R., and Klein, H. K. 2003. "Crisis in the IS field? A critical reflection on the state of the discipline," in *Journal of the AIS*, pp. 237-293.
- HMN 2005. "What is HMN?."
- HMN 2008. "The Health Metrics Network Framework."
- HMN 2013. "What has HMN achieved," WHO.
- Hoogervorst, J. 2004. "Enterprise architecture: Enabling integration, agility and change," *International Journal of Cooperative Information Systems* (13:03), pp 213-233.
- Hunter, J. 2003. "Enhancing the semantic interoperability of multimedia through a core ontology," *Circuits and Systems for Video Technology, IEEE Transactions on* (13:1), pp 49-58.

- ICD-10 2010. "International Statistical Classification of Diseases and Related Health Problems." IHP+ "History."
- IHP+ "Key issues."
- iHRIS "Health Workforce Software."
- ISO "International Organization for Standardization."
- ISO 2011. "Systems and software engineering — Architecture description".
- ISO/IEC 1993. "Information. Technology - Vocabulary -. Part 1: Fundamental Terms."
- ISO/IEC 2004. "Guide 2," in *Standardization and related activities - General vocabulary*.
- Iyer, B., and Davenport, T. H. 2008. "Reverse Engineering: Google's Innovation Machine," *Harvard Business Review* (86:4).
- Janssen, M. 2012. "Sociopolitical Aspects of Interoperability and Enterprise Architecture in E-Government," *Social Science Computer Review* (30:1) February 1, 2012, pp 24-36.
- Jonkers, H., Lankhorst, M. M., ter Doest, H. L., Arbab, F., Bosma, H., and Wieringa, R. 2006. "Enterprise architecture: Management tool and blueprint for the organisation," *Information Systems Frontiers* (8:2) 2006/02/01, pp 63-66.
- Katz, M., and Shapiro, C. 1986. "Technology Adoption in the Presence of Network Externalities," in *Journal of Political Economy*, pp. 822-841.
- Kemmis, S., and Wilkinson, M. 1998. "Participatory action research and the study of practice," *Action research in practice: Partnerships for social justice in education*, pp 21-36.
- Kimaro, H. C., and Nhampossa, J. L. 2005. "Analyzing the problem of unsustainable health information systems in less-developed economies: Case studies from Tanzania and Mozambique," *Information Technology for Development* (11:3), pp 273-298.
- King, J. L. 2006. "Identity in the I-school movement," *Bulletin of the American Society for Information Science and Technology* (32:4), pp 13-15.
- King, J. L., Gurbaxani, V., Kraemer, K. L., McFarlan, F. W., Raman, K. S., and Yap, C. S. 1994. "Institutional Factors in Information Technology Innovation," in *Information Systems Research*, pp. 139-169.
- King, J. L., and Lyytinen, K. 2004. "Reach and grasp," *Mis Quarterly* (28:4), pp 539-551.
- King, J. L., and Lyytinen, K. 2006. "The Market of Ideas as the Center of the IS Field," *Communications of the Association for Information Systems* (17:1), pp 841-850.
- Klein, H. K., and Myers, M. D. 1999. "A set of principles for conducting and evaluating interpretive field studies in information systems," in *MIS Quarterly*, pp. 67-94.
- Kossi, E. K., Kanjo, C., Moyo, C., and Braa, J. 2011. "Developing Integrated National Health Information Systems in Malawi: Oriented emergence of flexible architecture," in *IFIP Working Group 9.4 International Conference on the Social Implications of Computers in Developing Countries: Kathmandu, Nepal*, pp. 512-528.
- Kossi, E. K., Sæbø, J. I., Braa, J., Jalloh, M. M., and Manyà, A. 2012. "Developing decentralised health information systems in developing countries—cases from Sierra Leone and Kenya," *The Journal of Community Informatics* (9:2).
- Kruchten, P. 2000. in *The Rational Unified Process: An Introduction B2 - The Rational Unified Process: An Introduction*, Addison-Wesley, Inc.: Reading, MA.
- Kubicek, H., and Cimander, R. 2009. "Three dimensions of organizational interoperability," *European Journal of ePractice* (6).
- Kyng, M. 2010. "Bridging the Gap Between Politics and Techniques," *Scandinavian Journal of Information Systems* (22:1), pp 49-68.
- Lamb, R., King, J. L., and Kling, R. 2003. "Informational environments: Organizational contexts of online information use," *Journal of the American Society for Information Science and Technology* (54:2), pp 97-114.
- Lankhorst, M. 2012. *Enterprise Architecture at Work: Modelling, Communication and Analysis*, (Springer).

- Lankhorst, M. M. 2004. "Enterprise architecture modelling—the issue of integration," *Advanced Engineering Informatics* (18:4) 10//, pp 205-216.
- Lankhorst, M. M. 2013. *Enterprise Architecture at Work: Modelling, Communication and Analysis*, (3rd ed.).
- Lanzara, G. F. 2013. "The Circulation of Agency in Judicial Proceedings: Design for Interoperability and Complexity," in *The Circulation of Agency in E-Justice: Interoperability and Infrastructures for European Transborder Judicial Proceedings*, F. Contini and G. F. Lanzara (eds.), Springer Netherlands.
- Latour, B. 1986. "The Powers of Association," in *Power, Action and Belief B2 - Power, Action and Belief*, J. Law (ed.), Routledge and Kegan Paul: London, pp. 261-277.
- Law, J. 2004. *After method : mess in social science research*, (Routledge: London ; New York.
- Leakey, R. 2010. "Understanding humans: serendipity and anthropology," in *Serendipity: Fortune and the Prepared Mind*, M. d. Rond and I. Morley (eds.), Cambridge University Press, p. 152.
- Lee, A. S., and Baskerville, R. L. 2003. "Generalizing generalizability in information systems research," *Information systems research* (14:3), pp 221-243.
- Lopez, D. M., and Blobel, B. G. M. E. 2009. "A development framework for semantically interoperable health information systems," *International Journal of Medical Informatics* (78:2) 2//, pp 83-103.
- Lungo, J. H., Sheikh, Y. H., Igira, F. T., Titlestad, O. H., Braa, J., Bakar, A., and Suleiman, O. 2007. "Implementation of ICTs in Health and Management Information System for Zanzibar,").
- Lusch, R. F., and Nambisan, S. 2015. "Service Innovation: A Service-Dominant Logic Perspective," *Mis Quarterly* (39:1), pp 155-175.
- Lyytinen, K., and King, J. L. 2004. "Nothing at the Center? Academic Legitimacy in the Information Systems Field," in *Journal of Association for information Systems*.
- Makri, S., and Blandford, A. 2012. "Coming across information serendipitously – Part 1," *Journal of Documentation* (68:5), pp 684-705.
- Marcus, G. E. 1995. "Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography," *Annual Review of Anthropology* (24), pp 95-117.
- Marlow, E., Wilson, P. O. C. O. C., and Marlow, H. 2012. *The Breakdown of Hierarchy*, (Taylor & Francis.
- McGann, S. T., and Lyytinen, K. Year. "The improvisation effect: a case study of user improvisation and its effects on information system evolution," ICIS 20082008.
- McGovern, J., Ambler, S. W., Stevens, M. E., Linn, J., Sharan, V., and Jo, E. K. 2004. *A practical guide to enterprise architecture*, (Prentice Hall Professional.
- Mintzberg, H. 1979. in *The Structuring of Organisations B2 - The Structuring of Organisations*, Prentice-Hall: Englewood Cliffs, NJ.
- Mulley, C., and Nelson, J. D. 1999. "Interoperability and transport policy: the impediments to interoperability in the organisation of trans-European transport systems," *Journal of Transport Geography* (7:2), pp 93-104.
- Nadler, D., Tushman, M., and Nadler, M. B. 1997. *Competing by Design: The Power of Organizational Architecture*, (Oxford University Press, USA.
- Nelson, P., Lawrence, T. B., and Hardy, C. 2004. "Discourse and Institutions," *The Academy of Management Review* (29:4), pp 635-652.
- Nerur, S., and Balijepally, V. 2007. "Theoretical reflections on agile development methodologies," *Commun. ACM* (50:3), pp 79-83.
- Nielsen, P., and Hanseth, O. 2010. "Towards a design theory of usability and generativity,").
- Nielsen, P., and Sæbø, J. I. 2016. "Three Strategies for Functional Architecting: Cases from the Health Systems of Developing Countries," *Information Technology for Development* (22:1), pp 134-151.
- Obrst, L. Year. "Ontologies for semantically interoperable systems," Proceedings of the twelfth international conference on Information and knowledge management, ACM2003, pp. 366-369.

- Omran, A. R. 1998. "The epidemiologic transition theory revisited thirty years later," *World Health Statistics Quarterly* (51:2-4), pp 99-119.
- OpenHIE 2013. "Architecture."
- OpenMRS "About OpenMRS."
- Orlikowski, W. 1996. "Improving Organizational Transformation Over Time: A Situated Change Perspective," in *Organization Science*, pp. 63-92.
- Orlikowski, W. J. 2002. "Knowing in Practice: Enacting a Collective Capability in Distributed Organizing," *Organization Science* (13:3), pp 249-273.
- Palazzo, G., and Scherer, A. G. 2006. "Corporate legitimacy as deliberation: A communicative framework," *Journal of business ethics* (66:1), pp 71-88.
- Papastergiou, S., Kaliontzoglou, A., and Polemi, D. Year. "Interoperability Issues of a Secure Electronic Invoicing Service (Selis)," Personal, Indoor and Mobile Radio Communications, 2007. PIMRC 2007. IEEE 18th International Symposium on, IEEE2007, pp. 1-5.
- Papazoglou, M. P. Year. "Service-oriented computing: Concepts, characteristics and directions," Web Information Systems Engineering, 2003. WISE 2003. Proceedings of the Fourth International Conference on, IEEE2003, pp. 3-12.
- Pardo, T. A., and Burke, G. B. 2008. "Improving Government Interoperability: A capability framework for government managers," *Center for Technology in Government, University of Albany*.
- Pardo, T. A., Nam, T., and Burke, G. B. 2012. "E-Government Interoperability Interaction of Policy, Management, and Technology Dimensions," *Social Science Computer Review* (30:1), pp 7-23.
- Peltz, C. 2003. "Web Services Choreography and Orchestration," in *IEEE Computer*, pp. 46-53.
- Pereira, C. M., and Sousa, P. 2004. "A method to define an Enterprise Architecture using the Zachman Framework," in *Proceedings of the 2004 ACM symposium on Applied computing*, ACM: Nicosia, Cyprus, pp. 1366-1371.
- Peristeras, V., and Tarabanis, K. 2000. "Towards an enterprise architecture for public administration using a top-down approach," *European Journal of Information Systems* (9:4), pp 252-260.
- Perrey, R., and Lycett, M. Year. "Service-oriented architecture," Applications and the Internet Workshops, 2003. Proceedings. 2003 Symposium on, IEEE2003, pp. 116-119.
- Powell, W. W., and DiMaggio, P. J. 1991. "The New Institutionalism in Organizational Analysis ", University of Chicago Press: Chicago.
- Puri, S. K. 2007. "Integrating Scientific with Indigenous Knowledge: Constructing Knowledge Alliances for Land Management in India," *MIS Quarterly* (31:2), pp 355-379.
- Ribes, D. Year. "Ethnography of scaling, or, how to a fit a national research infrastructure in the room," Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing, ACM2014, pp. 158-170.
- Ritti, R. R., and Silver, J. H. 1986. "Early Processes of Institutionalization: The Dramaturgy of Exchange in Interorganizational Relations," *Administrative Science Quarterly* (31:1), pp 25-42.
- Rodon, J., and Hanseth, O. "Digital Infrastructure Innovation and Evolution: The Co-Functioning of Architecture, Governance and Process Strategy,").
- Rolland, K. H., and Monteiro, E. 2002. "Balancing the Local and the Global in Infrastructural Information Systems," *The Information Society* (18:2) 2002/03/01, pp 87-100.
- Rond, M. d., and Morley, I. 2010. *Serendipity: Fortune and the Prepared Mind*, (Cambridge University Press.
- Ross, J. W., Weill, P., and Robertson, D. C. 2006. *Enterprise Architecture as Strategy: Creating a Foundation for Business Execution*, (Harvard Business School Press.
- Rozanski, N., and Woods, E. 2011. *Software Systems Architecture: Working with Stakeholders Using Viewpoints and Perspectives*, (Addison-Wesley.
- Sabherwal, R., Hirschheim, R., and Goles, T. 2003. "The Dynamics of Alignment: Insight From a Punctuated Equilibrium Model," in *Strategic Information Management B2 - Strategic Information Management*, R. Galliers and D. Leidner (eds.), Butterworth Heinemann: Amsterdam, pp. 311-346.

- Sahay, S., Monteiro, E., and Aanestad, M. 2007. "Configurable politics: trying to integrate health information systems in developing countries," *Special Issue of JAIS on eInfrastructure*).
- Sanchez, R., and Mahoney, J. T. 2002. "Modularity, flexibility and knowledge management in product and organization design," *Managing in the modular age: architectures, networks, and organizations*), p 362.
- Schekkerman, J. 2004. *How to Survive in the Jungle of Enterprise Architecture Frameworks: Creating Or Choosing an Enterprise Architecture Framework*, (Trafford).
- Schelp, J., and Aier, S. Year. "SOA and EA-sustainable contributions for increasing corporate agility," System Sciences, 2009. HICSS'09. 42nd Hawaii International Conference on, IEEE2009, pp. 1-8.
- Schilling, M. A. 2000. "Toward a General Modular Systems Theory and Its Application to Interfirm Product Modularity," in *Academy of Management Review*, pp. 312-334.
- Schmidt, M.-T., Hutchison, B., Lambros, P., and Phippen, R. 2005. "The enterprise service bus: making service-oriented architecture real," *IBM Systems Journal* (44:4), pp 781-797.
- Schmidt, S. K., and Werle, R. 1998. in *Coordinating Technology: Studies in the International Standardization of Telecommunications B2 - Coordinating Technology: Studies in the International Standardization of Telecommunications*, MIT Press: Cambridge, MA.
- Scholl, H. J. Year. "Interoperability in e-Government: More than just smart middleware," System Sciences, 2005. HICSS'05. Proceedings of the 38th Annual Hawaii International Conference on, IEEE2005, pp. 123-123.
- Scholl, H. J., and Klischewski, R. 2007. "E-government integration and interoperability: framing the research agenda," *International Journal of Public Administration* (30:8-9), pp 889-920.
- Segars, A., and Grover, V. 1994. "Communications architecture: towards a more robust understanding of information flows and emergent patterns of communication in organizations," *European journal of information systems* (3:2), pp 87-100.
- Shapiro, D. Year. "Participatory design: the will to succeed," Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility, ACM2005, pp. 29-38.
- Sharifi, H., and Zhang, Z. 1999. "A methodology for achieving agility in manufacturing organisations: An introduction," *International Journal of Production Economics* (62:1), pp 7-22.
- Sheth, A. P. 1999. "Changing focus on interoperability in information systems: from system, syntax, structure to semantics," in *Interoperating geographic information systems*, Springer, pp. 5-29.
- Simonsen, J., and Robertson, T. 2012. *Routledge Handbook of Participatory Design*, (Taylor & Francis).
- Smith, M. L., Elder, L., and Emdon, H. 2011. "Open development: a new theory for ICT4D," *Information Technologies & International Development* (7:1), pp pp. iii-ix.
- Smolander, K. Year. "Four metaphors of architecture in software organizations: finding out the meaning of architecture in practice," Empirical Software Engineering, 2002. Proceedings. 2002 International Symposium n2002, pp. 211-221.
- Spewak, S., and Tiemann, M. 2006. "Updating the enterprise architecture planning model," *Journal of Enterprise Architecture* (2:2), pp 11-19.
- Spewak, S. H. 1992. *Developing a Blueprint for Data, Applications and Technology: Enterprise Architecture Planning*, (QED Technical Publishing Group, US).
- Stansfield, S., Orobato, N., Lubinski, D., Uggowitz, S., and Mwanjika, H. 2008. "The Case for a National Health Information System Architecture; a Missing Link to Guiding National Development and Implementation."
- Suchman, L. A. 2007. *Human-Machine Reconfigurations Plans and situated actions* (Cambridge University Press: Cambridge).
- Suchman, M. C. 1995. "Managing Legitimacy: Strategic and Institutional Approaches," *The Academy of Management Review* (20:3), pp 571-610.
- Sæbø, J. I., Braa, J., Sahay, S., Kossi, E. K., and Settle, D. 2011a. "Networks of Networks – Collaborative efforts to develop health information systems across developing countries " in

- IFIP Working Group 9.4 International Conference on the Social Implications of Computers in Developing Countries*: Kathmandu, Nepal, pp. 674-687.
- Sæbø, J. I., Kossi, E. K., Titlestad, O. H., Tohouri, R. R., and Braa, J. 2011b. "Comparing strategies to integrate health information systems following a data warehouse approach in four countries," *Information Technology for Development* (17:1), pp 42-60.
- Sæbø, J. I., Kossi, E. K., Tohouri, R., Titlestad, O., and Braa, J. Year. "Integrating health information systems in Sierra Leone," *Information and Communication Technologies and Development (ICTD)*, 2009 International Conference on, IEEE2009, pp. 379-391.
- Thompson, M. 2003. "ICT, power, and developmental discourse: A critical analysis," in *Global and organizational discourse about information technology*, Springer, pp. 347-373.
- Timmermans, S., and Berg, M. 1997. "Standardization in Action: Achieving Local Universality through Medical Protocols," *Social Studies of Science* (27), pp 273-305.
- Tiwana, A., and Konsynski, B. 2010. "Complementarities Between Organizational IT Architecture and Governance Structure," *Info. Sys. Research* (21:2), pp 288-304.
- Urry, J. 2004. *Global Complexity*, (Polity: Cambridge).
- Van Maanen, J. 1979. "The Fact of Fiction in Organizational Ethnography," *Administrative Science Quarterly* (24:4), pp 539-550.
- Vassilakopoulou, P., and Grisot, M. 2013. "Exploring the concept of architecture in Technology and Organization studies."
- Veltman, K. H. 2001. "Syntactic and semantic interoperability: new approaches to knowledge and the semantic web," *New Review of Information Networking* (7:1), pp 159-183.
- Vernadat, F. B. 2007. "Interoperable enterprise systems: Principles, concepts, and methods," *Annual Reviews in Control* (31:1), pp 137-145
- von Hippel, E. 2005. "Democratizing innovation: The evolving phenomenon of user innovation," *Journal für Betriebswirtschaft* (55:1) 2005/03/01, pp 63-78.
- WAHO 2009. "About WAHO."
- Wainright, D., and Waring, T. 2004. "Three domains for implementing integrated information systems: redressing the balance between technology, strategic, and organizational analysis," *International Journal of Information Management* (24:4), pp 329-346.
- Walsham, G. 1995. "Interpretive Case Study in IS Research: Nature and Method," in *European Journal of Information Systems*, pp. 74-81.
- Weick, K. E., and Sutcliffe, K. M. 2006. "Mindfulness and the Quality of Organizational Attention," *Organization Science* (17:4), pp 514-524.
- Williams, R., and Pollock, N. 2012. "Research Commentary-Moving Beyond the Single Site Implementation Study: How (and Why) We Should Study the Biography of Packaged Enterprise Solutions," *Information Systems Research* (23:1), pp 1-22.
- Winter, R., and Fischer, R. Year. "Essential Layers, Artifacts, and Dependencies of Enterprise Architecture," *Enterprise Distributed Object Computing Conference Workshops*, 2006. EDOCW '06. 10th IEEE International2006, pp. 30-30.
- Winter, R., and Schelp, J. Year. "Enterprise architecture governance: the need for a business-to-IT approach," *Proceedings of the 2008 ACM symposium on Applied computing*, ACM2008, pp. 548-552.
- Xiaoye, J., Xianhui, L., and Weidong, Z. 2013. "The convergence of SaaS and SOA magnify effect,").
- Zachman, J. A. 1987. "A framework for information systems architecture," *IBM Systems Journal* (26:3), pp 276-292.
- Zachman, J. A. 1997. "Enterprise architecture: The issue of the century," *Database Programming and Design* (10:3), pp 44-53.
- Zittrain, J. L. 2006. "The generative internet," *Harvard Law Review*), pp 1974-2040.

Appendices of publications

I

Integrating Health Information Systems in Sierra Leone

Johan Sæbø, Edem Kwame Kossi, Romain Tohourri Golly-Kobrissa, Ola Titlestad, Jørn Braa

This paper presents an ongoing project in Sierra Leone to integrate health information systems at district and national level through a novel approach. Employing solar-powered low-energy computers running Linux, a wide consortium of local and international actors have tried to counter the severe problems of electricity supply breakdowns and computer viruses. The paper discusses the experiences from this effort, as well as the integration process itself, and the corresponding capacity building strategies. The findings so far suggest that alternative technologies, namely solar power and open source software, can be fruitful to apply in such infrastructural settings as Sierra Leone presents. Furthermore, the technical solution to an intermediary step towards integration shows some promising results.

Index Terms—Sierra Leone, health information systems, integration, solar power

I. INTRODUCTION

IN this article we describe and discuss a project to develop an integrated Health Information System (HIS) in Sierra Leone, which has been going on since early 2007. The article focuses on the key challenges facing the project;

1) Building agreement on the need for an integrated approach to HIS in order to solve the prevailing fragmented situation of multiple vertical reporting systems which have no coordination and shared data standards – and building a consortium to carry out the task.

2) Handling the extremely poor infrastructure in Sierra Leone by establishing a “new” solar powered computer infrastructure.

3) Developing a free and open source database application which may handle the problem of interoperability with existing systems and include and manage data from the various health programs and data sources.

4) Capacity development; how to establish a training scheme and a support structure sufficient for rendering the new computerised system sustainable.

Ravaged by a prolonged civil war, which was declared over on 18 January 2002, Sierra Leone consistently scores extremely low on human development indicators. The public

health system, suffering from a huge loss of both personnel and infrastructure during the war, is slowly rebuilding the capacity to improve the service provision across the country. This effort is supported by the government and the international community through many agencies such as UNAIDS, WHO, UNICEF, GTZ etc. and aims at achieving health millennium development goals. The rapid growth of various health initiatives has created a situation of fragmented information systems, common also in other developing countries [1, 2]. An initiative to counter this fragmentation by integrating and strengthening the HIS together with using novel ICT solutions to cope with the extreme infrastructural challenges has been initiated and piloted over the last year. This initiative is supported by the Health Metrics Network (see <http://www.who.int/healthmetrics/>) together with other agencies such as the World Bank and UNAIDS.

In order to address the fragmentation, an integrated district based data warehouse approach has been followed. As a first step, data reported from the health facilities to the district using various health program specific reporting formats and systems are all being captured in one database application, the District Health Information Software (DHIS version 2, from now referred to as DHIS). Unified processing and analysis of these previously disparate information flows have then made it possible to better assess the quality of data and discrepancies between the different data reporting formats. As a result overlaps, gaps and inconsistent definitions of data variables between the different reporting formats have been identified. As a result of this, a revision of the data collection tools within an integrated framework is being planned. Furthermore, the district based database application supports unified data management, data disaggregating (e.g. make it possible to “follow” the data from the national level down to the health facility where it is collected), data analysis, programmatic reporting, changes in health units organisation, and local system integration.

A number of paper based reporting formats and routines are currently in place in Sierra Leone. Some of these are also computerized, such as HIV/AIDS reporting, which consists of paper forms reported from the facilities, and a database application called Country Response Information System (CRIS, from UNAIDS) located in the districts, where the HIV/AIDS reporting forms are captured. One of the goals is to

establish interoperability and data exchange between DHIS and CRIS and other software. In order to achieve this integration, many other critical issues such as infrastructure that the system will rely on and human capacity need to be addressed. The national power supply system is extremely poor, as many other national infrastructures. The main power source of the existing computerized HIS are generators. As the government is not able to provide fuel regularly to run generators, this reliance on diesel contributes to undermining the system. Human capacity both in terms of data analysis and information use and IT skills is another key issue that has to be tackled. Many information/IT officers (called M&E officers; Monitoring and evaluation) at district level have received on-the-job IT training, but because of power shortage, computer troubles (viruses, damaged and old computers) and absence of follow-up, the training endeavors were not capitalized on and they are still unskilled or uncomfortable in IT.

The rest of the article will present the case of Sierra Leone by focusing on the challenges described above. Some background to HIS and integration, as well as the methods applied, will be described first.

II. BACKGROUND: HIS AND INTEGRATION

Fragmentation and poor quality and use of data are major problems with health information systems in African countries. Integration of information systems is often perceived as a technical task involving primarily incompatible software and infrastructures. While this is an important part of the picture, fragmentation and poor coordination between organizations, and, as in the case of health, between providers of different services, together with political and social aspects more generally, are as important [3]. This fragmentation leads to gaps and overlaps, and incompatible definitions in the data that is being collected, registered and reported. Experiences from other African countries, as well as from Sierra Leone, show that without shared data standards, data exchange cannot take place. Integration is therefore first of all about data standardization. However, while the practical system focus of integration is on standardization, the overall integration will need to involve and enroll as many as possible of the various actors in the health system in the process.

Over the last decade the Health Information System Programme (HISP, www.hisp.info) has addressed these problems. The DHIS software was successfully used for integrating data and health services in first South Africa, and later in many other countries [4]. Integration of data and interoperability between information systems as well as increased use of information are key issues in the HISP approach.

The health information infrastructure may be regarded as heterogeneous networks of actors (Latour 1987), which may

be more or less integrated, or aligned. Communication and interaction between the components of the network may be regarded as going through gateways. Integration can then be perceived as software exchanging data through gateways, but this can also mean integration between paper based and computer based components. An integrated HIS allows data to be collected and analysed at one point and to be shared among the modules or parts of the system. This makes the data analysis more meaningful as all data is analysed together. It also entails knowledge integration as well as solving challenges of political and economical nature [5], [3]. This process has shown to be non-trivial [6], especially in developing countries [3]. The fragmented HIS leads to poor quality health information which can be rendered useless. Integrated HIS is therefore relevant, but it does not solve all the problems of HIS in developing countries.

III. METHODOLOGY

The research enveloping the project in Sierra Leone has been carried out along the lines of Action Research (AR). AR is a form of participative research where the researcher takes part in the change processes in an organization, actively trying to improve some stated problem [7], [8]. While it was initially not used much in IS research, and had a lot in common with anthropology and social studies, it has over the last two decades increasingly become accepted as a way to generate very relevant research findings on technology in its human context [9].

While we acknowledge the critique often raised against using AR in the field of IS (or any field, for that matter), we also claim that we, through our active participation, gained knowledge we would not easily come by taking a more passive role. Baskerville and Wood-Harper provides an overview over common critiques of AR. However, they conclude that the traps found are not unique for AR as a specific method, but are likely to trouble a researcher using any method in social science [9]:

“A number of problems confront the action researcher such as lack of impartiality, lack of discipline, confusion with consulting and its context-bound nature. However, these problems confront researchers using alternative methods as well. The difficulty with action research may be a matter of degree, and the easy loss of scientific rigour” (ibid, 144)

The authors have been an active part in the consortium described in this paper. Through this role, we have been able to engage in a close collaboration with users at different levels. Our findings originate in analysis of our work, including software development and customization, database development, implementation of pilot sites in Sierra Leone, training of all monitoring and evaluation officers in the country over 6 weeks, on-site training in the pilot districts, and discussions with district personnel to clarify data flows,

reporting, work practices, and the like. The scientific rigour, to quote Baskerville and Wood-Harper, has been upheld by applying qualitative research methods in the daily work, such

as interviews and observational techniques, and carefully recording the findings.

IV. PREVIOUS SITUATION

Table 1 summarizes the strengths and weaknesses of the previous HIS, and Figure 1 depicts the overall fragmented HIS in Sierra Leone. At facility level, data is captured on multiple paper forms and registers. This is sent to the districts, where the data is entered into various software applications (CRIS, Excel spreadsheets, and other single-

program (only catering one health program) software). This fragmentation is replicated at the national level, with various standards for data storage. The result is poor accessibility of data, overlap between the many databases, and hence less use of data for processing and analysis.

