A Complexity Inspired Approach to Co-evolutionary Hospital Management Information Systems Development

Case studies from the “South”

By

Vincent Shaw

Submitted as partial fulfillment of the
requirements for degree of
Philosophiae Doctor (Ph.D.)

at the Faculty of Mathematics and Natural Sciences
University of Oslo
Norway

21 September 2009

Series of dissertations submitted to the
Faculty of Mathematics and Natural Sciences, University of Oslo
No. 905

ISSN 1501-7710

Cover: Inger Sandved Anfinsen.
Printed in Norway: AiT e-dit AS, Oslo, 2009.

Produced in co-operation with Unipub AS.
The thesis is produced by Unipub AS merely in connection with the
thesis defence. Kindly direct all inquiries regarding the thesis to the copyright
holder or the unit which grants the doctorate.

Unipub AS is owned by
The University Foundation for Student Life (SiO)

Dedicated to

My father,

who always wanted to do this, but was never afforded the luxury of time.

TABLE OF CONTENTS

Table of Contents ..... **v**
List of tables: ..... **ix**
List of Figures: ..... **x**
Abbreviations and Acronyms: ..... **xi**
Acknowledgements: ..... **xiii**
Abstract ..... **xv**
Preface: ..... **xix**

Chapter 1. Introduction: **1**
1.1. Background: 1
1.2. Thesis aims and research questions: 2
1.2.1. The Challenge in Designing Hospital Management Information Systems: 5
1.2.2. The Challenge of the Implementation Process 8
1.3. Research Motivation 9
1.4. Theoretical Perspective 10
1.5. Research setting and approach: 13
1.6. Positioning the research: 15
1.7. Expected contributions 15
1.8. Structure of thesis 16

Chapter 2. Theory and Related Research: **19**
2.1. Introduction: 19
2.2. An Overview of Complexity Theory: 20
2.2.1. Defining Complexity Theory and related fields of study: 20
2.2.2. A Brief History of Complexity Theory: 23
2.3. Key Features of Complex Adaptive Systems: 25
2.3.1. The components of a CAS - Agents with schemata adapting to the environment: 25
2.3.2. Non-linearity resulting in unpredictable long-term outcomes: 26
2.3.3. Self-organising groups and networks displaying emergent behaviour: 27
2.3.4. Co-evolution at the edge of chaos: 29
2.3.5. Summary: 31
2.4. The Elements of a Co-evolutionary Framework: 31
2.4.1. Introduction: 32
2.4.2. Application of non-linearity to organisation science and information systems: 33
2.4.3. Application of autogenesis to organisation science and information systems: 35
2.4.4. Application of co-evolution to organisation science and information systems: 37
2.5. Summary of Theoretical Perspective: A Co-evolutionary Framework 49
2.5.1. Applying the Co-evolutionary Framework to Hospital Information Systems Design, Development and Implementation: 49
2.5.2. Aspects of HospMIS Design, Development and Implementation that this thesis seeks to address: 52

Chapter 3. Research Methods and Case Overview **55**
3.1. Introduction: 55
3.2. Research approach: 55
3.2.1. Ontological and Epistemological Basis for the Study 56
3.2.2. Action research approach: 57
3.2.3. Qualitative case study method: 59
3.2.4. Interpretive research approach: 60
3.3. Research setting: 64
3.3.1. Fieldwork 64

3.3.2. The Research Context 1: Eastern Cape Province: 67
3.3.3. The Research Context 2: Northern Nigeria: 72
3.3.4. The Research Context 3: Malawi Central Hospitals and Zambia: 76
3.3.5. The Research Context 4: HISP-SA: 78
3.3.6. My role as researcher 79
3.3.7. Data collection methods 81
3.3.8. Data analysis and the use of theory: 83
3.3.9. Validity of data 85

Chapter 4. Research Findings: 87
4.1. Introduction: 87
4.2. Summary of individual research papers: 89
4.2.1. Paper 1: The Development of an Information System for District Hospitals. 89
4.2.2. Paper 2: Health information system reform in South Africa: developing an essential data set. 90
4.2.3. Paper 3: Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability. 91
4.2.4. Paper 4: Developing Health Information Systems in Developing Countries - the flexible standards strategy: 93
4.2.5. Paper 5: Considering the Options for Hospital Management Information Systems. 96
4.2.6. Paper 6: Scaling of health information systems in Nigeria and Ethiopia - Considering the options. 98
4.2.7. Paper 7: “Developed in the South” – an evolutionary and prototyping approach to developing scalable and sustainable health information systems. 101
4.3. A comparison across papers: 103
4.4. A synthesis of the findings: 107
4.4.1. The complexities of the context: 107
4.4.2. Flexible Standards as central features in the design of hospital information systems 109
4.4.3. Five core implementation strategies for hospital information systems 112
4.5. Concluding remarks: 114
4.5.1. Evolution of insights into HospMIS design, development and implementation: 114
4.5.2. Balancing micro- and macro- level analyses: 114
4.5.3. The co-evolutionary framework for managing the complexity of HospMIS development in resource constrained settings: 115
4.5.4. Critique of the co-evolutionary framework: 116

Chapter 5. Theoretical and Practical Contributions: 117
5.1. Introduction: 117
5.2. Understanding the Context 1: As Extreme Heterogeneity: 118
5.2.1. Extreme heterogeneity manifested in hospitals: 118
5.2.2. Extreme heterogeneity creating nested effects: 120
5.2.3. Practical implications 1: Managing heterogeneity in resource constrained settings: 121
5.2.4. Summary – Expanding the Co-evolutionary approach: 123
5.3. Understanding the Context 2: As Non-linear Effects 124
5.3.1. Conceptualizing Non-linearity: 124
5.3.2. Practical Implications 2: Managing Non-linearity: 126
5.4. Understanding the Context 3: Self-organising networks displaying emergent behaviour 127
5.4.1. Self-organising groups in support of co-evolutionary HospMIS development: 127
5.4.2. Self-organising groups pushing for change: 128
5.4.3. Practical Implications 3: Managing self-organizing groups: 129
5.4.4. Conclusions: 129
5.5. Sustainable IS Development: The Co-evolutionary Model: 130
5.5.1. The challenge of sustainability 131
5.5.2. Sustainability and organizational absorptive capacity: 133
5.5.3. Organizational learning as a co-evolutionary process: 135
5.5.4. The co-evolutionary information systems development model: 137

5.5.5. Practical Implications 4: Effecting co-evolutionary health information systems development: ... 141
5.5.6. Conclusion: ... 142
5.6. Co-evolutionary Scaling of HIS: ... 143
5.6.1. The challenge of scaling: ... 143
5.6.2. Conceptualizing scaling as a complex adaptive system: ... 144
5.6.3. Defining scaling along four dimensions: ... 145
5.6.4. Effecting scaling using the co-evolutionary ISD model: ... 146
5.6.5. Practical implications 5: Scaling as an escalation of complexity: ... 147
5.6.6. Practical implications 6: Scaling in Hospitals ... 148
5.7. Summary of Theoretical Contributions ... 150
5.7.1. Research aim and objectives ... 150
5.7.2. Main theoretical contributions ... 151
5.8. Synthesis of practical contributions: ... 154
5.9. Future research: ... 156

Chapter 6. Conclusions ... 159

References ... 163

Appendices

LIST OF TABLES:

Table 1: Overview of Special Issues in Journals Featuring Aspects of Complexity Theory 24
Table 2: Characteristics of Non-Linear Systems Applied to HIS 34
Table 3: Properties of Co-evolutionary Processes 39
Table 4: Comparison of Perspectives on Organizational Change as a Result of Interaction with Technology 40
Table 5: Principles of Co-evolutionary Adaptation of HospMIS 42
Table 6: Absorptive Capacity of a Typical Public Sector Hospital in a Resource Constrained Setting 48
Table 7: Application of Theoretical Framework to a Failed Hospital Implementation System in a Resource Constrained Setting 51
Table 8: The Application of Action Research Characteristics to this Thesis 58
Table 9: Application of Principles for Interpretive Field Research to this Thesis 60
Table 10: Distribution of time across project activities.. 64
Table 11: Comparison of Key Indicators 69
Table 12: Access to Critical Resources for HIS Strengthening in Jigawa... 74
Table 13: Linking Papers to Research Objectives 88
Table 14: Comparison across research papers 104
Table 15: Changes in heterogeneities interacting with one another as nested effects 121
Table 16: Comparative Assessment of Absorptive Capacity between Public Sector and NGO Organizations 134
Table 17: Addressing the Research Objectives through this Thesis 151
Table 18: Contribution of Rich insight 152
Table 19: Development of Concepts 152
Table 20: Generation of specific implications.. 153
Table 21: Generation of Theory 154
Table 22: Identified Research Priorities Addressed by this thesis.. 160

LIST OF FIGURES:

Figure 1: Information systems contributing to a HospMIS 6
Figure 2: The origins of complexity science from a diverse range of fields (Source (Wikipedia 2009)) 21
Figure 3: The Zone of Complexity or Edge of Chaos 30
Figure 4: Perrow's Framework of Complexity (in Tan, Wen, et al (2005)) 43
Figure 5: Contextualism as the Ontological Basis (adapted from (Pettigrew 1985) 56
Figure 6: Timeline of Research Activities and Publications 65
Figure 7: Restructuring Local Government in the ECP 68
Figure 8: Organizational Structure of the District Health System in the ECP. 70
Figure 9: Jigawa State, Nigeria 73
Figure 10: The register in use at a dispensary 75
Figure 11: Jigawa Reporting Rates for 2007 (source DHIS data as at Feb 2008) 76
Figure 12: Conceptualizing Action Research as Three Inter-Linked Practices 80
Figure 13: Page from my research diary 82
Figure 14: DHIS Dayta compared to NICS Survey 85
Figure 15: Crafting Gateways to Link Heterogeneous Components 97
Figure 16: Considering the Spheres of ISD when effecting Geographic Scaling 99
Figure 17: Using blank spaces to incorporate flexibility in register design 110
Figure 18: Organizational Learning Framework as a Co-evolutionary Process 136
Figure 19: The Co-evolutionary Model for Hospital Management Information Systems Development 139
Figure 20: The Dimensions of Scaling Health Information Systems 146

ABBREVIATIONS AND ACRONYMS:

Abbreviation	Decsription
CAS	Complex Adaptive System
DHIS	District Health Information Software
DoH	Department of Health
ECDoH	Eastern Cape Department of Health
ECP	Eastern Cape Province
EDS	Essential data set
EMR	Electronic medical record
EPR	Electronic patient record
FOSS	Free and Open Source Software
HIP	Health Information Practitioner
HIS	Health information system/s
HISD	Health information systems design, development and implementation
HISP	Health Information Systems Program
HISP-International	The international network generally referred to as HISP
HISP-SA	Health Information Systems Program South Africa
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immuno Deficiency Syndrome
HMIS	Health Management Information System (a term used mainly in Nigeria, Zambia and Malawi for the national health information system)
HospMIS	Hospital management information system
HospMISD	Hospital management information systems design, development and implementation
ICT's	Information and communication technologies
IFI	Institute for Informatik
IS	Information system/s
ISD	Information systems development
JBER practice	Joint business change practice/empirical research practice (used in Methods chapter)
MDG's	Millenium Development Goals
MoH	Ministry of Health
NDoH	National Department of Health (usually refers to the South African NDoH)
NGO	Non-governmental organization
PAH	Provincially Aided Hospitals
PCIS	Patient care information system
PHC	Primary health care
SA	South Africa
SWAp	Sector Wide Approach

ACKNOWLEDGEMENTS:

Someone once said to me that undertaking a PhD is a lonely and tough journey. While undoubtedly it has demanded persistence and steadfastness, it has been anything but a lonely journey. Rather I can say that it has been an extremely stimulating exercise during which I have not only learnt about health and hospital management information systems, but also a great deal about myself, and about the different people with whom I have interacted along the way.

Firstly, I would like to express my gratitude to my two supervisors, who have always been available to provide support and insight, even at short notice. Professor Jorn Braa has shared freely his experience and practical insights into health information systems development in resource constrained settings. These are the settings where he thrives, and is able to identify practical solutions based on solid theoretical approaches. Jorn and his wife Uni have made a special point of exposing me and my family to the Norwegian culture, and have taken me to many special places in Norway, for which I am most grateful. I would like also to thank Professor Sundeep Sahay for his quiet and caring support, and for his assistance in helping to shape this thesis. I have also appreciated the many discussions we have had around the health information systems development in Africa and India, comparing the similarities and differences, and mechanisms to work across the continents to strengthen information systems development efforts.

In Norway I have made many special friends. Special amongst these are Edoardo Jacucci and Miria Grisot, who have always opened their home to me, even when it was less than convenient. They have provided me with a “home away from home”, and cared after my special needs. Many thanks to you for this Edo and Miria. A special mention also goes to Edoardo with whom I spent many hours walking the beaches of the Eastern Cape Province, discussing our experiences in the hospitals, thrashing out theories drawn in the sand, and debating approaches while we prepared meals in the kitchen. Thank you too Miria for the many useful discussions we have had, and your insights into the finer aspects of theory and information systems research. Special too have been Jo Herstad and his wife Gro. Thank you Jo for the runs through the snow and ice over lunch times, during which we shared our experiences and discussed progress, and for the weekends in the cabin and the boat. Other people who have gone out of their way to help me include Sisse Finken, Margunn Aanestad, Shegaw Mengiste and his wife Sofia, Petter Nielsen and Kristin Braa.

A special mention goes to the South African HISP team, in particular Calle Hedberg and Norah Stoops. Thank you for supporting me in this process, recognizing that it would place a bigger load on your already heavy shoulders, and for taking on increased shares of the management of HISP. The HISP team as a whole also needs to be thanked for their support and care, and tolerance of my neglect of their needs especially in the last few months. I really enjoy working with you all – thank you for the fun and sharing that has taken place, for the ideas and arguments, and the different ways of working which have contributed to the ideas in this thesis.

Through the years I have also gained hugely from my association with our HISP colleagues in other countries. In Nigeria, special thanks for your hospitality and free sharing of ideas and concerns go to Aluka Terpasse, Bill Agir, Jerome Shaguy, Lawrence Kwagga, and Ime Asanganzi, and Dr's Akin Oyemakinde and Bola Njoku. In Zambia a special word of thanks to Simon Muyambo who has become a special friend, and Dr Chris Simoonga in the Ministry of Health. Acknowledgement of the role played by colleagues, many of whom are associated with our sister organization Health Partners International especially Rodion Kraus, Andrew McKenzie and Brian Haddon. Its been a great partnership with you guys and your team through the work in Nigeria and Zambia in particular, but also in the heady days of health system restructuring in the Eastern Cape Province.

Then, mention is also needed of the HISP colleagues scattered around the world. Here I think of Arthur Heywood, John Lewis, Jyostna Sahay, Ola Titlestad, Knut Starring, Johan Saebo, Juma Lungo, Faraja Igira and Negussie Mengesha. My colleagues with whom I shared a den, Honest Kimaro, Shegaw Megiste, Elies Ostmo, and Marissa D'Mello.

I extend my gratitude to Michele Nysæter from the International Students Office, and to the staff in the Administrative Offices at IFI, especially Anne Cathrine Modahl and Lena Korsnes for their patience and support through the years.

Last, but not least, a word for my family. My sons, Carey, Garth, and Neil, and their partners, who have patiently accepted me taking time from them in order to pursue these studies - maybe now I will come and be a nuisance in your homes for a change. And then to my wife Stephanie, who from the beginning has only known me as "ABD", but who has been ever patient and supportive and caring in her encouragement of me. Thank you best WWW.

ABSTRACT

This thesis develops conceptual models based on complexity science to understand the design, development and implementation of sustainable and scalable hospital management information systems in resource constrained settings. More specifically, drawing on empirical data from the design and implementation of hospital management information systems in South Africa, Malawi, Zambia, and Nigeria, it uses an interpretive methodology to understand the nature of complexity in hospitals, and the implications of this complexity on the socio-technological aspects of hospital management information system design and development, and implementation. Hospital information systems are notorious for their failed installations, complexity, and inability to deliver on promised functionalities in both well resourced and resource constrained settings. The thesis contributes to the discourse on information systems in developing countries research, and in particular to the social embeddedness discourse. As such the research seeks to characterize local problems, and develop locally appropriate solutions that involve technological and organizational change.

In this thesis, a hospital management information system is defined as an information system that collates and integrates data from different sources (for example wards, out-patient departments, pharmacy, accounting departments) so that reports can be produced for clinicians, managers and administrators to enable them to manage the hospital, the services it provides, and to allocate resources appropriately. The empirical focus is on hospitals in resource constrained settings for three main reasons. Firstly, huge gains in efficiency and equitable resource allocation can be made from the effective use of management information Secondly, hospital information systems are notoriously difficult to design, develop and implement and therefore it is important to explore approaches that overcome the challenges. Thirdly, in resource constrained settings, hospitals are particularly vulnerable to unsuccessful implementations because they face the challenge of increased complexity of interactions between the political, financial, and infrastructural conditions in addition to the everyday efforts of dealing with very high disease burdens, such as those related to HIV/AIDS.

The two primary research questions that guide the research are:

- Given the complex nature of the hospital environment, what are the socio-technical considerations that contribute to the design of sustainable and scalable hospital management information systems in resource constrained settings?

- How can the implementation process be designed to accommodate unexpected contradictions that arise between the different realities of original intent and changing needs in the implementation process?

A complexity science inspired theoretical framework is developed to analyze the empirical data. Complexity science has been used to understand the processes of change in organizations since the 1990's, and since the 2000's is increasingly being used also to guide information systems implementation. Information systems development and implementation are particularly appropriate to analyze using concepts from complexity science as they are increasingly shaped by complex conditions such as the rapidly increasing rates of technical, organizational and societal changes and their interconnectedness. Contributing to these dynamics is the faster and different rates and modes of communication, which require organizations to be more responsive. While complexity science concepts have not been explicitly applied in the context of hospitals, they arguably provide a rich arena for such analysis. Hospitals are comprised of a rich mixture of different types of health care providers and managers, interacting with each other in complex ways in order to provide a multiplicity of patient care. But they are also part of a larger organizational framework of other health services provided locally, nationally, and globally. Three main features of complex adaptive systems (CAS) are explored, namely non-linearity, self-organizing groups, and co-evolution. These concepts are utilized to develop a co-evolutionary framework which represents an analytical process for studying and also supporting the design, and ongoing development and implementation of HospMIS.

The research reported in this thesis is based on a longitudinal case study analysis conducted within the ongoing, large-scale, multi-country Health Information Systems Program (HISP) research project. The research described in this thesis falls within the interpretive research tradition described by Walsham (1993; 1995).

This thesis provides rich insight into the context in which hospital management information systems design, development and implementation takes place in resource constrained settings. The complexity of the context is described as "extreme" heterogeneity because not only is the environment heterogeneous, but the heterogeneity spans a wide range of possibilities, is rapid and ongoing and results in compounded effects, imbalances and non-linearity.

The contributions can be briefly summarized as follows. The socio-technical design of hospital management information systems needs to incorporate flexibility into all components of the system, from the paper based data collection tools to the software. Modularization is used to achieve this. The flexibility in the technical design of the system is mirrored by flexibility built into the implementation process. A co-ordinating rhythm is described which supports the establishment of self-organizing groups and networks to gather ideas from a diverse range of stakeholders, in a framework of decentralized control. These groups should transect traditional organizational hierarchies and functional groupings. The public sector in resource constrained settings is characterized by skills shortages and a tendency to neglect exploratory drives required to take advantage of new developments in the ICT sector. To counter these shortcomings, a solution is to posit the public sector organization (such as a hospital) and a non-governmental organization (such as HISP-SA) as synergistic partners in support of hospital management information systems design, development and implementation. This is potentially a useful partnership because the organizations have complimentary exploitative/explorative drives, and organizational links with different domains of influence. An important outcome of this arrangement is the development of capacity within the public sector through health information practitioners.

A number of possibilities for future research are suggested by this study.

PREFACE:

This thesis is submitted as a partial fulfillment of the requirements for the degree of Philosophiae Doctor (Ph.D.) at the Faculty of Mathematics and Natural Sciences, University of Oslo, Norway. The research topic relates to the design, development and implementation of hospital management information systems in resource constrained settings. The research has been conducted under the aegis of the Globally Scalable Information Infrastructures Group at the Department of Informatics.

The thesis consists of an introductory essay and seven research papers. The introductory essay presents the problem area and research question in Chapter 1. I then discuss the relevant literature in Chapter 2, and present the context of the cases studies along with the methodological approach in Chapter 3. In Chapter 4 the findings of the research are presented followed by my theoretical and practical contributions in Chapter 5. Chapter 6 presents my concluding remarks. The seven papers listed below are included as appendices.

The papers from which the contributions are drawn are as follows (arranged according to year of publication):

1. Shaw, V. (2003). The Development of an Information System for District Hospitals. In S. Krishna & S. Madon (Eds.), *The Digital Challenge: Information Technology in the Development Context*: Ashgate.
2. Shaw, V. (2005). Health information system reform in South Africa: developing an essential data set. *Bulletin of the World Health Organization, 2005*(83), 632 - 639.
3. Jacucci, E., Shaw, V., & Braa, J. (2006). Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability. *Information Technology for Development, 12*(3), 225-239.
4. Braa, J., O. Hanseth, et al. (2007). "Developing Health Information Systems in Developing Countries - the flexible standards strategy." MIS Quarterly **31**(2): 381-402.
5. Shaw, V. (2007, 9 - 12 January 2007). *Considering the Options for Hospital Management Information Systems.* Paper presented at the Helena 12th E-Health Conference, 2007, Bamako, Mali.
6. Shaw, V., Mengiste, S., & Braa, J. (2007). *Scaling of health information systems in Nigeria and Ethiopia - Considering the options.* Paper presented at the IFIP 9.4, Sao Paulo, Brazil.

7. Shaw, V. and J. Braa (Forthcoming). "Developed in the South" - an evolutionary and prototyping approach to developing scalable and sustainable health information systems. Development Informatics and Regional Information Technologies: Theory, Practice and the Digital Divide. J. Steyn, IGI Global. Vol 3: ICT's for Development in Africa: Theory, Practice and the Digital Divide.

Chapter 1. INTRODUCTION:

1.1. Background:

As a result of globalization, and complex interactions between political, technical, economic and cultural forces, there is an increasing rate and scale of changes taking place globally with significant implications on local processes. These effects have elicited comments that “many of us feel in the grip of forces over which we have no control” (Giddens 1999, p. 6). However, organizational theorists are suggesting that by changing the way in which we view the world and our institutions, we can try to manage our “runaway world” (Anderson 1999; Lewin, Long et al. 1999). The shift in thinking on how organizations and society are viewed, from an ordered reductionist view to one which acknowledges the all pervasive complexity of life and existence (Urry 2005a; Urry 2005b) has strengthened since the 1990’s. Complexity science provides an understanding to the balance that exists between order and disorder, especially within social phenomena, and how being at “the edge of chaos” can potentially also stimulate creativity and innovation (Eoyang 1996).

While concepts from complexity science concepts have not been explicitly applied in the analysis of health information systems (HIS) in the context of hospitals, they potentially provide a rich avenue to do this. Hospitals are comprised of a rich mixture of different types of health care providers and managers, interacting with each other in complex ways in order to provide a multiplicity of patient care. But they are also part of a larger organizational framework of other health services provided locally, nationally, and globally. They are thus connected and inter-connected in many ways, reflecting political, cultural and organizational and technological influences. As hospitals respond to these dynamics, they arguably reflect strong characteristics of self-organizing complex networked organizations.

A specific arena of such self-organizing tendencies, we argue, are reflected in hospital IS which extends beyond the hospital itself. For instance, since the post-apartheid period in South Africa, equitable resource allocation has been a prominent component of the health reform agenda. Not only do resources need to be equitably distributed between former homeland and “white areas”, but the hospicentric health services of the apartheid era have to be transformed and oriented towards a the primary health care (PHC) approach (Health Systems Trust 1996; Wamukuo and Ntutela 2002). Similarly, in other developing country contexts, hospitals may consume up to 80% of the health services budgets (Wamukuo and

Ntutela 2002; Vander Plaetse, Hlatiwayo et al. 2005). Improving efficiency, and saving even 10% of the hospital expenditure can increase the allocation of funds available to PHC services by 50% (Newbrander, Barnum et al. 1993; Montoya-Aguilar 1994; Burn and Shongwe 2003). However, bringing about such transformations is a radical exercise, and requires addressing various interconnected influences, both within the hospital and external to it within the district and larger health system.

Designing, developing and implementing hospital information systems are invariably also influenced by deeply rooted political and technical networks. For instance, the factors that complicate design of hospital information systems relate to the organizational complexities of the hospital context (Lundberg and Tellioglu 1999; Hanseth and Lundberg 2001), the inability to agree on common standards for communication between sub-systems (Hanseth, Jacucci et al. 2006), and the difficulty of achieving a balance between loose and tight integration of sub-systems (Monteiro 2003). Implementation is complicated by the politics involved in the negotiation process around hospital information systems, including the pressure to “go big” and adopt global solutions (Ellingsen and Monteiro 2003). In addition, in developing countries, infrastructural problems such as inadequate power supply and inappropriate environments for computers contribute to failures in information system (IS) implementations (Littlejohns, Wyatt et al. 2003),.

Given this context, in the next section I explore the aims of the research, and the rationale for the research questions. In this section I define a number of terms that are used frequently in this thesis to help, explore my conceptualization of hospital management information systems (HospMIS) in greater detail. Section three presents the motivation for undertaking this research, and section four presents the theoretical perspective. Section five describes the research setting and approach, and section six the positioning of the research in the IS research domain. In section seven I discuss the expected contributions from this research, and section eight presents the structure of the remainder of the thesis.

1.2. Thesis aims and research questions:

This thesis aims to develop complexity inspired conceptual models to understand the design, development and implementation of sustainable and scalable hospital management IS in resource constrained contexts, and which take into consideration the

Text Box 1: Research Questions

1. Given the complex nature of the hospital environment, what are the socio-technical considerations that contribute to the design of sustainable and scalable hospital management information systems in resource constrained settings?
2. How can the implementation process be designed to accommodate unexpected contradictions that arise between the different realities of original intent and changing needs in the implementation process?

complexities of the hospital environment. In order to address the research aim, two research questions have been posed (see Text Box 1).

In order to address the research questions, five research objectives have been identified:

1. Describe the complexities of the environment which influence hospital management information systems design, development and implementation in resource constrained settings[1];
2. Given the complexities of the hospital environment, conduct research and develop theoretical and practical insights related to the design of hospital management information systems that takes into account the socio-technical resource levels that exist in developing countries;

---

[1] I use the term resource constrained settings in preference to "developing countries" for two reasons. Firstly, both "developing countries" and "developed countries" are terms that are all-encompassing and which suggest a homogeneity that seldom exists in reality. For instance, some developing countries have areas within them that resemble closely "developed country" contexts, and similarly, many developed countries have areas within their boundaries that resemble "developing country" contexts. For this reason, I prefer to use the term "resource constrained settings" to describe environments which are similar to the typical of "developing country" contexts in that the challenges relate particularly to uneven access to infrastructure, staff and other resource shortages (for example financial constraints), as well as the "typical" organizational and bureaucratic patterns found in so-called "developing countries". Secondly, as highlighted by Dr Hans Rosling during his presentation at the Global Health Council Conference in Washington on 28 May 2009 (see http://www.globalhealth.org/conference/view_top.php3?id=965), many world wide initiatives (e.g. MDG's) are setting targets for "developing countries" that have not ever been achieved in "developed countries" despite access to significant resources. In many cases, so-called "developing countries" are making improvements at a more rapid pace than any "developed country" has ever achieved. The allocation of countries to a pool of "developed" versus developing is thus somewhat arbitrary.

3. Develop theoretical and practical insights into the successful implementation of hospital management information systems that accommodate unexpected contradictions that arise between the different realities of original intent and changing needs in the implementation process;
4. Conduct research into the scaling of hospital management information systems, especially which aspects of IS development are universally scalable, and which require local customization; and
5. Suggest ways in which the design and implementation strategies described will contribute to sustainable HIS development in resource constrained contexts;

Before exploring the rationale behind the research questions and HospMIS in greater detail, the use of a number of terms need to be clarified in the context of the research aim of the “design, development, and implementation” of HospMIS. “Design” is used in the sense that it represents an “intentional future” (Heeks 2006, p. 128) and is used in its broadest sense to refer to not only the design of software or hardware dimensions of a HIS, but also other dimensions such as the implementation processes, the objectives and values embedded in the system, the staffing and skills required to manage the system, management structures and other support systems and other resources that the IS requires (Heeks 2006). The term “development” is used in the manner suggested by (ibid) whereby as a system is implemented and used, it requires ongoing “accommodation and adaptation” (ibid, p. 133) in response to the difference between the design of the system, and the (often messy) reality on the ground. Development of the IS impacts on all the dimensions of the HIS mentioned above. “Implementation” is used to suggest the processes associated with the installation, and use of the IS, and by its nature then implies ongoing design and development processes as well. I use the term “HIS” to include all types of HIS such as, PHC information systems, and hospital information systems including electronic patient record systems and HospMIS (HospMIS are defined in the next section). Where I use the term hospital information system it is used as a generic term for a variety of IS used in hospitals (see below) including HospMIS. While the focus of this thesis is on HospMIS, I draw on my experience in working with PHC based IS in a variety of contexts to develop concepts that are then applied to the hospital setting, and vice versa.

In the next two sub-sections, I explore the rationale behind the research questions.

1.2.1. The Challenge in Designing Hospital Management Information Systems:

Hospital information systems have been described from various viewpoints. For instance, one description suggests that hospital information systems must fit together three pieces of a puzzle, namely clinical work, the organization that supports the clinical work, and the information and communication technologies (ICT's) that are used to manage information (Aarts, Peel et al. 1998). This is a useful description because it immediately identifies three important aspects of a hospital information system, and implies intricate linkages between thee aspects. But, the puzzle is seldom as simple as this. In any hospital, multiple IS exist often independently of one another, including financial, human resources, patient administration and billing, and electronic patient IS (see Figure 1), and each has its own set of components and stakeholders. The process of designing, developing and implementing HospMIS must take these systems, and their associated networks into consideration.

Before exploring the design challenges in greater detail, HospMIS are defined. In this thesis, a HospMIS is defined as a socio-technical system that collates and integrates data from different sources (wards, out-patients, pharmacy, accounting departments, etc), so that reports can be produced for clinicians, managers and administrators to enable them to manage the hospital, the services it provides, and to allocate resources appropriately. The HospMIS is conceptually a data warehouse that integrates data from multiple sources, and also reflects and supports the various practices around the registration, processing, analysis and use of data. For example, the HospMIS should indicate which departments are experiencing busy workloads, and whether sufficient staff have been allocated to these departments. Figure 1 provides a visualization of the roles different groups of IS play in a HospMIS. Group 1 refers to the information that is linked to a patient, and includes demographic data. This data is usually captured during the course of a patient attending the hospital (either as an in-patient or an out-patient) and at the time of registration. They include diagnostic and procedural details, as well as outcome (admission, discharge, death, etc) of the interaction/s. This group is what has been referred to as "throughput information" and typically is the basic data that is needed to manage a hospital. This is the minimum essential data that is needed by management.

Group 2 includes the types of systems that are used in clinical departments, and those of the support services (radiography), etc. They are usually more specialized systems, and capture detailed data related to the clinical care process. Some authors refer to these systems as electronic patient records (EPR's) (see for instance Ellingsen and Monteiro 2003), or electronic medical record (EMR) (see for instance Seebregts, Mamlin et al. 2009) while others refer to patent care information systems (PCIS) (see for instance Berg 1999; Berg 2001). While not delving into the detailed definitions of each of these, it is important to recognize that a HospMIS should contain data from any of these specialized IS in order to provide managers with aggregated (annonomized) data for managing a range of services.

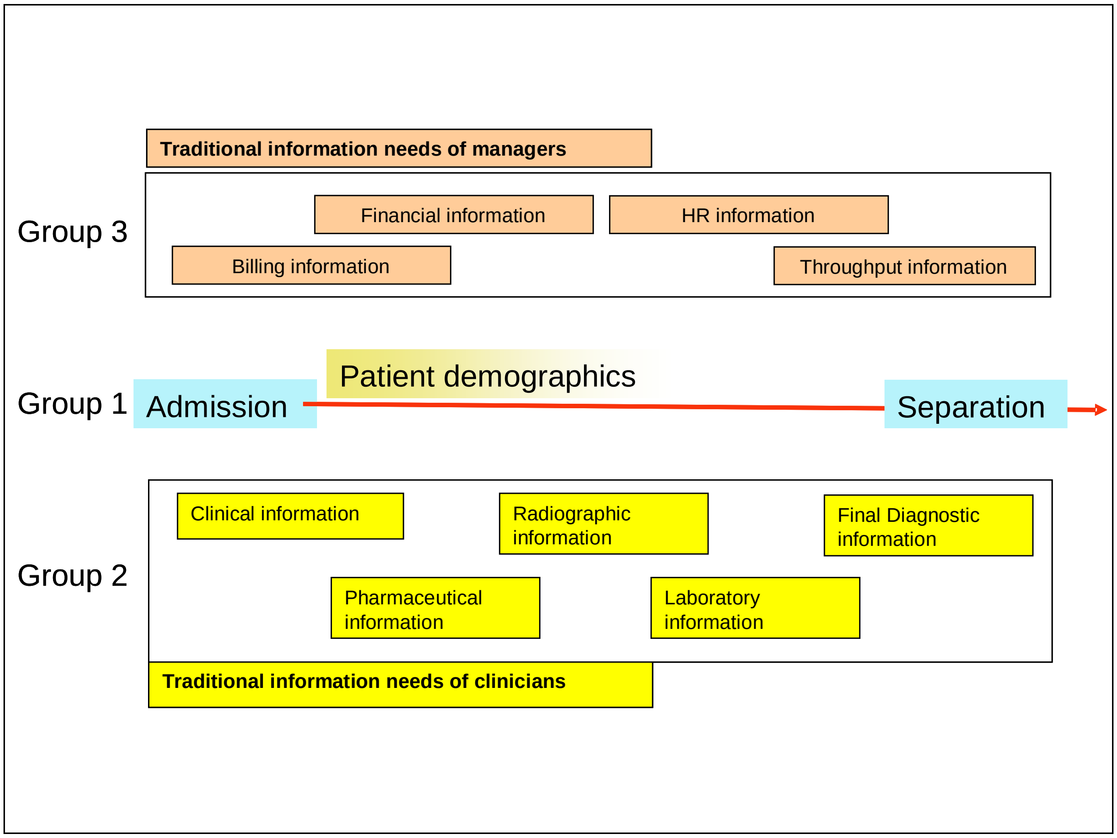


Figure 1: Information systems contributing to a HospMIS

(Source Shaw 2007)

Group 3 is often the group that incorporates the legacy systems, having been initiated by managers long before clinicians became interested in computers. It is important to note that in developing countries, the specialized systems in this group, although often electronic, are not accessible in the periphery, requiring a reliance on paper based systems to compliment the electronic system.

From a technical point of view, the challenge for HospMIS design is twofold. Firstly, the heterogeneous (the problem of integrating different software systems), and semantic (the different systems may not use the same naming conventions) requiring interoperabilities to be addressed. Each of these challenges are discussed in more detail below.

Addressing semantic interoperabilities is not a simple task, especially given the use of different systems in different hospitals (for instance, in South Africa there are at least three different financial IS that should feed into a HospMIS, and none of these use the same facility codes as those used by the human resource IS). This means that there is no single solution that can be used for all hospitals. Given the differences between hospitals, the implication is that some interfaces will need to be effected on-site, and will have to develop locally appropriate solutions for the local systems in use.

Transferring data between heterogeneous systems, even if semantic interoperabilities are addressed is equally challenging (see for instance Berndt, Hevner et al. 2003). In resource constrained settings, effecting the transfer of data between systems is complicated further by the shortage of skilled staff, the difficulty in accessing existing legacy systems that are centralized and not always accessible on the internet, and infrastructural difficulties such as unreliable power supplies and infrequent access to transport (for an example of these difficulties see Text Box 2). A review of various reports from developing countries (Montoya-Aguilar 1994; Wamukuo and Ntutela 2002; Bossert, Chitah et al. 2003; Vander Plaetse, Hlatiwayo et al. 2005) show that when specific information is needed, for example cost of care provision in hospitals, a variety of databases, at different levels within the health hierarchy need to be accessed, and the data from these sources manually integrated.

Text box 2: Interoperabilities as a frequent reality

"…because the interface between Oasis and Nootrooclin either does not exist, or staff do not know how to use it, or it is not working, patient demographic data has to be entered twice – on Oasis for ward management and on Nootrooclin for billing... This result in the Northern Cape Department of Health's Information system comprising of two separate non-interfaced software pieces instead of one solution with sub-modules. This is totally contrary to the National standard." (Hunter, De Jongh et al. 2002, Page 7).

But the challenges are not restricted to these interoperabilities alone. Interoperabilities are exacerbated by frequent changes in one system that connects with others. Thus for instance, during the intense reform that characterized the post-apartheid period in South Africa, health facilities were re-allocated to different local government authorities numerous times as new boundaries were formed, disputed and re-adjusted. This caused disruptions to the structure of organizational hierarchies, and with these changes, staffing and budgetary adjustments had to be mirrored in parallel human resource and financial IS. In addition to these structural changes, changes in health care provision have been precipitated by the advancing HIV/AIDS pandemic and accordingly, IS have had to be adjusted to accommodate new reporting requirements. Because hospital information systems have traditionally been designed as rigid, encoded systems, they have been unable to accommodate these kinds of changes. Driven by the need to justify expenditures, and defend service targets, donors and other agencies have then developed additional IS that operate in parallel to established systems, resulting in duplication of efforts and fragmentation of information (Monteiro 2003; Chilundo 2004).

The challenge for the design of HospMIS in resource constrained settings is to identify appropriate solutions to address both semantic and heterogeneous interoperabilities, as well as to design and develop systems that are flexible so as to be able to accommodate the frequent changes that characterize these environments. These are the challenges that are at the core of the first research question, namely to identify the socio-technical considerations that would contribute to the design of sustainable and scalable HospMIS in resource constrained settings. In this thesis, I define sustainability as "…an information system [that] work[s], in practice, over time, in a local setting. This involves shaping and adapting the systems to a given context, cultivating local learning processes, and institutionalizing routines of use that persist over time (as well as when the researchers leave and external funding is over)…" (Braa, Monteiro et al. 2004, p. 338). Scalability is defined as "…make[ing] one working solution spread to other sites, and be successfully adapted there. Beyond merely the technical aspects of scalability, our concerns lie in how to reproduce and translate the necessary learning processes alongside the spreading of artifacts, funding, and people." (Braa, Monteiro et al. 2004, p. 338)

1.2.2. The Challenge of the Implementation Process

But even if appropriate technical solutions are identified, these cannot be implemented and institutionalized without an appropriate processes that involves stakeholders and takes into consideration the networks and alliances that both complicate and support hospital information systems development. The second research question is focused on these issues, namely the implementation process. While the design is challenging, the implementation is even more so given the shortage of staff in resource constrained settings, the absence of sophisticated information implementation skills, and the broad range of implementation problems. Typically, many design-reality gaps exist across all dimensions of the IS (Heeks 2006). For example, technical problems such the difficulties associated with the negotiating standards (Berg and Goorman 1999; Hanseth, Jacucci et al. 2006) are not confined to well resourced settings. While most descriptions focus on the rigidity of standards, and the difficulty in achieving agreement on them, the reality is that securing agreement on common standards is a time consuming process (see for instance Berg and Goorman 1999), and must often be negotiated at a local level. The process of negotiating agreement is complicated, and requires a mix of skills that are often not readily available in resource constrained settings. The challenge of implementation is therefore firstly to access a team of people experienced enough to overcome the broad range of implementation problems described, and failing this, implementation must also seek ways in which skills transfer can be effected so that appropriate capacity can be developed in support of the system. A double agenda must therefore be pursued, to not only support the implementation process, but also a training and learning process must be superimposed on the implementation process. The aim in this thesis is to explore innovative ways in which these challenges can be addressed.

1.3. Research Motivation

Motivation for this research comes from numerous quarters. From a professional perspective as a clinician, hospitals are important role providers of key services (such as caesarian sections for instance) within the district health system. The HospMIS plays a central role not only in documenting the workload and resource allocations to hospitals, but also in improving the quality of care (Williams 1999; Committee on Quality Health Care in America 2001; AbouZahr and Boerma 2005; Shibuya, Scheele et al. 2005). Yet, hospital information systems are notorious in their inability to provide managers with reliable information (Herbst, Littlejohns et al. 1999; Heeks 2002; Littlejohns, Wyatt et al. 2003). While the literature points out the need for efficient hospital information systems (Hospital Advisory Group 1994; Montoya-Aguilar 1994; Wyatt 1995; Herbst, Littlejohns et al. 1999), there are very few articles describing design and implementation strategies for HospMIS in resource constrained countries. Rather, the literature emphasizes the development of electronic patient records, with scant attention being paid to the extraction of data from these systems for the use by managers at all levels.

A second motivation is related to the debate around balancing health service delivery and resource allocation within the health district between hospitals and PHC facilities (Van

Lerberghe and Lafort 1990; Vander Plaetse, Hlatiwayo et al. 2005). In 1978 the Alma Ata Declaration recognized the disparities in health status between the developed and developing worlds, and advocated greater community involvement in the development of health programs as a mechanism to improve access to health services (Alma Ata Conference 1978). One of the results of the Alma Ata Declaration was a shift in the emphasis of health services from hospi-centric care to a PHC approach through the district health system (Gorgen, Kirsch-Wolk et al. 2004). The role of the hospital in the district health system was redefined as a partner within the PHC team (Van Lerberghe and Lafort 1990; Montoya-Aguilar 1994). Despite the shift in emphasis, in many developing countries hospitals continue to consume inappropriately large proportions of district budgets. Shifts in resource allocations can only be effected if HIS are able to provide reliable information on who needs resources most and for what purpose.

A third motivation concerns the notions of decentralization of health services whose aim is to also devolve decision making power and authority. As a (former) manager of health services, I needed information to be an effective manager, and to be able to exercise my power and authority judiciously, yet, found that the systems I had access to did not address my needs.

Lastly, there is increasing recognition internationally that HIS in developing countries provide unreliable data (Godlee, Pakenham-Walsh et al. 2004; Boerma, Bos et al. 2008), and this hampers efforts not only for sector wide approaches (SWAp) to funding health systems, but also for monitoring progress towards Millennium Development Goals (MDG’s), and health system performance (Cassels and Janovsky 1998; GAVI Alliance 2005). As a result, there is significant focus of efforts to improve HIS in resource constrained settings (World Health Organisation 2003; AbouZahr and Boerma 2005; Boerma 2005; Boerma, Bos et al. 2008).

1.4. Theoretical Perspective

Both the organizational science and IS literature have argued that traditional views of the world are insufficient to accommodate a rapidly changing environment that characterises the “network” society (Castells 2000; Walsham 2001; Avgerou 2002). In particular, characteristics like rapid change, non-linear effects and unpredictable long-term requirements require approaches that are different to ones that assume stability and order (Anderson 1999; Merali and McKelvey 2006). Complexity science has been used to understand more broadly the processes of change in organizations since the 1990’s (Dooley 1997; Anderson, Meyer et al. 1999; Urry 2005a), and since the 2000s is increasingly being used also to guide IS implementation (Jacucci, Hanseth et al. 2006).

Information systems design, development and implementation are particularly appropriate to analyze using concepts from complexity science as they are increasingly shaped by complex conditions such as the rapidly increasing rates of technical, organizational and societal changes and their interconnectedness. Contributing to these dynamics is the faster and different rates and modes of communication, which require organizations to be more responsive by "learning quickly and reconfiguring flexibly" (Jacucci, Hanseth et al. 2006, page 5). Communication and societal networks span countries and continents, contributing to standardization, referred to as the McDonaldization of products and practices, yet they maintain their diversity and lead to new practices (Urry 2005) due to processes of local adaptation. Even within standardized networks, communication occurs in unexpected ways and through unpredictable passages. These can be described as the dynamics within self-organizing networks where change evolves, and adaptation to the environment occurs through positive and negative feedback loops (Urry 2005).

Although complexity based research "is not yet prominent in the IS field" (Jacucci, Hanseth et al. 2006, page 6), it is increasingly important from a number of perspectives. From a technical perspective, complexity has increased due to the increased power in computing, the increased number of systems and applications, and the increased inter-connectivity over large distances, all of which have an impact on the scale of systems. From an organizational perspective, organizations are having to rethink their structural and operational systems in order to respond to rapidly changing markets and workforce skills, and their ability to "learn quickly and reconfigure flexibly" (ibid, page 5)). From a societal perspective, complexity has increased due to increased globalization and networking that have resulted in the breakdown of boundaries and "local actions (that) propagate to a global level with unintended side-effects" (ibid, page 6).

There is increasing evidence of attempts to address various aspects of complexity in IS design and development (Eoyang 1996; Xia and Lee 2004). For instance, Alaa and Fitzgerald (2004) suggest that rigid software development methods should be replaced by methods that are able to respond to the rapidly changing needs of users in a timely fashion through self-organization and local control. Highsmith III (2000) suggests that rather than the traditional software development processes (like the waterfall technique), "adaptive development" techniques allow software developers to create expertise in complex and challenging environments through iterative cycles of learning and implementation. Co-evolutionary processes are advocated for aligning business and information strategies precisely because information needs change rapidly, and as a result, alignment is never a steady state – it emerges as business needs change and as opportunities for ISD become apparent (Benbya and McKelvey 2006b)

Recognising the close association between IS and organizational processes (Avgerou 2008), it is no surprise to find that the organizational science literature too has been calling for different approaches to understanding organizational change (McKelvey 1997; Lewin 1999; Volberda and Lewin 2003). Companies are facing significant environmental changes as the result of “discontinuities created by an interdependent global economy, heightened volatility, hyper-competition, demographic changes, knowledge based competition and demassification of some sectors accompanied by enormous growth in others” (Daft and Lewin 1993, p. i). In an attempt to theoretically understand such change processes, chaos and complexity theory are being applied to the study of organizations (Stacey 1995; Dooley 1997; Lewin 1999; Seel 1999). McKelvey (1997) argues for a quasi-natural based alternative epistemology which operates at the intersection between intentionality and naturally occurring behaviour, and it is argued that perspectives grounded in complex adaptive system (CAS) are better positioned to explain organizational dynamics that are neither regular nor constant (Dooley 1997). For instance, concepts from complexity theory help explain non-linear interactions within and between organizations (Anderson 1999), and feedback loops and innovation can be used to manage software development processes for IS characterised by frequent change and unexpected requirements (Eoyang 1996).

The CAS perspective also resonates with my medical background wherein the focus is often on understanding the relationship of the body with its environment, often using rules from nature and science (Gell-Mann 1995; Capra 2005). Positive and negative feedback loops are responsible for continually effecting adjustments to change, and explain actions and reactions to stimuli. In medicine, as in CAS, there is limited control over complex situations (Dooley 1997). CAS emphasise the value of decentralised control (which is a fundamental principle in district health systems) (Simon 1962; Waldrop 1992), and most interestingly, it moves from the concept of static to dynamic equilibrium (Waldrop 1992). In particular, CAS theory provides insights into two important challenges that characterise IS development in resource constrained settings. Firstly, CAS provide an understanding as to why situations might change rapidly and as a result of what are often considered insignificant factors or stimuli, representing “non-linear effects” of small changes (Gleick 1993, pp 23-24). Secondly, the CAS literature provides some insights into reasons for the lack of central control over IS development, and the associated indeterminism that accompanies the lack of control and non-linearity of interactions.

In summary, complexity based science provides an alternative perspective with which to explore environments characterised by rapid change, non-linear effects and uncertain futures. Increased access to ICT's has improved communication and networks and globalisation, and as a result complexity has increased technically, organizationally, and from societal perspectives. These changes demand different perspectives for viewing organizational change and IS development.

1.5. Research setting and approach:

The research reported in this thesis is based on a longitudinal case study analysis conducted within the ongoing, large-scale, multi-country Health Information Systems Program (HISP) research project. The empirical data has been gathered over a 10 year period from my research in South Africa, Malawi, Nigeria, and Zambia in the design, development and implementation of hospital and PHC information systems in the public health sector of these countries. The research described in this thesis falls within the interpretive research tradition described by Walsham (1993; 1995).

The core of the research is an action research project conducted by the Health Information Systems Program in South Africa (HISP-SA), in 13 hospitals in the Eastern Cape Province (ECP) of South Africa. The research spanned a range of hospitals of different sizes (from 100 beds to 1500 beds), different service types (tertiary level super-specialist services to district level services and psychiatric care), and in rural and urban locations. The ECP has a population of 7.1 million with 65% living in rural areas. The conditions are similar to those found in other "developing country" contexts. The unemployment rate for the province is 55% (but in some areas it is as high as 77%), and 8% of people live in informal housing "…, reflecting traditional unserviced sites. Only 7% of households have potable water on site and 47% have a flush toilet or pit latrine, reflecting major social backlogs" (Eastern Cape Development Corporation 2005). Hospitals in this province reflect the infrastructural backlogs, and the disparities that are found in many other resource constrained settings. Access to computers and internet are uneven[2].

The first part of the research was conducted while I was still employed in the Eastern Cape Department of Health (ECDoH), and working in Queenstown as a clinician (from 1992), and

[2] Uneven is used in the sense that the diffusion of a technology often does not happen uniformly and according to priority needs, but is often a haphazard and unequal distribution reflecting the active social and political networks.

later in Bisho (the administrative capital of the province) as a Manager of Hospitals for the ECP (from 1998). The balance of the research has been conducted through my association with HISP-SA in a number of countries. In Northern Nigeria the focus has been on strengthening HIS in both PHC and hospitals settings and where I have been involved since 2003. In Malawi the research has been focused on the design, development, and implementation of a HospMIS for the two biggest hospitals in the country located in Lilongwe and Blantyre. This research spanned a 2 year period from December 2003 onwards. In Zambia the focus has been the revision of the national PHC information system to address DART principles (namely a HIS that is Decentralized, Action Orientated, Responsive, and Transparent) and my involvement has been since 2007.

Being involved in the global HISP research program has provided an exposure that is unique in many respects. Firstly, because of the network that this organization represents, participants are exposed to a wide range of ideas related to HISD in a wide variety of contexts (see for instance (Braa, Monteiro et al. 2004)). Secondly, particularly because of its association with academia, students, and teaching, and writing, concepts related to ISD are constantly being challenged and tested, new ideas introduced, while others are adjusted and evolved as the network gains experience and exposure in different settings. Thirdly, the focus of the network on HISD in resource constrained settings has gradually emerged into a niche resource. The network is valuable in the effect it is having on improving the lives of underprivileged people in resource constrained settings, and exciting in that the ICT world is evolving rapidly and thereby constantly providing new opportunities to be explored. Fourthly, the network has pioneered the dispersed development of free and open source software (FOSS) for use in HIS and has provided many different examples of ways in which the software is developed, and appropriated in different countries.

While membership within the HISP network provides unique opportunities, the network itself has evolved over the period of this research from being a pilot project in South Africa (Braa and Hedberg 2002) to an association of independent organizations (such as HISP-SA, HISP-India and University of Oslo Institute for Informatics) that together seek to strengthen country health services through two main strategies. Firstly, through capacity building for health staff at all levels of the health system through informal training programs and formalized professional masters and doctoral programs in HIS. Secondly, through sharing of HIS best practices across countries and continents. Being part of this process, and reflecting on the changing role of the network has provided unique insights into sustainable health information systems design, development and implementation (HISD).

1.6. Positioning the research:

This thesis is located within the field of research into IS, and the social, organizational and technical implications of the use of technology. It contributes to IS research in developing country contexts and specifically to IS development in the health sector. Drawing on Avgerou's (2008) analysis of the discourses existing in the domain of IS implementation in developing countries, I would argue that this research contributes to two discourses of socially embedded action and the transformative techno-organization. The former is characterised by the construction of new techno-organizational structures within local contexts and understanding local meanings and appropriate approaches. The research contributes to this discourse in that it seeks to identify locally appropriate practices and models, rather than the adoption and local application of "western" models. The latter is associated with opportunities to improve socio-economic conditions locally as well as the use of IS innovation to leverage on large scale socio-economic change. The contribution of this research to this discourse arises from the history of large scale socio-economic change that has characterised the post-apartheid era in South Africa, and the strong desire to not adopt Western practices unquestioningly but to rather be circumspect about developing locally appropriate solutions (Mandela 2003). This research also explores the use of FOSS developed in the "south" and its use in the health sector as a tool for empowering health workers at the "local level"[3]. This research is a contribution to the "dissensus" discourse (Avgerou 2008) in the sense that the focus is on resource constrained settings in the "south", utilises FOSS which is locally developed (and rivalled by Western alternatives) and seeks to empower those who in the health sector are traditionally at the bottom of the hierarchy.

1.7. Expected contributions

In this thesis, my empirical and theoretical focus is on HospMIS. However, I expect that some of the theoretical concepts and practical insights will be able to be generalised to their application in HIS and IS in general.

---

[3] The HISP-SA vision is articulated as the "Development and implementation of sustainable and integrated health information systems that empower communities, health workers and decision makers to improve the coverage, quality and efficiency of health services" (see http://www.hisp.org/).

Besides making a theoretical contribution through the use of complexity science as a lens with which to view HospMIS design, development and implementation (HospMISD), I expect that this thesis will provide complexity inspired theoretical insights into the design, development and implementation of HospMIS in resource constrained settings that are characterised by rapid changes, non-linear effects and unpredictable long term requirements. I anticipate insights into sustainable HospMIS development, and by implication, systems that will be scalable as well. In particular, insights should be provided for sustainable development of human resource capacity in contexts where staff shortages exist and skills levels are basic.

The research has the potential to provide rich insights into the context of HospMIS and health IS in DC, and as such to make a contribution to the ISDC discourse. The research also aims to utilise a multi-level analysis to address a number of other research priorities related to ISDC discourse. For instance, by virtue of having conducted research across many countries within the HISP network, opportunities are provided to explore cross-cultural IS implementation (Walsham, Symons et al. 1988; Walsham and Sahay 2006), not only between different cultures in different countries, but also between different professional groupings that represent different cultures (for instance health workers like doctors and nurses and professional software developers), and between different cultures represented by different organizations (for example HISP-SA and government bureaucracies).

Because the research spans a ten year period it potentially provides insights into the development of sustainable and scalable HIS in resource constrained settings. The thesis seeks to explore ways in which the “digital divide” can be reduced through sustainable approaches which see health IS development as a gradual developmental process.

1.8. Structure of thesis

The remainder of this thesis is structured as follows. Chapter two provides a review of the relevant literature, and following this a theoretical framework is suggested. Chapter three provides an overview of the research approach and method and a detailed description of the fieldwork. The chapter concludes with a reflection on data analysis, the use of theory, and validity of my findings. In chapter four I present my findings by summarizing each of the seven papers that contribute to this thesis, and then synthesize the findings. Chapter five presents the theoretical and practical contributions developed in this thesis. The final chapter presents concluding remarks, and future research directions.

Chapter 2. THEORY AND RELATED RESEARCH:

"The central task of natural science is to make the wonderful commonplace: to show that complexity, correctly viewed, is only a mask for simplicity; to find pattern hidden in apparent chaos." (Simon 1969)

2.1. Introduction:

The aim of this thesis is to provide theoretical and practical insights into the design of sustainable and scalable HospMIS in resource constrained contexts that take into consideration the complexities of the hospital environment. In particular, the challenge in these contexts is to accommodate the unexpected contradictions that arise between the different realities of original intent and changing needs of the IS design, development and implementation process. To address this I develop a theoretical framework with which to understand the design and implementation processes of HospMIS. I do this by drawing on three main concepts from CAS theory. They are firstly the non-linear effects that characterize CAS (Gleick 1987; Anderson 1999), secondly the ability of CAS to create self-organizing networks that display emergent behavior (Dooley 1997; Merali and McKelvey 2006), and thirdly the ability of CAS to co-evolve at a state "far from equilibrium" (Stacey 1995; Plsek and Greenhalgh 2001). These lay the foundations for interpreting the empirical component of this thesis, and the development of theoretical and practical contributions.

This chapter is structured as follows. In the next section, I review the literature to provide an overview of complexity theory as it relates to organizational science and the IS literature. Section three describes four features of CAS's, and in section four I use these concepts to develop a theoretical framework with which to understand HospMISD. In section five I summarise my theoretical perspective, and apply the framework to a failed hospital implementation in a resource constrained setting. I use this to highlight areas requiring further research, and which will be addressed in this thesis.

2.2. An Overview of Complexity Theory:

Complexity theory is a highly multi- and inter-disciplinary field, having emerged from a number of different fields of study (for example cybernetics and systems theory, and as shown in Figure 2). Definitions of complexity theory therefore differ, and usually reflect the field from which complexity is explored. In the next section, some definitions of complexity theory and CAS's are provided, drawing largely from the organizational science body of literature. Chaos theory is also briefly discussed because it is an important field within complexity theory and helps to analyze more deeply the concepts of non-linearity and "attractors".

2.2.1. Defining Complexity Theory and related fields of study:

A complex system as one that is made up of a large number of parts that have many interactions (Simon 1969). Daft (1992) describes three dimensions of complexity in organizations. The vertical dimension consisting of the number of activities or subsystems within the organization (hierarchies), the horizontal dimension reflecting the number of job titles, or departments in the organization, and the spatial dimension or the number of geographical locations in which the organization operates. These dimensions are relevant in a hospital environment where the hierarchy is significant even in small hospitals. Besides a general hierarchy consisting of senior management, departmental heads, and workers within each unit, there is a professional hierarchy such as between the doctors and nurses. Across the horizontal axis are a wide variety of departments such as maternity, paediatrics, surgery, but also financial, administrative, pharmaceutical, and transport, and each with their own hierarchies.

Fontana (1999) suggests that complex systems "are typically organizations made of many heterogeneous parts interacting locally in the absence of a centralised pacemaker and control" (pg 14). This is also a useful definition for viewing hospitals and health services which typically have decentralised control, and where for instance in a casualty department or a theatre, the team will act locally in response to individual observations of critical patient parameters, the actions of others, and in accordance with prescribed roles, behaviours and procedures. While hospitals may be decentralized in terms of performing their professional

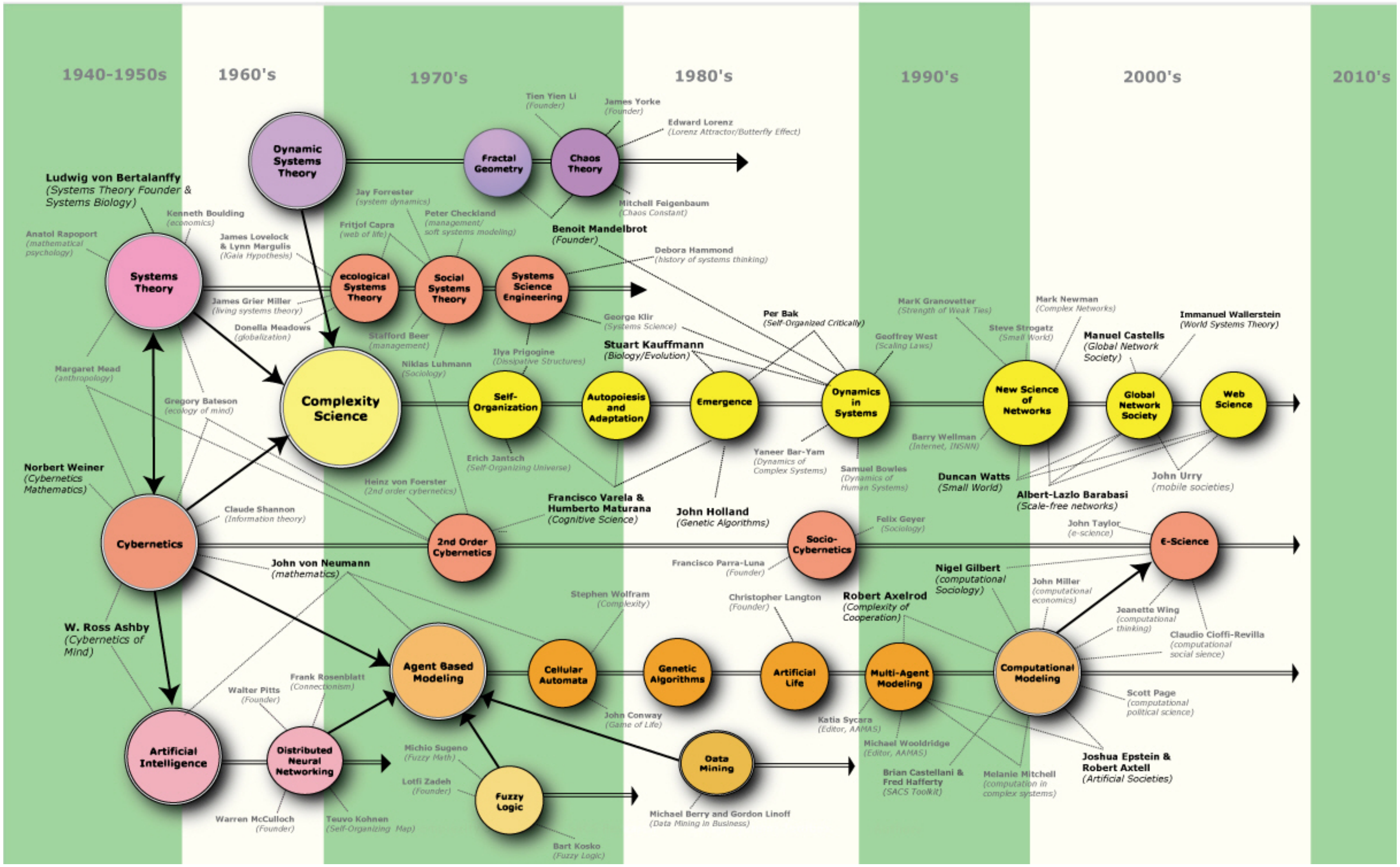


Figure 2: The origins of complexity science from a diverse range of fields (Source Wikipedia 2009)

roles, in the public sector they are generally not administratively decentralized, and this limits their ability to act independently.

Within the broad range of organizational theorists, there is a group that suggest that complexity theory is the study of CAS's (McKelvey 1997; McKelvey 1999b; Begun, Zimmerman et al. 2003). CAS's are defined by Axelrod and Cohen (1999) as systems populated by agents that seek to adapt to their environment. They highlight that the adaptation process does not only result in improvements, and that it may be only a part of the system that adapts, not necessarily the whole system. The notion of CAS has its origins in the study of biological systems (Gell-Mann 1995), and on their ability to self-organize and co-evolve (Dooley 1997; Benbya and McKelvey 2006a). CAS theory allows a holistic assessment of an organization that is both self-organizing and learning through a process of interaction with their environment. These systems demonstrate 'emergent' properties, as adaptations result in the emergence of new phenomena, although in unpredictable and non-linear ways (Holland 1995; Urry 2005b). Axelrod and Cohen (1999) describe emergent properties as those in the system that separate parts do not have – thus for instance a neuron does not have consciousness, yet the brain does have consciousness. Begun (2003), who describes health systems as CAS, suggests that complexity science is about *"indeterminism rather than determinism, variation rather than averages, and local control rather than global control"* (page 259).

Complexity science thus deals with systems composed of many interacting agents, in which behaviour may be hard to predict, but which can still have some structure (Axelrod and Cohen 1999). Within the broad field of CAS there is also a field of study related to systems that display turbulence, and which become rapidly disorderly and unmanageable. This is the filed of chaos theory. The existence of this field is highlighted because within what appears to be chaos, patterns begin to emerge around "attractors". The nature of the patterns vary depending on the initial conditions, and thus "unpredictable yet patterned results can be generated, with small causes on occasions producing large effects and vice versa…" (Urry 2005b). Importantly, while two similar systems may start off with very similar conditions, small changes can produce very different effects, highlighting the indeterminacy of outcomes – an aspect that is explored more deeply in relation to the empirical data. Thus, while all chaotic systems are CAS's, not all CAS's are chaotic (Eoyang and Berkas 1998).

2.2.2. A Brief History of Complexity Theory:

A brief summary of the history of complexity theory is presented because complexity theory is an emerging field within IS research it is therefore useful to understand how thinking about complexity and CAS's originated (Anderson 1999; Begun, Zimmerman et al. 2003). Complexity theory emerged from physics and chemistry around 1984 from the work of Prigogene and Stengers (1984). They described self-organizing systems based on their work on thermodynamics (Waldrop 1992). Chaos theory, and the "butterfly" effect (based on the work of Lorenz who was a meteorologist studying weather patterns), was popularised around 1987 by the work of Gleick (1987). Soon thereafter, popular books on complexity theory were published (Lewin 1992; Waldrop 1992; Kauffman 1993; Kauffman 1995a) and the "adaptive" component of complex systems was applied to economics. Around the turn of the century, artificial intelligence and agent-based modelling emerged (Axelrod and Cohen 1999). Interestingly, special issues of journals on "complexity" began to appear from 1998 onwards, and covered a range of topics (see Table 1 for details) representing the increased attention paid to this academic field.

In the field of organization science, complexity theory is applied to the study of organizational processes like change and innovation (Van de Ven and Poole 1995) and more recently to networks (Urry 2005a; Urry 2005b) and emergent global organizations (Knorr Cetina 2005). Co-evolutionary theory has emerged in the organizational science literature as a field within CAS theory, and has been applied to the study of emergence of new organizational forms (Lewin, Long et al. 1999), competition between organizations (McKelvey 1999a), and organizational absorptive capacity (Van den Bosch, Volberda et al. 1999).

In the IS literature, CAS's theory has been used to describe co-evolutionary software development processes (Highsmith III 2000; Kim and Kaplan 2005; Benbya and McKelvey 2006a), and the co-evolutionary development of strategic alliances (Koza and Lewin 1998; Benbya and McKelvey 2006b). The value of the co-evolutionary approach is that it provides the tools and concepts with which to understand, and document the changes that are effected through diverse groups (individuals) participating in a joint process.

Table 1: Overview of Special Issues in Journals Featuring Aspects of Complexity Theory		
Journal	**Topic related to complexity**	**Publication**
Complexity	Complexity and Business	1998 Vol 3 Issue 4
	Complex Adaptive Systems part 1	2002 Vol 8 Issue 2
	Networks and Complexity	2002 Vol 8 Issue 1
	Complex Adaptive Systems part 2	2002 Vol 8 Issue 4
	Understanding Complex Systems	2005 Vol 10 Issue 4
Organization science	Jazz Improvisation and Organization Science	1998 Vol 9, Issue 5
	Application of Complexity Theory to Organization Science	1999 Vol 10, Issue 3
	Co-evolution of Strategy and New Organizational Forms	1999 Vol 10, Issue 5
Emergence	Theory, culture and society	2005 Vol 22, Issue 5
Communications of the ACM	Adaptive Complex Enterprises	2005 Vol 48, Issue 5
Journal of Information Technology	Special issue on Complexity Science	2006 Vol 21 Issue 4
Information Technology and People	Complexity in IS research	2006 Vol 19 Issue 1

Complexity science began to appear in the health care organizational theory from the mid 1990's (Begun, Zimmerman et al. 2003). Quality Management in Health Care journal carried numerous articles, particularly to describing clinical pathways as non-linear, evolving systems (Priesmeyer and Sharp 1995; Priesmeyer, Sharp et al. 1996). Health care organizations also came to be described as CAS when three eldercare organizations were analysed from a complexity science perspective (Marion and Bacon 1999).

Complexity theory is used to explain health care management and leadership (Zimmerman, Lindberg et al. 1998; Arndt and Bigelow 2000), to develop recommendations on health sector reform in the United States in 2001(2001), and recently, to discuss issues of management and leadership of the British Health Services (Fraser and Greenhalgh 2001; Plsek and Greenhalgh 2001; Plsek and Wilson 2001; Wilson and Holt 2001)

This brief overview of the use of complexity science in the organizational science, IS and health systems literature is presented to highlight the recent emergence of the field over the last ten years, and to provide a brief overview of the ways in which complexity science has been used. The overview helps to frame my use of CAS as an analytical framework in this thesis.

2.3. Key Features of Complex Adaptive Systems:

In this section, a CAS is defined in terms of its parts, the behaviour of the parts, and the emergent behaviour of the whole system. Following this, three key phenomena related to the features of a CAS to adapt in response to changes in their environment are discussed, namely non-linearity, emergent behaviour through self-organizing networks and the co-evolutionary nature of a CAS adaptation to the environment. Each of these phenomena is also discussed in section five in relation to their application to IS and organizational science.

2.3.1. The components of a CAS - Agents with schemata adapting to the environment:

CAS are made up of active elements called agents, or "adaptive agents", and they could be individuals, groups or coalitions of groups. These, can be grouped, or aggregated into meta-agents which represent the hierarchical arrangement of levels of agents. The ability of CAS to arrange themselves in hierarchical patterns is important from the point of view of adaptation and evolution for two reasons. One, due to the hierarchical structure of systems and their sub-systems, each operates both independently and interdependently of one another (Simon 1969). Two, because of their relative independence, hierarchical "systems evolve to a level of organization through self-adaptation, rather than control" (Tan, Wen et al. 2005) implying a quicker evolution.

An agents' behaviour is dictated by a schema (a set of rules) representing a cognitive structure that will determine what action the agent takes in response to an evaluation of the environment. Schema can evolve over time, and different agents may or may not behave according to the same schema over time. Schemata may be composed of one rule from a set of possible rules, or a combination of rules, or may in fact be similar to a neural network where a set of stimuli will evoke a set of rules, and different combinations of stimuli will evoke different rules (Anderson 1999). Schemata are rationally bounded (Simon 1991) and are sometimes called "interpretive schemata" (Dooley 1997), but can undergo change through single loop and double loop learning (Argyris and Schon 1996).

Because schemata can be more sophisticated than a simple set of rules, agents are able to attribute meaning to a set of circumstances. Schemata can compete against one another internally, and this explains organizational adaptation (Gell-Mann 1995). Schemata can evolve more rapidly than agents can, and so competition amongst schemata allows those that are more efficient to receive positive feedback at the expense of less efficient schemata, and adapt accordingly. Organizational outcomes are influenced by the action of agents, their networks and their “fitness” levels (this is described in more detail in section 2.3.3) (Lewin, Long et al. 1999) Order is emergent based on lower-level behaviours. Before expanding on self-organizing groups as a characteristic of CAS, I now explore the notion of non-linearity.

2.3.2. Non-linearity resulting in unpredictable long-term outcomes:

Non-linear effects are a characteristic of CAS where small changes in behaviour can effect small, medium or large changes on the system according to a “power law”. The power law is typically described by the avalanche example – dribbling new sand onto an existing sand pile will allow the sand pile to grow up to a certain point, after which an additional grain of sand will set off an avalanche, representing a non-linear effect. Small avalanches are more frequent than large avalanches, and they occur at a frequency which is inversely proportional to their size, or power. The same principle exists for earth quakes and fluctuations in the stock market prices. The result is that CAS’s operate within a dynamic equilibrium (Waldrop 1992; Stacey 1995). This is also called “self-organizing criticality”, and refers to the fact that CAS are in a continual state of flux at the edge of chaos (discussed in more detail in Section 2.3.4), and small adjustments will sometimes result in large scale changes (Waldrop 1992, p. 304-306).

A slightly different view of non-linearity suggests that non-linear systems express relationships that are not proportional (Gleick 1993). Non-linear systems don’t add up and they cannot be solved. The result is that minor changes in the past can have surprisingly large effects in the present because small events are not forgotten, and adding two elementary actions together can have surprising effects.

Non-linearity and indeterminate outcomes evolve as a result of both negative and positive feedback (Stacey 1995). If negative feedback dominated (as in a situation where control is centralised and rules dominate), then inertia and stability would result. Alternatively, if only positive feedback was provided, then instability would result. In a situation where agents are free to choose whether or not to act according to a set of rules, then the rules and schemas which govern their behaviour can change. This creates a situation which is paradoxically both stable and unstable – it is stable in the sense that short-term outcomes are predictable (the weather for today and tomorrow can be predicted with reasonable accuracy), but there is instability in the sense that the long-term outcomes are unpredictable. This is also termed the “sensitive dependency on initial conditions”, meaning that slight changes at the initiation of a process may lead to very different long-term outcomes (Stacey 1995; Dooley 1997). Systems behaving in this way are termed deterministic and non-linear. They are deterministic in the sense that agents operate within the system in a certain pattern, but the systems are non-linear in that the agents cannot control the effects of positive and negative feedback, nor the way in which individual agents may adjust the rules and which result in unpredictable consequences.

2.3.3. Self-organizing groups and networks displaying emergent behaviour:

Autogenesis (the ability to self organize) is a characteristic of systems where independent agents behave according to a set of rules and not due to external control. Feedback loops, both positive and negative modify the behaviours of agents, and history serves to provide a trajectory for the future, as the system evolves (Anderson 1999).

Autogenesis occurs in open systems that import energy from the outside (Anderson 1999). Energy is imported in a variety of ways – through ingestion of food (as in living systems), through creation of energy through photosynthetic processes, or through the inclusion of new agents within the network of agents and meta-agents. These organisms are called dissipative structures (because of their ability to absorb energy, and dissipate it as they change and develop). The inflow of energy creates an instable state, and it is at this stage that new life forms and structures emerge (hence the term “emergence”). Within an organization, those with influence can inject energy (by bringing in new members, new suppliers and partners) setting new challenges and/or shaking up the organization (Anderson 1999).

Self-organizing groups and networks are important from an IS point of view for two reasons. First, it is the extent of inter-connections between networks within an organization that create opportunities for innovation. For instance, rather than view informal networks as unwanted structures within an organization, they should be recognized as the source of disorderly and unstable dynamics which can potentially result in evolutionary and transformational processes (Stacey 1995). Traditionally, organizations try to limit the creation of these informal networks through the formalization of hierarchical structures and rules by which employees are expected to behave. Stacey (1995) describes how the formal organizational structures that provide “stability, certainty and conformity” (page 484) are counter-forced through the presence of the informal organizations, that pulls the organization towards instability, fragmentation and division. The balance between these forces is what allows an organization to be both stable, while also allowing change to be enabled within the state of “bounded instability”. The stability within an organization will also vary depending on the connections between agents – instability results when the agents are very loosely connected, as well as when each agent is connected to each other. The greater the number of connections, and the more random they are, the greater the degree of instability. Where there are few and strong connections, greater stability will ensue (Stacey 1995). Most effective change happens when agents are loosely connected with one another, in naturally evolving networks allowing evolution to take place in neighbourhood networks (Dooley 1997; Anderson 1999). The degree of order within the networks depends on the degree of interconnectedness, and when order emerges it is a surprise, because there is nothing in the random behaviour of the individual agents that suggests that order will result.

Secondly, the alteration of networks and bonds between networks allows CAS to evolve. It is recognised that the constituent elements (agents, their rules and schemata, and the nature and strength of connections between agents, and networks, and their fitness) of a CAS are able to evolve and change. But it is the alteration of their networks, and recombination of agents into different networks that allows CAS to adapt on rugged fitness landscapes[4] (Kauffman 1995b; Lewin, Long et al. 1999; McKelvey 1999a). Technological innovations allow different types of connections to be formed (see for instance the effect of the internet, or of skype in changing networks and relationships) between networks, which allow organizations to evolve in different ways. Similarly, mergers and task forces allow organizations to better adapt to changing global markets (Anderson 1999).

CAS can have what appears to be chaotic phases in their evolution, displaying random patterns, or "strangely stable" behavior that has a highly complex order. The patterns exhibited during change 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. Different types of attractors are described. A "fixed-point attractor" results in a

[4] The fitness landscape is a tool to understand biological evolution. It is a space which depicts qualitative values geometrically. The vertical axis displays "fitness" to the environment, and on the horizontal a specific location will for instance represent a genetic element. The height of the peak at that location will represent the relative fitness contribution of that element for the organism as a whole. Landscapes are "rugged" where one attribute has implications for other attributes. Evolution on "rugged landscapes" is focussed on finding the high ground. The fitness landscape is a constantly changing landscape as other agents and meta-agents adjust their fitness.

system gravitating to a single state, or set of states, where it remains. Other attractors are "limit-cycle attractors" which would create a steady pattern of events whereby the cycle is repeated over and over and stability results. "Strange attractors" result in apparently random patterns that are non-linear in nature, and have a complicated set of rules that govern their behavior and the apparent chaos that results. All attractors operate within a set of fixed parameters or boundaries, but within these the system is unpredictable. Attractors in general are useful as they can help describe the stage of a system's evolution (Butz 1997).

2.3.4. Co-evolution at the edge of chaos:

Co-evolution is the process whereby agents change with one another as they adapt to improve their fitness to the environment. Co-evolution results in a "critical state" at the edge of chaos described as "perpetual novelty" (Axelrod and Cohen 1999, p.10), where small changes can have marked effects leading to the "avalanche effect".

The adaptation of a system to the environment is the result of the adaptive efforts of individual agents improving their fitness to the landscape. The fitness landscape that has to be attended to by a CAS is a multi-dimensional landscape with frontiers in a number of different areas, which need to be managed at the same time, and over time (Anderson 1999; Fontana and Ballati 1999). As discussed above, it is not only that fitness is achieved, but also the process (the history) that is important in defining the overall degree of fitness (Anderson 1999). The focus on both system and process, is probably the single most important difference between complexity theory and reductionist approaches to organizational theory (Fontana and Ballati 1999; Urry 2005b).

Complex systems operate at a position "far from equilibrium", or at the "edge of chaos" (see Figure 3 below) (Waldrop 1992) representing the state between stability and chaos (Stacey 1995; Wilson and Holt 2001), or the balance between forces of order and disorder (Waldrop 1992). Waldrop describes this state as the difference between a solid state (where there is order, and little change), and a liquid, where the atoms tumble over one another. In between these two states is the "edge of chaos" where complexity is found. The further a complex system is from a state of equilibrium, the more complex it is, and the higher the degree of non-linearity. It is at this "far from equilibrium" position that order emerges out of the instable state.

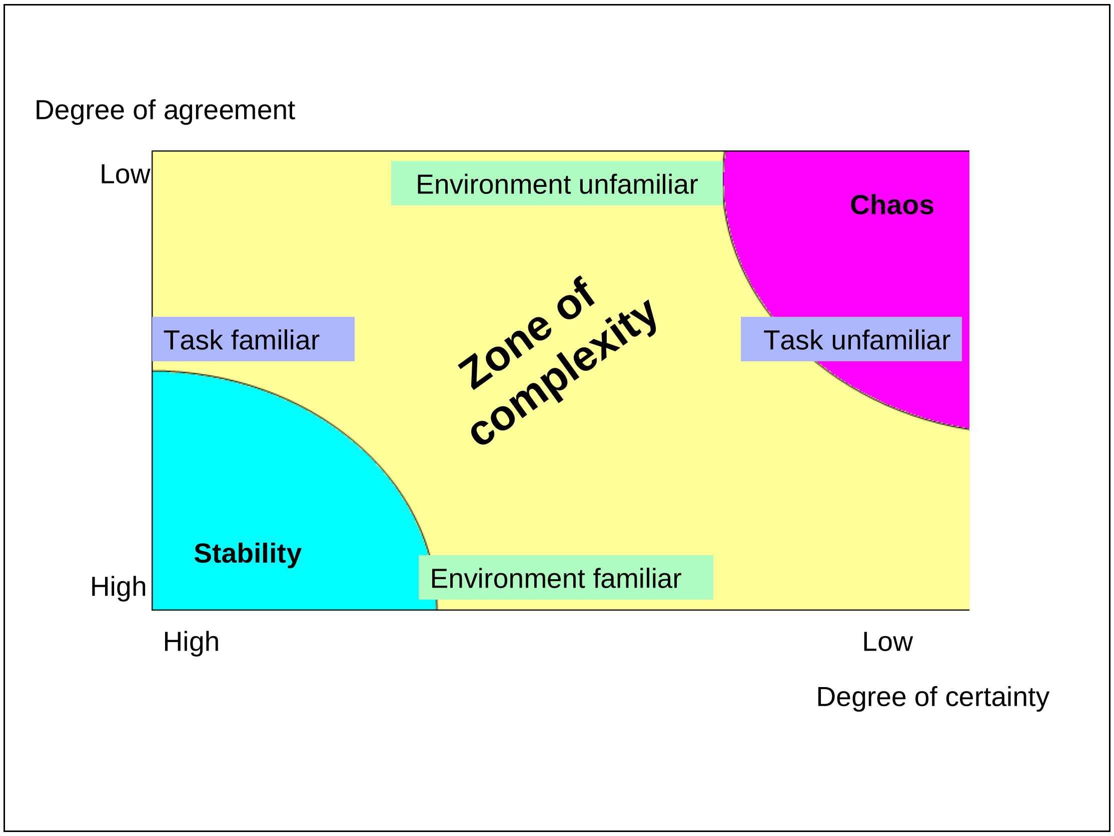


Figure 3: The Zone of Complexity or Edge of Chaos

(Modified from Wilson and Holt 2001)

Anderson (1999) presents two explanations why CAS evolve to this “critical state” at the “edge of chaos”. One is because the co-evolutionary processes over time have eliminated the “least fit” element of the system. The weakest link in the organization (or in the landscape) is replaced by another that fits better, and so the CAS evolves to a state where the remaining elements are able to adapt and change to the environment – at the edge of chaos.

The second view suggested by Kauffman (1995b) is that CAS evolve to the edge of chaos because that gives them a competitive advantage. If small changes result only in small co-evolutionary changes, then the species is unlikely to survive because it would not change significantly. On the other hand, in chaotic systems, small changes may result in radically different fitness levels which are a better fit with the landscape, but which are difficult to maintain because of their chaotic state. As a result, they crash to lower levels of fitness with the next injection of energy, and so do not survive. However, CAS that are able to maintain a state at the “edge of chaos” where they are experiencing sufficient change to allow co-evolution to occur, yet not so much that sends them into a chaotic state are the ones that are most likely to evolve to the best fitness to the landscape. This is a balance between flexibility and stability (Stacey 1995). Effective organizations should strive to evolve a strategy that maintains them at the edge of chaos where frequent small evolutionary adjustments are made from time to time, and punctuated by occasional large changes representing radical innovations.