Table 1 Strengths and weaknesses of previous HIS

Strengths	Weakness
<ul style="list-style-type: none"> • Clear and understood reporting procedure • CRIS used in all districts • Computers in all districts • Information awareness and computer usage very good in one of the districts visited; multiple spreadsheets designed and used for particular program activities, up-to-date graphs on program activities displayed on the wall. 	<ul style="list-style-type: none"> • Poor IT skills of data management teams at all levels • Lack of power supply • Lack of resource to fuel regularly the generators • Lack of IT support and recurrent viruses problems • multiple and not well coordinated tools and formats for data reporting from facility to district, with overlaps and gaps, are in use; • Multiple computer based tools in use, also with overlaps (same data captured in different systems), and they are not linked • Data analysis and local reporting carried out in districts by re-capturing data in excel spreadsheets • Data aggregated to district totals before reporting to national; making quality check of data difficult • No feedback on reports from national to district; • Reporting from hospitals very poor (e.g. incomplete, poor coverage); morbidity and admissions/discharges reported, but not time spent by patients in hospital (laying days/bed-days), resources utilisation therefore not possible to deduct • Anti RetroViral therapy (ARV) patients managed by not-optimal paper record system; very difficult to provide outcome and cohort indicator reports based on current system

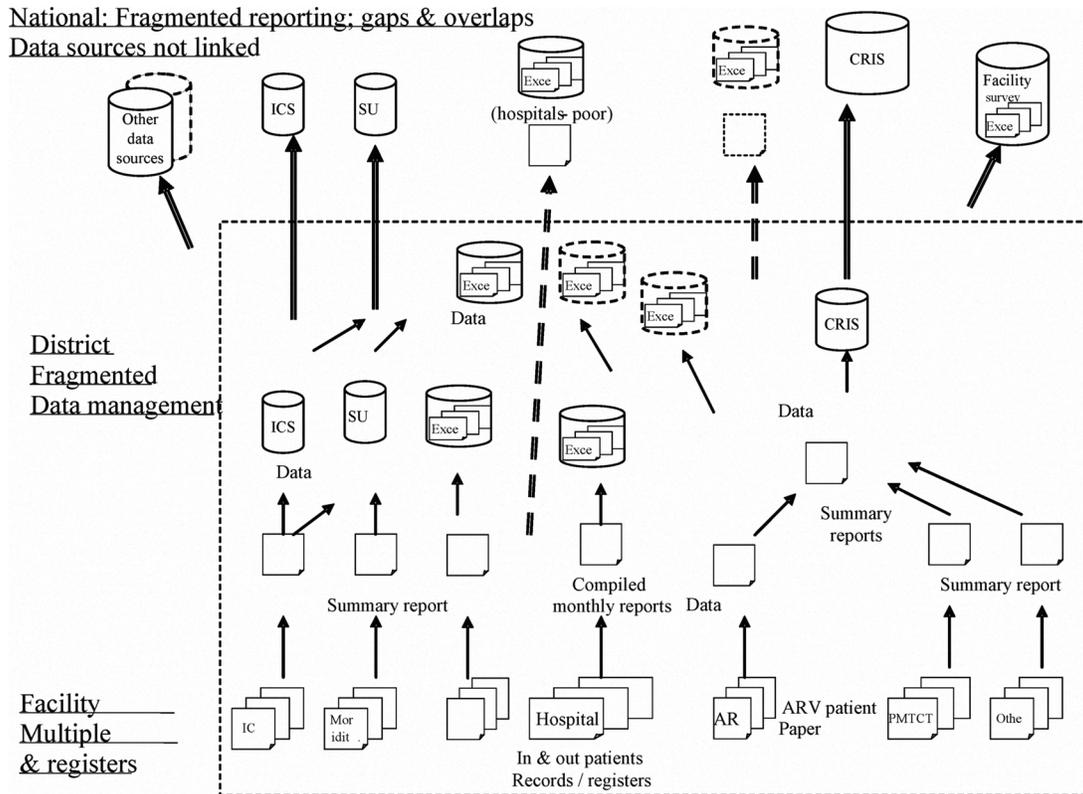


Fig. 1. The previous Health Information System in Sierra Leone was characterized by fragmentation and overlap between data collected by the different actors

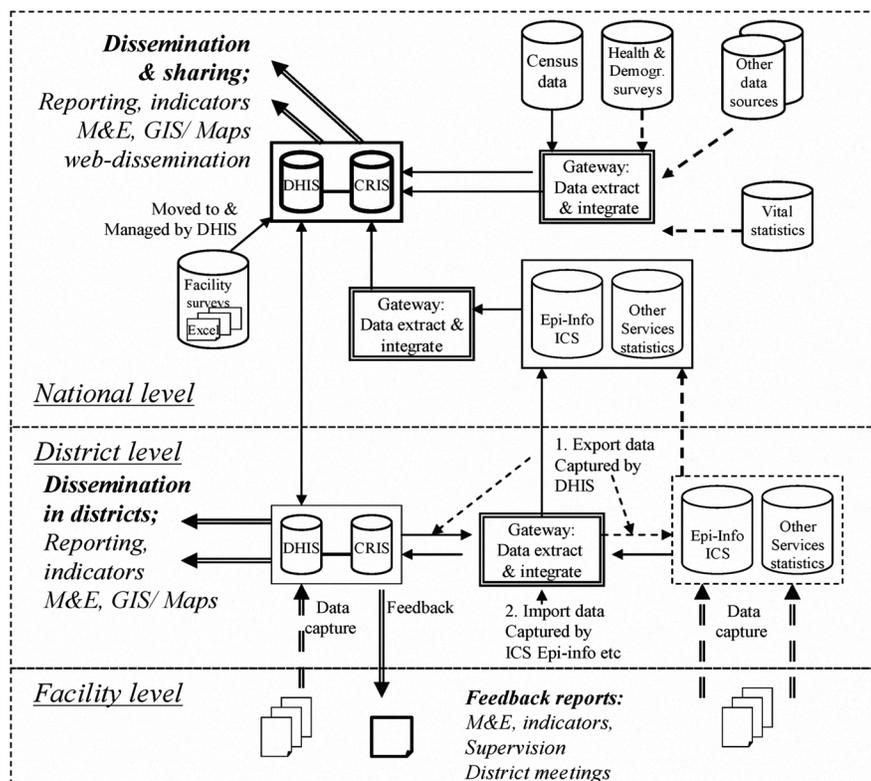
V. PROPOSED SOLUTION

From the current fragmented HIS described above, the main aim was to provide meaningful and relevant information for decision making and to diminish the workload of staff who is collecting and reporting the data. The key concepts used to address this issue are “integration” and sustainability. The suggested way forward depicted in figure 2 is to use DHIS to integrate the various data flows and data sources and thereby to provide an integrated framework for M&E and data management. The approach is to design data entry interfaces that are similar to existing ones in order to enter all data in

DHIS. But at the same time, data can be imported from existing applications into DHIS. So instead of entering overlapping data at district level in many databases, now data will be entered in one application (DHIS) and then exported in appropriate format to other applications. This model brings together essential data and indicator sets from all relevant sources disintegrated at the level of the reporting unit.

Revision, harmonization and standardization of data and indicator sets and tools for registration, collection and reporting of data are part of this process and particular attention must be given to the infrastructure that support the system as well as capacity building.

Figure 2:
Vision -
Integrated &
Linked data
Sources
 All information
 available through
 “one point” /
 Data repository



VI. INTERVENTIONS

A. The consortium :

Once a decision was made to improve the HIS in Sierra Leone based on the findings of the initial assessment, the Ministry of Health (MoH), the Health Metrics Network (HMN) and HISP had organized several meetings during which many questions regarding project aims were addressed. In doing so, some key actors were identified and enrolled in an alliance of complementary and experienced actors to run the project:

Ministry of Health of Sierra Leone: is represented at all levels of the project purposefully to make its participation and ownership very strong – as manager, user and beneficiary. Its experience in health management in the local context and its good understanding of what is needed both as a supplier and consumer of health information was crucial.

Health programs: it is useful to look at health programs within the MoH as separate entities, as they are key actors of the integration process. They have their own HIS, which is the main reason for the current fragmentation. Some have computerized HIS and some not. They are autonomous vis-à-vis the MoH. Examples: Mother & Child Health, EPI (immunization), HIV/AIDS, Tuberculosis program

Health Metrics Network –HMN : is a global agency under the WHO and aims at strengthening developing countries' HIS. They have developed a HIS framework and tools for

assessing country HIS (see <http://www.who.int/healthmetrics/>). In this project, HMN plays the role of executive sponsor and project manager.

Health Information System Program – HISP: is a global network in HIS development, open source software, ICT for Development and research and education. It comprises several actors from a number of countries and has been successfully implementing sustainable and integrated HIS in developing countries. The software named District Health Information Software (DHIS) is developed within the HISP network. HISP started in South Africa 1995 and has been instrumental in developing the HIS there. Since 2000 HISP has developed into a global South-South-North collaborative network with nodes in South Africa, India, Tanzania, Nigeria, Mali, Vietnam and Norway (see <http://hisp.info>).

ICT Development Center – IDC Sarl : is an international IT company based in Mali, specializing in open source and eHealth solutions for Africa. It offers eHealth consultancies, eHealth software development such as telemedicine applications and has a strong experience in HIS and IT project implementation in developing countries. IDC is also member of HISP and has contributed in the design and implementation in Sierra Leone. The task in Sierra Leone is to provide regional support and help enabling the local core team assume full ability in running the system.

Invenco: is a US IT company specialized in open source and low power computing and has deployed low power infrastructures in many developing countries. Invenco's strategy is to build alliances with local IT companies that can

be empowered in order to provide support for the low power equipment and avoid expensive and problematic traveling from US.

The attracting characteristics of this consortium lay in the diversity and the synergy of the actors enrolled. As depicted in table 2, their expertise cover all fields requested and are overlapping (Three pluses indicate that this is the core :

Table 2: Expertise of the consortium members

Actors	Politic	Policy making	Health	HIS	Open source	Hardware
MoH	+++	+++	+++	++		
Health programs		+	+++	+		
HMN	+++	+++	+	+++		
HISP	++	++	+++	+++	+++	
IDC			+++	+++	+++	+
Inveneo					+++	+++

B. Infrastructure

To face the challenging infrastructure context of Sierra Leone, a decision was made to deploy Inveneo low power hardware running Linux operating system. In doing so, we use one stone to kill two birds: respond durably to the lack of power, and counter computer virus.

The Inveneo hardware is an open hardware design (all plan and software are published through the Inveneo website) that operates using open sources software.

Each site in the project was provided with an Inveneo computing station and an Inveneo hub server. These computers are designed for challenging environments and have the following capabilities:



Figure 3 Inveneo server

- Very low power consumption (total power consumption of 18 watts at peak operation including LCD monitor) allowing the units to operate efficiently on 12 volts DC, with renewable power from solar panel, generators, etc.
- Solid state design (fanless, driveless) eliminates fans, hard disks, or moving parts of any kind, improves durability in hot, humid and/or dusty environments, making it ideal for use in Sierra Leone.

competency and responsibility, two pluses indicate substantial competency and involvement, while one plus indicates some involvement only. This only relates to the roles in Sierra Leone, specifically). This overlapping contributes a lot in the common understanding of the problem in its context.

- The use of Ubuntu Linux OS makes the system virus free and unlikely to corrupt database files. System start or restart erases any changes in system files. This reduces significantly the system maintenance need.
- The server runs also Ubuntu Linux and hosts the DHIS application. DHIS is then accessed remotely from other computers regardless its operating system.

In each site one Inveneo desktop, one server and a mixed – wired and wireless – local area network(LAN) were deployed. All equipment deployed are based on low power. The 12v power is provided by a car battery which can supply the system for 8 to 12 hours of working when it is charged and can be charged by either solar panel or the existing generator when this is turned on.

The LAN allows M&E officers to smoothly and seamlessly access DHIS both from the existing MS Windows computer and from the new Inveneo desktop. Existing computers can be used only when the generator is running since they are not low power based. But the Inveneo desktop and laptops can access DHIS at anytime when the battery is charged. Thus both M&E officers as well as the district medical officer are able access DHIS over a LAN even in times where no external power source is available. The server comprises two hard drives, synchronized. In case of a problem, the currently running (now faulty) hard drive can be replaced by the second one as an emergency solution.

Inveneo unsuccessfully sought an eligible local partner that could be trained to be responsible for the in-country support. Nevertheless, the emerging local core team for the project described here came to constitute this role during the pilot implementation phase.

C. Software Development

The software application used for the new integrated HIS solution is called DHIS, and is an open source software application developed in the global HISP software development community. Briefly the DHIS can be described as a tool for data collection and visualization of statistical data, tailored to support integrated health information management activities. It is a flexible tool which allows for extensive customization to meet local needs for HIS standardization of collection forms, reports and data analysis. The process of customizing the DHIS to the Sierra Leone context has been ongoing since July 2007 and has gone through many feedback cycles between users and stakeholders in the field in Sierra Leone, the IDC team responsible for the local customization, and the developers in Norway. During the more intense periods the online communication (chat, e-mail lists, issue tracking, source code repository) between Sierra Leone and Norway has been so active that new builds (versions) of the software have been released on a weekly basis with rapid response to user feedback. Furthermore, the innovative designs of feedback reports in Sierra Leone, created in collaboration with HMN, local M&E officers and the IDC/HISP have pushed and inspired the global developers to come up with a better and more generic report solution that later has benefited users also in other countries.

While the DHIS software is based on web technologies and can be used in networked settings, it also supports stand alone installations in locations with no internet. This adaptability to a varying infrastructure has been especially important in Sierra Leone as there have been local networks in each district set up around an Inveneo server, but at the same time no network connectivity between most of the districts and the national server has been present. DHIS has been installed on a district Inveneo server enabling multiple desktops in the same building to access and use the application simultaneously. This enables sharing of the district data warehouse and access to all data to all program managers, M&E officers and other users, as well as a secure server environment where the data are protected on a virus free Ubuntu Linux system. On a monthly basis each district exports its data to an external XML file and sends it to the national level either using a dial-up connection or using a flash-drive and physical transport.

To address the problems of the previous situation of the HIS, a new computerized system was introduced following best practices from HMN and HISP, and implemented using

the DHIS software. Key principles of DHIS design strategy are; 1) a modular data approach focusing on data item as the atomic unit rather than the larger data collection forms, 2) disaggregation of data enabling drill-down to health facilities from all levels, and 3) to collect and process data across health programs on an integrated data warehouse. All these principles, although arising from many years of implementation in various other African and Asian countries, were highly relevant to the Sierra Leone context.

A major problem in the previous solution that had to be addressed in the DHIS was the duplication of data reporting from the health facilities, as the same data items was collected in multiple forms. At the same time it was an important requirement from the users that the computerised form in DHIS would look exactly like the paper forms they were familiar with. The software was customised so that all data items collected in the various paper forms were defined as individual elements in the database, but without duplication. In the DHIS these data elements are the atomic units and the data collection forms are just visual representations of a given collection of such elements, as illustrated in figure 4. While the user interface for data collection maintained the look of the fragmented paper system, the database behind was organised so that no duplication took place. E.g. if a data element was shared by two collection forms, then after registering its value in one form the value would automatically appear in the second form without a need to enter it again. Another benefit of such a modular approach was that all data elements are stored in the same integrated data warehouse and available for processing and correlation independent of any collection form. It was also possible to define calculated indicators based on these data elements to analyse coverage and rates as opposed to the “raw” numbers. E.g. BCG coverage (rate of infants given the BCG vaccine against tuberculosis) could be calculated by dividing the monthly reported data on BCG doses given, by the population estimate under 1 year for the same area and thereby provide the M&E manager with information comparable across time and space. A set of feedback reports were designed to provide districts and chiefdom administrations with a summary report of last month’s data, which combined a few selected key data elements and indicators and used charts to visualise trends over time, comparisons across areas, as well as an overview of the reporting completeness.

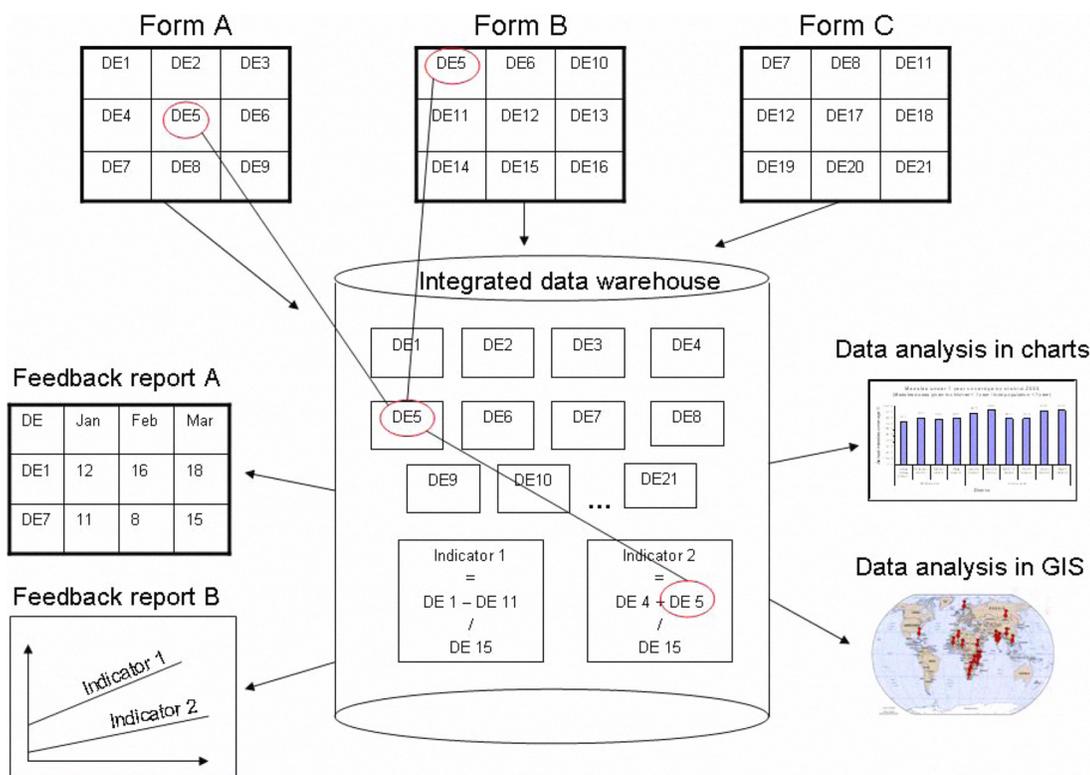


Figure 4 Overview of integrated data warehouse

D. Capacity building

In each district, two M&E officers are working to collect, prepare, report, and analyse aggregated data. During six weeks in May-June 2008, extensive training was given for all M&E officers.

The training was given as a three-module course, each module taught one week. Given the authors earlier experiences with training similar positions in the use of the same software in other countries, we opted for a one-week introductory course to the use of computers in general, followed by one week of training in the use of DHIS and one week in use of health information. In the end then, only 1/3 of the training was actually in the use of the software in question. Two weeks extra training were seen as necessary to increase the level of post-training use. First of all, few M&E officers actually had any experience with computers at all. So one week was dedicated to lift everyone to the same basic level of computer literacy. Second, sustainability can only be achieved if the HIS actually serves a need. In a context of poor information understanding and use, the collection and analysis of data will not be institutionalised. Therefore, the third week was dedicated to public health administration using primary health care data, and challenges and implications of a supporting HIS. Data entered during the week of DHIS

training was analysed, interpreted, and presented, and actions to improve the situation were discussed. A clear distinction between the three modules were not drawn, on the contrary, efforts were made to integrate them, for example by using epidemiological data in excel spreadsheet training. But on the whole, the capacity building was centred on the three following components:

- 1) Using computers, to get the most of DHIS training
- 2) DHIS operation, including regular tasks and basic database maintenance
- 3) HIS and data use, to create understanding and motivation. Using data from DHIS and analytical and presentation tools taught in the first week.

This approach had a few benefits that justify the relatively long time spent by M&E Officers away from office. First of all, the basic computer skills taught in the first week were essential to both understand how to use DHIS, and also to use Microsoft Excel, Powerpoint, and Word, which are common to analyse and present data once entered and processed in DHIS. Furthermore, it enabled a faster progress during week 2 and 3, which meant that a few, inexperienced M&E officers would not slow down those already familiar with computers. Secondly, special topics relevant for the context could be examined, with the students, in depth. The training schedule was revised daily based on the progress so far, and what the students wanted to learn. Motivation and inclusion played a

major role in forming the curriculum. For instance, while most of the districts are not connected to the internet, we found time for a session on browsers, free email hosts, search engines, and how to connect with mobile broadband through one of the local mobile network providers. Another example is the issue on computer viruses and possible solutions to the problem, which were explained in depth by, so to say, popular demand.

Thirdly, and quite importantly, the extensive training was used as an arena for user feedback to the system implementers. Especially the third week focused on plenary discussions on topics such as factors influencing the health status of the community, the validity and use of data forms, and data quality. In addition, requirements to DHIS and report designs were voiced during the training of the software. The training was a dialectical process, in which both trainers and students learned from each other and converged on a common understanding of the challenges ahead and the way forward for the project. A few examples can highlight the mutual learning experienced.

One form, for filling in among other things stocks of antigens at the facilities, was fraught with errors. Using the validation rules we had set up in DHIS, we could catch these errors after entering the data into the software. Running these validation checks, on one occasion only 5 of the 21 M&E officers found no errors in the form they had just filled in. The errors had two causes; one was wrong calculation of stock balance, another was a wrong interpretation of the data that was to be entered. It turned out that the M&E officers, and most likely also the nurses filling in the forms at the facilities, were not fully aware of what should be recorded; vials or doses. For example, BCG vaccines come in vials of 20 doses each. If you don't use all 20 doses at once, you are supposed to discard the rest, because rapidly they lose potency. So the data elements of Start Balance, Received, and End Balance should be dividable by 20. Distributed and Discarded, however, could be different, but should add up to vials of 20 doses too. Counting the various data elements differently was quite common, however, and several M&E officers did not understand the correct procedures when the errors showed up in the software. A quite lively discussion erupted, only to calm down when a representative from the EPI program at national level clarified correct use. Then, for another data element, where the header was "Doses discarded due to", and the sub-header was "Expiry date", many forms actually contained the expiry date of the various antigens in stock, rather than amount of doses discarded due to them being too old. This revealed both a lack of understanding of the forms at facility level, and also a possible ambiguous design of the form itself.

A similar example comes from the inconsistent closing dates for the data recording books at the facilities. For one form, which was supposed to cover one month, we would find that some facilities reported as early as the 25th day of the month. Since some facilities were far away from the district

center, they closed the books and did the aggregation for the district health team a few days earlier. Other facilities just filled in the form when they had time, and the exact day could vary from month to month. Thus some forms could contain data from 23 days, some for 34 days, etc. The M&E officers being trained knew about these varying practices, although they did not initially see this as a problem affecting data inconsistencies.

Lastly, efforts have been made to include the new technology applied to the capacity building activities. This has been done by focusing on strong on-site support by local partners who have been given extensive training in the Inveneo technology.

VII. DISCUSSION:

Our discussion builds on an ongoing project, and it would be too early to draw many conclusions at this time regarding sustainability and the long-term implications of the applied approaches. Nevertheless, the project can already show to interesting findings regarding the four topics presented in depth earlier; the consortium, infrastructure and software solutions, and capacity building.

A. *The consortium*

As we have seen above, the previous HIS was extremely fragmented, but the solution proposed was not to solely provide a new system that aimed at integrating everything. The focus was not merely on the application but on the whole information infrastructure, which comprises both technical and non-technical components. The diagnosis of the HIS went in depth and revealed that existing infrastructure and applications as well as human capacity were weak and needed to be addressed with equal attention.

Being mindful of users and collective participation, the strategy was to start with a prototype that would contain data from several existing data sources such as EPI, facility survey and population estimates. The prototype was then a useful concrete example of what and how the proposed integrated HIS could be like. It acted as a boundary object and enabled actors participation that gave more input to the project [5] [10]. On the one hand, by showing this concrete example, first, major actors such as HMN and MoH got a good understanding of the potential and benefits of such system. Second, it helped health programs that were reluctant to collaborate within the newly proposed framework to realize that everybody will get more output from the new system by gathering all different sources in one data warehouse, while at the same time pursuing their own trajectory. For health programs that did not have any computerized HIS, it was a great opportunity to move forward. On the other hand, those who are feeding the system with data immediately saw that i) at district level, the capability of the system to avoid overlapping data by displaying automatically the value of one

overlapping data element already typed for a given facility and a given period will considerably reduce their workload, since overlapping rate among two forms can be as high as 50 %. The system's capability of networking was also attracting for them. ii) at the grass root level, health care providers who are also those who are producing data had understood that the proposed solution can trigger a process that will lead to harmonization of reporting tools which in turn will diminish the 17 overlapping forms they have to fill at the end of each month. The alignment of interest of actors at all levels [11] made a large alliance of actors that was strong enough to get a momentum in the project and got them very involved and active. During several months, they all worked together through a process of improvement, feedback, and feed-forward between developers, implementers, managers and users. The heterogeneous and complementary nature of the consortium was useful in this regard.

At the early stage of the project, an important attention was given to the infrastructure issue. The team wanted a sustainable and flexible solutions that suit the context of Sierra Leone – lack of power supply, no resource to fuel generators, viruses to name a few. Then came the idea of bringing Inveneo experts with their low power computers that can work with solar panels and car batteries and based on Linux and open source applications. In the field, IDC experts were trained by Inveneo because by then, they were the only able to have a good understanding of the technical system. They are supposed to continue the training of the core team as well as organizing a local company to provide ongoing technical support. The overlapping expertise or the continuous expertise domain of the consortium helped keeping in place the expertise of one member even when he left. The fact that IDC has a good background in hardware and open source helped to acquire knowledge from Inveneo and give it back to the local core team on the basis of learning by doing. The HISP-IDC team is engaged in a long term support of the project and local expertise building.

B. Infrastructure

The new infrastructure ensures data safety, and since its deployment, users have not experienced loss of data as they used to previously. Even when their existing computers are infected by viruses, the server as well as the Linux desktops still work. So now they have power to run computers and computers to practice what they have learned during the intensive training without spending more money for generator fuel. One month after deployment in four piloting district and at the MoH, one sever stopped working and the diagnosis has revealed that the motherboard was off because of overheating, while it was supposed to be designed to overcome heat. The problem was reported to Inveneo who sent a new motherboard and it was an opportunity for them to improve the design of their computers. All computers were then upgraded and since then, similar problems have not been reported. By “black-

boxing” DHIS on the server without screen, keyboard and mouse, the equipment is kept out of reach of local “IT experts” in districts who used to format hard drives as the standard solution for any trouble shooting.

The approach chosen in Sierra Leone has been to go around the problem of the current infrastructural problems of no power supply by establishing a new technical infrastructure based on solar power and low-power computers. Technically, this is an innovative and wise solution. However, it will only work if the consortium succeeds in establishing an effective technical support structure, including training and maintenance.

C. Software solution

As far as the integrated data warehouse is concerned, the prototype strategy helped users at all levels to grasp the system and give more input to its improvement. The DHIS is continuously being improved through these feedback processes involving all the stakeholders; computer users, information users, implementers, hardware builders. Users in the field are aware of the flexibility of the DHIS and see this as an opportunity to make the work as easy as possible for them. For instance, both users and project managers acknowledged that it is time to improve feedback and reporting system from district M&E to the health programs by shifting from a manually generated report to one “push button” report generation. This was the highest priority local requirement for the DHIS from the users. But at the developer's level, the credo is to always make the globally used software as flexible and generic as possible and keep the adaptation to the local context for the customization phase. This mechanism and philosophy improved the software a lot at the global level as feedback and experiences from the field in Sierra Leone were highly relevant to other countries as well. The win-win alliance between local needs and DHIS development at global level was enabled by the prototyping strategy at local level and the need and philosophy of developing DHIS as a flexible standard; that is, flexible both in terms of use and change.

For the new software solution to be accepted among the local users it was important that the DHIS was customized so that the electronic data collection tools looked exactly like the paper forms. The modular data element design enabled collection forms to be generated simply by combining data elements and without disturbing the carefully designed integrated data warehouse underneath. The way already registered values would be automatically filled in the electronic forms when opening a second form using the same data element was highly appreciated by the health workers that had previously wasted a lot of their time on manually filling the exactly same data in various multiple forms.

Modularizing data in fine-grained data elements as opposed

to the traditional collection forms has several advantages. This metadata model enabled collection forms similar to the paper versions to be generated, which was an important requirement to get buy-in among the end users, simply by combining data elements, and without disturbing the carefully designed integrated data warehouse underneath. Furthermore, in an environment with changing requirements and a range of stakeholders with different needs, the modular design is flexible to change as standardization takes place at the data element level. New collection forms, indicators or report formats are just new compositions of data elements which can easily be defined in the user interface without changing the underlying integrated data warehouse. This flexibility has been important in the early phases of implementation when the formats of feedback reports and indicator definitions went through many feedback cycles among the users, the HMN specialists and the developers.

The introduction of feedback reports has been an important step in the DHIS implementation process and a maturing stage towards a revision of the entire HIS reporting system. The integrated data warehouse at district level has provided the local M&E officers access to their data across health programs, and the tools for processing and analyzing data have helped to illuminate gaps and problems with the existing data collection forms. Feedback reports, in stark contrast to typical data collection forms, have focused on data analysis and use and not upward reporting, and have given local M&E officers a quick overview of the situation from month to month. These reports have enabled local monitoring of key performance indicators of the services provided, and identified gaps in reporting from the chiefdoms and health facilities. Instead of presenting data in fragmented and overcomplicated forms, these reports have used just a fraction of the data collected, extracting only the most relevant data from the health programs, and used charts and simple tables to visualize the information.

D. Capacity building

The extensive training provided some benefits, which were briefly mentioned above. These were:

1. A week-long general computer-course enabled a higher quality of the HIS-specific training.
2. Time was given for student-led discussions on relevant topics, which clarified both for the student body and the trainers various issues of relevance
3. The training was used to get feedback on the software and HIS from the students

As mentioned earlier, the extensive training was given to develop a solid base both for using the software developed, and for creating the demand that could make it sustainable, by fostering a culture for using information. While it is too early to make any conclusions regarding sustainability, the preparatory week of general computer knowledge had the

effect that the main aim of the training, namely correct use of DHIS, was attained to an acceptable level. In addition, it gave the trainers and students some time to get to know each other, which proved crucial when health information issues were discussed at a later stage. In this case, the benefits of spending more time with the students became apparent during the third week.

The examples from the immunization forms show how the training facilitated peer learning. Discussion amongst the M&E officers established a common understanding on important issues like standards and routines. It also provided the trainers with an understanding of the situation “on the ground”, and what could be done to counter any challenges.

Lastly, since the trainers were also the authors of this paper, the points about discussions and user-feedback highlights the potential power of action research. Being part of the consortium and taking an active role in the process to improve the current situation, in this case as trainers for the district M&E officers, the authors gained knowledge about the issues raised in the previous paragraphs. As the training unfolded, and over time the students became more secure on each other and the trainers, the discussions flourished and provided an extremely rich arena for learning about the Sierra Leone health system.

VIII. CONCLUSION

The HIS in Sierra Leone, presented in this article, has been developed in an evolutionary participative manner, and it is still in the making. Earlier approaches to develop HIS in Sierra Leone have been to focus on partial solutions for one organization or health program, or, in some occasions, to implement new reporting formats including several of the health programs. A major problem has been that fragmentation has rather increased than decreased. In the latter cases where all-encompassing reporting formats have been introduced, various groups of users and health programs have not been satisfied, and they have continued to use the old reporting formats in addition to the new ones, and thereby worsening the situation.

The particular approach chosen by the ongoing project in Sierra Leone has been different from earlier attempts in that it is trying to incorporate all the various requirements for reporting and use of data in a step-wise approach. By taking the existing data as a point of departure, users have been able to join all the various reports being collated at district level within one database framework. In this way they have also for the first time been able to assess the quality of the data they are collecting – through being able to access and analyze the data – and they have been able to compare the data across the fragmented reporting structure. Through this integrated access to their own data, they have been enabled to identify the

problems with the current reporting formats; inconsistent data definitions between formats, missing data and overlaps. This learning process is now triggering, and feeding into, a much needed revision and overhaul of the entire reporting system, planned for early 2009. A principal difference between the chosen approach and the previous approaches is the allowed - and promoted - flexibility to change the system as users and involved health programs learn concretely about current shortcomings and potentials for improvements.

Ideally, of course, revisions of reporting formats should have taken place up-front, as part of the initiation of the project. Despite the high level profile of the project (Ministry of Health, HMN/WHO), however, the various health programs and donor agencies could not agree on shared revisions and new standards for data reporting. By having demonstrated how the reported data could be integrated, and the usefulness of such an approach, the flexible software and general approach have served as an effective means in negotiating new data standards, unifying the actors, and thereby building the consortium pursuing an integrated approach.

The evolutionary approach followed is relying upon, and feeding into, the ongoing formal and informal on-the-job training that is carried out as part of the capacity developing activities. By basing the training on real data and the use of the system in practice, the training sessions become a key participatory input for the improvement of the system, while at the same time enhancing the learning process.

Introducing radically new technical infrastructure and type of computers, as the Inveneo technology, represent a considerable capacity development challenge. The best way to approach this challenge is to make the technical part of the HIS integral to the training. Contextualizing the training by basing it on the problems in the district, including the hardware parts, is the best way to approach also this part of the sustainability challenge.

1. Braa, J., et al., *Developing Health Information Systems in Developing Countries. The "Flexible Standards" Strategy*. MIS Quarterly, 2007. **31**.
2. Sæbø, J., J. Braa, and O. Chandna. *A Flexible Approach to Integrating Health Information Systems: The case of Data Warehouse as Integrator in Botswana*. in *IFIP WG 9.4*. 2007. São Paulo.
3. Sahay, S., E. Monteiro, and M. Aanestad, *Configurable politics: trying to integrate health information systems in developing countries*. Special Issue of JAIS on eInfrastructure, 2007.
4. Braa, J., E. Monteiro, and S. Sahay, *Networks of Action: Sustainable Health Information Systems Across Developing Countries*. MIS Quarterly, 2004. **28**(3): p. 337-362.
5. Puri, S.K., *Integrating Scientific with Indigenous Knowledge: Constructing Knowledge Alliances for Land Management in India*. MIS Quarterly, 2007. **31**(2): p. 355-379.
6. Hanseth, O., et al., *Reflexive Standardization: side effects and complexity in standard making*. MIS Quarterly, 2006. **31**(2): p. 355-379.
7. Checkland, P. and S. Holwell, *Action Research: Its Nature and Validity*. Systemic Practice and Action Research, 1998. **11**(1): p. 9- 21.
8. Avison, D., et al., *Action Research*. Communications of the ACM, 1999. **42**(1): p. 94-97.
9. Baskerville, R.L. and A.T. Wood-Harper, *A Critical Perspective on Action Research as a Method for Information Systems Research in Qualitative Research in Information Systems*, M.D. Myers and D. Avison, Editors, Sage Publications. p. 129-145 (2002).
10. Bowker, G.C. and S.L. Star, *Sorting Things Out: Classification and its Consequences*. 1999, Cambridge, MA: MIT Press.
11. Timmermans, S. and M. Berg, *Standardization in Action: Achieving Local Universality through Medical Protocols*. Social Studies of Science, 1997. **27**: p. 273-305.

II

Comparing strategies to integrate health information systems following a data warehouse approach in four countries

Johan Ivar Sæbø*, Edem Kwame Kossi, Ola Hodne Titlestad, Romain Rolland Tohouri and Jørn Braa

Department of Informatics, University of Oslo, P.O. Box 1080, Blindern, 0316 Oslo, Norway

This paper addresses one of the major obstacles of reaching the Millennium Development Goals (MDG): inefficient and unreliable information systems. Leading international organizations have called for integrated data warehouses as one of the solutions, but this remains hard to achieve. This paper presents four country cases of standardizing and integrating health data which are all following what is here termed a data warehouse approach; data from across different health programs are organized in one database framework – or data warehouse. In all countries, fragmentation of health information in different partly overlapping subsystems run by different vertical health programs represented a major problem for the efficient use of health information. While South Africa developed a new integrated system in addition to the existing fragmented subsystems, Zanzibar, Sierra Leone and Botswana all aimed to encompass all or most of the data from the existing systems. The three latter countries all followed slightly different approaches, more or less incremental in the approach to standardizing health data, and more or less strict in whether to include “all” data, and whether to solve all inconsistencies between the various data sets included early on. The four cases demonstrate that integration is as much, and maybe more, about aligning organizational-political actors as it is about technical solutions. The technical solutions are, however, important in aligning these actors and in enabling integration. We argue that “attractors,” technical solutions or standards that achieve a certain level of success and enable the building of momentum, are important in aligning the various political actors. In turn, these attractors need to evolve within the changing context of a growing health information system in order to achieve the scale needed to address the MDGs with full force.

Keywords: integration; standardization; health information systems; data warehouse

1. Introduction

In 2010, 10 years have passed since world leaders agreed to eight Millennium Development Goals (MDG), which are to be achieved by 2015. Three of these goals are health-related, namely: goal 4, reduce child mortality; goal 5, improve maternal health; and goal 6, combat HIV/AIDS, malaria, and other diseases. To reach these goals, managers at all levels need to base their decisions on reliable, timely information for the resources spent to have the most impact. International organizations need to monitor progress and adjust policies and funding priorities, national health administrations need to strengthen the health services by identifying bottlenecks and emerging trends, and distribute health personnel and resources, and local managers need to respond to the needs of their communities. All this depends on well-functioning health information systems (HIS), one of the six pillars of a health system (WHO, 2005, 2007). At the same time, there has been a realization that many of the problems with HIS in

*Corresponding author. Email: johansa@ifi.uio.no

Elaine Byrne, Brian Nicholson and Fadi Salem are the accepting Guest Editors for this article.

developing countries stem from the practice of installing specific, narrow information subsystems, often covering limited information needs. Without a comprehensive strategy, these subsystems evolve into a range of fragmented, expensive, often overlapping, and inefficient systems, in turn leading to less use of information for health improvement. With the number of global health initiatives focussing on specific health priorities still rising (IHP+, 2010), this fragmentation of efforts, and their HIS, seriously undermines the work toward the MDGs.

This has led to several international organizations that specifically address these challenges with new strategies. The International Health Partnership (IHP+ established in 2007), aims to *harmonize* aid agencies, and *align* international efforts with national systems. The partnership in statistics for development in the twenty-first century (PARIS21, established in 1999) helps countries adapt *evidence-based* policy-making and implementation to reach the MDGs. The Health Metrics Network (HMN, established in 2005) was created to strengthen country HIS and information use, through *integration* of subsystems and data sources. Other international donors, the initial source of many of the fragmented systems, have as a result adapted a strategy of improving integrated national HIS rather than implementing new, narrow, specific subsystems.

This process of integration, however, is less than trivial. Integration takes place at several levels at the same time, from the purely technical to the organizational, and the interplay of these levels throughout the process very much determines the appropriate strategy. A central part of the HMN technical strategy to overcome the problems of fragmentation and lack of data standards is the establishing of data warehouses, or data repositories, for the storage of essential data and indicators from multiple data sources. This data repository will then provide shared access to information across the various health programs and user groups (HMN, 2008). In this article, we describe and discuss different varieties of such a “data warehouse approach” as they are applied in four countries. Botswana, Zanzibar and Sierra Leone represent relatively recent developments (since 2005/2007), whereas in South Africa, the process has been ongoing since 1995. While in Botswana, Zanzibar and Sierra Leone they have followed various strategies to include all data routinely collected from the health services by different health programs in one data warehouse system, in South Africa they started out with a minimum essential data set strategy (i.e. only a subset of data reported), which has gradually evolved to include more data through a longitudinal standardization process.

Integration as demonstrated in the four cases, however, is not primarily a technical process, but rather a political one. Nevertheless, the technical and the non-technical dimensions sway one another. In all cases, the overarching problem of fragmentation was caused by different organizational actors working independently. Providing a technical solution to integrate two different systems is relatively easy, but the politics of negotiating this among the actors involved is key to attain any use, and hence sustainability. However, in turn, the potential of the technical solution to get actors to understand it and perceive their interest is not to be neglected. Our cases show that mindfully using ICTs can align different actors toward a common goal; the development of strong and use-oriented HIS so necessary to reach the MDGs.

This article will proceed as follows. First, we present the methods applied. Then we present relevant literature on the issues of integration and standardization in developing countries, before presenting the four cases, the discussion and finally the conclusion.

2. Methodology

2.1 Action research in four countries

This article draws on case material from direct involvement and experiences in the development and assessment of HIS in South Africa, Zanzibar, Sierra Leone, and Botswana. The authors are all involved in one or more of the four countries, as well in the broader network of the Health

Information Systems Programme (HISP) (Braa, Monteiro, & Sahay, 2004; see also <http://www.hisp.info>). HISP started in South Africa in the 1990s as a conscious effort to adapt and apply central features of the Scandinavian action research tradition in IS development, such as user participation, evolutionary approaches, and prototyping, to the context of Africa (Braa & Hedberg, 2002). Action research aims at generating new knowledge through taking part in the full cycle of design, development, implementation, use, and evaluation and analysis together with all involved parties before the interventions are adjusted accordingly, and the cycle starts all over again (Susman & Evered, 1978). In each of the four countries, the authors have been engaged in repeated prototyping cycles of the DHIS software, system development such as revision of data sets (i.e. what data to collect and process) and capacity building, and exploration of ways to access, present and analyze the information in the system.

The authors have through this immersion in the system reform processes played various roles. The work spans from the purely technical domains (software development) to the political (strategy meetings with directors, ministers), but it has been in the role as interpreters and mediators between these various domains that we have been able to address the very complex task of integration from many angles. In all countries, one or more of the authors have been involved over several years, both through many on-site visits (length of stay varies from a week to a year, with a total length of over 6 months in all countries), and also through continuous communication via email and telephone.

The selection of countries came naturally as South Africa was the place the HISP started, and the subsequent involvement in other countries came about due to specific projects funded by external partners, partly based on the proven success in South Africa. Following the increased focus on HIS globally, increasingly international donors and agencies play a role in the circulation of best practices, also in the countries included in this study; the European Union funded the project in Botswana, DANIDA (the Danish aid agency) initiated the one in Zanzibar, and WHO and HMN initiated the project in Sierra Leone. The authors have also been involved in similar processes in other countries, but the four presented here were found to best highlight the distinct approaches to integration. They are also countries where the authors have been the most involved, and would thus provide richer material to analyze.

2.2 *Linking global and local efforts*

The research and lessons in South Africa, where HISP was initiated in 1995, forms the basis for the research and interventions in the three other countries. The overall HIS development approach first used in South Africa, including the focus on the local district level, data standardization based on essential information needs, and local use of own data, has been adapted to the other country contexts. As the context differs considerably between the countries, a major research challenge has been to ensure a framework for cross-country comparative and collaborative learning and intervention. The methodological approach to address this cross-country challenge is based on a “network of action” strategy (Braa et al., 2004), where, first, a mutual beneficial “win–win” collaboration is sought between action projects, which then is fostered through, second, the circulation of people, best practices and lessons, and software and other materials. The PhD program at the University of Oslo is including 15–20 African students and is facilitating comparative action research within and between countries and thus enables the needed “circulation of people” and sharing of experience. Three of the authors of this article are part of this program. Shared development and application of the DHIS software, which is used in all four countries, make up an important generator of “win–win” collaboration between the countries, while at the same time providing a concrete vehicle of sharing material and experiences.

2.3 Data analysis process

The projects described in this paper have been ongoing for several years. Through the active involvement in the work in these (and other) countries, we have naturally gone through a maturation process in our approaches to integration. The development of the four models of integration discussed in this paper has come gradually, and coincides also with a change in climate toward integrated approaches from international donors, often a key source of funding for health systems in poor countries. Finally, the continuous development of the software used has led to more flexibility in terms of leveraging the software for the different integration strategies. The data analysis stems from the repeated evaluation cycles of action research, namely asking the questions what worked, why, or why not, which subsequently lead to a different approach in the “next” country. Over the years, this led to the distinct strategies explained in this paper, and the confirmation that there is no “one size fits all.”

3. Conceptual framework

3.1 Health information systems

National HIS in developing countries are often plagued by fragmentation, where vertical, disease-specific programs run their own information-gathering systems (Stansfield, Orobato, Lubinski, Uggowitz, & Mwanyika, 2008). A typical situation in a developing country is that: (1) there is a national HIS run by the Ministry of Health aiming at covering data from across the various health services and disease-specific health programs (e.g. HIV/AIDS, Tuberculosis, Maternal & Child Health, Disease Surveillance, Vaccination Programme (called EPI)); (2) the general health services and the national HIS are relatively weak with insufficient resources; (3) while many of the vertical programs are comparatively rich as they are funded from international sources (e.g. HIV/AIDS), and these programs need to provide their funders with quality information on their activities and achievement in order to maintain funding. As a consequence, (4) not being satisfied with the data from the national HIS, the vertical programs develop their own sub-HIS with international funding (Braa, Hanseth, Heywood, & Shaw, 2007).

There is often lack of data harmonization across these subsystems which both results in duplication of data collection and reporting requirements among health workers at community and facility-level, as well as extremely difficult conditions for health managers at all levels to get the full picture of the health status of their population. This can be illustrated by the challenging task for a manager to monitor and make evidence-based interventions on MDG 4, to reduce child mortality, which would involve the need to get data from many different programs and subsystems of the HIS; the reproductive health program for still births and neonatal deaths, the immunization program during the child’s first year, from the nutrition program, and for deaths due to major diseases they would need to get data from Malaria, Tuberculosis and HIV programs, and most likely from the program for Integrated Management of Childhood Illness. To add to the complexity, these data will normally be available in a range of different formats, from paper reports to a mix of different electronic outputs, and another key challenge for the managers is the struggle to get data from the private facilities, as well as from the community, in order to get a more complete picture of all the relevant health events in their area.

The involvement of multiple funders and organizational actors make integration highly political. HIS integration is thus a non-trivial process, involving more than just integration at a technical level. Sahay, Monteiro, and Aanestad (2009) bring the attention to the political aspects of integration, and claim that, with a few notable exceptions, literature on the topic seems to be too positive and too technology-oriented. For instance, integration would also

include aligning the efforts of several ministries (Sæbø, Braa, & Chandna, 2007), a challenge of institutional nature.

3.2 *Integration and interoperability*

Despite its common use and perceived attractiveness, the qualifier “integration” or “integrated” in the context of information systems remains notoriously slippery as “individuals often have a different understanding of the meaning of the word” (Gulledge, 2006, p. 5), or it can “mean all things to all people” (Wainwright & Waring, 2004, p. 229). During a one-week online forum organized by the RHINO network on “integrated HIS” in July 2009, it became evident that also in the global health HIS domain, there are different understandings of the term integration. While the more technical-oriented participants focussing on electronic medical record systems, argued that integration is not possible because it means monolithic rigid systems and that open standards and interoperability is the way to go, the public health participants tended to argue that integration is best understood as efforts to harmonize and bring together the various vertical disease-specific reporting systems and sub-HIS. The HMN framework (HMN, 2008) is in fact combining these two perspectives by arguing for a central data repository that integrates the different data sources to one harmonized system, and the key mechanism for doing so is to apply inter-operable solutions between the various subsystems and the integrated data repository itself.

The dominant perspective on integration in information systems research has largely been prescriptive in character and technical in orientation (Grimson, Grimson, & Hasselbring, 2000). Strategies and approaches to integration vary (Hasselbring, 2000) and include technical solutions at different levels and forms of integration frameworks or mechanisms are identified such as data base schema integration, middleware software platforms (Corba, COM2), application or service architectures (service-oriented architecture, SOA, .NET).

More recently, however, the complexity facing integration within and across organizations have been brought more into the foreground. Singletary (2004) surveyed practitioners’ perceptions of the downsides to integration including lock-in with vendors, costs, and project risks. Wainwright and Waring (2004) have identified four domains of integration, namely *technical*, *systems*, *strategy*, and *organizational*, and argue the importance of including the organizational domain in the integration strategy, which “is rarely acknowledged in the IS/IT literature” (Wainwright & Waring, 2004, p. 342).

3.3 *Understanding the integration process – mechanisms for harmonization and alignment*

We have pointed out above how the literature distinguishes integration as belonging to various levels, ranging from the technical to the organizational, or the political. What is missing, however, is a deeper understanding of the relationship and interaction between the different domains or levels of integration. In order to address this issue, we will adapt an integrative framework developed for managing knowledge across boundaries by Carlile (2004). The framework includes three progressively complex borders; syntactic, semantic and pragmatic, and three correspondingly progressively complex processes; transfer, translation and transformation. Communication, sharing and agreeing across these increasingly complex borders are about developing appropriate boundary objects that match the needs of the borders (Carlile, 2002; Star & Griesemer, 1989), an adequate common lexicon, or standards, at the syntactic border, shared meaning at the semantic border and aligning interests at the pragmatic, political or organizational border. A fourth element of the proposed framework is the iterative cycling

through the levels in order to step by step develop common understanding and alignment of interests. Repetitions are needed because consequences cannot be seen and addressed with one try, and new agreements and changes are developed through an iterative and evolutionary process. We draw on this concept in trying to understand the standardization processes needed to achieve HIS integration, and standards tend to be evolving through negotiations between actors facilitated through ongoing efforts to develop standards in practice, rather than through early agreements (Braa et al., 2007; Egyedi, 2002; Hanseth, Monteiro, & Hatling, 1996).

In the form of shared methods or technological artifacts, the boundary objects play an important role in providing the capacity to negotiate interests (Star & Griesemer, 1989), and may “facilitate the transforming of specialized knowledge into novel jointly produced knowledge that transcends each community’s local interests” (Barrett, Oborn, Orlikowski, & Yates, 2007). Barrett et al. (2007) go further in trying to understand how the boundary object (in this case a technological artifact) not only helps to translate meaning, but also plays an important role in reshaping boundary relations between occupational groups in an organizational setting, both positively and negatively, and draws on the notion of boundaries as dynamic and relational (Abbott, 1995).

Eoyang’s (1996) work from complexity science on the concept of “attractors” is helpful in understanding the role of technological artifact in enabling organizational change in our case studies. Eoyang argues that “attractors,” e.g. successful pieces of software, play a key role in adapting the various actors to common practices within a complex system by creating momentum through shared practices. Building on this concept again, Braa et al. (2007), argue that attractors are crucial in the evolution of new standards generally, and in the complex health system context particularly. An important part of HIS integration at the country level is to get the various actors to agree on shared standards. Attractors, such as successful examples of software or data standards, may be important in convincing, or aligning through practice, the various actors in health care (Braa et al., 2007).

Having worked extensively with national HIS in South Africa, Braa and Hedberg (2002) argues that inscribing flexible standards in the software used for an HIS could allow a “hierarchy of standards.” For health management, there are different information needs depending on the hierarchical distance to the patient. Doctors would need detailed information on patients, districts would need community information to supplement their core health indicators, while national levels would only need a few health indicators to prepare a budget and take strategic decisions. Typically, the amount of information required would diminish as one went higher in the hierarchy, that is, closer to the national level. Scaling of national standards to lower levels had to be complemented with the ability of lower levels to define their own, additional, information standards.

Drawing on the concept of inscriptions (Hanseth & Monteiro, 1997), we can see that certain solutions prescribe certain behavior, and that inscribing software with incentives to integrate can be a fruitful approach. If attractors, successful standards or artifacts that offer a gravitational field among seemingly disparate actors (Braa et al., 2007), embedding such inscriptions can be created, a powerful tool for integration has been developed.

4. Case studies

In this section, we present a series of four case studies from South Africa, Botswana, Zanzibar, and Sierra Leone, all related to the global HISP, and more specifically to the implementation of the DHIS software. First we provide a general background on the DHIS’ role in supporting an integrated HIS approach.

4.1 *The DHIS software – flexible design to enable integration*

Very often a computerized HIS is a direct computerization of the various forms and reporting structures that exists in the paper-based HIS. A result of such an approach is often lack of flexibility to modify the systems when the paper-based equivalent changes or to incorporate new needs like integrating additional programs or additional indicators. Such approaches, which strengthen the existing structures of fragmentation, are typically found in the various health programs where focus is often on reporting huge amounts of detailed data upwards in the hierarchy to the national level and to donor agencies.

To integrate information at the district level and to provide flexibility to meet the rapidly changing requirements of the healthcare domain, the DHIS design strategy is based on a more flexible model that goes beyond the typical “computerize the forms”-approach. Instead of computerizing the form as a whole, the DHIS is computerizing every data item or data element in the form independently. By breaking up the form into more fine-grained building blocks of data, the software also breaks up the fragmentation the forms represent and provides the possibility of manipulating and presenting data across health programs and forms, a prerequisite for integrated data analysis. This fine-grained or atomic design enables the user to define calculated indicators (combining data elements into formulas), custom reports, tables, and graphs for analysis that are completely independent of the collection forms and can instead be understood as user-defined assemblies or reconstructions of the data (elements) that was captured using the forms. This flexibility makes DHIS a more suited tool for public health management than the more typical computerized reporting tools that exist in the various fragmented departments of the health system. The DHIS allows, e.g. a district manager to combine all relevant data on child mortality (MDG4), originally from multiple sources and subsystems, into one common report that can be used for routine monitoring of interventions related to this specific target.

4.2 *South Africa*

In South Africa, the HIS reform process started in the 1990s after the abolishment of apartheid and was part of the ANC Reconstruction and Development Plan (ANC, 1994a; Braa & Hedberg, 2002). During apartheid, the health services were extremely fragmented and inequitable and health services and geographical areas were separated according to race and the system of “homelands.” Until May 1994, there were 14 departments of health at the central level; the general National one, separate “white,” “Colored” and “Asians” administrations, and 10 “black” homeland administrations. As a result, there were no health data standards and a multitude of forms for reporting data were in use. The new national health plan (ANC, 1994b) made it very clear that the health system needed to be reconstructed based on equity in health services provision to ensure the inclusion of those who had suffered during apartheid. In order to monitor to what extent this goal was properly addressed and to pinpoint communities in particular need, access to good quality essential health data, integrated across services and geographical areas, was seen as an absolute requirement.

HISP started in three pilot districts in Western Cape Province in 1995 with the aim of developing a district-based integrated information system. It turned out to be difficult to get all the actors to agree on common standards for reporting. After an “endless” array of workshops, the breakthrough came with the development of the DHIS in the conjunction with the testing of a first version of a minimum integrated data set in the pilot districts in 1997/1998. The Province agreed to test it further and the success was rather instant; for the first time, health managers had data available at their own desktop computer without having to wait for annual reports or enquire for data at various head offices. Having seen the success in Western Cape, the

neighboring Eastern Cape province also wanted to go for the DHIS software. In Eastern Cape, a project funded by USAID had developed and implemented a minimum data set in all the health facilities in the province, but had serious problems with the software they were using. They contracted HISP and implemented the DHIS successfully at the end of 1998 and could provide full coverage data for the province early 1999. Seeing the success in two provinces, other provinces also wanted to join the process and by 2001, the DHIS and data set approaches were endorsed by the National Health Information Systems committee of South Africa as a national standard. Since 2001, South Africa has established national standard essential data and indicator sets which all provinces are required to report. In addition to this, and given the federal institution of South Africa, each province is free to collect and manage the data and indicators they want. The principle of hierarchy of standards, enabled by the DHIS, was important in creating agreement among the provinces and other actors. According to this principle, each organizational unit in the health hierarchy is free to collect the data they want and thereby pursue their own interests, as long as they adhere to the standards of the level above. Each province could then continue to collect their own data as long as they reported the required standards to the national level. There are large differences between the data sets collected by the different provinces, but they all include the core national standards. The national core standards have gradually been expanded to more use areas since 2001.

This standard reporting format was in the beginning an addition and “on top” of all other reporting forms. Through its relatively instant success in terms of data quality and easy and immediate access, more provinces joined, but also, as the momentum grew, gradually vertical programs included their basic data requirements within the national minimum data set, which later changed name to “essential data sets.” The immunization program, for example, realized that the quality of their data that were included in the minimum report was higher than in their own data reporting system, and subsequently “gave in” and included their vaccine reporting in the now national essential data set.

There are several electronic record systems in South Africa, or computerized transaction systems as seen related to the data warehouse debate. For the Tuberculosis electronic register and from some Anti-retroviral Treatment electronic registries for AIDS patients, “extract, transform and load” functionality is established with the DHIS; the standard, more technically advanced “Western” data warehouse model is gradually being adopted.

4.3 Botswana

The HIS in Botswana is extremely fragmented, with several ministries involved in the collection, compilation, and use of health data. In 2005, a centralized initiative to integrate the HIS was established through the Health Statistics Unit, which was to collect one form containing the essential data from a range of health programs. However, the main reason for collecting this data was for the compilation of an annual book on health statistics, not for supporting local health information use. At the national level, the compilation of the health statistics book was two years delayed (Sæbø et al., 2007). As a response, various health programs still relied on their own systems, which were designed and run by each individual health program. At the district level, however, most of these information systems were handled by one or two persons in one office, representing a form of human data warehouse. Some of the richer health programs, most notably, the HIV program of Prevention of Mother To Child Transmission (PMTCT), set up their own infrastructures to collect timely data by hiring their own people and equipping them with computers and software solutions.

The approach in Botswana was to make a direct mapping of the paper-based system into the DHIS version 1.4, meaning that each cell in the paper forms represented a unique definition in the

software. Even if the paper forms had overlaps and duplications, the duplications were transferred to DHIS, without standardization of, in essence, equal data definitions. This approach would not reduce the amount of data to be entered, it would not solve the duplications (which turned out to sometimes contain different figures in different forms), but it did allow for a fast implementation by avoiding “political” obstacles in the set-up of the database. As long as no paper form was changed as it was copied to an electronic format, a database could easily be agreed upon by the various stakeholders. This strategy opted for a quick solution in an environment where the capacity to negotiate an integrated solution was not present at the time. The semi-integrated data collection tool, the DHIS, was then to be used as a platform for further integration. The nature of the project organization posed severe limitations in this direction.

As part of an EU-funded research project (BEANISH¹), the Ministry of Science, Technology, and Communication oversaw the initiation of the data warehouse implementation. Assigning the administration of the implementation to their IT-unit seconded to the Ministry of Health, the project was distanced from the health domain from the start. While the IT-unit physically worked at the Ministry of Health building, its main activities here consisted of setting up the network, assigning e-mail addresses, procuring hardware, and the like. The placement of the project implementation with the IT-unit meant that the project came to be seen as a “computer project” by the various health-affiliated stakeholders. This division between health and IT became stronger over time, and the project failed to enlist “champions” in the health programs. To complicate further, public health services at the district and facility levels were run by yet another actor, the Ministry of Local Government. Unable to tie the necessary links with the Ministry of Health-run national health programs and the Ministry of Local Government, the IT-unit, formally under the Ministry of Science, Technology, and Communication, became increasingly focussed on just the computer-technical side of the implementation.

A spin-off of the data warehouse project in 2007 is worth mentioning. Looking for software to ease data collection for their CRIS analytic software, UNAIDS adopted DHIS. Driven by local champions both at national and district level, UNAIDS rolled-out this new software bundle nationwide over the following year. Representing so far a new, independent, vertical reporting structure, the network UNAIDS has established, comprising national and local actors, might also manage to integrate the other HIS in place, from which UNAIDS retrieves their HIV/AIDS specific data.

4.4 Zanzibar

In November 2004, a joint survey to study the HIS status was conducted by the Danish International Development Agency (DANIDA), World Health Organization (WHO), Ministry of Health and Social Welfare (MOHSW) and University of Oslo. The survey revealed poor HIS characterized by fragmented data collection and reporting due to many subsystems in healthcare service provision, and little use of information. As a result of this, in 2005, HISP started working with the newly established Health Management Information System Unit (HMIS Unit) at the Ministry, to implement a computerized HIS. Key objectives of the project were to (1) strengthen information use at the district level, and (2) set up an integrated data warehouse at the national level to facilitate access to information by all health programs and stakeholders. Ministry stakeholders, health program managers and district medical officers, and HISP consultants conducted a series of meetings to agree on a set of standardized data collection forms (data sets) that would form the basis of the integrated data warehouse.

To implement the same integrated data repository approach throughout the country (10 districts and a population of 1 million), a combined paper and computer strategy was implemented. The glue between all levels were the standardized essential data sets including essential data

from all health programs taking part in the integrated approach (Reproductive and Child Health, Immunization, HIV/AIDS, and Disease Surveillance). These standard data sets were both made available on paper forms to be used for data reporting between the health facilities and the district level, and electronic forms as part of the DHIS software used to register, validate, analyze, and report data at district and national levels.

In 2005, the customization and implementation of DHIS started by using the new version 1.4, which was actually under development. This caused some technical problems during the first 1–2 years, as Zanzibar acted as a test site and bugs documenter for the new DHIS version being developed in South Africa. The approach to visually break up the harmonized database into multiple essential data sets to accommodate health program needs was different from the South African way of using only one essential data set for all the data collected, and this was an important feedback to the global DHIS development process. Communication of requirements and testing of new functionality from Zanzibar became an important process in supporting the development of a more flexible and globally relevant DHIS software.

Every year since the first version of the unified data collection forms, there has been a revision process (a 3–5 day workshop), whereby the data sets are revised and updated based on negotiations among key stakeholders (health programs and other departments at the MOHSW), and as a result, the paper and electronic forms are updated on an annual basis to adapt to these revisions. While the standardization process in Zanzibar toward one harmonized system has been relatively successful due to solid political backing the other key objective from the reform process, to strengthen information use at the district level, has been a slower process. Changing the culture of dealing with health data from a hierarchical reporting perspective to one of information for local management has proved to be a long-term process and still requires lot of emphasis on capacity and awareness building.

4.5 Sierra Leone

Sierra Leone, a relatively small country in West Africa, is one of the poorest countries in the world and was ravaged by civil war that lasted for ten years before it was officially declared over in January 2002. The public health system, which suffered from a huge loss of both personnel and infrastructure during the war, is slowly rebuilding the capacity to improve the service provision across the country. This effort is led by the government and supported by many international agencies, and aims at achieving the health MDGs. The rapid growth of various health initiatives has created a situation of fragmented information systems, common also in other developing countries (Braa et al., 2007; Sæbø et al., 2007). Figure 1 depicts the fragmented situation characterized by overlapping data collection tools and data elements. The overlapping rate between two different forms can vary from 0% to 50%. In 2008, each facility reports about 17 forms.

From the fragmented HIS described above, the main issue was to provide meaningful and relevant information for decision-making and to diminish the workload of staff who are collecting and reporting the data. The suggested way forward was to use DHIS to integrate the various data flows and data sources and thereby to provide an integrated framework for M&E and data management. To achieve this, attention was devoted to the data warehouse as a starting point. All data elements were identified and sorted out in order to identify and avoid (a) duplication from overlapping data forms (b) overlapping data elements – in term of their definition. As a result, a coherent integrated data warehouse was built, where one data element in the database can be related to a field in several data collection forms. Figure 2 shows how multiple, duplicate data elements from the existing paper system were integrated “behind the scenes” in the data warehouse.

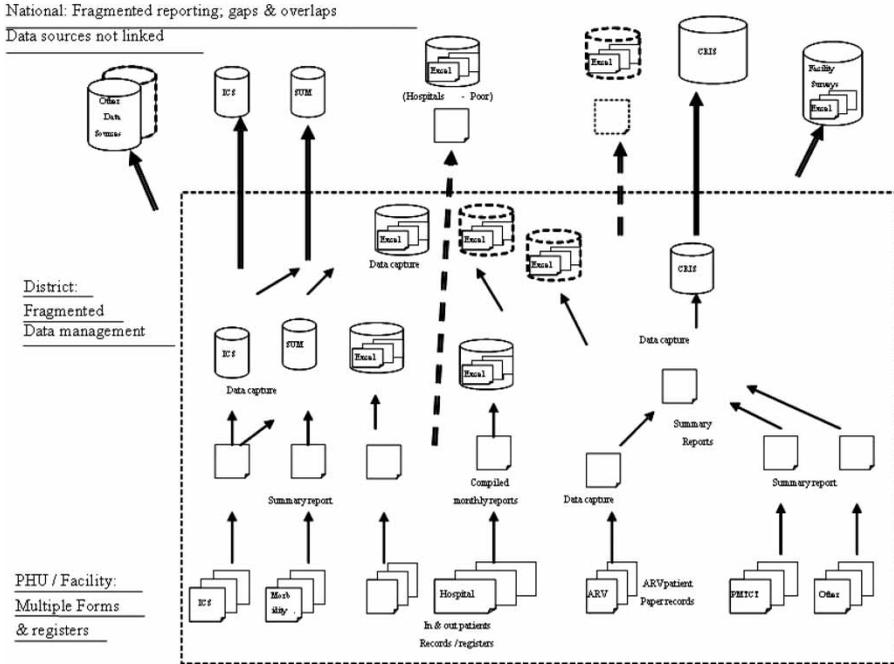


Figure 1. Illustration of the fragmented HIS in Sierra Leone in 2005.