2.3.5. Summary:

I wish to highlight four key messages from the analysis in the preceding sub-sections. First, CAS are able to evolve independently and interdependently of one another and free of central control. Their ability to evolve free of central control is the result of their behaviour according to schema which can change over time through first and second order learning processes. Secondly, non-linear effects are to be expected when studying organizations characterised as CAS’s. While the non-linear effects cannot be avoided, careful attention needs to be paid to opportunities to create non-linear effects. Non-linearity is a paradoxical situation which is described as a state of dynamic equilibrium where short term outcomes are predictable, but long term outcomes are not. Thirdly, within an organization, the formal structures, rules and systems provide stability and order, but these are counterbalanced by the existence of self organising groups which represent the counter balance of disorder and dissent. Balancing these forces allows an organization to achieve “bounded instability” which is an optimum state in which innovation can occur, and which can be achieved by changing the number of interconnections between networks and agents, and the strength of the connections. Fourthly, co-evolution is the process of adaptation of the system in the zone of complexity.

2.4. The Elements of a Co-evolutionary Framework:

In this section I explore the elements for a complexity inspired theoretical framework with which to analyze HospMISD. In the next sub-section I provide an overview of the application of basic principles from CAS’s theory to hospitals and HospMIS. The three sub-sections thereafter explore non-linearity, self-organizing networks, and co-evolution as applied to organization science and IS. In the last sub-section (that is the application of co-evolution to organizational science and IS), I elaborate on three main ideas, namely that adaptive tensions play an important role in CAS to identify potential areas for co-evolution and innovation, that organizational change and technological change are co-evolutionary processes in support of one another, and that the co-evolutionary process is an organizational learning process. In the next section (Section 2.5) I use these concepts to develop a theoretical framework which is then applied to a failed hospital information system implementation to demonstrate the potential of the framework in suggesting alternative strategies for effecting HospMISD.

2.4.1. Introduction:

The health care sector can be conceptualized as a CAS, and described using concepts of adaptive agents and meta-agents to develop a framework for understanding the functional units in hospitals, including hospital information systems (Begun, Zimmerman et al. 2003; Tan, Wen et al. 2005). In the case of hospitals, the agents, or “adaptive agents,” are the health care workers like doctors and nurses, or managers, or patients. These, can be grouped, or aggregated into meta-agents (wards, clinics, or departments or other teams), which represent the hierarchical arrangement of levels of agents. As with other CAS, the hierarchical arrangement of health systems allows them to operate both independently and interdependently of one another (Simon 1969). For example, a paediatrics ward operates relatively independently of other units, yet it is influenced by events in other wards (for example it sometimes has to respond to a new delivery of a sick neonate in the maternity ward). Secondly, they are able to evolve more quickly: “to a level of organization through self-adaptation, rather than control” (Tan, Wen et al. 2005, p.39) in accordance with accepted rules. For example, nurses and doctors know how to respond to an emergency without having to follow written rules. In a medical emergency, agents adapt roles automatically and synergistically in response to actions and reactions of colleagues and linked networks. Adaptation happens at a relatively rapid pace at the “edge of chaos” as the agents and teams respond to the emergency. Slowly a new equilibrium is established, and adaptation takes place as the agent fits into the changing environment and learns through experience. Adaptation may take place over different time scales (for example in an accident related emergency the response is immediate, while the response to the HIV/AIDS pandemic takes place over years). The processes of adaptation are mediated by feedback loops (both positive and negative) through interactions with other agents of the complex system.

The value of the CAS perspective is that it provides a mechanism for understanding the multiplicity of interactions and forces that can influence “agents and meta-agents” involved in the development of hospital information systems. In addition, it provides a mechanism to analyse and understand hospital information systems development at multiple layers of the hierarchy as well as horizontally across the hierarchical layers, a research priority highlighted by Walsham and Sahay (2006). In particular, it provides concepts to explore the dynamics of individuals (as agents and meta-agents) in relation to their interactions with others and with technology (see for instance Kim and Kaplan 2005).

2.4.2. Application of non-linearity to organization science and information systems:

In his recommendations for the redesign of the American Health System, Plsek (2001) describes the health care system as being non-linear, and "not predictable in detail" (p. 313). He suggests that forecasting is an "inexact, yet bounded art". Unlike machines, whose behaviour is predictable, the behaviour of CAS is creative and emergent, and therefore the only way to know what a CAS will do is to observe it. From an organizational dynamics perspective, non-linear effects mean that small actions taken by an individual, or a network of individuals, acting at a micro level, may have major organizational impacts at the macro level. However, the consequences of specific actions are unknowable and unpredictable. The links between cause and effect become blurred, and so rather than look for these, we should focus on "patterns and their systemic implications" (Stacey 1995, p 493). Yet, paradoxically, there is an "inherent order" that is evident, a result of self-organization, and free of central control. The challenge though is how to manage such a system and enable a balance between the convergent and divergent forces. The following strategies are suggested (Dooley 1997; Zimmerman, Lindberg et al. 1998; Plsek 2001):

- Establish a good enough vision and create space for creativity to emerge from local actions;
- Provide simple rules and minimum specifications, especially as they relate to structural and behavioural issues;
- Create linkages and networks, and encourage diversity;
- Cultivate enquiry, experimentation and divergent thinking;
- Create conditions in which the system can evolve over time; and,
- Establishing rapid feedback cycles to support self-reference and self-control.

Drawing on the work of Dooley (2002), who identifies eight characteristics to contrast linear and non-linear systems, I have used Table 2 to highlight characteristics of non-linear systems that can be influenced to enhance or mitigate non-linear effects. The challenge is to

Table 2: Characteristics of Non-Linear Systems Applied to HIS (Source Dooley 2002)			
Characteristic	**Linear systems**	**Non-linear systems**	**Application to Health Information Systems**
Connectivity	Dedicated lines of connectivity	Common-mode connections with two-way traffic	Traditionally HIS are vertical and with little cross-communication. However, there is a need for increased connectivity and communication across programs because there is a great deal of common data to be communicated. Changes in "connectivity" can be brought about through meetings, fora, and establishing a unifying vision. Where integration is too tight, mechanisms to delink units should be sought, through for instance creating different types of functional groupings and shifting the emphasis to other focal areas.
Sub-systems	Segregated sub-systems	Interconnected sub-systems	Many sub-systems within the HS and HIS, each demanding their own information system (e.g. transport, finance, service delivery – if fragmented even these will be multiple systems). Changes in "connectivity" between sub-systems can be brought about through similar mechanisms to those discussed above.
Feedback loops	Few feedback loops	Many feedback loops	Multiple feedback loops exist in the health system because of multiple units each belonging to separate systems, multiple connections, and multiple controls. The effect of feedback loops can be ameliorated or enhanced through adjusting the number of inter-connections between groups and units (Stacey 1995).
Controls	Single control	Multiple controls, or no clear control centre	Controls are located in multiple sites, including in local manager, managers of sub-systems, politicians, and patients. Structure can be balanced with self-organizing networks – where the situation begins to spin out of control, structural adjustment can be effected (this may require either an increase or a decrease in structural support, depending on the circumstances).
Information	Directly communicated and available	Indirectly communicated and not always available	Multiple sources of information, including managers, patients, and politicians. As indicated above, an observant manager will adjust the amount of information, or the mechanisms for circulating information, in response to the context and events. Crises may be precipitated by either too much information or a lack of information, and each situation will need to be judged accordingly.
Understanding context	Context is clearly understood, and is extensive and complete	Context can never be fully understood due to the complexity of networks	Understanding of the context is limited, given the multiple connections and mechanisms of communication and multiple systems interacting with each other. Yet, an awareness that this is the case will spur the careful manager to explore connections, networks and seek out alliances even with opponents

manage the non-linear effects in such a way that the system is maintained in the zone of complexity, balanced on the edge between stability and chaos.

Stacey (1995) suggests that organizations that wish to be innovative and creative need to create an “internal property” (p 489) of changeability. Organizational changeability can be achieved by establishing three important features within an organization. First, enable the creation of sufficient self-organising networks which cross internal and external boundaries and which create sufficient internal instability “far-from-equilibrium” so as to be the “engines of enquiry”. Secondly, organizations should allow open-ended choices to their members which are constrained by the organizations feedback structure. He suggests a balance between structure (which should be deterministic) and the outcome of open-ended informal networks. Thirdly, focus on short-term emergent processes rather than long term intentional outcomes.

At this stage I wish to highlight three concepts of non-linear systems, namely connectivity, controls, and feedback and information (Dooley 2002). These three concepts are key to managing CAS, and are discussed in more detail in the sub-sections that follow. The notions of connectivity and control are key characteristics of self-organizing groups (and are discussed further in Section 2.4.3). Connectivity between agents and meta-agents is central in enabling feedback, and supporting the flow of information. Decentralized control is effected through establishing self organizing groups and utilizing the hierarchical arrangements within CAS. These structures (the self-organizing groups and hierarchical structures) within CAS are networked and interconnected, and therefore are the mechanisms whereby communication (including feedback and provision of information) is effected.

I now explore the application of autogenesis to organizational science and IS.

2.4.3. Application of autogenesis to organization science and information systems:

While the term “self-organizing” groups has been used to describe independent agents that behave according to a set of rules and free of external control, this does not imply that self organizing groups are not amenable to external influence. Self-organizing groups need to be seen as agents or meta-agents within the larger CAS, and therefore co-evolving with other agents in the system to obtain the best fit for the whole. It is within this context that I describe how self-organizing groups can be managed as part of the co-evolutionary process.

Alaa and Ftzgerald (2004) apply the concept of self-organising groups to the concept of the "Practice" which is defined as a "discourse [between developers and other stakeholders, including users] during which requirements for software development activities and responses evolve" (p. 16 (my emphasis between square brackets)). This approach allows developers to establish the context in which they can be creative and innovative driven by opportunity and events, rather than being constrained by a detailed specifications and requirement analysis. Similarly, in discussing the dynamics between software developers and users, Eoyang (1996) suggests that teams of diverse members can be left to work together, recognising that diversity brings with it opportunities for innovation.

Co-evolution is discussed in more detail in the next sub-section, but two concepts related to the role of self-organising groups in the co-evolutionary process require specific mention here. First, the size of self-organizing groups warrants consideration. Self-organizing groups are suggested for achieving business and IS alignment (Benbya and McKelvey 2006b). The co-evolutionary process must span multiple levels of the organization (namely the individual, the operational, and the strategic), and must effect communication between the levels and between units at each level. Effective communication between the three levels of the firm and the units is a function of the size of the self-organizing groups. If the size of groups are too big, then they cannot organise easily and quickly, and cannot respond to changes in the business strategy and effect changes in the IS strategy. On the other hand, if the units are too small, and function independently of one another, then disjuncture results between units at each level, and between levels, resulting in a misalignment between the units and their individual business/information strategies. Identifying the "appropriate size" for self-organising units, is critical, and modularity is an important consideration in expanding or shrinking group size in order to increase or decrease group responsiveness.

Secondly, feedback processes are an important aspect of co-evolutionary processes (Anderson 1999; Benbya and McKelvey 2006a) . Eoyang (1996) describes how the length and breadth of feedback cycles can be adjusted to manage the co-evolutionary design process for software. The length of a feedback cycle is the time between feedback processes, and the breadth of a feedback cycle is the amount of information provided during the feedback process. Both the length and breadth of feedback cycles can be adjusted to maintain the co-evolutionary processes in the zone of complexity. For instance, with respect to the length of feedback cycles, during periods of turbulence (usually at the start of a project and near the end), short feedback cycles can introduce stability, while long feedback cycles can result in instability. Similarly, with respect to the breadth of feedback cycles, early on in a project, the feedback is focussed on the vision and conceptual aspects of the project, while later on the detail. Providing the wrong type of information can result in confusion and instability.

Before exploring co-evolutionary processes, I summarize the development of the theoretical framework so far. The theoretical framework seeks to manage non-linear effects and highlights the importance of connectivity, feedback and information, and control between sub-systems in a CAS (Dooley 2002). Sub-systems can be units, or self organizing groups. Self-organizing groups are important in that if they are composed of a diverse range of actors, then they can potentially become sites of innovation. Connectivity has been briefly explored in terms of efficiency of communication as influenced by the size of groups, and the nature of feedback cycle length and breadth. Decentralized control is an inherent property of self-organizing groups, and of the hierarchical arrangement of sub-systems.

2.4.4. Application of co-evolution to organization science and information systems:

In the preceding sections, I have discussed the application of two main concepts from CAS theory to IS and organizational science, namely the role of non-linear effects and self-organizing groups. This has mirrored the discussion on the characteristics of CAS. In this section I further expand the theoretical framework developed in the preceding sections by exploring co-evolution as a process in support of HospMIS development. In this section I develop three main ideas:

a) Adaptive tensions are important to identify potential areas for co-evolution and innovation;
b) Organizational change and technological change as co-evolutionary processes in support of one another;
c) Characterizing technological change as an organizational learning process

a) Adaptive Tensions as Opportunities for Co-evolution and Innovation

The forces between order and disorder, stasis and chaos described in section 2.3.3 are frequently referred to as adaptive tensions in descriptions of health systems as CAS (Plsek and Greenhalgh 2001; Wilson, Holt et al. 2001). Adaptive tensions represent the variation between different parts of the system, and the object is to use them "…to generate a creative tension that acknowledges the special benefits of all the systems' components" (Eoyang 1996, pg 34). They provide the potential for innovation and learning (Plsek and Wilson 2001). Adaptive tensions present in hospitals in various ways, namely:

- They might appear as the variation between independence and inter-dependence where for instance departments work independently of one another yet are also inter-dependent on others for services and assistance in patient management; or
- As the variation between homogeneity and heterogeneity as agents work in teams which sometimes have similar skills (doctors in a paediatrics department), and at other times different skills that complement one another (for example software developers and health workers who are the users); or
- The balance between accommodating innovation and divergence with uniformity and conformity. For example, in an emergency, doctors and nurses need to be innovative within the confines of acceptable treatment regimes, sometimes in the theatre as well. Similarly, while hospital departments are granted a certain degree of autonomy to be innovative and individualistic, they are also expected to act in the best interests of the hospital as a whole and in consultation with other departments; and
- Adaptive tensions also arise between the hospital and forces external to hospitals. For example, adaptive tensions frequently arise through the interactions and responses of a hospital to the global (for example, new ICTs) and local (for example, patient diseases) forces of change.

Being aware of the existence of adaptive tensions, and examining them in greater detail can provide practical insights on how to develop HospMIS. Innovation takes place at the interface between the adaptive tensions – through contact and exposure to alternate viewpoints. This is where “adaptive tensions” surface, and which give rise to change.

As indicated above, adaptive tensions frequently arise between global forces of change in the ICT sector and local organizational processes (see for example (Barley 1986)). The notion of integration between organizational and technological change processes is important to understand, especially given the global demands for organizations to adapt to changing ICT (Castells 1998; Castells 2000; Walsham 2001). For instance, IS research demands a deeper understanding of both the IT artefact, and the organization in which it is deployed and used (Kling 1980; Orlikowski and Iacono 2001). If both of these components are changing at disproportionate rates, and in response to different and similar pressures, then the challenge is how organizations can accommodate these changes. In the next two sections I explore the unfolding interaction between organizational and technological change in more detail.

b) Co-evolution of Organizational and Technological Change

The concept of co-evolution has been extensively explored in the organizational science literature (Koza and Lewin 1998; Koza and Lewin 1999; Lewin, Long et al. 1999; McKelvey 1999a; Van den Bosch, Volberda et al. 1999). Properties of co-evolutionary processes have been defined by Lewin and Volberda (1999) (see Table 3). The value of these properties are that they highlight the value of CAS as a theoretical lens, and co-evolution specifically, with which to understand HospMIS development. In Table 3 I highlight the four main properties that I wish to draw on in developing my theoretical framework for analysis of HospMIS development.

Table 3: Properties of Co-evolutionary Processes

(Source Lewin and Volberda 1999)

Property	Description
Multi-levelness and embeddedness	Co-evolution takes place within and between organizations, and between or at micro and macro levels.
Multidirectional causalities	Co-evolution takes place within and between organization parts and their environment. Changes in the environment affect other organizations as well (at both micro and macro levels), and changes in these can create feedback effects in other firms.
Non-linearity	Co-evolution can take quite surprising paths as a result of indeterminate feedback paths between agents. These may be the result of lagged and nested effects which are often not anticipated.
Path and history dependence	Variation in adaptation in firms in a population may be the result of heterogeneity in the population at an earlier point in time.

It is only recently that the concept of co-evolution (between organizational and technological change) has been drawn up in the IS literature to study change (see for instance Jansen and Nielsen 2005; Kim and Kaplan 2005; Allen and Varga 2006; Benbya and McKelvey 2006b). While the IS literature has explored organizational change as a result of the interaction with technology in different ways (see Table 4 for a brief overview), other than the co-evolutionary view, none explain the type of change we expect to see in CAS. As discussed in section 2.3.4, if an organization is effective at maintaining itself within the zone of complexity, we can expect to see small evolutionary adjustments being made from time to time, and punctuated by occasional large changes representing radical innovations.

Table 4: Comparison of Perspectives on Organizational Change as a Result of Interaction with Technology		
Perspective on Organizational Change as a result of interaction with technology	**Main perspective**	**Comment**
Planned change (Dunphy and Stace 1988)	Managers are primary source of organizational change. Change is deliberately initiated.	Change is seen as a discrete event and removed from daily organizing practices; Undue importance given to managers role
Technological imperative (for example (Huber 1990)(and technological determinism (Perrow 1967))	Technology drives predictable change	Agency is discounted as a mechanism for introducing change; Too rigid in the current global context of agility, flexibility and innovation; Cannot accommodate "radically tailorable tools" (refer Malone, Lai et al. 1992))
Punctuated equilibrium (Loch and Huberman 1999; Silva and Hirschheim 2007)	Suggest that change does not need to be slow and technology driven; Change happens rapidly, radically and in an episodic manner; Long periods of equilibrium are interrupted by radical change	Regard organizations as stable; A steady state (equilibrium) is regarded as the preferred status
Situated change perspective (Orlikowski 1996) (also called continuous change (Weick 2001))	A micro-level perspective that change is grounded in every-day practices of actors and emerges out of their actions with the environment. This view is presented as a challenge to concepts that: Organizational change must be planned; Technology is the primary cause of technology-based organizational change; Radical changes always occur rapidly and discontinuously.	A useful perspective for understanding gradual change within an organization, and in particular applicable to the health sector. However, it does not explain radical change that is evident in organizational dynamics.
Co-evolutionary theory (Lewin, Long et al. 1999; Lewin and Volberda 1999) and its use in studying information systems (Kim and Kaplan 2005)	Organizations, their populations and their environment as an inter-dependent outcome of managerial actions, institutional influences, and extra-institutional changes (including technological, socio-political, and other phenomena)	They use concepts from CAS to describe macro- and micro-level influences to evolution and adaptation which provide a different understanding of organizational dynamics as a dynamic equilibrium punctuated by periods of radical change.

The situated change perspective (Orlikowski 1996) is useful for studying micro-level organizational change through the interaction with technology. However, it does not account for the observation that gradual change occurs over time, and is punctuated by radical change occurring unpredictably as a result of “multidirectional causalities” and “nonlinear feedback” paths (Lewin and Volberda 1999). Co-evolutionary theory accommodates and explains these patterns. The question that requires more intense discussion though is how is the co-evolution of technology and organizational change effected in relation to each other?

A partial answer to this question is provided by Benbya and McKelvey (2006a) who describe seven principles to support “co-evolutionary adaptations of information systems” through a combination of top-down and bottom-up process (ibid, page 13). While the authors admit that these principles are still conceptual in nature, and require further testing, they suggest that they represent a more beneficial approach to ISD than the traditional engineering perspective. Together they constitute a “co-evolutionary stance” that accommodates frequent change and non-linear effects of the environment and their impact on software development.

The seven principles are summarized below (Table 5). However, given the conceptualisations of HospMIS development as a CAS, I would suggest that the principles do not adequately distinguish between characteristics of the system and characteristics of the co-evolutionary process. Thus for instance, I would suggest the 7 principles represent three distinct sets of characteristics of the co-evolutionary software development process, namely characteristics of the environment (such as adaptive tensions, frequent change rate and causal intricacy – which manifests as non-linearity), of the software or system that is developed (namely requisite complexity and modular design – both of which enable a system to accommodate the characteristics of the environment), and of the process (namely positive feedback and a co-ordinating rhythm). Table 5 expands on this analysis of the co-evolutionary stance.

I wish to draw specific attention to one principle of the co-evolutionary stance, namely that of modularisation as a mechanism to achieve flexibility. While the need for flexibility in HIS has been described by a few authors (for example (Ramanathan 2005)), its application to hospital information systems remains limited. Given the difficulties of developing effective hospital information systems, and understanding the divergent information needs of the different hospital sub-systems, loose coupling between for example the clinical and reimbursement systems is advantageous, and allows the independent development of systems in a decentralized manner (Monteiro 2003). A further view supporting “loose integration” is presented by Tan, Wen et al. (2005) who draw on the work of Perrow (1999) to describe the balancing process to maintain IS in the zone of complexity (see Figure 4). By adjusting the coupling between components of a system, the tension between simplicity and

Table 5: Principles of Co-evolutionary Adaptation of HospMIS (Source Benbya and McKelvey 2006a)		
Principle	**Brief description**	**Critique**
Characteristics of the environment:		
Adaptive tension	The "pressure to change" as a result of contradictions that arise between the different realities of original intent and changing needs in a complex environment. The system will demonstrate adaptive tensions, and has to be able to accommodate the new realities if it is to remain relevant to organizational needs. The "expansion of diverse requirements" will result in several development spirals. (Benbya and McKelvey 2006, pg 21).	This is a characteristic of the environment in which IS get deployed. The system and process must be able to accommodate adaptive tensions as a design –reality gap (Heeks 2006)
Change rate	This principle is based on the work of Davis (Davis 1982), and suggests that in organizations with a high rate of change, and in which there is a high degree of uncertainty, unexpected issues arise which require "interpretation, articulation and resolution" in real time. IS need to be able to reflect the changing context. In order to achieve this, users and designers need to accommodate one another in an iterative cycle of discovery and adaptation. Rapid development and implementation cycles are suggested, with frequent releases of new versions.	This is a characteristic of the environment, and needs to be accommodated in the information system development and implementation. Changes present as adaptive tensions.
Causal intricacy	Technological, organizational and institutional forces interact to create unexpected effects. These effects influence the system at many levels in unpredictable ways, and provide non-linear forces of change. Benbya and McKelvey (2006) suggest that a "co-evolutionary" stance is needed to recognize that ISD is a "dynamic interplay of co-evolving interactions, relationships and effects."	This is a characteristic of the environment, and needs to be accommodated by the information system and the implementation process.
Characteristics of the system/software:		
Requisite complexity	A system must be able to respond to the changes in the environment – the internal complexity of the system must reflect the external complexity of the environment. Systems need to evolve in order to maintain their 'fit' with the changing context in which they are located.	This is a characteristic of the information system or product that is developed
Modular design	After Simon's (Simon 1969) description of hierarchical systems ability to evolve faster and independently of top-down control, designers develop modular systems which because of decreased interdependencies, improves flexibility and reduces development time.	This is a characteristic of the information system or product that is developed, and is seen as a solution to adaptive tensions.

Principle	Brief description	Critique
	Characteristics of the process:	
Positive feedback	Through the process of generating positive feedback developmental spirals are initiated through a bottom-up process. Based on the understanding that "self-organizing agents can create significant new structures and processes apt to create better functioning IS" (Benbya and McKelvey 2006, pg 25).	This is a characteristic of the implementation process. Negative feedback also occurs, and needs to be considered.
Co-ordination rhythm	The dynamic balance between a number of adaptive tensions such as users needs and developers ability to respond to them, top-down control and bottom-up autonomy, and the more unpredictable influences generated by the organization and environment on the technology.	This is a characteristic of the implementation process, and could be viewed as a characteristic of the "co-evolutionary stance".

complexity can be balanced. Tight coupling occurs when the "spatial, temporal, or other patterns of buffering among components" are lacking, and potentially increases complexity because flexibility is reduced, and accordingly, the ability to respond to change. Effecting a looser coupling between components can decrease the complexity and improve flexibility and ability to accommodate change.

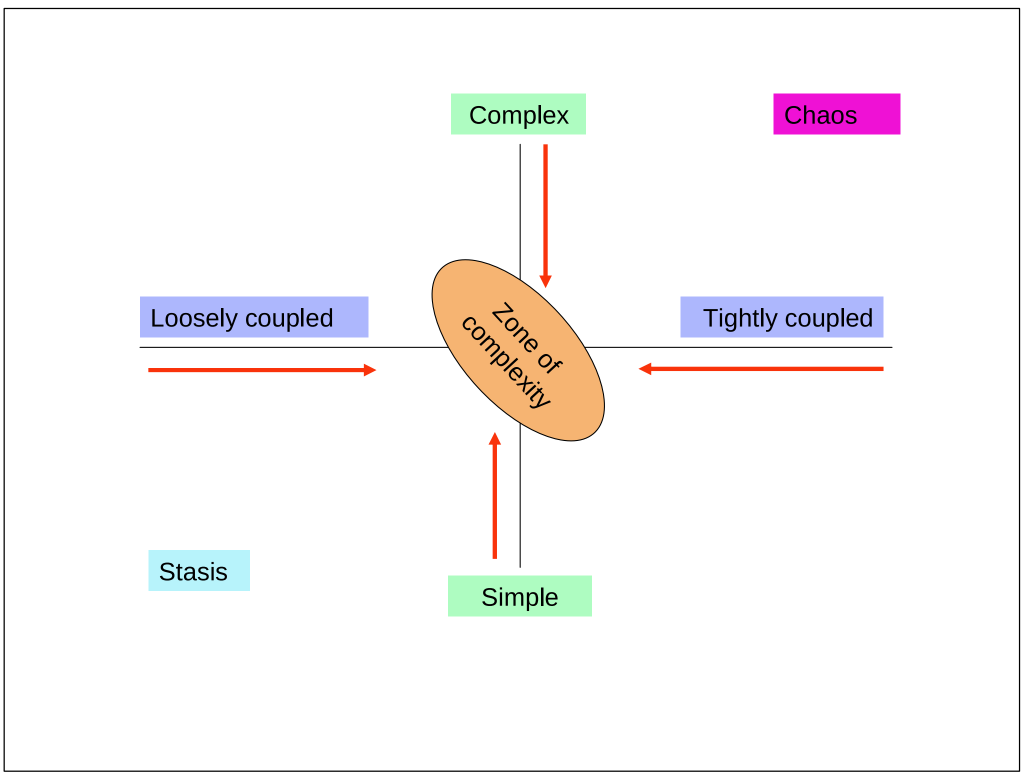


Figure 4: Perrow's Framework of Complexity (in Tan, Wen, et al (2005)**)**

The “co-evolutionary stance” is therefore seen as a useful framework for understanding the co-evolution of IS, although it does not adequately explain the nature of the relationship between organizational and technological change. In particular, the challenge is how to achieve co-evolution between organizational and technological change within the relatively rigid bureaucratic structures that health departments and hospitals represent.

In summary, the conceptual framework for understanding the co-evolutionary development of HospMIS which initially focused on connectivity, feedback and information, and control, has been expanded with concepts from the co-evolutionary stance (Benbya and McKelvey 2006a). I suggest that a co-evolutionary process is required where HospMIS are being designed, developed and implemented in situations characterized by adaptive tensions (some of which, for example, are manifested by a rapid change in information needs, or access to technology), and non-linearity. These characteristics are a result of causal intricacies and multi-directional causalities. The design of the HospMIS must reflect the (requisite) complexity of the context in which it will operate (including the ability to accommodate rapid change and non-linear effects), and modularization should be employed to achieve this. The co-evolutionary process must demonstrate a co-ordination rhythm, be sensitive to the positive (and negative) feedback loops that will emerge, and demonstrate an ability to respond to the adaptive tensions that arise, and which demand frequent changes. The co-evolutionary process should utilize self-organizing groups to support decentralized control, and to manage flow of information between and across structures within the organization. Maintaining the co-evolutionary process in the zone of complexity can be achieved by modularization (for example of software components, or self-organizing groups), and by managing the length and breadth of feedback cycles.

I now explore technological change as an organizational learning process.

c) Characterizing Technological Change as Organizational Learning

Conceptualizing organizational change as a co-evolutionary and learning process within the organization and between the organization and the external environment has recently received a lot of attention in the organizational science literature (Brown and Duguid 1991; March 1991; Crossan, Lane et al. 1995; Lewis and Madon 2004). While the body of literature on organizational learning is extremely large, in this thesis I focus on two main themes of organizational learning, namely the balance between exploitative and explorative drives in organizational change (March 1991; Koza and Lewin 1998; Lewin, Long et al. 1999), and the ability of organizations to absorb new knowledge (Van den Bosch, Volberda et al. 1999). I believe that these provide useful insights with which to explore the co-evolutionary approach as a partnership between a rigid bureaucratic organization (such as a hospital, or a public health facility, district, regional or national structure) and an external agency providing support for HospMIS development.

Balancing exploration and exploitation drives in organizational change:

Exploration is the extent to which organizations engage in experimentation and identification of alternate approaches (March 1991). An organization that engages in exploration activities undertakes risky behavior, experiments, explores diversity and flexibility and seeks innovation. On the other hand, exploitation is associated with the refinement of competencies, technologies and processes in order to increase efficiency. The returns from exploration are significantly less certain than those from exploitation, are more remote in time, and efficiency is often compromised (ibid).

Exploitation offers increased returns which are more proximal in nature and fairly predictable, and therefore are usually more attractive to firms. Adaptive processes usually drive exploitation because the feedback is immediate and positive, and closely aligned to the part of the organization which effects the exploitation strategy. Yet, this trend is potentially self-destructive in that if exploitation is neglected, an organization may become efficient at performing inferior activities, and never move onto embracing superior activities with which it has little experience (ibid).

March (1991) models the development and use of knowledge in an organization that exhibits “mutual learning” between its members and the organizational code, and uses this to suggest mechanisms for organizations to balance exploitation and exploration drives. I summarize these findings below. In any organization, individuals modify their beliefs as a result of their socialization into the organization, and their adoption of its code of beliefs. Similarly, the organizational code adapts to the beliefs of organizational members whose beliefs correspond more closely to reality than that of the organizational code. Over time, the adjustment in beliefs on the part of organizational members, and the organizational code, results in members beliefs and the code converging. The rate of socialization of organizational members to the organizational code is usually faster than the rate of adaptation of the organizational code to the members’ beliefs. Higher rates of learning result in equilibrium being reached more quickly. Slower socialization of organizational members, or a turnover of members, maintains diversity, and allows exploration to occur, which ensures that the knowledge pool within the organization improves. The organizational code learns from members who deviate from the organizational code, and so equilibrium between the organizational code and members beliefs is reached at a higher knowledge point than would occur if socialization of members was rapid. Rapid socialization of members results in less opportunity for the organizational code to learn from members. New organizational members may have less knowledge on average, but what they know is less redundant than that in the organizational code, and occasionally better, and they are thus more likely to contribute to the improving the code. The old-timers in the organization may know more on average, but their knowledge corresponds closely to the organizational code, and so is redundant in terms of contributing to the organizational code evolution. Rapid turnover of a high percentage of staff can result in loss of knowledge from the organizational code, with resultant loss of exploitation and exploration capabilities.

Turbulent environments (defined as a situation characterized by rapidly changing environmental reality) make learning from experience difficult. In the absence of turnover, degeneracy results because the individuals knowledge and the organizational code rapidly reach equilibrium, and once attained, re-inforce one another and have difficulty in changing regardless of changes in reality. But even with mild turnover, degeneracy is avoided, and the code continues to evolve in relation to changing realities.

This review provides a useful framework with which to understand the factors influencing an organizations ability to absorb knowledge and pursue exploratory or exploitative drives. Hospitals are organizations with a complex organizational code. Not only does it address medical practices, but from our point of view must also address hospital information systems. The above analysis supports the assertion that diversity in teams serves to expand the organizational code. Importantly, it exposes the factors that contribute to or detract from knowledge absorption process within organizations. The analysis raises two key issues for HospMIS implementation in a sustainable manner in resource constrained settings. First, how does one achieve a balance between exploratory and exploitative drives, especially given the pressures within the public sector to focus on efficiency rather than innovation? Secondly, understanding that the organizational code is influenced by the pace of socialization, and turnover rates, how can knowledge absorption be effected in organizations that are characterized by high staff turnover, significant staff shortages and lack of IT skills (Kimaro 2006; Padarath, Chamberlain et al. 2007)? In the next sub-section, I expand the understanding of organizational capacity to absorb knowledge from the environment by exploring the concept of organizational absorptive capacity.

Organizational Absorptive Capacity:

An organizations absorptive capability is defined as the ability of an organization to assimilate knowledge from the environment (Cohen and Levinthal 1989). Absorptive capacity is related to both micro- and macro co-evolutionary effects, within the firm and between the firm and the external environment (Van den Bosch, Volberda et al. 1999). Absorptive capacity is not only a function of prior related knowledge, but also influenced by the organizations forms and combinative capabilities (Van den Bosch, Volberda et al. 1999). Combinative capabilities are described as the ability of a firm to establish links across individuals' capabilities within an organization and are assessed in terms of three dimensions, namely efficiency, scope and flexibility. Efficiency of knowledge absorption is the ability to identify, assimilate and exploit knowledge from a cost and economy of scale perspective. Scope of knowledge absorption is the breadth of knowledge that is utilized, and flexibility of knowledge absorption is the ability to access additional and reconfigure existing knowledge. Exploitation ability is associated with efficiency of knowledge absorption, while exploration with scope and flexibility of knowledge absorption.

Three types of combinative capabilities are described. Systems capabilities are the policies, procedures, and manuals that are used to integrate explicit knowledge. They ensure that "behaviors are programmed in advance of their execution" (ibid, p 556). They are efficient in supporting knowledge absorption, but tend to be limited in scope and flexibility, and so their overall effect on absorptive capacity is regarded as negative. Co-ordination capabilities refer to the ability to communicate between members of a group, and between groups. They are effected through natural liaison mechanisms, such as self-organizing groups which cut across layers of authority (hierarchy) and functional groupings. They are less efficient in effecting knowledge absorption, but have an ability to be flexible and cover a broad scope of knowledge absorption, and are therefore considered to have a positive effect on absorptive capacity. Socializing capabilities reflect the ability of the organization to create a corporate identity as well as a collective interpretation of reality. Socialization capabilities are path dependent and shaped by the history of the organization, and tend to foster isolationism. As a result, organizations with strong socialization capabilities tend to reject outside knowledge that is different to their organizational code. Socialization capabilities have a negative effect on absorptive capacity because while they have a high potential for efficiency, they have a narrow scope and are inflexible.

Table 6 suggests a framework with which to assess organizational absorptive capacity, and applies this framework to my understanding of a typical public sector hospital in a resource constrained setting. The analysis suggests that overall, the public sector hospital has a low absorptive capacity. This implies that its ability to accommodate new knowledge related to expanding the organizational code on ICT is low. This suggestion implies that successful HospMIS development in resource constrained settings will require specific innovations to address the low absorptive capacity. This has not received any significant attention in the ISDC literature.

Table 6: Absorptive Capacity of a Typical Public Sector Hospital in a Resource Constrained Setting

Combinative Capability	**Hospital as an organization**	
	Explanation	**Effect on absorptive capability**
Organizational form	Functional form, or perhaps divisional form depending on size (low scope and low flexibility of knowledge absorption)	Negative
Systems capabilities	Bureaucracy with strong and very formalized systems capabilities (low scope and low flexibility of knowledge absorption)	Negative
Co-ordination capabilities	Strong relationships within and across functional groupings in hospitals (high scope and high flexibility of knowledge absorption)	Positive
Socializing capabilities	Reasonably strong corporate identity, tending to be insular (low scope and low flexibility of knowledge absorption)	Mostly negative
Overall Combinative Capability Assessment		**Mainly negative**
Staff turnover	Reasonably high with low levels of institutional memory	**Mainly negative**

In this section I have conceptualized the health sector as a CAS. I then highlighted the application of three characteristics of CAS, namely non-linearity, self-organizing groups and networks, and co-evolution in the organization science and IS research literature. This analysis highlighted key elements that have been used to develop a co-evolutionary framework, which is first detailed below, and then applied to an empirical setting. The chapter ends with an analysis of the gaps in the literature related to HospMISD in resource constrained settings that this thesis seeks to address.

2.5. Summary of Theoretical Perspective: A Co-evolutionary Framework

The theoretical perspective that I propose is a co-evolutionary framework which provides insights into the design, development and implementation of HospMIS in contexts that are characterized by frequent change, non-linearity, and adaptive tensions which are often the result of causal intricacies and multi-directional causalities. The design of the information system should reflect the complexity of the context, and should utilize modularization to maintain flexibility. The co-evolutionary approach represents an analytical process for studying and also supporting the design, and ongoing development and implementation of HospMIS. The co-evolutionary approach lays emphasis on the need to demonstrate a co-ordination rhythm which should include supporting the establishment of self-organizing groups and networks to gather ideas from a diverse range of stakeholders, in a framework of decentralized control while maintaining a clear understanding of their roles and responsibilities. These groups should transect traditional organizational hierarchies and functional groupings, and should be managed to ensure they communicate effectively, and are innovative by operating in the zone of complexity. This can be achieved by adjusting the size of groups, the frequency of feedback sessions and the breadth of information provided at feedback sessions. Because the design, development and implementation of HospMIS takes place in public sector hospitals which are characterized as having low absorptive capacities, innovative approaches will be required to develop sustainable solutions.

I now illustrate my co-evolutionary framework by analyzing the story of a failed hospital information system installation in a resource constrained setting in South Africa. This illustration helps to elaborate the potential of the proposed theoretical perspective and also to describe some of the contours of the concepts I am drawing upon in the analysis of the hospital information system design, development and implementation..

2.5.1. Applying the Co-evolutionary Framework to HospMISD:

Littlejohns, Wyatt et al. (2003) and Mbananga, Madale et al. (2002) provide some insights into the nature of complexity of HospMISD in resource constrained settings. In describing a £14million hospital information system project in Limpopo Province of South Africa as a failure, attributing this to multiple interconnected factors, including:

- infrastructural problems (such as unreliable power supply including surges when the local bakery switched on its ovens, air conditioning problems and networking problems),

- application problems (such as too many different modules all being implemented at the same time, some modules not created in time, and aspects of the application were not reliable and had not been tested)
- organizational problems (poor organization of the implementation left users unhappy, and the focus on getting the system working rather than on providing quick wins (e.g. management reports),
- computer malfunctions left unattended for up to 6 weeks. They describe the system as a failure, and describe reasons for failure as arising from multiple causalities.

In the table below (Table 7), I analyze the case from the complexity perspective, and suggest how a co-evolutionary approach may have helped to develop alternative strategies. Strategies are grouped in three main areas, namely the context, the information system design, and the co-evolutionary approach. The complexities are analyzed at three levels, related to the external environment, the internal environment, and the hospital information system.

While it can be argued that the analysis of a failed implementation in a resource constrained setting is a simplistic way of identifying what should have been done, it is interesting in that it highlights the value of the co-evolutionary approach and the role of complexity in IS research (Bada 2002; Silva and Hirschheim 2007). It is also interesting to note that none of the issues identified in the case were seen to be related to the problem of skills transfer and local adoption of the new system by the hospital "IT department". While mechanisms for the sustainable development and implementation of locally appropriate IS in resource constrained settings has been identified as an issue that warrants further research (Sahay 2001; Walsham, Robey et al. 2007; Avgerou 2008), this issue has attracted limited attention (Braa, Monteiro et al. 2004; Lewis and Madon 2004; Madon, Reinhard et al. 2007).

Table 7: Application of Theoretical Framework to a Failed Hospital Implementation System in a Resource Constrained Setting	
Complexity	**Strategy to address the complexity**
Complexities associated with the external environment	
Unanticipated power surges in electricity supply	**Context:** This is a tricky and unanticipated problem, but not uncommon in resource constrained settings. **Co-evolutionary approach:** Through adoption of an adaptive process the implementation team should be able to accommodate this eventuality through use of alternate power supplies or other strategies.
Complexities associated with the health system	
Differing health cultures between managers and health workers, and different expectations between these levels	**Context:** This is to be expected in these settings, and can be an asset to the process if the value of diverse opinions is recognized and harnessed by the process. **Co-evolutionary approach:** Establishment of self-organizing groups within each of the hospitals, clarifying a unifying vision for the system, and clarification of micro- and macro-level priorities.
Complexity	**Strategy to address the complexity**
Health workers reluctant to utilize a system that increased their workload, and which shifted their priorities from patient care to information reporting.	**Context:** This is a classic problem that is well documented in the literature. **Information system design:** Design process based on self-organising groups in a participatory and co-evolutionary process as described by (Highsmith III 2000; Alaa and Fitzgerald 2004). **Co-evolutionary approach:** Through the use of self-organizing groups, clarify expectations and needs of users at different levels of the system. Identify areas of most pressing need, and prioritise implementation there first, using approaches that do not impact on workload, but which would encourage buy-in from users.
Rapid changeover of staff	**Context:** This is a classic problem that is well documented in the literature. **Co-evolutionary approach:** Projects of this magnitude should be able to accommodate these unanticipated effects, and address the challenge through adaptation of the implementation process.
Complexities associated with the health information system	
Fully integrated software system developed "off-site" and "deposited" in the hospitals for implementation.	**Information system design:** Modular development, with local customization, and implementation of modules according to local priorities.
Delays in development of modules of system	**Co-evolutionary approach:** Adapting the implementation plan to bring forward implementation of other modules, or effect implementation in other sites while addressing the delays.

Complexity	Strategy to address the complexity
Modules not tested prior to implementation	**Co-evolutionary approach:** Innovation is closely linked to experimentation and testing. Through the use of self-organizing groups, opportunities are created for experimentation and testing prior to full scale implementation.
Too many modules implemented at the same time	**Co-evolutionary approach:** Recognition of increased complexity and impending chaos, countered by slowing down the process, and reducing the number of modules being implemented at the same time.
Air conditioning problems in server rooms	**Co-evolutionary approach:** Creating experimentation sites prior to full scale implementation.
Networking problems	**Co-evolutionary approach:** Creating experimentation sites prior to full scale implementation.

After providing this illustration, I focus on the specifics of my research problem.

2.5.2. Aspects of HospMISD that this thesis seeks to address:

Three important issues this research seeks to address are now introduced..

First, is the process of skills transfer and capacity building for IS design, development and implementation within organizations. In the literature from well resourced settings, assumptions are generally made that the “IT department” within organizations will drive the organizational and technological change processes (see for instance Barley 1986; Berg 2001), or will interact with external organizations contracted to support implementation of a product within the organization (see for instance Ellingsen 2004; Hanseth, Jacucci et al. 2006). In resource constrained settings, the absence of expertise within the IT department is highlighted (see for instance Kimaro and Nhampossa 2005; Kimaro 2006; Sahay and Walsham 2006; Sahay, Monteiro et al. 2009), often requiring partnerships to be forged between the public sector organization and an external support agency. In particular, the challenge here is to effect knowledge absorption in organizations that are characterized by high staff turnover, significant staff shortages, lack of IT skills, and having a low absorptive capacity for new knowledge. How this skill transfer can be carried out in the face of adverse conditions is an important research issue which has not received the research attention it deserves.

Secondly, this concern is sharpened by the recognition that the public sector faces a significant challenge in balancing exploratory and exploitative drives. While strategic choice to pursue exploratory or exploitative drives is important in private sector organizations, I argue that it is also an important (even if neglected) issue for IS development in the public sector. Given the relative rigidity of public sector organizations in resource constrained settings, and their focus on improving efficiency, the evidence suggests that they will be less effective at pursuing exploratory agendas. This suggests that public sector organizations, such as hospitals, will be reliant on innovations that are pursued by organizations external to the public sector. If that is the case, how will this be effected, and what is the nature of the partnership to enable the skills transfer? These are important questions that require answers if hospital information systems development is to be sustainable.

A third area that warrants further research is the use of complexity theory to understand HISD. Despite the recognition by numerous authors of the complex nature of hospital information systems development (Berg and Goorman 1999; Berg 2001; Ellingsen and Monteiro 2003; Littlejohns, Wyatt et al. 2003; Ellingsen and Monteiro 2005), few authors have explicitly used complexity theory to explore IS design and ongoing development. Berg for instance describes the implementation of patient care information systems (PCIS) as extremely uncertain and unpredictable, and suggests that these are inherent characteristics of the process, fed by the complexities of the health care context, the information system itself, and the number of parties involved in the PCIS implementation. He argues against the application of business process re-engineering principles to the health sector in a "top-down" manner because it ignores the complex and unpredictable nature of health care work which is "knowledge-intensive, professional work typified by a complexity that defies the predictability and standardisation required for simple re-engineering" (Berg 2001, p 150).

Chapter 3. RESEARCH METHODS AND CASE OVERVIEW

3.1. Introduction:

This chapter describes the research approach and methods utilized to effect the research presented in this thesis. It also provides an overview of the case setting. The chapter is structured as follows: In the next section I first discuss in detail the research approach. In clarifying my research approach I highlight four key areas – the ontological and epistemological basis for the study, the use of an action research approach, the qualitative case study method, and the use of interpretive methods for data analysis. The second main section details the case setting.

3.2. Research approach:

This thesis draws on an in-depth case study analysis of data gathered since 1992 when I began working in the Queenstown district in the ECP and first began to be involved in PHC IS development. It spans research that has been conducted in 4 countries (South Africa, Malawi, Nigeria, and Zambia) while being a member of the HISP-SA organization as well as a member of the broader HISP network (Braa, Monteiro et al. 2004; see also www.hisp.info). My experience has been influenced by the action research approach adopted by the HISP network and by the Scandinavian action research tradition in IS development where user participation, evolutionary approaches, and prototyping are emphasized (Greenbaum and Kyng 1991). Action research aims at generating new knowledge through taking part in the full cycle of action, reflection and learning (Wood-Harper 1984; Baskerville and Wood-Harper 1996). While action research is the major modus operandi in generating the empirical data presented in this thesis, contextualism is the ontological basis for the research.

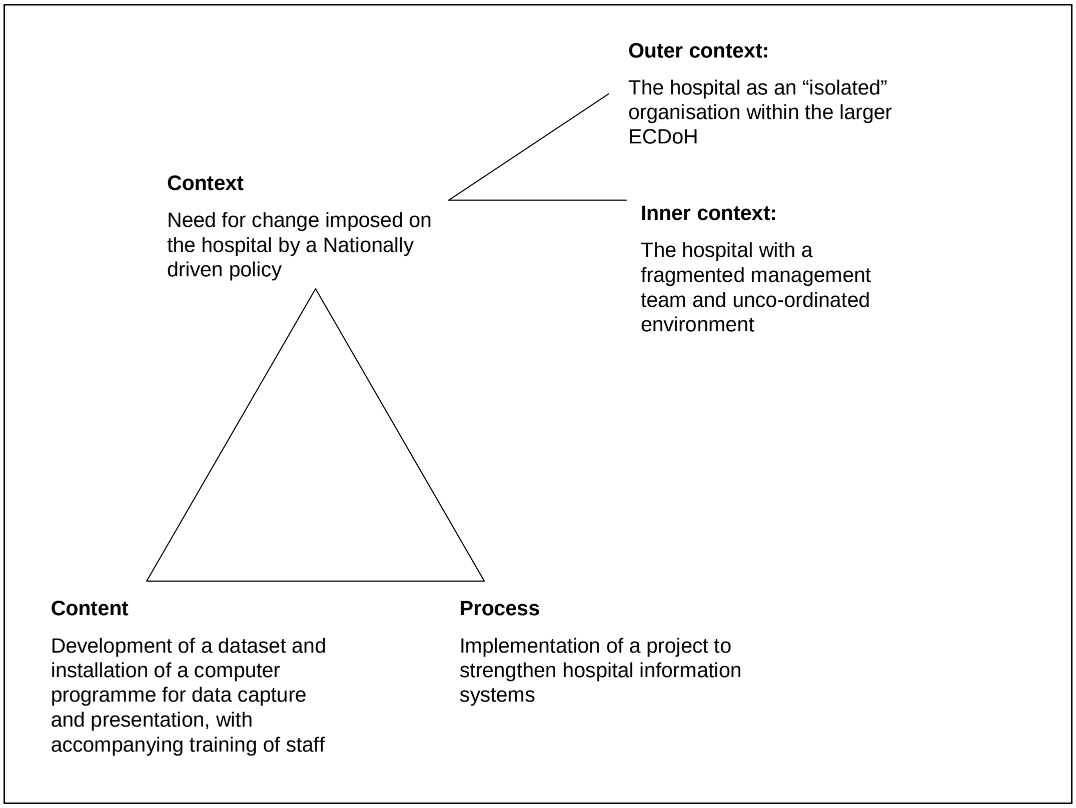


Figure 5: Contextualism as the Ontological Basis (adapted from Pettigrew 1985)

3.2.1. Ontological and Epistemological Basis for the Study

Contextualism emphasizes the importance of the context–content–process axis (Pettigrew 1985; Pettigrew 1987). This model resonates with my understanding of the process of change that characterized the South African health sector in the post-apartheid era. During that period, the issues we were trying to address through health sector reform were heavily influenced by our history, and yet the reform was heavily influenced by the context of the "new" South Africa. The context-content-process model (depicted in Figure 5 above) allows an exploration of horizontal influences (historical events) as well as the vertical influences (policy implementation, reporting requirements) that have contributed to the HIS. The analysis of change within the organization requires analysis at multiple levels, across time, and needs to incorporate cross-sectional categories.

These characteristics of contextualism resonate with the use of complexity theory as the theoretical basis for my research, in that complexity theory provides a mechanism to analyze actions and interactions at multiple levels of the organization, including networking and self-organizing groups that transect hierarchical and formal groupings over time. Complexity theory recognizes the multifactoral nature of interactions in complex environments, and their origin from within and outside the organization. In addition, a key aspect of complexity theory is the focus on both system and process.

As a researcher, I ascribe to an interpretivist epistemology, which suggests that "our knowledge of reality is gained only through social constructions such as language, consciousness, shared meanings, documents, tools and other artifacts."(McKinney 2002). Writing about grounded theory, Piantanda, Tananis et al. describe their understanding of the interpretivist epistemology as "*probe(ing) contextual nuances as interpreted by ourselves in concert with others. ………..through discursive exchanges within the inquiry process we come to challenge our own self-understandings by bringing our tacit knowledge to light, recognizing our taken-for-granted assumptions, and examining our preconceptions (and perhaps misconceptions). In the process, we strive to understand and portray the range of meanings that we and others might bring to our discursive exchanges, thereby expanding our capacity to respond wisely within "discursive moments" of practice"* (2002, p. 3).

My assumptions about human nature are that actors construct their reality through interaction with others and their environment (Wood-Harper 1984). The study draws on hermeneutics as the philosophical stance for understanding the actions and decisions of the health workers and managers involved in the study. Lee (1994) describes this approach succinctly. He explains that while the hermeneutic tradition originated in the study of texts, it *"has evolved to address the general problem of how we give meaning to what is unfamiliar and alien"* (Lee 1994, pg 148). He explains further that hermeneutic scholars have included *"human actions, group behaviours, and even social institutions…as text analogues"*.

3.2.2. Action research approach:

Action research has been used as a research approach in IS research since the early 1980's (Wood-Harper 1984; Baskerville and Wood-Harper 1998). Its value lies in providing a mechanism for understanding complex social events in the real world. It allows us to analyze a "multidimensional world in which it is very difficult to analyze cause and effect" (Wood-Harper 1984, p. 180). The characteristics of the action research approach are defined and highlighted below (see Table 8) to provide a basis for explaining my choice of action research method (Baskerville and Wood-Harper 1998):

Table 8: The Application of Action Research Characteristics to this Thesis	
Characteristic of action research	**Application to the research in this thesis**
Action research aims at an increased understanding of an immediate social action	Reasons for certain behaviours (processes, or patterns, or choices) need to be understood from the perspective of the individual involved
Action research simultaneously assists in problem solving and expanding scientific knowledge	This is a key reason for the choice of action research as a research approach. Intervention in IS research need to be effected and evaluated for their appropriateness. This cannot be done through observation or non-interventionist studies alone(Baskerville and Wood-Harper 1996).
Action research is performed collaboratively and aims to be an empowering process.	Contained in this statement are two main reasons why I appreciate the action research approach. First, in many of the resource constrained settings where I have worked, participants in the process have feelings of inferiority, and a sense that their knowledge is insufficient or inferior to that available in the "developed world". The HISP approach is to emphasize the value of local knowledge developed in the "South" as being of equal value to that from the "North" and often more relevant. Secondly, where there is a constant struggle to increase understanding and address inequities, the action research approach provides a vehicle for joint learning and empowerment. As a "researcher[5]" I do not assume to have superior knowledge to other participants – rather my experiences and knowledge is different, but has an equivalent value.
Action research is primarily applicable for understanding change processes in social systems	While this is an important aspect of action research, it is secondary to my aim of empowering participants.
Action research uses feedback in a cyclical approach	I use a simplified approach to action research which suggests iterative cycles of action, reflection, and learning. Feedback is inherent in this process. Cycles can be short or long, depending on the aspect under investigation.

There is a strong emphasis in my approach to empowerment and emancipation. This approach is aligned with the philosophical underpinnings of the FOSS District Health Information Software (DHIS) which, by design, seeks to empower users in health facilities to use information for improving the health system. It is also aligned with the HISP vision and mission statements (see www.hisp.org). I would not go so far as to suggest that I see myself as an "emancipator" or "social therapist" (Hirschheim and Klein 1989), but would acknowledge that my approach and that of HISP fall into the neohumanism paradigm (ibid), because our iterative, developmental and action research approach utilizing FOSS to support HISD goes against many of the established mainstream approaches to ISD. Our approach,

[5] This is a false term as in an action research cycle, all participants are "researchers"

as indicated earlier, fits into the “dissensus” research approach which disrupts and challenges the dominant structurings of knowledge and social relations (Avgerou 2008).

In summary, the action research methodology provides an extremely useful approach for exploring, understanding, and learning about the design, development, implementation and use of IS in the health sector. It provides a mechanism to explore jointly the opportunities for improvement, while also empowering us. The approach seeks to develop locally appropriate solutions using available resources.

3.2.3. Qualitative case study method:

The use of qualitative research methods is an obvious approach given my research aim to understand the relationship between technology and its use in a social and cultural context. An in-depth and longitudinal multi-site case study method has been selected. I have had a wide range of exposure through opportunities afforded through my association with HISP-SA and the HISP international network, and related to my doctoral studies. As longitudinal action research case-studies related to FOSS are an identified research priority in the health sector of resource constrained settings (Walsham 2001; Walsham and Sahay 2006; Walsham, Robey et al. 2007; Avgerou 2008), I am aware of the “privilege” I have of working and living in this context.

In this research, the object of study are the individuals (including myself) working within the health sector to develop appropriate HIS. The focal level of analysis has varied from the micro (individuals in health facilities such as clinics, and wards of hospitals, including managers at various levels of the health system hierarchy), to the macro level (for example organizational policies and procedures). I am privileged to have been exposed to multiple sites over extended periods of time, thus affording the opportunity to not only study multiple sites, but also compare sites, and explore application of concepts between sites within the action research framework.

The selection of sites for my research has not always been purposeful (Benbasat, Goldstein et al. 1987), but has been influenced by requests for support (e.g. as in the case of the work in Zambia), project activities related to HISP-SA (for example the work in hospitals in the ECP and in Nigeria), and opportunities related to my doctoral studies (for example contributions made in Zanzibar). However, I differentiate between my exposure to action research through my professional work as a health information practitioner (HIP) working in the HISP network, and my prerogative as a researcher to select specific data for analytical purposes. In this thesis I choose to report on my experiences in selected sites based on two main criteria. First, given that my aim is to focus on the design, development and implementation of IS in hospitals, these are my primary case study sites. Secondly, I incorporate experiences from sites where I have a longitudinal exposure, as that affords me opportunities to explore issues related to sustainability and scaling of HIS. Thirdly, I include sites where ideas developed in one site have been used and adapted, successfully or otherwise in other sites, thus testing the generalizability of concepts, theories, or implications (Walsham 1995).

3.2.4. Interpretive research approach:

In conducting the research I use a broadly hermeneutic interpretive approach (Klein and Myers 1999; Webb and Pollard 2006) in line with my epistemological position, namely to *"enrich people's understanding of the meanings of their actions, thus increasing the possibility of mutual communication and influence. By showing what people are doing, it makes it possible for us to apprehend a new language and form of life."* (Chua 1986).

A framework for guiding interpretive research, and assessing its quality is defined by Klein and Myers (1999). I use this as a framework to structure my research approach, and to demonstrate that I meet the criteria for interpretive research (see Table 9 below).

Table 9: Application of Principles for Interpretive Field Research to this Thesis

Principle	Brief description	Application in this thesis
The fundamental principle of the hermeneutic circle	Fundamental to all other principles, this principle suggests that understanding is achieved by iterating between the interdependent parts and the whole	In the thesis I move between the micro and macro level, and describe steps and processes which impact the whole. This concept is fundamental to the complexity theory, while recognizing that not all individual parts of a large whole are apparent all the time
The principle of contextualization	Provides reflection of the social and historical background of the research setting so that readers understand how the situation under investigation emerged	This principle is particularly relevant to the context of HIS research in the post-apartheid period in South Africa, but also to understand the context in a country like Nigeria. My case studies describe the context using nuances to highlight certain issues (such as "Jigawa … is the sixth Nigerian state to introduce Sharia Law" (Shaw, Mengiste et al. 2007, p. 5)

Principle	Brief description	Application in this thesis
The principle of interaction between researchers and subjects	Provides for critical reflection on how the research data was socially constructed through the interaction between the researcher and participants	This is elaborated upon in section 3.3.8 of this chapter dealing with data analysis
The principle of abstraction and generalization	The mechanism whereby data is interpreted through the above principles to derive theoretical concepts describing the nature of human action	This is elaborated upon in section 5.7 of this thesis
The principle of dialogical reasoning	Requires a sensitivity to the contradictions between the theoretical preconceptions and the actual findings	I address this below in a more detailed discussion.
The principle of multiple interventions	Requires a sensitivity to possible differences in interpretations among participants	I address this below in a more detailed discussion.
The principle of suspicion	Requires sensitivity to possible biases and systematic distortions in the narratives collected from participants	I address this below in a more detailed discussion.

Three of the principles warrant further elaboration here. The principle of dialogical reasoning requires the researcher to declare the type of interpretivism s/he prefers, declare its roots and relate the strengths and weaknesses of the approach to the purpose of the research. This principle has manifested itself in at least two ways in my experience to date. First, I have indicated my preference for hermeneutic interpretivism, and my support for emancipatory approaches and the neohumanism paradigm. The strength of these approaches are that they are closely aligned to the use of complexity theory and co-evolutionary approaches to IS development which support learning processes through interactions with others and the environment. However, the weakness that this philosophical approach brings is that in my enthusiasm to see the “right thing done” I may take the lead and use my “authority” to exert influence which goes beyond that expected in an action research approach. Secondly, in the early days of my enrolment as a doctoral student, I was deeply attached to the outcome of the hospital project in the ECP, so much that it was difficult for me to distance myself from the project and reflect objectively about the success or otherwise of the project. Similarly a few years ago I was deeply attached to the DHIS as the “be all and end all” of systems for use in the South African HIS sector. Over the course of these studies, I have come to realize for instance that there are roles for other systems to play, and in fact it is advantageous to have diversity in the sector, and that there are advantages to fluctuating relationships between seeking alliances and partnerships sometimes and positioning ourselves as opponents at other times.

While I have always tried to be aware of the principle of multiple interpretations, it has recently been presented to me as an issue. In response to my trial defense presentation in June I received an email from a fellow student who very politely questioned my statement that the DHIS was in use in all of South Africa, highlighting that as far as she was aware, it was no longer in use in the Western Cape, and that this raised questions about my statement that the DHIS has been a sustainable system in South Africa (see Text Box 3 below). My response to this was to check this with my colleagues who are more familiar with the

Original Message

Sent: 02 July 2009 01:15 PM

Hi Vincent

I do however have a few comments on your presentation of HISP and DHIS in a timeline, and your use of this in your argumentation later related to scaling and sustainability; HISP here presented as being an external and third partner in hospital system development that would account for sustainability.

I find it problematic to find HISP and DHIS described as if it is still deployed and used in the whole WC province. You do not say this explicitly, only that this is what happened in the beginning of the HISP history, but you also do not tell that DHIS is actually not in use in the provincial/city health facilities (or hospitals for that matter).

HISP is not an active third partner in WC province - as far as I could find out during my stay recently. On the contrary, both the Provincial health department and the CT City Health have developed their own patient based information systems, where the Province's Primary Health Care Information system (PHCIS)-developed by MSF, UCT and the PGWC in cooperation, with a number of modules - and linked to the hospital system Clinicom (replaces Delta 9), seem to be very comprehensive and promising.

Response 1:

I forwarded this email to some of the HISP-SA team members, saying " I find these comments interesting – an [sic] perhaps reflecting a view that we are less open to - namely that the DHIS has essentially "failed" in the Western Cape. Could I ask you to read her comments, and comment from your understanding of the situation whether she is in fact correct?"

One of our team forwarded the email on to a colleague who works more closely with the Western Cape DoH than we do, requesting her opinion. This was her reply:

Response 2:

Sent: 06 July 2009 02:02 PM

With regard to Vincent's message - I am not aware that the DHIS has essentially "failed" in the Western Cape. They use Sinjani by choice. They still use DHIS 1.3 to send the data to NDoH. They received an installation CD from Calle for 1.4, but with several outstanding issues and they don't want to use it unless DHIS 1.4 is 100% what it should be. It appears that Calle don't have time to do the corrections (not a good marketing of DHIS).

The only message that I get nowadays from them is that they battle with DHIS to export data to data mart to update pivot tables. The IT people then informed them that the data become too much for Access to deal with.

Text Box 3: The Principle of Multiple Interpretations in Practice

situation in the Western Cape. The email exchange is transcribed in the text box below to illustrate the principle in practice, and to highlight that vigilance is constantly required to the possibility of different interpretations. It is interesting too to observe that the study of CAS suggests that diversity should be welcomed as it is at the point of interchange between divergent views that new ideas arise. This principle therefore is closely aligned with those espoused under CAS theory.

In examining the principle of suspicion, I must admit that this is an issue that I am aware of, and about which I have reflected critically. For instance, I have been troubled by the fact that colleagues have written quite extensively about the power-play involved in ISD (see for instance Puri and Sahay 2004; Sahay, Monteiro et al. 2007; Sahay, Monteiro et al. 2009), yet I have only raised this issue in passing. Am I ignoring the issue, or choosing to focus on other priorities? Am I being unfair to my co-researchers by not raising these issues more openly? I do not as yet have the answers to these questions, but I can suggest that there may be two reasons behind this apparent discrepancy. First, it may be that these issues are more prominent in other contexts (such as that in India, which is comparable to half the African continent for example) where the stakeholders are many more, and the politics play a more prominent role than in the contexts in which I work. Secondly, perhaps I do raise these issues but in a more subtle manner (for instance I criticize the National Department of Health (NDoH) for their stance on hospital datasets (Shaw 2003, p. 8)). When writing about action research projects, I have always been wary of being overly critical in my approach given that this may offend colleagues, and jeopardize not only my, but also other research team members' ability to gain access to people or data should I be seen to be biased in my criticism. To this end, I have always tried to be constructively critical, so as to ensure that doors are not closed on our access.

I conclude this section suggesting that adherence to the principles for interpretive field studies requires constant vigilance and rigor in the research approach. Perfecting the technique does not happen overnight but rather as a process of learning and reflection over time. How we respond to the principles can change from day to day, depending on the context, and what at that time is seen to be the correct approach. I now provide insight into the selected research sites.

3.3. Research setting:

In this section I describe the fieldwork that was conducted as an introduction to the research context. Next, the context is described with respect to the ECP of South Africa, Northern Nigeria, Malawi and Zambia, and then in relation to the HISP-SA organization. I then describe my role as researcher, the data collection methods, data analysis and use of theory, and lastly data validation.

3.3.1. Fieldwork

Data presented in this thesis is drawn from four research sites. The table below provides an overview of the amount of time spent on site for each research project, and the total amount of time allocated to that project. This data is drawn from my diary and timesheets. Figure 6 provides a timeline which demonstrates my employment position or role played, the research projects relevant to this thesis, and the time period and publication date that the seven papers that constitute this thesis cover.

Table 10: Distribution of time across project activities

Country	Period	Total days	On site (Notes 1 and 2)
ECP Hospitals	April 2004 - March 2005	100	60
Malawi	December 2003 - August 2005	161	72
Nigeria	Oct 2003	21	20
	Feb 2006 - present	200	185
Zambia	Feb 2007 – Dec 2008	159	140
Zanzibar	2005	10	10
Total		**651**	**487**

Note 1: On-site means working with health care workers or in training sessions with workers, or attending meetings and discussions, either with team members, or with managers in the health service at departmental, hospital, provincial/national level

Note 2: The balance of the time (that is difference between on-site and of-site work) was spent on administrative issues, emails, project management issues and office support (this includes the production of reports, documents and policies).

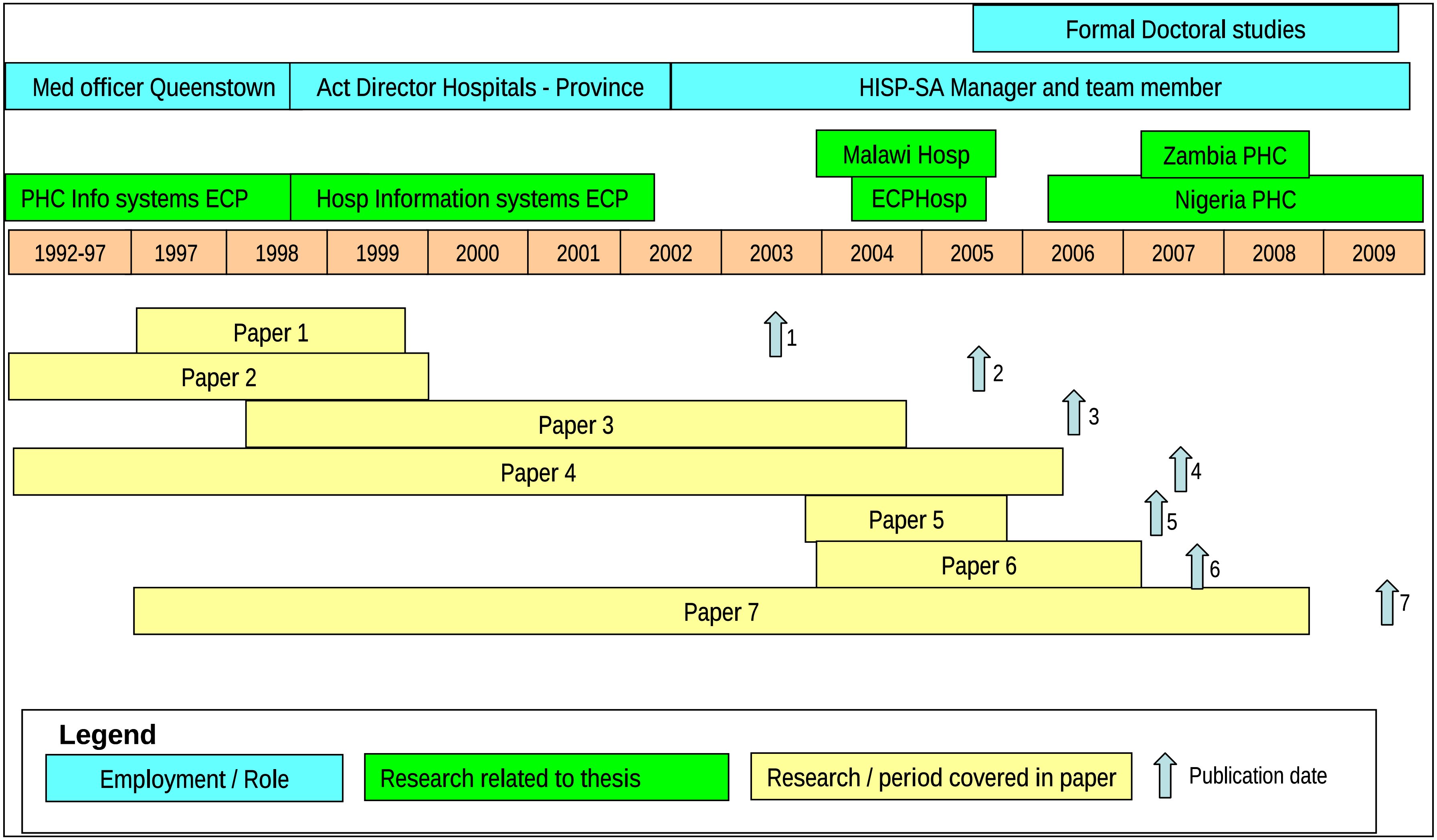


Figure 6: Timeline of Research Activities and Publications

Most of the publication/development of papers presented in the figure above took place over a 5-6 year period, but the experiences they describe are drawn from a much longer time span. Each paper reflects a distinct phase of my professional life and doctoral program. They also depict the development of my ideas and thinking across a number of areas. For example, the first papers are far more practice based, and focused on specific technical issues, while the last papers contain more theoretical insights and pay closer attention to the close interdependencies between the social and technical aspects of ISD.

The first paper was written just at the time when I was thinking about embarking on the doctoral program, and still working for the Eastern Cape Provincial Department of Health. The second paper describes experiences of developing a standardized dataset in a remote Queenstown region of the ECP from 1992 to 1999, at a time when the health systems were being reformed with a view to a post-apartheid health system. The third paper is special in the sense that it is a product of an extremely important phase of my PHD life which was influenced by Eduardo Jacucci's field visit to South Africa for his PhD studies and during which we had many opportunities to discuss experiences in the field, theorise, and develop ideas. The hospital described in this paper is one of the Provincially Aided Hospitals (PAH) that were particularly important in my professional life as we were able to develop innovative programs with them, partly due to the fact that they were legally constituted independently from government (and could therefore do things differently). The fourth paper is probably the most significant in the collection seeing that it was published in MIS Quarterly, but it is also special because I was brought into the writing team just at a time when I discovered CAS theory as a possible lens through which to view HIS. Being part of a "high-powered team" involved in developing the paper was a new experience for me, and I enjoyed seeing how the paper emerged out of the contributions of a wide variety of people. The fifth paper marks an important milestone as it draws on my experience with the HISP-SA team in 2004/2005 during which we worked in 13 hospitals in the ECP to strengthen their HospMIS – the first significant project we effected as an independent NGO. The sixth paper is an important piece for me because the concept of balancing human resource development, access to technology, and information processing capacity was one which emerged in the HISP-SA team reflections on challenges in ISD in the Nigerian context. This model still resonates with me and other practitioners, and should probably be developed further for publication. The last paper is interesting in that it provides some reflection on 10 years of HISD in Africa supported by the HISP-SA team. Particularly interesting to me are the approaches to scaling of HIS that are being considered in Nigeria, and the development of regional networks of HIPs.

3.3.2. The Research Context 1: Eastern Cape Province[6]:

a) Introduction: Overall indicators for the province:

A large portion of the empirical data on which this thesis is based comes from the development of HospMIS in the ECP. At the time of the project, the post-apartheid reform process (10 years post 1994) was still ongoing. In this section I provide some insight into the research context in this province.

Prior to 1994, the ECP consisted of three independent administrations (two of which were homeland administrations) which had to be merged with one another into a single administrative unit in the post-apartheid era (see Figure 7). This process was extremely complicated, and took much longer than initially planned (Engelbrecht and McCoy 1999). Not only did staff have to change employers and have conditions of service standardised, but administrative and financial routines had to be homogenised and standardised. At the same time, at the national level, political processes were recreating boundaries of provinces and local government areas (which affected the health district boundaries and the hospital catchment areas), and standards for patient care, drug supplies, and financial allocations were being determined. Multiple change processes were being enacted at different levels within and outside of the health care sector.

The ECP has a surface area of 169,580 km^2, (that is just less than ¾ the size of the United Kingdom). It has a population of 7.1 million people, with 65% living in rural areas. The Province is one of extreme diversity and inequity, and can be described as consisting of two worlds. It consists of a very well developed western section, around Port Elizabeth, which falls within the area of the former South Africa; and a more underdeveloped area in the East which falls into the area known formerly as the Transkei. The indicators differ remarkably across these two areas, as shown in Table 11, with the Eastern area tending to reflect health status of a developed country, and the Western area reflecting that of a developing country. The ECP has an overall unemployment rate 48.5% (but in some areas it is as high as 77% - this compares with 20.1% in the Western Cape Province and 28.2% in Gauteng Province (Mahlalela, Rohde et al. 2000)), and 98% of people live in informal housing "… reflecting traditional unserviced sites. In 2005, only 7% of households have potable water on site and 47% have a flush toilet or pit latrine, reflecting major social backlogs" (Eastern Cape Development Corporation 2005)

---

[6] A large portion of this section has been published in Shaw, V. (2003).

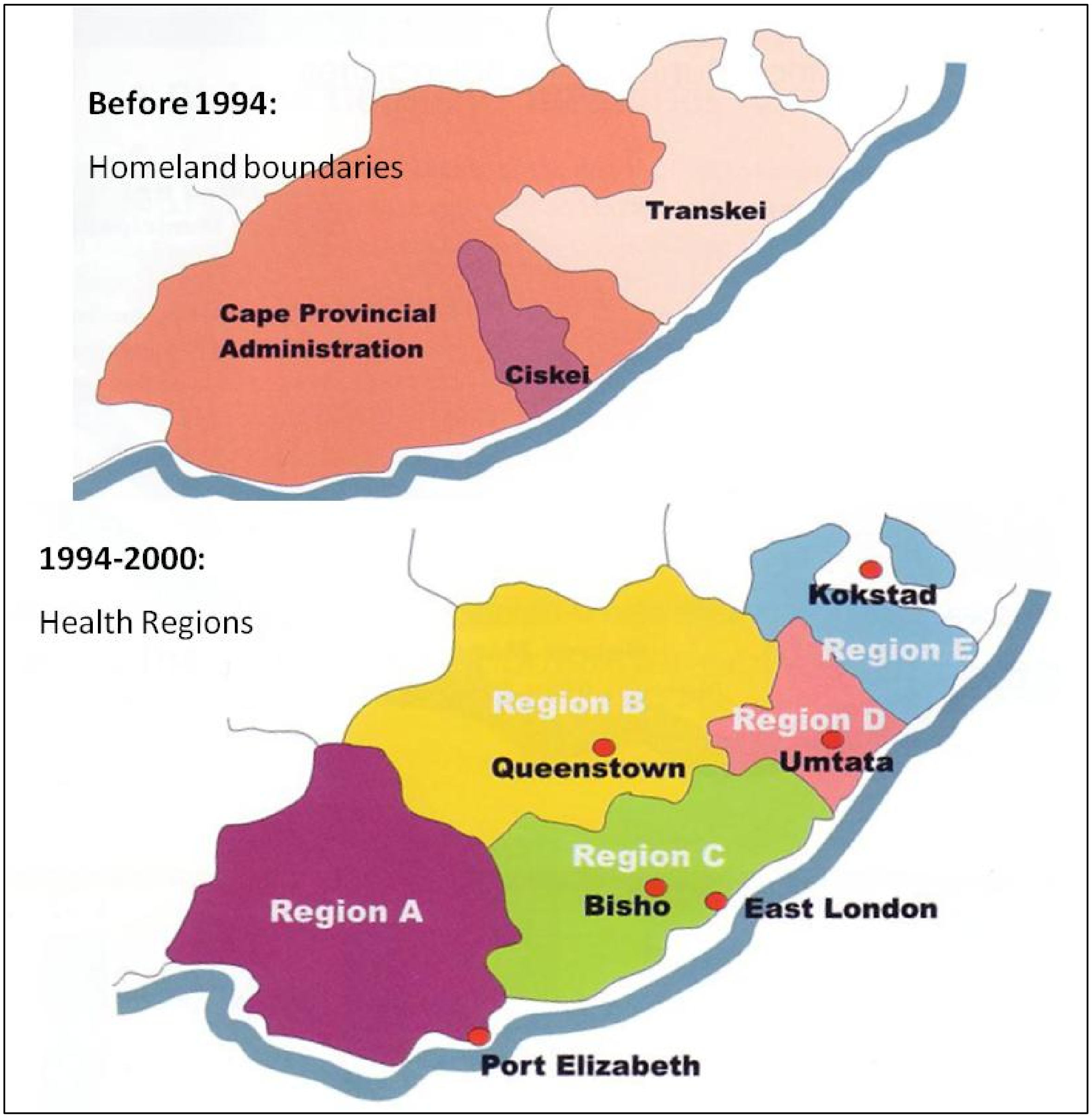


Figure 7: Restructuring Local Government in the ECP
(Adapted from Mahlalela, Rohde et al. 2000)

.

Table 11: Comparison of Key Indicators

(Source Eastern Cape Development Corporation 2005)

Indicator	Eastern Cape Province	Port Elizabeth Region	Kokstad Region	South Africa Average
Infant Mortality (1998) (Deaths per 1000 live births)	61.2	35	99	45.4
Under-5 Mortality rate (1998) (Deaths per 1000 live births)	80.5	35	108	59.4
% Clinics with piped water (1999)	61	100	19	
% Clinics with water-borne toilets (1998)	72	100	65	100
Percentage children fully immunised	52.6	65	37	
% clinics with access to grid electricity (1998)	82.4	100	66	

The former Transkei area also has a very poor road infrastructure, with many roads to hospitals being impassible in the summer rainy months. Vehicles quickly rattle to pieces in the bad conditions, leaving hospitals with little or no transport to transfer critically ill patients. In the Western half of the province the road infrastructure is much better developed.

b) Restructuring the health services:

Post 1994, the need to re-organize services was highlighted during the development of the "District Health System" which had to incorporate, within a single structure three homeland governments (see Figures 7 and 8), and numerous other service providers, both local government and the fragmented departmental systems. The District Health System that has emerged consists of clinics providing PHC services and grouped into geographic areas called sub-districts. Clinics generally refer patients that require more sophisticated care to district hospitals, or community health centres. The district hospitals in turn refer their patients to regional hospitals. Each district is managed by a district management team, and the team is made up of supervisors who work at the sub-district, or district hospital level. District Managers report directly to the Provincial Management.

The hospitals in the province reflect the same diversity that is reflected in the population indicators. Infra-structural backlogs need to be addressed, particularly in those hospitals in the former Transkei area. Inequities exist between staffing ratios in the Western areas,

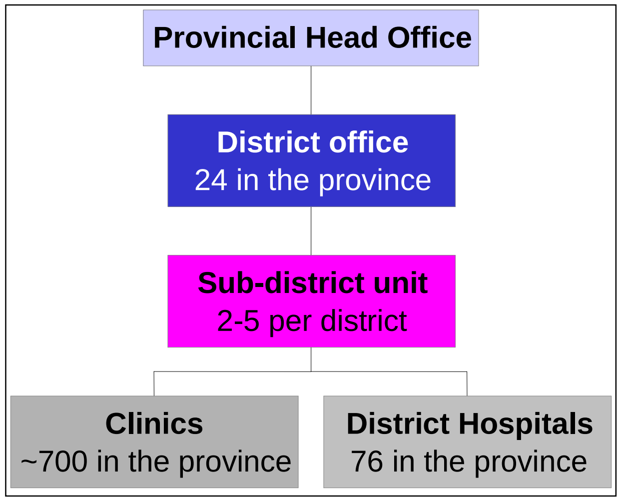


Figure 8: Organizational Structure of the District Health System in the ECP.

particularly in the East London area (which includes some of the former Ciskei homeland), and the Eastern half of the province (see Text Box 4).

Text Box 4: Background to staffing inequities in the ECP:

In the Ciskei area, during the apartheid era, staff went on strike, and were dismissed, and new staff were employed. The Government was overthrown, and the successor found the dismissal of staff to be an unfair labour practice, and had the dismissed staff re-instated. The result was that in several facilities, there were twice as many staff as are actually needed. On the other hand, in the former Transkei area, staff have not been replaced as natural attrition occurred, resulting in staff shortages in these facilities.

Because the hospital sector has seen significant reduction in real terms in its per capita allocation as a result in the shift of services towards the PHC approach, there has been a critical evaluation of the services hospitals provide and how best to improve efficiency levels. This is the context in which the hospital information systems required re-assessment.

c) Restructuring the health information system:

Even today, access to computers and internet are uneven[7], as demonstrated by the fact that some hospitals have access to internet, but this is not universal. Within hospitals, computers are also not evenly distributed – often the administrative departments are the first to gain access to computers, reflecting the priorities of those that control the budgets.

The data set for the hospitals in the ECP was determined shortly after the new government was elected in 1994. It consisted of 13 data elements, and was largely inherited from the former Cape Provincial Administration dataset. Of these, 5 related to financial data, and were seldom completed, as many facilities did not have access to the (legacy) computerised Financial Management System (FMS) that was operational in the former "Cape Provincial Administration" part of the province, and as a result the collection of these elements were meaningless. In addition, although clear definitions were provided, data was not collected in a uniform manner. The result was that the data submitted for a single data element, often meant different things, depending on the nature of the facility and how the data was collected. The result was that the data could not be used to compare across facilities. An example of this was the data element "casualty" visits. In some facilities, casualty patients and out-patients were seen at the same place, and recorded in a single register. However, no distinction between these groups was made, and as a result in some instances data submitted reflected all patients seen in that venue, while in others, it reflected only the casualty patients.

Data from hospitals was supposed to be submitted regularly to the provincial office. However, in the provincial office there was no system for collection of this data, its recording, evaluation, and no feedback to facilities was ever given. A spiral developed whereby facilities lost interest in the data collected, submission became haphazard, and the data was not used by anyone at the provincial level.

During 1999, an assessment of information use in various hospitals in the province was undertaken. The resultant report indicated that:

- Data is collected "at all levels in hospitals, but most of it is never used"
- Indicators are submitted to the district offices, but give a "very bland picture of administrative activities, and no *feeling* of what goes on inside hospitals"

---

[7] Uneven is used in the sense that the diffusion of a technology often does not happen uniformly and according to priority needs, but is often a haphazard and unequal distribution reflecting the active social and political networks.