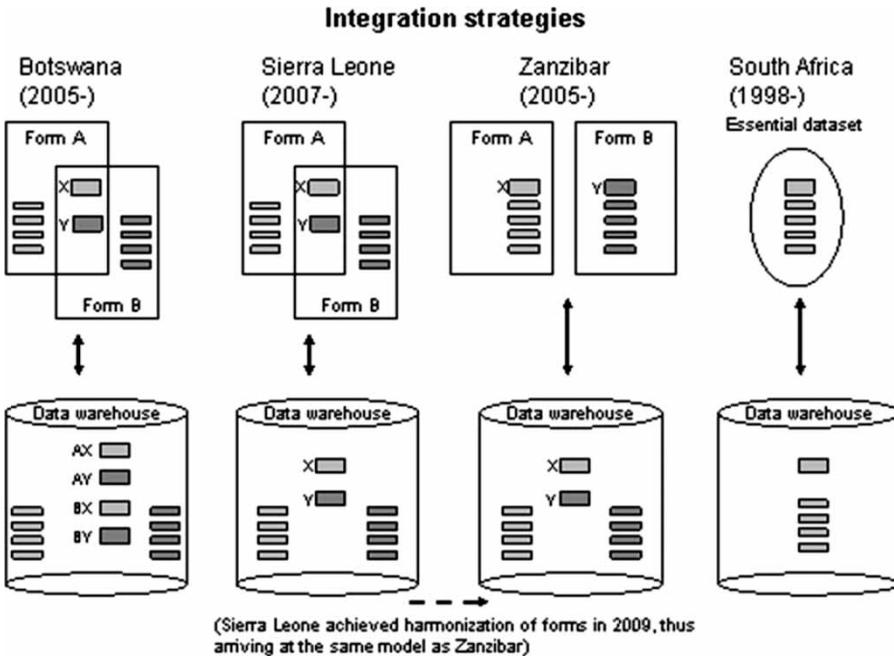


Figure 2. Integration strategies and degree of integration.

In January 2008, this integration approach was implemented in four of the 13 districts in Sierra Leone, and 6 months later in three more districts. Intensive training was carried out, each district captured their data in the DHIS and exported the data to the national DHIS by the use of memory sticks. An extensive process to capture and import backlog data from the various electronic systems from all districts was put in place, and a rather extensive national data set was available for analysis during the second half of 2008. All stakeholders were made part of the process which convincingly documented the problems with the current system such as overlapping data collection forms, inconsistent data definitions, poor data quality in terms of both correctness and completeness. At the same time, through actually doing it, it was also documented that shared common data sets in a national repository was possible to achieve. This learning process sparked an increased interest to revise the current collection forms, and during 2009, a series of meetings took place among the key stakeholders to negotiate a new set of harmonized data collection forms. As a result, since January 2010 a new set of completely rationalized and harmonized forms have been in use, very different from those of the previous years.

Coupled with extensive training in the analysis and use of the resulting information, districts are starting to show improving health indicators. With the availability of data from across the country, one district medical officer was appalled at his district's comparatively low institutional delivery rate, an indicator directly linked to MDG Target 5a (reduce maternal mortality rate), but also MDG 4 (reduce child mortality rate). Involving health staff and civil society in discussing approaches to improve the situation, they managed to significantly increase the rate both in urban and rural areas over the course of 2009.

4.6 Summary of the case studies

Figure 2 illustrates the different approaches to HIS integration in the four countries. The fine-grained data element design of DHIS allows for breaking up the forms into smaller atomic data elements which may or may not (in the case of Botswana) be harmonized in the data warehouse. From left to right, we see increased harmonization of data both in the forms and in the data warehouse. Table 1 summarizes the four case studies on key topics related to the integration process.

5. Discussion

As we have seen from the cases, there are both similarities and differences between the countries that highlight certain lessons. The similarities are perhaps the easiest to pinpoint; an initial situation of fragmentation and independent information structures, quite obstructive to efficient management to improve the health situation, including reaching the MDGs (not to forget, the poor information systems also influence other health areas than those spelled out in the MDGs). The differences are more diverse, and stem from the socio-political entity of the wider health system, including power structures, skill levels, pressure to see quick results due to funder's priorities, and entrenchedness of the former systems. In the following discussion, we try to categorize the main findings according to concepts introduced in Section 3.

5.1 Contrasting the cases – data warehousing and integration

South Africa and the three other countries represent distinct integration strategies. While in South Africa, the new system was built bottom-up and incrementally in addition to an existing array of partly inconsistent subsystems, the other three countries tried to encompass all the

Table 1. Summarizing the cases.

	South Africa	Botswana	Zanzibar	Sierra Leone
Data warehouse standardization approach	Essential data sets. Specific paper reporting forms collected uniformly across country, eventually in addition to other forms	Including all existing report forms – little revision of overlap and inconsistencies between forms and data elements. Fragmented db.	Full revision of all report forms – no overlap between forms and data elements. Annual revision process	All existing report forms – no revision of forms, overlaps solved in database, inconsistencies identified and addressed. Harmonized db.
Process started	1995	2005	2005	2007
Why this approach was selected	Extreme fragmentation caused effort to establish new unified reporting forms in addition to all other reporting routines	Capacity to lead integration not available. Data warehouse to highlight to stake-holders the need for integration	All stakeholders agreed to revise and coordinate their reporting forms and solve problems of overlaps	Previous efforts failed because not all programs were included. Now include all data reporting and stakeholders. Show overlaps and inconsistencies
Main challenges with the approach	Keep pace with new developments and technologies and remain in the forefront; e.g. on top of HIV/AIDS reporting development	To direct the early momentum gained into real integration. Avoid entrenchment of fragmented system by computerizing it	Integrated data warehouse does not automatically lead to more local use of information. More capacity in the use of information needed	Align all actors in the integration process. Local capacity building. Supporting infrastructure. Harmonization of collection tools and indicators
Main benefits of this approach	The smaller and simpler data sets gives better quality and availability of needed data from across programs	Quick computerization, fast results in populating the data warehouse	Systematic approach, combine management of data from all programs	Reduce amount of manual data entering, highlight overlaps, all data available in database. Shows early the benefits early.
Status	National standard. High quality data and level of use. Being gradually extended to new data sets and use areas	Slow to gain momentum within MoH, but full local responsibility assumed by 2008. UNAIDS-fork in nationwide use	National standard. Use of data and data quality is slowly increasing through regular district data use workshops	Stakeholders agreed on shared harmonized data sets which are implemented countrywide in February 2010

existing data and systems, each following different strategies. South Africa has gradually extended the scope of the data sets by convincing and enrolling new service areas and programs through providing good results and thus creating a momentum (Braa et al., 2007). Zanzibar represents the opposite approach: to a large extent, the old reporting systems were revised and combined into a newly integrated system. This was possible through strong political and financial support, and because they met the basic requirements of the important stakeholders, not met by the old systems. In Sierra Leone, the aim was similar, but they went through an intermediate process of including all the existing reporting formats and data sets in the data warehouse while at the same time solving the inconsistencies in the internal data structure. Through this process, problems with the existing fragmented system and the advantage of integration was documented and the stakeholders have been convinced to revise and integrate the entire system of data collection, and new integrated data standards have been decided upon. Solid political support from the Ministry of Health and the HMN was important. In Botswana, also the aim of the intermediate process was to document and convince stakeholders, but the results were less convincing. Lack of political support and commitment from within the Ministry of Health were major obstacles, and the results from the pilots did not create sufficient interest.

At the technical database level, the different strategies may be outlined as follows:

South Africa is different from the others in that they followed a data for the decision-making approach, only including the most important data from each area. As the momentum grew, gradually more areas and data were added, which was easily accommodated through the flexible database structure. In this way, national standards for essential data were developed “on top of” other existing systems. The three other countries, Botswana, Sierra Leone, and Zanzibar, all followed different all-encompassing strategies; (1) Botswana: include all data “as they are,” without solving inconsistencies between them, (2) Zanzibar: start with revising the data collection tools and solving the inconsistencies before setting up the data warehouse, (3) Sierra Leone: two phases; (a) accept that there are different overlapping data collection forms in use, but solving the inconsistencies in the metadata structure of the database, (b) use this approach to demonstrate that “full” integration similar to the approach in Zanzibar is possible.

Ideally, the best approach to standardizing health data and integrating different vertical data reporting systems would be to make all actors agree upon and implement a revised and harmonized set of standards. This is to some extent what was achieved in Zanzibar. However, due to the wide variety of vertical donor initiatives, which all tend to have their own separate reporting requirements, and overall changes in information requirements within and between the various vertical health programs, standardization of health data is a complicated process. Standards tend to be evolving through negotiations between actors facilitated through ongoing efforts to develop standards in practice and by good examples working as “attractors” that are creating momentum rather than through early agreements (Braa et al., 2007; Egyedi, 2002; Eoyang, 1996; Hanseth et al., 1996). This is illustrated well by the case of South Africa, where the first limited data set and database became successful, first in one, then two provinces, before later being adopted across the country as a result of the momentum created by successful use. The first phase in Sierra Leone also managed to create an attractor as the usefulness of the data warehouse approach was demonstrated in such a way that the involved actors agreed to go for full integration in a phase 2.

In Botswana, however, the problems of fragmented health and lack of standards were addressed mainly through a technical solution, which turned out not to be very useful; the problem of fragmentation was addressed by including all data in one data warehouse. By “dumping” all data from different health programs in one data warehouse, without solving the overlaps and inconsistencies between the data sets, analysis and use of data across the

data sets were still difficult. Overlap of data will still produce different and confusing figures for the same phenomenon. The number of pregnant women receiving antenatal care, for example, is reported through both the Mother and Child Health program and the PMTCT, resulting in different figures for the same number of pregnant women. It is therefore obvious that integration and standardization of data between these two health programs need to be negotiated between the two organizations, and they will have to agree on shared data definitions at the semantic level. There are no technical short-cuts.

It may be added that maintaining a heterogeneous data warehouse as in Botswana will require more skilled data managers interacting with advanced data warehousing tools to produce an abstracted, harmonized level on top of the heterogeneous data sources, than what is required for a strictly standardized one. Consequently, this approach is not recommended for developing countries where human resources make up the bottleneck.

Contrary to the case of Botswana, we see that in the three more successful cases, the processes of developing the system and standardizing the health data reporting have taken place at the organizational level. To what extent the solution supports integrated information use is the key criterion for success.

5.2 *Spanning boundaries through flexibility*

Carlile's integrative framework is helpful in highlighting how the four countries have followed different paths in their quest for integrated HIS, and in understanding how software and implementation strategies collectively developed in the global network of HISP have played the role as boundary objects in this longitudinal collection of case studies.

The integration process in Sierra Leone followed Carlile's processes of (1) transfer – adoption of the technical solution to share data and identify indicators and data elements, while collection forms were kept as before. (2) Translation – a new common lexicon of harmonized data elements was created in the back-end of the data warehouse, removing overlaps and duplicates that existed in the collection forms. Examples of integrated data analysis were produced and shared among stakeholders. (3) Transformation – in 2009 after using the integrated data warehouse for more than one year, stakeholders acknowledged problems of data quality with the existing fragmented collection forms and were convinced of the need for data harmonization. A revision process was started, and in February 2010, the new harmonized and standardized data collection forms were implemented countrywide. And (4) iteration – during the harmonization process, stakeholders agreed to meet on regular basis to review and renegotiate the shared and harmonized standards. This iterative process, similar to the development of the gradually expanded essential data set in South Africa and the annual revision of forms in Zanzibar, allows for integration of new and emerging initiatives and information needs, such as the country-wide launch of the free health care initiative in Sierra Leone, April 2010.

Although we have demonstrated that the political and organizational dimensions of integration are critical, there is also a role to play for the technology. Furthermore, the cases of South Africa and Sierra Leone show that the DHIS data warehouse was instrumental and worked as a boundary object in providing the capacity to negotiate interests between the actors and to transform knowledge and practices. In the first phase in Sierra Leone, the flexible data element design of DHIS allowed for a harmonized data warehouse at the back-end while keeping the clear borders of the health programs' collection forms in tact at the front-end. The inherent flexibility of the technology could this way show the benefits of integrated data analysis and attract interest (Braa et al., 2007), while at the same time delaying the political battle to harmonize the collection forms until the stakeholders had been convinced. This maturation process was followed by a second phase where the data standards and collection forms

were harmonized in a negotiation process between the health programs and the national HIS unit. In this process, the relational borders between these subsystems were reshaped into a mutually beneficial integrated information system (Barret et al., 2007).

In Botswana, the DHIS failed to play the role as a successfully attractive boundary object and did not enable any change to the relational borders between health programs, departments, and ministries, and as a result little integration took place. While the data warehouse in Sierra Leone was harmonized at the back-end and therefore could communicate the benefits of integration, in Botswana the clear borders of the health programs' forms were mirrored in the technology (Figure 2). This way, the DHIS was not able to demonstrate integrated information use and consequently failed to bridge the technical and the organizational levels of the HIS in Botswana.

5.3 *Maintaining attractiveness in a changing environment*

To explain the difference in approaches, especially the contrasting cases of Sierra Leone and Botswana outlined above, it is important to look at how the boundary objects and attractors have evolved over time. As noted in chapter 2, this study spans many years, in which changes have occurred at different levels. The implementers (and authors) have been part of an evolving network, in which both feedback and ideas from countries and research institutions have shaped the understanding of HIS and approaches toward integration.

The DHIS application has gone through many development cycles since its first use in 1996. The needed flexibility in the design, as well as the necessary experience of the DHIS implementers were not available in 2005 in Botswana, but had been developed in time for a more successful data warehouse design in Sierra Leone in 2007. Important lessons were learned in Botswana and Zanzibar, especially in dealing with multiple data sets and accommodating collection forms across health programs, which was very different from the one essential data set approach of South Africa. These new experiences and emerging requirements were fed back into the global HISP network, which again benefitted other countries, including Sierra Leone.

Furthermore, the global community of health has changed, with global partnerships like HMN and IHP+ campaigning for harmonization and integration, and giving legitimacy to formerly more marginalized groups advocating this at the country level. The strong backing of HMN in Sierra Leone played an important role in pushing the agenda for change and strengthened the effect of the DHIS as a boundary object, in contrast to the more difficult political context in Botswana 2 years earlier.

On top of all this, the projects themselves changed in nature as they scaled; from pilots to established systems which a lot of people depended on for their daily work. What was useful for bringing two initial groups together, might not be sufficient to keep growing, reaching the crucial scale necessary to offer a comprehensive system supporting the MDGs.

In South Africa, more than ten years ago, a relative simple but flexible software application supporting a minimum essential data set created an attractor, which was both addressing immediate needs for many users but also demonstrating how "similar" problems could be solved. The easiness with which to define and implement new data sets integrated with other data sets using the DHIS led to innovations and new use areas, and it led to the spread of the DHIS and HISP approaches to new countries. The strategy that has led to success in South Africa and to some extent also in Sierra Leone and Zanzibar, and generally in the DHIS and HISP networks, has been to create an attractor by initially providing easy to make, but useful solutions, which may later evolve and become more comprehensive as new actors and use areas are included (Braa et al., 2007).

Through the changing context brought by external and internal factors, as well as scaling of the initiatives themselves, the forces of gravity emanating from the attractors grow and wane in strength. Maintaining attractiveness, then, becomes a key goal. The first efforts in South Africa started before the MDGs were formulated. The projects in Zanzibar and Botswana were initiated as HMN was just starting to build global legitimacy for an integrated approach. By the time Sierra Leone reformed their HIS, an integrated system supporting the MDGs was very much a core requirement. The DHIS software has over the years closely followed this trend. Flexibility to integrate various data sets and to customize data collection forms and reports have ensured that health programs could opt for a quick win; joining the “integrated” data warehouse without having to reform their data collection tools and to use the data warehouse as an active instrument in the continuous process of standardization and integration, as we have seen in Sierra Leone.

The reason why DHIS is still used to create attractors in new countries and use areas is that it has been under continuous development and has managed to evolve with the requirements of the ever-changing needs of global health, and has thus managed to stay attractive over time. The fact that DHIS is still an attractor, however, also demonstrates that the problems of fragmentation and challenges of integration are not yet solved.

6. Conclusion

With 10 years spent pursuing the MDGs, there is still a lack of adequate HIS for management and monitoring capacity in many countries. In response to this, and the sorry overall state of HIS and use in developing countries in general, the international community has advocated integration to reduce the inefficiencies of the fragmented legacy systems of decades of uncoordinated development interventions. This paper has addressed the challenges to such an integration by investigating four country cases, all of which had different approaches to integration.

We have argued that integrated information systems and quality information are needed in order to achieve the MDGs. In order to, for example, substantially reduce maternal and child mortality and to successfully combat HIV/AIDS, both targeted action and coordination of health services will be needed. This again will require the use of quality data for both local level decision-making and services delivery, as well as integration of information across health programs.

We have described and discussed four cases of applying a shared data warehouse – as a tool to facilitate practical integration of information across different organizational structures. The lack of success in Botswana and the relative success in the other three countries, clearly indicate that although following a technically termed “data warehouse approach,” in order to be successful, integration needs to be rooted at the institutional and organizational political level. The data warehouse approach, when applied successfully, has turned out to work as an important mediator and boundary object facilitating the negotiation between the organizational actors.

We argue that “attractors,” technical solutions or standards that achieve a certain level of success and enable the building of momentum, are important in aligning the various political actors. The networks of action approach followed in this longitudinal research project enables circulation of methods and software between country implementations, and facilitates learning and sharing over time. These networking mechanisms are important in making sure that the attractors evolve within the changing context of a growing HIS, in order to achieve the scale needed to address the MDGs with full force.

Note

1. Building Europe Africa collaborative network for applying IST in health care sector (see <http://208.76.222.114/confluence/display/BEANISH/Home>).

Notes on contributors

Johan Sæbø is a PhD Fellow at the University of Oslo. His interests are scaling and sustaining HIS. He is currently holding a JPO-position at the HMN, a partnership with WHO, in Geneva.

Edem Kwame Kossi is a PhD Student of Informatics at the University of Oslo. His interests are mainly focussed on HIS, including implementation and integration strategies, standards and soft regulation in IS.

Ola Hodne Titlestad is a PhD Fellow at the University of Oslo. His interests include HIS and open source development models, and he has extensive experience in participative development of open source health information software.

Romain Rolland Tohouri is a PhD Student of Informatics at the University of Oslo. His area of expertise covers HIS and open source development.

Jørn Braa is a Professor at the Department of Informatics, University of Oslo. His research topics include HIS, open source, standards, and implementation and scaling models. He has since the mid-1990s been a focal person for the global HISP network.

References

- Abbott, A. (1995). Things of boundaries. *Social Research*, 62, 857–882.
- ANC (1994a). *The reconstruction and development programme*. Johannesburg: African National Congress.
- ANC (1994b). *A national health plan for South Africa*. Johannesburg: African National Congress.
- Barrett, M., Oborn, E., Orlikowski, W., & Yates, J. (2007). *Boundary relations: technological objects and the restructuring of organizational boundaries* (Working Paper Series of the Judge Business School, Cambridge University. No. 16, 2007). Cambridge: Computer Society Press, Cambridge University.
- Braa, J., & Hedberg, C. (2002). The struggle for district-based health information systems in South Africa. *The Information Society*, 18, 113–127.
- Braa, J., Hanseth, O., Heywood, A., & Shaw, V. (2007). Developing health information system in developing countries: The flexible standards strategy. *MIS Quarterly*, 31, 381–402.
- Braa, J., Monteiro, E., & Sahay, S. (2004). Networks of action: Sustainable health information systems across developing countries. *MIS Quarterly*, 28(3), 337–362.
- Carlile, P.R. (2002). A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science*, 13(4), 442–455. doi:10.1287/orsc.13.4.442.2953
- Carlile, P.R. (2004). Transferring, translating, and transforming: An integrative framework for managing knowledge across boundaries. *Organization Science*, 15(5), 555–568. doi:10.1287/orsc.1040.0094
- Egyedi, T.M. (2002). Standards enhance system flexibility? Mapping compatibility strategies onto flexibility objectives. In *EASST 2002 Conference: Responsibility under uncertainty*. York, UK: European Association for the Study of Science & Technology, University of York, July 31–August 3.
- Eoyang, G.H. (1996). “Complex? yes! Adaptive? Well, maybe...”. *Interactions*, 3(1), 31–37. doi:10.1145/223500.223509
- Grimson, J., Grimson, W., & Hasselbring, W. (2000). The SI challenge in health care. *Communications of the ACM*, 43, 48–55. doi:10.1145/336460.336474
- Gulledge, T.R. (2006). What is integration? *Industrial Management & Data Systems*, 106(1), 5–20. doi:10.1108/02635570610640979
- Hanseth, O., & Monteiro, E. (1997). Inscribing behaviour in information infrastructure standards. *Accounting, Management & Information Technology*, 7(4), 183–211. doi:10.1016/S0959-8022(97)00008-8
- Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing information infrastructure: The tension between standardisation and flexibility. *Science, Technology and Human Values*, 11(4), 407–426. doi:10.1177/016224399602100402
- Hasselbring, W. (2000). Information system integration. *Communications of the ACM*, 43(6), 32–38. doi:10.1145/336460.336472
- Health Metrics Network (2008). *Framework and standards for Country Health Information Systems*. Retrieved from <http://www.who.int/healthmetrics/en/>
- IHP+ (2010). Retrieved 28 May, 2010, from <http://www.internationalhealthpartnership.net/en/about>
- Kossi, E.K., Braa, J., Tohouri, R., Uggowitz, S., Yumkela, F., Bye, K., ..., McEwen, E. (2008). De-fragmenting health information systems in Sierra Leone: Horizontal and vertical integration.

- In P. Cunningham and M. Cunningham (Eds.) *IST-Africa 2008 Conference Proceedings* (Ref. No. 95). IIMC International Information Management Corporation.
- Sæbø, J., Braa, J., & Chandna, O. (2007, May 28–29). *A flexible approach to integrating health information systems: The case of data warehouse as integrator in Botswana*. Paper presented at the IFIP WG 9.4, São Paulo.
- Sahay, S., Monteiro, E., & Aanestad, M. (2009). Configurable politics and asymmetric integration: Health eInfrastructures in India. *Journal of the Association for Information Systems*, 10(5), Article 4. Retrieved from <http://aisel.aisnet.org/jais>.
- Singletary, L.A. (2004). Applications integration: Is it always desirable? In *Proceedings of the 37th Hawaii International Conference on System Sciences* 1–9 (pp. 265–273).
- Stanford University (1998). Data warehousing at Stanford, Retrieved from <http://infolab.stanford.edu/warehousing/warehouse.html>
- Stansfield, S., Orobato, N., Lubinski, D., Uggowitz, S., & Mwanjika, H. (2008, July 13–August 8). *The case for a National Health Information System Architecture: A missing link to guiding national development and implementation*. Paper presented at the Making the eHealth > Connection: Global Partnerships, Local Solutions Conference, Bellagio, Italy.
- Star, S., & Griesemer, J.R. (1989). Institutional ecology. “Translations,” and boundary objects: Amateurs and professionals in Berkeley’s Museum of Vertebrate Zoology, 1907–39. *Social Studies of Science*, 19, 387–420.
- Susman, G., & Evered, R. (1978). An assessment of the scientific merits of action research. *Administrative Science Quarterly*, 23(4), 582–603.
- Wainwright, D., & Waring, T. (2004). Three domains for implementing integrated information systems: Redressing the balance between technology, strategic, and organizational analysis. *International Journal of Information Management*, 24, 329–246.
- WHO (2005). *Health and the millennium development goals*. Retrieved from http://www.who.int/mdg/publications/mdg_report/en/
- WHO (2007). *Everybody’s business: Strengthening health systems to improve health outcomes: WHO’s framework for action*. Geneva.

III

Developing Integrated National Health Information Systems in Malawi:

Oriented emergence of flexible architecture

Edem K. Kossi, Chipo Kanjo, Christon Moyo, Jørn Braa

Abstract

In this paper, development of an integrated health information system based on an iterative and data warehouse approach is discussed. Using a case from Malawi, the process was lead by a data standard task force whose mandate was to organize the overall HIS framework as a way of ensuring that both organizational politics & differences, and technical issues are taken on board. The need for open standards for interoperability is discussed and such standards are seen as important for enabling African countries to control their own systems development despite their relatively weak technical competencies. This development has benefited from collaboration with other African countries such as Sierra Leone and Tanzania through the sharing and exchanging practices and open source software. Based on commonality of the different programs, integration is done one program at a time. Initial success of first systems integrated ensures process continuity and the system gains strength and builds momentum. This encourages more actors to integrate their systems into the data warehouse. This approach improved the interoperability of the Malawian HIS as the initial integration gave a strong basis for its development. But how could such organization achieve its goal when it has no control on system development and lack skills for technical standard making? We explore how the emergence of the new HIS is influenced by both the data standard task force and conjunctures.

Keywords:

Iterative integration, HMIS, Data warehouse, HIS architecture, standard.

1. Introduction

This paper is about integration of health information systems (HIS) following an iterative data warehouse approach where data sets from various health programs have been included gradually and without introducing radical changes “over night”. Interoperability between systems is important in such an approach to integrated health information architectures and the paper is discussing the need for open standards for data exchange. The case being studied is from Malawi but the paper is arguing that the findings are relevant also for other African countries.

As most African countries, Malawi's health systems and health information system (HIS) remain weak and of poor quality. However the key to improving the health systems, health status and attaining the three health-related Millennium Development Goals (MDGs) is to have well-functioning HIS (WHO 2007). However, in many countries HIS remain fragmented between different health programs, and donor agencies, with little or no coordination between them (Braa et al, 2007). Efforts have been made to improve and strengthen HIS in developing countries, this include the establishment of the Health Metrics Network (HMN) by WHO in 2005 (HMN, 2008). The core role of the HMN strategy is working for integration of different data sources and sub-systems. HMN adopted a data warehouse approach as a way of achieving this strategy. According to the HMN strategy, countries should develop a country data warehouse (repository), for aggregate data and indicators to be shared across a Ministry of Health (MoH), health programs and agencies. Using a case from Malawi, we explore how the emergence of the new integrated HIS that uses the HMN data warehouse approach is influenced by both the data standard task force and conjunctures. We discuss how the new approach improves fragmentation of health information systems within the MoH. The Malawi HIS is called Health Management Information System (HMIS).

Causes of Fragmentation within the Health System

The Ministry of Health is dominated by health programs which are rich in resources than the ministry itself. The budgets for the different health programs are not centrally controlled by the ministry. Each of the health program deal with a particular disease, such as HIV/AIDS, Malaria, Tuberculosis (already three different programs organised as separate entities). They also deal with areas of the health services, such as the Extended Program on Immunisation (EPI) responsible for vaccination; Reproductive and Child Health (RCH) responsible for the health services addressing pregnant women, deliveries and new born, infants and children; Family Planning program; and so forth. Each of these health programs will have funding from external donors who will require reports on how their funds are used. As a consequence of such demands for data and reports (combined with the fact that the official reporting system is not able to provide such data), each vertical health program will establish their own reporting and information system. This leads to a situation where there is no coordination of information resources and no shared data standards. Given this situation, an iterative approach to integration was followed rather than having total integration of data and reports from the different vertical health programs.

Iterative Integration Process as a Solution

Starting with the official information system of the Ministry of Health (MoH) called the HMIS in the data warehouse, iteratively vertical programs were integrated into the data warehouse, one at a time. Integration was done taking into consideration the needs of each health program integrated and the commonality of the different programs. The aim was to create “win-win” situations. By working together each program would get a system that satisfies their requirements. After demonstrating some initial success; which indicated that integrating iteratively actually worked, the project gained momentum and is attracting increasing interest from other stakeholders. The decision of which programs to be integrated first was collectively done by the data standard task force members. Some lessons were learnt from this process, a key lesson was that the obstacles to integration are not only technical by nature, but organisational, political and social. As Latour expressed, integration of systems fail not because of technical reasons alone, but due to a combination of other more complex issues such as institutional, political, and social (Latour, 1996), particularly in cases where technology develops independently from social contexts.

This paper describes a situation where a “one size fits all” integration where all vertical programs of the Malawi health care system were integrated into an HMIS at once, failed. The reasons for its failure and the architecture of the failed system are also explained. The paper then describes the proposed iterative and data warehouse approach that addressed the problem. It also illustrate soft influence from a steering committee combined with conjunctures can impact the development of the overall HIS. We address the following research question:

How can political will and conjectures influence emergence of an integrated HIS architecture in contexts where there are limited human resources for technical standardization?

2. Conceptual Framework – Health Information Systems in Developing Countries and Integration

Health Information Systems in developing countries

Effective Health Information Systems (HIS) are seen as being important in the process of improving health systems and health status in developing countries (e.g. AbouZahr and Boerma 2005). However, developing and successfully implementing such systems have proven to be difficult due to unrealistic expectations (Heeks, 2002), the problem of sustainability (Kimaro and Nhampossa 2005) and the fragmented and uncoordinated organizational structures in health (Chilundo and Aanestad 2004). The problem of sustainability is generally related both to the need for technical support structures to maintain

systems and ICT technology and the need for human capacity to manage, analyse and use the information (Kimaro and Nhampossa 2005). Fragmentation and lack of coordination is a major characteristic of the health sector in developing countries. International donor agencies target their support to specific health programs, such as HIV/AIDS, immunization, or maternal health, and develop their own reporting structures and information systems to monitor and control their activities and impact. By supporting their own vertical HIS, they contribute to the weakening of the overall national “official” HIS and reporting structures. The Health Metrics Network (HMN), Technical Framework for HIS development (HMN, 2007) identified fragmentation of HIS and uncoordinated vertical systems as the major problem in countries and recommended integration using a data warehouse approach as a strategy. According to the HMN Framework, integration is achieved by extracting essential aggregate, statistical data from different data sources and loading it into a data warehouse. Following this approach, information from different sources considered as essential by the different programs and areas of health management, are made available at “one point”..

A similar approach to integration has been followed by a network called HISP (Hedberg, 2002; Braa, Monteiro, Sahay, 2004). Starting in South Africa in the 1990’s, HISP has been developing an open source database application suit, called the District Health Information Systems (DHIS), which is enabling the integration of aggregated data from across different health programs and services and from different types of data sources. This is more or less what we are labeling a data warehouse approach in the context of the HMN Framework. In a recent study (Sæbø et al., 2011), four different country cases following a data warehouse approach to integration from the HISP network and using the DHIS were analyzed. The findings indicate that they differ in the way they include data sets and official reporting routines in the DHIS applications. Zanzibar, Sierra Leone and Botswana include all data sets and official reporting routines in the DHIS applications in an effort to make a new all-encompassing system), whilst South Africa use a summary of the most important data in the DHIS application without replacing the other more comprehensive systems. The following three cases and strategies are important for analyzing the case of Malawi:

Two countries that followed an “all encompassing” approach:

Zanzibar: All stakeholders agreed to a standardization approach where the various datasets were harmonized; overlaps, inconsistencies in definitions, and gaps were solved. This process was funded and supported politically. New revised paper forms for data collection were distributed and the DHIS was customized accordingly.

Sierra Leone: A two-steps approach was followed. As stakeholders did not agree to abolish the existing paper forms and routines – they did not trust that the process would benefit them

– the approach was to use the two systems in parallel first for data collection forms, until the inconsistencies were solved in the DHIS database, and the datasets were fully integrated and harmonized. Second, after the stakeholder saw that collaboration and integration was indeed possible, after about a year, they agreed to revise and harmonize all the data collection forms.

One country followed “essential data and indicator sets” approach:

South Africa: The essential data and indicators used for management and decision making are collected, managed and used through the DHIS application. Since the late 90’s, these data sets have been constantly revised and extended as new requirements and needs have emerged.

Health data standards are key to HIS integration and they typically emerge through a standardization process rather than being decided in committees (Braa, et al. 2007). In that way the iterative process in Sierra Leone may be regarded as typical. In this article we will show how Malawi is following a similar approach to Sierra Leone.

Integration

Integration is a term with different meanings in different contexts and which could mean different things to different people. In the organizational context of HIS we may use the term integration as related to goals of better efficiency, effectiveness and co-ordination in organizations (Wainright and Waring, 2004). In the current landscape of HIS in developing countries numerous systems are in use and integration will denote processes to bring these systems together and make them “talk” to each other. In the IS field, the concept of integration has evolved over time from the narrowly technical perspective to a complex socio-technical one. The desire to integrate the different systems in order to have better information and better control has often resulted in greater risks and less control. A study of efforts to integrate information systems in hospitals in Norway has shown that it eventually led to more fragmentation and less control (Hanseth et al., 2006). The number and role of side effects increased with increased integration (Hanseth and Ciborra, 2007). Integration may therefore lead to increased complexity.

In order to analyse levels of integration better, we will adapt a framework developed by Carlile (2004) to share and assess knowledge across boundaries in organizations. The framework includes three progressively complex borders; syntactic, semantic and pragmatic. It also uses three corresponding progressively complex processes; transfer, translation and transformation. Communication, sharing and agreeing across these increasingly complex borders are about developing an adequate common lexicon, or standards, at the syntactic border, shared meaning at the semantic border and aligning interests at the pragmatic, or political or organizational border. The proposed framework has a fourth element which is the

iterative cycling through the levels in order to step by step develop common understanding and alignment of interests. This framework describes an ongoing and iterative process where one attempt may not suffice and stresses the need for continuous adjustment or re-adjustment. It considers that the environment in which integration takes place is complex and unstable.

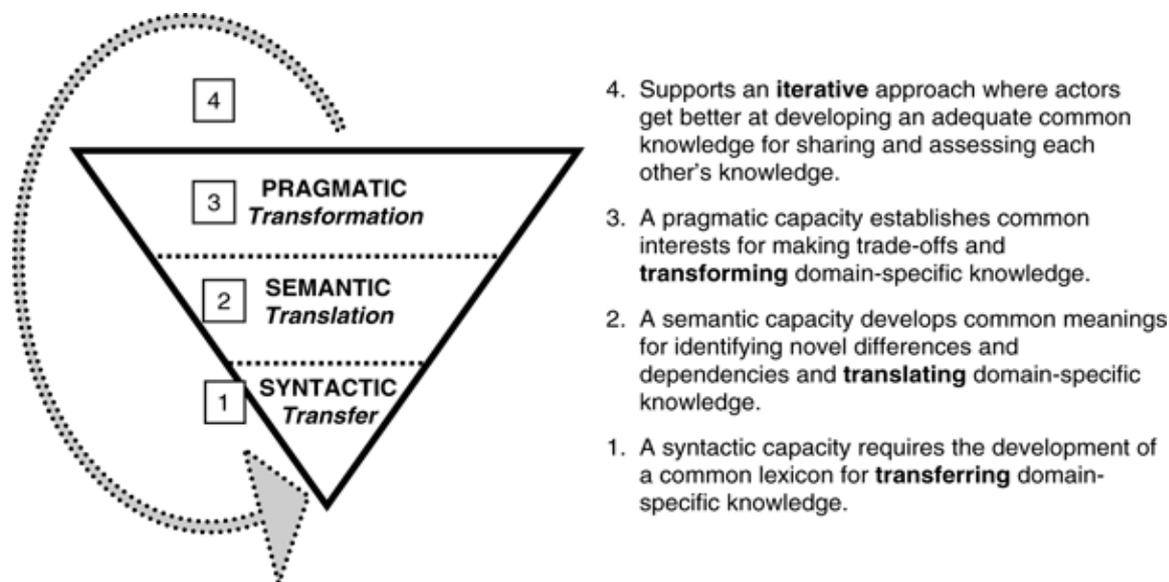


Figure 1: Carlile's framework and the four characteristics of a "Pragmatic" boundary Capability.

Interoperability is, contrary to integration, a term which may be given a more formal definition; in our context interoperability refers to the ability of a system to use information or functionality of another system by adhering to common standards. Without agreed standards shared by at least the systems, processes or other actors which are aiming at interoperability, interoperability is not possible.

Architecture is formally defined by the standard (IEEE) as representing the fundamental organisation of a system embodied in its components, their relationship to each other, and to the environment, and the principles guiding its design and evolution. In this article we build on the Health Metrics Network (HMN) Framework as representing agreed overall health information systems architecture to be used by countries. The HMN Framework architecture approach is to use a central data repository/data warehouse for aggregate data which is integrating data from multiple sources as a key component. Standard based interoperability needs to be established between these data source systems and the data warehouse.

3. Methods

All the authors have been actively involved in all phases of the HIS implementation project described in this paper since its inception. The study followed an action research approach. In

this context, action research aims at generating new knowledge through participation in the iterative process of HMIS system development and to feed back this new knowledge to the process. Feedback is through a cyclic approach of (adjusting) design and planning, development, implementation, use and evaluation, and then adjustment before the next cycle (adapted after e.g. Susman, Evered, 1978). All authors are involved in project in Malawi, and one was also involved in the Sierra Leone, whilst one was involved in the South Africa, Sierra Leone, Zanzibar projects as well as in the wider Health Information System program (HISP) network . The free and open source District Health Information Software version 2 (DHIS2) has been used as a data warehouse in the actual development of the harmonized data sets (www.DHIS2.org).

The research behind this paper has also used document analysis, participatory approach involving data collection from national data standard workshop and task force meetings (which all the authors took part), experiences from the other countries mentioned above, and participation in the design of the iterative approach. In Malawi, one author was involved in the processes that led to the implementation of the initial HMIS system and the monitoring and evaluation processes. One of the authors participated in the 2007 annual sector wide approach (SWAp) performance review. The authors work with the Central Monitoring and Evaluation Division (CMED), a department responsible for HMIS. In this case the authors used the “researcher as employee” (Easterby-Smith, Thorpe, and Lowe, 1991) method. This helped to experience the processes surrounding HMIS integration at first hand. Three authors are members of the national data standards task force and are directly involved in the design of the data warehouse approach. To come up with a good situation analysis, five papers and a thesis were reviewed. The papers and the thesis were part of the results of studies conducted by the authors.

In addition, other literatures (and HMIS bulletins) were reviewed to have a clear understanding of the context in which the iterative approach was taking place. These included the 2007 annual joint sector wide approach (SWAp) performance review and the 2008 landscape survey of the health information systems in Malawi reports. To ensure that the information needs of the vertical programs are met, members from the vertical programs are directly involved in the process of designing the system. This is being done using a prototype system. The integration is to be done in an iterative manner starting with expanded programme on immunization (EPI) and HIV/AIDS systems.

4. The case of Malawi

4.1 The HMIS System: the initial integration process

An integrated HMIS was implemented in Malawi in 2002. Prior to this system, the national health information system was just a compilation of a number of separate data reporting systems organized by the various health programs. During a process of workshops and committee work 2001-02, the stakeholders agreed to new national minimal and essential data sets to collect data and new paper forms for data collection were designed (Chaulagai et al., 2005). In collaboration with HISP South Africa, the DHIS v1 was customized to manage the data flows. The new data sets included a sub-set of the data being collected by each of the health programs. Initially, health programs and other stakeholders regarded the national HMIS as the main system providing the official and best quality data. However, as time went by, and disease burden and health system changed, the vertical health programs did not wait for the official HMIS to adapt to the changes and focused on improving their own reporting systems. The official HMIS did not adapt to the changing requirements on time. By 2009 there was consensus to develop a new integrated system. Malawi was part of the HMN process of developing new strategic plans for strengthening country Health Information Systems, and the Central Monitoring and Evaluation Division (CMED) of the MOH decided to start a project to develop a new integrated system following a data warehouse approach, as recommended by the HMN Framework. This new strategy consists of integrating the current HMIS managed by CMED with the systems being used by the HIV/AIDS and EPI programs.

The approach of minimum data and indicator sets followed by Malawi in the first phase of developing the HMIS 2001-02 had been successfully followed in South Africa since 1998 (Braa, Hedberg, 2002). The focus was on essential information and on reducing the number of data variables collected. The DHIS v1 database application developed in South Africa was used and implemented in Malawi. The DHIS was designed for flexibility in terms of user participation and prototyping in the development of the system and the meta data structures. This included the definition data variables, indicators, evaluation rules, and the organizational hierarchy of clinics, hospital, and districts from where data is reported.

The plan was for HMIS, to be the sole source of information from the health sector, or at least the dominant and most reliable source, as it would cover the essential information from all programmes. However, a few years after the implementation in 2002 it became clear that the minimum essential data sets approach had caused more fragmentation instead of solving the problem. The data elements and indicators generated from the HMIS were not seen as sufficient by the health programs as only a sub-set of their data needs was met. For example, while the immunisation program (EPI) wanted data on all the vaccines they provided, the official HMIS only reported data on a subset of the vaccines. Furthermore, the procedures

and routines for data collection followed by the HMIS were not well aligned with the needs of the health programs as, for example, the EPI wanted monthly reports and the HMIS collected data only quarterly (Galimoto, 2007). As a result, the vertical programs continued to use their own reporting systems resulting in duplication of data collection and following inconsistencies between data reported from vertical programmes and the national HMIS. It became difficult to know what was the official, or best, data on health services and status in Malawi. Access to data is another problem, as the central HMIS database is “standalone” and not accessible by districts and health programs at central level.

4.2 The New Data Warehouse Approach

An assessment of the overall HIS in Malawi was conducted in 2009 as one of the first steps to strengthen the HIS and as part of the process of implementing the HMN framework. The assessment revealed weaknesses of the existing system as related to fragmentation, poor data quality and limited access to the data and it concluded with the need for integration. Data from different sources would be integrated in one web based data repository based on the data warehouse approach. This would improve the access and availability of data to stakeholders (Figure 1). A strategic plan for strengthening the HIS was developed as a second step of the HMN roadmap. The approach agreed upon by stakeholders was to integrate different sub-systems gradually and to make sure that the requirements of the various stakeholders were met through a collaborative process. In order to ensure interoperability of existing systems at different levels and in different domains, the need for adopting open standards was written into the strategic plan document. There was however no clear idea about what standards to adopt, but the concrete aim was that all systems should be able to exchange data with dhis2 which would function as the backbone of the HIS architecture.

4.3 Integrating routine subsystems

The proposed approach was that each vertical program should have their routine dataset included in the integrated data warehouse without duplications of data collected by various health programs. Furthermore, the health programs agreed to conduct the integration process gradually in order to be able to negotiate agreements between programs with overlapping interests. In the end, the plan is to arrive at an integrated HIS with harmonized metadata and collection tools.

The integration process started in October 2009 with three systems; the national HMIS based at MoH, and the HIV/AIDS and the EPI systems. These three actors were chosen because of their strategic importance in the health system and their strong influence on decision makers and other health programs.

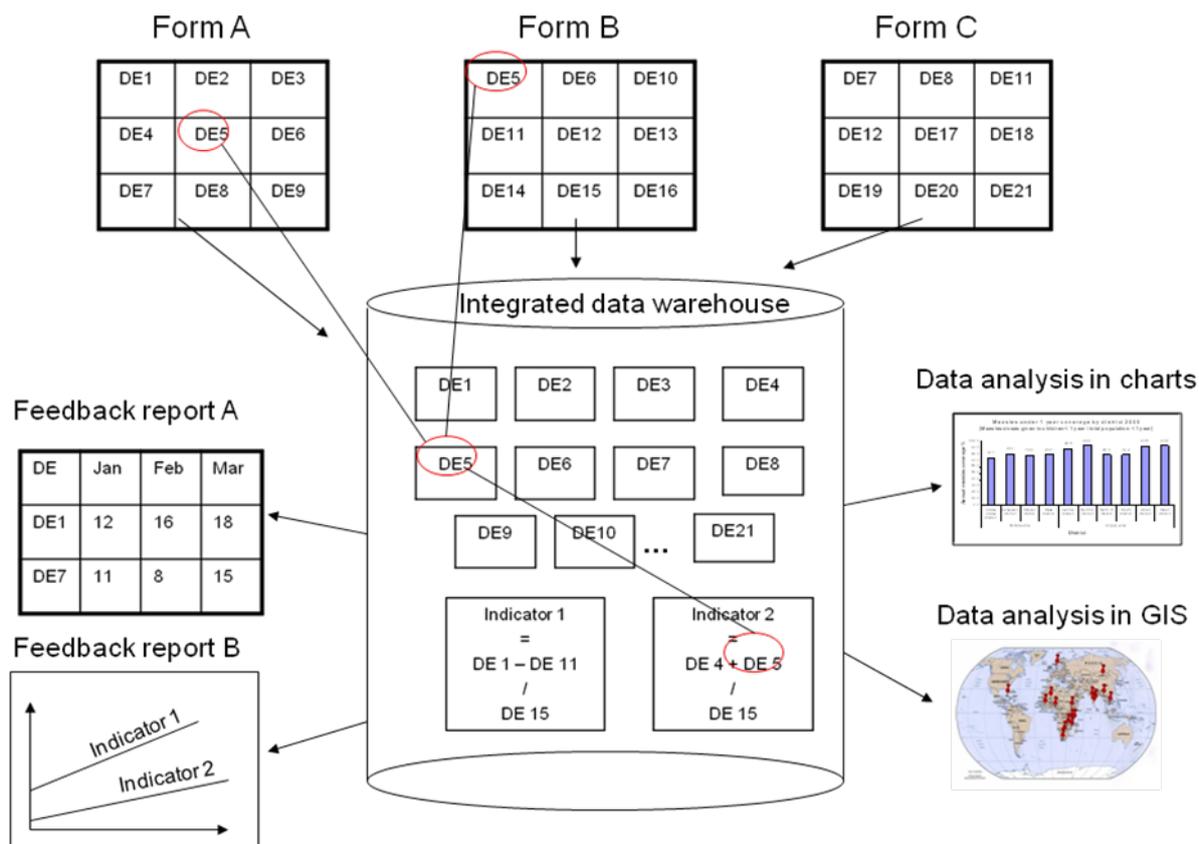


Figure 2 – Data warehouse approach for integrating HIS

The aim is to start with these three actors and once the process yields result more vertical programs systems can be brought on board and integrated into the data warehouse iteratively. The choice of the two initial programs to be integrated into national framework was made based on a number of factors: i) the EPI unit and CMED were already collaborating on data collection as the EPI was from 2008 providing the official national figures for EPI data in HMIS; ii) the HIV/AIDS program is the “richest” and most powerful of all the vertical programs and with them on board the integrated system may be more attractive for others. Furthermore, the HIV/AIDS program has access to financial resources from Global Fund which can be used for strengthening HIS. Since 2005, the HIV/AIDS program has developed its own HIS based on the MS Access platform.

In order to ensure user involvement the prototype system is demonstrated regularly to the whole team to make sure that the requirements are met and get feedback. Most of the problems discussed during the feedback sessions are more of political than technical character; such as what to do with the overlapping data collection forms? What to do when the same or similar data elements appear on different data collection tools, owned by different health programs? As the health programs seem to have more ownership to the paper forms than to the data, it is not an option to simply remove or change paper forms. In principle,

everybody agreed to the need for harmonising the paper reporting tools, but it was difficult to achieve it in practice. The chosen strategy was to develop the system in close cooperation with the health programs and other users so as to ensure that the new system was meeting their requirements. This way, stakeholders “trust” to use the new system was enough for them to abolish parts of their “own” data reporting tools.

4.4 Broader integration: integrating at different levels

The broader HIS ecosystem in Malawi comprises different actors ranging from institutional data sources – National Statistic Office (NSO), National Registration Bureau (NRB) – to other HIS subsystems – Human Resource, Finance, Logistics. Other actors such as software development and implementation organizations (Baobab and Luke International Norway, HISP) are also part of the framework and play critical roles in the evolvement of the system as they are also members of the data standard task force.

Having noticed the complexity of the HIS framework, CMED and other stakeholders took the lead in 2008 to establish a national data standard group which is a collaborative framework to engage stakeholders in ongoing planning and implementation of the health information infrastructure. The national data standard group aims at building consensus on HIS policies, integrated HIS, appropriate standards, interoperability to support loosely-coupled systems and promoting innovative and scalable solutions. In sum, the data standard group is responsible for developing a more coherent, genuine and integrated HIS architecture. According to the standard task force group, existing systems operating at aggregated data and individual patient levels should be integrated through a data warehouse approach and standards needed to be developed to enable interoperability between systems at different levels. However due to lack of qualified personnel and the absence of proven or effective open standard in this domain, the debate about strategies to achieve interoperability was to some extent left to the technical actors, the system developers and implementers.

As far as patient management information systems are concerned, there are two main actors. The first one is Baobab Health project which started in 2001. Baobab deals with medical records and has several modules – ART, Out-patient, Laboratory, HTC, patient registration, pharmaceutical inventory – and is based on OpenMRS. Furthermore, they use touch screen appliances to run Baobab system in the health facilities. Their system is currently deployed in 11 health facilities mainly in the central region of the country. The second system is Luke International Norway (LIN)-HIS which is also open source and has two main modules – EDS and pharmaceutical inventory system. The EDS module has two versions; one with touch screen technology and another with conventional computers. LIN systems are deployed in 5 health facilities in the northern region. Although LIN started its activities in Malawi in 2008, its HIS activities is just a continuation of what Taiwan Medical Mission was doing in assisting Mzuzu since 2002 to 2007. Taiwan medical mission has stopped because Malawi government decided to recognize China instead of Taiwan.

Baobab and LIN are both NGOs and they are competing for national leadership and each want to secure a sizeable share by having the strongest installed base. Both are members of the data standard group. The main selling arguments they have are the number of patients they are serving and the integration of their system to DHIS2. Both state that they export electronically aggregated data from their system to DHIS2 since November 2009 although nobody has witnessed such process yet.

As far as the standard issues are concerned the view of the data standard group is to adopt and promote open standards that will be internationally recognized because developing data exchange standard is beyond its capacity and politically it does not want to favour any of the two. However its concern is the interoperability of all existing systems. The newly released SDMX-HD standard for exchange of statistical health data is already implemented by the DHIS2 and the OpenMRS and will be implemented and used also by the Baobab and the LIN. The SDMX-HD standards represent a practical solution to interoperability between the DHIS2 and the other systems. In this way is solves the problem of the data standard group since SDMX-HD was like the missing link in architecting the overall HIS. The choice of implementing a new Human resource management project using iHRIS was motivated by the ability of the system to be interoperable with the DHIS2. Figure 2 shows the planned architecture which aim at extending gradually the implementation of SDMX-HD with other systems.

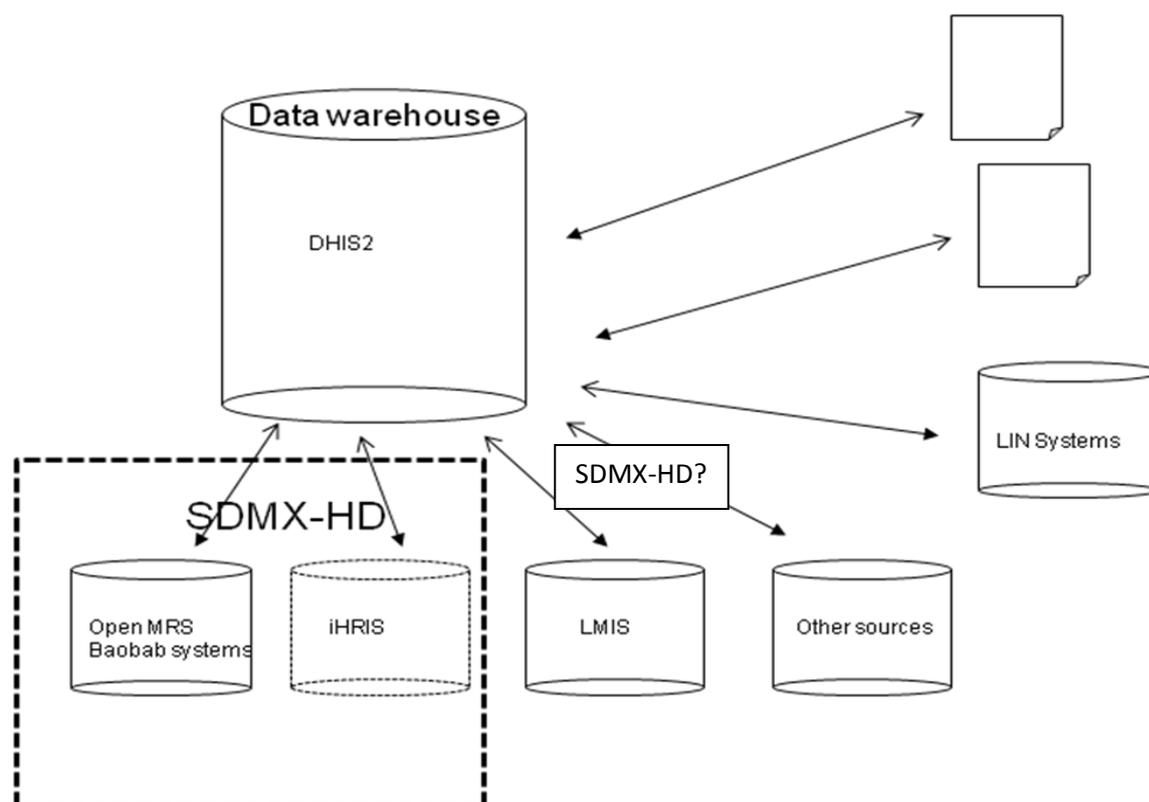


Figure 2: Planned architecture, following the HMN Framework

5. Discussion

5.1 HMIS Integration Process

The findings from Malawi confirm what other IS researchers have found, that standardisation and integration is evolving over time and that a narrow technical perspective needs to be extended to include a more complex socio-technical one (Braa et al, 2007, Hanseth, 2006). The initial HMIS process in Malawi followed the essential data set approach which had successfully been developed in South Africa. In Malawi, however, this approach was less successful, mainly because the “second part” of the South African approach was not included; the flexible and continuous process of revising and extending the essential datasets according to changing requirements. In Malawi, the initial datasets from 2001-02 remained unchanged, despite, for example, the tremendous increase in the HIV/AIDS program over the following years. After a few years, therefore, the HMIS became outdated and partly replaced by the health programs’ own reporting systems which were better in responding to their needs. Over the years, therefore, the HMIS lost its relevance and its position as the dominant health information system.

When the process to revise the system started in 2008-09, following the HMN initiative and technical framework, the practical approach was building on the experiences from Sierra Leone. In Sierra Leone, as in Malawi, it was regarded as possible to build a totally new system from scratch, including the revision of all the data sets and data collection forms. An iterative process of revising the data collection tools and integrating the procedures of data collection between the health programs was initiated.

Here we use Carlile’s integrative framework for solving differences to analyse how differences in perspectives and data sets between health programs were addressed through an iterative process:

- i) a common data dictionary has been developed among the three actors and duplication avoided in order to allow efficient data sharing (transfer),
- ii) inconsistencies, duplication or different way of managing data such as cohorts of HIV/AIDS patients on anti retroviral treatment (ART) was addressed to come out with standardized definition and meaning (translation) and
- iii) since the organisation units or facilities from which all involved actors are collecting data are not the same (private, different level of the hierarchy) and collection frequencies are different, the entire system has slightly changed to include private facilities, zones as new administrative units and the frequency of EPI and HMIS

data has been set to monthly instead of quarterly for the first and quarterly for the second (transformation).

These processes are iterative and not linear since the feedback and feed forward processes are introducing new issues that have to be negotiated. However, all the actors know that this is only a first step and that further negotiation will be needed in order to arrive at a standardized data dictionary agreed among all HIS stakeholders.

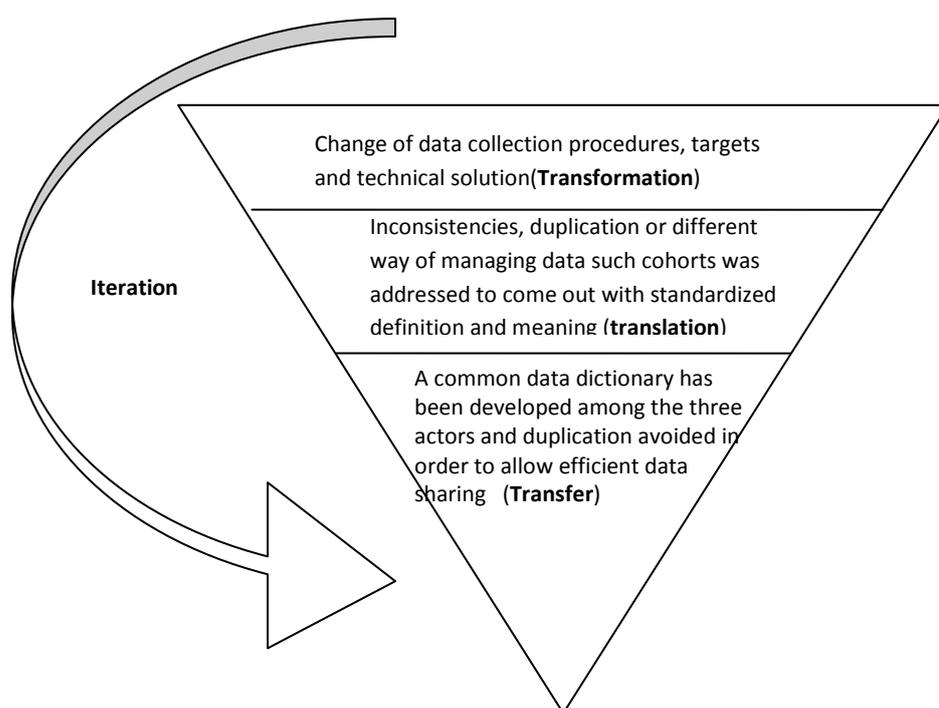


Figure 3: The three processes and iteration in Malawi

5.2 Emergence of the HIS architecture

The data standard task force is including the main HIS actors in Malawi and has a unique position and mandate in the HIS strengthening process. Although it has no official mandate to develop the HIS architecture, it is in charge of standardisation and integration along the three levels of Carlile's integrative framework and in bringing the "HIS boxes" together. Unlike other countries (Kossi et al, 2008) where such committee does not exist, the data standard task force include all the main HIS actors and they have agreed to work together towards an integrated HIS. Following the HMN framework, they are working on harmonizing metadata and the interoperability of existing system. All actors acknowledge that the new system needs to build on the "inherited" existing systems and that it would not be possible to redesign an all encompassing system form scratch. The need for standards for ensuring interoperability between the systems was regarded as a problem, as the task force did not have the needed skills. However, the development of the SDMX-HD (Statistical Data and Metadata Exchange

– Health Domain) standard may solve this problem as it provides a feasible solution for exchanging data between the various sub-subsystems and the DHIS2.

For the patient management systems, however, a two-step interoperability approach is needed first, the patient level data will need to be aggregated according to the needed meta data, second, the aggregate data need to be exchanged. Prior to the release of the SDMX standard, the approach followed by the teams from the patient management systems were to establish data exchange through a specially constructed gateway. The problem was that developing “bilateral” gateways for each system to the backbone would have been very costly and also very inflexible as related to future changes.

The successful testing of SDMX-HD in Sierra Leone and its launch in September 2010 made the MoH and the task force decide a shift in strategy from the current human resource management system to iHRIS, one of the partners in the SDMX-HD project. An iHRIS implementation project is currently being designed in Malawi.

Revisiting the two terms integration and interoperability, we see that while information from multiple data sources are integrated in the data warehouse, this is achieved by SDMX-HD standard allowing interoperability between these data source systems and the data warehouse. We may say that human resource data and medical record data are integrated in the data warehouse, but there is no interoperability between these two systems. Interoperability is only needed between these two systems and the data warehouse. The release of SDMX-HD came at the right time for the data standard task force as the missing link for its strategy to plan a flexible and interoperable HIS in Malawi.

6. Conclusion

Computerised HIS in developing countries has started without any proper plan or architecture trying to link together components in order to have a better functioning overall HIS. In Malawi the first attempt to implement an integrated HIS failed because i) it adopted a minimalistic approach which did not meet all information needs of stakeholder and ii) the integration process was static in the sense that the integrated HIS did not evolve to adapt to changes in its environment. However learning from the previous failure, the HIS actors constituted the data standard task force to address issues related to stakeholders needs and the planning or architecture of the overall HIS. Integration is now being addressed as a dynamic and iterative process in which different systems are integrated gradually. Despite its mandate, the data standard task force did not have the technical competence needed for engaging directly in the development of data interchange between different systems. Nevertheless, the task force required all stakeholders and system implementers to follow an open standard approach to achieve interoperability between systems. Because the task force lacks capacity and resource to make a technical standard it could not fully control the architecture of the HIS but has at least oriented the development of the HIS towards interoperable systems. This made

the Malawian case particular as compared with other less organised developments observed in other African countries (Kossi et al,2008) and the more top down Enterprise Architecture approach prescribed by HMN (Stansfield et al,2008). The release of the SDMX-HD was in this context a favourable conjuncture which is providing the important missing link in the HIS architecture and thereby avoiding the need to develop bilateral gateways between systems.

The SDMX-HD standard and its uptake among important open source software projects in the health domain, such as iHRIS, DHIS2 and OpenMRS, makes countries less dependent on specific technical competence to achieve data exchange between systems. Provided that the SDMX-HD is continuing to gain momentum, this new standard has the potential to significantly increase the ability of African countries to control the development of their own integrated HIS architecture.

7. References

- AbouZahr, C., and Boerma, T. "Health Information Systems: the Foundations of Public Health," Bulletin of the World Health Organisation (83:8), 2005, pp. 578-583.
- Braa, J., & Hedberg, C. (2002). The Struggle for District-Based Health Information Systems in South Africa. The Information Society, 18, 113-127.
- Braa, J., Monteiro, E., and Sahay, S. (2004) "Networks of Action: Sustainable Health Information Systems Across Developing Countries" MIS Quarterly (28:3) 2004, PP 337-362
- Braa, O., Hanseth, O., Heywood A, Shaw, V (2007) Developing health information system in developing countries: the flexible standards strategy. MIS Quarterly Vol 31 Special Issue August 2007
- Carlile, P. R. (2004), "Transferring, Translating, and Transforming: An Integrative Framework for Managing Knowledge Across Boundaries", Organization Science Vol. 15, No. 5, 2004, pp. 555-568.
- Chaulagai, C.N., Moyo, C.M., Koot, J., Moyo, H.B.M., Sambakunsi, T.C., Khunga, F.M. and Naphini, P.D., (2005), Design and Implementation of a Health Management Information System in Malawi: Issues, Innovations and Results, Oxford University Press in association with The London School of Hygiene and Tropical Medicine.
- Chilundo, B., and Aanestad, M. "Negotiating Multiple Rationalities in the Process of Integrating the Information Systems of Disease-Specific Health Programmes," Electronic Journal on Information Systems in Developing Countries (20:2), 2004, pp. 1-28.
- Easterby-Smith, M., Thorpe, R. and Lowe, A., (1991), Management Research: an Introduction, SAGE Publications Limited.
- Galimoto, M.S., (2007), Integration of Health Information Systems: Case Study from Malawi, Master Thesis, University of Oslo.
- Hanseth, O., and Ciborra, C. U., (2007) (eds.), Risk, Complexity and ICT. Edward Elgar.
- Health Metrics Network (2008) "Framework and Standards for Country Health Information Systems", <http://www.who.int/healthmetrics/en/>
- Heeks, R. "Failure, Success and Improvisation of Information Systems Projects in Developing Countries," The Information Society (18), 2002, pp. 101-112.
- Kimaro, H. C., and Nhampossa, J. L. "Analyzing the Problem of Unsustainable Health Information Systems in Less-Developed Economies: Case Studies from Tanzania and Mozambique," Information Technology for Development (11:3), 2005, pp. 273-298
- Kossi, E. K., Braa, J, Tohouri, R., Uggowitz, S., Yumkela, F., Bye, K., Turay, M., Koh, P., McEwen, E. (2008) "De-Fragmenting Health Information Systems in Sierra Leone: horizontal and vertical integration" in Proc. IST-Africa, 2008,
- Latour, B., (1996), Aramis or the Love of Technology, Cambridge, MA: Harvard University Press.
- Markus, M. L., and Robey, D., (1988), Information Technology and Organizational Change: Causal Structure in Theory and Research, Management Science, Vol. 34., pp. 583-598.
- Orlikowski W. J., and Barley, S. R., (2001), Technology and Institutions: What can Research on Information Technology and Research on Organizations Learn from Each Other? MIS Quarterly, Vol. 25, pp. 145-165.