- "Registers are non-standardised, and tend to be anarchic, and hand written", and often on an assortment of different types of paper and books
- "analysis of data is minimal at all levels".

d) Conclusion:

This brief analysis provides an understanding of the context in which a large part of the research takes place (papers 1, 2, 3, 4 and 5 draw on data collected in this province). It reflects the typical context in resource constrained settings, although the context was exaggerated by the post-apartheid reform processes. In the next sub-section I provide a brief overview of the Nigerian context, and thereafter I elaborate briefly on the situation in Malawi and Zambia.

3.3.3. The Research Context 2: Northern Nigeria[8]:

a) Introduction: Overall indicators for the province:

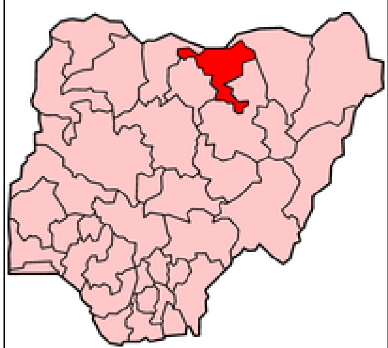
I have spent most of my time in Nigeria between Jigawa and Kano, two states located in the north of Nigeria. In this description I focus on the situation in Jigawa as representative of the area as a whole (see Figure 9).

Jigawa is a relatively new state, having been created out of the Kano state in 1991. Sharia Law was introduced to the state in August 2000, making it the sixth Nigerian state (out of 37) to adopt Islamic Law. The state is divided into 27 local government authorities, and state and local government councillors are democratically elected. The state of basic infrastructure is weak in Jigawa, as is evidenced by poor electricity supplies, and the absence of a fixed landline telephone network. Cellphone reception is available in most major centres, although

[8] An abridged version of this description was published in Shaw, V., S. Mengiste, et al. (2007)

Figure 9: Jigawa State, Nigeria

(adapted from Wikipedia http://en.wikipedia.org/wiki/Jigawa_State)

Location	Statistics	
	Surface Area	23,154 km^2
	Population 2005 est.	4,9M vs 131,5M for Nigeria
	Polulation under age of 15 years	49%
	Literacy Rate (2002)	22% for women and 51% for men
	Gross per Capita Income (2001)	$290 vs $1,188 Nigeria average

still scanty in the rural areas. The road network between major centres is fairly well developed with most main roads having been recently tarred. There are very few computers outside of the government offices, and internet access is limited. The government sector is the main employer in Jigawa, and the per capita income in this state is far lower than that in other states.

A concerted effort is directed at building capacity in the local government councils to manage local affairs, as for example with health services. Local governments are allocated budgets, and in the case of the health sector, are expected to use this to fund health services. However, there is often a significant mismatch between the allocation, and expectation in terms of service delivery. Funding for health services are supplemented by user fees, and donor driven aid projects. However, LGA's are still struggling with basic infrastructural issues like access to computers, internet, and computer literacy skills.

The maternal mortality rate is estimated to be 2000/100,000 live births in Jigawa – several times higher than that for Nigeria as a whole (Jigawa State Government 2005). This is understood to be multifactoral in causation, including the lack of utilisation of health services by the general population, reliance on traditional birth practices, inability to access health services when they are needed, often in an emergency, and poor health service delivery at the 508 public health facilities in Jigawa.

b) *Strengthening Health Information Systems:*

The PATHS project, is a 5 year GBP39 million DFID funded project, which has been supporting health systems development in 5 states in Nigeria (Jigawa, Kano, Benue, Ekiti, Enugu) through targeted programme support, particularly to maternal (safe motherhood and delivery services) and child health programmes, malaria and tuberculosis and sexually transmitted infections. Supporting the HMIS has been integral to these, and has involved the development of an essential data set (EDS), the introduction of the DHIS, and the development of data collection tools. The process of information flow from facility to state level, and the provision of feedback has been strengthened through numerous training initiatives, and the development of a data flow policy.

The health system is arranged in a hierarchical fashion, as depicted in Table 12. In this table we attempt to provide an understanding of the access to electricity and computers. Clearly, in this context, reliance is made on paper-based HIS for data collection and onward transmission, from facility, through local government authority level, and up to state level. However, resources are so limited, even the submission of monthly reports is often delayed because staff do not have money to transport the forms from the LGA level to the State HMIS offices.

Table 12: Access to Critical Resources for HIS Strengthening in Jigawa

Hierarchical level	Numbers of staff	Staff involved in the HMIS	Access to computers and electricty
Facilities	508	At least one person in each facility participated in training on use of information	Seldom have access to grid electricity. May have solar panels, which often are non-functional. Rely n paper based data collection, but paper itself is in short supply (see photo of register).
Local government	27	One PHC Co-ordinator (political level) and an Monitoring and Evaluation Officer[9]	Grid electricity is unreliable. Almost no computers at this level.
State Ministry of Health	1	State HMIS Officer, and 3 data entry clerks	Grid electricity is unreliable, and more often than not reliance is on a generator which usually only runs ”when certain senior officials are in the office”. Three computers and one laptop

[9] In reality, there are more people involved at this level, as many of the vertical programmes have their own “M+E officers” – reflecting the constant battle between integration and verticalization (fragmentation) of services, especially in an environment which has a large donor driven component

Training initiatives have focussed on three main areas – initially all facility staff, local government PHC co-odinators and M+E officers, and state HMIS officers received training on the importance of information in health service planning and assessment, and on the use of indicators for monitoring and evaluation of services. At local government level, the PHC co-odinators and M+E officers have participated in two three-day workshops during which they were presented with raw data that had been submitted, and indicators calculated from the raw data – a very practically orientated training programme aimed at using available information to assess and improve service delivery. At the state level training on the use of the DHIS has been provided to the HMIS unit, as this was the only level at which data capture was possible.

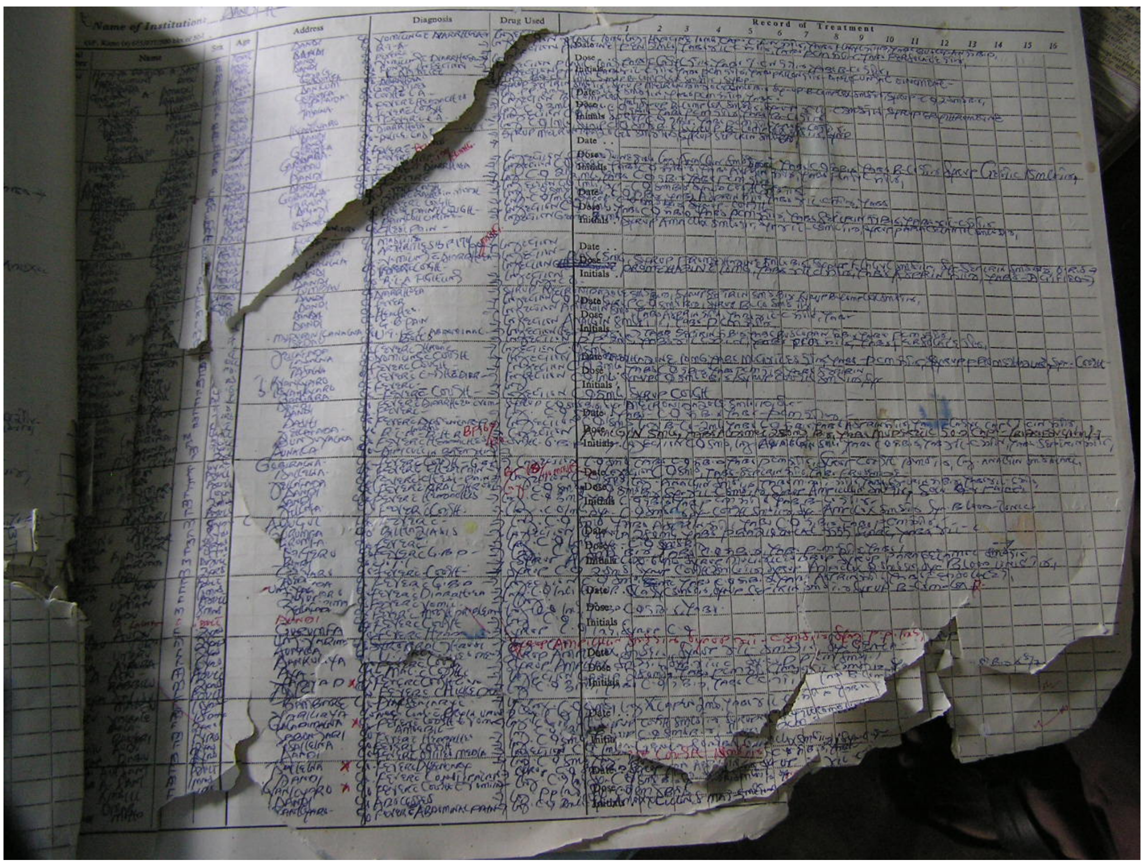


Figure 10: The register in use at a dispensary

Resources like paper, pens, pharmaceuticals, and equipment are scarce. For instance, the register highlighted above (Figure 10) had three patients names meticulously recorded on a line that was meant to take one patient’s details – this in an effort to save paper. While it is a magnificent effort on behalf of the health worker, it is not very easy to determine usage data from this type of register.

c) Conclusion:

This brief analysis attempts to show the extremely limited access to electricity and computers, and low levels of staff computer literacy in a state with a relatively large population and desperate need for improved health services. Despite these limitations over the last 5 years, a HIS has been developed and implemented, and at present regular data is received from approximately 50% of expected facilities (see Figure 11). This is one of the best HIS in all of Nigeria. The activities reported on here have been described in papers 6 and 7.

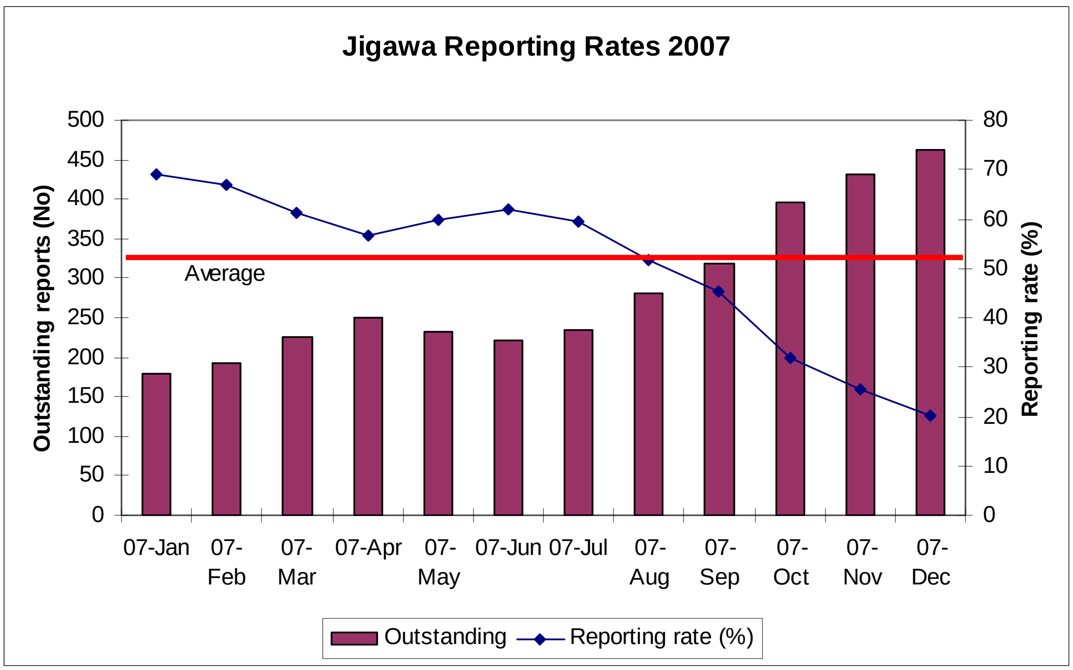


Figure 11: Jigawa Reporting Rates for 2007 (source DHIS data as at Feb 2008)

3.3.4. The Research Context 3: Malawi Central Hospitals and Zambia:

a) Malawi Central Hospitals:

Compared to the ongoing activities in Nigeria and the ECP Hospitals project, the activities in Malawi were relatively well circumscribed and concise to effect in that the locations were in large cities in Malawi, and reasonably reliable access to computers and power supply was available at least in the HMIS units in each hospitals. The aim of the project was to strengthen the data processing from wards and out-patient units to the HMIS units, so as to provide data to managers at all levels of the system. These efforts were part of a larger “Hospital Autonomy Programme”. The key interventions in this project were to enable data to be disaggregated down to reporting unit level, and the data set was clearly defined and reduced to a manageable number of data elements. As is reported in the thesis, one of the main problems in this project was to overcome the heterogeneity in terms of access to computers in different departments in the hospital, and to gain buy-in from various departmental heads – many of whom were only interested in clinical service provision and who viewed any administrative or managerial interventions as an invasion of their independence.

b) Zambia:

The Zambian Ministry of Health (MoH) identified a need to revise their national health management information system (called the HMIS) because the database in use was not able to be adjusted to accommodate new reporting requirements. While this database had been in use since 1996, it was a hard coded access database, and because of its inflexibility, a multitude of parallel IS were in use in the country to report for instance on HIV/AIDS indicators, TB data and malaria. We were asked to appraise the system in use, and utilize the DHIS to integrate the different systems, while ensuring that existing functionality and reporting abilities were maintained.

The project was EU funded, and five terms of reference were issued related to different pieces of the HMIS revision. Of these HISP-SA was contracted to work on three of them. Two interesting aspects about this project require mention. First was that we found that the envisioned sequence of events (that is, develop and implement the database) would not work well because it did not make sense to insert a dataset that had not been redefined to incorporate a comprehensive set of data elements and indicators. Because of our involvement in a number of consultancies, we were able to effect this re-organization despite the relative rigidity of the EU contracting mechanism. The result was that we first redefined the National Indicator Dataset, and then incorporated this into the DHIS database. Secondly, because of numerous delays on the project, we were placed under pressure by the MoH to collapse what had been planned as two sequential activities into concurrent activities – namely gaining consensus on the use of the system and the training materials, and building capacity in a team of trainers to use the training materials in the roll-out of the revised HMIS across Zambia. Because HISP-SA was involved in both activities, we decided to structure it in such a way that we could utilize the trainees to provide input into the draft training materials, and pilot the training materials as part of the capacity building program. A three phased approach was therefore adopted:

- Expose a group of "potential trainers" to a draft version of the training materials – as part of their first round of exposure to the materials, allow them to give input into the local customization of the materials;
- Allow the trainees to use the revised draft to effect a round of "pilot training" to build their skill as trainers, and to expose the training materials to a second round of exposure and modification;
- Revise the materials into a final format after these initial rounds of exposure, and then support the trainees in utilizing the materials to provide another round of training as part of the final step in their capacity building process.

This description provides another insight into the nature of HospMISD in resource constrained contexts, namely the frequent need to adjust the implementation strategy to accommodate deviation from original intent.

3.3.5. The Research Context 4: HISP-SA:

Over the period mid 2002 to mid 2009, HISP-SA has grown from a small 6 person consultancy firm to a 20 person team working in numerous countries on a regular basis. The way in which we function has had to undergo significant changes, and the organizational structure has changed as well, such that we now have an middle manager team emerging between senior management and more junior staff. We continue to have a diversified staff compliment composed of professional software programmers and staff with IT technical skills, health personnel (one doctor, several professional nurses, an environmental officer), educationalists, and administrative staff. There are many interesting facets to HISP-SA. For instance,

- we operate as a "virtual organization" with our team scattered across 6 centres (Windhoek, Durban, Cape Town, East London, Pretoria and Johannesburg, Maseru) and three countries (South Africa, Namibia and Lesotho). This creates opportunities in that we can utilize staff close to home for projects in and around these centres, but it also creates challenges in terms of maintaining a coherent team and effecting regular communication and sharing of experiences;
- despite very little marketing of our skills and products, the use of the DHIS, and our strategies for supporting HISD continue to be in demand and the demand appears to be escalating. Yet, what is the optimum size for our organizations and should we continue to expand in response to demand;

- how do we balance the apparent conflicting drives to maintain our organizational flexibility and informal ethos while also growing and establishing more formal structure to provides sufficient security to our team members;
- what are the implications of the apparent contradiction between freely sharing our software and training materials in accordance with the FOSS philosophy, while also attempting to maintain our position within what is potentially a competitive market;

I raise these issues because they reflect tensions that over the last 4 years have become increasingly important to explore and manage. These tensions are closely related to the research described in this thesis, in that a central theme that emerges from this thesis is that HospMISD requires a team approach to support it. As is discussed below, over the course of my doctoral studies, I have become increasingly aware of the important role that an organization like HISP-SA plays in supporting HospMISD in resource constrained settings.

3.3.6. My role as researcher

It has been suggested that action research is sometimes branded as “consulting masquerading as research” (Baskerville and Wood-Harper 1996). To differentiate between consulting and action research, four factors are identified (ibid, p. 241):

- Researchers require more rigorous documentation than do consultants;
- Researchers require theoretical justifications and consultants require empirical justifications;
- Consultants operate under tighter time frames and budgetary constraints;
- Consultancies are usually linear (engage, analyze, action, disengage), while the action research process is cyclical.

A useful framework that builds on this assessment, and which I found useful for my particular context is presented below (Figure 12) (Cronholm and Goldkuhl 2004)

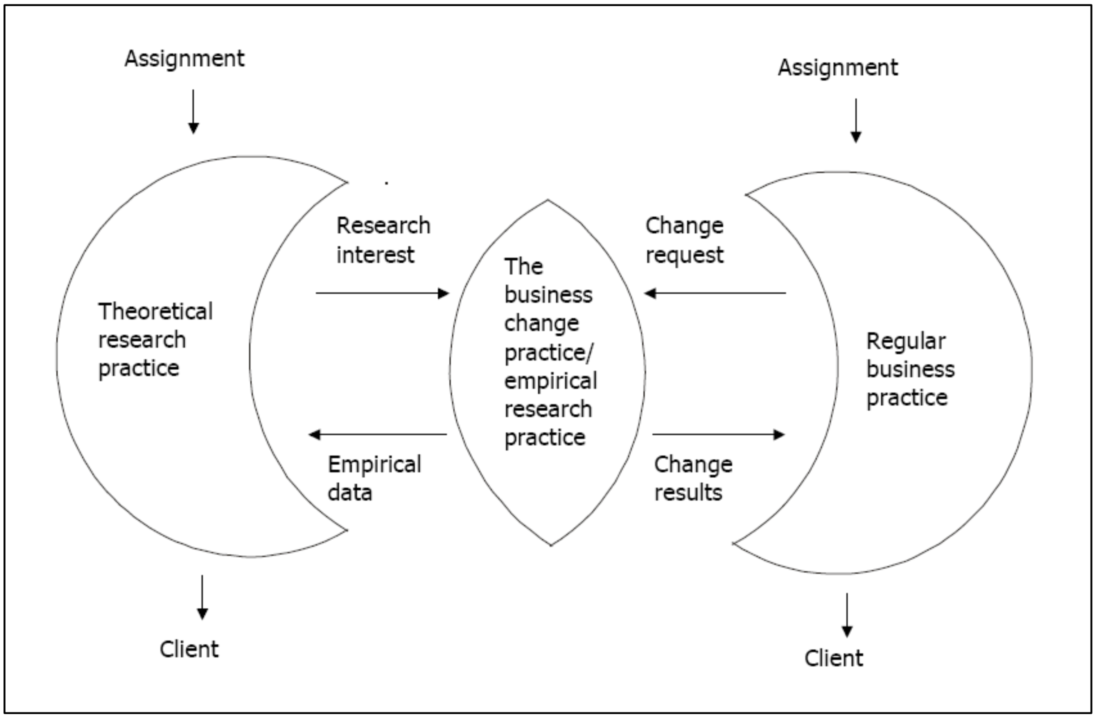


Figure 12: Conceptualizing Action Research as Three Inter-Linked Practices (Source Cronholm and Goldkuhl 2004, p. 54)

This suggests that the process of conducting action research with respect to effecting a business change can be viewed as three interacting practices, namely the regular business practice, the theoretical research practice, and the joint business change practice/empirical research practice (called JBER practice from now on). This analysis supports my understanding of the process that I have followed through my career. Using this framework, I can suggest that the location of the action research that I report on has been in the JBER practice. It is at this site that I have engaged with colleagues to explore options and possibilities, and it is at this level that first-order concepts are generated (Van Maanen 1983). These are the “facts” of the situation and are “the understandings held by the observed people themselves” (Lee and Baskerville 2003). In the case of an action research cycle, the “observed people” would include the researcher as a member of the action research team, who plays two roles, of researcher and change actor (Cronholm and Goldkuhl 2004). However, when the researcher steps back from the JBER practice, and develops theory, then second-level constructs are generated. These are the interpretations of interpretations.

I would say that during my specialization as a family practitioner I became aware of the importance of being a reflective practitioner, but that during my exposure to the doctoral studies program this aspect has become a more intense part of my professional life. The research process has therefore been an iterative one whereby experiences and new methods of working have been able to be shared, and tested between research sites – a new prototype in one site thus came to be tested in another. In this way, prototypes have been developed and tested, adjusted and then implemented again.

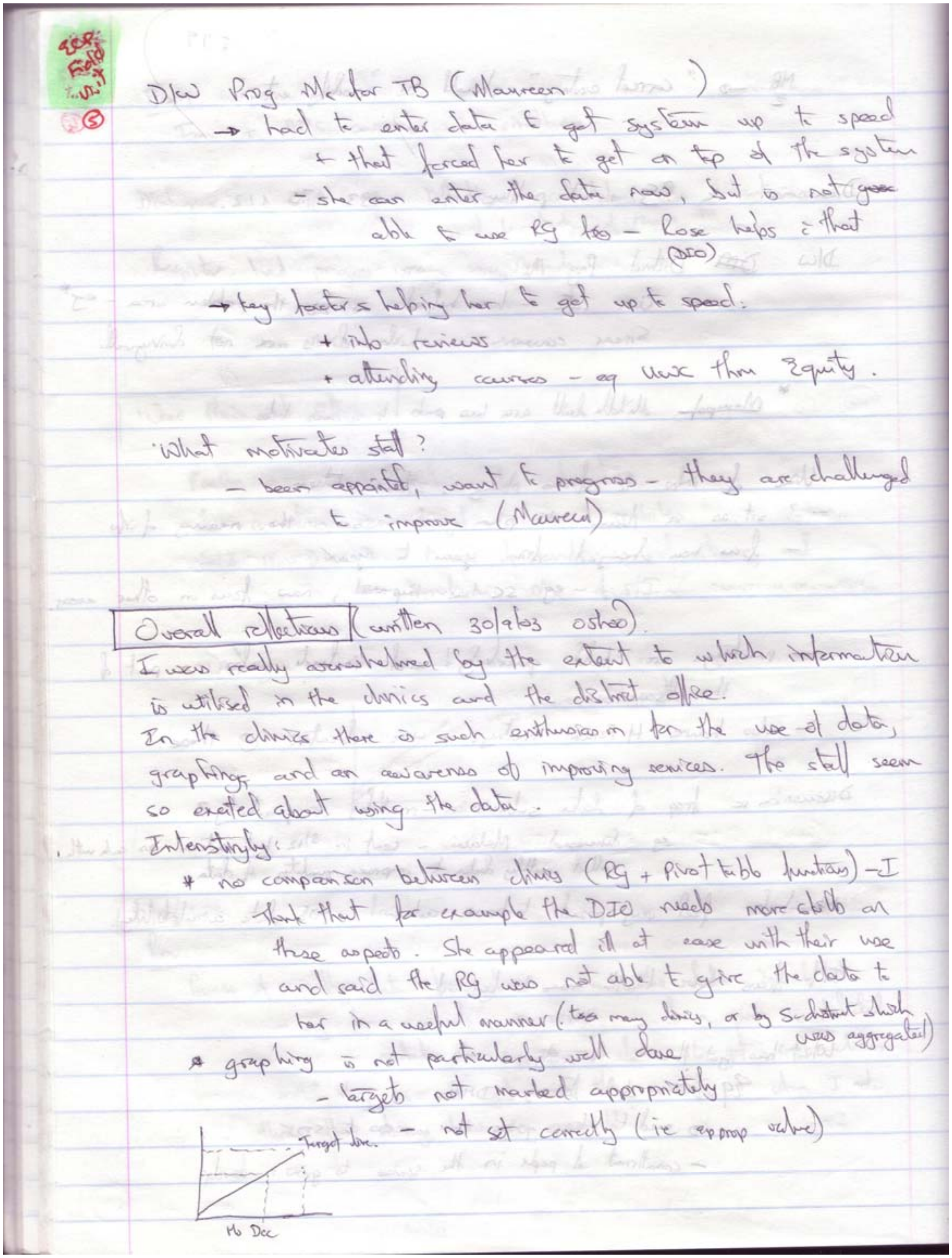
3.3.7. Data collection methods

Primary data for this research has been drawn from a number of sources: Most useful has been a personal diary. I used A4 sized notebooks during the various research projects to record interaction with people, meeting notes, and decisions. I also used these to record reflections, most often at the end of the day, or while flying home from an assignment (see Figure 13). As these diaries are sequential records of daily activities, I have found it easy to go back to them to re-assess my notes related to a particular event.

In addition I used a camera to document interesting artifacts, flipchart sheets of important decisions or flow patterns, and meetings and training sessions. At times I recorded meetings or interviews. If I had recorded a particularly important interaction, I sometimes would listen to it again in the evenings, and then make notes on my reflections related to the recording. Sometimes, if I felt I had been party to a particularly interesting process during the day, I would rather than write my reflections in my diary, dictate my reflections into my recorder.

The luxury of being involved in the research sites, if not the projects themselves, over an extended period of time, has improved the data quality from two perspectives. Firstly, it has provided the opportunity to reflect on the changes and progress in the research sites over time, thus providing insights into the sustainability of certain interventions, and secondly, has enabled me to develop strong relationships with health workers at all levels of the hierarchy, which has allowed me to be privy to many “inside” discussions and reflections that I might not have been exposed to as an external unknown researcher. For instance, in some sites, trust was not always as deep as it was in the ECP. I recall an instance in Malawi when I was meeting with the Director of the MoH HMIS unit, to discuss our approach in the central hospitals, and I asked whether I could record the interview. There was an uncomfortable pause, and then he responded to say that there was no need to record the discussions as we would have minutes to summarize the important decisions. I of course agreed to this, but recount it here to indicate that it is not always appropriate to utilize recording materials, and in fact, my experience is that the presence of recording materials may detract from interviewees’ feelings of trust and comfort.

I have on occasion used in-depth interviews with key informants, but this has not been



D/W Prog Mx for TB (Maureen)
→ had to enter data to get system up to speed
+ that forced her to get on top of the system
– she can enter the data now, but is not yet
able to use RG too – Rose helps with that
(DIO)

→ key factors helping her to get up to speed:
+ info reviews
+ attending courses – eg UWC thru Equity.

What motivates staff?
– been appointed, want to progress – they are challenged
to improve (Maureen)

Overall reflections (written 30/9/03 osheo)
I was really overwhelmed by the extent to which information is utilised in the clinics and the district office.
In the clinics there is such enthusiasm for the use of data, graphing and an awareness of improving services. The staff seem so excited about using the data.
Interestingly:
* no comparison between clinics (RG + Pivot table functions) – I think that for example the DIO needs more skills on these aspects. She appeared ill at ease with their use and said the RG was not able to give the data to her in a useful manner (too many clinics, or by sub-district which was aggregated)
* graphing is not particularly well done
– targets not marked appropriately
– not set correctly (ie approp value)

Target line.

Mo Dec

Figure 13: Page from my research diary

Notes re the diary:

a) the green marking top left corner – that was inserted later when I was organizing my field data so that I could reference specific pages when working on themes;

b) the reflections on the previous days activities utilized on a regular basis. On the other hand, focus group discussions, and informal discussions have been more frequently utilized.

Field visits and direct observation of staff at work have always been a favoured activity for me. This has been a major source of information and usually extremely stimulating form of research. It has provided insight into what actually works and what does not, and has been a useful method to triangulate data. For instance, when the provincial staff had suggested that "we should not use a certain data collection tool because "it would not work"", we decided to check this opinion with facility staff who told us while the tool was different to what they were used to, they were prepared to try it, and in fact subsequently they demanded it because it improved the way they worked in the facility (Shaw, Simoonga et al. 2008).

In many instances, smaller action research projects within the bigger projects have been effected, and data sources from these are useful micro-representations of the context. For example, in trying to understand why data capture processes were slow in Nigeria compared to other countries in which I have worked, we (my HISP-Nigeria colleagues, the HMIS staff in the State MoH) delved in depth into the amount of data captured by data capturers on a daily basis, the hours of electricity available, and the hours worked by the staff. In these processes reports were drawn up and submitted to the authorities in order to document our findings. The findings from these assessments informed the action research process, but also provided useful sources of data for this research.

Secondary data sources such as official documents, reports, policies, guidelines, published and unpublished materials and other independent evaluation materials have been useful to provide additional insights, or to triangulate findings. For example, secondary data is utilized to compare data in the DHIS data base with survey data such as that related to the demographic and health surveys, and National Immunizations Surveys (see for instance NICS 2006 Group 2007). This provides another mechanism of triangulating our data and understanding of the context (see below in relation to data validity).

3.3.8. Data analysis and the use of theory:

Interpretive research methods (Walsham 1993) are used to analyze the data. As indicated earlier, I discern a first-level and second-level data analysis. Second-order constructs feed back to co-researchers in various ways, either in the same or in other research projects. This serves to confirm the constructs, or modify them to have them fit better. Through this process, there is a process of first and second order analysis related to individual components of the whole, and later to a different and more holistic analysis of the whole. In this way there is a movement from the micro to the macro level and back again, and with each iterative cycle, my understanding is deepened and evolves. For instance, in the early days of my doctoral studies, my focus was on the technical aspects of the design of HospMIS, and then I began to realize that while that was important, it was in fact much more difficult to deal with the socio-political and organizational issues related to HospMIS development and implementation, and my understanding related to the intermingling of the two deepened, particularly related to the identification of the role of the HIP. Later still I began to realize that none of this would happen without an external support organization like HISP-SA playing the role that we have played, and so I began to test ideas related to this both within the team and with people external to the team. To some extent these are macro level concepts, and rather general and "parsimonious", as suggested by Langley (1999). But they are built from the micro level concepts and constructs and behaviours of individuals. I would suggest therefore that my journey has follows a similar path to the co-evolutionary organizational learning framework presented in section 5.5.3 of this thesis, with feedback cycles which serve to refine the concepts and feed forward processes which enable the exploration of additional or new concepts.

Interpretive analysis of the data has been enhanced by various doctoral activities. These include PhD Days held at the University of Oslo where students are afforded opportunities to discuss progress, problems, and draft papers. The process of writing papers, and attending group seminars has provided opportunities for further reflection and exploration of concepts and theories.

As I embarked on my doctoral studies, and became exposed to various theories related to IS research, I tested and played with the theories and my interpretation of the challenges we faced. Some provided valuable insights, others were less relevant. It was during this period of exploration that I became aware of complexity science, and in particular CAS, and the concepts embodied in these theories made a lot of sense for me. I began to interpret my understanding of reality in terms of theoretical concepts from CAS, and this provided interesting insights. In this way I moved ideas from the "theoretical research practice", into the JBER practice, to test them out and see how they worked. This was thus a process of deductive reasoning, but the exposure also enabled me to feel more confident in exploring inductive reasoning processes which were fed by my empirical experiences. Thus, while initially theory was not prominent in my understanding of the problems on the ground, it gradually came to be a more prominent feature in my analysis of data. I therefore use theory as part of the data analysis process, and also as a final product of my research (Walsham

1995). The penultimate sub-section of Chapter 5 (that is section 5.7) provides an analysis of my theoretical contributions and explores how I have generalized from the case study data.

3.3.9. Validity of data

Data and interpretations have been triangulated by moving between the micro- and macro levels to test opinions and claims with workers, managers, and senior managers at different levels of the health system. Being able to move between these levels has provided interesting insights and enriched the data. Statistical data in the DHIS has on occasion been triangulated with national surveys (see for instance Figure 14 below).

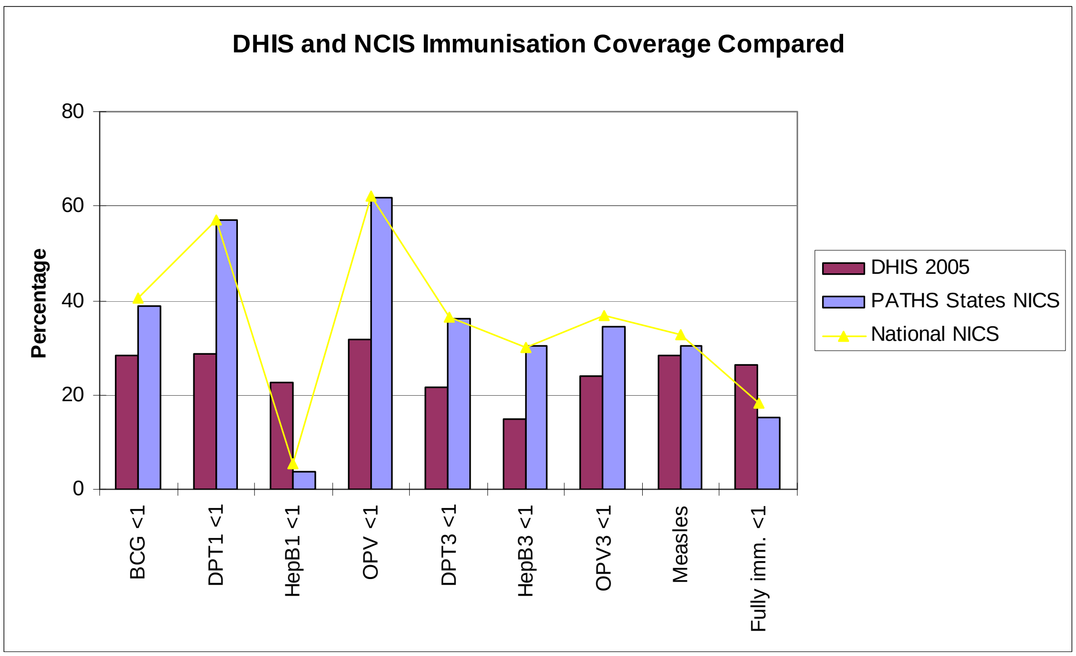


Figure 14: DHIS Dayta compared to NICS Survey

(Source: 2007 Nigeria Cross-State Data Analysis)

In addition, in order to ensure my interpretations are valid, my approach has been as follows:

- To attempt to adhere to the seven principles for interpretive studies, especially the interdependencies between them (Klein and Myers 1999);
- To explore my interpretations with colleagues and adjust them where appropriate based on comments and feedback;
- Attempt to apply the concepts in other sites, and thereby assess their generalizability beyond the case were they developed.

My understanding is that those interpretations that are valid will stand the test of time, and those that aren't, will be modified and adjusted and replaced by better interpretations.

Chapter 4. RESEARCH FINDINGS:

4.1. Introduction:

In this chapter, the findings of my research are summarized. Seven papers form the basis of my contribution. These are listed below. While this thesis focuses on the design and implementation of sustainable and scalable HospMIS, my theoretical and practical insights are drawn from research I have conducted in both the PHC and hospital sectors. In section two I briefly highlight the research question and the key implications that each paper addresses. In section three I summarise the findings from the papers in a tabular format. This step demonstrates the progression in the development of concepts across the papers, highlights the contributions that the papers make, and draws attention to the levels of analysis used in the papers. Thereafter the findings are synthesized with respect to the first three research objectives. The chapter concludes with a section in which the specific findings are linked to my co-evolutionary framework. The overall theoretical and practical contribution builds on this synthesis in the next chapter.

The papers from which the contributions are drawn are as follows (arranged according to year of publication):

1. Shaw, V. (2003). The Development of an Information System for District Hospitals. In S. Krishna & S. Madon (Eds.), *The Digital Challenge: Information Technology in the Development Context*: Ashgate.
2. Shaw, V. (2005). Health information system reform in South Africa: developing an essential data set. *Bulletin of the World Health Organization, 2005*(83), 632 - 639.
3. Jacucci, E., Shaw, V., & Braa, J. (2006). Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability. *Information Technology for Development, 12*(3), 225-239.
4. Braa, J., O. Hanseth, et al. (2007). "Developing Health Information Systems in Developing Countries - the flexible standards strategy." MIS Quarterly **31**(2): 381-402.
5. Shaw, V. (2007, 9 - 12 January 2007). *Considering the Options for Hospital Management Information Systems.* Paper presented at the Helena 12th E-Health Conference, 2007, Bamako, Mali.

6. Shaw, V., Mengiste, S., & Braa, J. (2007). *Scaling of health information systems in Nigeria and Ethiopia - Considering the options.* Paper presented at the IFIP 9.4, Sao Paulo, Brazil.
7. Shaw, V. and J. Braa (Forthcoming). "Developed in the South" - an evolutionary and prototyping approach to developing scalable and sustainable health informatin systems. Development Informatics and Regional Information Technologies: Theory, Practice and the Digital Divide. J. Steyn, IGI Global. Vol 3: ICT's for Development in Africa: Theory, Practice and the Digital Divide.

The way in which papers have contributed to the research objectives as tabulated below:

Table 13: Linking Papers to Research Objectives

Research Objective	Paper contributing to this objective
1. Describe the complexities of the environment which influence HospMISD in resource constrained settings	Paper 1 Paper 3 Paper 4 Paper 5
2. Given the complexities of the hospital environment, conduct research and develop theoretical and practical insights related to the design of HospMIS that takes into account the socio-technical resource levels that exist in developing countries	Paper 2 Paper 3 Paper 4 Paper 5
3. Develop theoretical and practical insights into the successful implementation of HospMIS that accommodate unexpected contradictions that arise between the different realities of original intent and changing needs in the implementation process	Paper 1 Paper 3 Paper 4 Paper 5 Paper 6
4. Conduct research into the scaling of HospMIS, especially which aspects of information systems development are universally scalable, and which require local customization	Paper 2 Paper 4 Paper 6 Paper 7
5. Suggest ways in which the design and implementation strategies described will contribute to sustainable health information systems development in developing country contexts	Paper 3 Paper 4 Paper 6 Paper 7

Addressing these research objectives help answer the two research questions that I pose, namely:

1. Given the complex nature of the hospital environment, what are the socio-technical considerations that contribute to the design of sustainable and scalable hospital management information systems in resource constrained settings?

2. How can the implementation process be designed to accommodate unexpected contradictions that arise between the different realities of original intent and changing needs in the implementation process?

4.2. Summary of individual research papers:

The following sub-sections describe each paper individually, and how they contribute towards the research objectives. Note that each paper has its own research question which should not be confused with the research questions posed in this thesis. Rather these research questions should be seen as contributing towards addressing the research objectives.

4.2.1. Paper 1: The Development of an Information System for District Hospitals.

This paper (Shaw 2003) describes the processes for defining an EDS and data collection tools for hospitals in the ECP of South Africa. The central research question that this paper addresses is as follows:

> *Given that a hospital can be viewed as living, political and cultural system, what is an appropriate approach to HospMISD in these organizations?*

The case description firstly describes the context in which most of my research into HospMIS has been conducted, and secondly, the process to develop data collection tools through a consultative and participatory process. This paper is especially important given the need to merge three different administrative systems (a heritage from the apartheid government) into a single common approach.

The key implications from this paper are the following:

- Utilization of a hermeneutic approach (in the sense that the goal of the information system is to enable users to analyze and interpret information so as to apply it locally to improve services) is important even if difficult to implement in bureaucracies which tend to be top-down and linear in nature (define the data set and expect facilities to submit accurate data). Through an interpretive and exploratory approach HospMIS can be potentially designed in a way that can contribute to improved data quality and use of information;

- The adoption of this approach is appropriate from the point of view of hospitals being living, political and cultural systems that are transforming over time. HospMIS must accordingly be developed in an evolutionary way that encourages participation and mutual learning in support of these tranformations.

4.2.2. Paper 2: Health information system reform in South Africa: developing an essential data set.

This paper (Shaw 2005) describes the process of defining an EDS in the post-apartheid period in South Africa, and is a contribution to the debate around developing appropriate IS for the health sector. The research question that this paper addresses is as follows:

> *How can health information systems be developed in a way that enables them to be flexible and adaptive over time?*

The case description highlights the importance of integration of health program information systems (for example an immunization program, or a family planning program). Yet integration is an approach that is foreign to most managers who are required to report on their narrow field of work. Many donor programs (for example USG/PEPFAR) and even multi-lateral organizations (for example the WHO) are also only concerned with a narrow program focus, and so the process of integrating information is one that requires extensive consultation and negotiation. Given that it is often a single nurse in the health facility that is required to report on all the "program" services that s/he delivers, it makes sense that these are integrated at that level even if they are dis-integrated at higher levels. The case describes the bottom-up process that began with the development of an EDS (defined as a set of data elements which "sensitively reflect health service provision" (Braa, Hanseth et al. 2007b, pg 7) and which are clearly defined. This enables data reported from a variety of health facilities to be aggregated up the health system hierarchy) that integrates program data in one district and gradually spread to include a regional area, later the province, and even later all of South Africa.

The key implications of this paper are the following:

- Development of a simple, common data set can help to integrate different vertical services as an EDS, which provides the foundation to develop a coherent information system;
- A top-down consultative process provides a forum for reviewing the experiences of local experimentation;

- A small data set (which does not impose onerous reporting requirements on health facility staff) should be balanced by collection of survey data;
- The use of the information hierarchy allows a flexible system which can accommodate changes over time;

Published as a “Round-table” discussion, one of the critiques is that the “bottom-up” process described can lead to chaos and result in incompatible systems (Cibulskis 2005). While this critique could be justified, in reality we have not seen that happening because it is invariably at some stage counter-balanced by a top-down negotiation process.

Additional round table responses suggest that the data set is too small (and should include data related to non-health sector programs). The argument presented is that the EDS should be driven by the need to have useful information to assist in planning and monitoring all levels of the health system, including the community level, an aspect that is not discussed in my paper (Cibulskis 2005). Another respondent suggests that the data set is too large (when compared to that developed in Ghana)(Adjei 2005). The varying opinions highlight the intensity of the debate that discussions around a ‘limited’ dataset evoke, and are not dissimilar to those that were experienced amongst managers in South Africa.

Braa (2005) highlights two issues in his response. Firstly, the EDS is depicted as a hierarchy of information needs and is a “flexible standard” that balances local experimentation with top-down national reporting needs. Secondly, the capacity of HIS software (in our case the DHIS) to store both routine data and survey data is a feature that is still not common in health information software today, but which allows the EDS to be kept small. The software should also accommodate changes in the EDS as health information needs change and expand over time.

4.2.3. Paper 3: Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability.

This case study (Jacucci, Shaw et al. 2006) provides a useful insight into the context in the ECP at the time I was involved in developing the HospMIS. The research question that this paper addresses is as follows:

What factors contribute to the achievement of sustainable health information system standards?

The paper is a contribution to the discussion around creating sustainable HIS, and in particular, the creation of sustainable standards that support the HIS. The main argument presented in the paper is that global standards can only be sustainable if they are locally appropriated and re-invented. The case describes the EDS that had been established for hospitals in the ECP, and the tools developed to support the data collection process. The data collection tools can be regarded as a standard, that supports data gathering for the EDS standard. The case describes how a small rural hospital adopted the EDS standard but, rather than also adopting the data collection and processing standards, they developed their own system for collecting and reporting on the EDS standard.

The key observations from this case are:

- that hospital staff are able to differentiate between the goal of the EDS standard (which must be maintained at all costs), and the mechanism by which data is collected to meet the EDS standard (and which can be changed to suite local circumstances);
- by linking different IS together (in this case the financial information system has a number of indicators that are drawn from the in-patient information system) an additional incentive is provided to ensure data is of a high quality (if the underlying information is inaccurate, the financial information will be inaccurate). This is termed the “layering” of IS on each other; and
- in the face of marginalization of small, rural hospitals, networking between user groups helps to create sustainable systems (including IS) which can potentially help to counter the marginalization process.

The implications drawn from this paper are that sustainable HIS are ensured when local organizations “proactively appropriate what is imposed by the global standard in order to follow local vision and entrepreneurship” (pg 227). Sustainability is improved through:

- Participatory approaches that encourage local ownership and innovation (in this case, the appropriation and adaptation of the data collection tools to improve compliance with the EDS standard;
- Networking amongst individuals and organizations which serve as an institutional amplifier of the individuals voice; and
- Layering of IS to provide incentives to improve data quality.

4.2.4. Paper 4: Developing Health Information Systems in Developing Countries - the flexible standards strategy:

This paper (Braa, Hanseth et al. 2007a) proposes a strategy for the development of IS for the health sector. The research question that this paper addresses is as follows:

> *In the face of increasing fragmentation of health services, especially in the face of the HIV/AIDS epidemic, how can integrated, scalable, and flexible health information systems be developed?*

The paper draws on the HISP experience of development of PHC information systems in South Africa and Ethiopia mainly, but also highlights issues from Mozambique, Vietnam, and Botswana, and compares this to the development of the HIS in Thailand (a country where HISP has not been involved in HISD).

The main findings from the cases are that:

- An attractor is a component of the information system that serves to focus resources around a new innovation or approach to HIS development;
- The creation of an attractor is an important step in the process of gaining buy-in from stakeholders for the adoption of the information system. In South Africa the attractor consists of two flexible, and linked components, which creates a flexible information system that accommodates the rapidly changing context of a post-apartheid South Africa. The two attractors are an EDS, and the DHIS that enables the data to be easily aggregated and analyzed by program managers. Similar to the EDS in South Africa, data standards are attractors in other countries as well. In Vietnam, the attractor is the data standards to effect reporting for the MDG's. In Botswana the attractor is the agreement to capture all program data in the DHIS, while in Ethiopia it is the use of an ART software system.
- While the creation of the attractor is seen as an initial step to the solution of a specific problem, once the initial problem is addressed, the IS naturally moves forward to address the next problem, and so it slowly develops, enrolling new actors as the attractor shifts focus.
- Gateways are another flexible standard that support the flow of data. Three types of gateways are defined, namely paper-paper, paper-computer, and computer-computer gateways. The Ethiopian case is used to demonstrate the use of a variety of types of gateways at different levels of the hierarchy to address the uneven access to technology.
- Gateways are important to allow the seamless scaling of HIS as access to technology increases and as computers and internet access become available in the periphery

and gradually replace the paper-based systems – they are thus a standard that supports the development of a robust and scalable information system in the typical context of a developing country setting where there is extreme heterogeneity regarding access to technology.

The key implication from this paper is the recognition that HISD takes place in a complex environment, and that the HIS's need to be able to respond to these complexities. Two strategies are proposed based on two principles.

The strategies are to create attractors (which may be standards) and to ensure that they are flexible and therefore adaptive to changes in the environment in which they operate. This is based on two interlinked principles. One principle is the principle of flexible standards, which suggests that standards should be developed in such a way that they are able to change over time. The second principle is the principle of integrated independence, which allows innovation and experimentation to occur while pursuing the goal of the standard.

The principle of flexible standards:

- Standards should be simple and small by clearly defining their use domains and geographical areas, and by limiting their functional scope. By adhering to this principle, the complexity of a standard is reduced because the constituting actor network is also kept small and simple and therefore manageable. This decreases the technical complexity of the standard, as well as the organizational complexity of the role-players that are involved in the use of the standard.
- Use flexibility (the ability to use a standard in a number of different environments or for different purposes) and change flexibility (the ability to effect a change without disrupting the system) are important characteristics of flexible standards.
- Change flexibility is achieved through modularization. The standards described (the EDS, and the DHIS) can easily be changed without disrupting the whole system because they are composed of smaller units or modules (a data collection form, data elements, or indicators) which can easily be changed. Standards are modularized vertically or horizontally.
    - Vertical modularization refers to the traditional layering of software where one layer offers services to the layer above. In the HISP experience, the data layer has been separated from the data communication layer, allowing the data to be transmitted by whatever system is appropriate (paper, electronic or internet based).

    - Horizontal modularization refers to the creation of small standards for different domains, and then linking them together. An example would be creating datasets for financial and health service delivery data, and then linking these together.
- Gateways are "objects" that link and translate between otherwise incompatible infrastructures, providing an opportunity to escape from the otherwise seemingly impossible trap created by heterogeneity and uneven development. The "objects" used as gateways are hybrids in the sense that they are composed of humans, procedures, paper, computers, software, etc. An example of a gateway is a paper form that is printed from one system and re-captured in another system. The paper form and its recapture represent a hybrid structure that bridges heterogeneous systems.

The principle of integrated independence:

- Through the use of flexible standards, a balance can be achieved between integration and independence.
    - For example, independence is facilitated because the hierarchy of the EDS standard allows users at lower levels to experiment with new standards (for example new data elements), and through a managed negotiation process, these can be adopted in the EDS over time. Experimentation in this way does not interfere with adherence to the EDS standard; and
    - Acknowledging and encouraging local experimentation is an essential aspect that has allowed both standards (the EDS, and the DHIS) to develop through small-scale participatory development and prototyping before being scaled up across a wider geographic or program domain.

Through the application of these strategies and principles, three effects can be achieved:

i) obtaining rich information from minimal data (representing the "must know" information to manage health services),

ii) achieving radical change through small steps (in contrast to the traditional large-scale business process re-engineering introduced in industrialized countries), and

iii) effective scaling of IS in developing countries.

Two strategies to achieve these effects are proposed. Firstly, focus on data standards (the 'message") rather than on technical standards (the means of communicating the data, or the "messenger"), accepting that in the developing country context there will always be technically incompatible systems, while at least data standards can be standardized, and scaled across geographic and program domains. Secondly, gateways can effect seamless flows between incompatible systems.

4.2.5. Paper 5: Considering the Options for Hospital Management Information Systems.

This paper (Shaw 2007) contributes to the discussion on the development of sustainable hospital information systems development in developing country contexts. The research question that this paper addresses is as follows:

What are the key design and implementation approaches for hospital management information systems?

The paper begins by identifying the factors that complicate IS development in hospitals, namely the organizational complexities of the hospital context, the heterogeneous interoperability (the problem of integrating different software systems), and semantic interoperability (the different systems may not use the same naming conventions) that exist in different systems used in hospitals. These create difficulties in achieving a balance between loose and tight integration of sub-systems. Implementation is further complicated by the politics around expensive hospital information systems and the invariable desire of decision makers to "go big". The environment also complicates the development of HospMIS, especially where power supply is irregular and where computers cannot be housed in secure and dust free environments.

An example from the ECP HospMIS strengthening project is used, where gateways integrate financial information from the legacy system with health service data in the DHIS (refer Figure 15 below). Three strategies are suggested to overcome some of the difficulties listed above. The first strategy is to use gateways of different kinds (paper-paper, paper-computer, and database-database) are used to successfully overcome heterogeneous and semantic interoperability. The second strategy is to "craft the gateway on the spot". The resultant gateway is influenced by

- the skills available in the team working on the system (as no programmer was directly available, a "non-electronic" solution had to be crafted);
- the access to technology – in this case internet access was limited, and so too access to the centrally managed financial information system;

- defining the degree of data granularity that is appropriate. As is depicted in the figure below, we merge data from two accounts into a single account (a simplification of the original situation, which results in coarser data granularity of aggregated data). The merged data is captured in an aggregated form at the hospital level (rather than disaggregated to cost centres within the hospital). This is the result of an assessment of the level of available effort to effect the data capture (more staff would have been needed to capture data at each cost centre within the hospital), and also influenced by the availability of computers, and staff skills.

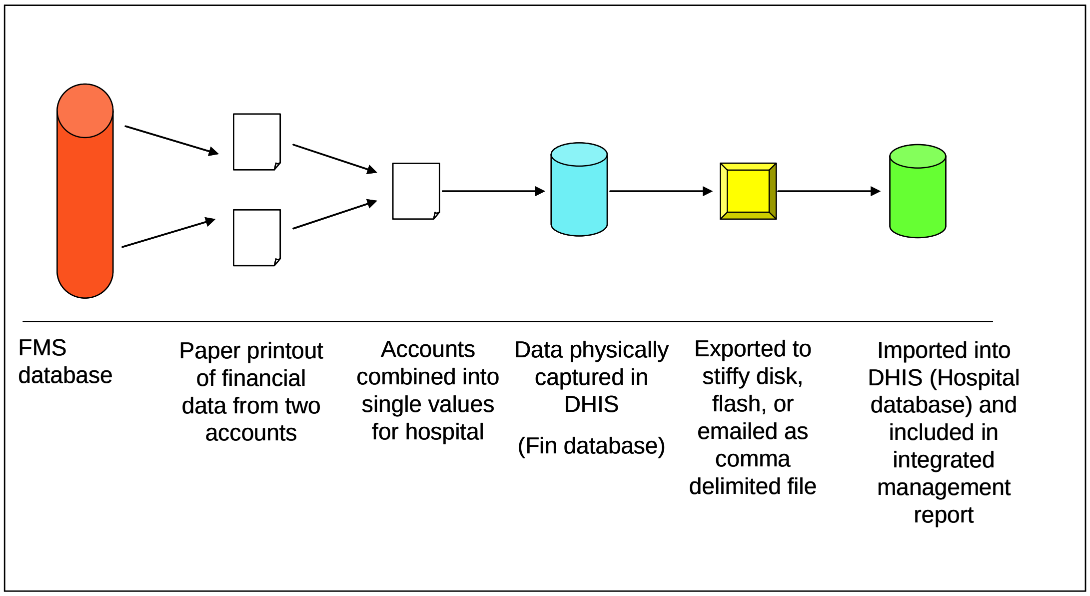


Figure 15: Crafting Gateways to Link Heterogeneous Components

The third strategy is to support the development of a new cadre of HIP through transfer of skills between the HISP facilitator and hospital staff. Initially information officers in the hospitals had only basic computer skills, but gradually they developed their skills through the process of developing the HospIS. Skills development takes place between two ends of a spectrum, from the highly developed skills of a programmer, to the highly developed skills of a health worker, and gradually the two develop skills from each other as the HospIS is developed through an evolutionary and developmental approach.

The implications for HospMIS development are that given the difficulties experienced, gateways should be used to bridge heterogeneous systems. The type of gateway that is crafted on the spot is dependent on three issues, namely the level of sophistication of the technology that is available, the skills levels of the users (and their ability to manage the changes), and the volume of data (granularity) that can be processed.

4.2.6. Paper 6: Scaling of health information systems in Nigeria and Ethiopia - Considering the options.

This paper (Shaw, Mengiste et al. 2007) addresses the research question posed by Sahay (2005) namely which aspects of an IS can be scaled “unproblematically” and which require local customization? Two cases are presented describing the development of PHC information systems in Jigawa State in Northern Nigeria and Amhara Regional State in Ethiopia. The two states are specifically selected because their different resource levels demanded distinctly different approaches to the development of the HIS. In Amhara Region, access to ICT has increased dramatically in the region as part of a governmental initiative, while in Jigawa outside of the main centers, ICT infrastructure is extremely weak. However, in Jigawa the staffing levels are higher (even if skills are low), while in Amhara the staffing levels are extremely poor.

The effect of these differences is that in Jigawa, the EDS is limited to 74 data elements, and reliance is placed on paper-based reporting from facility level to state level where data is captured. While plans exist for initiating decentralized data capture, these are limited given the lack of access to computers, reliable power supplies and a secure environment for placement of computers. In contrast, in Amhara, with the introduction of the DHIS, and provision of ICT infrastructure at the zonal and even the level below this, the “Woreda” level, the data flow changed and it was possible to capture data that was disaggregated to the facility level. This resulted in a tenfold increase in the volume of data to be captured because, in the past, data had been aggregated at the woreda level. A training program was initiated but on review a few months later, none of the trainees had successfully installed the DHIS on their computers. The reasons for this failure are ascribed to the low level of computer literacy amongst the staff, and unfamiliar procedures that they had to undertake to install the system.

The cases are used to highlight the following:

- The interplay between three dimensions of IS, relating to data (or information needs), technology, and human resources. Each of these dimensions represent a spectrum of possibilities, from simple and undeveloped (at the narrow end of the spectrum), to sophisticated and advanced (at the broad end of the spectrum). The interplay between the dimensions are presented below as a Process for Accommodating Non-linearity (PAN Model) (Figure 16). Development (or scaling) of

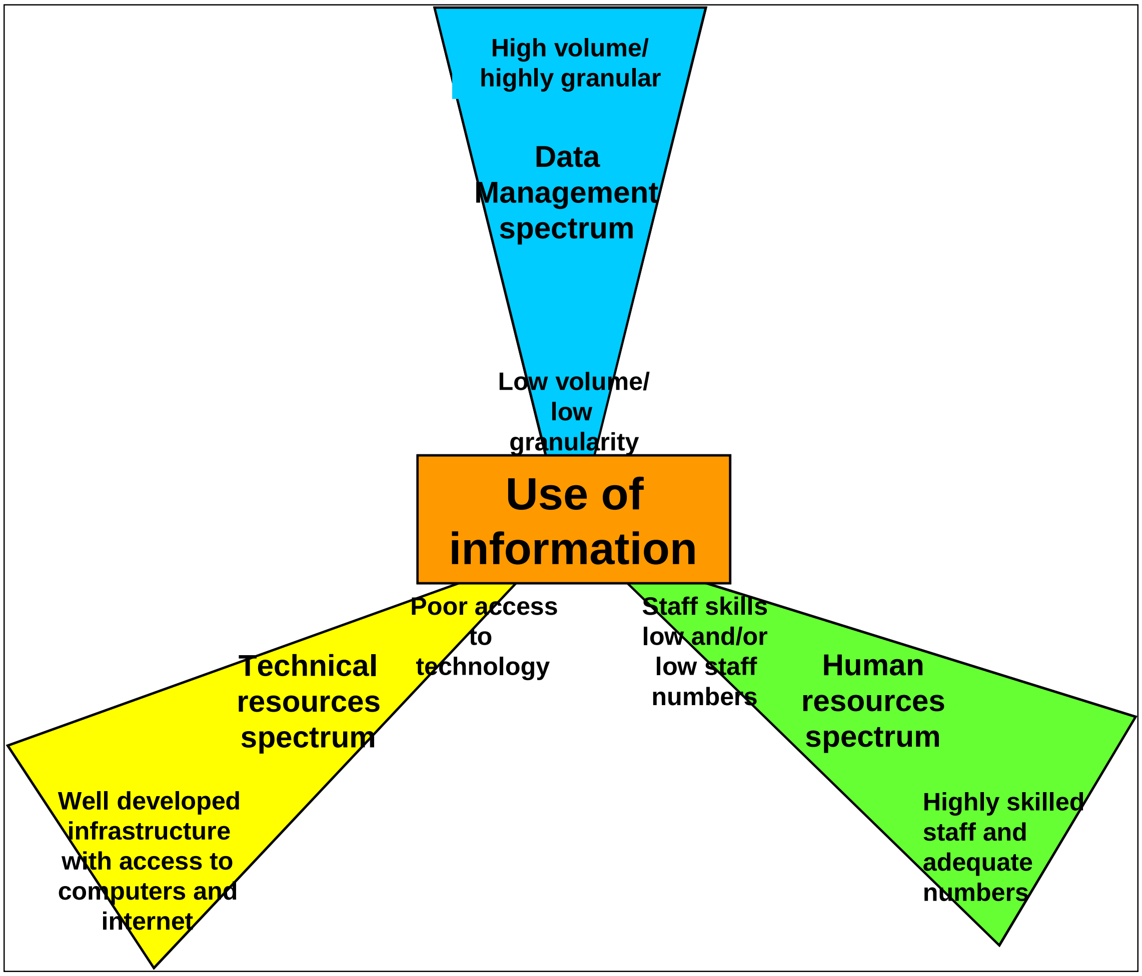


Figure 16: Considering the Spheres of ISD when effecting Geographic Scaling

the system occurs in iterative cycles which balance access to human resources and technology as demand for data and use of information changes.

- The three dimensions are interlinked with one another in complex ways, requiring a sensitive approach to addressing data demands. In Jigawa data volume was kept low because of poor access to technology. In Amhara, the volume of data could be increased (in other words more finely grained data could be captured) because of access to technology, although this was tempered by the lack of computer literacy among staff.

- An approach to ISD is advocated based on the concept of "mindful innovation" (Swanson and Ramiller 2004). Mindful innovation was originally suggested as an approach to avoid failures in high-reliability organizations that are faced with vulnerability, complex processes and complex technology (Weick, Sutcliffe et al. 1999). The concept of mindful innovation used in this research focuses on three characteristics of mindfulness, namely pre-occupation with the possibility of failure, commitment to resilience, and sensitivity to operations. We suggest that these are useful characteristics to bear in mind as scaling of IS occurs since changes in one dimension impacts on the others requiring sensitive and ongoing adjustments.

The implications for scaling HIS are as follows:

- There are three dimensions that need to be considered when scaling HIS, namely human resources, technical resources and data management. These three dimensions interact with one another in complex ways, and changes in one dimension influence the others;
- There are two standards that are important to effect scaling in developing country contexts, namely the creation of data standards, such as the EDS, and the use of gateways to effect seamless flow between heterogeneous systems. These standards are a necessary pre-requisite to accommodate the scaling of HIS that often occurs in an uneven manner (whether the scaling takes place across the geographic scope, or expansion of program data, or the expansion in access to technology);
- A strategy of mindful innovation should be adopted to balance changes in the three dimensions as scaling occurs.

In addressing the research question, two main conclusions are drawn. First, scaling processes can use standards and must accommodate the interplay between the three dimensions described above. These principles can be applied universally. Secondly, the application of these principles must be balanced by adaptation and adjustment processes that are uncultured in the mindful innovation approach to ensure the HIS is responsive to the local context. The research question is therefore answered as follows: "flexible standards" are strategies that can be scaled on a global level, but for the successful scaling of HIS, it has to be accompanied by a local cultivation process that balances the dimensions of volume of data, access to technology, and human capacity.

4.2.7. Paper 7: "Developed in the South" – an evolutionary and prototyping approach to developing scalable and sustainable health information systems.

This paper (Shaw and Braa Forthcoming) provides an overview of the HISP-SA experience in HISD in Africa over a 10 year period, particularly focusing on efforts towards scaling HIS and sustainable HISD. The research question that this paper addresses is:

> *What are the design and implementation strategies that have contributed towards sustainable and scalable health information systems in resource constrained contexts?*

The paper presents the challenges associated with ISD in Africa, highlighting the uneven access to technology, low level of resources including paper, power supply, and especially human resources. These conditions are influenced by social and political practices which reflect vested interests and inappropriate decision making processes. Consequently, the HISP approach adopts a multi-dimensional perspective acknowledging the complex interplay between individuals, technology and organizations making the information system beyond the control of any single individual. The challenge in many developing countries is to not only develop an appropriate HIS, but also to be able to scale and sustain it in a context which is rapidly changing, not only in terms of health sector demands, but also in terms of access to technology.

The paper presents a brief background to the HISP network, followed by a rationale for participatory and evolutionary design. Recent literature on scaling of HIS is discussed. The paper then describes three main areas of HISP's experience, namely the incremental approach to software development, the development of HR capacity through development of a cadre of "HIPs", and lastly the approach to HIS scaling. The key points from the case study are as follows:

- Regarding software development:
    - The DHIS is FOSS that requires ongoing and local configuration;
    - As evidenced over a 10 year period, software development happens as an iterative process influenced by user demands as the geographic and functionality scope increased. Scaling thus occurs across three domains of geography, software functionality, and user needs;
    - While most of the software development is managed by the HISP-SA team, there are notable examples where developers in widely dispersed locations contribute to software development;

- The impetus for the use of the system comes from surprising quarters, and unexpected effects. For example, the requirement by the NDoH that the DHIS be used for quarterly reporting system. This helps establish the DHIS as an "attractor" for submission of these reports, and has as a result forced a re-alignment of reporting from other systems with the DHIS standards);
- As the system develops, it becomes more sophisticated, and users as a result also become more sophisticated in their understanding of the system and in its use. This forces the HISP-SA team to carefully consider its own team composition, and team development strategies;

- Regarding human capacity development for sustainable HISD:
  - There is a great deal of variety in terms of people's ability to use computers and understand HIS. The HISP-SA team have to be prepared to begin the process of capacity development at whatever point in the spectrum from basic user to advanced developer the user is placed. As a result, the HISP-SA team must be multi-skilled, and have a range of tools at their disposal;
  - Development of capacity in the HISP-SA team requires a conscious process over a long period of time, ensuring a balance between health professionals and developers, doctors and nurses and other allied professions, and recruitment from the public sector and sources outside the public sector. The balance within the HISP team is always challenged by changing demands for information and changes within the public sector;
  - Identification of the new cadre of HIP is an important step in recognizing HIS as a new and emerging field in the health sector;
  - The original concept of "networks of action" expands with the establishment of regional networks of HIPs between teams located in South Africa, Zambia, and Nigeria;
- With regards to sustainable HISD
  - Innovative approaches to scaling HIS are being considered – the traditional pattern of scaling uniformly across a country has been applied in Zambia (following the South African approach), whereas in Nigeria, in response to slow progress with the "standard approach", two alternative approaches are being piloted – the "prioritized sample" approach (where the busiest facilities across a state are selected for focused HISD support, and the "hierarchical cluster" approach where a cluster of facilities linked by referral patterns are selected for integrated support, not only for HISD but also for other maternal and child health support programs; and

- These approaches paradoxically increase the unevenness of the landscape, yet it is hoped that they will suggest a more appropriate response to resource availability

The analysis and discussion section first explores the scaling of HIS as an iterative approach across the three domains described above. Secondly, the analysis and discussion section summarizes the requirements for sustainable HISD in Africa. This last section draws on the flexible standards concept to overcome heterogeneity and effect seamless scaling. FOSS is regarded as an appropriate approach in Africa where there is already a widespread culture of “ubuntu” and sharing, and continued innovation in support of small-scale bottom-up development processes that are complimented by top-down strategies. The paper also suggests that future research is needed into the different scaling approaches, and the emergence of regional networks of HIS practitioners, complemented by links to academia and non-governmental organizations.

4.3. A comparison across papers:

In this section I summarize the findings from the papers in a table format. The first column indicates the paper, while the second column highlights the facets of the complexity which the paper addresses – either complexity related to the context, or related to HISD. The third column identifies the level of analysis of each paper, and the significance of the paper or of the findings. The last column summarizes the product and process that is described in the paper. The product is often related to the design of a component of the HIS while the process is related to the process associated with the product design, development or implementation. Viewed from a CAS perspective, product and process are emphasized as they are closely intertwined in their interactions, and this is a key difference between viewing ISD as a CAS compared to standard reductionist approaches.

Table 14: Comparison across research papers			
Paper:	**Complexity manifested by**	**Level of Analysis and Significance of case:**	**Socio-Technical considerations emerging from the case:**
1 IFIP 2002	Hospital reform in post-apartheid period required to address multiple definitions of standard items, multiple mechanisms for collecting and collating data	**Level of analysis:** Mainly micro- Micro-level in terms of development of data collection tools for individual wards in hospitals, and the focus on local practices. But scales to the macro-level in the sense that this is an attempt to bring about uniformity across hospitals in the ECP. **Significance:** Significance of the participatory approach in hermeneutics: - building consensus amongst different views; - change attitudes; - sharing experiences and best practices;	**Product:** Development of paper standards and standard processes for data collection – flexibility built into paper systems to match flexibility in software; **Process:** Co-evolutionary process involving health workers at micro level (wards of hospitals) together to address a common vision.
2 WHO Bulletin	Negotiating with different stakeholders and different interest groups for an EDS	**Level of analysis:** both micro- and macro. Micro- in that initial case reflects the local context in a small region of the ECP; Macro in the sense that this process scaled up to address the EDS for all of South Africa. **Significance:** Flexible standard (a simple solution) that would be reviewed on a regular basis as an “open standard” that has achieved “temporary closure” – this has had huge effects in terms of HISD across many resource constrained countries (non-linear effect) Contentiousness reflected in the round table discussion – EDS was too small, and others said it was too large	**Product:** Development of EDS as a flexible standard that is also a hierarchy of standards; **Process:** Co-evolutionary process involving program managers at facility, district, regional and national levels through bringing divergent groups together to address a common vision; Vision of an essential data standard (as a minimum but integrating standard) with flexibility for innovation and expansion at lower levels.
3 IT4D	Global vs local priorities Accommodating uneven development (marginalized groups vs mainstream groups)	**Level of analysis**: Micro in the sense that it is a detailed case description of a process in a specific hospital, including the process at ward level. It does address the macro level in that standards at the national level can only provide quality data if they are locally appropriated. **Significance:** The surprising finding of local appropriation and re-invention of national data standards resulting in quality data; Non-linear effect on data quality as a result of the local adoption and appropriation of the national data standard; Layering of IS as an unexpected (non-linear) beneficial effect on data quality	**Product:** Sustainable standards through local appropriation; **Process:** Local networks evolving through self-organization based on a vision (standards for reporting); Co-evolution of a locally appropriate data collection and collation system based on the provincial/national standard; Encouraging innovation and self-organization through local autonomy

Paper:	Complexity manifested by	Level of Analysis and Significance of case:	Socio-Technical considerations emerging from the case:
4 MISQ	Frequent change due to: New diseases & changing patterns Changing targets Organizational factors Fragmented HIS Inappropriate expectations Uneven access to technology Need to scale	**Level of analysis**: both micro- and macro. Micro-level in terms of case studies in SA and Ethiopia, but scales to the macro-level in the sense that the scaling is addressed in the recommendations. **Significance:** Represented experience from a number of countries Attractors as sources of non-linearity Integrated independence as a source of innovation and potential non-linearity Problem with concept of self-same replication "like broccoli",	**Product:** Flexible standards - Small and simple - Modularization o Vertical (data flow through the HS hierarchy) o Horizontal (Data sets by Programs) Gateways as a flexible standard to link modularized components – "hybrids" **Process:** Attractors (EDS, DHIS, forms) as focal points for co-evolution of systems - Initial rally point; - Focus for further evolution; Integrated independence as a mechanism to stimulate innovation Scaling achieved through flexible standards and gateways
5 Helena	Heterogeneous and semantic inter-operability Balancing loose and tight integration Access to power supplies and secure environments for computers	**Level of analysis**: Micro- drawing on case studies from hospital implementation process in wards/units of hospitals in the ECP. **Significance:** Description of different gateways crafted "on-site" during the ECP Hosp project Type of gateway is a function of skills base, and will influence information granularity provided Scaling can still be effected as resources increase	**Product:** Gateways as a flexible standard to link modularized components – "hybrids" HIP emerges as a new cadre of health worker with advanced DHIS customization skills and IS's knowledge to complement skills as a health worker **Process:** Gateways "crafted" on site depending on resource availability as a co-evolutionary process; Indeterminacy of the process as a result of differing priorities, needs, and resources; Skills transfer across a continuum between pure health worker and pure developer

Paper:	Complexity manifested by	Level of Analysis and Significance of case:	Socio-Technical considerations emerging from the case:
6 IFIP 2007	Unevenness in terms of access to HR and technology	**Level of analysis**: both micro- and macro. Micro-level in terms of case studies in Nigeria and Ethiopia, but scales to the macro-level in the sense that the scaling is addressed in the recommendations. **Significance:** Model for balancing HISD in an c--evolutionary manner (as a developmental process) and clarified that it was "OK" to allow uneven development to take place	**Product:** PAN Model for accommodating non-linearity between access to health workers, technology and data (information) requirements that characterizes HISD in RESOURCE CONSTRAINED SETTINGS Standard requirements for scaling - identify data standards, - adopt gateways to bridge unevenness - local customization based on resource availability (and mindful innovation) **Process:** Mindful innovation Approaches to scaling Non-linearity manifests between different processes; Indeterminacy of the process.
7 Book chapter	As above	**Level of analysis**: both micro- and macro. Micro-level in terms of some of the case studies, but scales to the macro-level in the sense that the scaling is addressed in the recommendations. **Significance:** Longitudinal view on HISD in Africa as an evolutionary process across three domains of software development, geographic scaling, and expanded functionality.	**Product:** FOSS in the DHIS as a sustainable solution HISP as a network/flexible organization responding to changing needs HIP **Process:** Skills transfer through development of new cadre of HIP Innovation as contributing to uneven development; HISP as an actor in the scaling process Scaling as an inevitable outcome of successful implementation Indeterminacy of the process; Non-linearity between different components, and between different sites

4.4. A synthesis of the findings:

In this section I synthesize the findings from the papers in order to address the first three research objectives. The remainder of the research objectives are addressed in the following chapter.

4.4.1. The complexities of the context:

This sub-section synthesizes the complexity of the health sector, and by implication also the hospital environment. Where the complexities are specific to the health sector, this will be specifically mentioned. Complexity is described using five different perspectives. While some of these perspectives are unique to resource constrained settings, many are also found in well resourced contexts. The difference is that the heterogeneity experienced is far greater in resource constrained settings, and it is all pervasive (this is discussed in the next chapter in greater detail). Because of this, and the nested effects of the different types of complexity, the environment in which HospMISD takes place is extremely unpredictable.

a) Complexity as heterogeneity:

Complexity of the hospital environment is reflected in the heterogeneity described in the papers. The obvious manifestations of heterogeneity are the disparities in access to basic infrastructure (e.g. in terms of access to tarred roads, electricity supply, cell phone connectivity or internet access). However the extreme heterogeneity also manifests itself through less obvious disparities in for instance educational and skills levels amongst health workers. This results in different abilities to process information and access and use technology. These disparities are a result of the organizational and bureaucratic inefficiencies reported elsewhere (Jayasuriya 1999; Gladwin, Dixon et al. 2003) and uneven development that is so prevalent between rich and poor areas, urban and rural sites (Sen 1999).

HISD must accommodate the rapid rate at which changes in access to infrastructure takes place. The rate of change does not unroll evenly across all areas. Changes create their own complexities through compounded effects because they interact with heterogeneities and complexities in other areas of the health system (this is described below). The result is unexpected changes, imbalances and non-linear effects. For instance, a decision to capture facility level data in Amhara Region in Ethiopia resulted in an explosion of the volume of data to be captured, despite the lack of staff to do the data capture (Shaw, Mengiste et al. 2007).

b) Complexity as manifested by a broad range of challenges:

The range of tasks that have to be effected in HospMIS development in resource constrained settings are hugely varied. Because of the heterogeneity described above, and the lack of access to skilled personnel, not only are HIPs required to deal with the obvious infrastructural problems, but they also have to address sophisticated technical problems. For instance issues related to heterogeneous and semantic interoperabilities have to be addressed without access to sophisticated programmers, and decisions have to be made on the spot between loose and tight integration of systems.

c) Complexity as limited control over activities:

In a factory, shift managers oversee the workers inputting raw materials that are combined to create a product. But the production of quality data by a HIS is not a linear, controllable process (Garrib, Stoops et al. 2008; Mate, Bennett et al. 2009). Rather it is the outcome of a series of small, individually successful tasks from the point of interaction with the patient (e.g. correct recording of a diagnosis on a paper record), through to the point of data capture (e.g. correct aggregation of diagnoses from multiple care providers onto a monthly report, timely submission of the report to point of capture, correct capture of represented data, etc). Quality data is a result of complex interactions between a number of initiatives, not only technical in nature (for example data quality checks in the software at the time of data capture) but also procedural and individual, many aspects of which are beyond the direct control of the systems developer or HIP. HISD efforts therefore need to be able to not only design tangible products such as the software, but also set the broad parameters within which different stakeholders are encouraged to play their role optimally, far from the control of the centre. HISD (and by implication HospMISD) must effect products and processes at the micro- and at the macro-levels of the health system.

d) Complexity impinging on Hospital Management Information Systems Development:

The complexity associated with HospMIS is not related only to that of the HIS, but is compounded by complexities and changes in other areas which impact on the HospMIS. For instance, HospMISD is frequently effected during periods of health sector reform. This means that not only is the HIS changing, but organizational structures are undergoing change as well, and changes in the organizational structure impact on the HIS.

Fragmented health services are the result of historical factors (for instance the three different administrations created in an apartheid South Africa), and vested interests of program managers and other role players. Overcoming this type of fragmentation in order to develop an integrated HIS is not a simple task, and demands a careful negotiation process.

New diseases and changing patterns of disease (for example HIV/AIDS), demand changes in reporting requirements and frequent change in reporting requirements require flexible data management processes.

e) Complexity as non-linear effects:

HospMISD must accommodate non-linear effects which are common in this environment. They are precipitated by the complexities described above, and by the interactions between these complexities. They may be precipitated by the rapid pace with which infrastructural change is effected and by the multiple types of change that take place at the same time (for instance effecting HIS changes whilst undertaking health sector reform as discussed in paper 1). They result from the combined effect of decisions made by different people and of self-evolving groups which effect significant change without central control (paper 3).

f) Summary – Complexity as extreme heterogeneity:

In summary, I suggest that the complexity of the context is characterized by "extreme" heterogeneity. I use this term because not only is the environment heterogeneous, but the heterogeneity spans a wide range of possibilities, change is rapid and ongoing and results in compounded effects, imbalances and non-linearity. Because HospMISD often takes place in the context of other reforms, compound effects are created which contribute to non-linear interactions. The demands for support are hugely varied, and therefore practitioners must be multi-skilled or must draw on a team with a wide range of skills to not only address basic infrastructural issues, but also to be able to provide sophisticated technical solutions. In addition, strategies must accommodate the lack of direct control over nested actions, and therefore attention needs to be addressed towards processes that support HIS at the micro and macro-level.

4.4.2. Flexible Standards as central features in the design of hospital management information systems

The second objective focuses on the design of HospMIS as distinct to the implementation process. A core theme that emerges as a result of the complex environment is the ability to incorporate flexibility (adaptability) into the design of the HIS through the vertical and horizontal modularization of components. Modularization is one way of introducing flexibility so that change can be effected without disrupting the whole system. The need for flexibility in the design of HIS is described in the development of data collection tools in paper 1, in the definition of the EDS as a flexible data standard in paper 2 and paper 4, and in the use of gateways in paper 4. The DHIS as a software system that is able to respond flexibly to changes effected by organizational reform and adjustments to the data standards is described in paper 7. In this section I summarize key concepts related to four flexible standards, namely data collection tools, the EDS, the use of gateways, and the DHIS.

a) The Design of Flexible Data Collection Tools:

Paper 1 describes in detail the process of developing uniform data collection tools. A key aspect to the process is recognizing that flexibility in the design could be accommodated by leaving certain columns in the data collection register blank (see Figure 17 below). During the process of developing registers, many blank spaces are incorporated, but later on when user needs became more stable, some of the columns are printed with standard texts, while a few are left blank. The blank columns can then be used for locally identified fields, and can be changed as frequently as necessary without incurring the cost of re-printing a set of registers. The design of registers in this way accommodated not only local needs, but also anticipated changing reporting requirements by higher levels before a new set of registers is printed (which, due to economies of scale and budget allocation mechanisms, is usually done centrally (rather than locally) in the public sector in many countries).

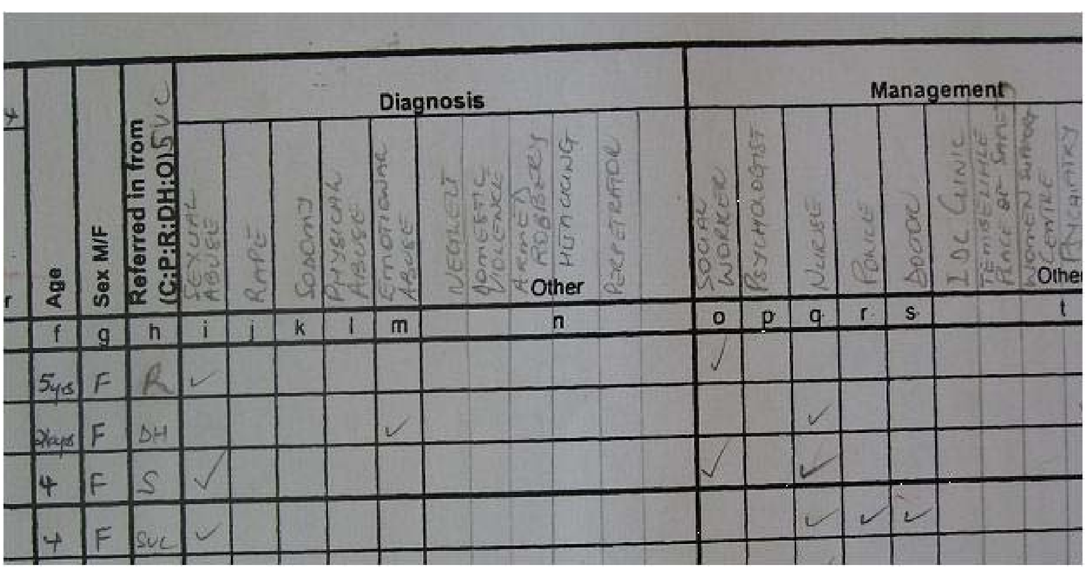


Figure 17: Using blank spaces to incorporate flexibility in register design

b) The Essential Data Set as a flexible standard:

The EDS is a flexible standard that accommodates a hierarchy of information needs, “dynamically combining flexibility as a right and adherence to the standards of the level above as a duty” (Jacucci et al. 2006). It is a tool for negotiating a common approach, which tolerates individuality within a common framework. It demands continuous review and is an open standard which never reaches closure, and it can change in response to changing demands over time, thus allowing it to evolve and adapt. The process of developing the data standards requires a careful negotiation between different stakeholders in a participatory process. This is a necessary pre-requisite for the adoption of standards and their local appropriation, as is discussed below. It also requires a combination of a bottom-up and top-down approaches, balancing experience from local level innovation with information needs determined at the national and inter-national levels.

c) Gateways as flexible standards:

Gateways are flexible standards because they can be locally crafted, and can change over time (a paper gateway can be replaced by an electronic file). They are ‘objects” that link and translate between heterogeneous systems. The “objects” used as gateways are hybrids, being composed of humans, procedures, paper, computers, software, etc. Gateways provide the means to communicate the data in contexts where heterogeneity and uneven development are common because they bridge heterogeneous systems. They allow seamless scaling to be effected between different levels of the HIS.

d) The DHIS as a flexible software:

Paper 7 describes the DHIS as flexible software in that it requires local customization of the organizational hierarchy, the data elements and the indicators, and through the multi-language enabling functionality allows further customization to the local language of use (Nielsen and Nhampossa 2005). The DHIS can therefore adapt not only in accordance with changes in its locations of use, but can also accommodate changes in reporting requirements and organizational hierarchy. For example, the ability to accommodate multiple organizational hierarchies, and frequent changes in these was a powerful feature of the software developed during the radical health sector reform process in South Africa as local government and provinces were democratized in the post-apartheid period.