- Stansfield S, Orobato N, Lubinski D, Uggowitz S, Mwanyika H, (2008) The Case for a National Health Information System Architecture; a Missing Link to Guiding National Development and Implementation. Making the eHealth Connection, Bellagio
- Sæbø, J., Kossi, E., Titlestad, O., Tohour, R. Braa, J., (2011), Comparing strategies to integrate health information systems following a data warehouse approach in four countries', *Information Technology for Development*, 17: 1, 42 — 60
- Wainwright, D, and Waring, T (2004) Three domains for implementing integrated information systems: redressing the balance between technology, strategic, and organizational analysis In *International Journal of Information Management* 24 pp. 329-246
- Wenger, E., (1998), *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press.
- WHO (2007) "Everybody's business: Strengthening Health Systems to improve Health Outcomes: WHO's Framework for Action", Geneva

IV

NETWORKS OF NETWORKS – COLLABORATIVE EFFORTS TO DEVELOP HEALTH INFORMATION SYSTEMS ACROSS DEVELOPING COUNTRIES

Abstract: The challenge of scale and sustainability in health information systems development, especially in resource-poor settings, is well known. Earlier studies have argued for organizing such development in networks to increase the chances of success, as well as the heterogeneity leading to better understanding and thus better products. This paper looks at ongoing efforts in West Africa, which have grown in scale to include networks of networks. This has large synergetic effects, much beyond linear growth. The study discusses these effects, as well as the strategies of achieving such second order networks, using notions of attractors, architecture, and standards. The specific case involved is the convergence of many efforts to strengthen health information systems across the region, linking networks whose primary focus vary from global to regional and local, from policies to software development and advocacy.

Keywords: health information systems, West Africa, Sierra Leone, networks, action research

Authors: Sæbø, J; Braa, J; Sahay, S; Kossi, E; Settle, D

NETWORKS OF NETWORKS – COLLABORATIVE EFFORTS TO DEVELOP HEALTH INFORMATION SYSTEMS ACROSS DEVELOPING COUNTRIES

1. INTRODUCTION

This article describes and discusses the way in which different processes and networks for strengthening Health Information Systems (HIS) in West Africa have developed, converged and mutually strengthened each other creating a significant momentum for change in the area of HIS in the region. At a more general level and building on the concept of “networks of action” (Braa, Monteiro, Sahay 2004), we describe the phenomena under development in West Africa as the building of “Networks of networks of action”. The concept of networks of action was developed in 2004 as a response to the fact that individual pilots and action research projects tended not to survive in the longer run unless they formed collaborative networks with other similar projects and other activists. Based on the analysis of the case from West Africa, we bring this concept one step further; when already existing networks are coming together through mutual benefit and shared interests, their combined momentum, relevance and impact will by far go beyond the sum of the networks. The effect of networking existing networks of action is far greater than networking singular units and actors.

In this earlier study, it was pointed out that each one of the projects or initiatives may be too weak to survive alone, but by combining forces by building collaborative networks sufficient strength may be achieved to build further momentum (ibid.). Furthermore, the individual projects will need to scale in order to get beyond the pilot phase. In general terms this is about building tools, knowledge, trust and competence enough to actually convince user organisations that the results of the pilot need to be implemented and scaled up. More specifically in the area of HIS, an added complication is that country health administrations tend to require country-wide solutions, causing the “all or nothing” problem. Both components of the networks of action concept are important in this story: 1) create more strength by joining disparate actors, and 2) create momentum through scaling.

Networks range from the formal to the informal. The West African Health Organisation, to be described in the case section, is a formally organised network of 15 member states. The Health Information Systems Programme (HISP) network, also to be described, is much less formal, but with many nodes run by budgets and other formalities. Networks of second order, networks made up by networks, are rarely developing and converging by design, rather convergence and growth of networks seem to be emerging. Central to the emerging of such new order are attractors (Braa et al, 2007). Attractors may emerge and become de facto, industry standard such as MS Windows, or they can emerge as networks that are attracting increasing attention and following as the network around the open source DHIS2 software, which is one of the networks in our case material. The development of this network has not been by design; the interacting networks are too many to make it possible to see far into the future. Rather this network has emerged as an attractor through directional improvisations and an ability to align other actors and forge strategic relationships, and in applying an open architecture that allows networks to link up.

The strive to achieve the United Nations Millennium Development Goals (MDG), where 3 out of 8 goals are health related, has led to a strong demand for quality health information in order to be able to see if efforts to improve the situation are working (see for example Chan 2007, HMN 2010a). The availability of quality information depends on well-functioning HIS, one of the six pillars of a health system (WHO 2005, 2007). The MDG process has led to increased donor support for many programs (such as TB, malaria, vaccination programs, maternal health care,

etc.). Unfortunately, donors often introduce particular systems for data collection and reporting that sidestep established reporting routines. The resulting complexity, coupled with poor human resources and infrastructure, easily leads to fragmentation and poor data quality.

This again has led to several international organizations specifically addressing these challenges with new strategies. The International Health Partnership¹, aims to harmonize aid agencies, and align international efforts with national systems. The Partnership in Statistics for Development in the 21st Century², helps countries adapt evidence-based policy making and implementation to reach the MDGs. The Health Metrics Network (HMN)³ was created to strengthen country HIS and information use, through integration of subsystems and data sources. Other international donors, the initial source of many of the fragmented systems, have as a result adapted a strategy of improving integrated national HIS rather than implementing new, narrow, specific subsystems. There thus seems to be a considerable consensus on the need for consolidation, integration and collaboration in health information systems globally (AbouZahr and Boerma 2005; Tierney et al. 2008).

Over the last 3-4 years more than 60 countries have applied tools developed by HMN to assess their current HIS, and then based on this assessment develop strategic plans for strengthening their HIS. The third phase of this HMN strategy is, obviously, for the countries to implement their strategic plans. The problem, however, is that there are no funds readily available to support countries to implement this. The current situation is thus that multiple countries are eager to get going with their HIS processes and are looking for partners and funding, while at the same time regional and global agencies and networks are increasingly looking for partners to assist countries. This is the fertile and enabling context for the building of networks of networks, which will be described and discussed in this article.

The development of the HISP network during the nineties and the early 2000s formed the basis for the concept of networks of action. HISP was engaged in HIS development, open source software, education and action research, and the development of the network during the period was more characterized by “up-hill” hard work and more by “push” than by “pull”. Pilot projects and educational schemes were established in different countries, and HISP was engaged in the global debate on strategies for HIS development, of which there were no global consensus. This situation changed by the establishment of HMN in 2005, first more generally by gradually establishing a kind of global consensus on the need for integrated HIS approaches, and second, more specifically linked to key HISP software activities; making the use of a country data warehouse a standard approach to HIS integration. The DHIS2 Open source application suite being developed by HISP was well aligned with this new standard promoted by HMN, as were the ten years of experience from HIS development in many countries, leading to a significant increase in global interest in HISP. The concept of networks of networks are developed as a way to better explore and understand the current enabling global context for HISP and HIS network building, the topic for this article.

Outline of the article; first we present methodological considerations, then we present a conceptual framework focusing on networks and the role of attractors before describing the case, discussion and conclusion.

2. METHODOLOGY

This paper builds on case material from a set of global and local activities that converge in West Africa, and that are the operational results of a long-term, ongoing, action research project the

¹ <http://www.internationalhealthpartnership.net/en/home>

² <http://www.paris21.org/>

³ <http://www.who.int/healthmetrics/en/>

authors are engaged in. Action research is a form of participative research where the researcher takes part in the change processes in an organization, actively trying to improve some stated problem (Checkland and Holwell 1998; Avison, Lau et al. 1999).

Our research then, centers on understanding the processes at work, while at the same time use this understanding to improve on the current situation. We are all, to various extents and changing over time, immersed in change-processes, working closely with the owners of the problems we try to solve. As such, we are involved in open-ended and continuous phases of design, development, implementation, and evaluation of interventions, with a stated aim at improving some given subject, as according to principles of action research (Susman and Evered, 1978). The authors have thus participated in most of the events described in the case description later.

In 2004, Braa, Monteiro, and Sahay articulated the networks of action approach for the HISP network, which discussed the value of learning and doing in networks rather than in isolated instances. The point of departure for this articulation was earlier studies of action research concluding with the need to situate the action within networks rather than on singular units because isolated action research projects did not manage to create enough momentum to attain sustainability. Therefore, the focus needed to be shifted “from single organizations and workplaces...to networks” (Engelstad and Gustavsen 1993, p. 209). Activities within an action research setting could be geared towards creating collaborative linkages, which would be harder applying a less participatory research method.

As the title of this paper suggests, the research in this study is even more broadly based, in networks of networks of action. In other words, the research described herein is based on active participation by the authors in various change processes (organized as networks of implementation and research localities), converging in a common, larger, process involving several such networks varying in nature. The concept of networks and the four networks involved are described later; here it suffices to say there are differences in scope, location, approaches, and legitimacy, while the similarities are strong enough to foster strong collaboration towards shared aims.

The authors hold pivotal positions in three of the networks portrayed in this paper, and have thus different perspectives on the processes described. In some sort of “perspective triangulation”, this has enabled us to look at events and processes from different angles, and we have also a broader set of experiences as we approached these events with different agendas and backgrounds in the first place. Furthermore, three of the networks are global, with related work going on in many different localities. Conceptualizing the herein described events builds on comparative experiences from many other countries, a base of experiences that help discern particularities from generalities.

2.1. Data collection

The authors have all been part of a wide range of activities in Sierra Leone, West Africa, and other countries implementing the same HIS applications. Two of the authors have spent considerable time in Sierra Leone for the University of Oslo and Health Metrics Network, key nodes of two of the networks, traveling the country developing, implementing, and adapting software, and above all engaging in capacity building. This amounts to several months each over the last three years. Combined, the authors have been involved in all aspects of the Sierra Leone implementation, from the technical aspects to discussing data reporting harmonization among health development partners, presentations with the Ministry of Health to donors and partner organizations, and coordinating feedback to the global distributed user and developer community around DHIS2. At the regional level, supporting implementation of the two applications DHIS2 and iHRIS in several countries, participation in workshops, and working closely with other partners, has been undertaken. All these heterogeneous activities have put the authors in contact and communication with a wide range of stakeholders, from nurses and information officers in facilities and districts, to ministers and directors of large organizations. A range of field diaries, trip reports, scientific

papers (see for example Sæbø et al. 2011) , reports for external funders (for example HMN 2010b), and email threads provide a rich source of information on the longitudinal processes.

2.2. Data analysis

The conceptualization of the events and processes described in this paper has taken place over many years. With all authors based in different geographical locations, recent workshops in relation to the work in West Africa were used to discuss the processes and events leading to the acceleration of scale and scope of implementation. The ideas around networks of networks, and more specifically how these meta-networks emerge, can thus be said to be greatly facilitated by these networks themselves, as they brought together the range of perspectives that shaped our understanding.

3. THEORETICAL CONCEPTS

In this section we *briefly* present some theoretical concepts that are useful for analyzing the networks of networks. Again, we draw on the research by Braa, Monteiro, and Sahay (2004), discussing and describing the growth of the HISP project into a network. The network was already then heavily engaged in the real world politics of competing agendas. Being involved in the development of national health information systems in India and several African countries, HISP was everywhere caught in the cross-fire of different political interests, as donors, health programs and health authorities would all pursue their own interests. The political context of competing agendas was played out very much as the issue of which network will end up dominating the others. In this context, Castells' (1996) analysis of the constitution, logic, and dynamics of networks was used to formulate the agenda of HISP, which was working in several countries, as the making and growth of networks. Furthermore, it was used to pose the questions such as whose networks are these, and who gets included or marginalized by certain dynamics.

Building on this theorizing, in this paper we outline and discuss the concepts and values of an approach that we term “networks of networks of action.” Networks of networks are qualitatively different than singular networks. The difference is surely not in linear terms and based on numbers (of networks), but in qualitative terms based on the substantive interests and roles of the networks.

A network is a relatively loose construction consisting of individual, projects and organizations bound together and networked through a more or less shared agenda. For example, if we regard HISP as one network, other open source software groups working in health are also making up networks. Another such network consists of various projects and implementers related to the OpenMRS software. The Health Metrics Network (HMN) represents another typical network engaged in strengthening HIS in countries. While having their base formally located within WHO, a number of countries, organizations and individuals are being networked through the HMN and their activities. The notion of networks of networks is referring to the situation where such different networks are aligning their interests, or gravitating around an attractor, and forming exactly that; networks of networks.

To better understand how networks are being aligned and converged into networks of networks, we draw on the theories of complex adaptive systems (CAS). CAS is concerned with the dynamics with which complex systems, or networks in our case, evolve through adaptation. CAS are seen as being made up of semiautonomous agents with the inherent ability to change and adapt in response to other agents and to the environment (Holland 1995).

Of particular importance is to understand how order within such systems is created without a “designer”, but rather emerges. Central to the emergence of orders are attractors; a limited range of possible states within which the system stabilizes. The simplest attractor is a single point (Braa et al. 2007; Eoyang 1996). Patterns exhibited during changes of complex systems are described as attractors, “which have the ability to concentrate activity around them, for example the sun. A

smaller planet that is attracted by two suns would have a more erratic path, being attracted at different stages of its orbit to each of the two suns.” (Shaw 2009, page 28).

Orders emerge around attractors through various feedback mechanisms, and through path-dependent processes of many small steps that may end in lock-in situations (David 1986). A de facto, or emergent, standard, such as MS Windows or the QWERTY keyboard, is a typical example of an attractor. The use of “attractors for change” is recommended when seeking to bring about changes in areas where there is only moderate certainty and agreement (Plsek and Wilson 2001). More generally, attractors are useful as they help describing the stages of the evolution of systems (Butz, 1997).

Attractors then provide a focus on which the different networks can converge. In the case study, we discuss the SDMX-HD standard on interoperability and how it has evolved into a status of an attractor to which different networks are converging. As contrasted to a singular network, in a network of networks the forces of convergence (as well as divergence) are magnified allowing the attractor to take on even more significant roles.

Networks of networks heighten the nature of indeterminacy of processes and with it both potential and challenges to new efforts. When different networks are linked, new attractors may be created with potential to attract even others, as in the example of the SDMX-HD standard will show.

4. EMPIRICAL CASE – THE CONVERGENCE OF NETWORKS

4.1. Summary of events

While the story in this article is unfolding in West Africa, two of the networks involved are of global nature. The Health Metrics Network (HMN) at WHO, initiated in 2005 to strengthen HIS globally, developed a set of three steps to be followed by countries; assessment, develop strategic plan, and implementation. Important in this story is that 1) they selected Sierra Leone, in West Africa, as one of five pilot countries to generate knowledge about implementation processes, and 2) they developed the HMN Framework; an overall HIS architecture describing different building blocks, all of which feeding data into a pivotal integrated data repository, building on general data warehouse principles. For the pilot in Sierra Leone, HMN required an open source application filling the requirements of a data warehouse in the context of one of the poorest countries in the world, just recently emerging from civil war. Given these requirements, and the track records of the MS Office based DHIS v1 in other African countries, HMN chose to use the DHIS2 software, being developed by the HISP network, the second significant network in this story. Development of the web based and fully open source software DHIS2, started in 2004 and had in 2007 been implemented in pilots in India. During 2008-2009, the DHIS2 as well as the overall HIS in Sierra Leone developed into a best-practice project in West Africa, which was widely communicated by HMN as they approached the end of their first five years and needed to show results. Due to this, more countries in West Africa started to look into the DHIS2, with the Gambia as a first newcomer in 2009. International focus on interoperability led to a pilot setup of an integrated suite, starting in Sierra Leone, where the OpenMRS (medical records) and the iHRIS (human resource records) Open Source applications exported their aggregate data to DHIS2. At this point the West African Health Organisation (WAHO), the third significant network here, got interested. Their Human Resource department would like the member countries to use the iHRIS application, developed by the fourth network, CapacityPlus, who was in discussion with HISP, HMN, and Sierra Leone about iHRIS implementation there. WAHO started to use the fact that it was integrated with DHIS2 (by now well established as part of HMNs success in Sierra Leone) in their promotion of the use of iHRIS, which again was increasing the interest by countries to use the DHIS2.

4.2. Presentation of the networks

The Health Information Systems Programme (HISP)⁴ is a loose network of universities, developers, implementing agencies, and individuals. Many nodes are formalized around certain budgeted activities, such as implementation of DHIS in a country, or managing programs of higher education at universities. The main activities are software development of DHIS, both v1 (South Africa) and v2 (distributed, coordinated from Norway), research, education at Master and PhD level in several countries, and HIS strengthening.

The Health Metrics Network⁵ is based at the WHO headquarters in Geneva, Switzerland, and was established by this organization to strengthen HIS in countries. It has since 2005 supported more than 60 countries in doing HIS assessments, half of those leading to strategic plans for HIS strengthening, and been an important voice in advocating for investment in integrated information systems assisting monitoring and evaluation of the health systems as a whole in several seminal conferences and workshops.

WAHO, the West African Health Organization⁶, was officially created in 1998 as a health division of ECOWAS, the organization for political and economic integration and cooperation of West Africa. It consists of 15 member countries; 2 lusophone, 5 anglophone, and 8 francophone, and is mainly self-funded through regional import taxation. This makes it independent from changes in donor priorities, often a huge problem for national health initiatives. Being a fairly young organization operating in a landscape of shifting political stability, WAHO is still building capacity to help countries improve their health systems and meet the challenge of an increasingly integrated and mobile population.

CapacityPlus⁷ is a donor/project-driven network; the USAID-funded global project uniquely focused on the health workforce needed to achieve the Millennium Development Goals. CapacityPlus helps partner countries achieve significant progress in addressing the health worker crisis while also having global impact through alliances with multilateral organizations. The project builds on the accomplishments of the Capacity Project, which worked in 47 countries.

The table below shows some important features of the networks in this study.

	HISP	WAHO	HMN	CapacityPlus
Main activities	Research and implementation of HIS, specifically DHIS2, an open source HMIS platform	Guiding member states with policies, capacity building (workshops), and technical support	Assist countries in doing HIS assessments and make strategic plans. Standard setting and advocacy for HIS investment	Build country HRH capacity; strengthen health workforce information
Base of legitimacy	Scientific, sustainable and participatory approaches. Capacity building in implementing countries. Proven success. Members from implementing countries.	Ownership and self-financing from member states (15). Health arm of ECOWAS, political support. Proximity and personal relations with key actors	Framework and Standards for HIS becoming both de facto and de jure standard. Partnership with WHO, professional for over 50 years.	USAID flagship global project for HRH, open source iHRIS software becoming reference implementation
Important actors in	Universities, HIS	Ministries of Health,	WHO, global actors	USAID,

⁴ www.hisp.uio.no/

⁵ www.healthmetricsnetwork.org

⁶ www.wahooas.org

⁷ www.capacityplus.org

network	units in ministries of health, distributed development centres.	Donor organizations, ECOWAS political umbrella	like Global Fund, UNAIDS, CDC Other collaboration centres and initiatives	IntraHealth, TRG, Abt, LATH, IMA – formal partners, many regional and country HIS partners
---------	---	--	--	--

Table 1. Presentation of the networks

4.3. The first attractor – Creating a success story

As mentioned, the first two networks to come together were HMN and HISP, collaborating on the implementation of a data warehouse at national and district level in Sierra Leone from late 2007. HMN had signed a letter of agreement with the Ministry of Health and Sanitation, forming a relationship at the highest political level, while HISP was contracted as an implementing partner largely working with the national HIS unit and in the districts. In early 2008, four out of 13 districts were selected to pilot the new data warehouse, and substantial efforts were laid down to train district staff in using the application to collect, process, analyse, and use health information. By the start of 2009, the data warehouse had been implemented in the rest of the country. Consolidation of the implementation took place throughout the following year, with steadily increasing data reporting rates, and a few districts beginning to see results on health indicators from their use of information for planning. This was capitalized on by HMN, who sent an information officer to write up a story about the emerging success (HMN 2009a). The HMN secretariat also reported to the board, in October that year, “Sierra Leone’s example of demonstrating the performance and utility of the information produced by the DHIS is a best practice that must be shared with other countries” (HMN 2009b, p 13). HMN was facing increasing pressure to document and disseminate results as their main financial grant was coming to an end. They had achieved much less success in their other pilot countries, reflected in the amount of weekly information bulletins distributed to around one thousand readers globally over the last 2 years; 3 on Sierra Leone, and 1 on another country building on the lessons from Sierra Leone, compared to 3 from the other four pilot countries combined⁸. HMN needed a success, and it was found in Sierra Leone. The country in turn dominated the HMN Results Report, summing up the achievements of HMNs investment in country support (HMN 2010b).

The success of the new system in Sierra Leone was real. In 2009 a review of the current data reporting forms in Sierra Leone was done, and a harmonized, reduced, set of forms were implemented from 2010 (for a discussion on these processes, see REF comparative paper). The fairly instant improvements in data reporting rates were received positively by a domestic network of health development partners, consisting of the main donors and NGOs active in the country, including WHO, UNICEF, JICA, IRC, CARE etc. By late 2009, several of them agreed to rely on the national data warehouse for their reporting needs, thus discontinuing parallel information systems, and they were included in subsequent workshops to build capacity in the use of the system. In 2010 then, with the introduction of the latest generation of harmonized reporting forms, the system was acknowledged as the national HIS when it was decided that it, and only that system, would be used to track and evaluate a major initiative to offer free mother and child health care, a program funded by a major donor and in which the president put his prestige. These events undoubtedly represent a huge success, though there still are challenges as expected from such a long-term process to sustainably change a whole set of institutions. The important issue here is that HMN made this success *visible*, by using it for advocacy, self-legitimacy, and fund raising at

⁸ See http://www.who.int/healthmetrics/news/weekly_highlights/en/index.html for all bulletins

the global level. An example had been pushed forward, and an attractor for other countries in the region had been created. This would grow to be a major force for bringing the networks together.

4.4. The second attractor – Interoperability enabling modular architecture

In late 2009, WHO had initiated a process to develop a data exchange standard for health metadata and statistics, building on an existing standard for financial transactions. This new protocol, SDMX-HD⁹, was still not implemented by any application, far less in any real use-case setting by early 2010. Nevertheless, HMN and HISP decided to push this forward with implementation in Sierra Leone of a system that could both track patients on Anti-Retroviral Therapy (ART), and share this data with the data warehouse running on DHIS2, as stipulated in the original strategic plan for the country. OpenMRS, a medical record application, was set up in the main hospital, and in the weeks before this took place in February 2010, major advancements were made to SDMX-HD, spurred by the fact it was now implemented in two applications. The main idea is that OpenMRS has the functionalities needed for doctors and nurses to track patients over time, while the aggregate data from this system is used for general health management at hospital, district, and national level. This two-level use applies to other domains and applications also, such as logistics management, human resource management, lab systems, health finances etc. With SDMX-HD set to go live in Sierra Leone at a given date, developers behind DHIS2 and OpenMRS not only pushed development forward by implementing this standard in the respective applications, they also contributed the necessary use-case to solve outstanding issues.

The development of SDMX-HD made an HIS architecture of various applications for different business domains a reality, through a standard developed and promoted by WHO. Anyone able to share data on this protocol could now be “plugged in” in a country HIS. In addition, this important step was clearly associated with Sierra Leone, a fact which greatly spread the knowledge about the ongoing activities there. These two facts combined; the interoperability being possible and backed by WHO, and that it was seen as growing out of the Sierra Leone implementation, spurred further events.

While HMN and HISP were collaborating in Sierra Leone, *CapacityPlus*, a partner of HISP and HMN specializing in strengthening health workforce information systems, was partnering with WAHO to pilot open source HRIS software in Ghana.

In May 2010, fairly short after the first implementation of the simple interoperable architecture with DHIS2 and OpenMRS in Sierra Leone, WAHO presented the results of the Ghana pilot to the human resource and IS leadership of countries in the ECOWAS region. *CapacityPlus* participated in the meeting and encouraged WAHO to invite the participation of HMN to discuss the planned expansion of the “Sierra Leone architecture” also with iHRIS, their suite of applications for human resource (HR) management. Since iHRIS was also implementing the SDMX-HD standard, aggregated data could be shared with DHIS2. Many of the participating countries planning implementation of iHRIS were by now also planning implementation of DHIS2, and WAHO, HMN, and *CapacityPlus* decided to host a joint workshop to offer training in both, and quickly included HISP and WHO in the planning.

With a tight schedule, the workshop being planned for September 2010, things moved fast. The prospect of demonstrating interoperability with DHIS2, which was attracting considerable interest in the region due to the Sierra Leone implementation being pushed as a big HMN success, led *CapacityPlus* to finalize SDMX-HD compatibility of iHRIS. WHO also sponsored lead developers to join, for a second “Connectathon”, the first of which was the initiation of work on SDMX-HD the previous year. Present were also organizations of other applications planning the implementation of SDMX-HD compatibility. At the end of the workshop, interoperability of DHIS2, iHRIS, OpenMRS, and the WHO Indicator Measurement Registry (IMR), was officially

⁹ see www.sdmx-hd.org

launched, with one WHO representative pointing out the appropriateness of this taking place among countries adopting the standard-supporting applications.

During the workshop, several countries made more formal request to HISP, HMN and CapacityPlus representatives there for support of implementation of DHIS2 and iHRIS. WAHO was already supporting iHRIS implementation, and invited HISP, CapacityPlus, and HMN to the first annual WAHO HIS strengthening workshop and Partner's Forum in November the same year, where HIS staff from all 15 WAHO member states were present. There, it was decided that HMN, WAHO, HISP, and CapacityPlus should collaborate to develop a centre of excellence at WAHO for supporting member countries in adopting the interoperable solutions which had grown out of Sierra Leone.

5. DISCUSSION

In this section, we would like to highlight two key aspects drawing upon the case study presented. The first concerns the synergies that have emerged from the creation of networks of networks. The second concerns our reflections on the strategies – formal and informal – that have helped enable these synergies.

5.1. The synergies emerging from networks of networks

In simple terms, synergies can be understood as the value added effects that arise when two or more singular events or parties come together ($1+1>2$), and in this process both events and parties benefit mutually. Through the case described, we can discern several kinds of synergistic effects from the creation of networks of networks.

Often health information systems implementations are impeded by the lack of political legitimacy from the multiple levels (global to local) that are needed to make them work. Local field efforts while building user level legitimacy run into roadblocks while trying to scale because they have not obtained the buy in from the national level. The HISP network for many years focused on small scale pilots, for example two districts in Cuba, which never scaled because of the lack of legitimacy of the central unit in Havana (Sæbø and Titlestad 2004). Similarly, often national level efforts require the endorsement of global actors like the WHO and HMN. For example, the routine immunization system in India could be mandated to every district in the country because it had the legitimacy of WHO behind it. Any one group of actors cannot come with the legitimacies representing these different levels, and fundamentally requires networking that creates such legitimacies and visibility that mutually feed on each other.

For example, in our case, HMN with its global legitimacy derived from its WHO links opened the possibility of the HISP network to work on the ground in Sierra Leone which again helped to create local legitimacy through the successes achieved. This success was important and used by HMN to showcase and enhance their own legitimacy, and of course both HISP and the country gained by showing what could be achieved in the most trying of conditions. The success was then spread to other countries in the region and then taken up by the WAHO network, leading to further invitations by them to support efforts of the WAHO countries. Creating and reinforcing such legitimacy at multi-levels, which becomes easily visible in the contemporary context with the help of the Internet and rapid movement of people, was a definite synergistic effort gained through the network of networks.

5.2. Self-reinforcing effects and the role of attractors

Attractors help to provide a consistent point of convergence which helps to bring a sense of order in a situation of relative chaos. Attractors can help to create self-reinforcing effects, where as events and people converge on the attractor, the legitimacy of the same gets reinforced which helps to attract more and create more order. And particular forces that converge to the attractor themselves gain in legitimacy and strength by aligning itself to the attractor. From the case, we discuss the role of two attractors that provided significant networked effects.

The first can be described as the “showcasing of the Sierra Leone success” in the country, the region and the global HMN. The HMN started with 5 countries including Sierra Leone in which they sought to demonstrate their interventions with respect to health systems strengthening. For various reasons, efforts in the other countries did not show much positive results (except in Belize, a country “adopted” as success story after the success had taken place), and it was only Sierra Leone where positive results were in evidence. HMN needed to show some success, and only Sierra Leone qualified to be described as one, leading to HMN declaring it as a success. With this, it became more of a success, making it an attractor, and more of a “political attractor.”

We can further describe two “technical attractors”, first in the form of the DHIS2 software application, and then as the SDMX-HD standard developed by the WHO to enable the interoperability of aggregate data. The HMN technical framework, established as a standard for country HIS integration and strengthening, included the establishment of a country data repository to manage aggregate data from various sub-systems. The DHIS2 was the data repository used in Sierra Leone, and when Sierra Leone was declared a success, implicitly DHIS2 was also. Furthermore, there were no other open source software applications of generic and shareable nature used in other countries, so DHIS2 emerged as a key technical attractor from the Sierra Leone case during 2008 and 2009. In 2010 the WHO project to develop the SDMX-HD standard for interchanging aggregate data was first implemented and tested to transfer data from OpenMRS and DHIS2 in one hospital in Sierra Leone. A few months later, in September 2010, the standard was officially launched at a WAHO workshop in Accra where the interoperability between DHIS2, iHRIS and OpenMRS was the case in question. The efforts to develop a standard for exchange of aggregate data had been ongoing in WHO for some time before without much success. But now that first the efforts in Sierra Leone had been initiated and had high visibility, it led to a large focus on the workshop in Accra, and thereby to establish the SDMX-HD as a second technical attractor in this story. This time by bringing together the various networks of WHO, HMN, WAHO, iHRIS/CapacityPlus, OpenMRS and DHIS2/HISP, a strong and fundamental technical attractor was created.

The evolving of this second technical attractor has significant further implications – the positioning of an architecture over an individual system solution. Although the DHIS2 is what the countries want to implement first, the fact that DHIS2 is a central piece of a larger architecture, the first step of implementing the DHIS2 becomes more inviting for others to join, it is more inclusive. The iHRIS network wants to plug in to this architecture, thus furthering the networking effects. Sierra Leone themselves are keen to explore how other systems like for example logistics management can also plug into the architecture. In this architecture approach, we may say that whole networks are literally “plugged in” by being included in the architecture. At the global level, WHO will like to showcase the success with the standard they have developed and this may lead to other effects.

However, it is also important to note that while attractors can trigger of self-reinforcing effects, they themselves can be redefined with time, and with different meanings for the actors that have been attracted to it. For example, as the focus of HMN is becoming redefined from health information systems strengthening to vital events registration, the attractors described above – both technical and political – will not have its original meaning, and may need to be redefined to the new setting of vital events for it to be useful.

5.3. Strategies enabling these synergies

What have been the HISP strategies to enable such synergies? Strategies have not been formal or well planned and documented which all members are trying to follow. Yes, despite this, there has been a definite direction, a path in which constant movement has taken place. On reflecting over events say over the last 5 years or so, we can try to identify some key elements of our strategic effects.

Directional improvisation is a term we coin to describe the process of our movement. In her classic book “Plans and Situated Action,” Suchman (2007) describes the differences in approaches of a European and Trukese navigator. While the former works by first creating a plan and then acts in relation to that, the Trukese has a vision of direction in place, and then takes advantage of the existing conditions (the wind, the waves, stars etc) to navigate the path. The HISP approach is akin to that of the Trukese, the broad direction (of wanting to create such enabling networks) is known, but the conditions –such as political support, available technologies, resources etc – are a product of the here and now which have to be acted upon with best effects.

To enable the above, we use the acronym of AAA. **A**wake means HISP tries to be present in situations where they perceive opportunities may arise. For example, being present in Dakar in the WAHO meeting provided the opportunity to network with 15 countries in one framework. **A**lert means to be alive to the different possibilities that exist given the conditions, and use the experience and understanding to make choices. **A**gile means the quality to act quickly and decisively, for example by being able to provide support to countries in the West African region that are in the process of implementing the DHIS2, such as Liberia, Ghana and Burkina Faso

The second element of the strategy can be seen as understanding and working towards the **networking role of architectures**. Architectures are not only technical artefacts as is described by many of the technologists today. The important and neglected aspect of architectures is that it creates networking effects and with it the resulting synergies.

The interoperability SDMX-HD standard not only brings three technical systems (DHIS2, iHRIS and OpenMRS) together, but with it the surrounding networks and their further networks. Such networking provides then the pooling of interests, resources, and opens up strategies for scaling. Put differently, the architecture approach, made possible by shared standards, allows not only technical artefacts to be integrated (in our case software), but so also the networks that surround and support these artefacts.

An important and conscious aspect of the HISP effort is to see how different actors through networks can **leverage complementarities**. In the WAHO-HISP relation for example, WAHO comes in with the strength of its political legitimacy and mandate to support the countries in the region. HISP has its legitimacy as a strong technical support group in HIS; with roots in the University of Oslo and educational processes. Through its networking, WAHO gains in strengthening its technical capacities, HISP strengthens its presence in the region, while simultaneously their original capacities are reinforced.

6. CONCLUSIONS

In this paper we have described synergies arising from the growth of networks of networks of HIS strengthening. While the benefits of such networks are many, the question arises as to how such networks of the second order can come to be. We argue that attractors of several domains play a large role, as well as an application architecture promoting the linking up of several networks. In this context, directional improvisation, a proactive use of flexibility, is useful for taking full advantage of the emerging momentum, as well as directing where the momentum will lead. As for replicability in other regions and for other domains, the position held by WAHO seems so far to yield the crucial level and positioning of legitimacy for HIS scaling and sustainability, a lesson hopefully applicable with similar regional political units.

Future research on this topic in general should focus on how such networks of networks can be leveraged to strengthen local capacity in developing countries, an area where this approach has much potential. Also, given that one of the major networks described, the HMN, has recently scaled down operations and changed strategic direction, the landscape of global legitimacy and support for HIS strengthening has changed. How such a change influence the dynamics of the processes described is yet to be addressed.

7. REFERENCES AND CITATIONS

AbouZahr, C, and Boerma, T, (2005) “Health information systems: the foundations of public health”, in *Bulletin of the World Health Organization* 2005;83:578-583.
<http://www.who.int/bulletin/volumes/83/8/578.pdf>

Avison, D., F. Lau, et al. (1999). "Action Research." *Communications of the ACM* **42**(1): 94-97.

Braa, J., Monteiro, E., and Sahay, S. (2004) “Networks of Action: Sustainable Health Information Systems Across Developing Countries” *MIS Quarterly* (28:3) 2004, PP 337-362

Braa, O., Hanseth, O., Heywood A, Shaw, V (2007) Developing health information system in developing countries: the flexible standards strategy. *MIS Quarterly* Vol 31 Special Issue August 2007

Butz, M. (1997), *Chaos and complexity: implications for psychological theory and practice*. Washington DC, CRC Press.

Castells, M. *The Rise of the Network Society*, Basil Blackwell, Oxford, 1996.

Chan, M (2007) Opening remarks at the Fourth Global Meeting of Heads of WHO Country Offices, November 12, 2007. Accessed March 4, 2011
http://www.who.int/dg/speeches/2007/20071112_geneva/en/

Checkland, P. and S. Holwell (1998). "Action Research: Its Nature and Validity." *Systemic Practice and Action Research* **11**(1): 9- 21

David, P. A., and Shurmer, M. (1996) “Formal Standards-Setting for Global Telecommunications and Information Services,” *Telecommunications Policy* (20), 1996, pp. 789-815.

Engelstad, P., and Gustavsen, B. (1993) “Swedish Network Development for Implementing National Work Reform Strategy,” *Human Relations* (46:2), February 1993, pp. 219-248.

Eoyang, G. (1996) "Complex? Yes! Adaptive? Well, maybe..." *Interactions* (3:1) , pp. 31-37.

HMN (2009a), “HMN focus” October 2009 issue, accessed November 28, 2010,
http://www.who.int/healthmetrics/HMN_Oct09_newsletter_web_new.pdf

HMN (2009b) “Secretariat’s Report to the Board” [B2009/13/3], in board proceedings for the 13th HMN Board Meeting, Geneva, 14-16 October 2009. accessed November 28, 2010,
http://www.who.int/healthmetrics/HMN_13Board_Meeting_web1.pdf

HMN (2010a) “Better country data needed to assess progress towards health MDG targets”, May 2010, accessed March 4, 2011
http://www.who.int/healthmetrics/news/weekly_highlights/MDG_targets_need_better_country_data/en/index.html,

HMN (2010b) “Results Report June 2010 – Building momentum and saving lives”, accessed November 28, 2010,
http://www.who.int/healthmetrics/news/HMN_Results_Report_2010_web.pdf

Holland, J. H. (1995) “Hidden Order - How Adaptation Builds Complexity”, Addison-Wesley, Reading, MA,

Plsek, P. E., and Wilson, T. “Complexity Science: Complexity, Leadership, and Management in Health Care Organisations,”

British Medical Journal (323), September 2001, pp. 746-749.

Shaw, V. (2009), A complexity Inspired approach to co-evolutionary hospital management information systems development. Case studies from the “South”. Faculty of Mathematics and Natural Sciences, University of Oslo.

Suchman, L. (2007). “Human and Machine Reconfigurations: Plans and Situated Actions.” Cambridge, Cambridge University Press.

Susman, G., and Evered, R. (1978) “An Assessment of the Scientific Merits of Action Research,” *Administrative Science Quarterly* (23:4), pp. 582-603.

Sæbø, J., and Titlestad, O. (2004). “Evaluation of a Bottom-Up Action Research Project in a Centralised Setting: HISP in Cuba”. Paper presented at the 37th Hawaii International Conference on System Sciences, Hawaii.

Sæbø, J., Kossi, E., Titlestad, O., Tohourri, R., Braa, J., (2011) “Comparing strategies to integrate health information systems following a data warehouse approach in four countries” *Information Technology for Development*, Volume 17, Issue 1, January 2011

Tierney, W. M., Kanter, A. S., Fraser, H.S.F, Bailey, C. (2008) “Establishing Partnerships to Promote eHealth in Developing Countries: Lessons from Africa”, available from

<http://ehealth-connection.org/files/conf-materials>

WHO (2005) "Health and the Millennium Development Goals",

http://www.who.int/mdg/publications/mdg_report/en/

WHO (2007) "Everybody's business: Strengthening Health Systems to improve Health Outcomes: WHO's Framework for Action", Geneva

V

Developing decentralised health information systems in developing countries -cases from Sierra Leone and Kenya

Edem Kwame Kossi, Johan Ivar Sæbø, Jørn Braa, Mohamed Mumeneeh Jalloh, Ayub Manyà

Introduction

The vast majority of communities in Africa, and in the developing world more generally, are plagued by poor health services and poor health status. Global efforts to improve this situation have recently gained momentum as part of the UN Millennium Development Goals (MDG) project, where three of the eight MDGs, MDGs 4 and 5 (reduce child and maternal mortality) and 6 (combat HIV/AIDS, malaria and other killer diseases), are health related. The MDGs are addressing the need for changes and improvements at the community level and can only be achieved through active community participation. Framed within the global efforts to improve health in poor communities, this article address the issue of community participation through strategies to engage the community level in the design and development of Health Information Systems (HIS). Without reliable information on current situation and trends in health status, it is not really possible to improve the situation, as one would not even know whether the MDGs are achieved or not. With only few years left until the 2015 deadline to achieve the MDGs, global agencies such as the WHO are giving considerable attention to efforts to develop efficient HIS to measure progress made towards achieving the health-related MDGs (see for example WHO 2011). In this article we present a case study on the development of the HIS in Sierra Leone, a project initiated and initially funded by the WHO/Health Metrics Network as a pilot for how a Least Developed Country could take advantage of modern ICT and develop their HIS despite very poor infrastructure.

Illustrated by a case study from Sierra Leone, this article addresses the issue of strategies for developing decentralised bottom-up HIS in developing countries more generally, and for the development of community based HISs aiming at empowering local communities and their structures in particular. The project was following a community based participatory approach which we term 'cultivation' (Braa, Sahay, 2012) in contrast to 'construction'. Cultivation denotes a way of shaping technology that is fundamentally different from rational planning and engineering methods as it is based on the resources present in the local social system. Given the provision of technology components such as software, hardware and standards, the overall information system is regarded as something that grows into place, based on the potential in what is already present in the community. This community based approach is strongly linked to the central role given to community participation in the WHO's Primary Health Care (PHC) approach (WHO, 1978), which requires and promotes maximum community trust in the system and participation in developing and running the health services.

In terms of information systems and technology, the project has applied a strategy of integrating various smaller subsystems into a data warehouse. The resulting integrated data warehouse includes information of different types, such as data on health services, health statuses and demographic surveys needed to address equity in health services provision and health status and thereby the needs of disadvantaged communities. Important in this context is that striving for equity between poor and rich geographical areas and population groups will require an HIS that, for core components, is shared across a country, state or region to measure and monitor the extent to which equity is being achieved and to pinpoint areas where more resources and efforts are needed. Thus, for an HIS to best address the needs of local communities, it will need to be an integrated part of a larger area HIS framework.

This paradox, that locally based HISs that are addressing the needs of communities need to be part of something bigger in order to be useful, will be described and discussed in this paper using the case study from Sierra Leone. Important in this context is that Sierra Leone is a small West African country ravaged by a civil war in late 1990s. It is one of the poorest countries in the world and was ranked 180th out of 182 in UNDP Human Development Index report in 2009 (UNDP 2009). In order to complement the case study from Sierra Leone, where the infrastructure is still poor, with cutting edge infrastructure development currently being established in some parts of Africa, we give a brief description of an HIS implementation in Kenya, which is similar in content and aim but different in the infrastructure used. In Kenya the system is implemented using one central server and "cloud infrastructure" using Internet over the mobile network. While in Sierra Leone the traditional Chieftdom structure is using the HIS to address equity and document their demands for improved health services, in Kenya the significant issue is that improved Internet and mobile telephone infrastructure is enabling the community level to get access to their own information and to analyse and to disseminate it within a larger framework, and thereby, potentially, to be better able to address their demands.

The research presented in this article has been part of the Health Information Systems Program (HISP) research network, which started in South Africa in the 90's and has since then been engaged in action research, participatory design and open source software development in a number of developing countries (Braa et al. 2007). The development and application of the free and open source software called District Health Information Software 2 (DHIS2) as a joint collaborative effort across countries and institutions have been an important part of the research in the HISP network. Development in both Sierra Leone and Kenya is based on the DHIS2.

This article will proceed as follows; the next section will provide some background on related research, then we will present the methods applied, before describing the case of Sierra Leone. Thereafter, the case and its implications are discussed using "snippets" from the Kenya case before the conclusion is finally reached.

Background

Trends in global health and the HISP project

The recent years have seen an increasing focus on HIS as important for effective and efficient health systems, especially in developing countries. The international community has also emphasized the need for better HIS to track the MDGs, and several initiatives have been set up to tackle the challenge. In 2005, the Health Metrics Network was created as "the first global partnership dedicated to strengthening national health information systems" (HMN 2005). At the same time, many of the challenges countries face with their HIS come from fragmented systems propagated by the diverse international organizations supporting them, leading HMN to become a strong advocate for the building of national HIS integrating data from the various health services and health programs as well as from various donor initiatives. Following the HMN initiative, many developing countries are in the process of strengthening and revamping their national HIS. On the ground, however, HIS development in developing countries has proved difficult due to organisational complexity, fragmented and uncoordinated organizational structures due to similarly uncoordinated donor initiatives all maintaining their own HIS (Braa et al. 2007), unrealistic ambitions leading to a "design-reality gap" (Heeks 2002), and more generally, due to the problem of sustainability (Kimaro and Nhampossa 2005, Sahay et al. 2000).

National HIS are including aggregate statistical data of various types from health services and the population served by these services. The primary aim of these information systems has, until recently, been to provide health management and service providers at all levels of the health services with timely and accurate data, based on which, for instance, resources can be allocated and epidemics can be monitored. As part of the HMN approach (HMN 2008), however, dissemination of information to community and political structures, media and the general public has been advocated as an equally important objective for national HIS, as a way to promote health advocacy, transparency, democracy and good governance. Following this, the HMN recommends countries to include free access to health information in their national legislation.

Communities, widely speaking, will have their interest linked to this latter outwards reaching aspects of the HIS. In this perspective, organized community structures will use information from HIS in their efforts to improve health services and for development of their communities more generally. The community is generally seen as a key level for social development in developing countries. Such development will rely upon community participation in decision-making for social development at the local level (Midgley 1986). Community based participatory design (Braa, 1996, Byrne, Sahay, 2006) is extending this perspective of social development to the field of information systems and the tradition of participatory design. Community based participatory design in health care in developing countries will most often refer to the design of systems for community health workers, or systems to support various outreach health services in the communities. In this article, however, we will use the term community participatory design in a much broader sense to address the design and development of systems aiming to serve and support the whole community, the organised community structures as well as the general population in the community. Furthermore, these systems are also addressing the needs of the health workers working in and for the community. In this way our perspective on community informatics is in line with de Moor and De Cindio (2007), who are arguing that the requirements for such systems are fuzzy and, as with the supporting ICT, in a constant state of flux.

The case studies from Sierra Leone and Kenya presented in this article are both reporting from development of HIS and software carried out within the HISP network. HISP started in three pilot districts in Cape Town at the advent of democracy in South Africa in 1994/95, as part of the new government's reconstruction and development program. Equity in service delivery and uplifting of those who had suffered during Apartheid, and the creation of a decentralised health system based on districts, were key objectives in the reform process. The role of HISP in this period was to identify information needs and to engage the community of end users and local management structures in the process of developing new health information systems supporting the decentralisation (see Braa, Hedberg, 2002, Braa et al. 2004).

It is important to note that the original key members of the HISP team in South Africa had background as social/political activists in the antiapartheid struggle and other social movements, or they had background from the Scandinavian participatory tradition. As a consequence of the background of the team members and the political context of South Africa during these formative years, HISP activists have always explicitly and implicitly seen themselves as political actors in a larger development process.

HISP, participatory design and the community based cultivation approach

The HISP participatory approach to action research and information systems design was initially influenced by the so-called Scandinavian tradition: a number of union-based action research projects carried out in Scandinavia during the 1970s and 1980s. The focus in the earlier participatory design projects was on empowering workers, who were affected or threatened by new technology, by exploring ways in which their influence over technological solutions could be ensured (Sandberg, 1979; Bjercknes et al., 1987). Later projects focused on more instrumental design issues and shifted toward producing technological alternatives by involving workers in cooperative design at the workplace (Greenbaum & Kyng, 1991). Adaptation of information systems to the local context, local empowerment through participation and practical learning, and the creation of local ownership through participative processes are central issues in the Scandinavian tradition, which, despite the differences in context, have been adapted to the contexts in Africa and Asia through action research in HISP.

The community based participatory approach to the design and development of information systems in developing countries developed within HISP may best be understood through the concept of 'cultivation'.

The concept of cultivation (Braa, Sahay, 2012), in contrast to construction, denotes a way of shaping technology that is fundamentally different from rational planning, engineering methods and the construction of technology. Cultivation is about interfering with, supporting and controlling natural organic processes that are in material; as the seeds sprout, they must be provided with proper cultivation; the soil must be prepared and the saplings cared for and nourished. The term cultivation covers these processes, and in our case, adapting the principles, tools and basic set-ups of the health information system, and then helps them grow into place within the local social system of work practices, culture and technologies, through processes of learning. The health information system being cultivated in this way may thus be regarded as a socio-technical system, or an organism, with a life of its own, with its ability to learn and grow. The spread of technology is therefore better understood as a process of technology learning, rather than 'technology transfer'. Technology, like institutions, is also shaped through such processes of learning and growing into place. Methodologically, cultivation is characterised by incremental and evolutionary approaches, described in terms of 'piecemeal engineering'.

The DHIS software

The key "organising" element in the HISP network has been the continuous and longitudinal development and application of the open source software platform called DHIS - District Health Information System. The DHIS is a software tool for collection, validation, analysis, and presentation of aggregate statistical data, tailored to support integrated health information management activities, but it can also be adapted to serve other areas. It is designed to serve as a district based country data warehouse to address both local and national needs. DHIS is a generic tool rather than a pre-configured database application, with an open meta-data model and a flexible user interface that allows the user to design the contents of a specific information system without the need for programming. The DHIS is developed to serve as a flexible tool in what is described as a cultivation approach above. The software is flexible and it can be easily tailored to particular needs and requirements.

DHIS development has evolved over two versions. The first - DHIS v1 - was developed since 1997 by HISP in South Africa on MS Access, a platform selected because it was, at that time, a de facto standard in South Africa. The second - DHIS v2 - is a modular web-based software package built with free and open source Java frameworks, continuously developed since 2004 and coordinated by the University of Oslo.

Methodology

This paper primarily describes a case from an ongoing action research project in Sierra Leone that the authors are engaged in. Action research is a form of participative research where the researcher takes part in the change processes in an organization, actively trying to improve some stated problem (Checkland and Holwell 1998; Avison, Lau et al. 1999), in this case, the poor provision of health services throughout Sierra Leone, in particular, at community level. Our research, then, centres on understanding the processes at work, while at the same time using this understanding to improve the current situation.

We are all, to various extents and changing over time, immersed in change-processes and working closely with the owners of the problems we try to solve. As such, we are involved in open-ended and continuous phases of design, development, implementation, and evaluation of interventions, with a stated aim at improving some given subject, as according to principles of action research (Susman and Evered, 1978). The authors of this paper have thus participated in most of the events described in the case description later.

Three of the authors have been involved in the project in Sierra Leone on an on-and-off basis, spending considerable time in the country through many visits of up to 2 months. The fourth author is a formal employee of the project and a national of Sierra Leone, working in the Ministry of Health there for the last 4 years. The fifth author is working in the Ministry of Health in Kenya and played a leading role in the project in Kenya, where also the third author participated.

The project started in 2006, with the authors given a mandate to improve data management through the establishment of an integrated data warehouse and build institutional capacity for data analysis. The background for this was a situation of fragmented data streams, duplication of data collection, and little use of information from community to national levels. The research approach was thus solution-oriented, without a clear formulation of hypothesis beforehand. Rather, the research part of the project was focused on the interaction between technology, organization, and community through a participative cultivation approach in reaching the above mandate. Over several engagements, research questions were formulated to help with the various practical challenges that would emerge. Central to these were the following two interrelated challenges, 1) to cultivate the system at local level in order to become relevant and useful to the local community, and 2) 'scaling' the system to multiple communities in order to ensure that local decision makers had access to not only their own, but data from across the country to allow for comparison and evaluation. Within the larger combined research area, local cultivation and scaling, research questions were open-ended and dynamic.

Over these years, all authors, apart from our co-author from the Ministry of Health in Kenya, have been repeatedly travelling through Sierra Leone, engaging in participatory design of software and data reporting forms, and training in the use of these. Furthermore, we have been actively engaged in promoting information use at all levels through preparing for and participating in review meetings.

The primary mode of engagement has been capacity building, at all levels. This has taken place not only as formal training workshops, but also as on-site training at district levels and in relation to national and district review meetings. These training sessions have all been used in the development process to include the users by getting feedback and inputs from them on how the system could be made more appropriate and relevant for them. Training has also been used to foster a culture of information use by discussing how districts could engage with their communities to improve health services. Thus it is fair to say that a clear-cut division between training and participative development, and research for that sake, did not exist.

In 2008, a three-week training for national and district staff was carried out, focusing on computer use (a large proportion was computer illiterate at the time), using the data warehouse application, and analysing data from an epidemiological point of view. All districts have later been given additional on-site training during their day-to-day work. Refresher trainings have been held when district supervisors were visiting the districts, and also as joint workshops for all districts. Training has also been an arena to engage with other actors; a workshop was held for representatives from international NGOs to look at their information needs and how they could get this information from the new system. All trainings were semi-structured, trying to promote informal discussions with the participants.

In addition, more quantitative research methods were employed, especially in relation to data analysis. Health data would be processed and analyzed to prepare for review meetings, both in relation to actual use of the data for health management, and for assessing data quality and areas of potential redesign of the reporting forms. For this we used two key data collection forms, for which we had data from most of the country's around 1000 health clinics. Data since 2008 were included in this work.

Kenya represents another action research project that is related to Sierra Leone in terms of technology, goals, strategy, and people involved. The same methodology has been applied in Kenya though the Sierra Leone involvement spanned more than 4 years compared to the about one and a half year research and implementation that took place in Kenya.

Community participation: the case of HIS development and use in Sierra Leone

This paper builds on events related to reforming the health information systems in Sierra Leone in the period 2006-2011; a process that is still ongoing. Sierra Leone is a small country in West Africa, with approximately 5 million inhabitants, and has, as recently as 2001, come out of a decade-long civil war. Picture 1 shows the innovative data collection tool for illiterate community health assistants, representing both the sorry state of the country and how this is often solved locally in communities. With this background, many international organizations have been present in the rebuilding efforts, and in 2006 Sierra Leone was selected along with a few other countries to be a "wave one" country by the Health Metrics Network (HMN), a Geneva-based partnership with the World Health Organization (WHO). This spurred the events described in this document, of which there have been many participants, from the local clinics and district health offices, to national authorities, NGOs and donors in-country, international organizations like WHO and HMN, universities, and other regional actors like the West African Health Organization.



Picture 1: Simple but genius data collection tool for illiterates, where stones are put into boxes representing outcomes of births.

Summary of events

The case is a longitudinal action research project spanning many years, and a full description of the process is beyond the scope of this paper, though a short summary is useful to put the discussion in context. First, from 2007, the HMN-led project focused on introducing software to handle aggregate health information from health facilities, with two early goals: geographical coverage of all 13 districts in the country, and content coverage by including as many monthly reporting forms in the software as possible. For this the HISP

group was engaged for implementing a data warehouse, using the DHIS2 software, and build capacity related to this at national and district level. The first two years were thus about piloting and rolling out this software, with the majority of effort going into capacity building. Once geographical coverage had been achieved, the utility of the data increased, and expansion in this phase (2009-10) shifted towards creating the demand for the information, including capacity building at national level and for NGOs, as well as development of information products and active dissemination of both these and the processes behind making them. It was in this phase that information use at the community level became a priority, which will be described below.

System development

System development In order to design or customize DHIS2 as an integrated data warehouse (IDW) that fit Sierra Leone, a technical team was established. The team was composed of HISP members, Monitoring and Evaluation (M&E) officers at national level and district levels, M&E officers from health programs, IT technicians, public health officers, and health workers. However, prior to the technical team creation, DHIS2 experts from HISP had created a prototype of the IDW showing how different data sources can be integrated together and enable a cross data analysis that would generate more meaningful information. The prototype contained the hierarchy of organisational units as given by the MoH: National level ? districts ? local councils ? health facilities. This geographical and hierarchical representation of the HIS matches with the MoH structures and channels of data reporting and use. In addition to this hierarchy, data from three different sources were integrated: namely population data, Extended Program for Immunization (EPI) and human resource data. Data available from 2005 was imported by district into the system for three reasons: show how data from different sources could be integrated, have data to perform training of the software with, and to give a base for comparing newly entered data. At that time, the system was able to generate automatically health worker distribution per population and per district. It was the first time such a graph was available from one system in Sierra Leone. This is shown in Figure 1 below. The prototype was purposefully designed to help stakeholders at different levels understand what an IDW is and thus enable their active participation. Having seen the potentials of this solution, the first concern of districts M&E officers was to be able to generate health information out of the system by chiefdom, local councils and health facilities. While generating health information and feedback reports by health facilities is obvious because data is captured by health facilities, there emerged a challenge to represent another sub-district level, the chiefdom. If health facilities can fit into chiefdoms and local councils, the hierarchical relationship between local councils and chiefdoms is not one "parent" to one or many "children". Local councils are hierarchically above chiefdoms but one chiefdom can belong to two local councils. The representation of such complex hierarchical relationship is not straightforward in the DHIS2 hierarchy logic. However, the participation of district M&E officers helped us understand their needs better and we used alternative hierarchies in DHIS2 to represent both local councils and chiefdoms. Through this participatory process we gradually integrated different data sources - HIV/AIDS, reproductive health, maternal and child health etc - and defined required indicators as well as feedback reports that would be used at different levels of the health system. Awareness meetings with local councils and other local stakeholders were conducted as part of this process.

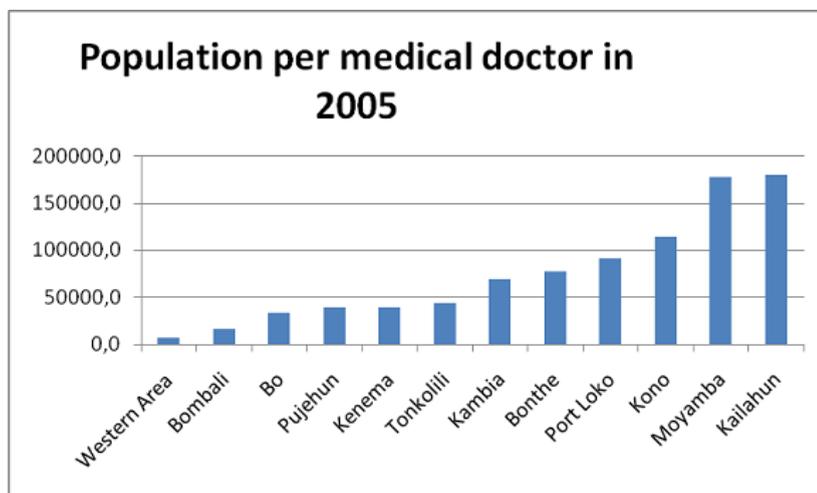


Figure 1: Population per medical doctor and per district

The initial customization described above took place within a training framework so that the core national team was trained to learn the software which enabled them to participate in the customization. Training of the larger group of users, district information officers, health program M&E officers, and the like, was then initiated and has been a core focus for the project.

While the software DHIS2 was the natural subject of training, it was also a platform to cover issues such as data quality, analysis, and general epidemiology to decide what kind of data was important and what kind of information products should be created. From the onset of the project, a three-week intensive course was held for all district M&E officers, with the aim of preparing them as independent teams for districts, able to work closely with communities and civil society in processing and disseminating relevant data. This was also used to foster local participation, as the training was used to discuss information needs, problems with data quality, and how they saw the new system as being representative of their needs. The developers of the software participated at this training, and discussions about functionality with district staff provided important input to the development process. Many new functionalities in DHIS2, for instance reporting on data completeness, originated from this training.

A second phase of training took place at the local level around the country. In relation to installation of hardware and software in the districts, training was given on-site to M&E officers, and supervisory visits that were carried out regularly also included re-training. In these sessions, the core team would sit with only 2-3 people, focusing on the information cycle from collecting data (at facilities and district offices), processing it (in relation to planned monthly review meetings), presenting and analyzing it and making action plans (at the review meetings with participation from facilities and civil society).

Infrastructure and HIS architecture

The civil war that ended in 2002 had destroyed many infrastructures and when full-scale implementation started in 2008, roads, power supply, and internet availability were still major problems. Internet availability was very limited both in the capital and in the upcountry. The main source of power supply was generators, and getting power from the national grid was incidental. These settings made running a computerized information system very challenging. In addition to these infrastructural challenges, lessons learned from the implementation of software in 2007 showed that keeping the computers virus free and up and running was not trivial. The lack of connectivity made it difficult to update antivirus software in the districts, and consequently the entire MS Access based database was often corrupted or destroyed by viruses. Moreover, when district health offices called local IT service providers for troubleshooting, the solution they often offered was to format the computer without regard to the existing data.

Being mindful of the issues mentioned above, and keeping in mind that DHIS2 is a web based system, a decision was made to go for a replication of instances of the system in every district. In each district a local server, one client computer and a local area network were thus deployed. Both the local server and the client computer were low power based and able to run on car battery that can be charged with solar panel or a generator - when there is fuel to run it. The operating system (OS) adopted was Ubuntu Linux to make sure that they will be less sensitive to virus and thus not rely on inadequate local IT support service. However, existing computers running MS Windows OS were also included in the network as clients. So while the local server is Linux based and runs DHIS2, client computers in the local network area can access the same system and work collaboratively on the same database even if they have different operating systems. This networking aspect of the settings was quite useful for district people because they could now work from different computers on the same database. At the national level DHIS2 was also installed on a server running the same Ubuntu Linux OS. A local area network was also set up within the MoH to enable access to DHIS2 within the MoH.

At the end of every month, district M&E officers are supposed to capture data coming from health facilities within their district, generate an export file from DHIS2 and send it to the national level. The export file is sent via email when internet is available or very often in person on a USB pen drive. At the national level the administrator of the system collect the district export files and import them into the national instance of DHIS2.

On the one hand, although this organization and these procedures look more appropriate to the context, it was very challenging to maintain and keep updated all the local instances of DHIS2. For instance, any changes to the metadata in the national database have to be replicated in all other instances to keep them compatible. Obviously this requires travelling to all the 13 districts on poor roads.