4.4.3. Five core implementation strategies for hospital management information systems

In this sub-section I highlight six key implementation strategies from the case material. These strategies are used to manage the complex environment characterized in particular by extreme heterogeneity and non-linearity.

a) The Principle of Integrated Independence :

The principle of integrated independence together with flexible standards accommodates experimentation and local level innovation without disrupting the overall system (described in paper 4). Particularly in environments where change happens frequently, and in a non-linear fashion, the ability to innovate provides opportunity to identify new solutions through small-scale initiatives. Innovations which allow the HIS to evolve in response to the complex environment are presented as examples, for instance gateways are created to effect an interface between the financial IS with the DHIS in a hospital (paper 5) and data capture is effected at different levels of the health system hierarchy in response to the availability of human resource skills and access to technology (paper 6).

b) The Process for Accommodating Non-linearity (PAN Model):

The PAN model provides an approach to balancing three dimensions of an IS, namely the demand for data with access to ICT and available human resource skills. The model provides a basis for an iterative approach to HISD that accommodates changes in these dimensions. The process of balancing the interaction between these dimensions requires mindful innovation (see below). The PAN model also provides an approach for scaling of HIS.

c) Using mindful innovation to accommodate the non-linear development of IT and human resource capacity:

Mindful innovation focuses on three characteristics of mindfulness, namely pre-occupation with the possibility of failure, commitment to resilience, and sensitivity to operations. It suggests a process of careful sensing and accommodating the bottom-up and top-down processes that influence the local context.

Mindful innovation is applied to the scaling of HIS in Nigeria and Ethiopia (paper 6), where scaling is allowed to happen at an uneven pace (which may mimic the expansion of technology and infrastructure) even though this is counter-intuitive to the philosophy that inequities should be reduced rather than increased. In paper 7 we describe different approaches to scaling of HIS in Nigeria, namely the “standard approach” (uniform and comprehensive scaling across provinces and a country), the “prioritized sample approach” (the busiest facilities are targeted for HISD support), and the “hierarchical cluster approach” (a group of facilities linked through the hierarchical referral network for maternal and child health services are selected for HISD support). Determining which type of approach to utilize and follow through while carefully evaluating strategies is an example of mindful innovation.

d) Attractors as growth points for sustainable systems :

Attractors serve as points around which the HIS can develop (paper 4). Attractors are objects or processes that provide a strong impetus for focusing HISD activities. They bind potential users together in a common purpose. Identifying attractors is closely linked to the concept of “mindful innovation” because an implementer who does not sense the presence of an “attractor” misses opportunities to gain critical mass to support the HISD process. Layering of IS (paper 3) is an example of an attractor which creates dependencies between different IS thereby reinforcing the value of the individual systems.

e) Creation of networks and interdependancies as a mechanism to support sustainability:

Sustainable IS development relies on local appropriation of standards, and the creation of networks to support the processes and approaches (paper 3 and 7). In the face of marginalization, sustainability is improved through the creation of networks amongst users, and the layering of IS on one another. The creation of regional networks of HIPs amongst the HISP teams in South Africa, Nigeria and Zambia (paper 7) suggests a maturing of the “networks of action” approach to HISD (Braa, Monteiro et al. 2004).

f) Development of a new cadre of health worker – the health information practitioner:

The development of skills to “manage” HIS is described as a process of transferring knowledge and skills between health workers and programmers so that the two gradually move from their skills base at opposite ends of a spectrum towards the common centre (papers 5 and 7). A cadre called the HIP is emerging within the South African public health sector. In addition, and in support of the HIPs, regional networks of HIPs are being established, with links to academia and other NGO’s.

4.5. Concluding remarks:

In this section I draw attention to two insights from the findings presented so far, and thereafter I compare the findings to the co-evolutionary framework developed in Chapter 3. The last subsection highlights aspects of HospMISD that have not been adequately addressed by the theoretical framework. In the next chapter I draw on this analysis to further expand the theoretical framework.

4.5.1. Evolution of insights into HospMIS design, development and implementation:

The first insight provided by the synthesis is how my thinking has progressed over the years that I have been involved in the PhD program. Four central themes emerge over this period. Firstly, the role played in developing the HIP gradually became apparent. The new cadre of health worker plays an extremely important role as a mediator in HISD. Secondly, it has became increasing apparent that co-evolutionary processes are central to many of our HISD efforts. These have been described in different ways in the papers (for example as a hermeneutic approach in paper 1, as a negotiation process in paper 2, and as mindful innovation in paper 6). Thirdly, it has gradually dawned on me that scaling of the information system is an inevitable outcome of successful implementations, and therefore makes demands on the design, development and implementation of HIS. Fourthly, the gradual recognition that HISP-SA as an organization is an important mediator and role-player for sustainable HISD.

4.5.2. Balancing micro- and macro- level analyzes:

The second insight provided by the synthesis is how the data is drawn from both the micro- and macro-levels of the health system. For instance, paper 1 focuses at the micro level, as do papers 3 (detailed description of data collection practices in one hospital) and 5 (implementation processes in wards and reporting units of hospitals in the ECP). But other papers balance the micro-level experiences with macro-level implications, for instance papers 2 (an EDS that balances the local and national information needs), 3 (appropriation of national standards at a local level), 4 (local practices that contribute to scalable IS), 6 (draws on local experiences at the micro- level to suggest approaches for scaling at the macro level), and 7 (local practices that contribute to sustainable IS).

4.5.3. The co-evolutionary framework for managing the complexity of HospMIS development in resource constrained settings:

In this subsection I summarise the research findings in relation to the first three research objectives and the proposed co-evolutionary framework for HospMIS development. While some concepts, such as that of integrated independence, attractors, and mindful innovation have been developed through research conducted in PHC settings, I believe that they are principles that can be appropriately generalized to the HospMIS environment in similar settings.

The complexity of the environment has been characterised as extreme heterogeneity (this notion is expanded in the next chapter), and subject to frequent change and non-linear effects. Because it is impossible to control change that occurs at multiple levels of the health system, the HospMISD must suggest strategies that support decentralised control at micro- and macro-levels of the system. Strategies related to the design and implementation are processes are discussed next.

With respect to the technical design of HospMIS, the research highlights the importance of incorporating flexibility into all components of the system, from the paper based data collection tools to the software. Flexibility is built into the data flow process as well, so that as access to technology increases, portions of the data flow can be replaced by technological processes without disrupting the whole. In this respect, modularization and flexibility are two sides of the same coin, and go hand in hand. The co-evolutionary framework is expanded by the design concept of ensuring the HIS has access to a wide range of tools (resources) that can be drawn upon as the situation demands. For example there are flexible paper based tools, flexible datasets, flexible databases, and a variety of gateways. These enable HIPs to balance supply of staff, skills, and the demand for data, with the available technology. In this way the information system develops around locally appropriated solutions, and can (usually) be adjusted by the users to accommodate unexpected changes in the environment.

The flexibility in the technical design of the system is mirrored by flexibility built into the implementation process. The co-evolutionary framework developed in Chapter 3 can now be expanded with a number of insights. Firstly, the co-ordinating rhythm is complemented by the concept of mindful innovation. While mindful innovation was conceptualized for use in high reliability organizations, its application in contexts characterized as CAS is not inappropriate given the nature of surprise that characterizes non-linear effects, and the need for watchfulness to manage and counter non-linear effects. Secondly, the use of integrated independence, attractors, networks and interdependancies are examples of ways to strengthen, and potentially create non-linear effects in support of HospMIS (this is discussed further in the next chapter).

In terms of balancing human resource development with HospMIS implementation, two solutions have emerged. The first is the emergence of the HIP as a change agent within the public sector. This is a new cadre with skills which are a mixture of health worker skills, and IT sector skills. The secondly is the use of the PAN model as a means by which to not only assess what is feasible in terms of data processing capacity, but also to manage the unanticipated changes in access to resources.

4.5.4. Critique of the co-evolutionary framework:

The preceding subsection expands the design and implementation components of the co-evolutionary framework, and provides initial insights into how capacity can be gradually developed within the public sector, despite staff shortages. However, two aspects are not addressed adequately by the co-evolutionary framework. Firstly, the process of building capacity in the public sector is not adequately described. Secondly, and related to the first, there is a need to identify mechanisms whereby the public sector can counter its tendency to neglect exploration processes. As suggested in the final section of Chapter 3, these issues warrant further exploration, and as they are key factors contributing to sustainable and scalable HospMISD, will be the focus of the next chapter.

Chapter 5. THEORETICAL AND PRACTICAL CONTRIBUTIONS:

5.1. Introduction:

In this chapter, drawing on the findings from the empirical data presented in Chapter 4, I develop the theoretical and practical contributions for the design, development and implementation of sustainable and scalable HospMIS. Three main contributions are presented in this chapter.

The first is to extend the understanding of the complexity of the context in resource constrained settings with the notion of extreme heterogeneity. This contribution builds on the description of complexity presented earlier, and introduces the concept of nested effects which complicate the environment, and create non-linear effects. Our understanding of the complexity of the environment is also expanded by drawing attention to two other concepts from CAS, namely non-linearity and self-organizing groups. Each is examined in terms of its significance to HospMIS development and implementation.

Given the environment characterised by extreme heterogeneity, non-linear effects and frequent and unexpected change, the challenge is to develop sustainable approaches to HISD. This is addressed by the second contribution which articulates a model called the co-evolutionary IS development model, which posits a NGO (like HISP-SA[10]) partnered with a public sector organization in a synergistic relationship. This partnership is arguably effective because the two organizations have different absorptive capacities, and complement one another not only in technical expertise, but also in that the public sector is less inclined to pursue exploratory drives compared to a networked and flexible NGO. Not only does this model ensure the survival of both organizations, it allows a gradual, and sustainable transfer of skills between the two organizations as a parallel process to the co-evolutionary IS development process. This transfer involves a process of co-evolutionary organizational

[10] In this chapter, where I refer to HISP-SA I do so because I have an intimate knowledge of how this organization has worked, and developed. However, I would presume that where I use HISP-SA as an example, it could equally apply to HISP-India, HISP International (a term used to describe the Oslo node of the network with or without members from the other HISP nodes), or the HISP-Nigeria teams. Where I use the term HISP it refers to the network as a whole.

learning that takes place through a four staged process of intuiting, interpreting, integrating, and institutionalizing.

The third contribution is to conceptualize scaling as an “inevitable” co-evolutionary process, being a natural consequence of successful IS development. Scaling is conceptualized as a CAS, taking place along four dimensions, namely the geographic depth and breadth, and depth and width of scope.

This chapter is structured into six sections. Sections two, three and four describe the three characteristics of the environment which are inherent properties of CAS. Section five addresses HospMIS development as a co-evolutionary process, and section six examines scaling of HIS using the co-evolutionary learning model. Practical contributions are highlighted within each section, and therefore section seven summarizes the theoretical contributions only, while section eight identifies future research directions.

5.2. Understanding the Context 1: As Extreme Heterogeneity:

While heterogeneity can be expected to be an issue in hospital information systems development (Hanseth and Lundberg 2001; Ellingsen 2004), the extreme heterogeneity identified and the impacts of it on the process of HospMISD are surprising. In this section, I first expand on the nature of the extreme heterogeneity as discussed in Chapter 4, and then discuss the implications for health and HospMISD.

Heterogeneity features prominently in the IS literature with respect to large scale information infrastructures. In this context, heterogeneity is usually related to its constituent components (Hanseth and Lyytinen 2004), its developers and users (see for instance related to mobile communication platforms (Jansen and Nielsen 2005)), and the use and applications of information infrastructures (Monteiro 2003; Silva 2007). However, while these forms of heterogeneity also exist in the empirical settings described in this thesis, the “extreme heterogeneity” that I refer to has additional dimensions associated with it. These are elaborated in the next section.

5.2.1. Extreme heterogeneity manifested in hospitals:

Typically, in the context of IS development in hospitals, heterogeneity has been discussed in terms of heterogeneous and semantic interoperabilities (Ellingsen and Monteiro 2003;

Hanseth, Jacucci et al. 2006; Lopez and Blobel 2009), a diverse range of users (Berg 2001), and legacy software systems (Ciccarese, Caffi et al. 2005). The heterogeneity found in hospitals is closely linked to the autonomy and relative independence afforded hospital departments (or specialties), allowing them to behave relatively independently of other departments/units (Glouberman and Mintzberg 2001b; Glouberman and Mintzberg 2001a). This means for example that they might secure funding for, or develop their own IS and ICTs independently of those present or envisaged in other departments (Aanestad, Jensen et al. 2009). A good example of this is demonstrated by the extreme heterogeneity in one of the academic hospitals in Malawi where the paediatrics department staff use touch screen computers to capture patient related data, and bar-code scanners are used in the patient registration department to record patient attendance, while the anaesthesia department uses a hand-me-down computer and enters data by typing (Douglas, Deula et al. 2003; Shaw and Braa Forthcoming). In these contexts then, not only does one deal with the more sophisticated forms of heterogeneity such as system (non) interoperabilities, but also more basic conflicts between the computer capacity (as determined by its operating system and processor) and the software programs that demand advanced operating systems. The varying institutional arrangements that are required to manage these different technologies further magnify the nature of heterogeneity that has to be addressed while developing an integrated HospMIS.

While the finding of differences between units in a hospital may be expected, finding that there are dramatic differences in access to resources between hospitals within a region or province is surprising. Hospitals of a similar size can differ significantly in their access to resources like computers, staff, paper, or internet access. The reasons for the differences are a complex interaction of factors associated with, amongst others, the local environment and the history of that institution. An example of this is described in the paper by (Jacucci, Shaw et al. 2006) where PAH are “different” to other public sector hospitals because they generate 10% of their own revenues, and this allows them greater autonomy than other public sector hospitals. This autonomy allows them to pursue initiatives sometimes independent of public sector policy.

Heterogeneity also manifests in surprising ways in relation to professional and support staff. With respect to the types of professional staff found in hospitals, heterogeneity ranges across health workers, specialists and administrative staff. In resource constrained settings the heterogeneity is multiplied by disparities in terms of staff skills (Bhatnagar 1992; Kimaro and Nhampossa 2005), staffing levels (Kimaro 2006), and staff performance (unpublished reports from Nigeria and Eastern Cape).

5.2.2. Extreme heterogeneity creating nested effects:

The various forms of heterogeneity described (for instance related to staffing, hardware, software, and infrastructure, but also along other dimensions[11]) interact with one another in unexpected ways. Interactions arise from any of a variety of sources, and can change rapidly from one period to the next changing the context dramatically (Akpan-Obong 2007; Owei, Maumbe et al. 2007). Changes in one dimension are not always visible, but they create effects in other dimensions that then become visible as non-linear effects. These interactions leading to non-linear effects I call "nested effects" since they are small changes that are effected across a spectrum of possibilities, as depicted below.

In an attempt to analyze the nested effects in more detail, I have depicted some heterogeneities as positions across a spectrum. Thus for instance access to technology can be viewed as a functionality spectrum depicted below.

No computer	Basic computer	Computer with dial-up email access	Computer with high speed internet access	Web-based data storage and analysis

For example, in resource constrained contexts, the computer will not function without electricity, and electricity supply may not be reliable. Even if there is electricity, and the computer is available, there may be insufficient staff to operate the computer, and if there are sufficient staff, there is no guarantee that the available staff will be computer literate. These nested effects have a compounding effect on the ability to implement health IS. To have a fully functional system, each component of the system (and its sub-components) must be functioning in one way or another (ref Table 15), and in relation to each other.

[11] For instance Heeks (2006) refers to the dimensions of an IS as ITPOSMO being information, technology, processes, objectives and values, staffing and skills, management systems and structures, and other resources of the IS.

Table 15: Changes in heterogeneities interacting with one another as nested effects					
System Component	**Subcomponent**	**Scale of functionality from nil/basic to sophisticated**			
Reliable Power Supply	**Access to grid electricity**	None	Intermittent	Reasonably regular	Reliable
	Alternate power sources - generator	None	Stand-by generator available on ad-hoc basis	Sophisticated generator kicks in automatically when power fails	
	Alternate power sources - UPS	No UPS	UPS partially functional	UPS fully functional	
Access to computers and technology	**Computer/internet**	None	Basic computer	Computer with dial-up email access	Web-based data storage and analysis
	Environment for computer	Not acceptable	Secure but not dust free	Secure and dust free	
	Mobile reception/coverage	None	Intermittent	Reasonably regular	Reliable
	Mobile technology	None	Basic functionality	Sophisticated functionality	
Staffing issues	**Staffing levels**	No staff	Relatively few staff	Reasonable number	Adequate staffing level
	Staff skills	Not computer literate	Basic computer functions	Reasonably skilled	Advance skills

In conclusion, I use of the term “extreme heterogeneity” to emphasise the heterogeneity that spans a wide range of possibilities, and the rapid and ongoing nature of changes which result in nested effects, imbalances and non-linearity.

5.2.3. Practical implications 1: Managing heterogeneity in resource constrained settings:

In this section I highlight three approaches that are used to address the extreme heterogeneity found in resource constrained settings. A fourth approach is identified for building capacity within the public sector. Thereafter I discuss the implications of this analysis for the co-evolutionary framework (developed in Chapter 3) to help manage the technological, organizational and institutional forces that interact to create unexpected effects.

a) The PAN Model:

A good example of an "approach" to manage heterogeneities across multiple aspects of the HIS (for instance access to technology and staff shortages) is the PAN model which focusses on the need for flexibility to deal with an uncertain environment (see Figure 15). The model emerged out of an analysis of the dilemmas we faced in the field in relation to changing scenarios between access to technology (either rapid or static technological change) and staffing issues. It regards the process of building capacity as a set of activities that need to be enacted over time, requiring mindful innovation as a strategy to manage the process. In addition, given that changes occur on an uneven basis, and in unpredictable ways, we suggest that "fast advancers" (sites where new changes have been effected) can provide opportunities for testing new methods and approaches, which can be later modified and scaled across other areas. This approach resonates with the co-evolutionary concept of "rugged landscapes", where the CAS presents many frontiers that need to be managed at the same time. These frontiers provide the stimulus for development and competition at the "edge of chaos". The principle of integrated independence conceptualizes the explicit adoption of an approach to support the development of rugged landscapes. Local innovation is then allowed to occur within a bigger framework of a common vision, with accompanying feedback to the vision itself (Braa, Hanseth et al. 2007b).

b) Modularize to reduce complexity

In order to manage heterogeneities related to both staff shortages and inexperience, we[12] identify at least two strategies. One relates to training programs, and the other to the number of people trained. Initially, training programs were comprehensive and extended over a number of days, but this meant staff were away from their posts for extended periods and opportunity costs associated with the training were significant. Over the years, the training programs have been curtailed, and scaled back to small simple modules which can be implemented as a series of modules as skills improve and as funds become available. Modularisation does not negate the ability and need for more comprehensive training, but seeks to have a specific focus based on needs such as a basic training module for first time computer users. The current thinking is to link participation in further training to performance measures, and to register the modules as accredited academic programs. These actions are

[12] I use "we" in the sense that these initiatives were not my idea, nor necessarily my initiative, but have emerged as a strategy through working with colleagues in the HISP-SA and HISP-Nigeria teams and ministries of health.

an attempt to retain and motivate users and ensure that training is translated into productivity gains and help to cultivate a sense of empowerment.

c) Introduce redundancy to counter uncertainty:

Because most public sectors experience high rates of staff turnover, we adopt a maximalist approach to the selection of trainees in the sense that we will often request two or three people (rather than just one) per unit to undergo training. The effect is to introduce redundancy into the system in order to cope with losses. It also provides opportunities for a team to work together and support one another in the post-training period, and lastly, it expands the pool of people exposed to the system. For instance, often additional training slots are given to senior managers in an effort to increase their exposure to the system which invariably supports ongoing HospMISD efforts, which is especially useful when their authority is needed. The increased pool of people exposed to the system has implications for creating self-evolving networks of support.

d) Identify a set of resources for coping with heterogeneity:

Tools are concrete solutions to common problems, and can be regarded as essential resources for survival in heterogeneous environments. Examples of these “tools” include ensuring that facilitators have a range of DHIS installations that can function on older versions of the Windows OS as well as older versions of MS Office, and ensuring that data capture takes place on a local machine rather than relying on web-based access to the database. Facilitators carry with them freeware versions of anti-virus software to install and clean user computers that often do not have virus protection. These kinds of solutions are relatively simple to effect, and contingent on local needs. Yet they are important, and often neglected as part of the HIPs toolkit.

5.2.4. Summary – Expanding the Co-evolutionary approach:

In this section I briefly highlight how aspects of the co-evolutionary framework have been used to address extreme heterogeneity and non-linearity that results from nested effects, and I expand the co-evolutionary framework with one concept, namely the introduction of redundancy. The co-evolutionary framework has been used as follows:

- Firstly, modularization is effected in at least two areas. The modularization of the training materials results in greater use and change flexibility in order to accommodate the complexities of the environment. And nested heterogeneities are unpacked into their constituting components (for instance access to internet is effected (or avoided) based on access to resources) and managed as smaller units.

- Secondly, use of mindful innovation is integral to the successful application of the PAN model.
- Thirdly, integrated independence is encouraged amongst “fast advancers”, harnessing unevenness to potentially identify innovations.
- Fourthly, redundancy is introduced in various ways. For instance, HIPs carry a variety of tools with them, “in case” they are needed, and excess staff are trained to accommodate staff losses. Training excess staff may seem inefficient, but it serves the purpose of providing a pool of staff “in reserve” who can be used to fill gaps when needed.

5.3. Understanding the Context 2: As Non-linear Effects

While the organizational science literature has described the phenomenon of non-linearity (Stacey 1995; Anderson 1999) and approaches to managing it (Anderson 1999), the IS research literature has not specifically addressed non-linearity in any detail. However, some authors have described “unexpected effects” in health and hospital information systems development, even if the have not labeled the effects as “non-linear” (see for instance (Silva 2002; Littlejohns, Wyatt et al. 2003; Sahay, Monteiro et al. 2009). The empirical data in this thesis shows that non-linearity is the result of complexities of the environment, and in particular the rapid pace of small-scale changes in many parts of the health system. It is the result of changes occurring simultaneously (or not), and across multiple levels of the health system hierarchy and which defy control and anticipation. In this section, I first examine two interesting conceptualizations of non-linearity which are provoked by Urry (2003). Thereafter I explore our approach to coping with non-linearity.

5.3.1. Conceptualizing Non-linearity:

Non-linearity has been characterized by a lack of equivalence between the individual, and the statistical (Urry 2003). This suggests that when analyzing patterns, what may be statistically correct at the system level, may bear little resemblance to the individual within the system. In addition, the statistical or system effects are not the result of adding together all the individual components – there is something else involved called emergence. This definition of non-linearity is interesting when viewed from the perspective of performance within the public health hierarchy, where the range of performance is measured across the hierarchy. In this case, the individual level would be the patient or community member, or health facility, and the statistical level would be a few levels above this, such as the regional, country level. The analogy can be interpreted in at least two ways.

a) Non-linearity from the public health perspective:

First, an interpretation from a public health perspective, data viewed at the statistical level is an average, and usually appears uniformly uninteresting. As the data is disaggregated to the individual level it becomes much more interesting as differences become more evident. It is the differences between reporting units which depict success or struggle. Typically in the public health sector, data analysis and intervention is about identifying the deviation from the norm rather than the normative values (where is HIV/AIDS incidence highest and why, or where is it lowest and why?), and so it is more about the individual than the statistical. Effecting a change in disease patterns (whether enhancing the spread of successful practices, or curtailment of outbreaks), is about focusing resources on the “deviants” (which are usually a small number of few critical areas), and carefully testing ideas before scaling them beyond the critical areas.

b) Non-linearity as a dimension of hidden organizational turbulance:

The second interpretation is that what is seen from the organizational level (or statistical level) does not reflect accurately what is happening at the individual level. For instance, the individual level may be chaotic, and uneven, and filled with currents and eddies like the seabed, while the surface appears calm and smooth.

The importance of both these interpretations is that they emphasise the relevance of the individual. Tipping points (which are non-linear effects) in effecting widespread change are brought about by focusing resources in a few key areas (Gladwell 2000). Any non-linear effects resulting in improvement at the national level would be the result of improvements in the individual level (see for instance (Garrib, Stoops et al. 2008; Mate, Bennett et al. 2009). This phenomenon raises two questions – first, what gave rise to these improvements? We know the answer to this question is that these effects are the result of multiple complex interactions resulting in nested effects which are beyond the control of any single individual. But more importantly, the question is how do we create similar non-linear effects? This is a question that is not usually asked when HIS strengthening interventions are designed, developed and implemented. Because non-linear effects are neither under the direct control of any single person, nor are they predictable, they cannot be guaranteed. Rather, the challenge is to create the environment in which non-linear effects in support of HospMIS efforts can happen, or where the effect of adverse non-linear effects can be countered. Despite increasing literature in the IS research field on CAS, managing non-linearity is an issue that has not received much attention to date (see for example articles related to co-evolutionary theory, many of which hardly address non-linearity in any detail such as (Dooley 1997; McKelvey 1997; Anderson 1999; McKelvey 1999b; Benbya and McKelvey 2006a; Merali 2006). One of practical contributions of this thesis is to expand the range of approaches to manage non-linearity.

5.3.2. Practical Implications 2: Managing Non-linearity:

I suggest three approaches in support of creating non-linear effects. First, focus resources in a few key areas (Gladwell 2000). An application of this approach is suggested in the “hierarchical cluster approach” to HISD (Shaw and Braa Forthcoming) which focuses not only HMIS resources, but also other resources on facilities identified to be priority target facilities. Secondly, encourage the creation of self-organizing groups. This is discussed in more detail below. Thirdly, establish processes to ensure the key contributing factors to non-linear systems are supported and developed. The key contributing factors to non-linearity are an efficient communication network that links levels and sub-systems within the organization, mechanisms establishing close links between sub-systems, frequent feedback, and decentralized power and control within a framework that encourages self-organization and innovation (Dooley 2002).

While these approaches have been suggested to create non-linear effects, they can also be used to mitigate or counter the unwanted effects of non-linearity. In other words, non-linearity cannot be countered with linear deterministic approaches, rather, non-linearity should be managed with non-linearity. If unwanted non-linear effects are predominating, they can be countered by increasing or decreasing feedback width or breadth, increasing or decreasing size of groups, and increasing or decreasing integration. For instance, linkages between HospMIS and sub-systems will always require careful consideration whether to increase fragmentation, or to decrease it, and whether to link systems tightly or loosely. The answer to this will usually be apparent from the context, and the availability of skills and resources, and may change from time to time, depending on changes in other areas of the CAS as a whole.

5.4. Understanding the Context 3: Self-organizing networks displaying emergent behaviour

The notion of “networks of action” have been used to effect sustainable HISD in resource constrained contexts (Braa, Monteiro et al. 2004). In this conceptualization, not only are the networks local groupings constituted by a diverse range of actors (academics, students, health workers, developers, HIPs), but they are also interconnected networks across countries and regions. They are loci of action and learning. At times the networks are “marginal, alternative…opposing the …dominant network” (p. 342). In a similar vein, (Mosse and Sahay 2005) develop the notion of “counter networks” in support of Castells’ (2000) assertion that despite advances in technology and networks, there remain islands of people who cannot join the networks and take advantage of increased interconnectedness and globalization afforded by increased access to ICT’s. They use the term counter networks to emphasise the need to avoid technologically deterministic assumptions. For example the assumption that by providing access to ICT, people will automatically be able to take advantage of them. Rather, because of contextual peculiarities, a variety of approaches, over time, and at multiple levels of the system are required to optimize the use of ICT. They identify the numerous networks that health workers belong to, not only professional but also social and familial, and recognize that efforts at strengthening the HIS do not take into account these sometimes conflicting alliances. Complexity science helps us understand that individuals belonging to professional networks can utilize their membership of other networks (such as the social and familial) to not only expand their knowledge and experience, but also spread their knowledge and experience, thereby creating non-linear effects in support of HISD.

5.4.1. Self-organizing groups in support of co-evolutionary HospMIS development:

In this thesis, I seek to advance the understanding of self-organizing groups as contributing to the co-evolutionary stance. The self-organizing groups described in the cases in this thesis are “networks of action” focused on achieving specific objectives. For example, in Zambia, the groups were established to effect the roll-out of training across the country, and in the anesthesia department in Malawi to develop the departmental IS. New Hope Hospital in the Eastern Cape (Jacucci, Shaw et al. 2006) is an example of a network of action for PAH to improve their management and financial reporting. The development of the self-organizing group is an outcome of a process of bringing diverse people together and providing a vision that they can buy into, and then helping to create the circumstances that allow further sub-groupings to develop. Similar to the "Practice", in each of these cases an attractor focuses the groups action (Alaa and Fitzgerald 2004).

Creating "attractors" is not an insignificant task, and does not happen overnight. Attractors emerge as a balance between a bottom-up and a top-down process of negotiation between stakeholders with divergent views. By incorporating people with diverse skills, experience and from different levels of the hierarchy in the process, turbulence arises through the expression of different views. These are the areas which provide opportunities for constructive engagement, adaptation and learning (Eoyang 1996; Dooley 1997). The attractors not only focus resources, but also are the sources of instability and innovation in that they unsettle the established status quo. The self-organizing networks serves not only to adopt the attractors locally, but also to debate the validity and expand the application of the attractors through other networks. Rather than having the end result as a trade-off between the parties involved which does not engender support for the system or its use (Silva and Hirschheim 2007), a win-win solution should be sought. The nature of attractors described (namely a flexible EDS and a customisable software program that can adapt to changing circumstances) provide solutions that accommodate different perspectives and thereby generate support and commitment to the product (Braa, Hanseth et al. 2007b).

5.4.2. Self-organizing groups pushing for change:

An implicit purpose is to use the group to stimulate the expansion of the network of supporters (on the assumption that participants would be "converted" at best, or even if they remain "agnostics" at least they will talk about their experience) and self-organizing groups. In the case of the PAH group this happened by the creation of committees to help one another, and to look into financial issues. In the Zambian case, the MoH specifically asked 'tutors" from the nursing colleges to attend the training so that they could grow into important roleplayers in the undergraduate training process by becoming aware of the training materials, and adopting the content in their courses. An attestation to the effect of this is the fact that subsequent to the "training of trainers" course, one of the schools contacted my Zambian counterpart to ask for his assistance in effecting a training course that they wished to offer. This example demonstrates how both the network was expanded and potentially a new self-organizing group could emerge.

The expansion of the network has a purpose in that it helps create a critical mass pushing for change. This is a very different approach to the "revolution" suggested by Silva and Hirschheim (2007). Instead, the focus is on creating networks of support which gradually increase the critical mass supporting change. Not only do these networks effect the change required, but potentially they become agents of continuous change, underpinned by empowerment processes that allow the participants to grow, learn, and adapt to changes in their local environments. Through this process the pace of change fluctuates – at times it is rapid, but at times is slow. The landscape is thus constituted by an upward gradient (improvement) with small peaks representing punctuated revolutions of small change. This is the nature of the co-evolutionary process we strive for, and which is discussed in more detail below.

5.4.3. Practical Implications 3: Managing self-organizing groups:

The self-organizing groups are thus also learning networks, and networks of innovation. This is in some instances an explicitly stated purpose. In all these groups I try to establish them in a way which draws heavily on participatory action research (PAR) approaches of action, reflection and learning (Crabtree and Miller 1992; De Koning and Martin 1996). This approach not only helps to empower participants (for instance on the attractor and its use), but also establishes an informal authority in the group to moderate behaviour. The expected standard for performance (akin to the formal structure referred to by Stacey (1995)) is set through formal documents (memos, circulars, training guidelines), but the group inevitably takes on the responsibility to critique deviants, and emulate best practice. No "policeman" is needed in this environment as it is established as a "learning environment". Through the process of learning and empowerment, the self-organizing groups are a means of diffusing the power and control located in the centre. They become a mechanism for enabling local action that can adapt to local changes within the confines of the rules and regulations of the rigid bureaucracy of the health system, the source of bounded instability (Stacey 1995).

The challenge then, having enabled the creation of these self-organizing groups and networks, is to keep abreast of the emergence of new self-organizing networks, and to encourage them to share their experiences with others, especially given the expectation that these networks will come up with innovative solutions to local problems. The very forum that legitimized the establishment of self-organizing groups can then become a forum for feedback and further development of innovations arising from these processes.

5.4.4. Conclusions:

In concluding this section, I suggest that the role of self-organizing groups is not only to address a specific set of tasks, but also to stimulate learning and change in a "learning environment". At least three other useful roles are discerned. One is to stimulate the expansion of the network of supporters through including “connectors” (after Gladwell (2000)) explicitly in the groups so that they can “spread the gospel”. Second, support the creation of other self-organizing groups. Third, expand the critical mass of supporters pushing for continuous change.

5.5. Sustainable IS[13] Development: The Co-evolutionary Model:

The aim of this section is to provide a conceptual framework for the sustainable development of HIS. The conceptual framework for sustainable HospMISD is drawn from two main literature streams. Organizational sustainability has been conceptualized as the outcome of successfully balancing exploration and exploitation drives (March 1991; Koza and Lewin 1998; Lewin, Long et al. 1999). The challenge within the public sector with respect to IS development in resource constrained settings is to achieve a balance between these approaches, especially given the staff shortages, shortage of skills and lack of flexibility. Organizational learning and absorptive capacity have been prominent themes in the organizational science literature (Crossan, Lane et al. 1999; Van den Bosch, Volberda et al. 1999; Zahra and George 2002), and organizational learning is central to the process of balancing the explorative and exploitative drives (March 1991; Crossan, Lane et al. 1999). I bring these streams together (organizational learning and balancing exploratory and exploitative drives) by building on the work of Crossan, Lane et al. (1999). Using the notion of combinative capabilities as a measure of organizational absorptive capacity, I compare the public sector organizations with HISP-SA (as an example of a NGO organization working in partnership with the public sector). This analysis suggests that public sector organizations are less likely to pursue explorative drives, while an NGO like HISP-SA is more inclined to do so. This suggests that a co-evolutionary partnership between the two organizations might be synergistic. A useful framework with which to view sustainable HISD is presented. I then expand this theoretical framework to account for the HISP-SA experience in evolutionary software development in Africa as a co-evolutionary process which is effected across three

[13] In this section and the next, I refer mainly to IS development since the insights I present here are based on my longitudinal involvement in health IS development with the HISP-SA organization in particular. I do this recognizing that my experience in hospital information system development is shorter. However, I suspect that the principles suggested here will apply equally to hospital information system development.

areas of practice, namely within HISP-SA, within the public sector organization, and between the two organizations.

The remainder of this section is structured as follows. In the next sub-section, I examine the challenge of sustainability. Drawing on the case studies from this thesis, and other literature, the possibility that a dynamic partnership can potentially exist between the public sector and an implementing agency (such as an NGO like HISP-SA) is presented. Thereafter, in an effort to further asses the complimentary skills between an NGO and the public sector, the absorptive capacities of the two organizations are compared. In the next subsection, I explore organizational learning as a co-evolutionary process, and suggest a model for co-evolutionary HISD. A summary is provided in the last sub-section.

5.5.1. The challenge of sustainability

Sustainability is "…the challenge to make an information system work, in practice, over time, in a local setting. This involves shaping and adapting the systems to a given context, cultivating local learning processes, and institutionalizing routines of use that persist over time (as well as when the researchers leave and external funding is over)." (Braa, Monteiro et al. 2004) (p. 338). In addressing the challenge of sustainability in HISD in resource constrained settings, the importance of establishing networks of sites engaged in learning processes around working prototypes of HIS is stressed (Braa, Monteiro et al. 2004). Interventions are aligned with "existing institutions, competing projects and efforts as well as every day practices." (p 359). They suggest mechanisms for the vertical and horizontal flows of software training and expertise based on an action research approach called "networks of action". These are characterized by a network of sites (organizations located in different countries) linked together in a framework to encourage vertical and horizontal flows of information and experiences between the sites. The network is comprised "neighbourhood networks" (Dooley 2002) of a diverse range of actors who are aligned around a sufficiently uniform agenda, and who also pursue local interests and innovations linked to local practices and every-day actions of existing institutions.

This description of the HISP network provides some insight into the ongoing development of the network, and the circulation of ideas and approaches within the network. But what this conceptualization does not elaborate on is the differences between the HISP actors and the MoH officials, nor does it elaborate on the nature of the partnership between the HISP network and the respective MoH. They (the HISP network and the MoH) are not a uniform group, and are not a single close-knit organization. Rather, they are individuals who establish links across the networks within each of the organizations. In the remainder of this sub-section I explore the differences between these organizations in an attempt to identify insights that might strengthen the partnerships and alliances.

A complimentary view to that of (Braa, Monteiro et al. 2004) is presented by Shaw and Braa (Forthcoming) who, drawing on 10 years of experience in HISD in Africa, suggest that the development of sustainable HIS is a “continuously evolving balance between ISD, human capacity development and scaling approaches” (p.18). The approach depicted in this description is supportive of strategies suggested by (Kimaro and Nhampossa 2005) to increase the sustainability of HISD initiatives. In exploring reasons for “unsustainable” HISD projects, they identify two partnerships that are problematic. First, the partnership between the MoH and donor organizations is weak because of the inadequate institutional and technical capacity of the MoH, the tendency to allocate short-term contracts to (often foreign) agencies for software development, and the inappropriate balance exerted by donors over the MoH. It is interesting to contrast these problems with the approach described by Shaw and Braa (Forthcoming), where HISP-SA is seen as a partner to government. As such HISP-SA complements the lack of technical HIS capacity in the public sector, both at a micro level (for instance the interactions between the HISP team practitioners and the emerging cadre of HIP) and at the macro level (where for instance the HISP team is appointed to support and advise government in the re-design of their HIS (as occurred in Zambia)). Short term contracts remain a problem because they generally reflect a linear approach to HISD, and often the contracted organizations approach the problem with a purely technical solution. The third area, namely the inappropriate balance exerted by donors, is increasingly being challenged because of the availability of FOSS solutions such as the DHIS (see for instance http://dhis2.com/), Care2X (see for instance http://www.openclinical.org/prj_care2x.html) and OpenMRS (See for instance http://openmrs.org/wiki/OpenMRS, and Seebregts, Mamlin et al. 2009) all of which have a significant track record of successful implementations in resource constrained settings. The availability of these solutions is shifting the power of control over software development projects from private, for-profit-orientated software developers, into networks composed of public sector institutions, academia, NGO’s, and some private sector organizations.

The second partnership that is identified is that between the MoH and software development agencies. Three problem areas are identified, namely the lack of co-ordination of software development efforts, the poor and inadequate understanding of user requirements, and rigidity in design efforts. While the first remains a problem, there are significant efforts directed towards addressing the fragmentation of HIS (see for instance Evans and Stansfield

2003; Boerma 2005; Boerma, Bos et al. 2008; Health Metrics Network 2008). User requirements are increasingly being addressed through the availability of a range of FOSS products (as described above) which has a certain inherent flexibility. Given these efforts, the possibility of a long term relationship between a NGO, and the public sector, to support ongoing development of the HIS becomes increasingly attractive.

In summary, in response to the suggestion that HISD are unsustainable because of predominant organizational and institutional arrangements, two views on sustainable HISD from the body of literature on the HISP network are presented. The one describes the "networks of action" approach, but is critiqued for not detailing explicitly the mechanism by which skills are transferred to the public sector. The other views HISD as a continuously evolving balance between ISD, human capacity development and scaling approaches, which provides resources that counter the factors resulting in unsustainable systems. These resources are the availability of FOSS, and the establishment of partnerships between the public sector and an implementing agency, such as an NGO. The partnership allows the NGO to complement the public sector organization with HISD skills, and to support HISD at both the micro and macro levels. In the next sub-section I examine organizational absorptive capacity in relation to sustainability.

5.5.2. Sustainability and organizational absorptive capacity:

In order to further develop the complementary nature of the relationship between an NGO like HISP-SA and a public sector organization, I expand the framework developed in Chapter 2 on absorptive capacity (Van den Bosch, Volberda et al. 1999) (see Table 16). The analysis shows that an organization like HISP has the characteristics to have a high absorptive capacity and can potentially complement the relatively slow absorptive capacity that is evident in the public sector. The question is how can such a partnership be established? Before addressing this question, the question of staff turnover warrants some discussion.

Table 16: Comparative Assessment of Absorptive Capacity between Public Sector and NGO Organizations				
Combinative Capability	**Hospital[14] as an organization**		**HISP-SA[15]**	
	Explanation	**Effect on absorptive capability**	**Explanation**	**Effect on absorptive capability**
Organizational form	Functional form, or perhaps divisional form depending on size	Negative	Matrix form with extensive networks and self-organizing groups and local autonomy	Positive
Systems capabilities	Bureaucracy with strong and very formalized systems capabilities	Negative	Weak, rules and procedures based on oral	Mostly positive
Co-ordination capabilities	Strong relationships within and across functional groupings in hospitals	Positive	Strong relationships within the organization and between the organization and many external partners	Very positive
Socializing capabilities	Reasonably strong corporate identity, tending to be insular.	Mostly negative	Reasonably strong corporate identity but not so strong as to prevent external knowledge from being assimilated	Positive
Overall assessment		**Mainly negative**		**Mainly positive**
Staff turnover	Reasonably high with low levels of institutional memory	**Mainly negative**	Reasonably stable, with high levels of institutional memory and sufficient injection of new ideas	**Mainly positive**

The rapid turnover of staff within the public sector is an issue that has been described in the literature (Schneider, Blaauw et al. 2006; Padarath, Chamberlain et al. 2007), and which is frequently experienced in the health information sector of public sector organizations in

---

[14] I have used a hospital as an example of a public sector organization because it provides a more focused unit of analysis. However, the same pattern for absorptive capacity is likely to be found for the health department as a whole, or a district office as a whole. It is therefore legitimate to generalize this finding to the case of HISD within the health sector as a whole.

[15] I use HISP-SA as an example of an external support agency for two main reasons. First, my empirical research was largely conducted within this organization. Secondly, as is indicated in the thesis, the HISP-SA team provides a broad range of skills across the spectrum from professional software developers to medical professionals. It would not be appropriate at this stage of our understanding to generalize the role/influence of this team to other NGO's, or to other HISP teams.

resource constrained settings. For instance, a survey amongst health information officers done in South Africa in late 2006 indicated that only 20% of information staff had been in their positions for more than 5 years, and 30-40% less than one year (Loveday, Smith et al. 2006). The impact of the staff turnover is advantageous in the sense that new staff bring new ideas into the team, and in many cases information officers have been promoted up the hierarchy, thus increasing the organizational knowledge about HISD. However it is disadvantageous in that the leaving staff are often not available to act as a resource for the incoming person, positions that are vacated remain unfilled for long periods of time, and investment in temporary appointments may not support long term sustainability. For example, in one instance, the team had to train 4 different people as a hospital information officer over a 6 month period[16]. The net result is a decrease in institutional knowledge on HIS at the local (micro) level. In contrast to this, the HISP team have had a reasonably stable team. While too much stability can be disadvantageous, there has been sufficient turnover to inject new ideas into the team. In addition, new ideas have come through team members undertaking further studies, and links with other nodes in the HISP network (Braa, Monteiro et al. 2004; Shaw, Simoonga et al. 2008).

The assessment tabled above suggests that overall, an NGO like HISP-SA would be more inclined to pursue exploration drives than would the public sector hospital, and therefore there is a complementarity which helps to improve the hospital organization’s absorptive capacity. This understanding provides insights into the meaning of co-evolution in the domain HISD in resource constrained settings.

5.5.3. Organizational learning as a co-evolutionary process:

Organizational learning is based on four premises (see Text Box 5) (Crossan, Lane et al. 1999). The key aspects of these premises are the balance between new learning and using existing learning, the multilevel nature of the learning process, and the social and psychological learning processes. The latter warrants some discussion.

[16] Project report for the Eastern Cape Hospitals project, 2005.

Text Box 5: Premises for an Organizational Learning Framework

- Organizational learning involves a tension between assimilating new learning (exploration) and using what has been learned (exploitation);
- Organization learning is multi-level and involves the individual, the group, and organization;
- The three levels of organizational learning are linked by social and psychological processes. These are intuiting, interpreting, integrating, and institutionalizing (4I's);
- Cognition affects action (and vice versa).

(Source Crossan, Lane et al. 1999)

The learning process takes place across three levels within the organization, namely the individual, the group, and the organizational level (see Figure 18). Intuiting is the pre-conscious recognition of a pattern or process based on personal experience. It is enacted at the individual level. Interpreting is the process of explaining (verbalizing) an idea or concept, and happens at the individual and group levels. Integrating is the process of developing a shared understanding among individuals or members of a group, and involves taking action

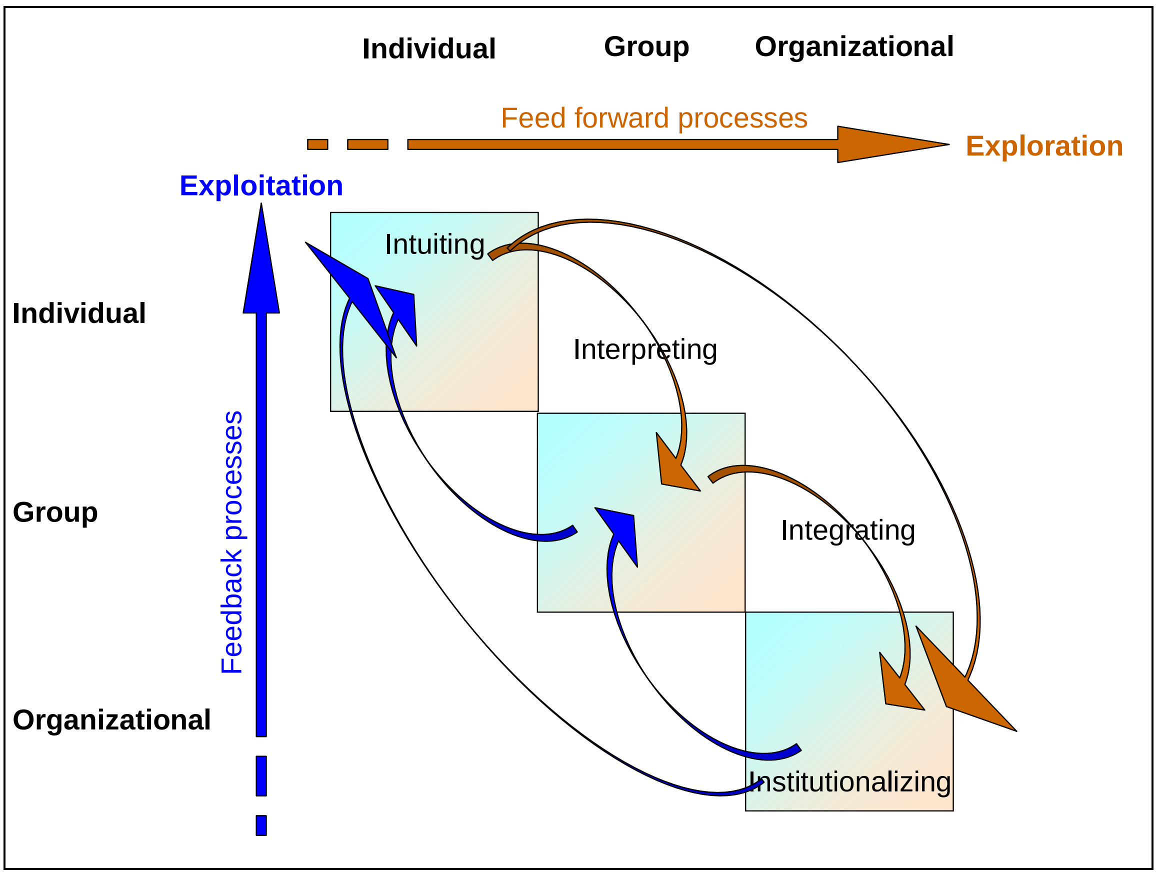


Figure 18: Organizational Learning Framework as a Co-evolutionary Process

(Adapted from Crossan, Lane et al. 1999) through mutual adjustment, or adaptation of existing processes and procedures. This may be an ad hoc process initially, but gradually becomes more formalized, and if it begins recurring on a regular basis, then it becomes institutionalized. It takes place at the group and organizational levels. Institutionalisation is the routinization of actions, processes, procedures or systems (Crossan, Lane et al. 1999). It is the process of embedding learning that has taken place at the individual and group level into the organization.

The processes depicted in the organizational learning framework (OLF) meet the criteria of co-evolutionary processes in that they are subject to multilevelness and embeddedness, multidirectional causalities, non-linearity, and path and history dependence (Lewin and Volberda 1999). The OLF suggests concurrent processes that are fed by positive and negative feedback processes.

To illustrate the co-evolution process between the two organizations, I first, draw on the description provided earlier of the identification of an attractor (see section 5.4.1). Our experience demonstrates that the identification of a solution to a problem is not immediately recognizable as an “attractor”. The identification of the attractor has emerged through co-evolutionary processes taking place at and between at least three areas of practice, namely networks within HISP-SA and between HISP-SA and other networks (for instance with the HISP international network), between HISP-SA and the public sector hospital, and within the public sector hospital networks and between these networks and their external environment. Once an “attractor” becomes obvious, its subsequent utilization as a point around which to rally stakeholders becomes part of an ongoing co-evolutionary process. The attractors can then be offered for use in other contexts, but “attractors” cannot be guaranteed to have the same effects in the new sites. Rather their acceptance needs to be the modified and adjusted through feedback loops between the macro and micro levels as the co-evolutionary processes unfold and move through the phases of interpreting, integrating, and institutionalization. These processes continue to occur as co-evolutionary processes between the respective organizations, and their environments. The net result is that the co-evolutionary process is a dynamic equilibrium as the organizations undergo change in response to changes in their immediate environments.

5.5.4. The co-evolutionary information systems development model:

In conceptualizing the organizational learning framework as a co-evolutionary process for learning about HospMISD, two aspects of the model are developed. First, a co-evolutionary process between an NGO and a public sector organization is potentially a relationship which allows the strengths of each organization to complement one another. Secondly, co-evolutionary processes do not happen only between the two organizations, but also within each organization, and between each organization and other organizations with which it interacts. These two aspects are explored in detail in order to define a co-evolutionary ISD model.

Given the analysis of absorptive capacity provided above, it is clear that a public sector hospital (and likely public sector organizations in resource constrained settings) will be more likely to pursue exploitative processes than explorative processes, and this is also our experience. In fact, most public sector organizations in South Africa are focused on exploitative activities. In contrast to this, it would appear as if the ability of the HISP-SA network to balance explorative and exploitative activities is well developed. While this is an issue that warrants further research, for now I will focus on the HISP-SA teams' ability to pursue the exploration drive, and assume that the exploitation drive is sufficiently developed to not result in the organizations' downfall. The exploitative activities are driven internally through its team support structures and by its need to compete with similar organizations for work. Because HISP-SA has access to a diverse range of markets, end-users, and researchers (through its own networks and project activities in Nigeria, Liberia, Zambia, and South Africa for instance, and linkages with the HISP international network in sites such as India and Vietnam), potentially it should be able to maintain the explorative drive while also balancing the exploitative drive. This suggests that the HISP-SA team is well placed to manage both legacy systems (such as the DHIS) and disruptive technologies that may threaten the legacy systems (Dosi 1982; Christensen 2000), and to facilitate public sector access to these technologies through the co-evolutionary relationship.

As is suggested above, the co-evolutionary processes occurs in at least three areas of practice (see Figure 19), and in relation to changes in the health and ICT sectors.

- First, intra-organizational co-evolution takes place in the public sector hospital in response to its internal dynamics, and in relation to the environment. The co-evolutionary process within the hospital is strongly influenced by the close link between the hospital and the health sector as a domain of influence. For instance, as the health sector understands more about the HIV/AIDS pandemic, this knowledge is influencing the way patients are treated and managed, and the kinds of information that are important (see for instance (Rugg, Carael et al. 2004; Wolf, Bicego et al. 2004). Similarly for the more recent H1N1 pandemic. Unlike the strong links between the health sector and the hospital, the links between the hospital and the ICT sector

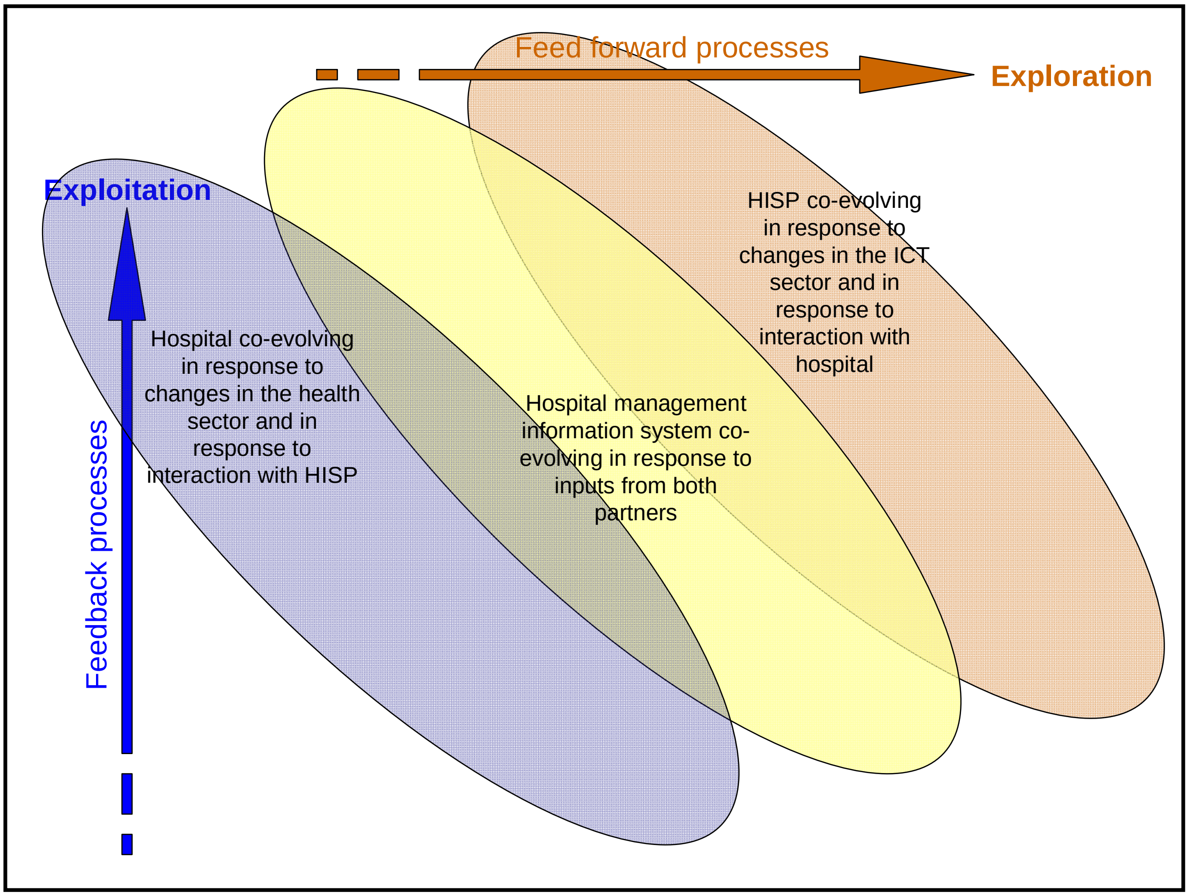


Figure 19: The Co-evolutionary Model for Hospital Management Information Systems Development

are much weaker, and often non-existent (Kimaro and Nhampossa 2005; Bada 2006).

- Secondly, intra-organizational co-evolution takes place in the HISP-SA team, and between the HISP-SA team and its networks. This is strongly influenced by developments in the ICT sector (as an important domain of influence), and to some extent, by developments in the health sector (as another domain of influence). For instance, intuiting around a new concept might originate in the HISP-India part of the HISP network, be interpreted within the HISP-International network, integrated within the HISP-SA team, and then be introduced as a concept to the hospital (Braa, Monteiro et al. 2004; Shaw and Braa Forthcoming). The complimentarity between the public sector hospital and HISP-SA is that HISP-SA as an external support team provides strong links to the application of ICT's in the health sector, and therefore mediates between the health sectors need for information related to changing health care practices, and the most appropriate solution available from the ICT domain. This is the third sphere of influence, namely between HISP-SA and the hospital

- Inter-organizational co-evolution takes place between the hospital and HISP-SA team, at numerous levels between the micro and macro levels, as the hospital management IS evolves through the co-evolutionary processes, and as each organization changes in response to its co-evolution with its own networks of influence. The interactions that take place at these three levels are a complicated web of intuiting, interpreting, integrating and institutionalization since newly developed concepts introduced by any of the organizations may require some time to be re-interpreted, and integrated before becoming institutionalized. In this process, it may also be modified, and changed, which then allows feedback to the respective organizations as an improvement (exploitative effect) or even as a new development (exploratory effect). However, from the preceding discussion on absorptive capacity, we can assume that the nature of new developments from the HISP-SA side of the partnership are likely to be exploratory in nature, while the public sector side will likely drive the exploitative component.

Crosson, Lane et al. (1999) suggest that there are two particularly problematic relationships, namely the interpreting-integrating (feed forward process) and the institutionalizing-intuiting (feedback) process. The former is a challenge because it requires not only changing a shared reality, but also the ability to vocalize and express an idea in a way that can shift the existing group code. Experiential learning and action research provide a mechanism to overcome this challenge through joint action (such as described in the section on self-organzing groups) which can then create a shared understanding (Crossan, Lane et al. 1995; Braa, Monteiro et al. 2004). For instance, focusing on an attractor provides the opportunity for shared experiences that can potentially support integration processes.

The second challenging relationship is that between institutionalizing and intuiting, and is the feedback process. This relationship is problematic because institutionalization can easily drive out intuiting. Intuiting tends to go against the drives towards exploitation because it upsets the status quo. Organizations overcome this by establishing research and development units and specifically allocating resources to ensure that exploration persists. However, as is pointed out by Christensen, many organizations that did have effective research and development units were still not able to maintain their competitive advantage, largely due to the challenge to match new innovations to a market, given that customers of today seldom appreciate the products of tomorrow (Christensen 2000). The HISP international network is potentially an interesting model to overcome this challenge, being chatacterized by intra-organizational diversity comprising different professionals (doctors, nurses, programmers, information technologists, and environmental health workers), different professional areas of interest (academics, HIPs, use of information, data quality issues), self-organizing groups ensuring cross fertilization across a range of diverse markets and contexts, and with a range of technologies and approaches.

5.5.5. Practical Implications 4: Effecting co-evolutionary health information systems development:

The co-evolutionary model potentially becomes a vehicle within which the co-evolutionary framework for ISD can be applied. For instance, as indicated earlier, "attractors" and the principle of integrated independence can be usefully utilised within this model to stimulate intuiting, interpreting, integrating, and institutionalizing products and processes. The co-evolutionary model can potentially maintain many rugged landscapes on various fronts which can balance exploitative and exploratory processes, and address the extreme heterogeneity that characterizes the environment. HISP-SA is already engaged in this type of co-evolutionary model, and my understanding is that HISP-India has a potentially long-term arrangement with the National Rural Health Mission which can be conceptualized as a co-evolutionary model. However, viewing sustainable HISD through this model opens a whole vista of approaches for sustainable HISD from the perspective of the public health sector, and for the HISP international network.

The way in which I have described the public sector hospital can be critiqued for being too "all encompassing" because within any large organization, there are likely to be "fast advancers" as well those who are slow on the uptake. This reflects the challenge between developing macro level concepts and their micro level application. I recognize this, and as will be seen in the next section, suggest that any co-evolutionary process should identify the fast advancers, and involve them in the processes. In this way, micro level initiatives can drive the macro level processes. The more "fast advancers" there are, the greater the likelihood that the system will be driven from within.

The co-evolutionary model for sustainable HISD warrants further scrutiny through application of the model in different environments to those described, and through more detailed analysis at micro and macro levels. The application of the model should be further evaluated with respect to the optimum length and the specific focus of the partnership. For instance, the partnership for strengthening the hospital IS in the Eastern Cape was only one year long, and had a very specific focus, yet HISP-SA has maintained contact with the ECDoH through a variety of other mechanisms, such as other (short term) projects, through providing support funded from organizational overheads, and by virtue of joint participation in networks and forums. The partnership is therefore in reality a long term one (even if informal in nature) characterized by shorter periods of more intense partnerships secured by formal contracts. Should HISP-SA and the MoH strive for formal partnerships of longer duration, or do short term partnerships help to maintain the competitiveness between HISP-SA and other external support agencies?

Understanding HISP-SA as a networked organization dependent and contributing to innovations and developments in the health information sector suggests that the links within the HISP international community, and with HISP nodes in other countries should be strengthened. But, these linkages can only be strengthened if HISP nodes have a similar understanding, and so this model has implications for the HISP international network as well.

Lastly, the model brings to the forefront questions about the breadth of scope that the HISP exploratory drive should pursue in the health information sector. For instance, to date HISP-SA has focused on strengthening systems for aggregated annonomised data, but is increasingly being pressured to pursue work in the field of EPR systems. The model needs to be researched further to consider how this drive should be addressed. For instance, should HISP-SA develop the internal capacity to strengthen EPR systems, or should this be done through partnerships between HISP-SA and other external agencies that have experience in this area, or perhaps left unattended so that the public sector pursues its own solution possibly through the private sector, or through a separate external support agency?

5.5.6. Conclusion:

In conclusion, I have used the example of HISP-SA and a public sector hospital to suggest that HospMISD in resource constrained settings can potentially benefit from a co-evolutionary process that is effected between organizations with complimentary exploitative/explorative drives. This model also applies to HISD with the public health sector. At the same time, and in parallel to the co-evolutionary HISD between the two organizations, each organization undergoes intra-organizational co-evolutionary processes and inter-organizational co-evolution with its specific domain of influence. To this end I conceptualize HISP-SA as an organization that is co-evolving with the public health system on one hand and development in information technology and IS research on the other. I suggest that this is an appropriate way to envision future health systems development given the dynamic nature of technological advancement, and the relative limited ability of government to keep abreast of developments in the ICT domain. I further suggest that the HISP-SA team (and potentially the HISP international network) is different to that of private sector companies because of its academic and non-profit motives, and that these enable it to maintain a position within the zone of complexity that reflects the cutting edge of HISD. The co-evolutionary process is a delicate process of initiating organizational change through mutual learning processes that will eventually be institutionalized.

The model accommodates the concepts and approaches detailed under the co-evolutionary framework very well, although the application of the model raises a number of questions related to the long term nature of the relationship and the breadth of scope of the exploratory drive should pursue. These are issues that will be explored in the next section where I examine the impact this understanding has on the scaling of HIS. In this next section I first use the district health system as my unit of analysis, and then generalize the findings to the hospital sector.

5.6. Co-evolutionary Scaling of HIS:

In this section I first explore the current conceptualization of scaling of HIS, and then conceptualize scaling as a CAS in order to provide some useful insights. This conceptualization is then further developed by examining the scaling process along four dimensions. A CAS inspired theoretical understanding of scaling of HIS is presented, using key concepts from co-evolutionary theory.

5.6.1. The challenge of scaling:

The challenge of scaling has been described as "…the problem of how to make one, working solution spread to other sites, and be successfully adapted there. Beyond merely the technical aspects of scalability, our concerns lie in how to reproduce and translate the necessary learning processes alongside the spreading of artifacts, funding, and people." (Braa, Monteiro et al. 2004, p. 338)

Scaling of HIS has received substantial attention over the last few years, particularly in relation to the HISP network and its use of the DHIS (Sahay and Walsham 2006; Saebo 2008; Shaw and Braa Forthcoming), but also in relation to the costs of scaling health services (Johns, Torres et al. 2005), and in particular in relation to the scaling of HIV/AIDS programs (Hanson, Ranson et al. 2003; McCoy, Chopra et al. 2005). Scaling has been likened to a cultivation process (Bergqvist, Dahlberg et al. 2002) with the emphasis on growing of the system from the bottom-up. This builds on the existing base. It assumes that the process of change should not “upset, an organization more than what is absolutely necessary to accomplish the task at hand” (ibid). Rather, weaker parts of the system should be pruned away, allowing the stronger parts to persist. The focus here is on the users being cultivated to perform their tasks differently in response to changes in the IT infrastructure. In contrast to this, Hanseth (Hanseth 2002) describes the cultivation of the information infrastructure using a bootstrapping approach to bring about change without disrupting the installed base. In resource constrained contexts however, the heterogeneity of the context presents a range of additional issues that need to be considered during scaling operations. For instance, the implementing team’s skills need to be expanded, so that they can “seize opportunities” from unplanned events, and use them to their advantage (Sahay and Walsham 2006). In scaling HIS in Nigeria and Ethiopia, scaling is described as a balancing act between access to human resources, technology, and data transmission (Shaw, Mengiste et al. 2007). In addition, scaling requires mindful innovation to support the process given that scaling typically proceeds in an uneven manner and “fast advancers” can then be used to support the slower areas. Uneven development results in heterogeneity, which increases the complexity of scaling processes (Shaw, Mengiste et al. 2007). In India, the scaling of HIS is about “the escalation of complexity” characterized by the scaling of institutional issues, politics and growing the implementing team itself (Sahay and Walsham 2006).

5.6.2. Conceptualizing scaling as a complex adaptive system:

A number of aspects of the scaling processes described above suggest that CAS may provide meaningful insights into the process. First, scaling is a multi-level process that is enacted across multiple levels of the health system hierarchy from national to community levels. Understanding the hierarchy, and its tendency to evolve quickly free of central control is a useful conceptualization allowing scaling to be modularized into manageable components. Secondly, within this hierarchy, groups and networks interact with one another in ways that are not always visible, nor controllable. Scaling must therefore take into account that it is a multi-dimensional process influenced by staffing issues, access to technology, and escalating political complexity. Thirdly, scaling is likely to occur at an unequal pace, resulting in heterogeneity, and increasing complexity, but also providing opportunities for innovation. Fourthly, scaling is described as a developmental process that gradually builds on earlier iterations of the system (Shaw and Braa Forthcoming). This suggests that scaling can be conceptualized as a co-evolutionary process similar to that described in the preceding section. Fifthly, co-evolutionary processes are characterized as “perpetual novelty” (Axelrod and Cohen 1999) (p. 10). Similarly, the imperative to achieve coverage of “all or none”, suggests that HISD is an inevitable scaling process that will never end. Scaling of HIS can thus clearly be conceptualized as a CAS that is likely to experience non-linearity and frequent change in response to an environment characterized by uncertainty and nested effects.

5.6.3. Defining scaling along four dimensions:

Before applying CAS principles to the scaling processes, I would like to explore how scaling is currently defined. (Sahay and Walsham 2006) define scaling as “the expansion of this system in scope and size (for example, making the system accessible to more users or increasing its functionalities)” (p. 185). Scaling often includes the extension of the existing system down the health system hierarchy, within the same geographic area (when for instance the data hierarchy is expanded by adding data from community health workers and related to a parent health facility) (see Figure 20). This we[17] term “deepening” the geographic scale (Saebo 2008) The geographic scope is widened when new geographic areas are included in the system. Scope is used to describe the functionality (for example represented by system modules) of the system in use, or the range of health programs (e.g. immunization, maternal health, financial information, hospital services, etc) that are incorporated in the system. The scope is “widened” when new functionality is brought into use in the system, or when additional datasets are added. But the scope is “deepened” when the existing functionality or existing program data is used for more sophisticated purposes, for instance when user maturity increases and the existing information is used to inform advanced health planning.

[17] I am grateful to Johan Saebo for sharing his insights with me into the deepening of the geographic and scope dimensions. These are based on his PhD research and experiences in scaling the DHIS in Sierra Leone.

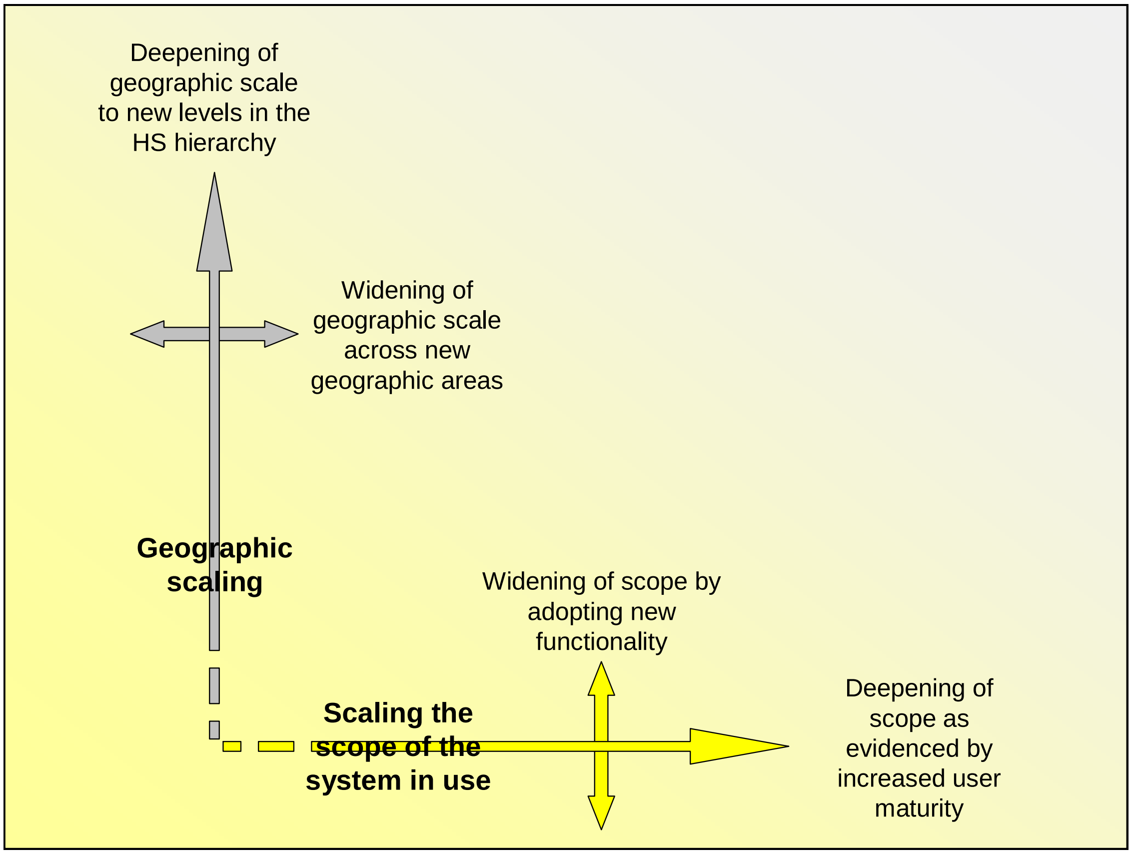


Figure 20: The Dimensions of Scaling Health Information Systems

5.6.4. Effecting scaling using the co-evolutionary ISD model:

While the above conceptualization allows the different dimensions of scaling to be examined individually, in reality the scaling processes usually happen in parallel to the evolution of the software and other components of the HIS (Shaw, Mengiste et al. 2007). Widening the geographic scale is usually the first dimension to be effected as this serves to satisfy the "all or nothing" imperative (Braa, Monteiro et al. 2004, p. 340). While the scaling of one component is being effected, software development, or development of other components continues and new functionalities are added, or existing components improved – as a result of the processes taking place within HISP-SA and its interactions with other networks described in the co-evolutionary ISD model. But as the new pool of users come to understand the system, and its application to their context, they invariably identify additional functionalities (the demand for expanded scope) to address their specific contextual needs. Gradually the system is expanded with the new users' requirements, and additional requirements of other users. So the system co-evolves in relation to scaling efforts. The re-introduction of the new components of the system can then happen as a conscious effort of "updating" the existing pool of users with the new functionality, or it can happen through a gradual diffusion process of self-exploration as pool of users install updated versions of the system at their own pace.

Whatever the process, the existing pool of users are exposed to not only the functionality (scope) they required, but also different functionalities that potentially expand their use of the system. I suggest therefore that scaling can be conceptualized as an inevitable scaling process (Shaw and Braa Forthcoming) as geographic scaling is succeeded by co-evolutionary waves of deepening the scale, and/or expansion of the scope, and/or increase in user maturity

Viewing scaling as a co-evolutionary process within a CAS potentially provides useful insights into the management of the process. For instance, applying the organizational learning model to the scaling process suggests that “fast advancers” might be pockets of organizational capacity that demonstrate explorative tendencies, and could be harnessed to support processes in other sections of a large bureaucracy. They can also become sites of innovation, especially if allowed to pursue their interests within a bigger organizational framework as suggested by the principle of integrated independence. The model recognizes the difference between the three levels of the organization, and reminds us that scaling is about the individual, and that the key to scaling is in fact the dynamic that Crossan, Lane et al. (1999) identified as problematic, namely the interpreting – integrating process. Identifying activities (such as attractors) that can bind potential users in this process would be important for a successful scaling operation.

5.6.5. Practical implications 5: Scaling as an escalation of complexity:

Scaling in any dimension can be conceptualized as a process that increases the complexity of the system (Sahay and Walsham 2006). This is because scaling in any of the four dimensions expands the pool of users and the networks in which they operate. For instance, it is obvious that geographic scaling (whether widening or deepening) expands the pool of users. But each user is part of a network, for instance PHC facilities belong to a network that is usually distinct to that of the hospital network. Widening the scope brings in another set of networks associated with additional functionalities, or different programs. And deepening the scope expands the complexity because not only does it bring in another set of users, it also escalates the technical complexity by creating interdependencies between different datasets (see for instance Jacucci, Shaw et al. 2006) and demands sophisticated information processing. Each of these networks and groups belong to various self-organizing groups and networks that transects formal hierarchical structures of the health system. Understanding scaling processes along these dimensions helps to explain how HISD is susceptible to non-linear effects and indeterminacy. This understanding re-inforces the value of restricting the dimensions of the system that are to be scaled so as to reduce the complexity to manageable proportions. It also provides a conceptual framework for understanding how to manage non-linear effects when scaling is being effected.

The experiences of scaling PHC systems in the HISP network suggest that not all dimensions can be scaled at the same time. In Zambia the focus was on scaling the geographic dimension, while the other dimensions were held static (Shaw and Braa Forthcoming). In Botswana, before scaling up, a "scaling down" process took place (Saebo 2008). This decision was the result of the restricted capacity of the implementing team to manage the increased complexity that scaling across a wide range of programs would entail. We see in these examples the decision on what to scale being informed by resource availability. In effect, the geographic scaling was deemed more likely to be successful if the volume of data to be collected was reduced. Drawing on the PAN model, I would therefore suggest that widening the geographic scale is the most complex process because as the first scaling effort it has to balance the human resource capacity, the technical and infrastructural resources available, and the volume of data that the system can process. Once a system is scaled to cover a certain geographic area, adjustments in the other dimensions of scaling can be "piggy-backed" on the existing system. Thus, widening the scope of the system by adding new functionality, or expanding the range of data sets used, does not necessarily require establishing new data collection procedures, or training a new pool of users. Rather, existing processes and systems can be used to accommodate the new components, or existing users can be taught to apply similar routines to different datasets. The nature of this process is different to that of geographic scaling, and requires different types of inputs. This is an aspect that is seldom taken into consideration in the literature on scaling.

5.6.6. Practical implications 6: Scaling in Hospitals

The processes described above suggest an inevitability in the scaling process – the pressure of user demands fuels the scaling across the different dimensions, and success in these areas fuels further technical demands of the software. But does this framework of scaling also apply to hospital IS?

In the case of HospMIS development, the geographic scaling takes place in two dimensions. The first is within the hospital, as additional units (wards) are incorporated into the IS. This scaling corresponds to the widening of the scope of PHC programs because the data needs of different hospitals wards, or departments are similar to the different data needs of programs. The difference is that the scaling across all the different departments and reporting units in one hospital is intense, and takes time (Berg 2004; Aanestad, Jensen et al. 2009). Unlike the PHC context, where widening the geographic scale incorporates new users without expanding the scope of the system, in the hospital context, new units expand the scope of the system in use. In this case, it is not about the “replication of the similar in a network” like the “self-similarity between the branches and sub-branches of broccoli” (Braa, Hanseth et al. 2007b, pg 19), but rather about bringing together apples, oranges and pears in a fruit basket. Unlike the PHC context described above, scaling in hospitals demands the concurrent scaling across not only the geographic dimension, but also widening the scope of the system as new wards and departments are incorporated in the pool of users. This increases the complexity of scaling HIS in hospitals significantly. The implementation of HospMIS will require significant time to be invested in each hospital, and this must be multiplied across all the hospitals in which the systems are to be developed (Berg and Goorman 1999).

The geographic scaling of hospital IS is not only about working in a single hospital, but also multiple hospitals. This means that scaling across hospitals must take into account the implications of scaling in different sized hospitals (the configuration of a 1500 bed hospital is very different to that of a 150 bed hospital, and the development of a hospMIS for a 1500 bedded hospital will be significantly more complex) and different types of hospitals (psychiatric hospitals have more uniform demands for information compared to general hospitals which have more heterogenous demands).

In summary, scaling of IS across hospitals and the health sector, must take into consideration the dimension that is being scaled (geographic deepening or widening, and deepening or widening of the scope). Secondly, while PHC facilities are generally fairly homogenous in their information demands (as reflected by a fairly limited scope), hospitals exhibit a great deal of heterogeneity in their scope because of variations in size and type. Greater heterogeneity suggests greater complexity. The increased complexity can be mitigated by restricting the geographic scaling process (reduce the speed of scaling, or restrict scaling to certain units in each hospital e.g. maternity services only, OPD only, etc), or restrict the scope that is scaled (therefore scale only basic throughput data in all hospitals, and follow this with an expansion of the scope some time later).

5.7. Summary of Theoretical Contributions

In this section I first review the research objectives, and then briefly summarise my theoretical contributions.

5.7.1. Research aim and objectives

Two main research questions were posed in order to address the aims of this research, namely to develop complexity theory inspired conceptual models to understand the design development and implementation of sustainable and scalable hospital management IS in resource constrained contexts, and which take into consideration the complexities of the hospital environment. The two research questions were:

1. Given the complex nature of the hospital environment, what are the socio-technical considerations that contribute to the design of sustainable and scalable hospital management IS in resource constrained settings?

2. How can the implementation process be designed to accommodate unexpected contradictions that arise between the different realities of original intent and changing needs in the implementation process?

It is important to recognize at this stage that while I initially set out to explore the "socio-technical design, development and implementation" strategies in the objectives, the model which emerges from this research does not specifically delineate these as distinctly independent processes, but rather as iterative phases along a continuum of design, development, implementation and re-design, develop, and implement. This pattern is along the lines suggested by Heeks when he suggests that HIS projects should be viewed as a "dynamic improvising developmental process" (2006, p. 132). For this reason, while in chapter four I delineated clearly between design and implementation, in this chapter the delineation is described in a much less clear form.

The research questions were clarified by framing five research objectives, which are tabled below. By addressing the research objectives, the two research questions have been addressed, and the research aim achieved.

Table 17: Addressing the Research Objectives through this Thesis	
Research Objective	**Section contributing to this objective**
1. Describe the complexities of the environment which influence HospMISD in resource constrained settings	Section 4.4.1 and section 5.2
2. Given the complexities of the hospital environment, conduct research and develop theoretical and practical insights related to the design of HospMIS that takes into account the socio-technical resource levels that exist in developing countries	Section 4.4.2 and sections 5.2.3, 5.3.2, 5.4.3, 5.5.5 and 5.6.5
3. Develop theoretical and practical insights into the successful implementation of HospMIS that accommodate unexpected contradictions that arise between the different realities of original intent and changing needs in the implementation process	Section 4.4.3 and sections 5.2.3, 5.3.2, 5.4.3, 5.5.5 and 5.6.5
4. Conduct research into the scaling of HospMIS, especially which aspects of IS development are universally scalable, and which require local customization	Section 5.6
5. Suggest ways in which the design and implementation strategies described will contribute to sustainable IS development in developing country contexts	Section 5.5

5.7.2. Main theoretical contributions

In summarizing the theoretical contributions, I draw on the work of Walsham (1995) to identify four categories of generalizations from the cases presented in this thesis, namely contribution of rich insight, development of concepts, generation of specific implications, and generation of theory. While it is noted that these categories are not mutually exclusive, I present them in this order as it suggests a flow to building theory. Each category is discussed separately, and expanded by using Lee and Baskerville (2003) analysis of generalizing and generalizability.

a) Contribution of rich insight:

While the individual papers each provide detailed descriptions of IS development in both hospital and PHC settings in a variety of countries, in this thesis I have synthesized the findings from these settings to describe the complexity of the environment and detail the notion of “extreme heterogeneity” (see Table 18). In both these cases, the type of generalization has been from data to description. As highlighted by Lee and Baskerville (2003), the description of these findings does not mean that they can be generalized to all other settings, rather, these findings may have implications for other contexts, but, the appropriateness of this description would need to be tested in other settings, and may well be further modified through such an exposure.

Table 18: Contribution of Rich insight		
Description	**Detail in section**	**Category**
Extreme heterogeneity	Section 5.2	Generalizing from data to description
Complexities of the environment	Section 4.4.1	Generalizing from data to description

b) Development of concepts:

A number of concepts have been developed through the research process. These are tabled below (Table 19). Two types of generalization have been used in the development of concepts. One approach (utilized for example in the development of concepts such as integrated independence, and the EDS) has been to generalize from data to description. The second has been to generalize from an existing theoretical concept, to the research finding (as in the case of the concept attractor, or gateways). The latter therefore expands our understanding of the existing theory by applying it in a new way in the research setting.

Table 19: Development of Concepts		
Description	**Detail in section**	**Category**
Principle of Flexible Standards	Section 4.2.4 and 4.4.2	Generalizing from data to description
Modularization (horizontal and vertical)	Section 4.2.4 and 4.4.2	Generalizing from theory to description
Essential Data Set	Section 4.2.2 and 4.4.2 (b)	Generalizing from data to description
Gateways	Section 4.2.4 and 4.4.2 (c)	Generalizing from theory to description
DHIS as a flexible standard	Section 4.2.7 and 4.4.2 (d)	Generalizing from data to description
Principle of Integrated independence	Section 4.2.4 and 4.4.3 (a)	Generalizing from data to description
Mindful innovation	Section 4.2.6 and 4.4.3 (c)	Generalizing from theory to description
Attractors	Section 4.2.4 and 4.4.3 (d)	Generalizing from theory to description
Creation of networks and interdependencies	Section 4.2.3 and 4.4.3 (e)	Generalizing from theory to description
Recognition of the new cadre of health worker (HIP)	Section 4.2.5, 4.2.7 and 4.4.3 (f)	Generalizing from data to description
Public sector organizational absorptive capacity	Section 5.5.3	Generalizing from theory to description

c) *Generation of specific implications:*

The third category of contribution is the generation of specific implications (see Table 20). Examples that comprise this category are tables below. This category provides implications for the ISDC discourse, and in the health sector specifically. In these examples, the generalization has been from theory to description in that I test, or suggested the relevance of existing concepts or theories, or methodological approach to the empirical data, and other similar empirical contexts. I identified in Chapter 2 that although many authors recognized the complex nature of hospital information systems development, few had explicitly utilized complexity as a theoretical framework. This thesis attempts to fill this gap in the literature.

Drawing on a longitudinal action research methodology, this thesis also provides an example for other IS researchers on the value of this type of study in exploring the micro and macro level factors that contribute to successful HospMIS development.

Table 20: Generation of specific implications

Description	**Detail in section**	**Category**
Extension of CAS theory to • HospMISD and to • Scaling of HIS	Section 2.4 Section 5.6	Generalizing from theory to description
HospMISD as a co-evolutionary organizational learning process	Section 5.5.4	Generalizing from theory to description
Research methodology	Chapter 3	Generalizing from methodological data to descriptions

d) *Generation of theory:*

The last category describes the contributions of this thesis to IS theory. Four contributions make up this category. The PAN model provides a useful way in which to view the balance between access to technology, human resources, and the ability to process data in the HIS. While the model was initially identified in Nigeria, it found useful application to the Ethiopian context (Shaw, Mengiste et al. 2007), and has continued to be used by the HISP-SA team in influencing practical approaches to HIS strengthening.

The second contribution to theory is the development of a co-evolutionary framework for HospMISD. This contribution builds on the framework developed by Benbya and McKelvey (2006a) in which they acknowledged was conceptual in nature and required further testing. It provides a framework for understanding the role of different strategies and approaches for ISD in resource constrained settings, and can be applied with in the co-evolutionary model, which is the third theoretical contribution made in this thesis. The co-evolutionary model addresses the research priority identified in Chapter 2 related to the mechanism for skills transfer between the public sector and external support organizations. While I suggest that the model requires further development and testing in a variety of settings, the conceptualization of this model has been a very useful process for me personally because it has helped me to understand more deeply the relationship between HISP-SA and the public sector organizations with whom we work. The model provides a format which other organizations can potentially utilize to analyze their comparative strengths and weaknesses and structure their partnership accordingly.

The last theoretical contribution emerged during reflection on the role of HISP-SA in supporting HISD in Africa (Shaw and Braa Forthcoming) and the continual dilemma we faced as an organization in having to choose between consolidating our team and expanding in new and untested areas. The concept of scaling as an inevitable process has helped us to understand where to make the choices, and how to seek partnerships that can complement our skills base, and issue that I identify as an important area for further research.

Table 21: Generation of Theory

Description	Detail in section	Category
Process for Accommodating Non-linearity (PAN) Model	Section 4.4.3 (b)	Generalizing from description to theory
Co-evolutionary framework for HospMISD	Section 4.5.3, 4.5.4 and 5.2.4	Generalizing from concepts to theory
Co-evolutionary ISD model	Section 5.5.4	Generalizing from description to theory
Scaling as an inevitable co-evolutionary process	Section 5.6.4	Generalizing from description to theory

5.8. Synthesis of practical contributions:

In this chapter, I have summarized the practical contributions after each section. This section is used to highlight the practical implications of this research in relation to capacity building within the public health sector in resource constrained settings, and the practical implications of this thesis for the HISP-SA team.

One of the biggest challenges in IS within resource constrained settings is that of developing capacity within the public sector (Avgerou and Walsham 2000; Kimaro 2006; Avgerou 2008). This research addresses this by describing the emergence of the HIP. At the micro level, skills are developed in this practitioner through on-the-job mentoring and partnership with HIP in the HISP-SA team, through formal and in-formal training, through scholarships to academic institutions for further studies, and through email lists and discussion forums. At the intermediate level, the establishment of self-organizing groups is encouraged and facilitated between the HIP in the public sector, and other organizations like HISP-Nigeria and HISP-SA and other NGO's. And at the macro level we have seen these mechanisms supported through formal and informal partnership arrangements between HISP-SA and various public sector organizations. Recognizing the power of self-organizing groups to be agents of change and to effect decentralized control suggests that a concerted strategy to strengthen self-organizing groups may pay dividends and counter the skills shortage.

But what if the staff are just not there? For instance Saebo (2008) suggests, but does not expand, that the use of the PAN model, and the choices made to balance volume of data collected with available skills and staff suggests a the choice of "pragmatism … over absolute requirements in terms of scaling, [is] a rare luxury in many other settings". This hints at the problem of staff shortage, and the pressure to capture and process data despite these challenges. However, the essence of this thesis is that rather than pursue efforts to collect vast quantities of data at the cost of data quality and clinical service provision, efforts should be directed at discerning the key pieces of information that can be collected by the available staff, within the time limitations that they have, and using appropriate technology for their context. Effecting this balance is not a luxury, it is essential. It is precisely in these contexts were the hard choices have to be made between the allocation of time for recording interactions with patients, the degree of data aggregation, and the point of data capture.

Another way of addressing the staff shortage problem is to differentiate between health workers who provide clinical services, and who may record the basic data related to the patient-health worker interaction, and HIP who assist in the further processing of information. In these cases, capacity is developed amongst staff who fill the ranks of statisticians, or other administrative staff who are "more" available than the scarce health workers, rather than drawing health workers away from their clinical duties. But, even if this happens, the capacity of the HIP are limited, and the demands made of them in terms of data needs to be limited to manageable proportions. It is precisely in this context that a co-evolutionary approach over an extended timeframe is important. In this respect, we have seen in South Africa, over the 10 years of HISP-SA (and other NGO's work there) the demands from the HIP become increasingly sophisticated. Thus, despite the ongoing staff turnover, the organizational code in the public sector related to HIS has gradually increased, and is in turn making increasingly sophisticated demands on the HISP-SA team. This has ongoing implications for the HISP team, to ensure that it recruits and trains its staff so as to lift its own organizational code to higher levels.

5.9. Future research:

I conclude this chapter by highlighting future work that can arise from this research.

This thesis has identified extreme heterogeneity as a notion that characterizes the context in resource constrained settings. A range of actions are required to manage the extreme heterogeneity. I think it would be interesting to contrast the heterogeneity found in well resourced contexts (see for instance some reference to this in Aanestad, Jensen et al. 2009) with that described in this thesis, and to compare the different ways in which heterogeneity is managed in the two contexts. Potentially this will provide useful insights into hospital information systems development for both settings.

But perhaps the most interesting research area that I would like to pursue has been highlighted in section 5.5.4 related to the co-evolutionary HISD model. I think that a deeper understanding of the growth and development of the different HISP organizations (for example HISP-SA, HISP-India, HISP-Nigeria) is essential in order to deepen our understanding of the HISP international network, and how it needs to evolve in order to continue to be relevant in the HIS sector. The relevance of the HISP international network is not only important in terms of its role as a source of innovation in HIS, but also in terms of its role in building institutional capacity through academic programs, an aspect that has not been explored in depth in this thesis. I suggest that the two roles are closely linked with one another, but without a deeper understanding of their interaction, we cannot harness these opportunities to strengthen the HISP network.

A related field of research focuses on the nature of the relationship between an NGO such as HISP-SA, and the public sector. For instance, from a business perspective, as at present, HISP-SA does not have any significant competitors in terms of similar organizations that provide similar types of solutions. While this may change in the future, the issue that warrants further exploration is whether NGO’s such as those involved in the HISP network might be an example of “future organizations” that co-evolve in partnership with government, and where the driving force for continued innovation is not market forces but rather internal competition for appropriate solutions and excellence similar to that which drives the FOSS industry.

Chapter 6. CONCLUSIONS

This thesis presents a longitudinal action research study on the design, development and implementation of HospMIS in resource constrained settings. The particular dilemma that faces HospMISD in these settings is not only related to the absence or shortage of skilled staff and access to ICT, but also the need to accommodate unexpected contradictions that arise between the different realities of original intent and the changing needs during the implementation process. In addressing these challenges, this thesis explores solutions which can be implemented at the individual or micro level but which also accommodate the needs at the macro levels of the health system. Examples of this include the development of flexible standards such as the EDS and the principle of integrated independence. This thesis also addresses the vexing problem of building local capacity to support the ongoing design, development and implementation of HIS and HospMIS in contexts where the skills base is low and staff shortages are common. In this respect, the research suggests that sustainable HISD can be achieved by supporting a co-evolutionary approach to HISD between public sector organizations and NGO's such as HISP-SA. I suggest that a synergistic relationship between these organizations is fed by their complimentary exploitative/explorative drives, and domains of influence. This relationship supports the inevitable scaling process that characterizes the health sector in resource constrained settings.

This thesis contributes to a number of important HIS research priorities in developing country contexts. For example, Avgerou and Walsham (2000) call for research and action on the importance of the context in harnessing the potential of ICT's to aid economic and social conditions in the developing world, and Sahay and Avgerou (2002) highlight the importance of local adaptation of ICT solutions rather than the replication of western solutions in developing country contexts. As part of their call to action, emphasis is placed on the importance of developing local expertise in the design, implementation and management of IT-related projects. In their review of the literature on IS in developing countries published between January 2000 and May 2004, Walsham and Sahay (2006) suggest that research emphasis should focus on four key areas, namely the development to which ICT's contribute, the key issues being studied, the theoretical and methodological stance, and the level and focus of analysis. The contribution of this research in these areas is summarised in the table below.

Table 22: Identified Research Priorities Addressed by this thesis	
Identified Research Area	**Contribution of this thesis**
Development to which ICT's contribute	Development of locally appropriate FOSS in the "south" for the health sector, with a focus on hospitals. The development of local capacity in the health sector to better manage HospMIS. Development of sustainable organizations and processes to support ongoing HISD
Key issues being studied	The context of HospMISD in resource constrained settings. In-depth study of open source software development and implementation in the public health sector with a focus on hospitals including approaches to scaling and sustainable ISD and implementation
Theoretical and methodological stance	Longitudinal action research study drawing on interpretive research approach and using CAS theory
Level and focus of analysis	Multi-level (micro and macro) approach to analysis of data from resource constrained contexts.

I identify three main limitations of this thesis, which are also potential areas for future research. One of the limitations relates to the relatively short periods of intervention in HospMIS described in the cases. The description of HospMISD in the ECP was a 13 month initiative, while that in Malawi was 19 months. Both of these timeframes are relatively short periods for assessing the long term effects of interventions and their sustainability. While I am aware that the hospitals continue to utilize the systems that were implemented, it would be interesting to explore how the networks supporting the use of these systems have changed over time.

A second limitation of this research relates to the limited focus on cultural diversity and the impact that this has on the HospMISD (Walsham 2001). Given the multi-country nature of the research, there have been obvious opportunities to consider cross-cultural issues, even within countries which have huge cultural diversities.

A third limitation is related to the lack of depth to the analysis at the inter-organizational level, particularly related to HISP-SA and the broad HISP network. This is an area that has emerged from this thesis as important and as has been indicated in Chapter 5, this is an area that clearly demands further research.

I conclude with a quote from Suchman (1987, p. vii) on plans and situated action which, in my view, provides an invaluable insight into the approach that is necessary for sustainable HospMISD in resource constrained settings:

> **"The Trukese navigator begins with an objective rather than a plan. He sets off toward the objective and responds to conditions as they arise in an *ad hoc* fashion. He utilizes information provided by the wind, the waves, the tide and current, the fauna, the stars, the clouds, the sound of water on the side of the boat, and he steers accordingly. His effort is directed to doing whatever is necessary to reach the objective. If asked, he can point to his objective at any moment, but he cannot describe his course."**

References

Aanestad, M., T. B. Jensen, et al. (2009). "How to Get There from Here? An Analytical Framework for Dealing with Complexity in Information Infrastructures in Healthcare." Information Systems Research **Special Issue on the Role of Information Systems in Healthcare Organizations**(Forthcoming).

Aarts, J., V. Peel, et al. (1998). "Organizational issues in health informatics: a model approach." International Journal of Medical Informatics **52**(1-3): 235-242.

AbouZahr, C. and T. Boerma (2005). "Health information systems: the foundations of public health." Bulletin of the World Health Organisation **83**(8): 578-583.

Adjei, S. (2005). "Indicators for a health information data set in Ghana." Bulletin of the World Health Organisation **83**(8): 637-738.

Akpan-Obong, P. (2007). Information and Communication Technologies in Development: contextuality and promise. IFIP 9.4 9th International Conference on Social Implications of Computers in Developing Countries, Sao Paulo, Brazil.

Alaa, G. and G. Fitzgerald (2004). Evolving Self-Organizing Activities - addressing Innovation and Unpredictable Environments. IT Innovation for Adaptability and Competitiveness. B. Fitzgerald and E. H. Wynn. Boston, USA, Springer. **141**.

Allen, P. and L. V. Varga (2006). "A co-evolutionary complex systems perspective on information systems." Journal of Information Technology (Palgrave Macmillan) **21**(4): 229-238.

Alma Ata Conference. (1978). "Declaration of Alma-Ata, International Conference on Primary Health Care, 6-12 September." Retrieved 1 December, 2006, from http://www.who.int/hpr/NPH/docs/declaration_almaata.pdf.

Anderson, P. (1999). "Complexity Theory and Organization Science." Organization Science **10**(3): 216-232.

Anderson, P., A. Meyer, et al. (1999). "Introduction to the Special Issue: Applications of Complexity Theory to Organization Science." Organization Science **10**(3): 233-236.

Argyris, C. and D. A. Schon (1996). Organizational Learning II - Theory, Method and Practice. Reading, Masachusetts, Addison-Wesley Publishing Company.

Arndt, M. and B. Bigelow (2000). "Commentary: The potential of chaos theory and complexity theory for health services management." Health Care Management Review **25**(1): 35.

Avgerou, C. (2002). Information Systems and Global Diversity. Oxford, Oxford University Press.

Avgerou, C. and G. Walsham, Eds. (2000). Information Technology in Context - Studies from the perspective of developing countries. Hants, UK, Ashgate Publishing Ltd.

Avgerou, C. C. A. (2008). "Information systems in developing countries: a critical research review." Journal of Information Technology (Palgrave Macmillan) **23**(3): 133-146.

Axelrod, R. M. and M. D. Cohen (1999). Harnessing Complexity: Organizational Implications of a Scientific Frontier. New York, USA, The Free Press.

Bada, A. O. (2002). "Local Adaptations to Global Trends: A Study of an IT-Based Organizational Change Program in a Nigerian Bank." Information Society **18**(2): 77-86.

Bada, A. O. (2006). "Enhancing Human Resource Development Through Information and Communications Technology - Editorial Introduction to the Special Issue." Information Technology for Development **12**(3): 179-183.

Barley, S. R. (1986). "Technology as an Occassion for Structuring: Evidence from Observations of CT Scanners and the Social Order of Radiology Departments." Administrative Science Quarterly **31**(1): 78-108.

Baskerville, R. L. and A. T. Wood-Harper (1996). "A critical perspective on action research as a method for information systems research." Journal of Information Technology (Routledge, Ltd.) **11**(3): 235-246.

Baskerville, R. L. and A. T. Wood-Harper (1998). "Diversity in information systems action reserach methods." European Journal of Information Systems **7**: 90-107.
Begun, J. W., B. Zimmerman, et al. (2003). Health Care Organisations as Complex Adaptive Systems. Advances in Health Care Organisation Theory. S. M. Mick and M. Wyttenbach. San Francisco, Jossey-Bass**:** 253-288.
Benbasat, I., D. K. Goldstein, et al. (1987). "The Case Research Strategy in Studies of Information Systems." MIS Quarterly **11**(3): 369-386.
Benbya, H. and B. McKelvey (2006a). "Toward a Complexity Theory of Information Systems Development." Information Technology and People **19**(1): 12-34.
Benbya, H. B. and B. M. McKelvey (2006b). "Using coevolutionary and complexity theories to improve IS alignment: a multi-level approach." Journal of Information Technology (Palgrave Macmillan) **21**(4): 284-298.
Berg, M. (1999). "Patient care information systems and health care work: a sociotechnical approach." International Journal of Medical Informatics **55**(2): 87-101.
Berg, M. (2001). "Implementing information systems in health care organizations: myths and challenges." International Journal of Medical Informatics **64**(2-3): 143-156.
Berg, M. (2004). Health Information Management - integrating information technology in health care work. New York, Routledge.
Berg, M. and E. Goorman (1999). "The contextual nature of medical information." International Journal of Medical Informatics **56**(1-3): 51-60.
Bergqvist, J., P. Dahlberg, et al. (2002). "Scalability through Cultivation - designing IT support for co-ordination work." Retrieved 13 November, 2006, from http://citeseer.ist.psu.edu/cache/papers/cs/23947/http:zSzzSzwww.dahlberg.sezSzpubzSzmaster.pdf/scalability-through-cultivation-designing.pdf.
Berndt, D. J., A. R. Hevner, et al. (2003). "The Catch data warehouse: support for community health care decision-making." Decision Support Systems **35**(3): 367-384.
Bhatnagar, S. (1992). Information Technology and socio-development: Some strategies for developing countries. Social Implications of Computers in Developing Countries. S. Bhatnagar and M. Odedra. New Delhi, Tata McGraw Hill.
Boerma, T. (2005). "WHO News - Getting the numbers right." Bulletin of the World Health Organisation **83**(8): 567-568.
Boerma, T., E. Bos, et al. (2008). A common framework for monitoring performance and evaluation of the scale-up for better health. Geneva, World Health Organisation and World Bank.
Bossert, T., M. B. Chitah, et al. (2003). "Decentralization in Zambia: resource allocation and district performance." Health Policy Plan. **18**(4): 357-369.
Braa, J. (2005). "A data warehouse approach can manage multiple data sets." Bulletin of the World Health Organisation **83**(8): 638-939.
Braa, J., O. Hanseth, et al. (2007a). "Developing Health Information Systems in Developing Countries - the flexible standards strategy." MIS Quarterly **31**(2): 381-402.
Braa, J., O. Hanseth, et al. (2007b). "Developing Health Information Systems in Developing Countries - the flexible standards strategy." MIS Quarterly **31 Special Issue**
Braa, J. and C. Hedberg (2002). "The Struggle for District Based Health Information Systems in South Africa." The Information Society **18**: 113-127.
Braa, J., E. Monteiro, et al. (2004). "Networks of Action: Sustainable Health Information Systems Across Developing Countries." MIS Quarterly **28**(3): 337-362.
Brown, J. S. and P. Duguid (1991). "Organizational Learning and Communities-of-Practice: Toward a Unified View of Working, Learning, and Innovation." Organization Science **2**(1): 40-57.
Burn, A. and G. Shongwe (2003). Monitoring Hospital Care. South African Health Review 2003/04. P. Ijumba, C. Day and A. Ntuli. Durban, Health Systems Trust**:** 29-41.
Butz, M. (1997). Chaos and complexity: implications for psychological theory and practice. Washington DC, CRC Press.
Capra, F. (2005). "Complexity and Life." Theory Culture Society **22**(5): 33-44.

Cassels, A. and K. Janovsky (1998). "Better health in developing countries: are sector-wide approaches the way of the future?" Lancet **352**(November 28, 1998): 1777-79

Castells, M. (1998). End of Millenium. Oxford, Blackwell.

Castells, M. (2000). The Rise of the Network Society. Oxford, Blackwell.

Chilundo, B. (2004). Integrating Information Systems of Disease-Specific Health Programmes in Low Income Countries. Faculty of Medicine. Oslo, Norway, University of Oslo. **Doctor Phillosophiae:** 121.

Christensen, C. M. (2000). The Innovator's Dilemma. New York, Harper Business.

Chua, W. F. (1986). "Radical Developments in Accounting Thought." The Accounting Review **LXI**(4): 601-632.

Cibulskis, R. E. (2005). "Information is not only for managers." Bulletin of the World Health Organisation **83**(8): 637.

Ciccarese, P., E. Caffi, et al. (2005). "Architectures and tools for innovative Health Information Systems: The Guide Project." International Journal of Medical Informatics **74**(7-8): 553-562.

Cohen, W. M. and D. A. Levinthal (1989). "Innovation and Learning: The Two Faces of R & D." The Economic Journal **99**(397): 569-596.

Committee on Quality Health Care in America, I. o. M. (2001). Crossing the Quality Chasm: A New Health System for the 21st Century. Washington, D.C., National Academy Press.

Crabtree, B. F. and W. L. Miller (1992). Doing Qualitative Research: multiple strategies. Newbury Park, California, SAGE Publications.

Cronholm, S. and G. Goldkuhl (2004). "Conceptualising Participatory Action Research - three different practices." Electronic Journal of Business Research Methods **2**(2): 47-58.

Crossan, M. M., H. W. Lane, et al. (1999). "An Organizational Learning Framework: From intuition to institution." Academy of Management Review **24**(3): 522-537.

Crossan, M. M., H. W. Lane, et al. (1995). "Organizational Learning: Dimensions for a theory." International Journal of Organizational Analysis (1993 - 2002) **3**(4): 337.

Daft, R. L. (1992). Organization Theory and Design. St Paul, Minneapolis, West Publishing.

Daft, R. L. and A. Y. Lewin (1993). "Where Are the Theories for the "New" Organizational Forms? An Editorial Essay." Organization Science **4**(4): i-vi.

Davis, G. B. (1982). "Strategies for Information Requirements Determination." IBM Systems Journal **21**(1): 4-31.

De Koning, K. and M. Martin (1996). Participatory Research in health: setting the context. Participatory Research in Health - issues and experiences. K. De Koning and M. Martin. Johannesburg, National Progressive Primary Health Care Network (NPPHCN)**:** 242.

Dooley, K. (1997). "A Complex Adaptive Systems Model of Organization Change." Nonlinear Dynamics, Psychology, and Life Sciences **1**(1): 69-97.

Dooley, K. (2002). Organizational Complexity. International Encyclopaedia of Business and Management. M. Warner. London, Thompson Learning**:** 5013-5022.

Dosi, G. (1982). "Technological paradigms and technological trajectories." Research Policy **11**: 147-162.

Douglas, G., C. Deula, et al. (2003). The Lilongwe Central Hospital Patient Management Information System: A Success in Compuyer-Based Order Entry where One Might Least Expect it. Americam Medical Informatics Association Conference, AMIA.

Dunphy, D. C. and D. A. Stace (1988). "Transformational and Coercive Strategies for Planned Organizational Change: Beyond the O.D. Model." Organization Studies **9**(3): 317-334.

Eastern Cape Development Corporation. (2005). "ECDC Website." Retrieved November 14, 2005, from http://www.ecdc.co.za/districts/districts.asp?pageid=32

Ellingsen, G. (2004). Global Reach, Local Use - Design and use of electronic patient record systems in large hospitals. Faculty of Information Technology, Mathematics and Electrical Engineering, Department of Computer and Information Science. Tromso, Norwegian University of Science and Technology. **Doctoral thesis:** 244.

Ellingsen, G. and E. Monteiro (2003). "Big is Beautiful - electronic patient records in large hospitals in Norway 1980s-2001." Methods for Information in Medicine **42**(4): 366-370.

Ellingsen, G. and E. Monteiro (2005). The slight surprise of integration. IFIP W.G. 8.2 Designing Ubiquitous Information Environments: Socio-Technical Issues and Challenges, Cleveland, Ohio.

Engelbrecht, B. and D. McCoy (1999). Establishing the Disrict Health System. South African Health Review. N. Crisp and A. Ntuli. Durban, South Africa, HST Press**:** 439.

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

Eoyang, G. and T. H. Berkas (1998). Evaluation in a Complex Adaptive System. Managing Complexity in Organisations. M. Lissack and H. Gunz. Westport, Connecticut, Quorum Books, an imprint of Greenwood Publishing Group, Inc. **2005**.

Evans, T. and S. Stansfield (2003). "Health Information in the new millennium: a gathering storm?" Bulletin of the World Health Organisation **81**(12): 856.

Fontana, W. and S. Ballati (1999). "Complexity - why the sudden fuss." Complexity **4**(3): 14-16.

Fraser, S. W. and T. Greenhalgh (2001). "Complexity Science: Coping with complexity: educating for capability." British Medical Journal **323**(6 October): 799-803.

Garrib, A., N. Stoops, et al. (2008). "An evaluation of the District Health Information System in rural South Africa." South African Medical Journal **98**(7): 549-552.

GAVI Alliance. (2005). "Opportunities for Global Health Initiatives in the health system action agenda." Retrieved 12 September, 2008, from http://www.gavialliance.org/resources/17brd_5_HealthSystemsGHIs_6Dec2005.pdf.

Gell-Mann, M. (1995). The Quark and the Jaguar - Adventures in the Simple and the Complex. London, Abacus.

Giddens, A. (1999). Runaway World. Reith lectures.

Gladwell, M. (2000). The Tipping Point - how little things can make a big difference. London, UK, Abacus.

Gladwin, J., R. A. Dixon, et al. (2003). "Implementing a New Health Management Information System in Uganda." Health Policy and Planning **18**(2): 214-224.

Gleick, J. (1987). Chaos - making a new science. London, Abacus.

Gleick, J. (1993). Chaos. London, Abacus.

Glouberman, S. and H. Mintzberg (2001a). "Managing the Care of Health and the Cure of Disease - Part I: Differentiation." Health Care Management Review(Winter): 56-69.

Glouberman, S. and H. Mintzberg (2001b). "Managing the Care of Health and the Cure of Disease - Part II: Integration." Health Care Management Review(Winter): 70-84.

Godlee, F., N. Pakenham-Walsh, et al. (2004). "Can we achieve health information for all by 2015?" Lancet(July 9, 2004): 1-6.

Gorgen, H., T. Kirsch-Wolk, et al., Eds. (2004). The District Health System - Experiences and Prospects in Africa.

Manual for Public Health Practitioners. Wiesbaden, Universum Verlag.

Greenbaum, J. and M. Kyng, Eds. (1991). Design at Work:Cooperative design of computer systems. Hillsdale, NJ, Lawrence Erlbaum Associates.

Hanseth, O. (2002). "From systems and tools to networks and infrastructures - from design to cultivation. Towards a theory of ICT solutions and its design methodology implications." Retrieved 2 September, 2005, from http://heim.ifi.uio.no/~oleha/Publications/ib_ISR_3rd_resubm2.html.

Hanseth, O., E. Jacucci, et al. (2006). "Reflexive standardisation: Side effects and complexity in standard-making." MIS Quarterly(Special Issue on Standards).

Hanseth, O. and N. Lundberg (2001). "Designing Work Oriented Infrastructures." Computer Supported Cooperative Work (CSCW) **10**(3 - 4): 347-372.

Hanseth, O. and K. Lyytinen (2004). "Theorizing about the design of information infrastructures - Design kernel theories and principles." Sprouts Working Papers on Information Environments, Systems and Organizations **4**(4).

Hanson, K., M. K. Ranson, et al. (2003). "Expanding access to priority health interventions: a framework for understanding the constraints to scaling-up." Jounal of International Development **15**(2003): 1-14.

Health Metrics Network (2008). Framework and Standards for Country Health Information Systems, Health Metrics Network: 72.

Health Systems Trust, Ed. (1996). South African Health Review. Durban, South Africa, Health Systems Trust and Henry J. Kaiser Family Foundation.

Heeks, R. (2002). "Failure, Success and Improvisation of Information Systems Projects in Developing Countries." The Information Society **18**: 101-112.

Heeks, R. (2006). "Health information systems: Failure, success and improvisation." International Journal of Medical Informatics **75**(2): 125-137.

Herbst, K., P. Littlejohns, et al. (1999). "Evaluating computerized health information systems: hardware, software and human ware: experiences from the Northern Province, South Africa." Journal of Public Health Medicine **21**(3): 305-310.

Highsmith III, J. A. (2000). Adaptive Software Development - A Collaborative Approach to Managing Complex Systems. New York, Dorset House.

Hirschheim, R. and H. K. Klein (1989). "Four Paradigms of Information Systems Development." Communications of the ACM **32**(10): 1199-1216.

Holland, J. H. (1995). Hidden Order - How Adaptation Builds Complexity. Reading, Massachusetts, Addison-Wesley Publishing Company.

Hospital Advisory Group (1994). A Review of the Determinants of Hospital Performance. Geneve, Division of Strengthening of Health Services, Geneve.

Huber, G. P. (1990). "A Theory of the Effects of Advanced Information Technologies on Organizational Design, Intelligence, and Decision Making." The Academy of Management Review **15**(1): 47-71.

Hunter, J., B. De Jongh, et al. (2002). An Evaluation of the Hospital Information System (HIS) in The Northern Cape Province. Kimberley, Northern Cape Province, South Africa, Information Management Unit, Northern Cape Provincial Department of Health: 37.

Jacucci, E., O. Hanseth, et al. (2006). "Introduction - taking complexity seriously in IS research." Information Technology and People **19**(1): 5-11.

Jacucci, E., V. Shaw, et al. (2006). "Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability." Information Technology for Development **12**(3): 225-239.

Jansen, A. and P. Nielsen (2005). "Theorizing Convergence: Co-Evolution of Information Infrastructures." Scandinavian Journal of Information Systems **17**(1): 67-100.

Jayasuriya, R. (1999). "Managing Health Information Systems for Health Services in a Developing Country: a case study using a contextualist framework." International Journal of Information Management **19**: 335-349.

Jigawa State Government (2005). Jigawa Economic Empowerment and Development Strategy (Jigawa SEEDS). Dutse, Jigawa, Jigawa State Government.

Johns, B., T. T. Torres, et al. (2005). "Costs of scaling up health interventions: a systematic review." Health Policy Plan. **20**(1): 1-13.

Kauffman, S. A. (1993). The Origins of Order: Self Organisation and Selection in Evolution. New York, Oxford University Press.

Kauffman, S. A. (1995a). At Home in the Universe. New York, Oxford University Press.

Kauffman, S. A. (1995b). "Technology and Evolution: Escaping the Red Queen Effect." McKinsey Quarterly(1): 118-129.

Kim, R. M. and S. M. Kaplan (2005). "Interpreting Socio-Technical Co-evolution: Applying Complex Adaptive Systems to IS Engagement." Information Technology and People **19**(1): 35-54.

Kimaro, H. C. (2006). "Strategies for developing human resource capacity to support sustainability of ICT based health information systems: A Case study from Tanzania." The Electronic Journal of Information Systems in Developing Countries **26**(2): 1 - 23.

Kimaro, H. C. and J. L. Nhampossa (2005). "Analysing the Problem of Unsustainable Health Information Systems in Less-Developed Economies: Case Studies from Tanzania and Mozambique." Information Technology for Development **11**(3): 273-298.
Klein, H. K. and M. Myers (1999). "A Set of Principles for Conducting and Evaluating Field Studies in Information Systems." MIS Quarterly **23**(1): 67-94.
Kling, R. (1980). "Social Analyses of Computing: Theoretical Perspectives in Recent Empirical Research." ACM Comput. Surv. **12**(1): 61-110.
Knorr Cetina, K. (2005). "Complex Global Microstructures - the New Terrorist Societies." Theory, Culture and Society **22**(5): 213-234.
Koza, M. P. and A. Y. Lewin (1998). "The Co-Evolution of Strategic Alliances." Organization Science **9**(3): 255-264.
Koza, M. P. and A. Y. Lewin (1999). "The Coevolution of Network Alliances: A Longitudinal Analysis of an International Professional Service Network." Organization Science **10**(5): 638-653.
Langley, A. (1999). "Strategies for theorizing from process data." The Academy of Management Review **24**(4): 691-710.
Lee, A. S. (1994). "Electronic mail as a medium for rich communication: an empirical investigation using hermeneutic interpretation." MIS Quarterly **18**(2): 143-157.
Lee, A. S. and R. L. Baskerville (2003). "Generalizing Generalizability in Information Systems Research." Information Systems Research **14**(3): 221-243.
Lewin, A. Y. (1999). "Application of Complexity Theory to Organization Science." Organization Science **10**(3): 215.
Lewin, A. Y., C. P. Long, et al. (1999). "The Coevolution of New Organizational Forms." Organization Science **10**(5): 535-550.
Lewin, A. Y. and H. W. Volberda (1999). "Prolegomena on Coevolution: A Framework for Research on Strategy and New organizational Forms." Organization Science **10**(5): 519-534.
Lewin, R. (1992). Complexity: Life at the Edge of Chaos. New York, Macmillan.
Lewis, D. and S. Madon (2004). "Information Systems and Nongovernmental Development Organizations: Advocacy, Organizational Learning, and Accountability." Information Society **20**(2): 117-126.
Littlejohns, P., J. C. Wyatt, et al. (2003). "Information in Practice - Evaluation computerised health information systems: hard lessons still to be learnt." British Medical Journal **326**: 860-863.
Loch, C. H. and B. A. Huberman (1999). "A Punctuated-Equilibrium Model of Technology Diffusion." Management Science **45**(2): 160-177.
Lopez, D. M. and B. G. M. E. Blobel (2009). "A development framework for semantically interoperable health information systems." International Journal of Medical Informatics **78**(2): 83-103.
Loveday, M., J. Smith, et al. (2006). Health Information Audit Report South Africa. Durban, South Africa, National Department of Health
Health Systems Trust**:** 50.
Lundberg, N. and H. Tellioglu (1999). "Understanding the Complex Coordination processes in Health Care." Scandinavian Journal of Information Systems **11**(1).
Madon, S., N. Reinhard, et al. (2007). Digital Inclusion Projects in Developing Countries: Processes of Institutionalisation. 9th International Conference on Social Implication sof Computers in Developing Countries, Sao Paulo, Brazil, International Federation for Information Processing.
Mahlalela, X., J. Rohde, et al. (2000). Primary Health Care in the Eastern Cape Province 1997 - 2000. X. Mahlalela. Bhisho, Eastern cape Province, South Africa, Equity Project, Management Sciences for Health**:** 123.
Malone, T. W., K.-Y. Lai, et al. (1992). Experiments with Oval: A Radically tailorable Tool for Cooperative Work. ACM Conference on Computer Supported Cooperative Work (CSCW '92), Toronto, Ontario, Canada, ACM Press.

Mandela, N. (2003). Speech on New Patriotism at the State of the Nation address, Houses of Parliament, Cape Town, 7 February 1997. Nelson Madela - From Freedom to the Future: Tributes and Speeches. K. Asmal, D. Chidester and W. James. Johannesburg, Jonathan Ball Publishers**:** 159-162.

March, J. G. (1991). "Exploration and Exploitation in Organizational Learning." Organization Science **2**(1): 71-87.

Marion, R. and J. Bacon (1999). "Organizational Extinction and Complex Systems." Emergence **1**(4): 79.

Mate, K. S., B. Bennett, et al. (2009). "Challenges for Routine Health System Data Management in a Large Public Programme to Prevent Mother-to-Child HIV Transmission in South Africa." PLoS ONE **4**(5).

Mbananga, N., R. Madale, et al. (2002). Evaluation of the Hospital Information Systemm in the Northern Province in South Africa. Durban, South Africa, Health Systems Trust**:** 87.

McCoy, D., M. Chopra, et al. (2005). "Expanding Access to Antiretroviral Therapy in Sub-Saharan Africa: Avoiding Pitfalls and Dangers, Capitalizing on the Opportunities." American Journal of Public Health **95**(1): 18-22.

McKelvey, B. (1997). "Quasi-natural Organization Science." Organization Science **8**(4): 352-380.

McKelvey, B. (1999a). "Avoiding Complexity Catastrophe in Coevolutionary Pockets: Strategies for Rugged Landscapes." Organization Science **10**(3): 294-321.

McKelvey, B. (1999b). "Complexity Theory in Organization Science: Seizing the Promise or becoming a Fad." Emergence **1**(1): 5-32.

McKinney, E. H. J. (2002). "Leveraging the Hidden Order of Systems." Retrieved 20 October 2005, from http://www.bauer.uh.edu/parks/fis/systemsMckinney.htm.

Merali, Y. M. (2006). "Complexity and Information Systems: the emergent domain." Journal of Information Technology (Palgrave Macmillan) **21**(4): 216-228.

Merali, Y. M. and B. M. McKelvey (2006). "Using Complexity Science to effect a paradigm shift in Information Systems for the 21st century." Journal of Information Technology (Palgrave Macmillan) **21**(4): 211-215.

Monteiro, E. (2003). "Integrating Health Information Systems: A Critical Appraisal." Methods Inf Med **42**: 428-32.

Montoya-Aguilar, C. (1994). Measuring the Performance of Hospitals and Health Centres. Geneve, Division of Strengthening Health Systems, World Health Organization.

Mosse, E. L. and S. Sahay (2005). "The Role of Communication Practices in the Strengthening of Counter Networks: Case Experiences from the Health Care Sector of Mozambique." Information Technology for Development **11**(3): 207-225.

Newbrander, W., H. Barnum, et al. (1993). Hospital Economics and Financing in Developing Countries. Geneve, World Health Organization.

NICS 2006 Group (2007). Nigerian National Programme on Immunization - National Immunization Coverage Survey 2006. Abuja, Nigeria.

Nielsen, P. and J. L. Nhampossa (2005). Internationalization of Information Infrastructures and Control: Cases from Mozambique and Norway. 8th International Working Conference of IFIP WG9.4: Enhancing Human Resource Development through ICT, Abuja, Nigeria.

Orlikowski, W. (1996). "Improvising Organizational Transformation Over Time: A Situated Change Perspective." Information Systems Research **7**(1): 63-92.

Orlikowski, W. and C. S. Iacono (2001). "Desperately Seeking the "IT" in IT Reasearch - A call to Theorizing the IT Artifact." Information Systems Research **12**(2): 121-134.

Owei, V., B. Maumbe, et al. (2007). Toward a Mobile e-Government manifesto for Developing Countries: issues and recommendations for future research directions. IFIP 9.4 9th International Conference on Social Implications of Computers in Developing Countries, Sao Paulo, Brazil.

Padarath, A., C. Chamberlain, et al. (2007). Health Personnel in Southern Africa: Confronting maldistribution and brain drain. EQUINET Discussion Series. R. Loewenson and C. Thompson. Durban, South Africa, EQUINET
Health Systems Trust
MedAct**:** 41.

Perrow, C. (1967). "A Framework for the Comparative Analysis of Organizations." American Sociological Review **32**(2): 194-208.

Perrow, C. (1999). Normal Accidents: Living with High Risk Technologies. New Jersey, Princeton University Press.

Pettigrew, A. M. (1985). Contextualist Research: a natural way to link theory and practice. Doing Research that is Useful in Theory and Practice. E. Lawler. San Francisco, Jossey-Bass.

Pettigrew, A. M. (1987). "Context and Action in the Transformation of the Firm." Journal of Management Studies **24**(6): 649-670.

Piantanida, M., C. Tananis, et al. (2002). Claiming Grounded Theory for Practice-based Dissertation Research - a think piece. Conference on Interdisciplinary Qualitative Studies. Athens, Georgia.

Plsek, P. E. (2001). Appendix B: Redesigning Health care with Insights from the Science of Complex Adaptive Systems. Crossing the Quality Chasm: A New Health System for the 21st Century. I. o. M. Committee on Quality Health Care in America. Washington, D.C., National Academy Press**:** 89-110.

Plsek, P. E. and T. Greenhalgh (2001). "Complexity Science: the challenge of complexity in health care." British Medical Journal **323**(15 September): 625-628.

Plsek, P. E. and T. Wilson (2001). "Complexity Science: Complexity, leadership, and management in health care organisations." British Medical Journal **323**(29 September): 746-749.

Priesmeyer, H. R. and L. F. Sharp (1995). "Phase Plane Analysis: Applying Chaos Theory in Health Care." Quality Management in Healthcare **4**(1): 62-70.

Priesmeyer, H. R., L. F. Sharp, et al. (1996). "Chaos Theory and Clinical Pathways: A Practical Application." Quality Management in Healthcare **4**(4): 63.

Prigogene, I. and I. Stengers (1984). Order Out of Chaos: Man's New Dialogue with Nature. New York, Bantam.

Puri, S. K. and S. Sahay (2004). The Politics of Knowledge in Using GIS for Land Management in India. Information Systems Research: Relevant Theory and Informed Practice. IFIP TC8/WG8.2 20th Year Restrospective. July 15-17, 2004, Manchester, United Kingdom. B. Kaplan, D. P. Truex III, D. Wastell, A. T. Wood-Harper and J. I. DeGross, Kluwer Academic Publishers**:** 597-614.

Ramanathan, J. (2005). "Fractal Architecture for the Adaptive Complex Enterprise." Communications of the ACM **48**(5): 51-57.

Rugg, D., M. Carael, et al. (2004). "Global advances in monitoring and evaluation of HIV/AIDS: From AIDS case reporting to program improvement." New Directions for Evaluation **2004**(103): 33-48.

Saebo, J. (2008). "Scaling of Health Management Information Systems (PhD Upgrade Document)." Retrieved 1 July, 2009.

Sahay, P. S. (2001). "Editorial: Special Issue on "IT and Health Care in Developing Countries"." Electronic Journal on Information Systems in Developing Countries **5**(0): 1-6.

Sahay, S. and C. Avgerou (2002). "Introducing the Special Issue on Information and Communication Technologies in Developing Countries." Information Society **18**(2): 73-76.

Sahay, S., E. Monteiro, et al. (2007). Towards a Political Perspective of Integration in IS Research: The case of health information systems in India. 9th International Conference on Social Implications of Computers in Developing Countries, Sao Paulo, Brazil.

Sahay, S., E. Monteiro, et al. (2009). "Configurable Politics and Asymmetric Integration: Health e-Infrastructures in India." Journal of the Association for Information Systems **10**(5): 399-414.

Sahay, S. and G. Walsham (2005). Scaling of Health Information Systems in India: Challenges and Approaches. International Federation for Information Processing Working Group 9.4 Conference, Abuja, Nigeria.

Sahay, S. and G. Walsham (2006). "Scaling of Health Information Systems in India: Challenges and Approaches." Information Technology for Development **12**(3): 185-200.

Schneider, H., D. Blaauw, et al. (2006). "Health Systems and Access to Antiretroviral Drugs for HIV in Southern Africa: Service Delivery and Human Resources Challenges." Reproductive Health Matters **14**(27): 12-23.

Seebregts, C., B. Mamlin, et al. (2009). "The OpenMRS Implementers Network." International Journal of Medical Informatics(Forthcoming): 10.

Seel, R. (1999). "Complexity and OD." Retrieved 1 November 2005, 2005.

Sen, A. (1999). Development as Freedom. Oxford, Oxford University Press.

Shaw, V. (2003). The Development of an Information System for District Hospitals. The Digital Challenge: Information Technology in the Development Context. S. Krishna and S. Madon, Ashgate.

Shaw, V. (2005). "Health information system reform in South Africa: developing an essential data set." Bulletin of the World Health Organisation **2005**(83): 632 - 639.

Shaw, V. (2007). Considering the Options for Hospital Management Information Systems. Helena 12th E-Health Conference, 2007, Bamako, Mali.

Shaw, V. and J. Braa (Forthcoming). "Developed in the South" - an evolutionary and prototyping approach to developing scalable and sustainable health information systems. Development Informatics and Regional Information Technologies: Theory, Practice and the Digital Divide. J. Steyn, IGI Global. **Vol 3: ICT's for Development in Africa: Theory, Practice and the Digital Divide**.

Shaw, V., S. Mengiste, et al. (2007). Scaling of health information systems in Nigeria and Ethiopia - Considering the options. IFIP 9.4 9th International Conference on Social Implications of Computers in Developing Countries, Sao Paulo, Brazil.

Shaw, V., C. Simoonga, et al. (2008). Using Communities of Practice as a Lens for Understanding Adoption of ICT. IST-Africa Conference 2008 Windhoek, Namibia, International Information management Corporation.

Shibuya, K., S. Scheele, et al. (2005). "Health statistics: time to get serious." Bulletin of the World Health Organisation **83**(10): 722.

Silva, L. (2007). "Institutionalization does not occur by decree: Institutional obstacles in implementing a land administration system in a developing country." Information Technology for Development **13**(1): 27-48.

Silva, L. and R. Hirschheim (2007). "Fighting Against Windmills: Strategic information systems and organizational deep structures." MIS Quarterly **31**(2): 327-354.

Silva, L. O. (2002). "Outsourcing as an Improvisation: A Case Study in Latin America." Information Society **18**(2): 129-138.

Simon, H. A. (1962). "The Architecture of Complexity." Proceedings of the American Philosophical Society **106**: 467-82.

Simon, H. A. (1969). The Sciences of the Artificial. Cambridge, Massachusetts, The Massachusetts Institute of Technology.

Simon, H. A. (1991). "Bounded Rationality and Organizational Learning." Organization Science **2**(1): 125-134.

Stacey, R. D. (1995). "The Science of Complexity: An Alternative Perspective for Strategic Change Processes." Strategic Management Journal **16**(6): 477-495.

Suchman, L. A. (1987). Plans and Situated Actions - the problem of human-machine communication. Cambridge. , Cambridge University Press.

Swanson, E. B. and N. C. Ramiller (2004). "Innovating Mindfully with Information Technology." MIS Quarterly **28**(4): 553-583.

Tan, J., H. J. Wen, et al. (2005). "Health Care and Services Delivery Systems as Complex Adaptive Systems." Communications of the ACM **48**(5): 36-44.
Urry, J. (2003). Global Complexity. Cambridge, UK, Polity.
Urry, J. (2005a). "The Complexities of the Global." Theory, Culture and Society **22**(5): 235-254.
Urry, J. (2005b). "The Complexity Turn." Theory, Culture and Society **22**(5): 1-14.
Van de Ven, A. H. and M. S. Poole (1995). "Explaining Development and Change in Organizations." Academy of Management Review **20**(3): 510-540.
Van den Bosch, F. A. J., H. W. Volberda, et al. (1999). "Coevolution of Firm Absorptive Capacity and Knowledge Environment: Organizational Forms and Combinative Capabilities." Organization Science **10**(5): 551-568.
Van Lerberghe, V. and Y. Lafort (1990). The Role of the Hospital in the District - Delivering or Supporting Primary Health Care. Current Concerns. Geneve, Division of Strengthening of Health Services, World Health Organisation.
Van Maanen, J. (1983). Qualitative Methodology. Beverley Hills, Sage.
Vander Plaetse, B., G. Hlatiwayo, et al. (2005). "Costs and revenue of health care in a rural Zimbabwean district." Health Policy Plan. **20**(4): 243-251.
Volberda, H. W. and A. Y. Lewin (2003). "Guest Editors' Introduction Co-evolutionary Dynamics Within and Between Firms: From Evolution to Co-evolution." Journal of Management Studies **40**(8): 2111-2136.
Waldrop, M. M. (1992). Complexity - The Emerging Science at the Edge of Order and Chaos. New York, Simon and Schuster.
Walsham, G. (1993). Interpreting Information Systems in Organisations. Chichester, England, John Wiley and Sons.
Walsham, G. (1995). "Interpretive case studies in IS research: nature and method." European Journal of Information Systems **4**: 74-81.
Walsham, G. (2001). Making a World of Difference - IT in a Global Context. Chichester, England, Wiley.
Walsham, G., D. Robey, et al. (2007). "Foreword: Special Issue on Information Systems in Developing Countries." MIS Quarterly **31**(2): 317-326.
Walsham, G. and S. Sahay (2006). "Research on information systems in developing countries: Current landscape and future prospects." Information Technology for Development **12**(1): 7-24.
Walsham, G., V. Symons, et al. (1988). "Information Systems as Social Systems: Implications for Developing Countries." Information Technology for Development **3**(3): 189-204.
Wamukuo, J. and P. Ntutela. (2002, October). "Estimating the Cost of District Hospital Services." Retrieved 19 November, 2005, from http://www.doh.gov.za/docs/reports/2002/findc-report01.pdf.
Webb, P. and C. Pollard (2006). "Demystifying a hermeneutic approach to information systems research." Australian Journal of Information Systems **13**(2): 31 - 48.
Weick, K. E. (2001). Organisation Redesign as Improvisation. Making Sense of the Organisation. Oxford, UK, Blackwell Publsihing**:** 57 - 91.
Weick, K. E., K. M. Sutcliffe, et al. (1999). "Organizing for High Reliability: Processes of Collective Mindfulness." Research in Organizational Behavior **21**: 81-123.
Wikipedia. (2009). "Complexity." Retrieved April 25, 2009, from http://en.wikipedia.org/wiki/Complexity.
Williams, J. G. (1999). "The use of clinical information to help develop new services in a district general hospital." International Journal of Medical Informatics **56**(1-3): 151-159.
Wilson, T. and T. Holt (2001). "Complexity Science: Complexity and clinical care." British Medical Journal **323**(22 September): 685-688.
Wolf, R. C., G. Bicego, et al. (2004). "Developing and implementing monitoring and evaluation methods in the new era of expanded care and treatment of HIV/AIDS." New Directions for Evaluation **2004**(103): 81-100.

Wood-Harper, A. T. (1984). Research Methods in Informatin Systems: Using Action Research. Research Methods in Information Systems - Proceedings of the IFIP WG8.2 Colloquium, Manchester Business School, North Holland.
World Health Organisation (2003). Millenium Development Goals - WHO's contribution to tracking progress and measuring achievements. Geneva, World Health Organization.
Wyatt, J. C. (1995). "Hospital Information Management: the need for clinical leadership." British Medical Journal **311**: 175-178.
Xia, W. and G. Lee (2004). "Grasping the Complexity of IS Development Projects." Communications of the ACM **47**(5): 69-74.
Zahra, S. A. and G. George (2002). "Absorptive Capacity: A Review, Re-conceptualization, and Extension." Academy of Management Review **27**(2): 185-203.
Zimmerman, B., C. Lindberg, et al. (1998). Edgeware: Insights from Complexity Science for Health Care Leaders.

APPENDICES

APPENDIX 1

Shaw, V. (2003). The Development of an Information System for District Hospitals. In S. Krishna & S. Madon (Eds.), *The Digital Challenge: Information Technology in the Development Context*: Ashgate.

THE DEVELOPMENT OF AN INFORMATION SYSTEM FOR DISTRICT HOSPITALS

A case study from the Eastern Cape Province, South Africa

Dr. Vincent Shaw MBChB, D.A. (SA), DCH (SA), MFamMed.

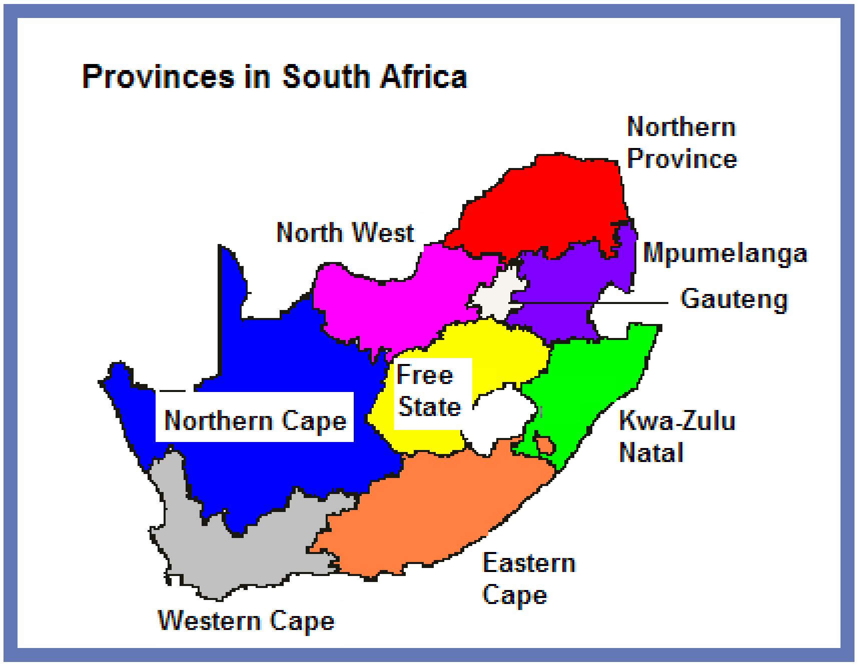
Manager: Health Information Systems Project
University Western Cape
South Africa

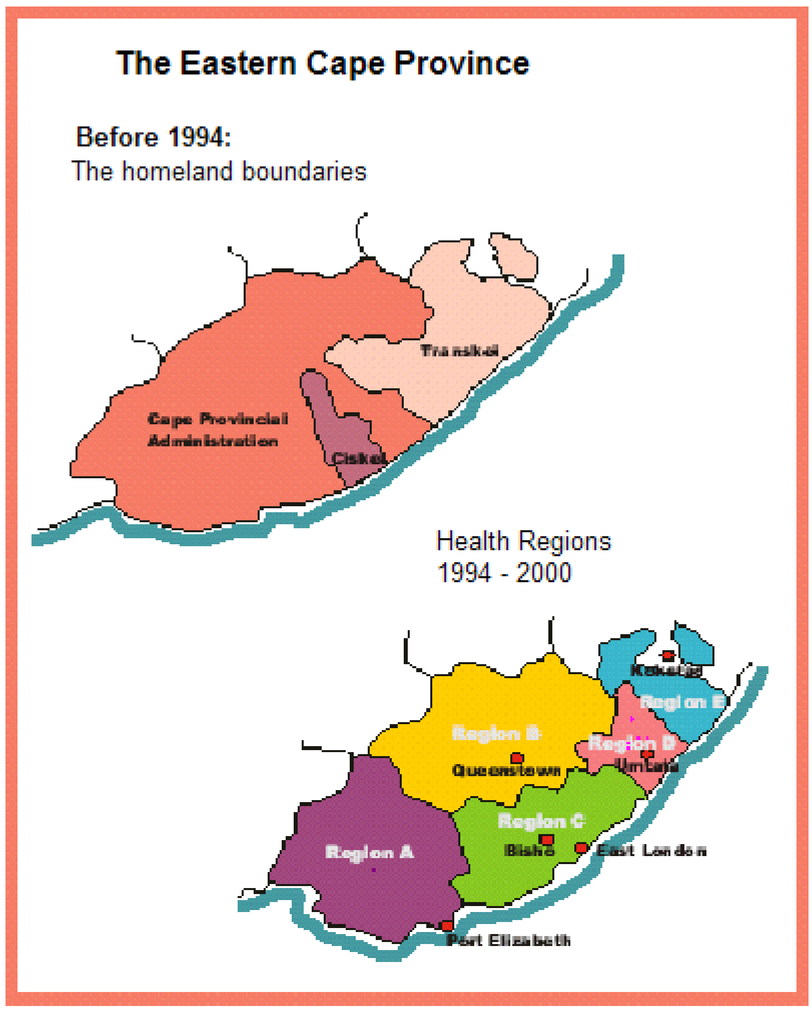
Tel: (027) 82 576 8246 work
(027) 43 748 6605 home

Email: vshaw@wol.co.za

Introduction:

This is a story about the development of a hospital based information system. It is presented as a story because one of the conflicts that we experienced in the process of developing the hospital information system was to establish a balance between a reductionist approach where local contextual issues were ignored (as so often happens in bureaucracies), and the need to be aware of local needs and practices. This is also a story about the difference between a system based on a positivist-empiricist paradigm, and one that adopts a hermeneutic approach, having as its aim the development of capacity to understand, interpret, and utilise information to improve services. Essentially, this paper describes how a participatory approach has been used in developing a hospital information system. The paper is divided into four sections. The first sketches the context in which the case study is described, the second describes the process followed in developing the District Hospital Information System. The third section explores two main themes arising from the participatory approach





adopted, and the fourth section is the conclusion.

I. The Context:

The story begins in the Eastern Cape Province of South Africa (See Map of South Africa and its Provinces).
This is a huge province, with many different aspects to it. The Eastern Cape Province and the Northern Province have the dubious honour of vying for the title "Poorest Province in South Africa", having as their unemployment rates 48.5% and 48% respectively, compared to that of the Western Cape Province which is 20.1% and Gauteng Province being 28.2% (Mahlalela, Rohde et al. 2000).

The Eastern Cape can be divided into two worlds. It consists of a very well developed western section, around Port Elizabeth. This is the area that falls within the area of the former South Africa, and a more underdeveloped area in the East which falls into the area known formerly as the Transkei. The indicators differ remarkably across these two areas, as shown in the table below, with the Eastern area tending to reflect health status of a developed country, and the Western area reflecting that of a developing country.

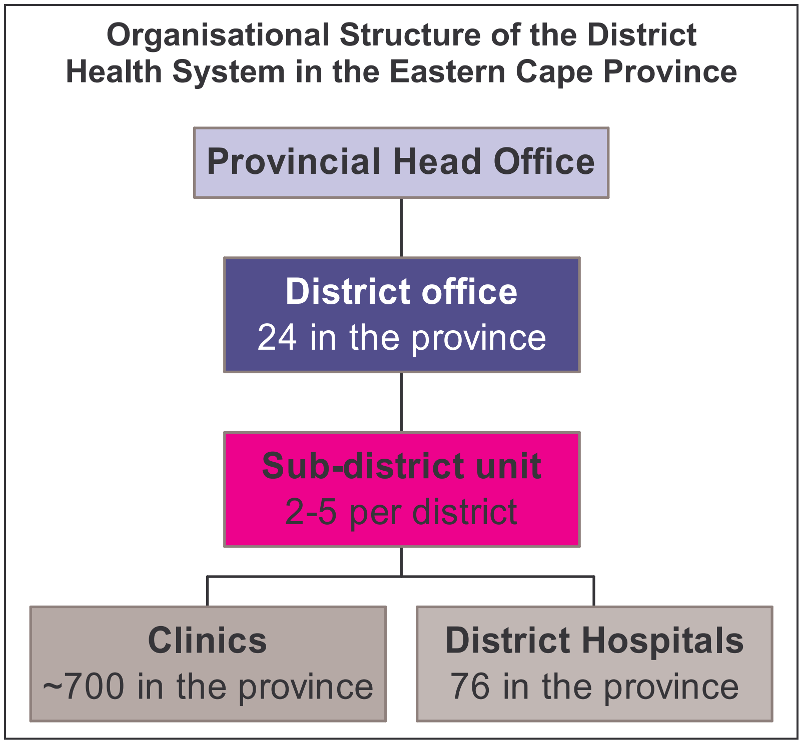
Table 1 highlights this discrepancy.

Indicator	Eastern Cape Province	Port Elizabeth Region	Kokstad Region	SA Average
Infant Mortality (1998) (Deaths per 1000 live births)	61.2	35	99	45.4
Under-5 Mortality rate (1998) (Deaths per 1000 live births)	80.5	35	108	59.4
% Clinics with piped water (1999)	61	100	19	
% Clinics with water-borne toilets (1998)	72	100	65	100
Percentage children fully immunised	52.6	65	37	
% clinics with access to grid electricity (1998)	82.4	100	66	

Table 1: Comparison of Key Indicators

Post 1994, the need to re-organise services was highlighted during the development of the "District Health System" which had to incorporate, within a single structure three homeland governments (see map), and numerous other service providers, both local government and the fragmented departmental systems. The District Health System that has emerged consists of clinics providing Primary Health Care services to the indigent population at various points in the health district. Clinics are grouped into geographic areas called sub-districts, and generally refer patients that require more sophisticated care to district hospitals, or community health centres. The district hospitals in turn refer their patients to regional hospitals. Each district is managed by a district management team, and the team is made up of supervisors who work at the sub-district, or district hospital level. District Managers report directly to the Provincial Management.

The Hospital sector in the province reflects the same diversity that is reflected in the population indicators mentioned in the table. There are huge infra-structural backlogs that need to be addressed, particularly in those hospitals in the former Transkei area. Huge discrepancies exist between staffing ratios in the Western areas, particularly in the East London area (which includes some of the former Ciskei homeland), and the Eastern half of the province. In the Ciskei area, during the apartheid era, staff went on strike, and were dismissed, and new staff were employed. The Government was overthrown, and the successor found the dismissal of staff to be an unfair labour practice, and had the dismissed staff re-instated. The result was that in several facilities, there were twice as many staff as are actually needed. On the other hand, in the former Transkei area, staff have not been replaced as natural attrition occurred, resulting in staff shortages in these facilities. The former Transkei area also has a very poor road infrastructure, with many roads to hospitals being impassible in the summer rainy months. Vehicles quickly rattle to pieces in the bad conditions, leaving hospitals with little or no transport to transfer critically ill patients. In the Western half of the province the road infrastructure is much better developed, and although distances are large, there are more vehicles per capita population than in the Eastern half. In addition to these woes, the new regime in South Africa has emphasised the development of the PHC system. This has resulted in a shift in finances from what used to be a hospi-centric service to one that seeks to develop the PHC services. The hospital sector has thus seen significant reduction in real terms in its per capita allocation, resulting in a critical evaluation of the services it provides and how best to improve efficiency levels.



II. The Development of a District Hospital Information System:

a) Introduction:

The data set for the Hospitals in the Eastern Cape Province had been determined shortly after the new government had been elected in 1994. It consisted of 13 data elements. Of these, 5 related to financial data, and were seldom completed, as many facilities did not have access to the computerised Financial Management System (FMS), and as a result the collection of these elements were meaningless. In addition, although clear definitions were provided, data was not collected in a uniform manner. The result was that the data submitted for a single data element, often meant different things, depending on the nature of the facility and how the data was collected. The result was that the data could not be used to compare across facilities. An example of this was the data element "casualty" visits. In some facilities, casualty patients and out-patients were seen at the same place, and recorded in a single register. However, no distinction between these groups was made, and as a result in some instances data submitted reflected all patients seen in that venue, while in others, it reflected only the casualty patients.

Data from hospitals was supposed to be submitted regularly to the provincial office. However, in the provincial office there was no system for collection of this data, its recording, evaluation, and no feedback to facilities was ever given. A spiral developed whereby facilities lost interest in the data collected, submission became haphazard, and the data was not used by anyone at the provincial level.

b) The process of developing a new Hospital Information System:

During 1999, an assessment of information use in various hospitals in the province was undertaken. The resultant report indicated that:

- Data is collected "at all levels in hospitals, but most of it is never used"
- Indicators are submitted to the district offices, but give a "very bland picture of administrative activities, and no *feeling* of what goes on inside hospitals"
- "Registers are non-standardised, and tend to be anarchic, and hand written", and often on an assortment of different types of paper and books
- "analysis of data is minimal at all levels".

The author, who was at that stage working in the Provincial Office of the Department of Health as Acting Director for District Hospitals, decided to convene a workshop consisting of a select group of people who had knowledge about hospital information systems. The aim was to identify key indicators that should be measured, at hospital, district, and provincial level. The group, consisting of workers at the provincial, district, and hospital level met and developed a series of indicators (see appendix 1). The next step was to assess how the data elements of the indicators could be collected.

In order to do this, we invited health care workers (doctors, nurses and administrators) from 10 hospitals in the province to meet at a district hospital. They were requested to bring along copies of data collection tools that were used in their facilities. We divided into teams and visited wards in the hospital, and evaluated the types of information that was collected, how it was collected, and who used the information. The findings were that:

- there were numerous systems in place in the province (different hospitals use different methods for collecting and aggregating data. This was a reflection of the historical background of different administrations and systems);
- duplication of data collected at various points in the hospital system occurred (in some wards, different registers were maintained. So for example a register was kept of all hypertensive patients, or diabetic patients, in addition to an admission register and a discharge register. Each register required the entry of the patients name and address);
- data was collected but there was very little analysis of data;
- data was often collected "in case" it was needed at a later stage;
- data was largely collected by the nurses, with little or no involvement of the doctors.

In order to address these issues, a system was developed which:

- can be reasonably uniformly applied throughout the province, utilising standardised registers which have space for local needs as well;
- tries to avoid unnecessary duplication;
- allows for ease of analysis;
- encourages all health workers (nurses and doctors and administrators) to work together to make sense of the data, and enables management to make decisions based on the information available to them, and to improve the quality of patient care through analysis of data collected;
- is a paper-based system, allowing local analysis of data as required (is not dependant on computers for analysis, but at the same time is a system which can in future be easily computerised).

The system was piloted in 13 district hospitals for a 6 month period, following which a workshop was convened where the users gave feedback for modification of the system. The adjustments have been incorporated in the final version, and this has now been printed and distributed (see extracts in Appendix 2).

The Hospital EDS utilises a register as a tool for collecting data at the hospital unit (these are for example various wards – paediatrics, maternity, etc, or theatre, out-patients or casualty department, pharmacy, stores) level, and report forms for transmitting the data to managerial level. Management then uses a Monthly Hospital report to collate data from the registers, and transmit the data to the district level. The flow of information through the system is indicated in Table 2.

It is envisaged that data will be entered into the District Health Information Software at the District Information Office level, following which it would be transmitted electronically through the system. In future, it is likely that as hospitals become computerized and linked to the departmental information network, data entry would take place at the hospital level. The District Hospital EDS concentrates on the collection of data elements at this stage. Once this has been implemented, the next phase will look at using this data to report on indicators, and systems to provide feedback to the various role-players.

Level	Reporting format
Hospital unit (ward, theatre, pharmacy) (Registers are the data collection tools)	Reports collate data from registers, and are submitted to management
Hospital management	Hospital monthly report collates data from wards for the hospital as a unit. Submitted to District Office
District Information Office	Data entered into District Health Information System, and submitted to next level electronically or via reports
District Management	Electronic data submission to province
Provincial Office	Data from districts collated and submitted to National office electronically

Table 2: Information Flow for the District Hospital Essential Dataset

The table below summarises the steps taken in the development of the District Hospital Essential Dataset.

Activity	Participants	Purpose
Workshop	Health workers at provincial, district + facility levels, + National office	Determine indicators to be assessed in an IS.
Visit District Hospital	Managers, clinicians from district hospitals across province	Evaluate existing data collection instruments + systems in use
Development of uniform registers	Subset of people visiting the district hospital	Establish a system that allowed data to be collected in a more standardised manner that also allowed comparison across facilities
Piloting of registers	13 District Hospitals	Test the newly developed system
Evaluate registers	13 District hospitals	Collate feedback and make final adjustments to system

Table 3: Steps in the Development of the District Hospital Essential Dataset

III. Discussion of themes arising from the Case Study:

As mentioned in the introduction, one of the challenges was to balance the reductionist approach adopted by the NDoH (See story in Text Box) with a more holistic approach, which took into account the local needs and context.

From the NDoH point of view, their need was for a set of data that would enable them to make certain decisions regarding hospitals. They had defined the data elements, but had little concern for how the data was collected. The assumption was that if the data elements were well defined, they could be compared across facilities and provinces. This is the typical reductionist approach that has been alluded to by many authors, and which, it has been asserted, has resulted in questionable data sets and inappropriate assumptions regarding information collected (Reason and Rowan 1981). Hirscheim and Boland mention in the Series Forward to Walsham (1993) that *"Research into IS failure has concluded that the primary cause of failure is the lack of consideration given to the social and behavioural dimensions of IS"*.

In order to understand the context within which the District Hospital Information System was developed, we need to evaluate a few socio-political dimensions of life in the South African health sector. These will be explored under two main themes, one looking at power issues. And the other at the process of capacity development.

a) Exploring the Issue of Power:

Within the medical hierarchy in the country, the NDoH is the ultimate authority, although the relationship between the provinces and the NDoH is sensitive of the relative independence of the Provincial management regarding health services. The NDoH plays an important role in co-ordinating services, and ensuring uniform systems are applied. Provinces are usually required to "comply with requests from the NDoH", and it is only

where strong leadership exists that Provinces will dare to deviate from National norms and standards.
Within the provinces, the Provincial Managers are more powerful than facility and district managers, and the same principles generally apply between the Provincial and District/Facility Managers as between the Provincial and NDoH.

There is another aspect to consider, and that is the hierarchy that exists within facilities. In general doctors are seen to be in charge, especially when they are South African doctors. However, some provinces are particularly dependant on Foreign Qualified Doctors (i.e. those that have obtained their degree outside of South Africa), because south African doctors are unwilling to work in rural hospitals or in unpopular places. Foreign Qualified Doctors are often less willing to adopt a leadership role because they feel that *"they only work in the system"*, and in some instances then nurses will take on a leadership role.

A Contrasting Scenario

During the development phase of the District Hospital EDS, an interesting interaction occurred with the National Department of Health (NDoH) whereby the NDoH indicated a list of data elements that they required to be collected from district hospitals. Initially the NDoH requested that hospitals should report to them directly on these data elements. Provinces reacted strongly against this, indicating that the reporting should be through the provincial office, as provincial offices were in charge of the district hospitals and not the NDoH.

The format in which the NDoH required the reporting was fixed, and did not take into consideration the local arrangement of district hospitals. An example is where the NDoH required reporting on the number of surgical beds, and surgical admissions, while in many district hospitals, surgical beds were not clearly identified, nor were surgical patients always specifically delineated. This is because in many district hospitals, the nature of the work performed is of a generalist nature, and often both medical and surgical, and sometimes even paediatric patients are mixed in a single ward, and the mix of these groups will vary from month to month, and season to season, depending on the health problems occurring during these periods!

NDoH indicated that they required this breakdown in order to be able to say at a National planning level that the country had XX number of surgical beds, and YY number of medical beds. While this may have been the need at the National level, at a local level this kind of breakdown does not make much sense! We agreed to adjust our data collection instrument in order to accommodate certain of the National requirements, but indicated that we were unable to meet all the National requirements.

A third aspect to consider is the historical context from which the New South Africa emerges, and in particular, the Eastern Cape, where, particularly in the former Transkei part of the country, the Homeland Head Office played an exceptionally strong, centralised role in the management of health services, with little autonomy or decision making authority vested in the peripheral facilities (Shaw 1995). The result has been that health workers in the periphery have taken some time since the establishment of the "New South Africa" to accept that they have some degree of decentralised authority and decision making capacity.

Given this context, it is understandable that if a data set is thrust upon health workers by a higher authority, it may happen that the response will be an unquestioning implementation of the set, with little or no consideration to the meaning of what is being collected, its accuracy, and its relevance.

Given the description of the power relationships that exist in the province, and between different levels, it becomes clear that developing an information system that is appropriate to the needs, and used at various levels, will require more than a top down instruction on data elements to be collected. John Heron (1981) describes a process of co-operative enquiry in Rowan and Reason, in which he argues that it is important for a relationship to be established between researcher and those researched, whereby the researcher and the subjects interact in such a way that they both learn from the process. Of relevance to the process described above, Heron argues that this process of co-operative enquiry is required because of

a) the nature of research behaviour, where, as researchers (in this case the author in the Provincial Office) we cannot expect our subjects to engage in a process which is unacceptable to ourselves, and thus we need to understand ourselves, and explore our own issues before we interact with our subjects, who then become our fellow researchers. Through the interaction that results, the generation of new ideas is *"not a logical product of empirical observation, but rather they arise unpredictably.."*
b) language enables us to communicate. When we have a common language, we are able to symbolise our experiences. When we agree on the use of language, we agree on the set of rules that govern its use.
c) Science involves propositional knowledge, practical knowledge, and experiential knowledge. For the researcher to be able to accurately reflect these forms of knowledge, there needs to be a special relationship between the researcher, and subject (or co-researcher) which allows the aspects of knowledge to be explored and understood.
d) A statement of truth can only be made when it gives credit to the *"values and norms of our sub-culture".* He argues that the first step is understanding the values of being, then the norms of language (and other practical procedures) and then the truth-value propositions. He suggests that *"our statements are true because we know how to formulate I to do justice to a valued experience".*
e) Lastly, traditional research reflects the power of the researcher over his/her subjects. Those in power make the decisions for others.

It is interesting to reflect on the provincial process in the light of the ideas raised by Heron. The provincial office has attempted to involve role-players from all levels in the process of developing the DHEDS from the beginning. The purpose of the process of consultation was to:

- flatten the hierarchical relationship so as to attempt to empower all levels of health workers to determine their information requirements and to encourage them to interact on the development of the system;
- determine the data set that is needed at each level, taking into consideration the existing data that was being collected, so as to ensure that those that were to collect the data would have a vested interest in the completeness and quality of the data (this resulted in some data elements being collected because *"we want to collect this data"* despite them being considered to be of less significance). This could be equated to a process of incorporating experiential and practical knowledge in the system;
- encourage an awareness of the value of information for evaluating, planning and developing health services at a local level;

- encourage the team of doctors and nurses and other health workers to meet and discuss the meaning of the information as a group, and to recognise the different roles that each contributed to the process.

While the provincial approach is yet to be formally evaluated, initial responses during the pilot phase have been encouraging:

- *"this has been a challenge, but it has resulted in an increased awareness for information"*;
- *"these registers have given hospitals the power to say "**No**" to ridiculous requests for information by matrons, Bisho* (the Provincial Head Office)*, and others*".

b) Exploring the Process of Building Capacity:

One of the findings into how data was used in hospitals was that a great deal of data was collected, but very little analysis applied. In many cases, information was collected *"in case we need it".* This may be a reflection of poor numeracy skills (experience with the PHC dataset has highlighted the lack of adequate numeracy skills amongst health workers), with health workers not feeling able to take the information to the next level of understanding, or it may be a reflection of the fact that nurses collect information for their reports, but because of their position in the hierarchy, feel it is not their role to take the initiative of analysing the data.

Zuboff (1988) speaks about processes that informate as well as automate. This is the process whereby technology not only automates operations, but through this process also provides a deeper level of understanding. She applies this to the use of machines and technology in the industrial sector. However, the Hospital Information system uses registers to help automate and standardise the recording of information, and collection of data. Through the use of this standardised data collection, the possibility exists that users at the local level can interpret and analyse the data with ease, thus, through a deeper understanding of their services, shifting the traditional power and knowledge hierarchy.

The further aim of the system despite the fact that it is a paper based system at the hospital unit level, is to allow users to determine basic indicators and targets by clearly defining numerators and denominators for each indicator. If this phase is to succeed, careful attention will need to be paid to the development of a system that allows the calculation of the indicators using basic mathematical skills.

An aspect requiring further consideration is on the nature of the organisation and how it is viewed. Walsham (1993) describes a number of metaphors for organisations – from that of cultures, brains, organisms, to machines, and political systems. How one views the organisation, will influence the behaviour patterns we display in dealing with the organisation. To this end, if we believe that it is purely a machine, we will be mechanistic and cold in our approach. On the other hand, understanding the organisation as a culture, or a political system, will require that we are sensitive to a different set of rules when dealing with the organisation. Mechanistic approaches have little consideration for the human element, and tend to rely more on machines, and even to see humans as machines within the system. On the other hand a culture, or political system is in a continuous state of evolution and growth and development. This is particularly the situation we experience in South Africa at present where new systems are being established, authority is being challenged and replaced based on a new set of rules and principles. People in general are eager to learn, explore, and improve their personal skills. Thus, one needs to create a space, and allow people to come into that space in order to grow and develop. The hospital information system strives to do this through taking the users on a journey, raising questions, and creating awareness, and encouraging them to think on their own needs and expectations. Jorn Braa (1996) suggests that "*the health system (in developing countries) must be developed in a holistic approach integrating the development of organisations, technology, and human capability. What is required is an evolutionary approach to systems development that encourages ongoing broad participation and mutual learning*".

IV. Conclusion:

This paper has, through the use of a case study, explored the steps taken to design a District Hospital Information System in a participatory manner. In the ensuing discussion, two themes identified during the process have been explored. I have argued that within our current context, a system that is based on a hermeneutic process is more appropriate if reliable data is to be collected, and if, as one of its aims, the information system wishes to instil a culture of information use at a local level. All too often, governmental bureaucracies tend to force systems on users in a mechanistic fashion, without adequate consultation, and with little concern for the development of their workers within the system. Managers are encouraged to reconsider how they view organisations, and to take cognisance of the fact that in general they are "living", constantly changing political and cultural systems, and to use this knowledge when developing information systems.

References

- Braa, J. (1996). Decentralisation, Primary Health Care and Information Technology in Developing Countries - case studies from Mongolia and South Africa. IFIP 9.4, Ivy League Publications.
- Heron, J. (1981). Philosophical Basis for a New Paradigm. Human Inquiry: A sourcebook of new paradigm research. P. Reason and J. Rowan. Chichester, John Wiley & Sons: 19-36.
- Mahlalela, X., J. Rohde, et al. (2000). Primary Health Care in the Eastern Cape Province 1997 - 2000. X. Mahlalela. Bhisho, Eastern cape Province, South Africa, Equity Project, Management Sciences for Health: 123.
- Reason, P. and J. Rowan (1981). Human Inquiry: A sourcebook of new paradigm reserach. Chichester, John Wiley & Sons.
- Shaw, V. (1995). "Decentralisation and Health Systems Change: Provincial Report on the Queenstown District."
- Walsham, G. (1993). Interpreting Information Systems in Organisations. Chichester, England, John Wiley and Sons.
- Zuboff, S. (1988). In the Age of the Smart Machine: the future of work and power, Heineman Professional Publishing.

Appendix 1: Set of Indicators for the District Hospital Information System:

	Proposed Provincial Indicators	Frequency	Numerator	Source	Denominator	Source
In Patient						
Activity	Bed Occupancy Rate (Bed utilisation rate)	M	Inpatient days	Midnight census	Active beds	Semi-permanent data
	Average length of stay		In patient days	Midnight census	Discharges + Deaths + Transfers out	Ward report
	% TB patient days	M	TB patient days	Ward report	Total inpatient days	Midnight census
Deaths	Crude Death Rate	M	# deaths in hospital	Ward report	Total hospital admissions	Ward report
	Perinatal Mortality Rate	A	Still Births + deaths in first week	Labour Ward Report	Total births	Labour ward report
	Maternal Mortality Rate		Maternal deaths	Maternity ward report	Total deliveries	Labour ward report
	Death audit rate		Total deaths audited	Ward Report	Total deaths	Ward report
Nutrition	% severe childhood malnutrition	M	# children with severe malnutrition	Paediatric Ward Report	# children < 5 admitted	Paediatric Ward report
Gynae	# ToP performed	M	# ToP performed	Theatre register	N/A	
	Couple year protection	M	# family planning methods utilised	Ward report	Female population 15-45	
Obstetrics	Low Birth Weight rate	M	# live babies with birth weight <2,500 grams	Labour ward report	Total live births	Labour ward report
	% Deliveries with WR recorded	M	# deliveries with WR recorded	Labour ward report	Total deliveries	Labour ward report
	% assisted deliveries		% Assisted deliveries	Labour ward report	Total deliveries	Labour ward report
	Caesarian Section Rate		# caesarian sections	Theatre book	Total deliveries	Labour ward report
	Teenage delivery rate	M	Deliveries to women <18 years	Labour ward report	Total deliveries	Labour ward report

Appendix 1: Set of Indicators for the District Hospital Information System:

Outpatient						
O P D	% Referrals from clinics	M	Patients with clinic referral letter	OPD report	OPD + casualty headcount	OPD report
	% Trauma		MVAs + interpersonal violence	OPD report	OPD + casualty headcount	OPD report
Support						
Pharmacy	% stores items out of stock	A	# store items out of stock	Store report	# items should be in stock	Store report
	% EDL items out of stock	A	# EDL items out of stock	Pharmacy report	# items should be in stock	Pharmacy report
	Items per script		# Items prescribed		# prescriptions	
Financial						
	Cost per PDE	M	Total amount spent in last calendar month	Financial Management System (FMS) Reports	Patient day equivalent	Hospital monthly report
	% Budget spent to date		Expenditure to date this year	FMS Reports	Budget for the year	Semi-permanent data
	% Target Income collected	M	Total income in last calendar month	Cash Book	Target for last month	

Appendix 1: Set of Indicators for the District Hospital Information System:

Annual Survey indicators						
Other Systems	Notifiable Diseases Submission rate	A	# Monthly reports submitted	Reports at District Office	12 months	Reports at District Office
	Termination of Pregnancy Submission rate	A	# Monthly reports submitted	Reports at District Office	12 months	Reports at District Office
	Maternal death notification	A	# Monthly reports submitted	Reports at District Office	12 months	Reports at District Office
	% Transaid reports sent	A	# Transaid reports sent	Reports at District Office	12 months	Reports at District Office
	PHC reports		# PHC reports	Reports at District Office	12 months	Reports at District Office
Finance	Budget allocation per PDE	A	Annual Budget	FMS	PDE for year	Hospital monthly report
	% Expenditure on					
	- Personnel	M	Total spent on personnel in last year	FMS	Total expenditure	FMS
	- Drugs	M	Total spent on drugs in last year	FMS	Total expenditure	FMS
Quality	% hospitals instituting					
	- PIPP program	A	Written record of meetings	Minutes	# monthly meetings scheduled	PIPP guidelines
	- Financial mgt checklist	A	Written record of supervisory visits	Minutes	# supervisory visits scheduled	
	Case fatality rate	A	# deaths	Hospital monthly report	# admissions	Hospital monthly report
Personnel	% Critical posts filled					
	- Management	A	# critical posts filled	Personnel data base (PERSAL)	# critical posts allocated	PERSAL
	- medical	A	# critical posts filled	PERSAL	# critical posts allocated	PERSAL
	% hospital managers with identified indicators	A	# hospital managers with indicators		# hospital managers	
Support	Cost per patient day for support service	A	Total money spent on service	FMS	PDE	Hospital monthly report
	% critical lab services performed (WR, Sputum, FBC;)	A		Lab register	# services should be performed (FBC, AFB sputum, U&E, CSF micro	

Appendix 2: Examples of Tools used for Data Collection at the Unit Level in the District Hospital Information System:

Extract from the Paediatric Ward Register

Ward: Paediatric ward		Month:			Age					
Admission Date	Name	Address	Next of kin/headman	Folder no.	< 5 yrs	=> 5 yrs	Sex M/F	T/F in from other ward/hospital	Private patient	Admission diagnosis
a	b	c	d	e	f	g	h	l	j	k

Appendix 2: Examples of Tools used for Data Collection at the Unit Level in the District Hospital Information System:

Extract from the Paediatric Ward Report:

Report from Ward: ________________ Month/Year: ______________________

All wards			
Admissions:	From ward register:	Male	
Transfers in :		Female	
From other Hospital		(Total)	
From other Ward			
Separations:	From separations tally:		
Discharges	Total		
Transfers out	To another hospital		
	To other ward		
Deaths		Deaths	
	Under< = 7 days		
	8-28 days		
	29 days - under 5 yrs		
	Total audits under 5 yrs		
	5 years - under 12 years		
	12 years and older		

Paediatric		
	Admissions < 5 yrs	
	Admissions = > 5 to < 12 yrs	
	BCG at birth	
	Immunised fully <1 year (new)	
	TB New	
	Severe Malnutrition < 5 yrs New	
	Gastro-enteritis/dehydration	
	Acute Respiratory Infection	
	Convulsions	
	Cardiac	
	Nephritis	
	Measles	
	Others	

APPENDIX 2

Shaw, V. (2005). Health information system reform in South Africa: developing an essential data set. *Bulletin of the World Health Organisation, 2005*(83), 632 - 639.