On the other hand the low power computers were not very strong and parts had to be changed because of various failures in the warm, humid, and dusty environment. Fortunately, as the government was investing in infrastructure, power supply improved and the system moved gradually from low power computers to regular ones. However, despite the progress in road construction and power supply, internet availability and reliability is still weak and hampering the shift from distributed instances to one central server.

Information use

As the use of the new data warehouse was maturing, work began to start utilizing the data it produced. This is, of course, the reason for the introduction of the system in the first place, but it is also a strategy to improve data quality, as only by use and self-interest in the data the quality would come under scrutiny and new solutions be proposed. The project thus initiated the use of quarterly bulletins, a modest 4-page leaflet comparing all districts on a handful of health indicators, as well as some indicators on data quality. The first bulletin was released in May 2009 and disseminated widely, including all districts and members of a group of international health partners (WHO, World Bank, DFID, etc.).



Picture 2: the front page of a quarterly bulletin in Sierra Leone

The bulletin contained charts derived from DHIS2, ranking the districts from worst to best performers. Picture 2 shows the front page of one bulletin. While the data was of dubious quality, based on partly incomplete data, the effect was at least to start discussions about how to improve it. Shortly after, data reporting increased significantly, so that the next bulletin had more complete data.

In addition to the bulletin, a league table was developed, in which a few key indicators were used to give each district an overall score, ranking them based on data quality, institutional delivery rate, immunization rate, antenatal care coverage and the like. This league table was presented at the annual review meeting at the Ministry of Health, with participants from all districts. The league table raised much discussion especially in relation to a few indicators that had much variation among the districts. One such example is institutional delivery rate, an indicator directly linked to the Millennium Development Goals about maternal and child health.'

The development of the bulletin and league tables were initiated at the national level. The selection of indicators to include was based on relation to the MDGs, and data quality, such as institutional delivery rate (linked to infant and maternal health), and reporting rates of the main data collection forms that contained this data. Since the data completeness was an issue, only indicators for which there would be adequate data available were included.

In 2009 Western Area (mostly consisting of the capital Freetown) was one of the districts scoring very low in term of institutional deliveries. Being very concerned by the poor performance of his district, the District Medical Officer (DMO) in Western Area decided on two strategies to improve. First, to collaborate with private facilities (of which the district has many more than rural districts) to get their data on institutional deliveries, and second, to release a note in the newspaper informing the public that maternal and child health care was now to be free of charge in Western Area district. As shown in the Figure 2 below, institutional deliveries have increased steadily in the district. The free maternal health care policy could not alone explain this increase, the involvement of private facilities has to be taken into account, but in any case the results are remarkable and were soon distributed globally by the Health Metrics Network as a strong case for investing in health information systems. The new figures in turn help them plan well and advocate for adequate resources for the district.

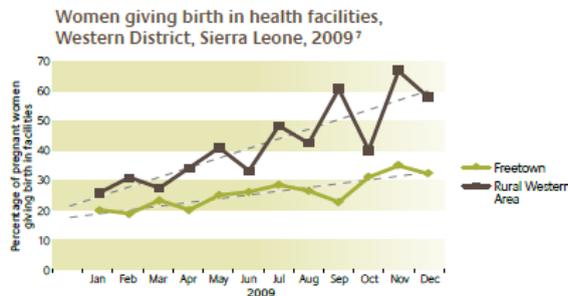


Figure 2: Increasing institutional delivery rates in Western Area, from the HMN Results Report (2010)

Districts also have their monthly review meetings, and following the example of the bulletin and league tables, several districts started to make chiefdom league table, ranking the sub-districts (chiefdoms) in a similar way. These review meetings are attended by all district stakeholders such as health partners, community counsellors, health providers, traditional and religious leaders, etc., and have led to a plethora of locally driven initiatives on improving service delivery in their respective communities. The development of a district and chiefdom league tables covering important health indicators, the active dissemination of these, and discussions with key stakeholders on how to improve on these indicators form the highlight of such review meetings. For instance, the use of the chiefdom league table showing performances of each chiefdom on key health indicators (such as institutional delivery, fully immunized children, etc.) in Moyamba district has raised a competitive feeling among the local communities. Table 1 shows an example of chiefdom league table.

Chiefdoms	% Full Immunized 2nd Quarter	% PHU Delivery 2nd Quarter	% 3rd ANC Visit	% 2nd Dose of IPT	% MMRC Submitted	% Exclusive Breastfeeding at Penta3	Average Score	Ranking
Kongbora	98.2	45	170.9	96.6	86.6	93.3	5.3	1
Fakunya	124.3	62	154.3	86.2	100.0	48.1	5.0	2
Dasse	134.9	57	90.5	86.3	100.0	45.9	4.8	3
Kaiyamba	90.3	55	162.7	93.4	75.0	71.3	4.8	3
Timidale	140.3	46	106.8	91.7	91.7	33.0	4.8	3
Kowa	118.4	52	96.5	46.7	100.0	78.2	4.7	6
Lower Banta	88.3	48	201.6	120.8	100.0	35.6	4.7	6
Bagruwa	61.4	37	110.3	92.4	93.0	32.1	4.3	8
Kamaje	55.6	35	69.7	140.7	100.0	86.5	4.3	8
Kargboro	80.4	45	93.2	77.6	100.0	36.5	4.3	8
Kori	49.8	40	92.6	89.4	86.6	64.0	4.3	8
Ribbi	71.8	26	53.7	57.4	100.0	60.5	3.7	12
Upper Banta	61.1	29	68.0	101.2	77.8	38.6	3.7	12
Bumpch	54.0	29	73.8	38.2	100.0	28.3	3.2	14
Total	91.4	43	114.3	32.4	93.6	20.8		

Table 1: chiefdom league table in Moyamba district

In this case, Kongbora chiefdom, after coming last in the first quarter review, improved to take the first place in both the second and third quarter reviews. Fakunya Chiefdom was the sixth in the first quarter review, but improved to take second and third places in the second and third quarter reviews. Dasse Chiefdom was eighth in the first review meeting

but took third and second places in the second and third quarter reviews. Certificates of this, provided to the paramount chiefs at the review meetings, were brought to local council meetings as proof of good performance, as shown in the Picture 3 below.



Picture 3: P. C Banya (Kongbora chiefdom) with chiefdom league table certificates (2nd and 3rd quarters) at Moyamba district council monthly meeting, where health and other local issues are discussed.

By comparing themselves and knowing more about health indicators, local community leaders decided to better organize health service delivery in their community and put more pressure on upper level for more resources and more support. In many communities, local counsellors are now putting in place bye-laws for the Traditional Birth Attendants (TBAs) to help pregnant women deliver in the health facility where they can have a clean and safe delivery with trained staff in attendance. The District Health Management Team also organized outreach activities eagerly requested by community leaders (Paramount chiefs) after the review meetings to increase the coverage for key health outcomes like childhood immunization. Some communities have also used these meeting to advocate for more resources (human, financial and infrastructure) in order to address the low uptake of services in their catchment areas. In some chiefdoms where institutional delivery rates are low, the paramount chiefs mobilized local resources to build birth waiting homes where pregnant women staying far away from health centres could stay until they delivered.

Involving the communities, including religious leaders, traditional health service suppliers, and the paramount chiefs, the districts are improving the institutional delivery rate, an efficient strategy to reduce infant and maternal mortality. The Moyamba DMO is very proud of the interest expressed by the community members who are now determined to improve service delivery coverage in their communities. "Using the data from the DHIS for the quarterly review meetings, the population better understand the health services performance and are happy and interested to be involved," claimed Dr Kandeh, the Moyamba DMO. "Without their interest, we could not move forward and have high performance". Being able to show improvement in service delivery by using health information at district level, and regularly share it with key stakeholders, led to a major change in prioritizing health services with the community involvement.

The possibility of being part of a larger set of other communities made it easier for local communities to compare themselves with neighbouring communities which in turn triggered the propagation of best practices leading to improvement of health services and high performance. While the data quality shown in table 1 is obviously an issue, as seen from the rather wild percentages for some of the chiefdoms, these problems have triggered a review into denominator data such as population figures which tend to be outdated and not take into account recent migration.

Online web based access in Kenya - Empowering rural communities

Participatory design in the cloud

Sierra Leone is one of the poorest countries in the world and the infrastructure is poorly developed. It has therefore not been possible to implement the DHIS on a central server, which would have been much easier and which is the "industry standard" of doing things in the industrialised world. As the Internet and mobile technology is spreading rapidly in Africa, we include a limited case study from Kenya, where the infrastructure is much better, and probably quite similar to what it will be in most of Africa relatively soon since it is driven by mobile network technology. DHIS2 is currently being rolled out in Kenya based on a central server solution. Initially, the plan was to implement standalone instances in districts around the country, the traditional African way, but during a field visit to Machako in October 2010, a district hospital not far from Nairobi, the course of action was changed. Testing the DHIS2 online server in the information office, everything went well until a power cut left the line dead. As it was a hospital, the generator started and power came back, but the Internet was gone as it would have to be restarted somewhere down the line. The team was just about to conclude that Internet was still not reliable when one of the staff suggested using his "dongle", the modem for the Internet over the mobile network, which, it turned out, worked fine as the mobile networks are not affected by local power cuts. Immediately after this revelation, Internet modems were tested around the country and found to work, and the decision was taken to go for a central server solution, probably the first time for such a

country-wide public sector project in Africa. However, the server in the Ministry of Health could not be used as the connectivity was too poor in the building and the server setup not reliable. As a temporary solution therefore, a commercial server was rented through a London based company, meaning cloud computing, although politically it may not be accepted to locate national health data outside the country in the long run. The Coast province was selected as a pilot, and the system was implemented in all districts and hospitals there in January 2011. All users were provided a modem and a budget for airtime. The network was working, but the bandwidth was limited many places, and the cost of the airtime restricted the amount of time online. In order to address a multitude of problems the DHIS2 lab was literally moved to Kenya; the lead developer and others took part in building a local team and engaging in rapid prototyping cycles on site with the users in the Coast province. In fact, "rapid prototyping" changed its meaning; working on an online server meant that the system changed as according to users' input, if possible, on the fly, or overnight.

After the initial pilot and testing in the Coast province, the system was rolled out country-wide during March-September 2011. During a field visit in the western parts of Kenya, in Nyanza and Western provinces, and to remote areas, such as Homa Bay district, where two of the authors participated, the most surprising finding was that the users in districts and health facilities said they had easier access to their own data, as well as data from the rest of the country, than they had had anytime before. The argument was that they could access their data regardless of power-cuts (when they used their laptop), viruses or computer problems, because the data was "up there", always available, "in the Internet". Furthermore, they really appreciated the dynamic updates of data from around the country and the messaging system in the DHIS that was used for communication between users and the system support team to report bugs and to get help when having problems. "Just like Facebook" as one user said.

The new HTML 5 standard has the potential to improve the robustness of Internet and cloud based technologies in Africa, as it allows for offline data entry because browsers implementing this standard are now including a small database. The first version of such a "semi-online" feature was implemented in DHIS late August 2011. The user can now capture data offline by using the memory in the browser and "flush" the data (i.e. transfer to the server) when online. This is a very useful feature in Africa since Internet is not available everywhere and all the time. The following message was posted by a user after the new feature of offline data capture had been included:

2011-09-13 Hi, this is wow! I have realized that I can now work with a lot of easy without any interruptions from network fluctuations since some of us are in the interiors where we have lots of challenges with the network. This is so good, a big Thank you.....

Offline data-use is another important optimization of DHIS2 for low bandwidth in remote areas: the ability to download data for off-line data analysis and use. A small "super lightweight DHIS2" application installed locally is used to download data from a local area and other areas specified by the user, including the indicators and aggregates generated by the system to a data mart, which is then used to generate Excel pivot tables used for data analysis. Reports, charts and maps are generated when "online" and downloaded in PDF format and archived in the offline application. As the Excel pivot tables are not easy to update online regardless of bandwidth, the offline local data mart is actually representing an improvement on some functionalities when compared with the web browsing (see figure 3).

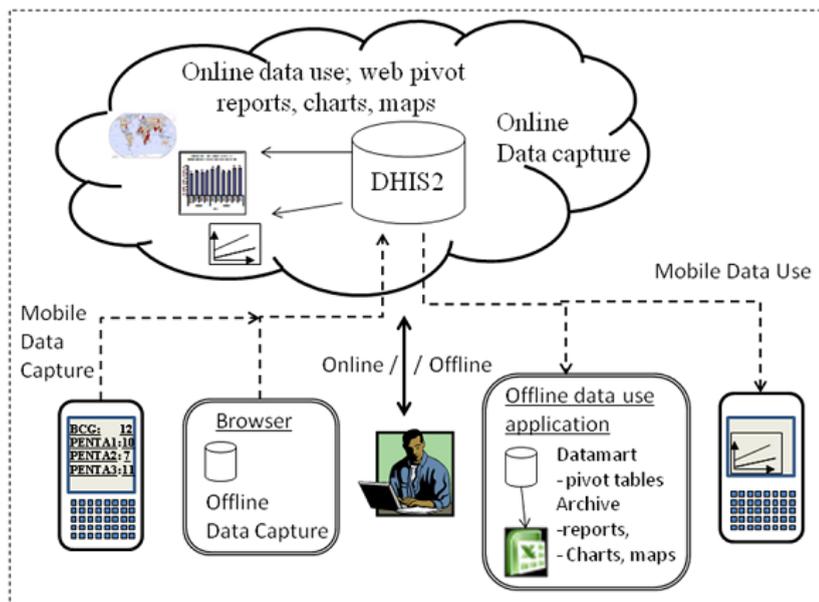


Figure 3: Semi-online DHIS2 design and implementation in Kenya.

Discussion

1. Health information in a community perspective: How communities can use HIS for their own development?
2. Design strategies: How to best include communities in participatory design strategies?
3. The technology dimension: Is modern Internet technology appropriate at community level in remote areas in developing countries?

- 4. The culture dimension: Are the HIS being developed culturally appropriate at the community level?

Health Information for community development

The case of Sierra Leone is, in the end, about improving health for communities throughout the country. This is done by improving access, quality, and use of health information, both for public health staff and for the communities themselves. The public health system is there to serve community health, so strengthening their capacities to analyze the health situation and make appropriate action plans is in itself a way to use information technologies to improve community health. However, as the case shows, the technology can also be utilized to share data with stakeholders in the communities, such as paramount chiefs, civil society, and NGOs. For example, preparing data from neighbouring districts or chiefdoms, available from an integrated data warehouse, in league tables that are then shared widely with these stakeholders has been a powerful result from several districts in Sierra Leone. While the "owners" of the technology are the organized public health services, the information contained therein is shared beyond the domain of public servants, enabling the communities themselves to shape their response to their health challenges. The information system introduced in Sierra Leone thus contributed both indirectly and directly in enabling communities to improve their situation.

Furthermore, the case shows that the real benefit was linked to evaluating your own situation in comparison with others. In a context where information about your own situation is sparse, and knowledge about what it should be is even sparser, the availability of comparative data from other districts and chiefdoms can at least give a relative performance indicator. The league tables were especially strong carriers not only of information about the community's own situation, but how the community performed compared with others. The maternal and infant mortality rates in Sierra Leone are among the highest in the world, but there are domestic differences that may earlier not have been well acknowledged. Public health service coverage and utilization vary across the country, and by learning from best practises, while fostering some community competition, the league tables enabled the health staff and the communities they are serving to improve piecemeal, striving to achieve small results that have a big impact on the health status. For instance, the example from Western Area, where several measures were tried to improve the institutional delivery rate, was in direct response to the poor standing in the district league table. For this to be possible, the data relating to the community, be it district, chiefdom, or village level, must have something to be compared with. The value of the community data increases manifold when available together with data from other communities. The league tables and health information bulletins served both as carriers of information and in a normative way as guidance relating to what indicators were considered of national importance. Thus, the local levels could both get feedback on how they performed, and knowledge relating to how they were evaluated. The important point here is that isolated information on the individual communities is of less value than the connection to information on other communities. Information technology projects that have a community focus, then, should be wary about the power of transparency and linkages to other communities. While a singular "community system" would provide the community with its own health information, the real benefit comes when comparing one's own information on health status and available health services with information from other communities.

Communities' use of information to promote their own development, as illustrated by the case of Sierra Leone, is providing concrete experiences on how the WHO Primary Health Care approach may be achieved. Community participation in the development of the health services is highlighted in the following way in the Primary Health Care (PHC) concept Article VII, paragraph 4 and 5 in the Alma Ata declaration:

"Primary Health Care: 5. Requires and promotes maximum community and individual self-reliance and participation in the planning, organisation, operation and control of primary health care, making fullest use of local, national and other available resources; and to this end develops through appropriate education the ability of communities to participate;" (WHO 1978)

We may argue that without access to good information on the performance and availability of the local health services, local health status, and an overview of trends in other communities, "participation in the planning, organisation and control of the primary health care", as stated by the Alma Ata declaration, would not be possible.

Cultivation - Community based participatory design

In this section we will discuss how community participation in the design of information systems may be seen as part of, and incorporated in, the participatory design tradition.

In the last section we saw how community participation was an integral part of the WHO Primary Health Care approach; the community is seen as the key participant in the development of the health services for the community. Here we will look into whether such a strategy may also be applied to the communities participating in the development of the information system, which, again, should be regarded as an important pillar in the development of the health services in the community. Tracing the history of the participatory design tradition, we see that it has its origins in the progressive movements of the 60s and 70s, in ways somehow similar to the origin of the PHC movement. Participation for empowerment and social development were the slogans for both movements.

There are however some significant differences between the participatory design (PD) tradition as it has evolved over several decades in industrialised countries and the context of community development in Africa. First, while in the PD tradition, the workplace has been targeted as the arena for empowerment and action. In the context of the development of health services and improving health in developing countries, it is the community that is the arena for social and political development. Second, while the PD tradition was born out of a situation in the industrialised world where workers felt threatened by modern technology and feared job losses, communities in developing countries are threatened by

being sidelined by new technologies and being left out from development. This second issue, that is, how communities may be either sidelined or made to master new technologies will be discussed in the next section. Here we discuss the first issue: Focus on the community rather than the workplace.

As underlined by the Alma Ata declaration, the health services are there for the community and the community needs to take part in their development. When developing health information systems at the community level, two levels of users are important: health workers and the community. While the health workers are users of the systems in the traditional sense, as being defined in the PD literature, the community is the users of the health services and, as participants in the development, control and planning for improved health services, users of the information systems with the aims to pursue these goals. We thus need to extend the PD tradition to also include the community. Greenbaum and Madsen (1993) put forward three rationales for using participatory design approaches:

- a pragmatic perspective, a functional way to increase productivity;
- a theoretical perspective, a strategy to overcome the problem of lack of shared understanding between developers and users;
- a political perspective, a democratic strategy to give people the means to influence their own work place.

In addition to the three rationales that they suggested, a community perspective has been proposed as strategy to enhance both the community as well as to prepare technical development that goes beyond mimicking the first world (Braa 1996):

- a community perspective, extending the political perspective and aimed at empowering communities to control and master ICTs to their own advantage by pursuing their own social and political development.

In the Sierra Leone case we have seen that the formal community structures, the chiefdoms, are taking part in the development of the system as part of their strategy to mobilise resources, create awareness and to improve the health services in their own community.

An example from the case shows how the districts and chiefdoms took initiatives to improve the system, for example, by being instrumental in the development of data completeness reports and incorporating them in the league tables which enabled the chiefdoms to control and check their own data; a task the district team did not know how to measure by themselves. Such direct engagements and initiatives have been important in creating a sense of ownership to the system in the community, which again has led to the development and dissemination of the health bulletins as a means for the formal community structures to communicate with and mobilise the wider community. Such dissemination of information from the HIS is important to develop further, both as a means for public health advocacy and as a vehicle for community participation. These bulletins may be regarded as first steps towards turning the HIS into a true interactive vehicle for wider community participation.

In Kenya, we have seen how direct and immediate access to own data through the Internet over the mobile network even at the most remote village level has created a significant level of local initiatives and participation in the further development of the system. Clearly, having direct access to your own data and being able to analyse and use it without having to rely on 'middle men', has both created a feeling of ownership of the system and commitment to participating in its further development. The development of the system in Kenya has from the start been driven by local initiatives seeking to release the potential on the ground. Even the fact that the system is based on the use of modems to connect to the Internet over the mobile network, which is the most significant technical feature of the system, was not planned for. The new solution popped up through interaction on the ground, and changed the course of the entire national project. Chatting functionalities enabling users to communicate is another example of unplanned design features developed through interaction on the ground. Cultivation is the term we use to depict such an open user centred design and development strategy where the potential in the context is released through active participation in the design and development process. The cultivation approach has been important in engaging at the community level because it provides a practical way for the community to have real influence and to get results through their participation.

Internet and ICT at the community level: Appropriate technology?

In the 70's and even later, the term appropriate technology was used in development aid circles to denote technology "simple" enough to be used in developing countries - which was a rather patronising attitude. In this section we will revisit the term and see whether "appropriate" can be given a new meaning in the age of the Internet and cloud computing.

When initiating the project in Sierra Leone, sustainability of hardware and software was a major concern. At that time, there were those arguing that computer technology was not appropriate for rural Sierra Leone. An initial survey showed that literally all computers were seriously affected by viruses. In order to address this problem a Linux based infrastructure was implemented in the districts; a computer without screen was used as a dedicated "no touch" Linux server running the DHIS software and accessed through wireless network by various users in the district headquarter by their browsers. This infrastructure turned out to be very successful, and indeed appropriate. Despite limited initial Linux knowledge, the trade-off was a running system without viruses. Early in the process, an additional smart technology was also tried: low powered 12 Volt computers running on batteries and, the plan was, solar power. This experiment, however, turned out to be not so "appropriate"; the low-powered server did not have sufficient capacity and speed, and users were not happy with screens and performance; various other technical problems put that pilot effort to a standstill.

In Sierra Leone, the Internet is not universally available across the country, a situation which is still similar in most parts of Africa. The norm when implementing country HIS in Africa has therefore been, as in Sierra Leone, until today (2011), to capture the data in stand-alone databases implemented in districts, hospitals and health facilities around the country, and to report data electronically by e-mail attachments or physically on a memory

stick to the next level. Significant human capacity on databases, data management and system support is needed, in order to manage a national HIS based on numerous standalone database applications with fragile flows of data between them. Problems of data reporting, completeness and the maintenance of numerous standalone applications across the country make it very complicated. Building a web-based data warehouse on a central server, as is the norm in industrialized countries, and even using a cloud infrastructure, is much simpler technically and in terms of human capacity and needed support structures, for hardware, software and data and database management. Ironically, Africa would need more human capacity for support and maintenance when implementing a country HIS than would, say Norway, when implementing a similar system, because in Africa would need to maintain numerous standalone implementations and complicated flows of data, whereas in Norway only one central implementation would have to be maintained. Cloud based infrastructure using a central server with universal access would therefore be a very appropriate infrastructure in Africa. Based on the rapid increase in mobile coverage in Africa, new cables down both the East and the West coasts of Africa, the situation may be about to change.

The semi-online solutions developed in DHIS enabled by the new HTML 5 standard which allows for offline data storage in the browser, has been successfully implemented in Kenya. This innovative technology is significantly improving the feasibility of web-based computing using another new technology: the cloud based infrastructure, even in rural remote communities in Africa. In Kenya also, mobile telephones are used to interact with the DHIS; data is reported from remote clinics to the DHIS and feedback is sent from DHIS to the mobile. These examples of new and innovative technologies, including the local wireless network running on a dedicated Linux server in the districts in Sierra Leone, are all characterised by 1) being very appropriate for even rural communities in Sierra Leone, and 2) being very modern and even cutting edge. Therefore, the term appropriate technology for developing countries needs to be given a new and different meaning in the age of the Internet and cloud computing; to exaggerate a bit - the more "modern" and "cutting edge", the more appropriate the technology.

How can culturally appropriate systems be developed?

In the section above we concluded that modern Internet technology is appropriate at community level in developing countries. In this section we extend the notion of technology beyond the mere "technical", the artefacts and the "things", and see it as being rooted in knowledge and people through use and innovation (Fagerberg, 1994) in a socio-technical web (Kling, Scacchi 1982). Furthermore, information systems, such as the community based health information systems in Sierra Leone, are best understood as social systems (Braa, Sahay, 2012). Following these perspectives, 'cultivation' is well suited as a metaphor to describe the approach followed to develop relevant and socially and culturally appropriate information systems. The argument is that the particular components of the information system, such as hardware, software and paper-based data collection tools may be planted in a local setting, so that the seeds may be similar and context free, but local growing conditions, such as culture, languages and social conditions, are infinitely variable. The developing plant therefore needs to be tended and nurtured by the local community who will then develop a sense of ownership and commitment towards it. In this way the information system understood as a social socio-technical system will grow into place as an expression of the local culture and language. Cultivation, as an approach to information systems development, relies upon the development of local ownership and commitment. A bottom-up participatory design and development process is therefore crucial in helping to create such ownership.

The Sierra Leone case demonstrates that the community level HIS needs to be part of the larger national system in order to be able to analyse data about the local health situation as compared with national standards areas and the situation in other areas. Only by enabling the community to use the HIS to analyse their own situation within the larger context will it be possible to achieve the objective of the Alma Ata PHC declaration which calls for maximum community participation.

This means that while local empowerment, commitment and bottom-up processes are crucial, there is an equally important need for making national standards part of the community based HIS. When striving for equity between communities and regions in a country, national standards are needed to identify and target areas of need (Braa, Hedberg 2002). This may cause some tension between the local need for flexibility and national need for standards, which may be addressed through a hierarchy of standards where each level in the health system is free to define its own standards and information requirements as long as they adhere to the standards of the level above (ibid.).

Concluding remarks

This paper has looked at how community participation in both the development and use of health information systems has led to a situation where the communities themselves are taking active part in improving their health status. The main contributors to success in this regard have been identified as involving the communities in the development and use of the health information system, sharing data among communities in a transparent and mildly competitive manner, and, as the case from Kenya shows, using a mix of cloud computing and offline support to further facilitate the above points also for communities not regularly connected to the Internet.

It is clear from the case that communities are not just users of the information system, but they are also participating in its development and they are themselves shaping the way information is handled and used at the community level. Conceptualising information systems as social systems, cultivation is used as a metaphor to understand how culturally appropriate information systems may be developed through local commitment and bottom-up participatory processes.

At the technical level, the cases demonstrates that modern ICT and Internet technologies may indeed become appropriate technology even for rural communities in Africa.

The case of Sierra Leone shows that while the HIS needs to be based on local ownership and freedom to define its requirements, the system must also include the national standards in order to be useful in a wider national comparative perspective. This implies that community HIS need to be connected in a larger, national HIS and that routines for feedback and dissemination are in place. Our case shows how communities are leveraging the national integrated data warehouse in Sierra Leone to make local decisions, which would not be possible without the wider system.

References

- Avison, D., Lau, F., Myers, M. & Nielsen, P.A. (1999). "Action Research." *Communications of the ACM* 42: 94-97.
- Bjerknes, G., Ehn, P., & Kyng, M. (Eds.) (1987). "Computers and democracy: A Scandinavian challenge." Aldershot, UK: Avebury; Brookfield, VT: GowerBraa, J., Hanseth, O., Heywood A, Shaw, V. (2007). Developing health information system in developing countries: the flexible standards strategy. *MIS Quarterly* Vol 31 Special Issue August 2007.
- Braa, J., & Hedberg, C. (2002). "The struggle for developing District health information systems in South Africa". *The Information Society*, 18 (3).
- Braa, J., Monteiro, E., & Sahay, S. (2004). "Networks of action: sustainable health information systems across developing countries". *Management Information Systems Quarterly*, 28(3).
- Braa, J., Sahay, S. (2012). "Integrated Health Information Architecture". Power to the Users. Maxwell Publishers, Delhi.
- Braa J (1996) "Community-based participatory design in the Third World." In Blomberg J, Kensing F, Dykstra-Erickson E (eds.): PDC'96: Proceedings of the Participatory Design Conference. Computer Professionals for Social responsibility, USA, pp. 15-24.
- Byrne, E & Sahay, Sundeep (2006). "Community-based health information systems: implications for participation." *Information Technology for Development*. ISSN 0268-1102.
- Checkland, P. and Holwell, S. (1998). "Action Research: Its Nature and Validity". *Systemic Practice and Action Research* 11(1), 9- 21.
- de Moor and De Cindio, eds. (2007). "Special Issue: Community Informatics and Systems Design", *Journal of Community Informatics*, 3(1)
- Fagerberg, J. (1994), "Technology and International Differences in Growth Rates", *Journal of Economic Literature*, Vol. XXXII (September 1994), pp. 1147 - 1175.
- Greenbaum, J., & Madsen, K. H. (1993). "Small changes: Starting a participatory design process by giving participants a voice". In D. Schuler, & A. Namioka (Eds.), *Participatory Design: Perspectives on Systems Design* (pp. 289-298). Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- Greenbaum, J., & Kyng, M. (Eds.) (1991). "Design at work: Cooperative design of computer systems". Hillsdale, NJ
- Heeks, R. (2002). "Information Systems and Developing Countries: Failure, Success, and Local Improvisations". *The Information Society*, 18, 101-112.
- HMN. (2005). What is HMN? Retrieved september 20, 2011, from <http://www.who.int/healthmetrics/about/whatishmn/en/index.htm>
- HMN. (2008). The Health Metrics Network Framework. Retrieved october 7, 2008, from http://www.who.int/entity/healthmetrics/documents/Rational_HIS_Capacity.pdf
- Kling R, Scacchi W (1982): "The Web of computing: Computer technology as social organisation", *Advances in computers*, Vol. 21, PP 1-90
- Kimaro and Nhampossa (2005) "Analyzing the problem of unsustainable health information systems in less-developed economies: Case studies from Tanzania and Mozambique", *Information Technology for Development*, 11, 3, pp. 273-298
- Malecki, E. J. (1991), "Technology and Economic Development: The Dynamics of Local, Regional and National Change", Longman Scientific & Technical, New York.
- Midgley, A., Hall, A., Hartiman, M. & Narine, D. (eds.). (1986), "Community Participation, Social Development and the State", Methuan, London.
- Sandberg Å. (Ed.) (1979), *Computers dividing man and work*, Swedish Center for working life, Demos project report no 13, Utbildningsproduktion, Malmö
- Sahay, S., Miller, J., and Roode, D. (Eds.), "Proceedings of the IFIP 9.4 Conference on Socio-Economic Impact of Computers in Developing Countries: Information Flows, Local Improvisation and Work Practices", Cape Town, South Africa, 2000
- Susman, G., & Evered, R. (1978). "An Assessment of the Scientific Merits of Action Research". *Administrative Science Quarterly*, 23(4), 582-603.
- UNDP (2009) Human Development Report. Retrieved September 20, 2011, <http://hdr.undp.org/en/reports/global/hdr2009/>
- WHO (1978) Declaration of Alma Ata, International Conference on Primary Health Care, Alma Ata, USSR, 6-12 September 1978, http://www.who.int/hpr/NPH/docs/declaration_almaata.pdf
- WHO (2011) Keeping Promises, Measuring Results. Health Accountability Report Presented at World Health Assembly. Retrieved September 20, 2011, http://www.who.int/topics/millennium_development_goals/accountability_commission/PR_Commission_19May2011.pdf