Round Table

Health information system reform in South Africa: developing an essential data set

Vincent Shaw[1]

Abstract Health services are increasingly under pressure to develop information systems that are responsive to changing health needs and appropriate to service objectives. Developing an essential data set provides managers with a clearly defined set of indicators for monitoring and evaluating services. This article describes a process that resulted in the creation of an essential data set at district level. This had a significant impact on neighbouring districts and resulted in the development of a regional essential data set, which in turn helped to influence the creation of a provincial and then national essential data set. Four key lessons may be drawn from the process. The development of an essential data set both requires and can contribute to a process that allows the reporting requirements to be adjusted over time in response to changing circumstances. In addition, it contributes to (and requires) the integration of programme reporting requirements into a coherent information system. While the case study describes a bottom-up approach, a top-down consultative process is advocated because it establishes a framework within which information needs can be reviewed. Lastly, the use of surveys can aid efforts to keep the essential elements to a minimum. In conclusion, the development of an essential data set contributes to strengthening health services because it necessitates dialogue between programme managers and defines indicators to be monitored by them.

Keywords Information systems/organization and administration; Health status indicators; Data collection/methods; Community health services; Delivery of health care; Program evaluation/methods; South Africa (*source: MeSH, NLM*).

Mots clés Système information/organisation et administration; Indicateur état sanitaire; Collecte données/méthodes; Service public santé; Délivrance soins; Evaluation programme/méthodes; Afrique du Sud (*source: MeSH, INSERM*).

Palabras clave Sistemas de información/organización y administración; Indicadores de salud; Recolección de datos/métodos; Servicios de salud comunitarios; Prestación de atención de salud; Evaluación de programas/métodos; Sudáfrica (*fuente: DeCS, BIREME*).

الكلمات المفتاحية: نُظُم المعلومات، مؤشرات الوضع الصحي، جمع المعطيات، طرق جميع المعطيات، الخدمات الصحية المجتمعية، إيتاء الرعاية الصحية، تقييم البرامج، طرق تقييم البرنامج، جنوب أفريقيا. (المصدر: رؤوس الموضوعات الطبية، المكتب الإقليمي لشرق المتوسط)

Bulletin of the World Health Organization 2005;83:632-639.

Voir page 635 le résumé en français. En la página 636 figura un resumen en español.

يمكن الاطلاع على الملخص بالعربية في صفحة 636.

Introduction

Increasingly, information systems for monitoring health services are being scrutinized for their appropriateness and ability to provide meaningful information to managers (*1–4*). The vision of the District Health Information System (DHIS) developed in South Africa is "to support the development of an excellent and sustainable health information system that enables all health workers to use their own information to improve coverage and quality of health care within our communities" (*5*). According to the basic principles of the DHIS, it supports the district-based primary health care approach, collects essential data used to calculate indicators, encourages decentralized use of information by health workers, includes all service providers at all levels, and integrates with and supports other information systems.

Over the past 10 years, a comprehensive primary health care information system has been developed in South Africa. One of its key elements is an essential data set, which may be defined as a set of the most important data elements, selected from all primary health care vertical programmes, that should be reported by health service providers on a routine basis, with the aim of being able to generate indicators that monitor the provision of health services in an integrated manner. An essential data set is thus important in that it contributes to the principles listed above and facilitates decentralized use of information by health workers because their monitoring needs are clearly defined.

There are two key messages in this definition, contained in the linked concepts of integration and an essential data set. Programme managers (e.g. coordinators of the Expanded Programme on Immunization (EPI) and programmes for women's health, HIV/AIDS and sexually transmitted infections, and tuberculosis), in an effort to ensure that all angles of service delivery are taken into consideration, often require a very large amount of information for their specific programmes. Their primary concerns are their programme needs, and little attention is given to the means of collecting the information or

[1] Manager, Health Information Systems Programme, School of Public Health, University of the Western Cape, South Africa (email: vshaw@hisp.org).
Ref. No. **04-015032**

the needs of other programmes. The requirements of various programmes may duplicate each other, and the vertical reporting of this information often requires separate data collection tools. As a result, the health worker is faced with a myriad of books and forms, all used to collect information for specific managers, but with little integration and no vision of its use at the local level. Experience has shown that the larger the number of data elements to be reported upon, the poorer the quality of the data (*6, 7*).

The creation of an essential data set is based upon two key principles: limiting the routine reporting requirements for primary health care and hospital services to a set of 100–150 data elements, enabling the calculation of 80–120 indicators; and integrating the reporting requirements of various programme managers, so that their needs are contained within the set of essential data elements and indicators.

This article describes a process that resulted in the creation of an essential data set at district level. This had a significant impact on neighbouring districts and resulted in the development of a regional essential data set, which in turn helped to influence the creation of a provincial data set.

Developing an essential data set at district level

In a remote district in the northern part of the Eastern Cape Province, the district management team found that the data collected by the clinic staff seemed inappropriate for the adequate management of services. Until then, data had been submitted to the head office on a routine (quarterly) basis, but no feedback was ever received. The requirements for data submission had been determined by head office staff many years earlier and had not been revised to accommodate recent changes in the priorities for health service delivery.

The decision to review the data collected at facility level took place in 1994, when the "new" South Africa was requiring an increasingly decentralized management structure and greater transparency in terms of access to information and health statistics. In addition, the focus had shifted significantly from a hospicentric health service to a health service orientated towards primary health care.

The district team evaluated all the services that they were providing, and identified data elements or indicators that would accurately monitor these services. This exercise included a process of evaluating existing data elements being collected. For each data element that health workers wanted to be included, they had to answer the questions: Why do we want to collect this information? How will we use it? The answers should underpin the need to monitor the integrated strategic plan for the district. If the health workers could not come up with a reasonable answer to either of the questions, the data element was discarded or reformulated so that the questions could be answered.

A long list of data elements and their associated indicators was developed. Then began a process of whittling away at the list until about 70 elements remained, which were considered the most essential data elements required to calculate about 75 indicators. This set of indicators was small enough to allow management to focus on the key aspects of service provision, yet was large enough to monitor services across all programmes. It provided management with an integrated system for assessing services. Along with the data elements and indicators, a set of data collection tools was developed.

Box 1. **An essential data set must be able to accommodate changes over time**

There were a number of important modifications that came about as a result of the process of establishing an essential data set. One example that highlights how experience influenced the development of the data set hinges on the data elements collected for antenatal services. Two of the antenatal indicators were:

- antenatal coverage (first antenatal visit divided by the expected number of pregnancies in the women of childbearing age);
- average antenatal visits per antenatal client (first antenatal visit plus follow-up antenatal visit divided by the first antenatal visits).

The district management team found a very high antenatal coverage rate in the district (112% for January–December 2000); with an average of three antenatal visits per antenatal client, it was apparent that the pregnant population was able to access the required services. The next step was to seek to improve the quality of services by first determining the percentage that accessed the services within the first 20 weeks of pregnancy and, if necessary, increase it. The team's gut feeling was that a very low percentage actually accessed services in the first trimester. Hence a new, more specific indicator was introduced and the existing data element "First antenatal visit" to be split into: "First antenatal visit within first 20 weeks of pregnancy" and "First antenatal visit after 20 weeks of pregnancy".

Managing upwards: the district influences the region

As the district implemented the new system, adjoining districts came to learn about the new data set and its efficiency. Gradually, pressure from other areas within the region to implement the same data set mounted; as a result a regionwide consultative meeting was convened, at which the district data set was assessed and adapted to accommodate the needs of the region. This, in turn, resulted in the region approaching the province to reduce the number of indicators being reported upon; finally, after some time, the province approached the national administration, and in June 2002 a national workshop adopted an essential data set for the country.

Important lessons learned from this process

Reporting requirements must be able to change over time

Changing needs of patients require changing reporting requirements, as evidenced by the emergence of the HIV/AIDS epidemic and increasing access to antiretroviral therapy. In the case of the HIV/AIDS epidemic, managers at the central level have generally been responsive to the needs of patients and the reporting requirements of donors. The reality is, however, that these managers operate from positions of power and are able to impose reporting requirements even if they have not been well thought through. Managers at facility level may have a better grasp of the needs of patients, but they have less influence in making these needs known. The result is that once reporting needs have been defined, they remain cast in stone.

Reviewing reporting requirements requires a broadly consultative process between managers of different programmes in order to ensure that duplication is avoided. This is not easy to achieve.

As managers use information, their understanding of its meaning improves and their demands become more sophisticated. Bodart & Shrestha (*8*) describe four types of indicator (count, proportion, rate and ratio). Our experience has shown that managers are initially most comfortable identifying count indicators (e.g. number of patients with hypertension). They should be encouraged to look beyond this, however, to identify how they would use this count indicator to improve service delivery. This often leads to the development of indicators which bring in another data element as the denominator, creating one of the other three indicator types. Box 1 provides an example from which it can be seen that an atmosphere needs to be created where the review of reporting requirements is acceptable, even the norm. This needs to be the case both at the central and the peripheral levels.

Programme reporting requirements must be integrated in order to ensure the development of coherent information

There should be agreement among programme managers to adhere to the principle of developing an integrated data set. In the absence of this, health workers at the facility level are likely to have to cope with uncoordinated and often duplicate demands for information that will result in their being distracted from their primary function — providing health services. An example would be where the nutrition programme requires reporting on the number of children under five years of age attending the clinic, number of children weighed, and number of children with malnutrition. In order to be sure that facilities report on these elements, the programme develops a data collection form specific to its needs. At the same time, EPI requires reporting on children attending under two years of age, and immunizations given to them (BCG, DPT1-2-3, OPV1-2-3, etc.). It also develops a report format specific to its needs. Both these programmes are targeting the same population group, without considering that, from a health care worker's point of view, the child who needs to be immunized also needs to be weighed and given vitamin A, and in the clinic it is the same health worker who provides all these services. Adopting an integrated approach would ensure that systems are developed which complement each other and are appropriate to the manner in which services are delivered.

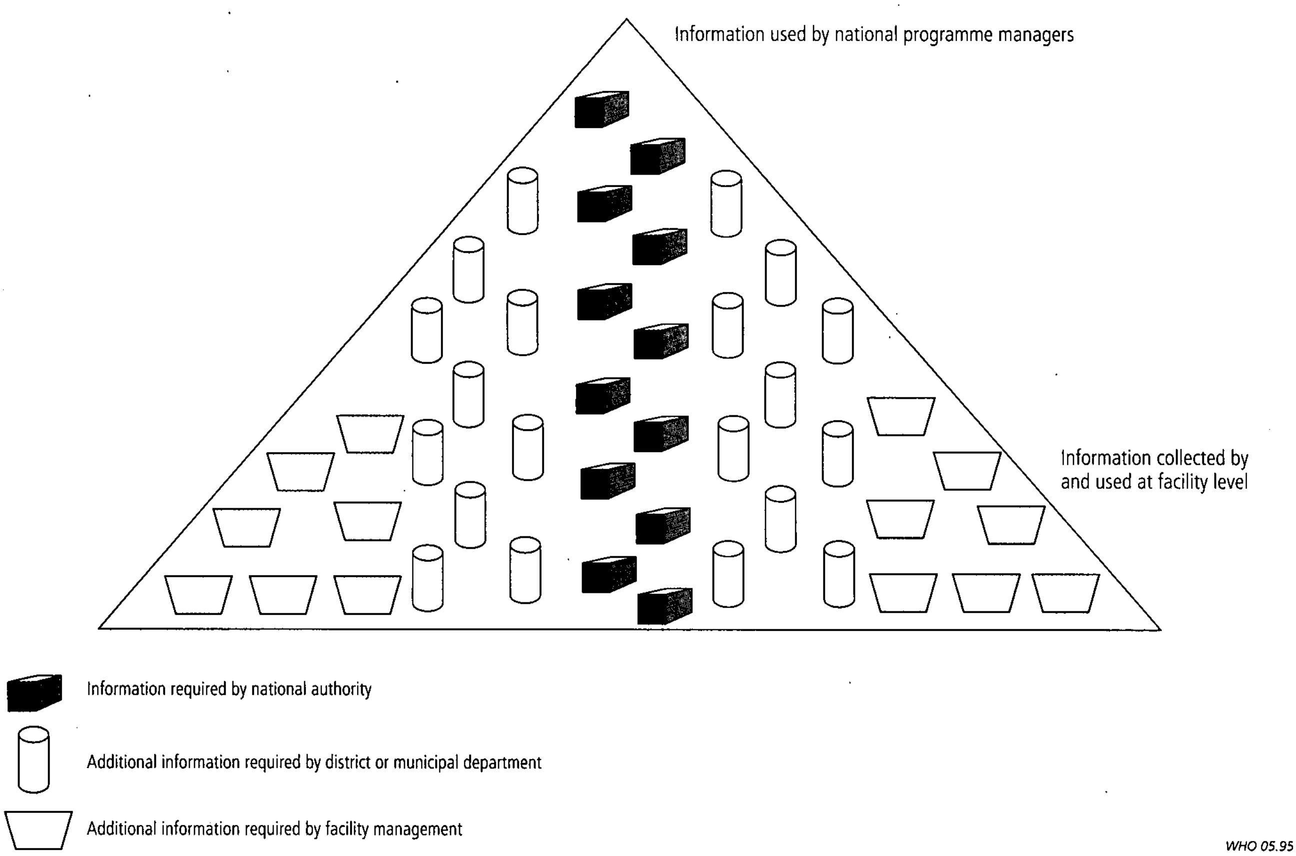
An integrated data set also provides managers at facility and district alike a clearly defined target to work towards, both in terms of collecting and using the information.

A top-down consultative process establishes a framework for review

The creation of an essential data set for South Africa began as a bottom-up process. Decentralized districts are often less bureaucratic in nature than central systems, and more responsive to the changing needs of patients. As a result, they are able to see the need to revise reporting requirements and are able to effect a change reasonably easily. It is also easier to bring different programme managers together at district level, to ensure integrated reporting.

A more strategic position to adopt, however, would be for a national ministry to take it upon itself to facilitate the development of an essential data set for the country. A concept in support of this process is a hierarchy of information needs (*5*, *9*).

Fig. 1. **The hierarchy of information needs**



A hierarchy of information needs operates at the following levels.

1. A national ministry determines an essential data set — this is the minimum reporting requirement for all facilities and health service providers in the country.
2. The next level of management (a region or province) adds indicators that they believe they should collect in order to be able to manage their services efficiently (e.g. in the example in Box 1 the original indicator was split in order to obtain more detailed information).
3. A district management team adds to the regional essential data set indicators they believe are important to manage their services (e.g. a district wants to improve the supervision process in clinics, so monitors the percentage of planned supervisory visits undertaken).
4. A facility develops an essential data set which includes indicators from the ministry, region and district, as well as their own indicators (e.g. if facility staff want to confirm that they carry an increasingly large workload of patients from outside their official catchment area, they develop an indicator "Percentage head count attendances from outside the catchment area"). The type of information important for a facility management committee, and possibly for a district, is not necessarily relevant at the national or regional levels.

Applying the concept of a hierarchy of information necessitates adherence to the principle of only transmitting the information that is required to the next level. With the advent of computers, and patient-based information systems, the temptation to transmit all the information through to all levels must be resisted.

Additional information can be collected through specific programme surveys

In order to ensure that the essential data set is limited in size, it is necessary to provide programme managers with an alternative mechanism for collecting programme data outside the routine reporting system. This is done by using surveys.

Surveys should be used to gather information that will complement the routine reporting. As some indicators do not change much over time, they do not need to be reported on monthly — they could be collected annually or quarterly through the use of surveys. Typical contents of a survey questionnaire would be questions about quality of care, availability of equipment, staffing and budget allocations. Surveys can be used creatively to strengthen health services. For example, it may be that in order to reduce the cost of surveys, a three-year rolling plan is developed, ensuring that each year a third of all facilities are surveyed: all are surveyed over the three-year period. A survey data set would contain core information that is common to all the years, and additional information could be changed from year to year according to need.

Conclusion

Developing an essential data set provides managers with a clearly defined set of indicators for monitoring and evaluating services. The process of developing an essential data set can strengthen the health services and the health information system because it requires coordination of reporting requirements among programme managers, and the creation of a framework for reviewing information needs over time. Applying the concept of a hierarchy of information needs allows each level within the health service to develop its own data set, while still responding to the needs of the central administration. This encourages the use of information at a local level because each level has been involved in determining the indicators and data elements that are collected. Annual surveys can be used to complement routine reporting, enabling the essential data set to be kept to a minimum. ■

Acknowledgements

This article would not have been possible without the innovations developed in the Ukhalhamba District under the guidance of Arthur Heywood, supported by the vision and leadership of Jenny Brown, Elsabe Schlebusch and, later, Rudi Thetard. The nurses who worked in the clinics in the Ukahlamba District are thanked for their perseverance in testing the hierarchy and in developing the initial set of indicators.

Competing interests: none declared.

Résumé

Réforme du système d'information sanitaire en Afrique du Sud : mise au point d'un jeu de données essentielles

Les services de santé sont de plus en plus incités à développer des systèmes d'information réagissant à l'évolution des besoins sanitaires et répondant aux objectifs de service. La définition d'un jeu de données essentielles fournit aux gestionnaires une série d'indicateurs clairement définie permettant de surveiller et d'évaluer les services. Le présent article décrit un processus aboutissant à la création d'un jeu de données essentielles au niveau du district. Cette opération a eu un impact important sur les districts voisins et a conduit à la mise au point d'un jeu de données essentielles pour la région, processus qui, à son tour, a contribué à l'élaboration d'un jeu de données essentielles à l'échelle de la province, puis du pays. Quatre enseignements peuvent être tirés de cette expérience. La mise au point d'un jeu de données essentielles nécessite un processus permettant d'ajuster les exigences de notification au cours du temps en réponse à l'évolution des circonstances, processus auquel elle peut en même temps contribuer. En outre, elle facilite (et impose) l'intégration des exigences de notification des programmes dans un système d'information cohérent. Bien que l'étude de cas décrive une démarche partant de la base, un processus consultatif descendant est préconisé car il fixe un cadre dans lequel les besoins en information peuvent être analysés. Enfin, la réalisation d'enquêtes peut contribuer aux efforts pour limiter le plus possible le nombre d'éléments essentiels. En conclusion, la mise au point d'un jeu de données essentielles participe au renforcement des services de santé car elle implique un dialogue entre les directeurs de programmes et la définition d'indicateurs que ces derniers doivent surveiller.

Resumen

Reforma de los sistemas de información sanitaria en Sudáfrica: desarrollo de un conjunto de datos esenciales

Los servicios de salud se encuentran sometidos a una presión cada vez mayor para desarrollar sistemas de información sensibles a las nuevas necesidades de salud y apropiados para alcanzar los objetivos fijados. Un conjunto de datos esenciales puede dotar a los administradores de un abanico claramente definido de indicadores para vigilar y evaluar los servicios. En el presente artículo se describe un proceso que permitió crear un conjunto de datos esenciales a nivel de distrito. Ello tuvo importantes repercusiones en los distritos vecinos y condujo a desarrollar un conjunto de datos esenciales de ámbito regional, lo cual influyó a su vez en la creación de un conjunto de datos esenciales provincial y más tarde nacional. Cabe extraer del proceso cuatro importantes lecciones. El desarrollo de un conjunto de datos esenciales exige y al mismo tiempo puede favorecer un proceso que permita ajustar las necesidades de información con el tiempo en respuesta a la evolución de las circunstancias. Además, propicia (y requiere) la integración de los requisitos programáticos en materia de presentación de informes en un sistema de información coherente. Mientras el estudio de casos describe un enfoque ascendente, aquí se preconiza un proceso consultivo descendente, pues así se establece un marco en el que pueden analizarse las necesidades de información. Por último, la utilización de encuestas puede ser una ayuda para reducir al mínimo los elementos esenciales. En conclusión, el desarrollo de un conjunto de datos esenciales contribuye a fortalecer los servicios de salud porque requiere que haya diálogo entre los gestores de los programas y define los indicadores que éstos deberán vigilar.

ملخص

مائدة مستديرة إصلاح نُظُم المعلومات الصحية في جنوب أفريقيا: إعداد مجموعة المعطيات الأساسية

تعاني الخدمات الصحية من تزايد الضغوط عليها لإعداد نُظُم معلومات صحية تتسم بالاستجابة للاحتياجات الصحية المتغيِّرة وللأغراض الملائمة من الخدمات. ويتيح إعداد مجموعة المعطيات الأساسية للمديرين مجموعة من المؤشرات المحددة تحديداً واضحاً لرصد ولتقييم الخدمات. وتصف هذه الورقة عملية انتهت بإعداد مجموعة المعطيات الأساسية على مستوى المقاطعة. وقد كان لهذه العملية تأثير واضح على المقاطعات المجاورة وأدت إلى إعداد مجموعة المعطيات الأساسية على صعيد المنطقة، والتي ساعدت بدورها على التأثير لإعداد مجموعة المعطيات الأساسية على صعيد الولايات، ثم على الصعيد الوطني. وهناك أربعة دروس مستفادة من هذه العملية. ويتطلب إعداد مجموعة المعطيات الأساسية عملية تسمح بتعديل متطلبات الإبلاغ مع مرور الوقت، وتساهم في تلك العملية نفسها للاستجابة للظروف المتغيرة. وبالإضافة إلى ذلك فإن هذه العملية تساهم في إحداث التكامل بين متطلبات الإبلاغ في البرامج وبين نظام متسق للمعلومات، كما أن هذه العملية تتطلب ذلك التكامل أيضاً. ورغم أن الحالة المدروسة تصف أسلوباً ينطلق من القاعدة ويتجه للقمة فإن ما ينصح به هو اتباع عملية تشاورية تبدأ من القمة وتتجه للقاعدة، لأن ذلك يرسخ إطاراً يمكن أن تراجع الاحتياجات من المعلومات ضمنه. وأخيراً يمكن لاستخدام المسوحات أن تقدم المساعدة للجهود المبذولة للمحافظة على العناصر الأساسية في حدها الأدنى. وبالنتيجة فإن إعداد مجموعة المعطيات الأساسية يساهم في تعزيز الخدمات الصحية لأنها تجعل الحوار ضرورياً بين مديري البرامج كما أنها تحدد المؤشرات التي ينبغي عليهم رصدها.

References

1. Green A. *An introduction to health planning in developing countries.* Oxford: Oxford University Press; 1999.
2. *White Paper on the transformation of health services.* Durban: South African Department of Health; 1997. Available from: http://www.doh.gov.za/docs/index.html
3. *Information support for new public health action at district level. Report of a WHO Expert Committee.* Geneva: World Health Organization; 1994. WHO Technical Report Series, No. 845.
4. Campbell B, Adjei S, Heywood A. *From data to decision making in health: the evolution of a health management information system.* Amsterdam: Royal Tropical Institute; 1996.
5. Heywood A, Rohde J. *Using information for action: a manual for health workers at facility level.* South Africa: EQUITY Project.
6. Stoops N, Williamson L. Using health information for local action: facilitating organisational change in South Africa. In: Krishna S, Madon S, editors. *The digital challenge: information technology in the development context.* Gateshead: Athenaeum Press Ltd.; 2003.
7. Williamson L, Stoops N. Using information for health. In: *South African Health Review 2001.* Available from: http://hst.org.za/sahr/2001/chapter6.htm
8. Bodart C, Shresta L. Identifying information needs and indicators. In: Lippeveld T, Suaerborn R, Bodart C, eds. *Design and implementation of health information systems.* Geneva: WHO; 2000:Chapter 4.
9. Braa J, Hedberg C. The struggle for district-based health information systems in South Africa. *The Information Society* 2002; 18:113-27.

Round Table Discussion

Information is not only for managers

Richard E. Cibulskis[1]

The product described by Shaw — a simplified health information system implemented on a national scale — is not new (*1*, *2*). What is interesting is the bottom-up process, as it is quite unusual for systems originating in one district to take hold over a wide geographical area. This may be because some districts are reluctant to use a system designed by other districts or because they do not have the same resources for implementation. Whatever the circumstances, bottom-up processes can produce a variety of incompatible information systems, each competing to be adopted as a national standard. South Africa does not appear to have succumbed to this problem, but it is still not clear if its system really works. It would be instructive to learn more about its reporting rate from institutions. This is a good indicator of an information system's performance as it requires several basic processes to be fulfilled, such as a complete listing of reporting units, compliance with reporting requirements and processes for monitoring compliance. A good reporting rate is also critical to the eventual interpretation of indicators.

Whether a top-down or bottom-up approach is preferred, the design of health information systems requires a clear understanding of why data are being collected; ultimately they should influence the behaviour of those in control of resources in ways that will enable the health sector to achieve its objectives. Data should certainly be used by health managers to plan and monitor programmes, enabling them to allocate resources to priority health problems or populations. The information required for this task, however, is wider than that provided by routine health information systems. Some relevant data systems — for population, finances, and staffing — are managed by other government departments, while some information is collected through censuses or surveys (particularly if many services are delivered through non-government providers). An optimal information strategy needs to consider how the different sources of information will work together. For example, it should be clear about the definitions of indicators and the coding systems used for geographical units. Some form of centrally coordinated approach seems inevitable. Such coordination should not be mistaken as being set up for the purpose of supplying central level managers with information: although they might benefit from information, they rarely have the capacity or authority to respond to large quantities of data. Rather, central coordination is primarily to bring together data from districts so that they can be summarized in such ways that districts can compare their performance with that of others.

Health managers are often ineffective users of information, despite efforts to train them, encourage them or provide them with new information systems. Time and again, inequities or inefficiencies in the use of resources go unheeded. This may be because health managers have little influence over key decisions in government or perhaps because they are not motivated to respond. There is a growing awareness that if we are interested in enhancing the performance of the health sector then external uses of information can carry greater weight than internal uses (*3*). Thus, public disclosure of information can help "politicians, patients and citizens to scrutinize the operations which they are financing" (*4*) and in this role it can encourage managers to be more responsive to their clients' needs. Similarly, information can be used by health managers to lobby external authorities for greater support. If external uses of information have greater impact than internal uses, should not the health sector take this into account when designing its minimal data sets? It may be that the minimal data set for politicians, citizens and the treasury are the same as that for health managers, but not necessarily so. Citizens may be more interested in learning whether basic inputs such as staff and drugs are available, whereas a ministry of finance may be interested in learning whether national development priorities are being delivered. Whatever the final content, minimal data sets need to begin with the key users and uses of information and they should not remain the preserve of health managers. ■

Competing interests: none declared.

1. Lippeveld T, Sauerborn R. A framework for designing health information systems. In: Lippeveld T, Sauerborn R, Bodart C, editors. *Design and implementation of health information systems.* Geneva: WHO; 2000:15-32.
2. Cibulskis RE, Hiawalyer G. Information systems for health sector monitoring in Papua New Guinea. *Bulletin of the World Health Organization* 2002;80:752-8.
3. The World Bank. *World development report 2004 – Making services work for poor people.* Washington (DC): the World Bank; 2003.
4. Smith P. The use of performance indicators in the public sector. *Journal of the Royal Statistical Society Series A* 1990;153:53-72.

Indicators for a health information data set in Ghana

Sam Adjei[2]

A health information system handles the recording, storage, retrieval and processing of health data. Broadly defined, the health information system should cover such data sources as vital registration, censuses, routine service-generated statistics, population-based surveys and research information, in order to provide evidence for decision-making in the health system.

Assessments of health information systems have given rise to several misgivings. Foremost among them is the fact that multiple data sources are not linked to each other; indeed, different instruments may generate different data on the same person or event. Routine service data are collected with the needs of higher-level programme managers and donors in mind; in addition, they may be incomplete or of doubtful quality, and timeliness can be a problem. Surveys are useful, but they tend to be expensive and donor driven and are often not linked to routine service data. Research data are generally available but are rarely included as part of the health information system because research is conducted outside the scope of ministries of health. Dissemination of the information collected is usually

[1] Monitoring and Evaluation Advisor, World Bank Office Jakarta, Jakarta Stock Exchange Building Tower 2, 12th floor, Jl Jenderal Sudirman Kav 52–53, Jakarta 12190, Indonesia (email: rcibulskis@worldbank.org).
[2] Deputy Director-General, Ghana Health Service, Private Mail Bag, Ministries, Accra, Ghana (email: sam.adjei@hru-ghs.org).

Round Table Discussion

Information is not only for managers

Richard E. Cibulskis[1]

The product described by Shaw — a simplified health information system implemented on a national scale — is not new (*1*, *2*). What is interesting is the bottom-up process, as it is quite unusual for systems originating in one district to take hold over a wide geographical area. This may be because some districts are reluctant to use a system designed by other districts or because they do not have the same resources for implementation. Whatever the circumstances, bottom-up processes can produce a variety of incompatible information systems, each competing to be adopted as a national standard. South Africa does not appear to have succumbed to this problem, but it is still not clear if its system really works. It would be instructive to learn more about its reporting rate from institutions. This is a good indicator of an information system's performance as it requires several basic processes to be fulfilled, such as a complete listing of reporting units, compliance with reporting requirements and processes for monitoring compliance. A good reporting rate is also critical to the eventual interpretation of indicators.

Whether a top-down or bottom-up approach is preferred, the design of health information systems requires a clear understanding of why data are being collected; ultimately they should influence the behaviour of those in control of resources in ways that will enable the health sector to achieve its objectives. Data should certainly be used by health managers to plan and monitor programmes, enabling them to allocate resources to priority health problems or populations. The information required for this task, however, is wider than that provided by routine health information systems. Some relevant data systems — for population, finances, and staffing — are managed by other government departments, while some information is collected through censuses or surveys (particularly if many services are delivered through non-government providers). An optimal information strategy needs to consider how the different sources of information will work together. For example, it should be clear about the definitions of indicators and the coding systems used for geographical units. Some form of centrally coordinated approach seems inevitable. Such coordination should not be mistaken as being set up for the purpose of supplying central level managers with information: although they might benefit from information, they rarely have the capacity or authority to respond to large quantities of data. Rather, central coordination is primarily to bring together data from districts so that they can be summarized in such ways that districts can compare their performance with that of others.

Health managers are often ineffective users of information, despite efforts to train them, encourage them or provide them with new information systems. Time and again, inequities or inefficiencies in the use of resources go unheeded. This may be because health managers have little influence over key decisions in government or perhaps because they are not motivated to respond. There is a growing awareness that if we are interested in enhancing the performance of the health sector then external uses of information can carry greater weight than internal uses (*3*). Thus, public disclosure of information can help "politicians, patients and citizens to scrutinize the operations which they are financing" (*4*) and in this role it can encourage managers to be more responsive to their clients' needs. Similarly, information can be used by health managers to lobby external authorities for greater support. If external uses of information have greater impact than internal uses, should not the health sector take this into account when designing its minimal data sets? It may be that the minimal data set for politicians, citizens and the treasury are the same as that for health managers, but not necessarily so. Citizens may be more interested in learning whether basic inputs such as staff and drugs are available, whereas a ministry of finance may be interested in learning whether national development priorities are being delivered. Whatever the final content, minimal data sets need to begin with the key users and uses of information and they should not remain the preserve of health managers. ■

Competing interests: none declared.

1. Lippeveld T, Sauerborn R. A framework for designing health information systems. In: Lippeveld T, Sauerborn R, Bodart C, editors. *Design and implementation of health information systems.* Geneva: WHO; 2000:15-32.
2. Cibulskis RE, Hiawalyer G. Information systems for health sector monitoring in Papua New Guinea. *Bulletin of the World Health Organization* 2002;80:752-8.
3. The World Bank. *World development report 2004 – Making services work for poor people.* Washington (DC): the World Bank; 2003.
4. Smith P. The use of performance indicators in the public sector. *Journal of the Royal Statistical Society Series A* 1990;153:53-72.

Indicators for a health information data set in Ghana

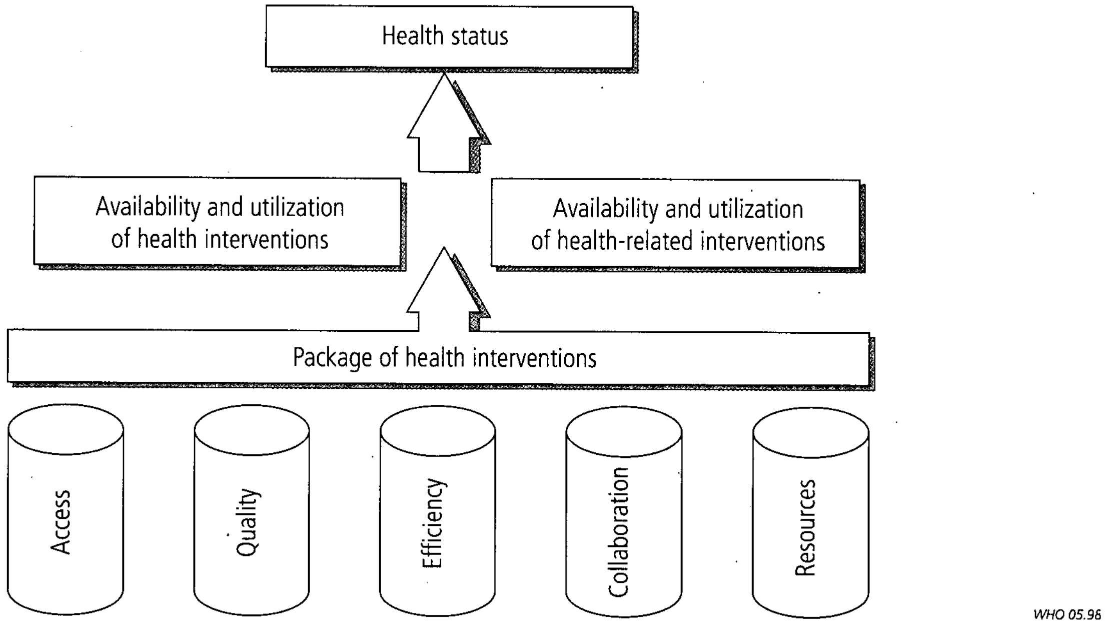
Sam Adjei[2]

A health information system handles the recording, storage, retrieval and processing of health data. Broadly defined, the health information system should cover such data sources as vital registration, censuses, routine service-generated statistics, population-based surveys and research information, in order to provide evidence for decision-making in the health system.

Assessments of health information systems have given rise to several misgivings. Foremost among them is the fact that multiple data sources are not linked to each other; indeed, different instruments may generate different data on the same person or event. Routine service data are collected with the needs of higher-level programme managers and donors in mind; in addition, they may be incomplete or of doubtful quality, and timeliness can be a problem. Surveys are useful, but they tend to be expensive and donor driven and are often not linked to routine service data. Research data are generally available but are rarely included as part of the health information system because research is conducted outside the scope of ministries of health. Dissemination of the information collected is usually

[1] Monitoring and Evaluation Advisor, World Bank Office Jakarta, Jakarta Stock Exchange Building Tower 2, 12th floor, Jl Jenderal Sudirman Kav 52–53, Jakarta 12190, Indonesia (email: rcibulskis@worldbank.org).
[2] Deputy Director-General, Ghana Health Service, Private Mail Bag, Ministries, Accra, Ghana (email: sam.adjei@hru-ghs.org).

Fig. 1. **Conceptual framework for health sector reforms and information**



weak and its use, particularly in policy-making, is infrequent. Several efforts undertaken to strengthen health information have not taken into account any general framework for designing the information system.

The paper by Shaw describes efforts to correct the multiplicity of data sets in South Africa, especially at the periphery, without describing an overall framework for how this is to be achieved. Even though the process reported has reduced the data set to 100–150 elements and 80–120 indicators, the numbers still appear too large to manage effectively. An overall vision of health information needs in the context of health development is important even at the district level beyond programme managers. The current wave of health sector reforms and health system strengthening will require this broader context for the development and standardization of health information.

In Ghana, a conceptual framework for health sector development (health sector reforms) helped to generate indicators for health information (see Fig. 1). This framework allows data required for policy development, priority setting and programme performance measurement, as well as monitoring and evaluation, to be determined in the sector as a whole. Sector-wide indicators that fell into three main categories were agreed upon; 20 indicators are collected and used at all levels, which does not exclude the use of more indicators at any level.

The three categories of indicator concern: health status, including mortality and morbidity; programme output, covering programme performance in public health and clinical care interventions as well as health-related indicators such as enrolment at school; and systems development, in which a package of five cross-cutting areas of access to care, quality of care, efficiency in the use of resources, collaboration with other sectors (communities, other providers of care, other ministries and donors) and financing of care is determined. Indicators in the first two categories are easily developed but are more difficult to define in the third category, where methods of data collection are also difficult as the indicators do not lend themselves to routine service statistics and surveys may be needed.

The impact of the process adopted in the South African experience is commendable, as it appeared to influence other districts, the regions and national levels. Its impact at the global level is not indicated but, given that global initiatives and donors have major information requirements, a process that links with global development is important.

With this in view, the Health Metric Network initiative is timely. Particularly welcome is the development of a simple framework to define the scope of the health information system. The framework should serve as a diagnostic tool for evaluating the state of a country's health information system, a road map for developing plans for improvement, and a process for monitoring and evaluating progress. Its application at the country level should build on experiences such as that described in South Africa. ■

Competing interests: None declared.

A data warehouse approach can manage multiple data sets

Jørn Braa[1]

Development of essential national indicators and data sets — or national *standards* — is regarded as the key issue in country health information system reform. Most countries, however, fail to achieve this goal. The reasons are: fragmentation (difficulty in reaching agreement on standards across health programmes); focus on reporting rather than on use of data and information; constantly changing needs (e.g. with regard to HIV/AIDS); and standards that are "cast in stone" (software and paper tools are difficult to change).

[1] Department of Informatics, University of Oslo, PO Box 1080, Blindern, Norway (email: jbraa@ifi.uio.no).

Despite these problems, South Africa has managed to develop national standards that are flexible enough to "absorb" local innovations and changes over time. The following points may help to explain why this is so.

- The "hierarchy of standards" ("information needs" in Shaw's figure) has been a powerful tool to negotiate a balance between the national needs for control with the local (e.g. province or health programme) needs for flexibility or more data. While all health units are required to collect and report the core national data, they are at the same time allowed to collect their own additional data.
- Use of information is highlighted by linking data sets to targets and indicators.
- The flexible approach to standards following the hierarchy makes it easy to absorb and implement changes over time; there is no "final" data set. Local innovations are allowed for and may eventually be included in the national data set.
- The flexibility of the South African District Health Information System (DHIS) database application is crucial to managing the ever changing national and local data sets. Data elements, indicators and data sets are added, edited and managed by the health services themselves, thus making it possible to manage multiple data sets at district level. This "data repository" or "warehouse" approach may be a key to how the lessons from South Africa could be applied in other countries.

Over the years, I have been involved in efforts to apply the South African lessons in many countries. It has not been easy. National health information system databases and reporting formats tend to be rigid and unable to respond to changes, thus leading to fragmentation of the system. The HIV/AIDS programmes are currently aggravating this situation.

So what can be done? Current efforts to establish integrated data sets in contexts as different as Addis Ababa (Ethiopia), Botswana, Zanzibar (United Republic of Tanzania), Andhra Pradesh (India) and Ho Chi Minh City (Viet Nam) may provide some answers. Here data sets from all or most programmes are combined and streamlined by sorting out overlaps, gaps and inconsistencies. Following the South African district data warehouse approach, the combined essential data set is then further improved and reduced by focusing on the need-to-know indicators. Programme-specific software applications are linked electronically to the DHIS, thus providing a shared data repository. The objective of integrating all indicators relevant to the Millennium Development Goals has proven important in building consensus.

Purists may argue that the data warehouse approach based on flexible standards advocated here is violating the spirit of the South African *minimum* essential data set approach, by taking a combined — *maximum* — data set as the point of departure. It may, however, be the most appropriate way to apply the South African indicator-driven approach in a situation increasingly dominated by strong programmes and multiple uncoordinated data sets and software applications. ■

Competing interests: none declared.

The data set must focus on service quality

Jens Byskov[1] & Oystein Evjen Olsen[2]

The paper by Vincent Shaw highlights some of the long awaited practical approaches to ensure relevance and use of health information systems in developing countries. The South African experience he recounts is very relevant as current "best practice". It is a very important step forward in the simplification and integration of programme areas and routine services into a shared essential set of routine data. The cohesion of health services and the whole system will be much strengthened by such a shared data reference and information base.

The essential data are still to be selected by programme managers, however, even though the definition of the data set emanated from the district level. It is not shown how the data will be turned into useful information that will assist in planning and monitoring at all levels of the health system. The examples taken from the nutrition programme and the Expanded Programme on Immunization only exemplify health status (outcome) and service provision (output) data.

In the section on specific programme surveys, resource and staff availability are mentioned as well as service quality. It is worrying that these are not shown to be included in an essential routine data set, as it is extremely important that an essential data set allows production and sharing of information on health management. It is also not shown whether quality of care will be viewed from both provider and user perspectives and whether user views on service priorities and other qualitative data are included.

In Shaw's figure, the column of information used by the national level on a routine basis within the triangle of information should be seen as the core data on facility performance that must be shared in an accessible database for the whole health service and other parts of the health system, and be available for sharing with users and the public.

The information needs triangle could also be depicted as service quality at the bottom, supervision and coordination needs at the intermediate level, and policy needs at the top. The main focus of the data set must be on service quality, with less emphasis on supervision and coordination and even less on policy. Service quality must relate to health management, service output and outcomes as viewed from both the provider and the user sides.

The number of data elements and indicators still seems to be high in relation to similar elements in the core part of the health information system in other African countries and may indicate a still limited degree of compromise and shared focus between the levels and programmes. A stronger emphasis is needed on the iterative nature of the health information system, and not so much on annual or quarterly "reporting". We need to move away from a culture of reporting to a culture of using the data for ourselves — facilities or districts first — on a continuous basis. Benchmarking and quality assurance processes exemplify some useful frameworks for continuous use of data. ■

Competing interests: none declared.

[1] DBL-Institute for Health Research and Development, Jaegersborg Allé 1D, Charlottenlund, DK-2920 Denmark (email: jbyskov@dblnet.dk). Correspondence should be sent to this author.

[2] DBL-Institute for Health Research and Development, Primary Health Care Institute, Iringa, PO Box 105297, Dar es Salaam, United Republic of Tanzania (email@dblnet.dk).

APPENDIX 3

Jacucci, E., Shaw, V., & Braa, J. (2006). Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability. *Information Technology for Development, 12*(3), 225-239.

Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability

Edoardo Jacucci
Department of Informatics, University of Oslo, PB 1080, Blindern N-0316, Oslo, Norway. E-mail: edoardo@ifi.uio.no

Vincent Shaw
Department of Informatics, University of Oslo, PB 1080, Blindern N-0316, Oslo, Norway; Health Information Systems Programme, School of Public Health, University of Western Cape, Cape Town, South Africa. E-mail: vshaw@wol.co.za

Jørn Braa
Department of Informatics, University of Oslo, PB 1080, Blindern N-0316, Oslo, Norway. E-mail: jbraa@ifi.uio.no

ABSTRACT

The implementation and development of routine health information systems continue to provide a number of challenges for managers—the more so in developing countries where resources are scarce and human resource and technical skills limited. This article conceptualizes the interdependence between the local adaptation and appropriation of global standards, and the value that this adds to the global standard through improved quality of data. These processes reinforce one another in the creation of sustainable information systems. The article draws upon a case study of a rural hospital in South Africa. A successful change process is documented, wherein the organization, through innovative management and leadership, actively and successfully appropriated the national standard. The case study is used to highlight three main messages, namely, that standards should be able to be locally appropriated, that the creation of networks helps to support the local adaptation of standards, and that the layering of information systems is important to encourage the use of information and helps to improve data quality. © 2006 Wiley Periodicals, Inc.

Keywords: standardization; district health information system; sustainability

1. INTRODUCTION

The implementation of routine health information systems in developing countries is widely seen as critical for improving the quality of health services (Lippeveld, Sauerborn & Bodart, 2000). By providing the management of the health sector with timely and accurate data, for instance, resources can be allocated more effectively and epidemics can be monitored and appropriately addressed. In order to address the health system of an entire country it becomes imperative to standardize the processes of data production and collection at

Shirin Madon was the accepting Special Issue Editor for this paper.

Information Technology for Development, Vol. 12 (3) 225–239 (2006)
Published online in Wiley InterScience (www.interscience.wiley.com).
DOI: 10.1002/itdj.20044

the various levels of the health sector. By standardizing the data set to be collected, all sorts of statistical analyses between facilities, districts, and provinces become possible. Although standardization is necessary to harmonize and integrate the information, the actual implementation of a standard at the local level often demands flexibility and adaptation (Hanseth, Monteiro, & Hatling, 1996; Rolland & Monteiro, 2002; Timmermans & Berg, 1997). Especially when considering implementation of Information Systems (IS) in developing countries, issues of diversity and context dependency of the implementation sites become extremely relevant (Avgerou, 2002; Avgerou & Walsham, 2000).

In South Africa the Health Information System Programme (HISP) addressed this challenge by means of a particular standardization and implementation strategy: the creation of a hierarchy of standards to allow flexibility, and particular attention to build "local capacity" (Braa & Hedberg, 2002; Shaw, 2002). Accordingly, a core set of essential health data is defined and used at all levels (from the facility to the national level) and additional data elements are added at each level to satisfy local management needs. The set of essential data and its hierarchy constitutes what can be called the *standard*. Once the standard is implemented, data quality in the entire system must be guaranteed to ensure its sustainability. Possibly, the best strategy is to make sure that the data are used at the level of collection. In order to obtain proper local use, the intervention should also build local capacity in terms of human resources, competencies, and infrastructural support. Hence, it can be argued that the sustainability of the "global" standard-based health IS is highly dependent on achieving a "local" sustainability of a local system that collects and reports the data.

Although larger hospitals tend to receive more attention due to the greater complexity of the intervention, smaller hospitals risk receiving less attention and being marginalized in the process. In fact, rural and smaller hospitals are statistically less significant, usually have less infrastructural support, and are less attractive for skilled workers. It also can be argued, although the opposite is demonstrated here, that information systems are not as important to run these small hospitals. This article tries to look deeper into the challenge of local sustainability in the particular case of small rural hospitals.

More in general, the following issues have been identified as main sources of problems in achieving the sustainability of IS in developing countries (Braa, Monteiro, & Sahay, 2004; Heeks & Baark, 1999; Littlejohns, Wyatt, & Garvican, 2003; Sanford, Kanga, & Ahmed, 1994):

- Limited duration of donors' financial support.
- Inadequate focus on local expertise.
- Too-narrow interventions (often a sustainable health information system requires a parallel reform of the health sector).
- Technical bias of projects (inadequate focus on human resource development).
- Pilot project orientation.

The article contributes to the ongoing discussion on implementation of sustainable health information systems in developing countries by better conceptualizing the role of local implementation in the quest for global sustainability. Introducing the concept of *local sustainability,* will stress a necessary condition in order to achieve the sustainability of the whole information system. The article will show how this concept addresses some of the above-mentioned recognized challenges of sustainability.

By drawing on a success case of a small rural hospital, the article shows how *local sustainability* is not simply an equilibrium state to be reached. On the contrary, it will be shown that sustainability at the local level means proactively appropriating what is imposed by the *global* standard in order to follow *local* vision and entrepreneurship.

The remainder of the article is structured as follows. First the current contribution to the ongoing discussion on sustainability of information systems in developing countries will be discussed. Then an account of the methodology for data collection, analysis, and the process of theorization will be provided. Subsequently, the case study will be described. A discussion of the main findings will follow, and the theoretical concept of *local sustainability* will be derived from the empirical evidence. Finally, conclusions will be drawn.

2. LITERATURE REVIEW

The overall aim of the article is to contribute to the discussion on sustainability of information systems in developing countries by developing a theoretical concept. The following section will provide an account of the ongoing theoretical discussion in order to better position the current contribution.

2.1 Sustainability of IS in Developing Countries

Sustainable development was first defined as ". . . development that meets the needs of the present without compromising the ability of future generations to meet their own needs . . ." (Brundtland, 1987). This definition has been reinterpreted in the domain of information systems to address challenges in the design and implementation of sustainable IT solutions (Korpela, Soriyan, Olufokunbi, & Mursi, 1998; Misund & Høiberg, 2003; Oyomno, 1996; Reynolds & Stinson, 1993). Within the IS field, other contributions addressed the challenge of overcoming the sociotechno divide (Roode et al., 2004), and discussed the role of donors (Kimaro & Nhampossa, 2004).

Here the focus is on a particular aspect of establishing a sustainable national-standard–based health information system. The specific goal is to analyze the *local* (hospital) dimension of creating a sustainable *global* (national) standardized system.

2.2 Sustainability and Standardization

If the implementation of the IS is not local but reaches a national dimension, standardization of the data, the tools for data collection, and the organization around them become key aspects. Especially in developing countries, IS implementation tends to be very sensitive to local context (Avgerou & Walsham, 2000; Walsham, Symons, & Waema, 1988). This implies that if the endeavor is one of developing the same idea (the standard) in many different contexts, the challenge of sustainability tends to split on two levels: A global level where the standard should be accepted by processes of institutionalization, support, networking, and funding; and a local level where the standard needs to be implemented in a way that becomes well integrated in the local context. This creates a tension between the local and global scale development of the information system (Braa & Hedberg, 2002). In terms of scalability of standards, the attempt to standardize across local contexts is mediated by the need for local flexibility of the standardized solution (Hanseth et al., 1996; Rolland & Monteiro, 2002). This is even more true in the case of standards for health care, where the local conditions and work practices tend to reinterpret, if possible, any universal solution as a localized solution, thus creating "local universalities" (Timmermanns & Berg, 1997).

In the context of the case study, the standardization of data, data-collection tools, and organization support was a necessary step to reduce the fragmentation of systems and channels of information nationwide. The aim was to reach a degree of coordination at national and provincial levels so as to improve efficiency of health management. It follows that the "... local-scale development relies on development at the global scale ...," because "... local health units are part of, and dependent on, the larger health system and will therefore need to interact with the higher level health system by way of standards for data collection ..." (Braa & Hedberg, 2002).

The problem then, of balancing the local and global, has been addressed by suggesting that sustainability should be built "... through ongoing and continuous *translations,* around both the vertical (local appropriation) and horizontal (diffusion) axes ..." (Braa et al., 2004). The concrete strategy suggested is to create an inherently flexible standard in the form of a hierarchy of standards. A core standard, an essential data set, is decided at national level and applied everywhere. At each lower level of the hierarchy (province, district, facility) the data set can be expanded to include other indicators, which will be collected in the level below.

These strategies, which so far proved to be adequate, tend to address the tension between standardization and flexibility and find a balance between the global and the local.

3. METHODOLOGY

This article uses an interpretive approach to case study for the research presented (Klein & Myers, 1999; Walsham, 1995). The interpretive approach has proven to be a suitable methodology to study IS as social systems, where the aim is to investigate the intricacies of social and technical aspects of IS development (Walsham, 1993). Moreover, case-study research constitutes an adequate empirical enquiry that helps in investigating a contemporary phenomenon within its real-life context, where boundaries between the phenomenon and the context are not clearly evident, and in which multiple sources of evidence are used (Yin, 1989). Sources of data used during this research include interviews, direct and participant observation, physical artifacts (PC and software programs, such as the district health information software and the budget spreadsheet, and the Excel ward register described in the case section), and documentation.

Initially, a considerable amount of data were collected during the visit to eight hospitals in Eastern Cape in the time span of 2 years (2003–2004): four district–rural, one district–urban, and three tertiary–urban. The hospitals approached were all experiencing evident problems in collecting and reporting health data. The majority of the hospitals visited were situated in rural areas in the Transkei region in the Eastern Cape Province. The data were collected during a total of 22 days of on-site fieldwork, which included interviews with hospital staff and observations of meetings and work performed by the HISP team. Hospital staff interviewed included the hospital superintendent, matrons, nurses, the information officer, data-entry clerks, and, in some cases, doctors.

Preliminary analysis of data from the hospitals indicated that the data were of poor quality and not suitable for use by managers to inform their decision making. This raised the questions of how to build local capacity, and adopt a context-sensitive implementation strategy of a national standard, that would ensure a sustainable HIS. It became clear at that point that visiting a hospital that was submitting high-quality data could provide insights and ideas on how to intervene in more problematic hospitals. New Hope[1] was selected from among a group of several hospitals in Eastern Cape with a "functioning" information system. Its rurality and small size make it a suitable case-study example. The initial idea was that it could be compared to a similar small hospital in a more rural area in the Transkei.

The first author spent 2 full days at the hospital conducting interviews with the hospital manager, the matron, the information officer, and nurses in the wards. During the same 2 days he participated in the budget review meeting conducted by the budget review committee of the network of provincially aided hospitals (see case chapter). Notes were taken during the observation and an interview session was recorded on minidisk (MD) and transcribed afterwards.

An additional source of data specific to the case of New Hope Hospital was provided by the first author, who previously played a role in the establishment of the network of provincially aided hospitals and (at the time of the research) acted as manager of the HISP program in South Africa.

A diary, updated on a daily basis, served as a first step in the data collection and analysis and was used, together with the interview transcript, to build the empirical section presented in the article.

As for the use of theory, the data presented in the article was collected with the aim of understanding what *sustainability* meant for the hospital in the case study. Hence, if not a theoretical framework, at least the discourse on sustainability (as presented in the theory section) served as initial guide to the field-work design and data collection.

Finally, the aim of this interpretive work (and type of contribution) is to generalize from the case by developing the theoretical concept of *local sustainability* in order to contribute to the discourse on sustainability of IS in developing countries (Walsham, 1995).

4. CASE DESCRIPTION

This section will present the case study. First some background information on the nation-wide health information system standardization program in South Africa will be provided. The information system analyzed in the case is a part of the South African standardization program. This will be followed by a description of how the information system works at New Hope hospital and how it was changed after the first implementation in 1999 as part of the standardization program. Finally, a preliminary analysis of contingent factors that contributed to the creation of a locally sustainable information system will be given.

4.1 The Quest for a National Standard for Routine Health Data in South Africa

As part of the Reconstruction and Development Program (African National Congress [ANC], 1994b) in South Africa an effort was launched for the restructuring of the health sector in all provinces. This effort included the creation of a unified health information system (HIS) (ANC, 1994a). The HISP (Health Information Systems Programme) initiative addressed the challenge in the Western Cape Province by defining an essential data set (EDS) of indicators and by developing a district health information software (DHIS) to support data collection, aggregation, and analysis at the district level. Eventually, the HISP initiative

[1]The real name of the hospital has been disguised.

scaled up to the national level and the standardization process was carried out in the other provinces in a coordinated manner (Braa & Hedberg, 2002; Braa et al., 2004).

In the Eastern Cape Province the implementation of the DHIS and the EDS standard was launched in 1999. As part of the implementation, hospitals were provided with new forms and registers for data collection, computers, and the DHIS software. In addition, training sessions were organized for the hospital staff (Shaw, 2002).

An assessment of many hospitals in Eastern Cape in 1999 indicated that (Shaw, 2002):

- Data are collected "at all levels in hospitals, but most of it is never used."
- Indicators are submitted to the district offices, but give a "very bland picture of administrative activities, and no feeling of what goes on inside hospitals."
- "Registers are non-standardized, and tend to be anarchic, and hand written," and often on an assortment of different types of paper and books.
- "Analysis of data is minimal at all levels."

4.2 Implementation at New Hope Rural Hospital

The following sections will provide an account of how a small rural hospital in the Eastern Cape Province managed to appropriate the standardized HIS in a successful and proactive way.

4.2.1 Background. The New Hope Hospital is a small hospital of 25 beds in the northern area of the Eastern Cape. The town of New Hope was founded in 1800 and is reachable via a tar road.

The hospital is staffed with two part-time doctors (amounting to a full-time equivalent doctor) and 40 staff (of which 20 are nurses) as well as a hospital manager, an administration officer, one information officer, and a clerk. The registers, the DHIS, and a computer were installed during the DHIS rollout in Eastern Cape in 1999. The intervention put in place an information work flow complete with registers, forms, a computer, and the DHIS application (see Figure 1 for a simplified overview).

The ward registers are books where the nurses should enter the data about the patients that are admitted and discharged. There is one long line to fill for each patient and often the fields (like the type of diagnosis or type of separation) simply require a tick (hence the name "tick register"). The midnight census is a form compiled by a nurse during the night shift indicating the number of patients present in the hospital during the night. A ward report is then compiled on a monthly basis. The data from the monthly ward reports are then aggregated at the hospital level and then usually entered in the dedicated software: the district health information software.

The hospital is one of a group of hospitals, called the provincially aided hospitals (hereafter called the PAH network). They have been functioning as semiautonomous hospitals in the Eastern Cape and other provinces for over 10 years. A service-level agreement (SLA) between the Eastern Cape Province and the hospitals defines their size (the number of beds) and the amount of financial aid. As part of the SLA, the hospitals are required to raise 10% of their budget through the provision of services to private patients, and the balance (which is 90% of their total budget) is funded through the province.

In order to run and sustain the PAH network a budget review committee periodically assesses the budget and the routine health data, and provides recommendations to the

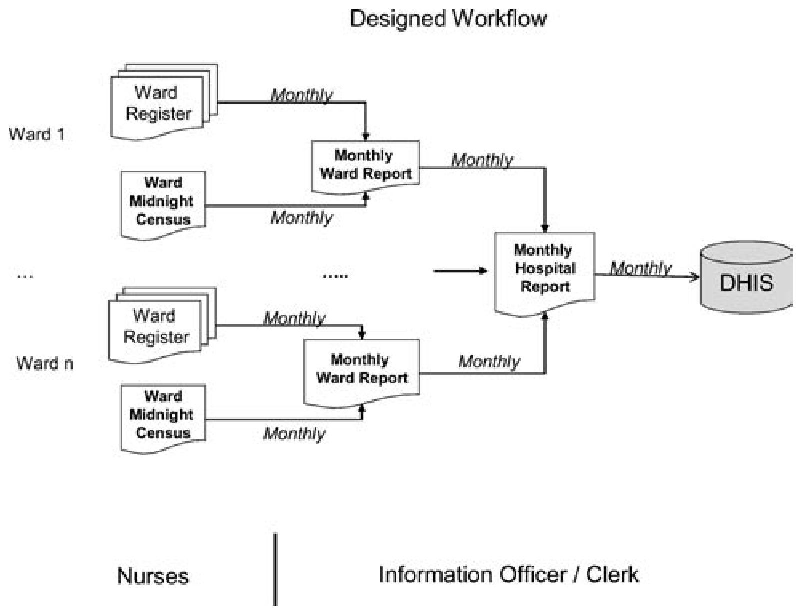


Figure 1 The work flow of information initially implemented by HISP in 1999.

managers of the hospital. To maintain the budgetary information, the hospitals are provided with an Microsoft Excel application developed by the budget review committee with the aid of the provincial office—the budget spreadsheet.

4.2.2 The information system of the hospital—creativity and teamwork. The situation found in New Hope was surprising. The registers and the midnight census form provided during the DHIS roll out were not in use. The staff in the hospital decided that these were too time consuming (especially for the nurses). Hence, the manager, the clerks, the administration officer, the sisters, and the matron discussed what information they needed to collect and how, and designed new forms according to their needs. They developed their own solution, which is now working (Figure 2), and provides data for the DHIS (which is mandatory) and for the staff in a manner more appropriate to their situation.

Interestingly and in contrast with basically all the other hospitals visited, they did not use an admission/discharge register, nor a midnight census. They substituted two forms compiled daily. One is the daily statistical return, the other is the night head count. The daily statistical return lists all admissions/discharges of the day and is filled in by the sisters as the patient arrives or is discharged. At the end of the day the administration clerk does a round of the wards, collects these forms, and copies each single entry into the ward register spreadsheet (a replication of the ward register in Microsoft Excel). The nurses now have to enter very simple data compared to those required on the ward register. They also do not need to calculate and compile the monthly reports. Overall, the nurses perceived that their administrative work was considerably eased.

The night head count is used by the sisters locally and provides a list of who is in the beds in the wards. At the end of the month the information officer easily counts and calculates the aggregated data from the ward register spreadsheet and enters them in the DHIS monthly report to be handed to the district information officer. At the same time

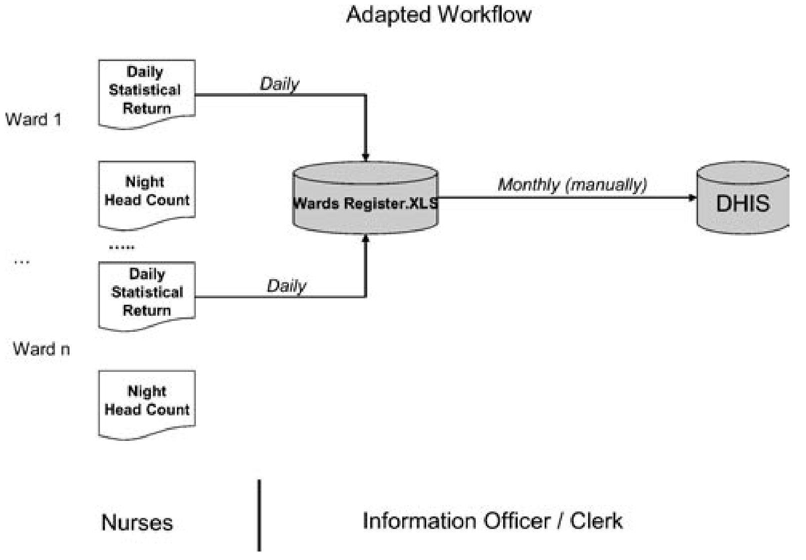


Figure 2 The redesigned information work flow: Most of the registers are gone.

she updates several graphs depicting various monthly statistics, which were found hanging in the manager's office. Examples of those statistics are: inpatient admissions, patient turnover, bed occupancy, theater activity (source of large costs), and number of private (paying) patients.

The observed reappropriation of the implemented standardized work flow was possible primarily because of the availability and teamwork of skilled and competent people. The roles of both the hospital manager and of the information officer where key to the change process: The manager had the vision of an improved local IS and the information officer had the necessary competencies and computer skills to implement it.

The main results of the redesign are as follows:

- Nurses have less and simpler data to enter and no monthly report to compile; they perceived that their administrative work was considerably eased.
- There is one less form—the midnight census is indeed redundant, as the same information can be calculated from the ward register spreadsheet.
- There are fewer steps in the work flow that require manual calculations and data entry; hence there is less possibility of creation and propagation of mistakes.
- As the ward registers are now replicated in the ward register spreadsheet, immediate/daily analysis of data is possible.
- A drawback, however, is that the clerk or the information officer must be more skillful and take on greater responsibility.

Observations have shown that the redesigned system still had considerable room for improvement, because not all the computing capabilities of Microsoft Excel were exploited. The manager stressed that all this was possible only through good cooperation and teamwork: *"We try our best and we really work as a team. You can't do anything if you don't have the support of others. Then you can close down the hospital."*

What was surprising was that no external intervention, aid, or pressure played a role in the vision and execution of the redesign. It was all possible with the given tools (by the DHIS rollout) and the local human resources.

4.2.2.1 Use of Information. As mentioned, graphs were regularly (on a monthly basis) produced from the DHIS. When the manager was asked what she did with all that information and the graphs, she replied that she used the data mainly to manage the hospital and as evidence to present during financial negotiations with the district health administration.

Looking at the graphs on the wall led the researchers to ask a more direct question:

Researcher: *What do you see from these graphs?*

Manager: [Looking at the in-patient admission statistics] *The in-patient admission is a lot. It shouldn't be so many admissions at the same time. So I must go and look that doctors don't just seek patients to admit them to set the stats high. Turnover tells me how quick the patients move out; also the average days per patient that they don't stay too long. That they don't stay longer than 5–6 days. Our bed occupancy is confronted also with the daily costing from kitchen and cleaning.*

[In the bed occupancy graph] 100% will be 25 beds. But we are using more.

R: *And the peak in the theater activity the end of last year?*

M: *There was a problem with cesarean sections. We had a lot of problem births. This other graph is to see how our private patients go because we need to make up our 10%* [10% of the hospital budget must be privately funded by 'private' patients].

Looking at the complete picture of the information system in place in New Hope Hospital (Figure 3) shows that there are several end users of the information at local (ward) level, hospital, and district (or higher). Also, the three computerized components (the DHIS, the ward register spreadsheet, and the budget spreadsheet) all play the central role of preparing and aggregating the data for the end users.

Generally, all the information is collected and used for a reason. There is no information collected but not reported or used, and the information channels are also sometimes integrated (e.g., the budget-review information builds upon an indicator calculated with the DHIS).

4.2.2.2 Layering of Information Systems. A final element to note is the relationship between the described hospital information systems and the budgetary system used in the PAH network. During the budget review session of this hospital, which was attended by the researchers, the most relevant indicator that was used to evaluate the overall management performance was the cost-per-patient-day indicator. This indicator is created by dividing the total costs of the hospital by the number of inpatient days. The number of inpatient days is taken from the statistics created from the hospital information system (particularly from the midnight census data) and entered in the DHIS. This indicator should be between 350–400 ZAR per inpatient day.

It is worth noting that poor quality of the inpatient-days indicator reflects an underreporting of the number of inpatient days. Hence, the more accurate the number of inpatient days, the lower the cost per patient day, the better the indicated performance, and the better the outcome of the budget review.

The layering of one information system over another creates dependencies and forms of incentives for keeping the quality of data accurate.

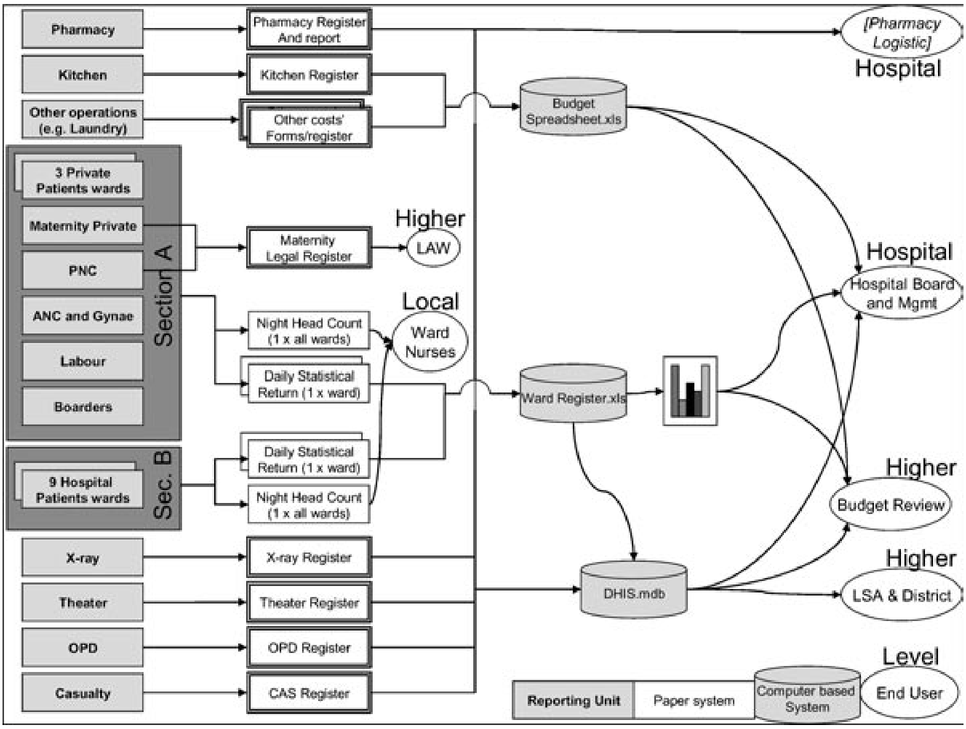


Figure 3 The overall view of the information system at New Hope Hospital.

4.2.3 Analysis of contingent factors. This section will contain a preliminary analysis of some themes that emerged from the fieldwork as being relevant for the positive outcome of the local redesign and change process.

There is no evidence to suggest that the training during the rollout of the DHIS was of a better or worse quality at New Hope than it was for other hospitals of the same size. Nevertheless, it was clear that the manager and the administrative officer had sufficient competence to fill any possible gap. The information officer of the hospital implemented the idea of replicating the ward register in Excel, so as to have continuous and accurate statistics. This shows a probably above-average level of computer literacy compared to her colleagues in other rural hospitals in Eastern Cape. The hospital organization acted as a team, sharing knowledge and creativity. This is evidently the main source of knowledge, rather than the simple sum of the individual skills.

Moreover, teamwork also meant participation, so that the nurses could have their requirement of a lessened administrative workload fulfilled. Being part of the final solution made them motivated to sustain it. This kind of teamwork and leadership evidently kept the motivation of the staff high.

The provincially aided hospitals (PAHs) are not financially advantaged compared to provincial hospitals (who get 100% subsidy, and are not autonomous). In reality the cost per patient day in the PAHs is less than that in the provincial hospitals. However, it appears that there is a caring ethos that has been created around being an employee of a PAH, that translates not only to care of patients but also to care of the environment. It therefore appears as if these hospitals are financially advantaged, but in reality their ethos translates to taking a greater interest in keeping the environment around them neat and tidy. Still, the hospital had to constantly negotiate with the district office to have their workload recognized financially.

Finally, as mentioned, New Hope managed to become part of a wider network of provincially aided hospitals. As illustrated, the network sustains itself by means of mutual assessment and mentoring. In addition, the network can act as one actor for bigger arguments with the province. In a way, the network helps the hospital to overcome its rural location and risk of isolation.

5. DISCUSSION

In this section the data will be further analyzed to understand the factors that positively contributed to the reinvention and sustainability of the system. In the light of such factors the generalization will be taken one step further in order to conceptualize what *local sustainability* means and why it is relevant to achieve the overall sustainability of the *global* system.

5.1 What Can Be Learned from New Hope

5.1.1 Creating space to allow local innovation to ensure local relevance. Building local infrastructure and human resources (HR) capacity is certainly a key aspect for a sustainable information system (Shaw, 2002). In New Hope Hospital this capacity manifested itself by the manager displaying her rigorousness, willingness to improve the situation, and determination to achieve the improvement. These skills were nourished by the PAH network, which met frequently (four times per year) and encouraged local innovation to improve care provided to patients. Her awareness of the importance of a participatory approach in the design of the new solution was probably the most important factor for the success of the change process. In this sense her authority was used to lead the change, rather than simply as a means for control of bureaucratic activities. Certainly, without the skills of the information officer the changes probably would not have been so radical.

The characteristic that is most likely at the core of the success is the willingness to improve and to reflect upon and question the status quo. In this hospital, the status quo created by the DHIS implementation was simply the starting point for a local reinterpretation of what that implementation meant. The people in the hospital managed to make a distinction that is not always understood: the distinction between the means and the goal of the implemented standardization. The actual standard (the essential data set, or EDS) is an abstract construct and constitutes the specific goal of the standardization process. The tools and the workflow design provided are elements around the standard, but are not the goal. They are the suggested means to achieve the specific goal of filling in the data sets with appropriate data. These tools (registers, forms, and work flow) are provided as a start-up kit, where the information system is lacking or is too fragmented. But the hospitals are not really bound to them. In principle, they can arrange their own information system as they see fit, as long as good-quality data are passed along (e.g., through an EDS). New Hope Hospital did not fall into the easy trap of simply following the orders of the province in a bureaucratic way. Instead, with a bit of entrepreneurial spirit, they reorganized the system to meet the goals of the province and their own as well. Here, the EDS and the DHIS, through their reflexive appropriation by the hospital, acted as enabling (i.e., not as constraining) factors.

Local adaptation of the standard is particularly important in obtaining adoption of the system, which is important to ensure long-term sustainability. Hospitals that have made the procedure their own have an interest in seeing it work and in continuing to invest in the systems and processes necessary to keep it working. In other hospitals, where there is less innovation, the system and tools are seen as coming from province and the product is for the province. In this case there is little interest in whether the product (the data in the EDS) is good or bad, because it has little local relevance.

5.1.2 Networking against marginalization. Rural hospitals always run the risk of being marginalized. Poor communication and transport, often together with poor socioeconomic conditions, make hospitals in rural areas less attractive for skilled employees. In the worst case a vicious circle of demotivation and lack of teamwork between professions in the organization can send the hospital into a dangerous downward spiral. Although this phenomenon has been observed in one particular hospital in Transkei,[2] it is certainly not the case at New Hope. But the risk is real, and should be taken into account seriously when implementation in other small and rural hospitals is being considered.

A possible counterstrategy to fight the risk of marginalization (whether real or potential) is becoming part of an active network of similar hospitals. By becoming part of the provincially aided hospitals, New Hope Hospital escaped this risk, gaining advantage at least on two fronts: (1) the hospitals in the network mutually support and learn from each other, by frequently monitoring and improving each other's management performance and (2) the network acts as an institutional amplifier of New Hope Hospital's voice and needs.

5.1.3 Layering of information systems. A last aspect to emphasize is the relationship between the financial budget information system and the information system for health data.

As mentioned in the case section, the cost-per-inpatient-day indicator constitutes a clear example of new possibilities opened by a working health information system: the better the health information system, the more accurate the inpatient-day indicator, the more accurate the evaluation of the management performance (cost per inpatient day).

Thus the layering of health and budget information systems creates a double incentive:

- In order to have the budget review working, the health information system of the hospital must also be working.
- The more accurate the inpatient-day indicator, the lower the cost-per-inpatient-day indicator (usually bad quality of the indicator reflects in an underreporting of inpatient days), the better the performance indicator and the outcome of the budget review.

[2] In previous fieldwork the researchers visited several rural hospitals in the Transkei region. In one of them (the smallest) it appeared that building a working information system was the least of the problems. The organization was under stress, the employees were demoralized, and there was very little teamwork between the various professions.

5.2 What Does Local Sustainability Mean?

In this section the findings will be summarized, and then generalized by explaining the meaning and the role of the concept of *local sustainability*.

In the theory section, it was argued that the (global) sustainability of a standard-based system is dependent on its use, which in turn is dependent on the quality of the information reported. Apparently, the best strategy is to make sure that the data are used locally (at the point where it is collected). This requires flexibility of the standard (to enable local adaptation and appropriation) and the establishment of local capacity (or unleashing the local potential) to maintain it.

What should be stressed is the perspective of the local site (in this case a small rural hospital). What is clear from this case is that local use, local capacity building, and local appropriation of the standard are part of the same effort of locally achieving a sustainable information system.

But local sustainability is more than sum of these parts; it implies a shift of responsibility from whatever hierarchical level above to the very people managing the data locally. Local sustainability is reached not simply when the data are collected and used properly, but when the local organization at the bottom of the hierarchy is also capable to proactively reinvent the standard by independent reflection on its own work.

In this sense, sustainability is not the reaching of a state of equilibrium; rather, it is created, reinvented, and continuously negotiated. All this implies a proactive engagement by the local authority in reappropriating (on its own terms and following its own vision with entrepreneurship) what is imposed on it by the global authority.

These findings address the more general set of common problems of building a sustainable system. Issues that contribute to the lack of sustainable systems in developing countries are listed in the introduction, and are addressed here. By creating the conditions for local sustainability:

- The implementation on the local level becomes less dependent on the limited duration of donors' financial support.
- An increased focus on local expertise is facilitated.
- Too-narrow interventions are not prevented. However, a precondition for local sustainability is a dialectic relationship with a more general or global effort.
- A more holistic (not purely technical) approach is forced which leads to leveraging local innovative resources.

6. CONCLUSIONS

This article has addressed the challenge of creating a sustainable standard-based nationwide health information system. An analysis of how the quest for sustainability splits on a global and a local level has been provided. On both levels sustainability needs to be created and managed, and each level is dependent on the other level. Hence, on the local level the main challenge faced by hospitals is to create a locally sustainable information system using what is provided by the global standardization process as a starting point.

A case study has demonstrated how *local sustainability* is not simply a state to be reached. It is rather a continuous-change process where the local organization reflects upon and proactively reinterprets its own way of working.

Finally, it has been shown that creating the condition for *local sustainability* is particularly important for small rural hospitals in order to reduce their risk of being further marginalized. The case suggests that cultivating a sense of entrepreneurship, networking with other similar hospitals, and interlinking information systems within the hospital may be possible strategies to create local sustainability.

ACKNOWLEDGMENTS

This project has been funded by the Norwegian Research Council and organized by the University of Oslo, Norway, and the University of Western Cape, South Africa. The authors would like to thank all the people involved in the project who contributed to the research with enthusiasm and expertise. Special thanks go to the anonymous reviewers and the guest editors for organizing an interesting conference and professionally editing this special issue. The authors are also deeply thankful for all the staff at the hospitals visited in the Eastern Cape for sharing their experiences and concerns. Particular thanks are due to the staff and management of the "New Hope" hospital for their active participation in the project.

REFERENCES

African National Conference (ANC). (1994a). A national health plan for South Africa. Johannesburg: African National Congress.

ANC. (1994b). The reconstruction and development programme. Johannesburg: African National Congress.

Avgerou, C. (2002). Information systems and global diversity. Oxford, United Kingdom: Oxford University Press.

Avgerou, C., & Walsham, G. (2000). Information technology in context: Studies from the perspective of developing countries. Hampshire, United Kingdom: Ashgate.

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., & Sahay, S. (2004). Networks of action: Sustainable health information systems across developing countries. MIS Quarterly, 28, 337–362.

Brundtland, G. H. (Ed.). (1987). Our common future: The World Commission on Environment and Development. Oxford, United Kingdom: Oxford University Press.

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing information infrastructure: The tension between standardization and flexibility. Science, Technology and Human Values, 21, 407–426.

Heeks, R., & Baark, E. (1999). Evaluation of donor funded technology projects in China (working paper). Manchester, United Kingdom: University of Manchester, Institute for Development Policy and Management (IDPM).

Kimaro, H. C., & Nhampossa, J. L. (2004). The challenges of sustainability of health information systems in developing countries: Comparative studies of Mozambique and Tanzania. In Timo Leino, Timo Saarinen, & Stefan Klein (Eds.), Proceedings of the 12th European Conference on Information Systems, Turku, Finland.

Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. MIS Quarterly, 23, 67–93.

Korpela, M., Soriyan, H. A., Olufokunbi, K. C., & Mursu, A. (1998). Blueprint for an African systems development methodology: An action research project in the health sector. In C. Avgerou (Ed.), Implementation and evaluation of information systems in developing countries (pp. 173–285). Vienna: International Federation for Information Processing.

Lippeveld, T., Sauerborn, R., & Bodart, C. (2000). Design and implementation of health information systems. Geneva: World Health Organization.

Littlejohns, P., Wyatt, J. C., & Garvican, L. (2003). Evaluating computerized health information systems: Hard lessons still to be learnt. British Medical Journal, 26, 860–863.

Misund, G., & Høiberg, J. (2003). Sustainable information technology for global sustainability. Digital Earth—Information Resources for Global Sustainability Symposium, Brno, Czech Republic. Retrieved August 2004, from http://www.ia.hiof.no/~gunnarmi/omd/dig_earth_03/

Oyomno, G. Z. (1996). Sustainability of governmental use of microcomputer-based information technology in Kenya. In Mayuri Odedra-Straub (Ed.), Global IT & socio-economic development. Marietta, GA: Ivy League.

Reynolds, J., & Stinson, W. (1993). Sustainability analysis, primary health care advancement program. Bangkok, Thailand: Aga Kahn Foundation.

Rolland, K. H., & Monteiro, E. (2002). Balancing the local and the global in infrastructural information systems. The Information Society, 18, 87–100.

Roode, D., Speight, H., Pollock, M., & Webber, R. (2004). It's not the digital divide—it's the socio-techno divide. In Timo Leino, Timo Saarinen & Stefan Klein (Eds.), Proceedings of the 12th European Conference on Information Systems, Turku, Finland.

Sanford, P., Kanga, G. J., & Ahmed, A. M. (1994). The management of health services in Tanzania: A plea for health sector reform. The International Journal of Health Planning and Management, 9, 295–308.

Shaw, V. (2002). The development of an information system for district hospitals. In S. Krishna & S. Madon (Eds.), Proceedings of the 7th IFIP 9.4 Working Conference, Bangalore, India.

Timmermans, S., & Berg, M. (1997). Standardization in action: Achieving universalism and localization in medical protocols. Social Studies of Science, 27, 273–305.

Walsham, G. (1993). Interpreting information systems in organizations. New York: Wiley.

Walsham, G. (1995). Interpretive case studies in IS research: Nature and method. European Journal of Information Systems, 4, 74–81.

Walsham, G., Symons, V., & Waema, T. (1988). Information systems as social systems: Implications for developing countries. Information Technology for Development, 3.

Yin, R. K. (1989). Case study research—Design and methods. Newbury Park, CA: Sage.

Edoardo Jacucci *is a Research Fellow in the Department of Informatics at the University of Oslo, Norway.*

Vincent Shaw *is the Manager of the Health Information Systems Programme in South Africa. The Health Information Systems Programme (HISP) started as a local pilot project in three health districts in the Western Cape in 1994–1998. It was a collaborative research-and-development effort between the University of the Western Cape, the University of Cape Town, the Norwegian Computing Centre/University of Oslo, and the Western Cape Department of Health.*

Jørn Braa *is an Associate Professor in the Department of Informatics at the University of Oslo, Norway.*

APPENDIX 4

Braa, J., O. Hanseth, et al. (2007). "Developing Health Information Systems in Developing Countries - the flexible standards strategy." MIS Quarterly **31**(2): 381-402.

MIS Quarterly

SPECIAL ISSUE

Developing Health Information Systems in Developing Countries: The Flexible Standards Strategy[1]

By: **Jørn Braa**
Department of Informatics
University of Oslo
Post-box 1080 Blindern
0316 Oslo
NORWAY
jbraa@ifi.uio.no

Ole Hanseth
Department of Informatics
University of Oslo
Post-box 1080 Blindern
0316 Oslo
NORWAY
ole.hanseth@ifi.uio.no

Arthur Heywood
School of Public Health
University of Western Cape
Diemaaar Way Kommetjie
Cape Town
SOUTH AFRICA
arthur@hisp.org

Woinshet Mohammed
Department of Informatics
University of Oslo and Addis Ababa University
Post-box 1080 Blindern
0316 Oslo
NORWAY
woinshem@ifi.uio.no

Vincent Shaw
Department of Informatics
University of Oslo and University of Western Cape
Post-box 1080 Blindern
0316 Oslo
NORWAY
vshaw@hisp.org

Abstract

The development of appropriate integrated and scalable information systems in the health sector in developing countries has been difficult to achieve, and is likely to remain elusive in the face of continued fragmented funding of health programs, particularly related to the HIV/AIDS epidemic. In this article, we propose a strategy for developing information infrastructures in general and in particular for the health care sector in developing countries. We use complexity science to explain the challenges that need to be addressed, in particular the need for standards that can adapt to a changing health care environment, and propose the concept of flexible standards as a key element in a sustainable infra-structure development strategy. Drawing on case material

[1]Dan Robey was the accepting senior editor for this paper. Gert-Jan de Vreede was the associate editor. Brian Butler served as a reviewer. Two additional reviewers chose to remain anonymous.

from a number of developing countries, a case is built around the use of flexible standards as attractors, arguing that if they are well defined and simple, they will be able to adapt to the frequent changes that are experienced in the complex health environment. A number of paradoxes are highlighted as useful strategies, integrated independence being one that encourages experimentation and heterogeneity to develop and share innovative solutions while still conforming to simple standards. The article provides theoretical concepts to support standardization processes in complex systems, and to suggest an approach to implement health standards in developing country settings that is sensitive to the local context, allows change to occur through small steps, and provides a mechanism for scaling information systems.

Keywords: Health information systems, standards, complexity science, developing countries

Introduction

This article addresses the issue of strategies for developing information infrastructure *standards* in general and for the development of information systems support for the health care sector in developing countries in particular. We identify *complexity* as the main source of the challenges that such strategies need to address and propose the concept of *flexible standards* as a key element in a sustainable infrastructure development strategy. The article contributes theoretical concepts to support standardization processes in complex systems, and suggests that the complexity of a standard is determined by its constituting actor network. We describe an approach to development and implementation of health standards in developing country settings that is both sensitive to the local context and scalable across geographic and programmatic areas.

Poor health status, rampant diseases such as HIV/AIDS, and inadequate health services are seriously hampering human, social, and economic development in developing countries. Considerable efforts are currently being made by international aid and United Nations agencies to address these problems. The United Nations' millennium development goals (MDGs) (UN 2000), which target the major health problems alongside other key development issues related to poverty reduction, constitute a coordinating framework for these efforts. Appropriate health information systems (HIS) are seen as crucial in this respect (AbouZahr and Boerma 2005; WHO 2000). On the ground, however, HIS development in developing countries has proved to be difficult due to organizational complexity (Gladwin et al. 2003; Jayasuiriya 1999), fragmented and uncoordinated organizational structures all maintaining their own HIS (Chilundo and Aanestad 2004; Jeppsson and Okuonzi 2000), unrealistic ambitions (Heeks 2002), and more generally due to the problem of sustainability (Kimaro and Nhampossa 2005; Sahay et al. 2000).

The health care sector in a country consists of a large number of institutions ranging from small and simple health care centers up to large and technologically advanced hospitals. These institutions are managed by a number of overlapping institutional bodies, organized into geographic areas (district, province, nation), and according to vertical programs (HIV/AIDS, maternal health, vaccination) and services (primary health care, hospitals, laboratories, drug supply). Programs are influenced at the national level through various international donor organizations and the World Health Organization. While global and national health policies normally recommend local management and integration of health information from various services and programs, the current reality is very different. National health systems are typically made up of a number of relatively independent health programs and services which, in the absence of central standards, each maintain their own vertical and uncoordinated reporting systems. The lack of shared standards for data collection means that the same data are often collected and reported many times through different structures, while at the same time there are gaps where important data do not get reported. Inconsistencies in definitions and procedures create further fragmentation (Chilundo and Aanestad 2004; WHO 1994) and lack of coordination, and inefficiencies. This results in excessive data of poor quality and generally poor use of it (Sandiford et al. 1992). The *integration* (de Kadt 1989, WHO 2000) and coordination of HIS is consequently a priority that needs to be addressed.

Fragmentation of HIS is aggravated further as donor funding targets specific areas and creates new information systems which are not integrated with the existing HIS (Okuonzi and Macrae 1995). The development of relatively cheap and effective antiretroviral drugs to treat AIDS patients has led to ambitious plans to roll out treatment to millions of people in developing countries, and multibillion dollar funds are raised to implement these plans. This large-scale funding for HIV/AIDS is contributing to disintegration, leading the WHO HIV/AIDS department to state: "[1] There is an urgent need for strategic information in conjunction with the antiretroviral treatment [of AIDS patients] programmes, including the developing of monitoring and evaluation systems…. [2] Efforts should be made to integrate antiretroviral treatment into existing HIS run by governments....[3] Strengthening existing HIS in countries can be one of the positive externalities produced by antiretroviral treatment programmes" (WHO 2003, p. 1, numbering added). Regarding standardization, [4] it is "urged that the monitoring and evaluation of ART [antiretroviral treatment] programs be simple, with data collection limited to only that information deemed to be essential for the well functioning of programmes" (WHO 2003, p. 3). However, [5] "The process of implementing ART programmes is difficult and open-ended…goals and objectives of therapy are varied and they have not yet been agreed upon" (WHO 2003, p. 4). The end result has been the development of independent and often burdensome information systems for ART.

From the above, it is obvious that an integrated health information infrastructure is important in developing countries and that such infrastructures need to be based on common standards for information sharing and exchange between information systems, programs, and institutions. We use the term information infrastructure in its broader sense, meaning the technological and human components, networks, systems, and processes that contribute to the functioning of the health information system. In developing countries in particular, access to the components of the infrastructure vary hugely between regions and geographic areas, resulting in inequities and uneven development of the infrastructure. These characteristics of information infrastructures in developing countries add to the complexity of developing integrated systems. The question is, then, what is an appropriate strategy for developing the required standards? This article suggests approaches that allow the development of specialized, but integrated, HIS, as expressed by these HIV/AIDS practitioners, through flexible standardization approaches that focus on simplicity and the essential needs for information.

At a first level, the challenge is to develop workable data standards, then, at a second level, the interface between the existing paper-based systems and the rapidly emerging computer-based infrastructure needs to be dealt with. In particular, ART programs are pushing implementation of electronic patient records that in many developing contexts, for the foreseeable future, will have to coexist with the paper-based patient record system. We will focus on the development of standards at two levels, at the technical level of software and at the service delivery level for data collection and communication. Standardization is understood in terms of the definition by De Vries (2003) as

> the activity of establishing and recording a limited set of solutions to actual or potential matching problems directed at benefits for the party or parties involved balancing their needs and intending and expecting that these solutions will be repeatedly or continuously used during a certain period by a substantial number of the parties for whom they are meant (p. 155).

The structure of this paper is as follows: In the theory and related research section, we explore complexity science as the point of departure for a framework within which to analyze and discuss standardization in the health care sector. The methodology section describes the study as a longitudinal, action research study, and explains the ontological and epistemological basis for the analysis. The empirical data are presented in the fourth section and draw mainly on material from the health information systems standardization experiences of the Health Information Systems Programme (HISP) group in South Africa, Ethiopia, and Thailand. In the discussion section, we highlight the key issues of flexible standardization in developing country contexts. The final section proposes concrete guidelines for HIS standardization.

Theory and Related Research

We present our theoretical framework and related research, based on the main concepts from the emerging field of Complexity Science, supplemented with insights and concepts from the study of complexity within the social sciences and complex technologies or socio-technical systems.

Complexity Science

Over the last couple of decades, the field of Complexity Science has emerged, primarily from the study of phenomena within physics, such as thermodynamics, and biology. Contributions are also made from studies of more social phenomena, in particular within economics, such as financial markets and the issue addressed in this article, standardization (Arthur 1994; David 1986). Complexity Science is made up of a broad range of disciplines including chaos theory and complex adaptive systems (CAS). CAS are concerned with the dynamics with which complex systems evolve through adaptation.

CAS are made up of semiautonomous agents with the inherent ability to change and adapt in response to other agents and to the environment (Holland 1995). Agents can be grouped, or aggregated into meta-agents, and these can be part of a hierarchical arrangement of levels of agents. Agents can respond to stimuli; they behave according to a set of rules (schema). Adaptation is the process whereby individual agents and the CAS change to fit each other and their environment. Adaptation, and creativity and innovation, are seen as being optimal at "the edge of chaos" (Stacey 1996), or more generally, adaptation occurs within the zone of complexity which is located between the zone of stasis and the zone of chaos (Eoyang 1996; Wilson et al. 2001). Dooley (1996) suggests that CAS behave according to three principles: order is emergent, the system's history is irreversible, and the system's future is unpredictable. In particular, attention has been directed at how order within such systems is created without a "designer" but rather *emerges*, for instance, like the order among cells in an organism, molecules in a fluid or other material, a beehive—or the emergence of a standard. Central to the emergence of orders are *attractors* (i.e., a limited range of possible states within which the system stabilizes). The simplest attractor is a single point. There are also attractors with specific shapes that are called *strange attractors*, that is, "unstable spaces to which the trajectory of dynamical systems is attracted through millions of iterations" (Capra 1996). 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 QWERTY, 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).

Even though complex systems may acquire persistent structures (around certain attractors), complex systems do *evolve*. The driving force behind such evolution and change is variety, the fact that the agents populating the systems are *heterogeneous* and different and that they seek to *adapt* to each other and their external environments.

Setting a new standard within this perspective means the active *creation* of an attractor. We will discuss how to do that by drawing upon some concepts from actor-network theory (ANT). Central in ANT, just like CAS, has been the emergence of order, or how actors succeed in their order-making efforts. In this context, order means widely accepted scientific theories or working technologies. ANT describes order-making as the building of socio-technical networks where elements of various kinds (technologies, humans, institutions, etc.) are translated (i.e., modified or reinterpreted) and enrolled into aligned actor-networks. Actors are also seen as heterogeneous networks (e.g., Callon 1991). Multiple actor-networks can be connected through so-called boundary objects (Star and Griesmer 1989), that is, objects which have some meaning in common across networks and more specific meanings within individual networks.

Complexity in Health Care and Information Systems

As Complexity Science has gained momentum, its concepts and insights are increasingly picked up in other disciplines, illustrated by special issues on complexity in journals such as *Organization Science*, *Theory, Culture & Society*, and *Information Technology & People*. Complexity Science is also increasingly being applied in the area of health care organizations (e.g., Plsek and Wilson 2001), and is adopted in Information Systems and Organization/Management Studies where it is applied in a rather optimistic tone: complex systems are best managed by enabling their self-organization (see, for instance, Axelrod and Cohen 1999; Benbya and McKelvey 2006). While we agree that a new order cannot be designed and imposed on a complex system, we believe that more ambitious strategies, where a more active interventionist approach is adopted, are needed in the domain we are addressing. The HIV/AIDS pandemic together with the human resource crisis in the health sector in developing countries make it clear that there is a desperate need to bring the evolution of health care systems and their information infrastructures on a different trajectory than the current one. One way to do this, while not detracting from the ability of a complex system to evolve as a self-organizing system, is to *create an attractor* that will lead to the emergence of a new and better order. At the center of this order will be a complex system of standards, crafted and maintained as a complex adaptive system where lock-ins are avoided.

Scalability is identified as a basic requirement for successful IS development in developing countries (Sahay and Walsham 2005). Scale is referred to as the *scope of an IS* (how many users use the system), and scaling as the *expansion of the system in scope and size* (expanding the use of the system across geographical areas, as well as technical areas). Escalating complexity, increasing population and area to be covered, in particular in relation to available resources and infrastructure, make scaling a tremendous challenge in developing countries (Sahay and Walsham 2005). Scaling is also a central concern in complexity science:

> Complex, adaptive systems exhibit coherence through scaling and self-similarity. Scaling is the property of complex systems in which one part of the system reproduces the same structure and patterns that appear in other parts of the system (Eoyang 1996, p. 36).

Broccoli is used as an example of scaling in a natural system as branches and subbranches have the same structure as the whole plant (Eoyang 1996). Drawing on empirical data, we will show how the development of simple standards can support the scaling process, while still encouraging diversity and experimentation (unlike the self-similarity of broccoli).

Standardization, Technology, and Creation of Attractors

Research on standardization acknowledges that the "world of standards" is rapidly changing—into a more complex one. The number of standards has increased substantially, and so have the links between them (Romer 1990; Schmidt and Werle 1998). However, complexity theory has not yet been applied explicitly beyond the concepts primarily coming out of the economic research on standardization mentioned above. Among those interested in research on standardization, consensus emerges about the growing complexity related to standards and standardization which implies that old models are not suited for current challenges. The bureaucratic models of standardization bodies make them all too slow, and various consortia models are becoming more popular (see David and Shurmer 1996; Shapiro et al. 2001). The world is changing more rapidly and standards need to be more flexible to adapt to this (Egyedi 2002; Hanseth et al. 1996). Hanseth et al. (1996) discuss two kinds of flexibility—use and change flexibility—and argue that standards need both. Change flexibility (the ability to change standards) is enabled by modularization. That means, in this context, combining simple standards with *gateways* translating between them (Hanseth 2001), not only gateways between computer-based infrastructures, but also gateways integrating paper- and computer-based infrastructures, as has proved very useful for improving the information systems in hospitals (Hanseth and Lundberg 2001). Use flexibility determines the extent to which a standard can support many different activities and tasks. Use flexibility makes it possible for users to change the practices supported by the standard without changing the standard.

This article will contribute to these strands of research by proposing a strategy for staging the emergence of new standards, and will highlight the importance of ensuring that they are an adaptive system of standards. We see this as a strategy for change within complex and self-organized systems. In particular, we see the importance of simple standards as a component to assist the process of scaling IS in health services. We now turn to an explanation of the methodology used in this research, before exploring the empirical data in detail.

Methodology

While this article draws on case material from experiences in the development and assessment of health information systems in three specific countries (South Africa, Ethiopia, and Thailand), the authors are all involved in the broader network of the Health Information Systems Programme (HISP) (Braa et al. 2004; see also www.hisp.info). As such, their experience has been gained from action research in a large number of additional developing country contexts such as Botswana, Cuba, India, Malawi, Mongolia, Tanzania, and Vietnam.

The authors, and HISP, draw on the Scandinavian action research tradition in IS development where user participation, evolutionary approaches, and prototyping are emphasized (Greenbaum and Kyng 1991). These perspectives have strongly influenced the involvement and approaches followed in IS development and standardization in the countries discussed in this article. Action research aims at generating new knowledge through taking part in the full cycle of planning, implementing, and analyzing the results from concrete interventions (Susman and Evered 1978). While action research has been the major modus operandi in generating the empirical data presented in this article, contextualism has been the ontological basis for the research.

Ontological Basis for the Study

Contextualism (Pettigrew 1985, 1987) emphasizes the importance of the context–content–process axis. Four key aspects of this view are highlighted, namely that the content, context, and process interact and influence one another; contextualism allows the exploration of the origins, development, and implementation of organizational change. The study of organizational change is described at the horizontal level—the *sequential interconnectedness of phenomena* across time (past, present, and future) and the vertical level (the interdependencies between the levels within and outside the organization) (Pettigrew 1985, p. 64)—and the analysis of change within the organization requires analysis at multiple levels, across time, and needs to incorporate cross-sectional categories. These aspects resonate with the approach adopted by the HISP network, which has followed a contextualist approach to information systems development, understanding and respecting historical influences (horizontal levels) as well as the vertical influences (policy implementation, reporting requirements) that have contributed to HIS development.

Pettigrew (1985) provides a description of the prerequisites for a contextualist analysis, and provides criteria for evaluation of contextualist research. We have addressed these by providing evidence in the case studies of longitudinal involvement in information systems development (in the South African case study, more than 11 years), as well as depicting the role of both vertical and horizontal influences in shaping the aspects studied. The use of multiple cases allows us to reflect on the differences between the contexts, and the factors that have contributed to these differences.

Interpretive research methods (Walsham 1993) have been used to make sense of the experiences, observations, and findings of the researchers. The data analysis process can be seen as an integral component of the action research process of the HISP network. All of the authors have at various stages taken on different roles, at times assuming the role of researchers, implementers, critical analysts, or a combination of all three.

The selection of the three countries for this article is purposeful. We wanted to present success stories found in Thailand and South Africa, and Ethiopia, a country which, in terms of potential for HIS development, provided challenges in a more difficult context. The selection of this range of cases provides for interesting opportunities to contrast the contexts that contribute to information systems development.

Data Collection Methods

The authors have been involved in HIS research and development in South Africa since 1994 and in Ethiopia since 2003, as participants in the HISP project (Braa et al. 2004). Two of the authors are permanent residents in southern Africa and one in Ethiopia.

Data were drawn from a number of sources: diaries, notes and reports maintained by the researchers and students, annual reports, and statistical bulletins. Additional sources of information included in-depth interviews with key informants, focus group discussions, and informal discussions, as well as field visits and observations. Direct observation of staff at work was a major source of information as authors worked with the HISP country teams.

The data for Thailand was obtained through a study commissioned by a development aid agency. The fact that the researchers had previous knowledge of Ethiopia and South Africa, but no knowledge about Thailand, led to different approaches to the data gathering. There was a focus on the national level of the Ministry of Health, although every level of the health system (subnational, district, and facility) was visited, including a relatively extensive tour of six key offices at national level, other HIS-related organizations outside of the health system (universities, parastatal organizations, the national statistics office), WHO, and site visits to two provinces (Nan and Nonthamburi), four districts, five hospitals, and four clinics.

Case Study: The HISP Experience

This case study focuses on efforts to develop standards and information infrastructures in the HISP project. Emphasis is on South Africa where the HISP project started and where the most significant results have been achieved. We will focus first on the development of a new standard as the creation of an attractor, and second on how this standard evolved into a complex adaptive system of standards. Next we will briefly present experiences from other countries where HISP also has been involved in order to contextualize the experience from South Africa by illustrating variety among countries and the broad range of issues and challenges that need to be addressed. Then we present the case of Ethiopia, a vast and poor country. Finally, we will present successful standardization efforts in Thailand, a country where HISP has not been involved, but which demonstrates useful experiences for the proposed approach. Table 1 presents statistical profiles of all three countries.

South Africa

During the apartheid era in South Africa, health services were fragmented into 17 different services, separated according to race and the system of "homelands" for black South Africans. This resulted in extreme inequity between populations and racial groups in health services provision and health status. The health information reporting systems and the data standards used were equally fragmented and incompatible. With the advent of democracy, "everybody" expected "everything" to change—including the health care system. Equity in health services provision and health status has, therefore, been a major political target in post-apartheid South Africa. In order to measure and monitor the extent to which equity is achieved, and to pinpoint areas where more resources and efforts are needed, a standardized system for collecting health data from the whole country and covering all population groups is seen as a necessity. This has to be achieved in a context where extremes in terms of access to information communication technologies exist. In the urban centers the infrastructure is well developed, while in the rural areas many hospitals and health centers lack a reliable electricity supply and passable roads, let alone access to the Internet (Day and Gray 2005).

Table 1. Country Profile (Statistics from UNDP 2003)

	South Africa	Thailand	Ethiopia
Population	45.8 million	62 million	68.6 million
Area (sq. km)	1.2 million	513 thousand	1.1 million
Life Expectancy at birth (years)	45.7	69.3	42
Fertility rate	2.8	1.8	5.6
Prevalence of HIV (% of population aged 15-49)	15.6	1.5	4.4
Maternal mortality rate (per 100,000 births)	150*	44	870
Infant mortality rate (per 1,000 live births)	53	23	112.0
Under 5 mortality rate (per 1,000 children)	66	26	169.0
Human development index rank	111	74	169
Gross national income per capita (US $)	2,750	2,190	90

*Data from Day and Gray (2005).

The process of standardization of health data has been a key aspect of the process of reforming the HIS, and the health system itself. However, achieving agreement on the standards has not been an easy process as is described in detail below.

The Creation of an Attractor

What became the HISP project started in 1994 as a small collaborative research project between the University of Cape Town, the University of Western Cape, and a Norwegian Ph.D. student. The aim was to provide health care workers within a poor township in Cape Town (Mitchell's Plain) with basic information to deliver better health services to the local population (see Braa and Hedberg 2002). At the same time, several projects were initiated to address the problem of HIS fragmentation. It was soon realized that the development of a set of tools for local clinics and districts needed to be coordinated with activities at higher (provincial) levels, in particular regarding data standards. In this case, the *data standard* was a uniform set of data elements (a data set) with clear definitions, reported on by facilities, and which sensitively reflected the provision of health services. In order to reach consensus on data sets, widespread negotiation and consultation with different health programs and services were carried out in the Western Cape Province, and in May 1997, a first experimental minimal data set was implemented in all clinics in the two HISP pilot districts. In parallel with the negotiations on data sets, HISP developed a desktop database application, the District Health Information Software (DHIS), for managing the data sets. DHIS was first developed as a typical action research experiment using rapid prototyping to support the implementation of data standards in the pilot sites. Later, as the user base increased, the development of the DHIS has turned into an ongoing evolutionary software development project where experiments and prototyping are limited to selected sites before new versions are released to all users (see Braa and Hedberg 2002).

In the negotiations about minimal data sets, it was difficult to get a real breakthrough because different programs had different needs. In addition, since the health facilities belonged to different authorities, it was difficult to get agreement to implement similar standards for data collection in their respective facilities. In the Cape Town area, for example, health services were organized either under the municipality (for citizens of the former "official" South Africa) or under the Regional Services Council, (for the peri-urban black townships). In order to address equity, information systems obviously had to be implemented across these structures. These problems were addressed by arguing, on the one hand, that since "it is not possible to agree on everything, we should agree on a basic minimum," and on the other hand, that everybody will continue to have the freedom to collect the additional data they wanted. This principle was encapsulated as a *hierarchy of standards*, and has been essential in arriving at basic consensus during the standardization process in South Africa (see Figure 1).

Finally, in January 1998, agreement was reached to implement, in all health facilities in the Western Cape Province, the minimum data set of 47 data elements that had been piloted and revised in the HISP pilot sites. Once implemented, this data set quickly became a success, basically for two reasons.

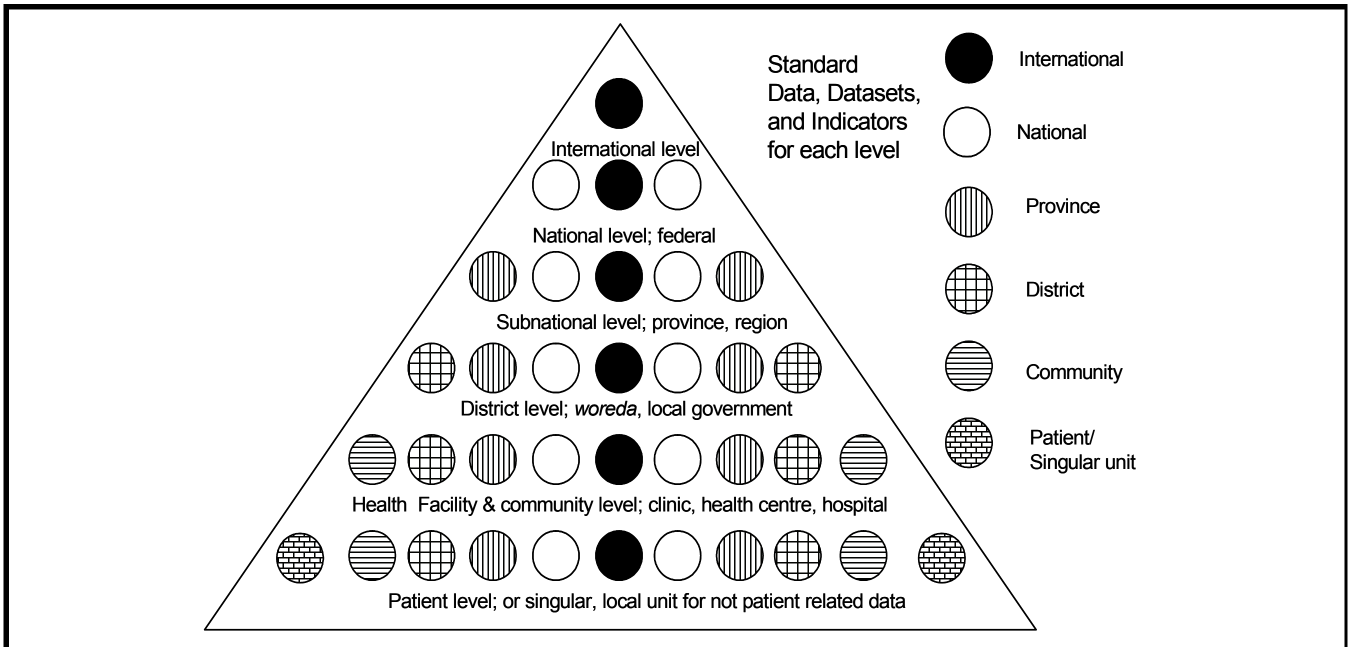


Figure 1. Hierarchy of Data Standards Used in South Africa with the Patient Level Added

First, it was the first time uniform data had been collected across the different health services in the province, and, second, the implementation was supported by the DHIS application which provided a coherent platform for data entry and processing, and presentation of data, as well as the ability to easily accommodate the changes brought about by the restructuring of health services in post-apartheid South Africa. Where previously the segregation practices resulted in separate information systems, the DHIS provided a complete data set on the desktops of both managers and health workers. In addition, the philosophy behind the development of the DHIS software, which emphasized the empowerment of users at a local level to use information to manage their health services, was coherent with that of empowering disadvantaged people in the "new" South Africa.

Almost simultaneously to these developments in the Western Cape, the Eastern Cape Province started to develop a different dataset. The provincial government, supported by EQUITY, a large USAID funded project, had a strong interest in developing data standards. However, they lacked a software system for data processing. In October 1998, HISP presented the achievements in the Western Cape, at which time the team was approached by the EQUITY manager who asked, "Are you able to customize the DHIS, import the data from our software, and implement it in all districts in the Eastern Cape before December?" The answer proved to be "yes," and the resulting implementation of internally uniform datasets in two provinces was a major step forward in developing flexible standards in South Africa.

Although the two data sets differed, the important issue was that key data were comparable. For the first time, data had been uniformly collected across black and white population groups, urban and rural areas, rich and poor, in two provinces previously divided into black homelands, and "coloured" and white administrative areas. The achievement of simple, practical results in two provinces sparked interest in other provinces and at the national level. As a result, consensus was achieved over a number of years on a national standard data set (Shaw 2005).

At this stage, we can say that an attractor for a new order, a new set of standards, was created. The standards component of this attractor consists of the two data sets defined and agreed upon in the two provinces (Eastern and Western Cape). What really made these data sets an attractor was the fact that collecting, sharing, and making decisions based on these data was supported by a working software system, a software system that was in use in all districts in the Eastern Cape and in pilot districts and at the regional level in the Western Cape Province. There are multiple reasons for the emergence of this attractor, among which is the fact that despite strong opposition to reducing the reporting requirements to a minimum data set, the presence of a coherent data set, and a functional tool to analyze the data, addressed an important need for managers. The attractor was created by enrolling users and their existing work practices, minimal data sets, a software package, and health care authorities plus some additional components into a heterogeneous but aligned actor network. This occurred in a political climate that strongly supported this change, and which drove donors and newly appointed managers in the same direction.

Making a Set of Standards an *Adaptive* System

The collaboration between the Western and Eastern Cape provinces initiated the countrywide standardization process which subsequently included all provinces and the national level, and the first national *essential* data set was agreed upon in June 2000. While all provinces maintain their own extended data sets, the national data set makes up the shared core which all provinces must collect and report. This data set has been revised several times since then. At each revision, the debate rages as to which data elements get included and which do not get included. Over time, additional data elements have been added, either as existing program data sets have expanded, or to accommodate new vertical programs (e.g., HIV/AIDS programs). By 2005, it was expanded to become a national indicator dataset (NIDS), reflecting the increased focus on the use of indicators, as compared to the earlier focus on data elements. The term *indicator* is used in public health to denote information, obtained from data elements, which is used to measure the extent to which health targets are met (e.g., achieve an immunization coverage [indicator] of at least 80 percent [target]).

The tension over which indicators are included in the NIDS is constantly present, and is in fact never resolved. The typical pattern in the development of the NIDS has been that new data sets for selected vertical programs are initially developed as a separate data set, and collected and collated in a separate database within the DHIS software. This allows experimentation and fine-tuning to occur, often in selected sites or specific geographic areas. Once the data elements have stabilized, the data set (or a subset) gets included in the NIDS, and becomes part of the national reporting system. This has happened with the development of a hospital data set in the Eastern Cape Province, and with the development of an Emergency Medical Rescue Service data set for the country.

The response to the HIV/AIDS pandemic has resulted in services being organized as separate vertical programs, with separate funding, which is seen as a threat to the unification of the health system. Different information systems are developed and provinces are not bound to use a specific system. Reporting is limited to the NIDS, and although the data may be collected through different systems, extracts are generally used for inclusion in the NIDS, using the DHIS as the *de facto* national standard for data processing and collation. Data on vertical programs such as the Prevention of Mother to Child Transmission (PMTCT) is thus uniformly collected in all health facilities (in accordance with the NIDS), even though data at the patient level are managed through many different systems in various provinces and institutions.

As managers use information, and understand the meaning of the data elements and indicators, they start changing their practices and their information needs change. This is illustrated by the example in Exhibit 1.

Braa (2005) suggests that two important aspects have contributed to the flexibility of the South African approach. First, the principle of the hierarchy of standards makes it easy to absorb and implement changes over time; there is no "final" data set in the sense that changes and experimentation are encouraged. Second, the flexibility of the DHIS software makes it easy to technically manage *the ever changing national and local data sets.*

Using Gateways to Accommodate Heterogeneity

Gateways translating data standards between the reporting levels and horizontally between subsystems have been important in the successful scaling of the standards in South Africa. The gateways are of three general types: paper to paper (e.g., registers for primary registration of patient data and aggregating monthly data sets), between paper and computer, and from computer to computer. The types of gateways that are needed are changing rapidly. Electronic patient record systems are increasingly used in hospitals indicating that electronic gateways will be important in the future. Over the last 10 years, computer availability has gradually moved down the hierarchy from district offices to hospitals and some health centers (mainly in large urban centers). Increasingly the gateways between paper reports from facilities and the DHIS is also moving down the hierarchy, as facilities enter their own data directly into the software. However, this is happening at an uneven pace between rich and poor areas.

Summary of the South African Case

In a post-apartheid South Africa, an attractor was created (a uniform data set, and the DHIS software to collate and analyze the data) in response to the need for integration and

Exhibit 1. Debating the Value of Data Elements

The process of defining and redefining the data sets in South Africa did not take place overnight. It was a journey that lasted years, and involved many iterations, as different role-players became involved. In some areas, there was intense debate about the inclusion or otherwise of certain data elements. The data elements collected for the immunization program serve as a good example.

The Expanded Programme on Immunization (EPI) Directorate required reporting on nine data elements. Their information requirements were largely focused on the numbers of immunizations given, with little attention paid to the development of indicators. On the other hand, one of the district municipalities in the Eastern Cape requested that the provincial data set be revised, omitting two data elements, which they argued could be calculated from the other data elements. The reason for the change was to focus health workers on the most important data elements. The purpose of the immunization program was not to count individual immunizations, but to have 90 percent of all infants "fully immunized" by the age of 1 year, hence the request for the inclusion of the data element "fully immunized under 1 year."

The counterargument provided by the province was that

- national required the data in a specific format, and province was not in a position to adjust this
- WHO required this data and therefore national was not in a position to change this
- the numbers of immunizations given were needed in order to determine stock levels
- the data set would be incomplete if this data was not submitted

Eventually it was resolved that the district council would carry on submitting the data required by province, and would continue to collect their new indicator (fully immunized under 1 year), but that the concerns would be raised at the national level and that the request for a process for review would be tabled. It took 3 years before the adjusted data set was accepted nationally, and occurred only after it could be demonstrated how useful the new indicator has been. Trying to introduce this data element in other countries has faced similar resistance, mainly because the WHO has not yet recognized the value of this data element.

equity. For the first time managers, had access to useful and current data. The success of this attracted more users, provinces, and health care programs. Besides the investment in the development of the technical parts of the information infrastructure, a huge investment went into training health workers in the 4,000 public health facilities spread across the 9 provinces. This contributed to the development and acceptance of the standards, and the creation of the attractors. Over time and as the process unfolded, standards (i.e., minimal data sets) could be modified and extended as needs changed. Another set of standards has developed, being the emergence of different gateways to communicate the information. During this process, the complexity of the system of standards increased, and the types of gateways in use has changed as access to infrastructure has improved. The adaptability of the system makes it easy to implement because it supports existing practices while its flexibility accommodates the transformation of practices. These practices are radically different from the practices used under the apartheid regime, which were bureaucratic, centralized, and inflexible.

Accommodating the changes in the data standards has been possible because the individual standards have been simple and accordingly flexible. They have been simple in the technical sense that modifications have been easy to make. Just as important, they have been organizationally simple because each has been limited in functional scope, and because each actor has been free to increase this scope by adding their own additional data standards as allowed for by the hierarchy of standards. The conflicts involved have been limited. Other standards have been restricted to a limited domain (geographic area), and, accordingly, the number of actors that needed to agree on modifications has been limited. Accommodating a variety of standards within related domains has increased the breath of experiences gained and increased the speed of learning and improved the overall information infrastructure as well as the health care system.

We believe that the South African experience can be considered a best practice that others should try to adopt. But all countries are so doing so is not a trivial matter. For instance, as demonstrated by many researchers mentioned above, complex socio-technical systems and their standards usually have strong inertia. According to Hughes (1987), their trajectory can only be changed in unique circumstances—during serious crises or external shocks. The regime change in South Africa was such a unique circumstance. In the next section we will discuss attempts at replicating this strategy in other countries, and use these experiences to propose a more generally valid recipe for best practice for IS standardization.

HISP Experiences in Other Countries

This section will briefly describe the main experiences gained in some of the other countries in which HISP has been active, in order to highlight the variety of approaches and the various challenges met when trying to get started with bottom-up standardization activities. These examples are provided in an attempt to illustrate the ways in which a bottom-up, and evolutionary, approach to standardization may be undertaken.

HISP has been active in Mozambique since 1998. The achievements have been modest in terms of standards being adopted. Implementation and testing in individual provinces has been fraught with problems. One of the main reasons is that the health care sector in Mozambique, as in the rest of the public sector, is highly centralized and HISP members have not been able to convince the central health authorities to provide strong support for a more experimental approach.

In India, HISP is established in two states, and in the state of Andhra Pradesh significant results have been achieved. HIS and health in general in India is organized in vertical programs with little horizontal collaboration and integration. HISP has managed to develop standards within the Health and Family Welfare program, a large program that includes vertical programs such as family planning, immunization, etc. Coordination among other programs and hospital services has been difficult to achieve.

Vietnam has a similar fragmented structure with little integration between program silos. Here it has nevertheless been possible to agree on the development of a shared data set for all data and indicators for one very specific purpose: to measure progress toward the United Nation’s millennium development goals. This approach will eventually motivate a minimum data set approach similar to the one in South Africa, although more limited.

In Botswana, because of a dysfunctional official HIS, each health program developed their own independent standards and systems. This created problems because only the “rich” programs managed to develop internally good systems, and there was no coordination between program-specific standards. In 2005, under strong managerial leadership in the health ministry, all program managers agreed to establish one shared HIS by combining the different subsystems. Since all data passes through the districts, the decision was to capture and include all program-specific data sets in one data warehouse, using the DHIS, at the district level. Programs at the national level could then gain access to all data in the data warehouse, including their own. This system is being piloted in four districts. As a next step, inconsistencies within and between the data sets are to be addressed, and standardization will be achieved through a piecewise harmonization of the various data sets. This approach is in contrast to that adopted in South Africa, where a *minimalist* data set approach was adopted. In this case, a *maximalist* approach has been adopted as a strategy to include all stakeholders by capturing all data across all programs in the shared data warehouse, with a view to streamlining and reducing it at a later stage. Since the essential data is included as subsets of the full data sets, the essential data will, as in South Africa, be made available to all user groups.

These experiences illustrate the importance of an attractor which allows a standard to emerge, and the fact that it is not always easy to do this. They also illustrate different ways in which an attractor may be created, although the common pattern is the creation of an attractor as a solution to a very specific problem or objective. Once the initial problem is solved, the process of developing the information system moves naturally forward, to address the next problem, the attractor gaining momentum and support, and becoming an increasingly important factor in the process.

The experiences from Mozambique show that in centralized systems, starting a standardization process through local, small-scale experiments is difficult if one is unable to convince (translate and enroll) central authorities. The positive experiences gained in other countries were obtained through close collaboration with central authorities. So while the activities in South Africa started at the bottom of the system (clinics in townships, then province, and finally reaching the national level), in other countries (Botswana, India at the state level) they started at the top. However, in these countries, activities have also followed a bottom-up strategy in the sense that a single, limited issue was addressed (MDGs in Vietnam, pooling data in Botswana, etc.), in a pilot site (before being scaled up), and an attractor was created by translating and enrolling human and nonhuman actors into a growing actor-network.

We will now explore more deeply HISP experiences in Ethiopia to provide some richer illustrations of challenges and opportunities involved in the creation of an attractor that becomes a new standard in a country where existing structures are not shaken up by radical change as occurred in South Africa.

Ethiopia

Ethiopia is a federal republic, consisting of 11 relatively independent regions with borders drawn along widely accepted ethno-linguistic lines. The regions are divided into zones, which are divided into *woredas* (district, the basic administrative unit in Ethiopia; there are 580 in all). Ethiopia is, even more than most developing countries, characterized by stark contrasts and uneven development between rich and poor and urban and rural areas, as well as between the capital and the rest of the country.

The overall HIS in Ethiopia is poorly developed. Formats for data collection have evolved over time as a result of decrees from the Ministry of Health (MoH) and from vertical program managers and agencies. When new reporting formats have been issued, the old often continue to be used since they are "owned" by a different agency, causing inconsistencies and duplication. The information unit at the MoH has tried to create some order by issuing an overall compilation of required formats, but these efforts have not improved the situation.

The government has recently initiated a fast-track implementation of e-governance solutions supported by a project to network all *woredas* in the country, with the health sector as one targeted area. The general assumption is that this will require one all-encompassing standardized system. As one key actor at the federal level said, "We want to give the contract to one company who will then be responsible for everything, regardless of the costs." This approach by a central ministry is consistent with that found in many other countries, and is in contrast to the South African case, and in the experimental, bottom-up approach described for three regions in Ethiopia (see below).

In an attempt to overcome the rigidity of the federal forms, different methods have been used at a regional level to collect region-specific information. Some regions have printed revised versions of the centrally defined forms to which they have added the additional data items to be collected, while others have used the centrally defined template and have added additional forms. In this way, each region has developed its own distinct system of formats and procedures for collecting, analyzing, using, and reporting data internally within the region and from the region to the federal level. The *de facto* data standards at each level are thus defined by the unsystematic array of "hard-coded" paper forms that are actually in use. It is very difficult to change these standards for a number of reasons, including the lack of coordination between programs, the absence of a strong vision for an integrated information system, and the difficulties in accessing and communicating with all parts of this vast country, particularly the more remote rural areas. In Exhibit 2 we highlight some of these problems in a description of a federal workshop with participants from four regions.

The problems highlighted demonstrate the top-down and all-inclusive approach to standardization common among ministries and central agencies. It also demonstrates the enormous variety and heterogeneity of needs, interests, and opinions among stakeholders, and accordingly the challenges involved in implementing such an approach.

HISP initiated activities in Ethiopia in early 2003. Initial approaches to the federal level were rejected on the ground that development and implementation of HIS would be carried out by their own experts, and that the ministry's priority was the development of a national HMIS strategy. Subsequently the Addis Ababa Health Bureau (AAHB), which has the autonomy to plan and execute its own development programs, accepted a proposal to utilize the DHIS software, mainly because the AAHB had difficulties with the existing paper-based HIS.

The HISP group, based at Addis Ababa University, developed a DHIS software prototype in parallel with a systematization of the rather complex datasets. The prototype demonstrated inconsistencies and problems in the current reporting formats. While such inconsistencies had been known but not acted upon previously, the process of computerization made these problems more transparent and triggered action. The prototype and findings were demonstrated at a workshop in March 2004, attended by health workers and managers from the Health Bureau, sub-cities, facilities, and some participants from MoH. The health bureau decided on a city-wide project and formed a committee to develop new standards and reporting formats. Subgroups reviewed the forms from each program area and over the next 2 months all data formats were revised and a set of uniform reporting formats were agreed upon and compiled in a book.

Having agreed on integrated data sets, the database for capturing and managing this data was finalized, computers were purchased, and the DHIS installed. Training and facilitation followed and a technician provided support across all sites. During 2004-2005, the information system was implemented in the 11 sub-cities, 5 city hospitals, and 23 larger health centers. Three city-wide workshops were conducted, each resulting in a range of modifications. In July 2005, the results of the first full year of data reporting were assessed at a workshop. The achievements were regarded as significant and, as a result, new programs such as pharmacies and drugs now wanted to be included in the "unification" and standardization process. Another area in which significant progress has been

Exhibit 2. The Difficult Process of Gaining Agreement on a Uniform Integrated Dataset

A 3 day federal workshop was convened (July 2004) to address the key information needs of the health services. The idea was to present a minimal indicator/data set that would provide a basis for developing the information system. This was meant to represent the *information needs* of a variety of programs, and would serve as the *standard* for reporting in the region. However, the workshop did not agree on the suggested data set for a number of reasons.

1. Most participants, who were representing the range of vertical programs and services, didn't find "their" data in the proposed data set. They all wanted the data for their vertical program to be included in the dataset, but this would have violated the minimalist approach that was perceived to be the correct avenue to follow. The proposal lacked a conceptual framework in which such additional information needs could be accommodated, and thus the participants found the proposed data set was far too limited.

2. The workshop arrived at a consensus on the need to reduce the number of data elements, but not on where or how much to cut. Said one speaker, "Reporting diagnosed diseases on the ICD format represents the major burden. Since the facilities are not able to diagnose correctly using these codes, this reporting format needs to be reduced drastically." Another responded that "reporting diseases using ICD is required internationally."

3. Agreement was also not reached on which areas to include in the standardization process: "The HIV/AIDS pandemic will have impact on the entire health system in Ethiopia and it is crucial that the reporting of HIV/AIDS data is included in the federal system" (federal level HIV/AIDS coordinator). To this, someone responded, "The federal data standards we are discussing here should be what is common for the 3500 health facilities in Ethiopia. The HIV/AIDS programs are so far only implemented in a few places. We cannot ask facilities to report on activities in which they are not involved. Besides, HIV/AIDS requires much more data than we can include here, and should therefore not be included but rather be part of a separate system."

4. The necessity of having one standard system (one set of paper forms, one software system) was emphasized by a few speakers, whereas others strongly opposed this and stated that the regions as well as the programs needed to be able to develop according to their own needs, but within the federal framework of data standards. There was, however, no shared understanding at the workshop as to how to best balance these opposite positions

5. The problem of being able to accommodate changes in an information system was raised by several participants: "We are all the time being given new reporting requirements by the federal level. I am sure this will continue in the future. So what do we do when we have our new federal formats? Are they also going to be changed all the time? And how will that be possible?"

made is in the implementation of the ART program for HIV/AIDS patients. In a recent development (2006), two HISP team members together with two doctors have developed and implemented a simple but effective, free and open source electronic patient record system in the ART clinics of two hospitals. The reporting requirements for ART patients are complex. It is a requirement that statistics provide the outcome (regimen effectiveness) for every monthly cohort of new ART patients, which is increasingly difficult to manage in a paper based system as each cohort needs to be monitored from their starting date. By providing these reports at the "touch of a button," the system gained instant success and within 2 months of its implementation has been requested by four additional regions; an attractor is being created.

We see thus that in Addis Ababa, the electronic infrastructure reaches down to all administrative units, hospitals, and health centers, and even to electronic records for HIV/AIDS patients. This is in sharp contrast to the situation in other regions. The standards and database solution created in Addis Ababa have created strong interest in other regions and Addis Ababa University has signed agreements to undertake similar projects with four additional regions; an attractor is being created here as well.

In the Oromia Region, the HIS reform process started after some key actors from the Oromia Health Bureau participated in the workshop in Addis Ababa. This region is the largest and most populous region in Ethiopia. It comprises one-third

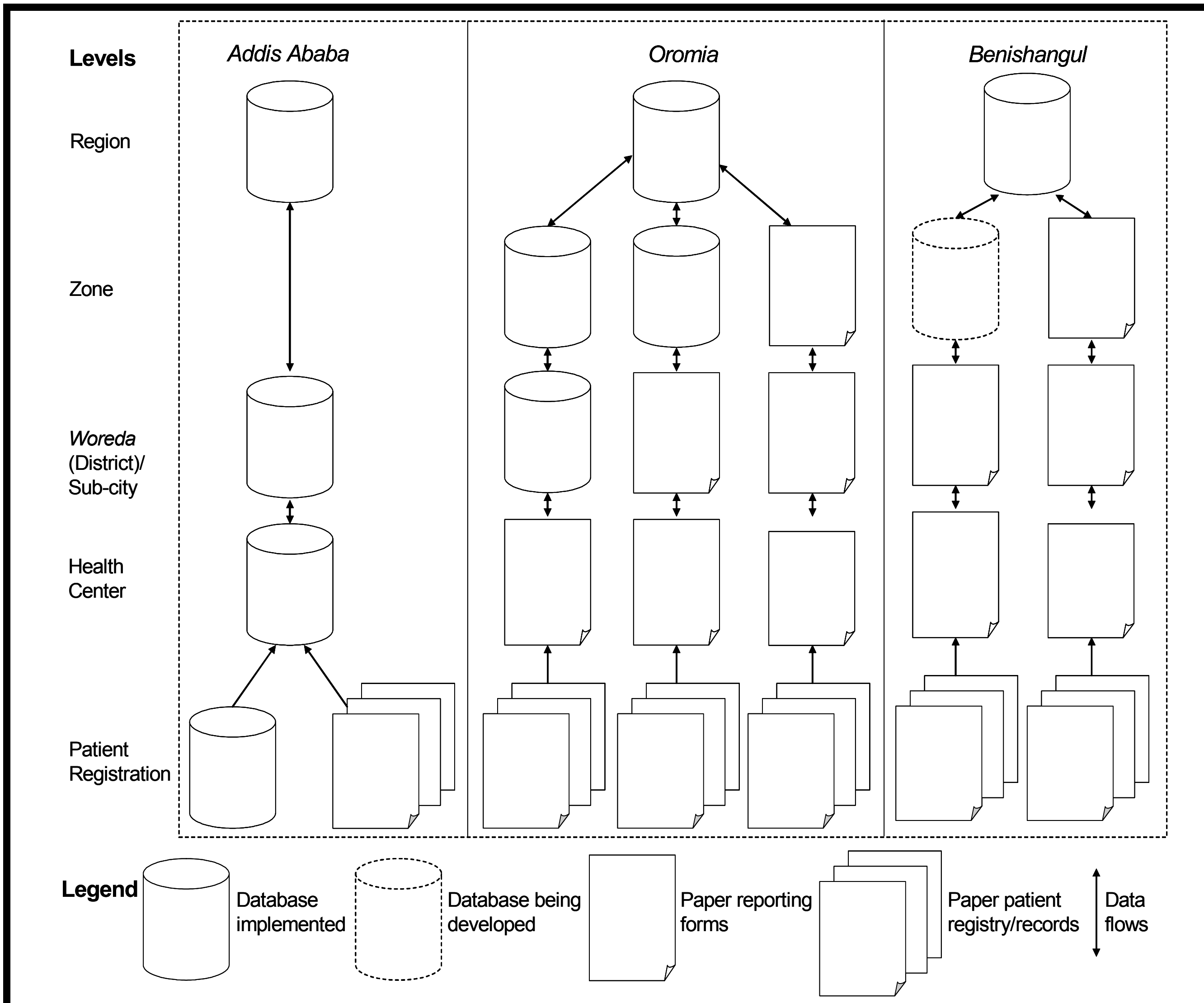


Figure 2. Uneven Development of HIS Infrastructure Across Regions in Ethiopia (Simplified)

of the total surface area (bigger than Italy) with a population of 25 million and 1,458 public and private health facilities. The major challenges in Oromia are the vastness of the region, the poor infrastructure, and the lack of human capacity. While drawing on the Addis Ababa experience in terms of the database development, the implementation process in this region varies across the zones. In two zones, training on computer basics and the use of DHIS application has been provided and the database application has been implemented in some *woredas*. In the remaining zones, the plan is to first train all zonal offices in the use of the DHIS database before extending to the *woredas*, which are in the deep rural areas. This strategy thus emphasizes horizontal extension across zones, before gradually reaching down to the *woreda* level (vertical extension).

In the Benishangul-Gumuz Region, one of the poorest regions, stretching 2,000 kilometers along the borders of Sudan, and populated by several smaller ethnic groups, the HIS relies on a paper-based system of reporting up to the regional level for most zones (Mengiste 2005). Figure 2 highlights the two important issues that emerge from this case: first, the use of gateways at different levels of the hierarchy, and the level of the gateway being influenced by access to technology; and second, the different types of gateway in use, again depending on access to technology.

In these three regions, we see how a federal structure with independent regions facilitates variety, innovation, and regional standards—in our view a requirement for successful health care infrastructure standardization and development. It is, however, necessary, as in South Africa, to develop shared core national essential data sets in order to enable monitoring of, for example, health status and health services delivery across all regions and *woredas* in this vast country. The cases highlight the extreme heterogeneity found in developing countries such as Ethiopia regarding user needs and human resources as well as the basic infrastructures required by a computer-based information infrastructure. The difference in the implementation processes between regions reflects the need to accommodate the unevenness between regions. Robust, flexible, and scalable approaches, where paper- and computer-based information infrastructures smoothly interoperate and where the computer-based systems gradually replace the paper based ones, are needed in contexts like this.

In the case of both the general HIS standardization and the specialized solution for ART patients, we see that an attractor has been created in Addis Ababa and thereafter spread to other regions, thus showing a similar pattern to the early phases of the standardization in South Africa. Furthermore, in both cases we see a bottom-up initiative that is increasingly getting involved in national-level negotiations as the spread of standards between regions needs to be compatible with national policy. Despite initial conflicts related to the role of regional bottom-up initiatives in the national standardization process, an agreement has been reached between the HISP group and the MoH to cooperate in the national task force to develop national HIS standards. In the case of the ART solution, however, future developments are less certain as there are multiple international and national actors involved—and significant funds.

We will now look briefly at experiences from a country that has not been involved in the HISP project and which successfully built an information infrastructure for health. The process used here will be contrasted to that used in the best practice case presented above.

Thailand

Thailand has a population of 64 million people and is divided into 75 provinces and 795 districts. The HIS in Thailand may be regarded as a best practice among mid-income countries and uses an extensive information and communication technology infrastructure that reaches all districts. Data on individual patients is captured electronically in most health facilities and standard data sets are submitted upward through the system to the central level, from where feedback and key information for the management of the health services is accessible through the web (www.phdb.moph.go.th). The health system works well, as indicated by the HIV/AIDS situation. HIV prevalence has dropped from 4 percent in 1990 to 1.3 percent in 2004, with the number of new infections reducing from 43,000 to fewer than 20,000 per annum. Eighty thousand people are on ARV therapy, for under $300 per year.

According to the 1997 constitution, every Thai has the right to health care. From the inception of the universal coverage scheme in 2001, there was a tremendous push to improve data quality in order to justify the decentralized distribution of funds based on capitation costs (paid per capita) for prevention and health promotion and for direct costs for hospital and high cost patient care. The National Health Insurance Scheme has established a system of contracting units (CUPs) in each district, consisting of a hospital and their network of clinics, which are then paid for the services they are rendering according to the data submitted. The actual payment, quality control, and accounting are decentralized to the province level. The CUPs are provided with ICT network access and computers as part of their payment.

Two sets of standard national data are identified: one covers community services and is made up of 18 subsets including immunization, family planning, disease surveillance, chronic diseases, etc.; the other covers hospital services and consist of 12 subsets including inpatients, outpatients, patient payment, referral, etc. Each of these 30 data subsets are specified as a file format to be sent to the national level as e-mail attachments.

Health facilities use various software applications for the primary capture of data and report electronically to the CUPs using Internet or USB memory sticks. Feedback from the central level and access to information is generally web-based, but numerous paper-based reports are also produced. As more and more districts get adequate web access, interchange of data and information between local and central levels is increasingly robust and scaleable. As long as the provinces report the required standard data sets and files, the provinces are free to collect and process the additional information they need and can use the software of their choice.

While standard software applications have been distributed to the CUPs for collating and transmitting the standard data files, a variety of other software applications have been developed in the provinces in order to pursue their particular information needs. Infrastructure and socio-economic conditions differ between provinces and between cities such as Bangkok and the rural areas. While freedom for local innovation enables more advanced provinces to develop solutions according to their potential, less advanced provinces benefit from sharing software solutions developed in other provinces. Standards are regularly revised through an ongoing HIS development program that has broad participation from all of the main role players in the process.

We see the approach to standardization followed in the implementation of this highly successful information infrastructure as basically the same as the one in South Africa. The first version of the standard and the infrastructure was built in order to solve one very specific problem: the model for financing the health services. The data required for this purpose turned out to be useful for other purposes as well. Based on user experiences and new needs, the infrastructure and standards have been extended and modified; it has evolved as a complex adaptive system.

Discussion

The aim of this article is to suggest a strategy for developing flexible IS standards to improve the HIS in developing countries. Using complexity theories to interpret the outcomes of the action research project, we propose a strategy whose two main components are to create an *attractor* that emerges as a new standard and which evolves into a system of standards, and second, to suggest that the individual standards must be crafted in a manner which allows the whole complex system of standards to be *adaptive* to the local context. Furthermore, the strategy is based on two principles, which we call the *principle of flexible standards*, and the *principle of integrated independence*. This strategy, we argue, while being rather general, is of particular importance when addressing the complexity caused by the uneven development of infrastructure in developing countries. We illustrate how this approach is supported by obtaining rich information from minimal data, how radical change can be achieved through taking small steps, and how gateways and a focus on data standards (as opposed to technical standards) are the important components when aiming at scaling national HIS in developing countries.

Creating Attractors

The real take-off for the South African pilot project came about when users were offered a simple software application to support a minimum data set. At this point, an attractor was created, which, through its success, enrolled additional users. In the other countries where attractors have successfully been created, this has happened by pursuing a strategy to rally scarce resources around solving a single specific, but large problem, shared by many. In Addis Ababa the problem was a fragmented HIS, and the solution was to standardize the data sets by solving incompatibilities and overlaps, establishing a uniform infrastructure to collate data, and presenting information in the form of indicators. A similar solution in Botswana made data available to users by establishing a DHIS data warehouse at the district level. The successful solutions, consisting of software and data sets, have been successful because they have been simple (easy to adopt; accommodate changes with ease) and have supported experimental development strategies. When users adopt the solutions, it demonstrates that systems are working properly seen both from an organizational and technical perspective. A working solution providing benefits is indeed powerful in the sense that it attracts more users and other stakeholders. This is illustrated by the instant success of the simple solution to manage ART for HIV/AIDS patients in Addis Ababa.

The cases demonstrate how this strategy might be adopted with success in different contexts. In principle, one can initiate a top-down or a bottom-up approach and develop a solution in support of work tasks, provided user needs are addressed. However, the cases as well as literature on HIS (AbouZahr and Boerma 2005; Shaw 2005) have shown that in order to attract interest from both local and national actors, it is important to start with a focus on key priorities of the health services. The starting points (i.e., the initial problem being addressed) will largely determine the next steps to be taken, and which actors should be enrolled. HIS standards have national importance and the role and involvement of health authorities will always be significant. However, as we have illustrated above, governments in developing (as well as developed) countries may easily become too ambitious in their aim at developing uniform standards. In South Africa, this tension between local need for flexibility and the need for central control has been managed through the application of the hierarchy of standards (Figure 1), which dynamically combine flexibility as a *right* and adherence to the standards of the level above as a *duty* (Jacucci et al. 2006). This is discussed below as the *principle of integrated independence*.

The Principle of Flexible Standards

A national HIS needs many interdependent standards—a complex system of standards. Individual standards easily arrive at lock-in states, which may result in the whole system being locked-in, a complex *non*-adaptive system. However, it is important to craft standards and their relations so that they emerge as a complex *adaptive* system that can adapt to a changing environment and thereby contribute to the sustainability of the HIS. That can only be achieved if the individual standards adapt to the changing environment and each other, which can only be achieved if the standards themselves are flexible.

What makes a standard simple (or complex) is partially its technical complexity in terms of the number of elements. But the complexity of a standard is also determined by its constituting actor network (i.e., the data elements, the user practices supported, the technological components implementing the standards, the people and organizations responsible for maintaining these components, the users of the standard, standardization bodies involved, etc.) and the links of various kinds between all of these actors. Simplicity and flexibility can be achieved by making these actor networks small and simple. That is partly achieved by defining independent standards for different use domains and geographical areas, and partly by limiting their functional scope. This mechanism decreases the technical complexity of the standards but, more importantly, it also decreases the organizational complexity in terms of the use practices that need to be analyzed and the organizational complexity required to involve all stakeholders.

Two forms of flexibility can be identified: use and change flexibility (Hanseth et al. 1996). A standard's total flexibility is the sum of these two. *Use flexibility* refers to the ability to use a standard in a number of different environments, or for a number of different purposes. The "need to know" principle, which emphasizes the importance of collecting essential information rather than "nice to know" information, is an example of how use flexibility helps to get maximum information out of minimum data, that is, using existing data elements in new combinations to address new information needs, rather than adding new data elements or reporting formats into the standard (see Exhibit 1). *Change flexibility* (and scalability) is achieved through the classical principle of *modularization*. This principle is crucial across all engineering disciplines; it should be no surprise that it also applies to standards. Rather than one complex standard covering everything one should make several small and *simple* standards and define simple interfaces—*gateways*—between them. The DHIS software has become popular and gained momentum primarily because of its change flexibility. Data elements and indicators are handled as individual components (records) and may be added, deleted, and edited by the user. The software also allows the data collection tools to be customized to the need of the individual reporting unit, such as a hospital or health center. These functionalities have made it possible to focus on the standardization process of the individual data elements, allowing for differences between provinces and use areas. In contrast, in other countries, as for example India, it has proven very difficult to change the paper formats which are often "gazetted" and appear to be cast in stone.

Standards should be modularized horizontally and vertically. *Vertical modularization* corresponds to traditional layering in software engineering where one layer offers services to the layer above. Separate standards are defined at each layer. This principle is beautifully demonstrated by the seven-layer open systems interconnection (OSI) protocol model. In our case, the separation of the data layer from the rest (the technical layers) has been found to be extremely important in order to, on the one hand, identify the data that can be collected in the various health care institutions and, on the other hand, transfer this data by available infrastructural services (electronic in some areas, physical in others).

Horizontal modularization means that rather than going for one "universal" standard for a domain, one makes several standards—one for each part of the domain—and interfaces are defined between them. The classical interface between standards is a *gateway*, a piece of software that links together different sub-infrastructures into an integrated one, by translating between data representations, formats, and protocols. In the computer communication community, gateways have been regarded as an anomaly, something you need when you have failed to achieve a shared standard (see, for instance, Stefferud 1994). In our view, gateways are just as important as standards in order to build and maintain flexible and successful infrastructures. We use the concept of gateways in a broader meaning, seeing them as boundary objects between actor-networks (Bowker and Star 1999; Star and Griesmer 1989). Gateways, then, also include *objects* that link and translate between paper based and electronic infrastructures, or between incompatible electronic infrastructures. The objects representing such gateways will be hybrids (Latour 1993), composed of humans, procedures, computers, and specialized software.

The typical gateway in the cases of South Africa and Ethiopia is between paper and computers. This gateway consists of a number of procedures for collating the paper forms received from the paper-based infrastructure and translating them to the required electronic format so that it can be transmitted in the electronic infrastructure. Gateways also include the procedures for analyzing the data and producing different reports (i.e., from computer back to paper and the paper-based infrastructure), feedback to those who collect the data, and other stakeholders. The paper–computer gateways take many forms and are rather complex in terms of people, procedures, and the paper- and computer-based tools involved.

Another gateway is that between electronic systems, the electronic record systems for HIV/AIDS patients and the DHIS in Addis Ababa being a typical example. In this case, the relevant patient-related data elements are mapped to the corresponding DHIS standards. The HIV/AIDS data is translated into aggregated monthly data and provided in a format appropriate for import into the DHIS. Similar gateways are in use in all districts in Thailand; in South Africa similar gateways exist between the tuberculosis control program data and the DHIS. These will become increasingly important in the next few years, particularly in relation to HIV/AIDS patients.

Without gateways we are trapped. We need to develop infrastructures based on single, universal standards, but in countries like Ethiopia this is impossible. In most other cases, universal standards are beyond our capacity or will be totally inflexible if built. Establishing a fragmented infrastructure composed of a range of small ones which are not connected is not a viable option. An appropriate blend of standards and gateways allows infrastructures to evolve by maintaining order at the edge of chaos.

The Principle of Integrated Independence

According to Kumar and van Hillegersberg (2000, p. 23), "Integration has been the Holy Grail of MIS since the early days of computing in organizations." With the diffusion of the Internet and other computer communication technologies, tighter and more integration has been enabled—and demanded. Improved integration of information systems is also at the center of the efforts presented in this article to enable smoother coordination and control of organizational processes and health care delivery. But integration may cause less independence—and less flexibility. The case of South Africa demonstrates that both integration and independence of data standards have been achieved between provinces (i.e., geographical areas) and health programs (i.e., functional areas). A sort of integrated independence has emerged through the interaction between and within different subsystems and the overall HIS environment. The way these agents of the overall HIS in South Africa have negotiated, adapted, and changed follows the dynamics of independence and interdependence of a complex adaptive system by combining simple and flexible standards and gateways. While there has been no central control or linearity, the standards developed through the HIS-processes have been developed through conscious design efforts, although by a very heterogeneous network of designers. In the South African case, a large information systems development project that has evolved over more than 10 years, the loose and flexible coupling between the evolving variety of designers and owners of the (sub)systems, such as the national level, provinces, health programs and the HISP group, is a significant feature.

We now summarize three key aspects that are linked to this strategy, namely rich information from minimal data, enabling radical change through small steps, and effective scaling of health information systems in a complex environment.

Rich Information from Minimal Data

Flexible standards must, we have argued, be simple and easy to change and at the same time support a wide range of work practices. One of the outcomes of applying this approach to the data set standard is the finding that we can get rich information from minimal data. A focus on the must-know rather than nice-to-know information, as illustrated by the emphasis on indicators and the minimal essential data set, can be extremely powerful in that it allows a simple, well-chosen data element to be used for several purposes. In addition, existing data can often be used for new purposes by innovation in the development of indicators, rather than adding new ones. These initiatives can stimulate transformation and improvement of work practices without changing the standards.

Developing a minimal dataset can best be achieved by means of the bottom-up approach to standardization, in combination (of course) with top-down implementation of best practices in new areas and micro–macro consultation and learning. As shown in the South Africa case, that means that a very simple draft data set is implemented. Based on user experience, one can develop it so that a wide range of work practices are supported without extending it or with minimal extensions. The data set is then extended only when this is absolutely necessary. The traditional top-down approach to standardization usually leads to huge sets of data where "need to have" has not been separated from "nice to have" data. And while these data sets have a huge array of data, often only a small portion of the data is actually used meaningfully, negating the purpose of having a large data set in the first place. Even if, as is described in the Botswana case, a shared data warehouse is developed, the long-term strategy is to integrate data sets and to make the essential data from each data set available to everybody. By making the availability of both useless and useful data transparent, the process toward the reduction of each data set by emphasizing "need to have" is initiated.

Radical Change Through Small Steps

The strategies described in the cases are not just for standards development, but also for radical change of complex systems whether these are systems of standards, infrastructures, health care systems, or others. This interpretation of the strategy allows one to achieve *radical change through small steps.*

Radical change is often an aim when introducing IT solutions into organizations. In the days of business process reengineering, the recommendation was to design the new organization and its ICT solutions together. That did not work in industrialized countries, and it will not work in developing countries, because it does not work in the world of complex systems. Accordingly, new solutions, including standards, need to be designed so that they support existing practices and then these practices can be modified incrementally. The standards need to be modified in parallel with the changes in practice, by following the strategy and principles described above.

We have seen this approach used in the development of data standards (the minimum data set in South Africa), and in the development of the DHIS software. What emerges through the analysis of this practice is the use of gateways as a mechanism to effect changes in small steps that are appropriate and synchronous with the process of infrastructure development. The use of gateways is thus in reality a set of procedural standards that accommodates change in small steps, but which can bring about radical change.

The change is radical in the sense that it brings about possibilities, and new ways of doing things, which previous practices, and particularly the BPR (business process reengineering) style processes did not achieve. The advantage of this approach is that it is sensitive to the needs of a complex adaptive system, and allows the systems to interact and adapt as the changes are introduced.

Scaling Information Systems in Developing Countries

Heterogeneity, as illustrated through the uneven development of economy and infrastructure between and within regions, is a key characteristic of developing countries. One particularly important requirement that we address through HIS standardization is to achieve full data coverage within an area (district, province, country). This has been termed the dilemma of "all or nothing" (Braa et al. 2004), and is important when, for example, the aim is to address equity across population groups in South Africa, or to implement the "health for all" insurance scheme in Thailand. As discussed earlier, this problem area can be analyzed within the framework of *scaling.* Using the self-similarity between branches and subbranches of a broccoli as a metaphor, CAS sees scaling as the replication of the similar in a network (Eoyang 1996). However, it is in this latter perspective that the scaling of IS in developing countries provides a stark contrast to the typical industrialized country where the "similar" infrastructure is relatively evenly distributed. We demonstrated how in Ethiopia, the HIS had to scale differently in the various regions.

We can summarize our experience in suggesting that there are two important strategies that need to be followed in order to scale information systems in this context. First, focus on data standards and information rather than on technical standards. The focus in South Africa and Addis Ababa on essential data and indicator sets is the case in point here. Second, accept that there will always be technically incompatible subsystems. Make them compatible in terms of data by building gateways between them. Scaling HIS in, for example, Ethiopia is along one axis about replicating data standards and information handling procedures throughout the hierarchy of health services covering the country. While technical standards cannot be uniformly replicated across the uneven heterogeneous infrastructure, data standards can be replicated. From a standards perspective, the focus needs to be on the content/message rather than the container/messenger. However, along another axis, scaling of HIS in Ethiopia is about *replicating*—establishing and maintaining—effective and seamless data flows which are appropriate throughout the country. The use of gateways helps us achieve this.

Conclusion

Many developing countries are currently engaged in strengthening their national HIS. This trend is reinforced by the launch in 2005 of the Health Metrics Network, a global initiative to support such efforts, and which is supported by WHO, the European Union, and a number of international agencies (http://www.who.int/healthmetrics). The challenge of coping with fragmentation, multiple data sources, and lack of standards is regarded as a key issue. An important contribution of this article is to provide a strategy to standardize HIS and information infrastructures which are appropriate for the context of developing countries.

In proposing a strategy for the development of information infrastructures for the health care sector, two issues related to complexity are of particular importance, and both are specific for developing countries. First, there is uneven development between rich urban and poor rural areas, characterized by the extreme differences in health service delivery and the availability of basic infrastructure. Second, there is the important role played by vertical programs (like HIV/AIDS programs), funded and partly managed by international donor organizations, in increasing complexity and HIS fragmentation.

Our strategy contains two main aspects. First, *create an attractor* by building an actor network. In our cases, we describe how the use of a simple set of data standards (in South Africa), a data warehouse (in Botswana), and a software program that made the data available to all user groups addressed a problem for a specific group of health workers. The creation of attractors enrolled and aligned a user group by providing the users with benefits (i.e., the solution must support existing work practices), and the standards were able to accommodate changes as the user base expanded. The cases also show that creating attractors in national priority areas, such as equity in South Africa and the universal coverage scheme in Thailand, are powerful attractors to drive change at the national level. Similar attractors are required at a global level to address workable solutions in the information systems arena to support initiatives to combat the HIV/AIDS epidemic and the attainment of the MDGs.

The second aspect is to ensure that the emerging *system of standards remain adaptive*, a complex adaptive set of standards. This is done through a number of mechanisms, including paying attention to use and change (modularization) flexibility, and the use of gateways to link different components/standards. Scaling of standards in developing countries is enabled by flexible gateways between both computers and paper-based systems and between different computer-based systems and by emphasizing the data standards rather than the technical standards.

The limitations of this study relate to the fact that the principles discussed, and the proposed strategy, have emerged as reflections on processes in the various countries in which HISP has operated. The applicability of these concepts needs to be tested outside the HISP network, and in different contexts, and as an explicit approach to strengthening information systems. The case studies used here reflect mainly on initiatives in strengthening public health services; space limitations have restricted detailing experiences in for example hospital information systems. Aspects requiring further research thus relate to the explicit use of these approaches as components of interventions in new contexts, and a reflection on how these principles can be applied, or differ, in hospital contexts, and in contexts outside of the health sector.

Acknowledgments

We wish to express our appreciation to health workers in the clinics and health facilities, often in remote areas, working under extreme pressure, and their managers in districts, regions, and ministries of health, who have contributed to the development of these concepts. We hope that this paper will make a small contribution to improving their lives as health workers. We also wish to thank the reviewers for their most helpful comments and suggestions for improvement.

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.

Arthur, W. B. *Increasing returns and Path Dependence in the Economy,* The University of Michigan Press, Ann Arbor, MI, 1994.

Axelrod, R. M., and Cohen, M. D. *Harnessing Complexity: Organizational Implications of a Scientific Frontier,* Free Press, New York, 1999.

Benbya, H., and McKelvey, B. "Toward a Complexity Theory of Information Systems Development," *Information Technology & People* (19:1), 2006, pp. 12-34.

Bowker, G. C., and Star, S. L. *Sorting Things Out: Classification and its Consequences,* MIT Press, Cambridge, MA, 1999.

Braa, J. "A Data Warehouse Approach Can Manage Multiple Data Sets," *Bulletin of the World Health Organisation* (83:8), August 2005, pp. 638-939.

Braa, J., and Hedberg, C. "The Struggle for District Based Health Information Systems in South Africa," *The Information Society* (18**),** 2002, pp. 113-127.

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

Callon, M. "Techno-Economic Networks and Irreversibility," in *A Sociology of Monsters: Essays on Power, Technology and Domination*, J. Law (ed.), Routledge, London, 1991, pp. 132-161.

Capra F. *The Web of Life: A New Scientific Understanding of Living Systems*, Harper Collins, London, 1996

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.

David, P. A. "Understanding the Economics of QWERTY: The Necessity of History," in *Economic History and the Modern Economist,* W. N. Parker (ed.), Basil Blackwell, Oxford, UK, 1986, pp. 30-49.

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

Day, C., and Gray, A. "Health and Related Indicators," in *South African Health Review 2005*, P. Ijumba and P. Barron (eds.), Health Systems Trust, Durban, South Africa, 2005.

De Kadt E. "Making Health Policy Management Intersectoral: Issues of Information Analysis and Use in less Developed Countries," *Social Science and Medicine, (*29), 1989, pp. 503–14.

De Vries, H. J. *Standardization: A Business Approach to the Role of National Standardization Organizations*," Kluwer Academic Publishers, Boston, 2003.

Dooley, K. "Complex Adaptive Systems: A Nominal Definition," unpublished paper, Arizona State University, October 1996 (available online http://www.eas.asu.edu/~kdooley/casopdef.html; accessed October 2005).

Egyedi, T. M. "Standards Enhance System Flexibility? Mapping Compatibility Strategies Onto Flexibility Objectives*"* in *EASST 2002 Conference: Responsibility Under Uncertainty*, European Association for the Study of Science & Technology, University of York, York, UK, July 31-August 3, 2002.

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

Gladwin, J., Dixon, R A., and Wilson, T. D. "Implementing a New Health Management Information System in Uganda," *Health Policy and Planning* (18:2), 2003, pp. 214-224.

Greenbaum, J., and Kyng, M. (eds.). *Design at Work*, Lawrence Erlbaum, Mahwah, NJ, 1991.

Hanseth, O. "Gateways—Just as Important as Standards. How the Internet Won the 'Religious War' about Standards in Scandinavia," *Knowledge Technology and Policy* (14:3), Special Issue on IT Compatibility, 2001, pp. 71-89.

Hanseth, O., and Lundberg, N. "Designing Work Oriented Infrastructures." *Computer Supported Cooperative Work* (10:3-4), 2001, pp. 347-372.

Hanseth, O., and Monteiro, E. "Inscribing Behaviour in Information Infrastructure Standards," *Accounting Management and Information Technology* (7:4), 1997, pp. 183-211.

Hanseth, O., Monteiro, E., and Hatling, M. "Developing Information Infrastructure: The Tension Between Standardisation and Flexibility," *Science, Technology and Human Values* (11:4), 1996, pp. 407-426.

Heeks, R. "Failure, Success and Improvisation of Information Systems Projects in Developing Countries," *The Information Society* (18), 2002, pp. 101-112.

Holland, J. H. *Hidden Order: How Adaptation Builds Complexity*, Addison-Wesley, Reading, MA, 1995.

Hughes, T. P. "The Evolution of Large Technical Systems," in *The Social Construction of Technological Systems*, W. E. Bijker, T. P. Hughes, and T. Pinch (eds.), MIT Press, Cambridge, MA, 1987, pp. 51-82..

Jacucci, E., Shaw, V., and Braa, J. "Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability,*" Information Technology for Development* (12:3), Summer 2006, pp. 225-239.

Jayasuiriya R. "Managing Information Systems for Health Services in a Developing Country: A Case Study Using a Contextualist Framework," *International Journal of Information Management* (19), 1999, pp. 335-349.

Jeppsson, A., and Okuonzi S. A. "Vertical or Holistic Decentralization of the Health Sector? Experiences from Zambia and Uganda," *International Journal of Health Planning and Management* (15), 2000, pp. 273-289.

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.

Kumar, K., and Hillegersberg, J. V. "ERP Experiences and Evolution: Introduction," *Communications of the ACM* (43:4), 2000, pp. 22-26.

Latour, B. "*We Have Never Been Modern*," Harvard University Press, Cambridge, MA, 1993.

Mengiste, S. "Challenges and Opportunities of Implementing District-Based Health Information System in Ethiopia: A Case Study from Benishangul-Gumuz Region," in *Enhancing Human Resource Development through ICT. Proceedings of the IFIP 9.4 on Enhancing Human Resource Development through ICT*, A. O. Bada and A. Okanoye (eds.), Abuja, Nigeria, May 26-28, 2005, pp. 256-267.

Okuonzi, S. A., and Macrae, J. "Whose Policy Is it Anyway? International and National Influences on Health Policy Development in Uganda," *Health Policy and Planning,* (10), 1995, pp. 122-132.

Pettigrew, A. M. "Context and Action in the Transformation of the Firm," *Journal of Management Studies* (24:6), 1987, pp. 649-670.

Pettigrew, A. M. "Contextualist Research: A Natural Way to Link Theory and Practice," in *Doing Research that is Useful in Theory and Practice*, E. Lawler (ed.), Jossey-Bass, San Francisco, 1985, pp. 222-249.

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.

Romer, P. M. "Endogenous Technological Change," *The Journal of Political Economy* (98), 1990, pp. 71-102.

Sahay, S., Miller, J., and Roode, D. (eds.). "Information Flows, Local Improvisations and Work Practices," in *Proceedings of the IFIP 9.4 Conference on Socio-Economic Impact of Computers in Developing Countries*, Cape Town, South Africa, May 24-26, 2000.

Sahay, S., and Walsham, G. "Scaling of Health Information Systems in India: Challenges and Approaches," in *Enhancing Human Resource Development through ICT. Proceedings of the IFIP 9.4 on Enhancing Human Resource Development through ICT*, A. O. Bada and A. Okanoye (eds.), Abuja, Nigeria, May 26-28, 2005, pp. 41-52.

Sandiford, P., Annett, H., and Cibulskis, R. "What Can Information Systems Do for Primary Health Care? An International Perspective," *Social Science and Medicine* (34:10), 1992, pp. 1077-1087.

Schmidt, S. K., and Werle R. *Coordinating Technology: Studies in the International Standardization of Telecommunications*, MIT Press, Cambridge, MA, 1998.

Shapiro, S., Richards, B., Rinow, M., and Schoechle, T. "Hybrid Standards Setting Solutions for Today's Convergent Telecommunication Market," in *Proceedings of the 2nd* IEEE *Conference on Standardization and Innovation in Information Technology*,

E. J. Iversen (ed.), IEEE Computer Society Press, Los Alamitos, CA, 2001, pp. 348-351.

Shaw, V. "Health Information System Reform in South Africa: Developing an Essential Data Set," *Bulletin of the World Health Organisation* (83), 2005, pp. 632-639.

Stacey, R. D. *Complexity and Creativity in Organisations*, Berrett-Koehler, San Francisco, 1996.

Star, S. L., and Griesemer, J. R. "Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39," *Social Studies of Science* (19:3), 1989, pp. 387-420

Stefferud, E. "Paradigms Lost," *Connexions, The Interoperability Report* (8:1), 1994.

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

UN. *United Nations Millennium Development Goals Declaration*, United Nations General Assembly, New York, September 2000.

UNDP, Human Development Report 2003. "Millennium Development Goals: A Compact Among Nations to End Human Poverty," United Nations Development Programme, 2003 (http://hdr.undp.org/reports/global/2003/).

Walsham, G. *Interpreting Information Systems in Organisations*, Wiley, Chichester, England, 1993.

WHO. *Design and Implementation of Health Information Systems,* World Health Organisation, Geneva, 2000.

WHO. *Information Support for New Public Health Action at the District Level*, WHO Expert Committee report, World Health Organization, Technical Report Series No. 845, Geneva, 1994.

WHO. *Report on the WHO/UNAIDS Workshop on Strategic Information for Anti-Retroviral Therapy Programmes*, Department of HIV/AIDS, World Health Organization, Geneva, June/July 2003.

Wilson, T., Holt, T., and Greenhalgh, T. "Complexity Science: Complexity and Clinical Care," *British Medical Journal* (323), September 2001, pp. 685-688.

About the Authors

Jørn Braa is associate professor at the Department of Informatics, University of Oslo, Norway. He has been heavily involved in the establishment and expansion of the HISP project for 10 years. His research interests focus on strategies and conditions for action research, and health information systems in developing countries.

Ole Hanseth is Professor in the Department of Informatics, University of Oslo. His research focuses mainly on the interplay between social and technical issues in the development and use of large-scale networking applications. He is also visiting professor at the Department of Information Systems, London School of Economics.

Arthur Heywood is a medical doctor who has worked in health information systems in a variety of developing countries around the world, was a founder member of HISP and has particular interest in using information for action to improve primary health care service delivery.

Woinshet Mohammed is a lecturer at the Department of Information Science, Addis Ababa University (AAU), Ethiopia. Currently, she is a Ph.D. student at the Department of Informatics, University of Oslo. Her research interests include information systems, database design, and implementation in general, and health information system in particular.

Vincent Shaw is a medical doctor who has been involved in the development and support of health services in the Eastern Cape Province of South Africa since mid-1999. He is currently a Ph.D. student at the Department of Informatics, University of Oslo. His research interests include district hospital information systems, and organizational development.

APPENDIX 5

Shaw, V. (2007, 9 - 12 January 2007). *Considering the Options for Hospital Management Information Systems.* Paper presented at the Helena 12th E-Health Conference, 2007, Bamako, Mali.

Considering the Options for Hospital Management Information Systems

Vincent Paul Shaw
University of Oslo, and University of Western Cape, South Africa.

Abstract:

Hospitals are an important consumer of resources, particularly in country contexts where resources are constrained. Yet, often managers of hospitals have only rudimentary information available with which to plan and develop hospital services. Due to the complexities in the health care sector, and in particular in hospital environments, the successful development of hospital management information systems is a significant challenge. Our approach builds on the successful evolutionary and participatory approach to the development of the District Health Information Software, and it successful application for primary health care information systems. We suggest that in the heterogeneous and dispersed environment of hospital information systems, integration between the different systems can be achieved through the crafting of gateways to effect data transfer between heterogeneous sub-systems. The choice of the appropriate gateway is a careful choice, and takes into account the relative availability of human resources, technology, and volume of data to be communicated. The information system components (registers, reports, and the District Health Information Software) are inherently flexible, and can thus accommodate the unpredictable and frequent changes that characterise complex environments.

INTRODUCTION

Designing and implementing information systems for hospitals are a particularly difficult task. Factors that complicate design of hospital information systems relate to the organisational complexities of the hospital context [1, 2], the inability to agree on common standards for communication between sub-systems [3], and the difficulty of achieving a balance between loose and tight integration of sub-systems [4]. Implementation is complicated by the politics involved in the negotiation process around hospital information systems, including the pressure to "go big" and adopt global solutions [5]. In addition, in developing countries, inadequate power supply and inappropriate environments for computers contribute to failures in information system implementations [6].

Yet, hospital information systems are important, particularly in developing country contexts where they can consume up to 80% of the available budget for health services [7]. Despite the central role that hospitals play in district health services [8, 9], there is a paucity of in depth descriptions of the design of hospital information systems particularly in developing country contexts. In particular, the literature has emphasized the development of electronic patient records, with scant attention being paid to the extraction of data from these systems to provide managers with information that integrates financial, human resource, and clinical data.

In this paper we draw from the experience of implementing a hospital management information system (HospMIS) in thirteen hospitals in the Eastern Cape Province of South Africa, and in two central hospitals in Malawi.

THEORETICAL PERSPECTIVES:

In this section, we wish to highlight the use of participatory evolutionary approaches to information systems development. Compared with industrialized countries in the "North", information systems design faces particular problems in the "South". Introduction of IT in Africa has proven to be difficult due to the 'foreignness' of the technology [10]. Apart from South Africa, design and development of application software and information systems are poorly developed in Africa [11]. African user organizations have little experience with ICT in general and ICT based information systems in particular. The case study presented in this article is drawn from first or very early computerization efforts in this type of context.

Information system design and development is generally categorized as a process of identifying problems and defining their degree of uncertainty (see [12, 13]. Davies (ibid) provides a framework for selecting an appropriate methodology for specification development of the information system based on the level of uncertainty. The level of uncertainty is related to the context (to what extent the users are familiar with the technology and its use), and the goals of the system. When uncertainty is high, experimental approaches, prototyping and user participation are recommended in contrast to more structured and phased approaches [12, 13].

Three rationales for using participatory design approaches have been suggested [14]:

- from a pragmatic perspective, it is a functional way to increase productivity;
- from a theoretical perspective, it is a strategy to overcome the problem of lack of shared understanding between developers and users;
- from a political perspective, participatory approaches are a democratic strategy to give people the means to influence their own work places.

METHODS AND CASE DESCRIPTION:

The research described in this paper falls within the interpretive research tradition described by Walsham [15]. The research is part of an action research project conducted by the Health Information Systems Programme. The case material draws specifically on experiences spanning an intense, one year period in the ECP (where the author worked in regional, district (level 1) and psychiatric hospitals), and about 30 months of intermittent support to academic and referral hospitals in Malawi. These experiences are supported by the authors' more than 10 years of experience in information systems development in the ECP at both PHC and hospital levels.

Background to the case:
The projects in the ECP and Malawi were implemented to improve the availability and access to critical information for managers. The central idea was to create a "central repository" of management information – a data warehouse that would assist a hospital manager in gaining access to the various types of information that's/he required to manage the hospital.

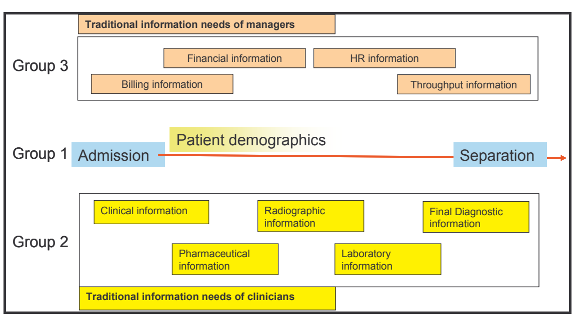


Figure 1: Sources of information for managers

The work in the hospitals was based on the use of the District Health Information Software (DHIS) [15] as the data warehouse, and the integration of paper based information systems with electronic systems (in this case the DHIS). Many developing countries rely purely on paper based information systems, in which case the deployment of the DHIS as a HospMIS is relatively easy, and largely influenced by access to technology and computer skills. On the other hand, situations arise where certain units or departments in a hospital have installed electronic systems (for example EPR systems), but still do not provide management with any substantial management information. We can group the different sources of information for a HospMIS into three groups (Figure 1). Group 1 refers to the information that is linked to a patient, and includes demographic and diagnostic data. This data is usually captured during the course of a patient attending the hospital (either as an in-patient or an out-patient) at the time of registration. They include diagnostic and procedural details, as well as outcome (admission, discharge, death, etc) of the interaction/s. This group is what has been referred to as "throughput information" and typically is the basic data that is needed to manage a hospital. Group 2 includes the types of systems that are used in clinical departments, and those of the support services (radiography), etc. Where they exist, they are usually more specialized technical systems, and capture detailed data related to the clinical care process. EPR systems sometimes address the functions of group 1 and 2, but often only partially, with other systems then complementing the EPR. This is what we call the "unevenness" of access to technology in the hospital environment – not all departments or service points have access to computers, or networks at the same time, and so integrating information between these different systems requires different strategies. Integrating these systems then is not a simple, uniform process. Group 3 is often the group that are sophisticated and sometimes called legacy systems, having been initiated by managers long before clinicians became interested in computers. Some of these may in fact be managed at a central level by ministries of health (e.g. human resource and financial information systems). For managerial purposes, information is required from all these different sources, and usually needs to be combined in various ways to inform resource allocation. For instance, financial information and staffing allocations can be linked to patient loads to assess inequities in resource allocation.

The empirical data describes how data can be extracted from these systems (whether paper or electronic) into a database warehouse, while coping with the unevenness of the technology, the heterogeneous interoperability (the problem of

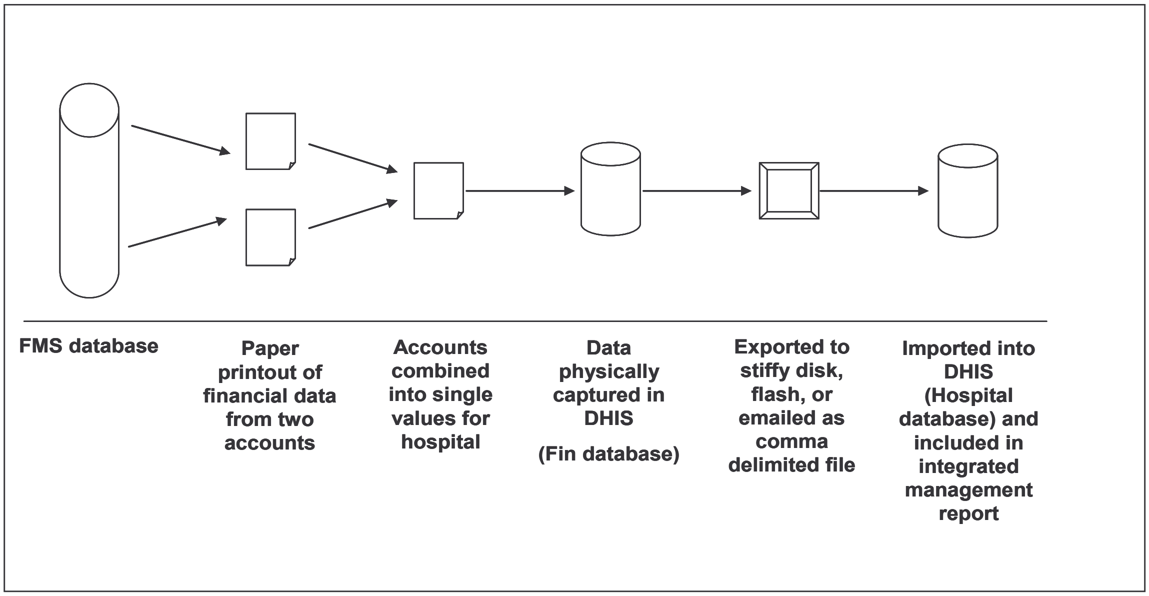


Figure 2: Crafting Gateways to link the components of different systems

integrating different software systems), as well as the semantic interoperability (the hierarchy may not even be duplicated across all systems) problems (Hevner, March et al. 2004).

Integrating financial information:
During the process of strengthening the IS in one of the hospitals, the chief financial officer (CFO) in the hospital expressed an interest in the use of the DHIS for financial information. He had access to the provincial system, the Financial Management System (FMS). The FMS allocated a budget to hospitals, according to distinct categories, and allowed hospitals to spend the allocation within each category. However, the reporting from the FMS was not in a user friendly format, and could not be linked to patient data. In addition, it transpired that there were in fact two accounts that were operational for the hospital, and that in order to have an overall view of the hospital budget, they needed to be combined. As one of the goals of the project was to include some financial data in the HospMIS, this was seen as an opportunity to experiment. Together with the financial officer, data elements were identified related to the financial budget allocations and 60 routine data elements related to monthly expenditure against categories (e.g. expenditure against personnel, pharmacy, etc). In capturing the 60 financial data elements, the data from both FMS accounts were combined. In the DHIS the data was processed, and through pivot table reports, a management report was produced.

In this case, the financial data was entered into a DHIS database on the CFO's desk, and then exported (as a comma delimited file) to be imported into the computer that was used to capture the patient related data. The process is depicted in Figure 2.

DISCUSSION:

In this case description, we wish to highlight three points. Firstly, we see how the use of "gateways" (Braa et al. Forthcoming) enabled data from different sources to be combined, and incorporated. The gateways are different at each stage of the process. In some instances they are paper printouts, in others electronic interfaces –depending on the available resources. As access to resources (technology) improves, the gateways and systems can be adjusted to capitalize on the available resources. Gateways are a vehicle for enabling loose integration of systems – particularly relevant for systems developed in complex organizations [16]. For example, Care2X is gaining increasing popularity as a free/libre open source software EPR system which is flexible, modular, and spans some components in all three of the groups depicted in Figure 1. As this system grows and expands across a hospital in an evolutionary manner, gateways will need to be crafted between it and other systems. As Care2X provides limited management reporting, the possibility of creating a gateway between it and the DHIS (an electronic-electronic gateway) is being investigated in order to feed an extract of data from the EPR into the HospMIS.

The second aspect we wish to highlight is how consideration of various factors influence the choice of the type of gateway to be used. In this case, the semantic interoperability of the databases (two accounts in the FMS for the one hospital), the access to technology, and the user skills level dictated what gateway could be used. Transferring data between the heterogenous systems requires a reconfiguration of the data into a "manageable format". This is not a unique approach – the CATCH database has to process data into the appropriate format before it can be "imported" (Berndt, Hevner et al. 2003). The data is first captured at hospital level, and then sent to state where it is used in spreadsheet format, and from there it needs to be transformed to fit the CATCH database structure. What is important is to recognize that different types of gateways have to be used, depending on the type of technology that is available. Creating the gateways is not a predetermined process – it has to be done on the spot, crafted from the available resources. This process is a very different one to the "one-system fits all" approach adopted by many vendors of HospMIS's. The "manageable" format in our case was dictated by the skills levels of the people involved in the process – if a programmer is not available, then a different type of gateway will be needed to effect the transformation process – in our case a paper-based transformation first, and later, an electronic interface.

Thirdly, a consideration was the degree of granularity of the financial data. It is feasible that if the financial allocations (both budget and expenditure) are allocated at service unit, then the DHIS could capture the financial data at this level. This would involve an explosion of the volume of data to be captured, because instead of capturing 60 data elements from the FMS generated reports for the hospital as a whole, the volume of data would increase to 60 data elements for each service unit – so approximately 1800 data elements for 30 service units. This would have to happen without an increase in access to staff (human resources) and computers. In contrast, in their article on the CATCH data warehouse, the authors indicate that they prefer to accommodate the additional data (despite the increase in database size that accompanies this) in order to allow access to detail (increased granularity) should it be needed. In the developing country context, where the critical issues are access to technology, and human resource capacity, this is a luxury that cannot be afforded. Instead the discussion needs to be centered much more on what is feasible given the limited resources. Increasing the volume of data would stretch existing "fragile" resources, increases the risk for errors, and the likelihood that data will then be less relevant. We see again an example of the delicate balance between data volume, and user capacity (as in skills level) and technical capacity.

Throughout both projects, users were involved in the development of the information system and in assisting in introducing the changes. As this happened, skills developed, and health workers who had no experience of computers became more computer literate. The DHIS software had been developed through a participatory prototyping process [15], which had seen software developers gaining a better understanding of the needs of health workers – thus the two groups of professionals from two ends of the spectrum gradually moved closer towards each other, sharing skills and empowering one another in the process.

Because there is a lack of experience of information technology and information systems design in African user organizations, designers have a high level of uncertainty regarding both the goals of the system and the context of its development and future use. The lack of shared understanding between designers and users may then be overcome through participatory approaches. It also follows that IS design under such conditions needs to follow an evolutionary approach starting with the basic needs and gradually building on these to expand the use of the system as the users learn more about the technology and its potential [17]. The case description highlights how an opportunity existed (an enthusiastic manager, access to a computer) which enabled an experimental approach to be adopted. While this was not scaled across all hospitals, it allowed the ability of the system to be demonstrated in one setting, and can be further scaled if required, and access to resources permit.

CONCLUSION:

In conclusion, we would like to suggest that in many developing country contexts, the "one system fits all" option is unlikely to work (it is often too rigid and tightly integrated a system for a complex environment), and can often not be afforded. Rather, an approach that is participatory, and evolutionary is suggested. Paper based information systems can be gradually replaced by more sophisticated systems through an evolutionary developmental approach. An integrated HospMIS can be developed from disparate information systems using scalable approaches in the design of the HospMIS, and by crafting gateways between disparate systems. We believe that in this way, different types of specialised information systems, particularly open source software systems, serving the different departments in hospitals, or different care processes, can be accommodated to provide an integrated HospMIS. However, the process of designing the gateways between different hospital systems has to be sensitive to three issues: the level of sophistication of the technology that is available (solutions must be realistic given the access and capacity of technical resources), the skills levels of the users (and their ability to manage the changes), and the volume (granularity) of data to be processed.

ACKNOWLEDGMENTS

The author wishes to acknowledge the role played by HMIS officers in the hospitals in Malawi and the ECP, their managers, and the management in the provincial and central ministry of health who contributed ideas and support for the projects discussed.

References

1. Hanseth, O. and N. Lundberg, *Designing Work Oriented Infrastructures.* Computer Supported Cooperative Work (CSCW), 2001. **10**(3 - 4): p. 347-372.
2. Lundberg, N. and H. Tellioglu, *Understanding the Complex Coordination processes in Health Care.* Scandinavian Journal of Information Systems, 1999. **11**(1).
3. Hanseth, O., et al., *Reflexive standardisation: Side effects and complexity in standard-making.* MIS Quarterly, 2006(Special Issue on Standards).
4. Monteiro, E., *Actor network theory and cultural aspects of interpretive studies*, in *The Social Study of Information and Communication Technology - innovation, actors and contexts*, C. Avgerou, C. Ciborra, and F. Land, Editors. 2004, Oxford. p. 129-139.
5. Ellingsen, G. and E. Monteiro, *Big is Beautiful - electronic patient records in large hospitals in Norway 1980s-2001.* Methods for Information in Medicine, 2003. **42**(4): p. 366-370.
6. Littlejohns, P., J.C. Wyatt, and L. Garvican, *Information in Practice - Evaluation computerised health information systems: hard lessons still to be learnt.* British Medical Journal, 2003. **326**: p. 860-863.
7. Vander Plaetse, B., et al., *Costs and revenue of health care in a rural Zimbabwean district.* Health Policy Plan., 2005. **20**(4): p. 243-251.
8. Wamukuo, J. and P. Ntutela. *Estimating the Cost of District Hospital Services*. 2002 October [cited 2005 19 November]; Available from: http://www.doh.gov.za/docs/reports/2002/findc-report01.pdf.
9. Montoya-Aguilar, C., *Measuring the Performance of Hospitals and Health Centres*. 1994, Division of Strengthening Health Systems, World Health Organization: Geneve.
10. Odedra, M., *Is Information Technology Really Being Transferred to the African Countries?*, in *Technology Transfer for Development: The prospects and Limits of Information Technology*, S. Bhatnagar and G. Cyranek, Editors. 1992, Tata MC Graw Hill: New Delhi. p. 47-58.
11. Korpela, M., *Traditional Culture or Political Economy?* Information Technology for Development, 1996. **7**(1): p. 29-42.
12. Andersen, N., et al., *Professional System Development*. 1986, Copenhagen: Teknisk Forlag.
13. Davis, G.B., *Strategies for Information Requirements Determination.* IBM Systems Journal, 1982. **21**(1): p. 4-31.
14. Greenbaum, J. and K. Madsen, *Small Changes: Starting a Participatory Design Process by Giving Participants a Voice*, in *Participatory Design: Principles and Practices*, D. Schuler and A. Namioka, Editors. 1993, Lawrence Erlbaum Associates: Hillside, N.J.
15. Braa, J. and C. Hedberg, *The Struggle for District Based Health Information Systems in South Africa.* The Information Society, 2002. **18**: p. 113-127.
16. Tan, J., H.J. Wen, and N. Awad, *Health Care and Services Delivery Systems as Complex Adaptive Systems.* Communications of the ACM, 2005. **48**(5): p. 36-44.
17. Braa, J., et al., *Developing Health Information Systems in Developing Countries - the flexible standards strategy.* MIS Quarterly, Forthcoming.

Address for correspondence
Vincent Shaw
Department for Informatics,
University of Oslo
Post-box 1080 Blindern,
0316 Oslo, Norway
Tel: (+47) 22840143
Fax: (+47) 22852401

E-mail vshaw@hisp.org

APPENDIX 6

Shaw, V., Mengiste, S., & Braa, J. (2007). *Scaling of health information systems in Nigeria and Ethiopia - Considering the options.* Paper presented at the IFIP 9.4, Sao Paulo, Brazil.

SCALING OF HEALTH INFORMATION SYSTEMS IN NIGERIA AND ETHIOPIA - CONSIDERING THE OPTIONS

Vincent Shaw (Email: vshaw@hisp.org)
Department for Informatics,
University of Oslo and University of Western Cape

Shegaw Anagaw Mengiste (Email mengisa@ifi.uio.no)
Department for Informatics,
University of Oslo and University of Western Cape

Jorn Braa (E-mail jbraa@ifi.uio.no)
Department for Informatics,
University of Oslo and University of Western Cape

Abstract: This paper addresses the IFIP 9.4 conference theme for papers that take stock of the development of ICT in the health sector, and in particular how infrastructure and human resource factors influence the implementation of e-development initiatives. Using case studies from the Health Information Systems Programme in Nigeria and Ethiopia, the interdependencies between three spheres are identified as being important in scaling health information systems. The three spheres that are explored are the volume of data collected, human resource factors and access to technology. We draw on concepts from mindful innovation with technology to illustrate that a cultivation approach is appropriate to bringing about change. We suggest that a balance needs to be achieved between the three spheres if scaling initiatives are to succeed, and identify a number of factors that can be used to achieve and maintain the balance. Three flexible standards are identified as being critical strategies to global health information scaling initiatives, namely an essential data set, a scalable process of information systems collection and collation consisting of gateways between paper based systems and hardware and software which can be interfaced with one another, and a cultivation approach.

Keywords: Health information systems, developing countries, scaling, district health information software, health information systems program.

SCALING OF HEALTH INFORMATION SYSTEMS IN NIGERIA AND ETHIOPIA - CONSIDERING THE OPTIONS

1. INTRODUCTION

The scaling of information systems (IS) is a field which has been explored for a number of years in relation to the internet (Monteiro, 1998, 2000) and with respect to the effects of globalization (Rolland & Monteiro, 2002). In the health sector, scaling of health information systems (HIS) is a "pre-requisite and not just a luxury" because in order to make sense of for example immunization coverage data, data from all facilities and services in a region, province, or country are needed (Braa, Monteiro, & Sahay, 2004, p. 341). Yet, despite this imperative for sustainable information systems (IS), this field of study has not been explored in depth. In this paper, we explore the choice of solutions in scaling HIS in one region from each of Ethiopia and Nigeria, and draw lessons for scaling of IS in general. The selection of these countries is purposeful – they represent the two most populous states in Africa, and together represent almost 30% of the sub-Saharan population. Scaling HIS in these contexts is about scaling of large scale systems so as to achieve an appropriate coverage of the population to make meaningful sense of the data. We address the request in the call for papers that papers take stock of the development of ICT in the health sector, and in particular how the infrastructure and human resource factors influence the implementation of e-development initiatives.

Although scaling of HIS has been alluded to in three papers related to the Health Information Systems Programme (HISP) network (Braa, Hanseth, Heywood, Mohammed, & Shaw, Forthcoming, Braa, Monteiro, & Sahay, 2004, Sahay & Walsham, 2005), little detail exists about the choices when implementing (and scaling) large scale HIS. Sahay and Walsham (2005) describe the tension between globalization and localization, and the need to consider which parts of a system are scaleable and which require local customization. This challenge is central to the scaling of large HIS in complex environments, and is the focus of our research. We address this by exploring the role that human resources and technological components play in influencing the type and volume of data that can be collected and processed as HIS are scaled.

IS should be designed in a manner that allows them to be scaled through an evolutionary process (Braa et al., Forthcoming). In this paper we build on the concept of cultivation of IS by drawing on the concept of "mindful innovation of IT" (Swanson & Ramiller, 2004). Mindfulness, is characterized by an openness to novelty, alertness to distinction, sensitivity to different contexts, implicit or explicit awareness of multiple perspectives, and orientation in the present (Weick, Sutcliffe, & Obstfeld, 1999). We suggest that for successful scaling of HIS, mindfulness is required to balance the available human resources, access to technology and the type and volume of data collected by the HIS. By paying attention to these spheres and their interdependencies, rational choices can be made regarding which aspects of the IS can be unproblematically scaled and which require specific attention and local adaptation.

This paper proceeds as follows. The literature review addresses the scaling of HIS, and the use of mindfulness as an appropriate strategy for cultivation and scaling of HIS in complex organizations. In section three the methodology is presented. Section four describes the case of HIS development in Jigawa State of Nigeria and Amhara Region of Ethiopia. The discussion section follows and lastly concluding remarks and acknowledgements are presented.

2. THEORETICAL CONSIDERATIONS

2.1. Scaling of Health Information Systems:

The scaling of information systems can be viewed along two axes (Table 1). The horizontal axis reflects the replication of processes across geographic spaces, or across new functional areas. (Braa et al., Forthcoming). Scaling along the vertical axis occurs through increasing the "depth" of penetration of the health system, or increasing the technological sophistication of the IS. Sahay & Walsham (2005) point out that scaling is not only about the technical aspects, but also about the people and processes, and escalating complexity. Not only does scaling require the implementing team to be cognizant of the needs that should be addressed by the scaling process – technical as well as human resource needs, but they also need to be aware that as scaling occurs, complexity (linked to "institutional practices (and) politics" (ibid, p. 51) is likely to increase. Building on this understanding, a third dimension to scaling IS is presented as the extent to which the system is rooted in people and work practices, and which describes how well the system is working (Table 1).

As IS are scaled horizontally or vertically, heterogeneity is likely to increase (Sahay & Walsham, 2005). Flexible systems are required to accommodate differences and changes (Braa, Hanseth, Heywood, Mohammed, & Shaw, Forthcoming). Flexibility is achieved in different ways. Along the horizontal axis, common data standards are used to provide uniformity across the geographic scope – for example the "essential dataset" (EDS) (Braa & Hedberg, 2002). The EDS is "a set of the most important data elements, selected from all primary health care programs, that should be reported by health service providers on a routine basis" (Shaw, 2005 p.632). Using the concept of the "hierarchy of information needs", the local users can expand the essential dataset to address their specific needs, while still reporting on the essential data required at the central level. In this way a dynamic balance is achieved between the local and the global information needs (Jacucci, Shaw, & Braa, Forthcoming; Rolland & Monteiro, 2002; Sahay & Walsham, 2005). The data standard is thus a "flexible standard" that allows "integrated independence" – the ability to experiment and develop local indicators while maintaining the data standard (Braa et al., Forthcoming).

Along the vertical axis, the challenge is to seamlessly integrate the flow of information between incompatible systems represented by the geographic periphery, and different technological systems, while also accommodating the need for change. To do this, gateways are used. Gateways are of the following types: paper-to-paper, paper-to-computer, and computer-to-computer, and will typically consist of simple software solutions and/or procedures. Utilizing gateways in various combinations accommodates flexibility and heterogeneity in that sub-systems of the IS can be changed or replaced without affecting the flow of information through the whole system. As access to technology in the periphery improves, computers can easily replace paper-based systems without negatively affecting the whole. Gateways provide flexibility as they are replaced and adjusted as sub-systems change.

Despite these insights, there is a need for practical guidance on strategies to effect scaling of IS. The cultivation approach is presented in the next section as an approach that is sensitive to the ever changing dynamics of the health sector environment.

Axis	**Horizontal Axis (Dimension 1)**		**Vertical Axis (Dimension 2)**	
Aspect of the health IS	Data standards - what data?	Geographic scope	Depth of penetration of the health system hierarchy	Technology standards (sophistication of the technical components)
Explanation	The message. From whom does the message come? Both geographic scope and spread across different programme areas.		How is the message communicated between levels, or from one system to another?	
	Essential data set	One facility	State/Region	Paper based systems
	Pharmaceutical data	Additional facilities till whole state included.	Zone/Gunduma	Stand alone computer
	Notifiable diseases	Additional states till whole country included.	LGA/District	Networked computers
Increasing sophistication	Other types of data, e.g. survey data	One country	Health clinic and hospital	Internet based IS
			Community	
			Individual patient record	
Dimension 3: The extent to which the system is "rooted" in the social system, information use & ownership – this drives the imperative to scale HIS vertically and horizontally				

Table 1: Understanding the different aspects of the Health Information System

2.2. Scaling HIS as a cultivation process:

The study of complexity within health organizations suggests that adaptability is an important characteristic (Begun, Zimmerman, & Dooley, 2003). It recognizes the ability of organizations to accommodate changes in their environment through a process of adaptation. This can be seen as a survival mechanism, and explains how organizations gradually adopt new ways of working as for instance technology changes. Change that occurs through incremental steps is appropriate in organizations because it accommodates change with minimal disruption to the existing processes (Bergqvist, Dahlberg, & Ljungberg, 2002).

The distinction between cultivation and construction dates back to Aristotle. For example, cultivation is seen as helping nature produce more perfectly things she could produce of her own accord, while construction entails reforming nature to produce things not found (Mitcham, 1994). "Another version of this distinction might contrast technological actions that are in some way in harmony with nature with those that are not" (ibid, pp 211). By "replacing" nature in this quote with a social systems perspective on IS (e.g. Braa & Hedberg, 2002), we might say that cultivation as a strategy in this context will entail being in harmony with the social systems and building on the resources already there, although in a "progressive" bottom-up perspective of change. Not only has cultivation has been used to describe an approach to organizational change in which people are central to the information system (Bergqvist, Dahlberg, & Ljungberg, 2002), but it has also been used as an appropriate strategy for effecting change in information infrastructures (Aanestad 2002; Hanseth 2002). However, in considering the scaling of HIS in India, the bottom-up cultivation approach that was initially adopted needed to be complemented by a top-down strategy that provided legitimacy for further scaling (Sahay & Walsham, 2005), and similarly in South Africa (Braa, et al, Forthcoming). Yet, even when the systems are officially accepted, access to resources do not necessarily improve, and the further scaling of information systems has to occur within the existing resource constraints. This is often the dilemma of those involved in the implementation (and scaling) of HIS – how to accommodate the increasing demands (the "all or nothing" imperative (Braa, Monteiro, & Sahay, 2004, p. 340) or face the risk of the system being replaced by yet another alternative system that is perceived to be more useful.

Weick, et al (1999) has used the concept of mindful innovation to describe the adoption of IT in high reliability organizations (HRO's) like naval aircraft carriers and nuclear power stations. These organizations utilize "complex processes to manage complex technology" (Weick, et al, 1999, p. 83) because the consequences of failure in an environment that is vulnerable and subject to unexpected changes are devastating. Organizations wishing to survive in these conditions must be able to adapt to unexpected changes. Adaptive responses to the unexpected requires mindfulness, as characterized by a pre-occupation with failure, a reluctance to simplify interpretations, a sensitivity to operations, a commitment to resilience and a reliance on expertise over formal authority (Swanson & Ramiller, 2004). Mindfulness enhances the cultivation approach for scaling HIS by suggesting a number of specific characteristics that should be incorporated in the approach to scaling HIS. Three of these are summarized in Table 2. Using empirical data from Ethiopia and Nigeria, the importance of paying careful attention to these characteristics, especially as they relate to the complex interactions between the skills and capacity of people in utilizing technology to communicate and process health information, is demonstrated.

Characteristic	Brief description and application to HIS
Preoccupation with the possibility of failure	Through constantly being aware that IT projects are prone to failure, a pro-active awareness of opportunities that can be harnassed to support the successful scaling should be encouraged. (we use empirical data to demonstrate how an "awareness of the possibility of failure" can be used to guide which aspects of the IS can be unproblematically scaled and which require specific attention and local adaptation.
Commitment to resilience	It is impossible to identify every possibility that might arise during scaling of HIS – therefore improvisation will be required to complement plans, adaptation will be necessary, and effectiveness required rather than efficiency.
Sensitivity to operations	small faults can cause major consequences if not addressed. This is the processes of local customization to ensure that systems and procedures are locally appropriate. It also entails responding to seemingly small problems before they create larger problems.

Table 2: Brief description of some characteristics of mindful innovation

3. METHODOLOGY:

The empirical basis for this study is derived from the large scale and on-going HISP action research project which is engaged in the design, development and implementation of HIS in many developing countries including Ethiopia (Braa et al., 2004) and Nigeria. We have purposefully selected a single state/region from each of these countries based on the in-depth knowledge by the authors, and because the scaling of HIS in the two regions present similarities and differences which allow interesting comparisons to be presented.

The principle author's involvement in Nigeria began in 2003 at the initiation of the 5 year, Nigerian Partnerships for Transforming Health Services (PATHS) project funded through the British Department for International Development (DFID). The project is active in 5 of the 37 Nigerian states. He has in the last year spent about 90 days in Nigeria in these two states, supporting the improvement, and scaling of primary health care IS. The second and third authors have been involved in IS development in Ethiopia since 2003 when HISP activities began through a collaboration with Addis Ababa University and the University of Oslo. The second author, an Ethiopian national and member of the HISP-Ethiopia team, has provided support to the RHB's, and in particular to the Amhara Region.

Data sources accessed during project activities includes on-site observations, notes made in a diary kept specifically for the purpose, photographs, documents, tools and project reports. The research data has been analyzed in the interpretivist research tradition as described by (Walsham, 1993).

4. CASE DESCRIPTION:

In the case descriptions we initially provide a background perspective on the development of the state and the health system, and then describe particular aspects related to the development of the HIS. In each case we have tried to detail aspects related to the three spheres under consideration, namely the data collected, the technology, and the staffing.

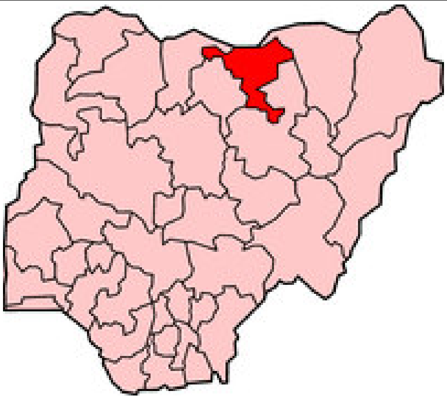
4.1. Background

Jigawa is a new state, having been created out of the Kano state in northern Nigeria in 1991(Table 3). It is the sixth Nigerian state to introduce Sharia Law. The state is divided into 27 local government authorities (LGA's), and state and local government councilors are democratically elected. As in the case of Amhara Regional State, considerable effort is being directed towards decentralization of services.

The two case study sites have remarkably similar indices (Table 3). Both have poorly developed infrastructure, and (in terms roads, electricity, telecommunications), although in recent months access to electricity and telephones has increased remarkably in the periphery of Amhara Region State. Human capacity is poor in both states, and immense geographical distance (e.g. one of the zones is located at a distance of more than 700 km from the regional capital) hinders communication and supervision.

Health services are poorly developed in both states. In Jigawa, the maternal maternal mortality rate is estimated to be 1,700/100,000 live births in Northern Nigeria (Kano State Economic Planning Committee, 2004; Shiffman, Okonofua, & Ved, 2006) – several times higher than that for Nigeria. It is estimated that in Amhara Regional State, basic services are provided to only about 60% of the population (Ministry of Health, Ethiopia, 2005).

A key difference between the two case study sites is that in Amhara Region, access to ICT has increased dramatically in the last few months as part of a governmental initiative, while in Jigawa outside of the main centers ICT infrastructure is extremely week. However, in Jigawa the staffing levels are higher (even if skills are low), while in Amhara the staffing levels are extremely poor. These differences have required different approaches to the development of the HIS, as is discussed below.

<table>
<tr><th colspan="2">Jigawa Statistics[1]</th><th>Amhara Statistics</th></tr>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td>23,154 km²</td><td>Surface Area</td><td>161,828.4 km²</td></tr>
<tr><td>4,9M vs 131,5M for Nigeria</td><td>Population 2005 est</td><td>19M vs. 74M for Ethiopia</td></tr>
<tr><td>49%</td><td>Population under age of 15 years</td><td>44%</td></tr>
<tr><td>22% for women and 51% for men</td><td>Literacy Rate (2002)</td><td>22% for women and 46% for men</td></tr>
<tr><td>US$290 vs. $1,188 Nigeria average</td><td>Gross per Capita Income (2001)</td><td>US$100 vs. $120 Ethiopian average</td></tr>
<tr><td colspan="3">Table 3: Selected Statistics for Jigawa State, Nigeria and Amhara Regional State, Ethiopia</td></tr>
</table>

4.2. Information systems development in Jigawa – limiting the dataset

In Nigeria, the PATHS project has been supporting health systems development through targeted program support, particularly to maternal and child health programs, malaria and tuberculosis and sexually transmitted infections. Supporting the HIS has been integral to these initiatives (Figure 1). HMIS development occurred in Jigawa and 2 other states as a parallel process based on the South African experience of HIS development using the DHIS software (Braa & Hedberg, 2002). Three aspects of the HIS development are highlighted. First, 8 of the 27 LGA's were identified to serve as pilots - allowing the implementation team to gain experience and learn lessons in the initial implementation. Secondly, an EDS was developed for use across the PATHS states. The process of developing and gaining acceptance of the EDS did not occur without controversy. Major

[1] Obtained from various sources, including data used in the DHIS for population data

opposition to the EDS was received from senior Federal Ministry of Health (FMoH) officials who were advocating use of over 1000 data elements and a software product that provide little benefit to its users. Eventually, through high level negotiations, an agreement was reached that an EDS of 127 data elements, which could provide data on 74 indicators, would be used as a pilot in the PATHS states only. Subsequently (in 2005) a slightly modified version has been used as the standard across the country. Thirdly, the DHISv1.3 software was adapted to the Nigerian context, and used at the state level for data capture and analysis of monthly facility reports.

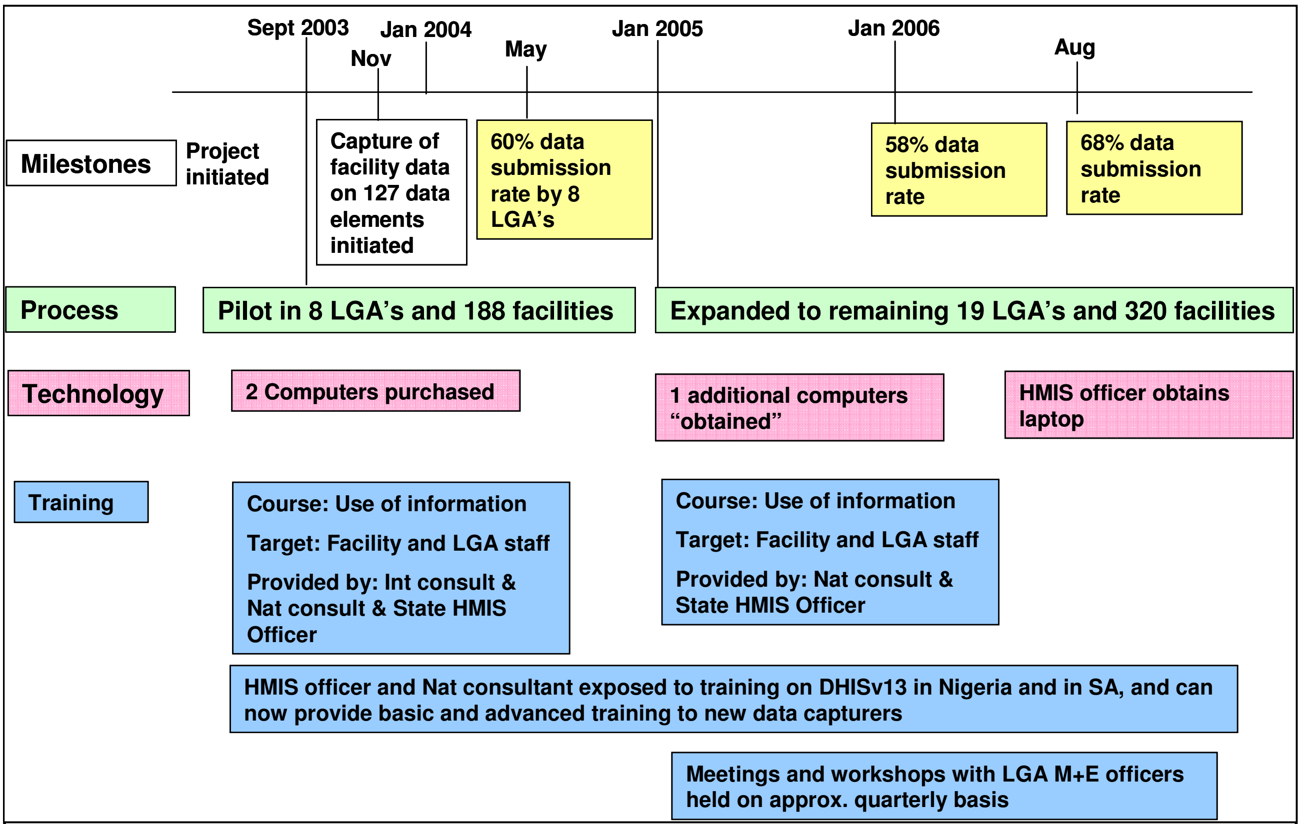


Figure 1: Timeline of initiatives in Jigawa, Nigeria

In the absence of technology, reliance is made on paper based IS for data collection and onward transmission, from facility, through local government authority level, and up to state level (Figure 2). Data capture occurs at state level. Gateways are used at two levels. A paper-paper gateway transfers data from patient registers to monthly reports (facility level), and a paper-computer gateway is used at the point of data capture (state level). Data is captured by two staff in the HMIS unit. The achievement of a 68% data coverage for the last 12 months (as at August 2006) is significant given the constraints (unreliable access to electricity, lack of funds for generator fuel and pressure on data capturers to perform other tasks), and only the PATHS states can claim similar data coverage rates.

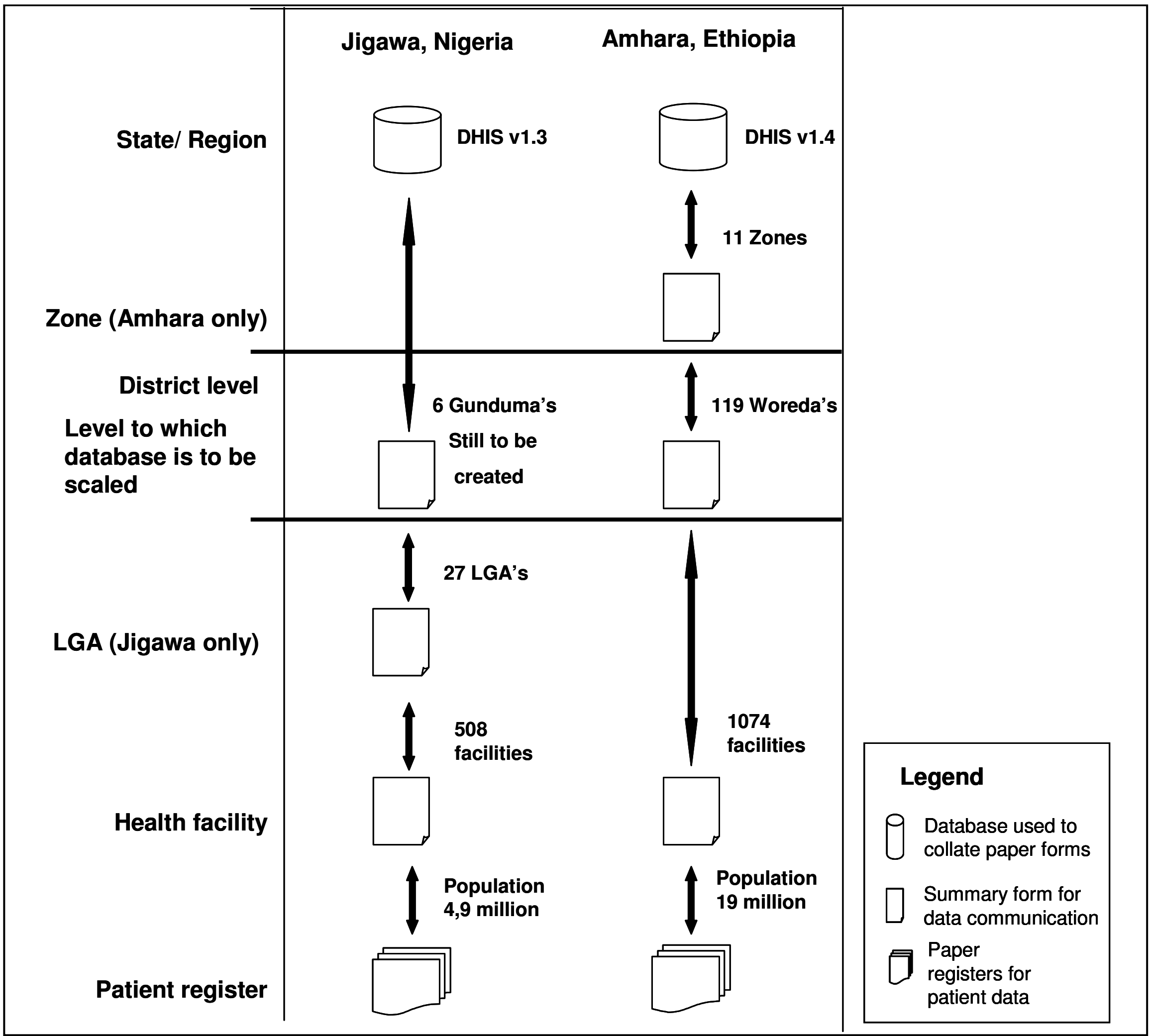


Figure 2: Data flows demonstrating the use of gateways between incompatible systems

A strength in Jigawa is that staff exist at each level, and have received training related to the HIS (Figure 1 and Table 4). Through these processes the in-country teams have developed capacity to continue basic training on their own. International support is available to support the more sophisticated aspects of the software, and of HIS implementation. Institutionalization of training initiatives is to be strengthened through establishing links with a local university.

Hierarchical level	Numbers of staff	Staff involved in the HIS	Access to computers and electricity
Facilities	508	At least one person in each facility participated in training on use of information	Seldom have access to grid electricity. May have solar panels, which often are non-functional. Rely on paper based data collection, but paper itself is in short supply.
Local government	27	One PHC Coordinator (political level) and an Monitoring and Evaluation Officer[2]	Grid electricity is unreliable. Almost no computers at this level.
State Ministry of Health	1	State HIS Officer, and 2 data entry clerks	Grid electricity is unreliable, and more often than not reliance is on a generator which usually only runs "when certain senior officials are in the office". Three computers and one laptop

Table 4: Overview of access to staff and computers in the Jigawa Health System

4.2.1. Summary:

The phases in the HIS strengthening initiatives in Jigawa are presented in Table 5.

Phase	Time period	Activity	Comment
I	Sept 2003 - Jan 2005	Pilot in 8 LGA's	EDS defined, data flow improved, new process of data capture using DHIS1.3 at state level introduced, intense training provided
II	Jan 2005 - Jan 2006	Horizontal scaling across geographic areas (LGA's)	EDS held static and data capture maintained at state level, increase in volume of data (additional LGA's), intense training by local team (demonstrating some capacity been developed)
III	Jan 2006 - Aug 2006	Consolidation period	Efforts directed at improving adherence to data flow and improving data capture process Efforts to encourage use of information Advocacy meetings with senior managers
IV	Nov 2006	Conversion DHIS13 – DHIS14	All else held static – training to be provided on new version of DHIS
V	Jan 2007 onwards	Decentralizing data capture to gunduma	Still to take place, but has been discussed, and planned for about 18 months.

Table 5: Phases in HIS Strengthening Activities

Phases three through five require specific mention. Phase three is a consolidation period. A number of workshops have been convened where existing data (even if incomplete) is used as a means to encourage LGA's to ensure that at least 90% of their facilities report. Interestingly, the ability to present and analyze data has created huge interest amongst program managers at the State and Federal levels as, for the first time, comparative data has been presented across the five

[2] In reality, there are more people involved at this level, as many of the vertical programmes have their own "M+E officers" – reflecting the constant battle between integration and verticalization (fragmentation) of services, especially in an environment which has a large donor driven component

PATHS states. The upshot of this has been that HISP-Nigeria has now been asked to implement DHISv1.4 and provide training to all remaining states in Nigeria!

Phase four involves the conversion from DHISv1.3 to DHISv1.4, and is currently underway. During 2003/04 a new improved version of the DHIS software, called DHISv1.4, was being tested in South Africa, Botswana and Zanzibar. In Nigeria though, the introduction of this more powerful and efficient version was delayed till late 2006, because at the time the team had limited capacity to absorb new initiatives. In August, Kano state began to use the DHISv1.4, and as implementation proceeded smoothly, training is currently being done in Jigawa (and offered to other states to attend as well). The process of transition to DHISv1.4 reflects the cultivation processes used so successfully – not only in that piloting in one region is initiated before larger scale implementation, but the translation to a newer version of the same software is also a cultivation process.

Phase five is still to be enacted, namely the decentralization of data capture to gunduma level. Ideally data capture should occur at the LGA level. But, in this case 27 computers accompanied by generators, UPS systems, and secure and dust free abodes need to be provided, as well as training and support to the 27 HIS Officers. This is not achievable given the current access to resources. Rather, the plan is to scale to gunduma's, and to provide an additional 6 computers, and generators, and to locate these at hospitals (where power supply would be more regular and a secure and dust free environment is more likely to be found). Each would capture data from about 85 facilities. Training on the use of the DHIS software will draw on those LGA HIS officers who are dedicated and reliable. New HIS officers from facility staff will be identified to support the LGA level. Scaling in this way potentially trebles the pool of data capturers, and also shifts the responsibility one step down the hierarchy in a manner consistent with resource availability.

4.3. Information systems development in Amhara Region State - increasing the data volume

The flow of information is similar to that in Nigeria (Figure 2). However, prior to the project initiation, the Woreda Health Offices compiled summary reports (using the health facility reports), and the aggregated report was submitted to the zonal office, which sent it to the ARHB (Amhara Regional state Health Bureau) and then to the FMoH. During the aggregation process, the identity and details of the original facility data was lost, making it impossible to trace data back to a single facility. Data capture occurred at the Regional level. Prior to the initiation of the HISP project, the existing HIS has been a one way reporting system designed to report data to higher levels and vertical programs without any feedback to the lower levels. An EDS was developed over an 18 month period (up to December 2005) using a participatory approach and with support of the RHB. Standardized reporting formats were developed, and the DHISv1.4 was customized for implementation at regional and zonal levels. The new reporting system brought about changes to the flow of information – facility reports would be captured instead of aggregated data. This created a tenfold increase in the volume of data, as instead of monthly reports from 119 woreda's, 1047 monthly facility reports were to be captured. As a result, there was a need to decentralize data capture to zonal, and possibly woreda level.

A survey of access to staff, computers, and internet was conducted (Table 6). This shows how access to computers, telephone and electricity both at zonal and district levels has improved remarkably in the last few months, although surprisingly the level of internet connectivity both at zonal and district level remains low (but is likely to be addressed through a large World Bank and

International Monetary Fund (IMF) funded project - WoredaNet). A critical problem though is the lack of assigned HMIS staff to specifically do HMIS related activities, and they do not have the skills and training with regard to modern information and communication technologies.

Zone	Districts (Woredas)	Districts with access to telephone & electricity	Districts with computers	Districts with internet (Dial-up) access	Districts with assigned personnel for HMIS
North Gondar	18	16	10	2	None (not even at Zonal level)
South Gondar	10	9	8	1	2
Wag Hemra	4	3	3	None (not even at zonal level)	0
North Wello	9	9	7	1	2
South Wello	18	14	11	1	None (not even at Zonal level)
Oromiya special zone	5	3	2	None (Not even at zonal level)	0
North Shoa	20	18	18	None	None (not even at Zonal level)
East Gojam	15	11	7	1	None (not even at Zonal level)
Awi zone	6	4	4	None (not even at zonal level)	0
West Gojam	13	12	9	None (Not even at zonal level)	None (not even at zonal level)
Bahir Dar Special zone	1	1	1	None (not even at zonal level)	0
Totals	**119**	**100**	**80**	**6**	**4**

Table 6: Analysis of access to computers, internet and staff in Amhara Regional State

To address the skills gap, a two week training course for staff from the 11 zones was conducted in May 2006 by the HISP-Ethiopia team. As many trainees had very limited computer literacy skills, the first three days were devoted to increasing their familiarity with MS Office applications, (specifically MS Excel and MS Access since they are linked to the DHISv1.4 for report generation and data analysis). The remainder of the training focused on the principles of data capture in DHISv1.4. At the end of the training, trainees were provided with installation CD's, and were instructed in the installation procedure for the software. However, shortly thereafter the HISP team started to receive phone calls from zonal health departments requesting support on the installation process. In July 2006, when a team of three HISP members (including one of the authors) conducted follow-up on-site training in the zones, they found that none of the trainees had managed to successfully install the software in their computers. This was due to the low computer literacy of the trained staff who had difficulty grasping the installation procedure. As the HIS focal person in one of the zones indicated:

> "…the training given for us in May 2006 in Baher Dar was good, but for most of us with less background and knowledge even on basic computer applications, the complex instructions and dialogue boxes popping up during installation of DHIS software makes it very difficult for me to successfully install and use the system."

We see in this example, how, the balance between the human resources (numbers, and skills levels) and the technology needs to be managed, otherwise the technology will not be used to its full potential. An alternative option that is now under consideration, instead of trying to achieve homogenous scaling to all levels at the same time, would be to scale to those woreda's that have the capacity to absorb the training and which have the technology available. We thus allow uneven development to occur, but through a cultivation strategy.

4.3.1. Summary:

In Amhara Region then, we can discern three phases to the HMIS strengthening activities (Table 7).

Phase	Time period	Activity	Comment
I	June 2004 - Dec 2005	Period of consultation and buy in	EDS defined, data flow changed with huge increase in data volume
II	Jan 2006 - current	Vertical scaling of data capture to zones	Training and support for data capturers
III	Oct 2006 – Jul 2007	Vertical scaling of data capture to selected districts	Training and support for data capturers

Table 7: Summary of HIS Implementation in Amhara Regional State

5. DISCUSSION:

We see in these examples, an interesting interplay between what we have termed the three spheres of the IS, the data sphere, the technology sphere, and the human resource sphere. These are presented in a model (Figure 3). The three spheres are interlinked with one another in complex ways, and understanding and being sensitive to the complexities of these inter-linkages is important in "innovating mindfully" with technology. The oval shapes represent an assessment of the capacity of each state in relation to the three spheres. Jigawa and Amhara Region differ in their human resource capacity and access to technology and this has had implications on the volume of data that they can effectively manage, and the process for strengthening the HIS.

In Nigeria, centralized data capture was initiated because of the absence of ICT infrastructure in the periphery, and despite the presence of sufficient staff there. However, data capture of 508 facility reports in a central office is not an easy task. It was kept manageable by limiting the EDS to a small number of data elements. Decentralization (scaling along the vertical axis) is proceeding "cautiously" as ICT infrastructure improves. In Amhara, the process was driven by the need for disaggregated data (increased depth of penetration of the hierarchy) resulting in an explosion in the volume of data. Given the relatively good access to ICT, decentralized data capture was possible, despite the limited availability of staff. However, the implementation plan had to be re-assessed because efforts at improving staff capacity were hindered by their limited ability to absorb the training. As HIS implementation proceeds, so the capacity in each of the spheres changes (skills improve, access to technology improves, and data volume may increase), and a never-ending spiral results as the balance is maintained. As the process spirals the HIS is scaled.

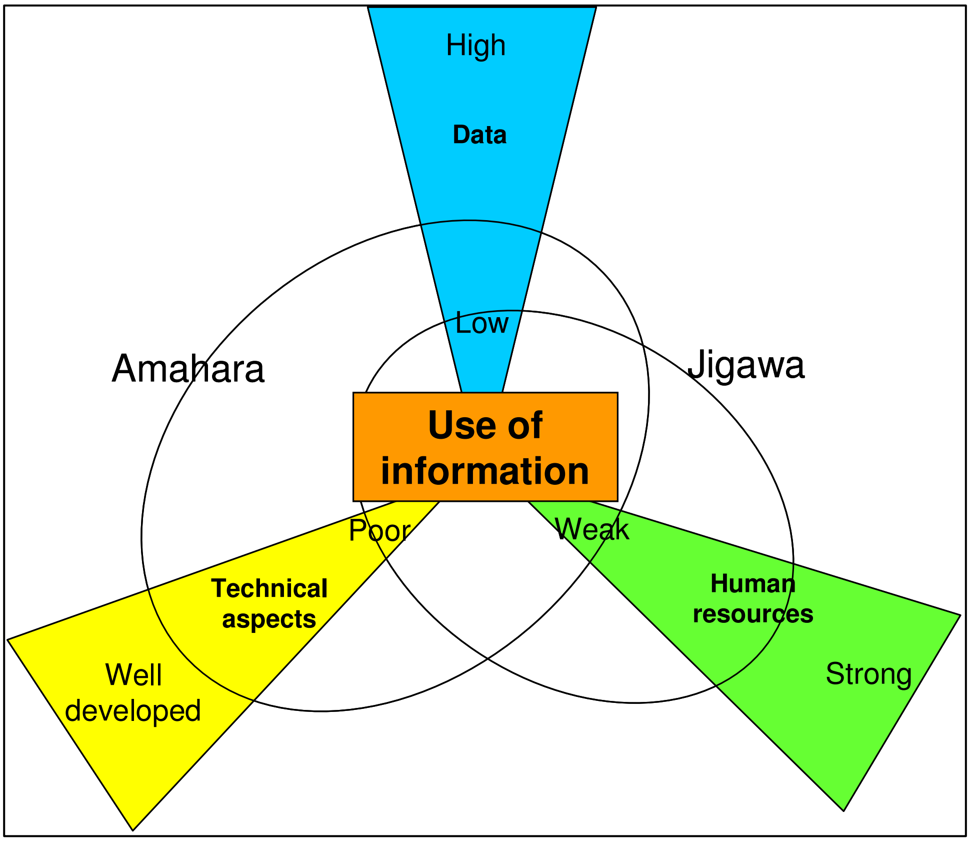


Figure 3: The influence of resource availability on HIS development

Based on an iterative process of analysis of the case material, the factors that affect each sphere are presented in Table 8. Given the importance of balance between the three spheres, this analysis is a useful checklist which can be used (in support of "a sensitivity to operations") to assess the strengths and weaknesses in an organization where scaling is planned. For instance in the Amhara example, the decision to capture facility data (meaning the depth of penetration of the health system by the HIS– Table 1) increased the volume of data to be captured, resulting in a need for increased data capturing capacity. How could this be achieved within resource constraints? Lead districts can be identified by assessing which best fit the criteria listed in the table. In this way, uneven development can be used to spearhead scaling of HIS. The analysis thus helps identify which areas can be successfully scaled ahead of others.

SPHERE	CONTRIBUTING FACTORS
Data components	Volume of data, affected by: Extent of integration from vertical programs (Jigawa) Geographic scope (e.g. In Jigawa, 8 of 27 LGA's piloted) Granularity of data (penetration of hierarchy from national to community and individual levels – the Amhara example)
Human resources aspects	Numbers of staff (Jigawa and Amhara) Skills level of staff (Amhara) Ability to provide support (Jigawa and Amhara) Ability to train and build capacity (Jigawa)
Technical aspects	Scalable processes integrated in the information system (Jigawa and Amhara) Software appropriate and scalable (Jigawa and Amhara) Access to computers (Jigawa and Amhara) Access to internet (Amhara)

Table 8: The Factors Contributing to Each Sphere

The concept of utilizing lead districts to spearhead scaling and HIS development warrants further exploration. Development of the HIS and local commitment, the level of its use and quality of data, will typically proceed at an uneven pace between districts. Local champions and otherwise favorable conditions in individual districts may typically lead to "best practice" districts. An effective scaling strategy needs to support these lead districts and actively use these best practices in the horizontal scaling of the HIS to other districts. More concretely we have seen how best practices have turned into "attractors for change" (Eoyang, 1996) by creating support and interests and thereby sufficient momentum and "critical mass" to bring about changes also in other districts.

A cultivation approach, characterized by mindful innovation is required to maintain the spiral as HIS are scaled. In order to minimize the risk of failure then, careful attention to the context is required, and in particular to the ability to accommodate and absorb change (a sensitivity to operations). Inefficiencies may need to be accepted because of imbalances between the three spheres (in the case of Jigawa the inefficiency of centralized data capture, in Amhara the need for a reconsideration of the decentralization strategy). Further examples are summarized in Table 9.

Characteristic	Examples from case material
Preoccupation with the possibility of failure	Nigeria: Careful planning prior to implementation at Gunduma. Constant consideration of how sustainable IS are developed Ethiopia: Conducting survey to assess capacity prior to implementation.
Commitment to resilience	Nigeria: Delaying introduction of DHIS14 till conditions were favourable. Ethiopia: Follow-up training support provided when trainees did not understand instructions sufficiently
Sensitivity to operations	Nigeria: Decision to first decentralise to Gunduma before going to LGA level. Holding other changes back when introducing DHIS14 Ethiopia: Allowing uneven development to occur

Table 9: Brief description of some characteristics of mindful innovation

In reality, as HIS are scaled, and experience is gained, the relative balance between the three spheres is likely to change. The position of the Amhara spiral in Figure 3 reflects the average situation across the state, but in fact it could be composed of 11 very different zonal spirals, or 119 woreda spirals, each depicting differences in access to resources. As changes are brought about, whether by a need for increased data volume, or as additional staff are brought on board, or as access to technology improves, the balance needs to be reestablished. The challenge in scaling is to keep the balance between the three spheres. This can be achieved through a process of improvisation, using the available resources optimally, and innovatively. Plans and implementation processes need to be constantly assessed and adapted. In our cases, mindful innovation has entailed the synergetic interaction between the three spheres, but has also been influenced by the use of information. This is the third dimension depicted in Table 1, and is required for vertical and horizontal scaling. Improved quality of data and information, such as reports that address managers' (and other users, as in the Nigeria case) needs, are both caused by and causing improved human resources, which again lead to an improved system including the technical aspects. While the users are learning how the system can serve their needs and thereby sparking gradually more advanced requests, those involved in the systems development are learning how to meet these requests. Through this iterative process, the software and overall system are being gradually improved. As ownership and perceived usefulness increase, vertical and horizontal processes will need to be replicated at each level (e.g. district, state/region, national) of the health system as scaling occurs. IS development occurred through small changes and problems are overcome through adjustments of the "ideal" plan to one which is dictated by practicalities (the factors that affect the spheres).

This brings us to our research question, namely are there aspects of an IS which can be scaled unproblematically?

6. CONCLUDING REMARKS:

Considering the factors depicted in Table 8, we cannot say with absolute certainty that there was any single factor that was able to be scaled "unproblematically" – the nature of the local context, and the access to resources, required specific adaptations to be made for each of the factors. But, drawing on the case descriptions, and similar accounts in the literature (Braa et al., Forthcoming; Braa et al., 2004; Rolland & Monteiro, 2002), it is clear that certain strategies are central to successful scaling. The first is the concept of the EDS (and which will not be further elaborated here). The second is in the technical sphere, and is depicted in Figure 2 - a scalable process of information collection and collation consisting of gateways between paper based systems and hardware and software which can be interfaced with one another at various levels of the hierarchy as access to technology changes, and which can accommodate heterogeneous (uneven) development across geographic areas. The third represents the cultivation process – or the spiral itself – which includes improvisations and a variety of ways to develop, facilitate and motivate increased information use, local champions, commitment and ownership. We have seen that the development of lead districts, good examples and attractors for change are crucial elements in the cultivation and scaling strategy These three strategies have been identified as "flexible standards" (Braa et al., Forthcoming), and as can be seen in Table 1, they support the scaling process (and the changes that accompany scaling) across geographic scope and depth of penetration of the hierarchy of the health system. We would thus conclude that "flexible standards" are strategies that can be scaled on a global level, but that for the successful scaling of HIS, it has to be accompanied by a local cultivation process that balances the spheres of volume of data, access to technology, and human capacity.

7. ACKNOWLEDGEMENTS:

We wish to pay tribute to all our counterparts working in the remote regions of Jigawa and Amhara, and those in the administrative offices at the district, or regional levels who have supported our efforts at improving the IS.

8. REFERENCES:

Aanestad, M. (2002). *Cultivating Networks: Implementing surgical telemedicine.* University of Oslo, Oslo, Norway.

Begun, J. W., Zimmerman, B., & Dooley, K. (2003). Health Care Organizations as Complex Adaptive Systems. In S. M. Mick & M. Wyttenbach (Eds.), *Advances in Health Care Organisation Theory* (pp. 253-288). San Francisco: Jossey-Bass.

Bergqvist, J., Dahlberg, P., & Ljungberg, F. (2002) Scalability through Cultivation - designing IT support for co-ordination work. Retrieved 13 November, 2006, from http://citeseer.ist.psu.edu/cache/papers/cs/23947/http:zSzzSzwww.dahlberg.sezSzpubzSzmaster.pdf/scalability-through-cultivation-designing.pdf

Braa, J., Hanseth, O., Heywood, A., Mohammed, W., & Shaw, V. (Forthcoming). Developing Health Information Systems in Developing Countries - the flexible standards strategy. *MIS Quarterly*.

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., & Sahay, S. (2004). Networks of Action: Sustainable Health Information Systems Across Developing Countries. *MIS Quarterly, 28*(3), 337-362.

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

Hanseth, O. (2002). From systems and tools to networks and infrastructures - from design to cultivation. Towards a theory of ICT solutions and its design methodology implications. Retrieved 2 September, 2005, from http://heim.ifi.uio.no/~oleha/Publications/ib_ISR_3rd_resubm2.html

Jacucci, E., Shaw, V., & Braa, J. (Forthcoming). Standardization of Health Information Systems in South Africa: The Challenge of Local Sustainability. *Information Technology for Development,* ( ).

Kano State Economic Planning Committee. (2004). Kano State Economic Empowerment and Development Strategy (K-SEEDS).

Ministry of Health (MOH) [Ethiopia]. 2005. *The Health Sector Strategic Plan (HSDP III).* Addis

Ababa, Ethiopia: Ministry of Health.

Mitcham, C. (1994). *Thinking through Technology. The Path between Engineering and Philosophy*. The University of Chicago Press, Chicago. 397 pages.

Monteiro, E. (1998). Scaling Information Infrastructure: The Case of the Next-Generation IP in the Internet. *The Information Society, 14*(3), 229-245.

Monteiro, E. (2000). Monsters - From systems to actor-networks. In K. Braa, C. Sorenson & B. Dahlbom (Eds.), *Planet Internet.* Lund, Sweden: Studentlitteratur.

Rolland, K., & Monteiro, E. (2002). Balancing the Local and the Global in Infrastructural Information System. *The Information Society, 18*, 87-100.

Sahay, S., & Walsham, G. (2005, 26-28 May 2005). *Scaling of Health Information Systems in India: Challenges and Approaches.* Paper presented at the International Federation for Information Processing Working Group 9.4 Conference, Abuja, Nigeria.

Shaw, V. (2005). Health information system reform in South Africa: developing an essential data set. *Bulletin of the World Health Organisation, 2005*(83), 632 - 639.

Shiffman, J., Okonofua, F. E., & Ved, R. (2006). The State of Political Priority for Maternal Mortality REduction in Nigeria and India [Electronic Version]. Retrieved 14 November 2006 from http://paa2006.princeton.edu/download.aspx?submissionId=60071.

Swanson, E. B., & Ramiller, N. C. (2004). *Innovating mindfully with technology. MIS Quarterly, 28*(4), 553-583.

Walsham, G. (1993). *Interpreting Information Systems in Organizations*. Chichester, England: John Wiley and Sons.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (1999). Organizing for High Reliability: Processes of Collective Mindfulness. *Research in Organizational Behavior, 21*, 81-123

APPENDIX 7

Shaw, V. and J. Braa (Forthcoming). "Developed in the South" - an evolutionary and prototyping approach to developing scalable and sustainable health informatin systems. Development Informatics and Regional Information Technologies: Theory, Practice and the Digital Divide. J. Steyn, IGI Global. Vol 3: ICT's for Development in Africa: Theory, Practice and the Digital Divide.

“Developed in the South” – an evolutionary and prototyping approach to developing scalable and sustainable health information systems.

Accepted for publication as Chapter in book Development Informatics and Regional Information Technologies: Theory, Practice and the Digital Divide. J. Steyn, IGI Global. Vol 3: ICT's for Development in Africa: Theory, Practice and the Digital Divide.

Vincent Shaw
University of Oslo and Health Information Systems Program, South Africa

Jorn Braa
University of Oslo, Norway

ABSTRACT

The expansion of ICT across Africa is influenced by many factors including political imperatives, donor priorities, private sector and NGO needs, and economic interests and as a result takes place in a haphazard and largely uncontrolled fashion. The health sector is no exception. The challenge, as in many developing countries, is to provide a robust and reliable health information system while effecting a transition between paper-based systems and computerized systems.

The transition involves not only the introduction of new ICT, and the accompanying social and educational transformations of people and processes that accompany the introduction of ICT, but also the development of scalable health information systems that can facilitate a smooth transition as ICT expansion and development takes place.

This chapter draws on 10 years of experience of the Health information Systems Programme, an action research orientated network of public health practitioners and academics who initiated a pilot project in health information systems development in the post-apartheid transformation of South Africa, and which has subsequently had a profound effect on the development of health information systems in Africa and Asia. Through an exploration of health information systems development in numerous countries in Africa, we highlight insights into approaches and methodologies that contribute to successful and sustainable health information systems in resource constrained settings.

1. INTRODUCTION

The expansion of ICT across Africa is proceeding at a rapid rate. Not only is access to computers becoming more pervasive, internet access is also increasing. The expansion of information and communication technology (ICT) networks is influenced by many factors including political imperatives (see for instance Sahay, Monteiro and Aanestad (2009)), private sector and NGO needs (Odedra, 1994) , and economic interests (for instance Madon, Reinhard, Roode and Walsham (2009)). The result is that the expansion of ICT networks takes place in a haphazard and largely uncontrolled fashion (Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007; Odedra, 1992). The health sector is no exception. The challenge, as in many developing countries, is to take advantage of the opportunities presented by increased access to ICT, to provide a robust and reliable health information system while effecting a transition between paper based systems and computerized systems (Boerma, 2005; Shibuya, Scheele, & Boerma, 2005; The Lancet Editorial, 2009). This chapter draws on 10 years of experience of the Health Information Systems Programme (HISP) network in health information systems development (HISD) in Africa to describe an evolutionary and prototyping approach to the development of scalable health information systems (HIS).

The transition from paper-based to computerized systems involves not only the introduction of new ICT, and the accompanying social and educational transformations of people and processes that accompany the introduction of ICT, but also the development of scalable health information systems that can facilitate a smooth transition as ICT expansion and development takes place. HISD is complicated by a number of factors, namely:

- In traditional business processes, information systems development (ISD) is expected to take place in a uniform and controlled manner. This is seldom possible in an environment where ICT development takes place at an uneven pace. For instance, in resource constrained contexts, access to computers and the internet does not become universally available at the same time – rather they are distributed from the centre to the periphery in a haphazard manner that reflects socio-political imperatives and economic realities. Not only is the expansion process uneven from a geographical perspective, but the access to technology is also uneven in the sense that a range of technologies may be simultaneously available from the very sophisticated to the very outdated. HISD must be able it to respond to the unevenness by ensuring that HIS can be easily scaled from paper to computerized systems as access to ICT improves in an uneven manner;
- A second major challenge is having to accommodate the low level of resources and infrastructure as reflected by the inadequate or absent power supplies, absence of paper on which to print reports, and restricted finances to purchase supplies;
- The third, and perhaps most significant challenge, is related to human resource issues – from low staffing levels, to dealing with staff who have a very poor educational background and who have not been exposed to ICT;
- Fourthly, but not least important, the influence of social and political practices, which often reflect vested interests and decision making processes unrelated to health information systems development, may have a profound effect on the outcome of development projects.

The traditional health information systems literature describes the development and implementation of health information systems as being a fairly uniform and deterministic process (Pan American Health Organization, 1999). The process is described as being the typical waterfall approach of planning, preparing, procuring, testing and implementation. In addition, it is claimed that the process is usually initiated in the financial and administrative area. Following this clinical systems should be added, and through the combination of financial and clinical data an assessment can be made of health improvements and best clinical practices. As additional pieces of information are added, the system will enable the institution to "focus its efforts on prevention of disease, rather than treatment, wellness instead of illness, and integration of continuum of care, rather than isolated practices"(Pan American Health Organization, 1999, Section B.1.2.2). Unfortunately, HISD is never as easy as this. The large majority of Health Information Systems in sub-Saharan Africa are not flexible, but specifically designed to mainly cater for the needs of (sub-) national managers and international stakeholders. It has been asserted that most systems are also developed by either international consultants working locally or international companies (Odedra, 1993; Siika et al., 2005), making modifications and improvements difficult and often costly. However, as will be demonstrated more fully in the theory section of this chapter, several authors (Ciborra, 2000; Hanseth & Braa, 2000) have alluded to the need for different, more flexible approaches to information systems development. This is particularly supported by the literature on complex systems (Benbya & McKelvey, 2006; Jacucci, Hanseth, & Lyytinen, 2006), and on information systems development in developing country contexts (Jayasuriya, 1999; Silva, 2007; Walsham & Sahay, 1999). Given the need to be able to accommodate change on a regular basis, information systems in complex systems cannot be developed in a "waterfall" type approach – rather an iterative, participative prototyping approach is required where systems are developed as loosely coupled systems which can be integrated and which can evolve over time (Ramanathan, 2005; Tan, Wen, & Awad, 2005).

As a result, HISP adopted a multi-dimensional perspective to health information systems development (HISD), acknowledging the complex interplay between individuals as social beings, and technology as a dynamic and rapidly changing field influenced by a huge range of factors, many of which are beyond the control of any single individual. Given this understanding, the challenge in many developing countries is not only to develop an appropriate HIS, but also to be able to scale the system and sustain it in a context which is rapidly changing. The health sector demands are rapidly changing, especially with the spread of HIV/AIDS and the changing patterns of care and treatment, while access to technology is increasing. The aim of this chapter is to analyze the approaches that have been used by the HISP network to scale health information systems (HIS) across Africa, as well as the factors that may contribute to the development of sustainable HIS.

The chapter is structured as follows. The next section provides some contextual background to the HISP network, and a review of relevant literature. In the main section of this chapter we describe three aspects of the development of HIS in Africa, namely the evolutionary and iterative nature of the district health information software (DHIS) development, the development of capacity and support networks to underpin HISD and lastly, approaches to the scaling of the system in Africa. In the analysis and discussion section we first discuss the scaling process, and elaborate on what exactly has been scaled, and then explore how this understanding, and the creation of support networks contributes to sustainable HIS.

2. BACKGROUND AND LITERATURE REVIEW

This section begins with a description of the HISP network, and is then followed by an exploration of the literature on two main issues, namely the evolutionary and participatory prototyping approach to software systems development, and the current thinking on scaling of health information systems.

2.1 Background to the HISP Program

The Health Information Systems Programme (HISP) network was initiated by the University of Oslo in 1994 (Braa, Monteiro, & Sahay, 2004). It includes academic staff and health information systems developers and implementers in South Africa, Mozambique, Ethiopia, Tanzania (including Zanzibar), Botswana, Malawi, Nigeria, Zambia, India and Vietnam. The HISP network seeks to strengthen HIS within these countries through five key mechanisms. The first is to design, develop, and implement free and open source software (FOSS). Secondly, the network works directly with the health services in the respective countries to deploy health information systems (HIS) within their health services to strengthen the informational basis for public health care delivery. Third, the network provides large scale and intensive capacity building for health staff at all levels of the health system with a key focus on "using information to support local action", and also through formalized professional masters and doctoral programs in HIS. Fourthly, the network supports institutional development at the national and state levels around monitoring and evaluation activities for the millennium development goals (MDG's) and lastly, the international sharing of best practices by drawing upon and contributing to HIS related knowledge across developing countries.

HISP South Africa (HISP-SA) was launched with Norwegian funding in 1994 as a joint collaboration between the Norwegian Computer Centre and University of Cape Town's Department of Community Health and University of Western Cape's School of Public Health (Braa & Hedberg, 2000). The approach and software developed by this project and piloted in the Western Cape is now adopted as the standard for monitoring primary health care and hospital services in all nine provinces in South Africa. HISP-SA, constituted as a not for profit non-governmental organisation now supports the development of HIS in South Africa, Malawi, Botswana, Nigeria, Zambia, Liberia and Namibia. It has been instrumental in the development of the district health information software (DHISv1.3 and DHISv1.4) (see below) which is used extensively in these countries, in both primary health care (PHC) and hospital settings, to support the process of making health information available to improve service delivery.

Located at the Department of Informatics, University of Oslo, the HISP-Oslo component provides expertise in the field of Information Systems - systems analysis, design and development; data warehouse design and development; systems integration and standardization within complex organisational settings and FOSS development. The group has 15 years of experience in applying these areas of expertise from the general IS field in the particular context of HIS in low and mid-income countries. Since 1999 the Oslo group has coordinated the growing international "HISP-network" for HIS strengthening and taken part in concrete development in a number of countries such as Mozambique, India, Tanzania, Cuba, Mongolia, Ethiopia and Vietnam.

In their description of the HISP network as a "network of action", Braa, et al (2004) suggest that sustainable HIS requires a "network" approach rather than implementation in single sites. Sustainable systems are created through balancing vertical flows (local appropriation of systems and processes) with horizontal (diffusion) of experiences through the use standards for HIS (for example standard datasets and associated processes), education and training, and software development.

2.2 The rationale for participatory and evolutionary design

We address the design and development of information systems from an action research perspective as carried out in the HISP network (Braa, Monteiro, & Sahay, 2004)). Action research was introduced in the 1940's as a way of generating knowledge about a social system while, at the same time, attempting to change it (Elden & Chisholm, 1993). Our approach to action research and information systems design was initially influenced by a number of union based action research projects in Scandinavia in the 70's and 80's. The focus in the earlier participatory design projects was on empowering workers who were affected by or threatened by new technology, exploring ways in which their influence over technological solutions could be ensured (Bjerknes, Ehn, & Kyng, 1987; Sandberg, 1979). The later projects 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, empowerment through practical learning, and the creation of local ownership through participative processes are central issues in the Scandinavian projects which, despite the differences in context, offer important lessons for third world IS design (Braa, Monteiro, & Reinert, 1995).

Because there is a lack of experience of information technology and information systems design in African user organisations (see for instance an analysis on the difficulties of introducing IT in Africa in Odedra, 1992), designers have a high level of uncertainty regarding both the goals of the system and the context of its development and future use (Davis, 1982). In these situations Davis (1982) suggests experimental approaches (incorporating user involvement through participatory prototyping) are appropriate as compared to more structured approaches. Similar recommendations are made by other authors (Korpela et al., 1998; Mash & Mohammed, 2000; Sandiford, Annett, & Cibulskis, 1992).

It also follows that IS design under such conditions needs to follow an evolutionary approach starting with the basic needs and gradually building on these to expand the use of the system as the users learn more about the technology and its potential (Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007; Korpela et al., 1998).

In summary then, the rationale for using participatory design approaches is based on three important priorities (Greenbaum & Madsen, 1993):

- as a means to increase productivity;
- as a strategy to overcome the problem of lack of shared understanding between developers and users;
- from a political perspective, participatory approaches are a democratic strategy to give people the means to influence their own work places.

In the case descriptions which follow, we will show how these principles have contributed to the development of significant capacity for HISD and sustainable HIS in a number of countries. However, in the health sector, the challenge is not only to develop HIS, but also to scale them (Braa, Monteiro, & Sahay, 2004). This is important because in the health sector, it is not only important to know how many children have been immunized. Health workers must also be able to compute the coverage achieved in a given area. Unless data is obtained from all health services in the area, this information cannot be calculated. This is the "all or nothing" imperative (ibid, p 341). For this reason, it is appropriate to reflect on the difficulties and approaches to scaling of health information systems.

2.3 Scaling of HIS

In this chapter we ascribe to the view suggested by Sahay and Walsham (2005) that scaling is the process by which the system is expanded in scope and size. Drawing on the information infrastructure perspective, they suggest that scaling of health information systems is a complex process that requires the spread of "heterogeneous networks around the technology" (ibid, pg 43). The heterogeneous networks consist of people, processes, software, infrastructure, technical support and political support. They describe scaling a health information system from an initial coverage of 9 PHC facilities to 49 and then up to 1500 health facilities over a vast geographical area in India, what is scaled, who is involved in the scaling process and how it is scaled. The authors allude to the inherent drive to effect scaling that characterizes health information systems that must have complete data coverage to be meaningful (Braa, Monteiro, & Sahay, 2004). Similarly, Eoyang (1996) suggests that complex systems have an ability to self-replicate. She describes scaling as the property of complex systems in which one part of the system reproduces the same structure and patterns that appear in other parts of the system (Eoyang 1996, p. 36).

But scaling does not occur without some support and intervention. Numerous authors advocate for a cultivation approach (Bergqvist, Dahlberg, & Ljungberg, 2002; Rolland & Monteiro, 2002) to the scaling process. Sahay and Walsham (2005) extend this concept to include scaling the HISP-India team, as well as scaling capacity within the government bureaucracy. They argue that the main challenge experienced is the scaling of complexity, particularly associated with having to manage the increased political exposure that goes with scaling efforts, and the frequent changes that are embedded characteristics of the health sector (influenced not only by changing disease patterns, but also changing demands and methods of providing care, especially in the face of the HIV/AIDS epidemic).

Using case studies from the Health Information Systems Programme in Nigeria and Ethiopia, interdependencies between human capacity, access to structural issues like technology and hardware and software, and data processing capacity are identified as important factors to be considered in scaling health information systems (Shaw, Mengiste, & Braa, 2007). The authors suggest that given the imbalances that exist between human capacity, and access to technology for instance, homogenous scaling across all levels of the health system may be impractical – rather the approach should be to scale to areas which have the capacity to absorb training and technology even if this means proceeding in an uneven manner. They advocate for a cultivation process – which would allow the implementation process to be responsive to local nuances and variations from the norm.

Given the heterogeneous environment within which scaling has to be accommodated, technical standards for the health information infrastructure can be used to support the scaling process (Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007). Data standards (namely defining a minimum dataset) are essential as a component of the scaling process especially where heterogeneous systems (for instance different computer systems, or paper-based and computerized processes that need to interface with one another to ensure the seamless flow of data) need to be taken into consideration. By establishing a set of standards for the handling and transmission of data through the health hierarchy, heterogeneity can be overcome by using gateways to address the incompatibility between heterogeneous systems while maintaining the flow of data.

Despite these descriptions, and guidelines very little has been written about the process of HIS development in Africa, how the challenges around resource allocation and low education levels have been addressed. In particular, how do choices get made and how do they contribute or detract from sustainable systems development, especially given the need to be flexible so as to respond to ad hoc requests or opportunities. In the next section we describe HISD in South Africa, Malawi, and Nigeria over a five to ten year period, and draw on the case studies to suggest a comprehensive approach to sustainable HISD.

3. HEALTH INFORMATION SYSTEMS DEVELOPMENT USING THE HISP APPROACH

In this section we describe HISD in four countries (South Africa, Malawi, Nigeria, and Zambia, and allude briefly to our experience in Liberia) by examining three aspects of the HISP approach, namely the incremental development of software in response to users needs, approaches to HR capacity building and the emergence of a new cadre of health worker skilled in HISD, and lastly we examine HISD and HIS implementation through three approaches to scaling HIS, namely the standard approach, the prioritized sample approach, and the hierarchical cluster approach.

3.1 HISD in South Africa as incremental software development

a) DHIS as a tool to empower health workers to improve health services

While HISD in South Africa has been described more comprehensively in a number of other publications (Rohde et al., 2008), this section focuses on the contribution to HISD in Africa through the development of the DHIS. The DHIS has been developed through a participatory prototyping approach (Braa & Hedberg, 2002). The software has gone through numerous iterations in response to inputs received from users in the health sector in many developing countries (Braa, Monteiro, & Sahay, 2004), and has been developed as a generic database system that requires customization to reflect the context in which it is used. Most of the initial DHIS design and development has taken place in South Africa, using MS Access as the underlying technological platform. While coding was initially in VB, increasingly Java based code is being used. Through the links within the network, together with masters and PhD students, the DHIS2.0 system has been developed which is a web-based, platform independent, and database independent version of the DHIS database. While the development of DHIS2.0 so far is coordinated from and for a significant part also carried out in Norway/Europe, the “drive’ behind the system is the requirements on the ground in India for a system that is “license-free” and FOSS. The aim is to distribute more of the development to the South, and increasingly designers and programmers in Ethiopia, India, Vietnam, and Nigeria are being incorporated into the network. In this chapter the focus is on the development of DHISv1.3 and DHISv1.4, and its use across Africa.

The DHISv1.4 provides the tools to capture, and validate anonymized, aggregated data, and to process it into indicators. It enables the data to be presented as both raw and processed data using either Excel pivot tables, a report generator function or a GIS interface. While the software is described as FOSS (in the sense that the code is freely available and the software is freeware), the system does require MS Access and MS Excel and a Windows environment to function. This arrangement began as a pragmatic compromise to “hardcore” FOSS principles based on the almost universal availability of Windows and MS Office in the public sector in South Africa (Braa & Hedberg, 2002).

The main philosophical standpoints that have driven the software development are:

- The software should empower health workers at facilities and district levels to use information to improve health services, and there is therefore a strong focus to allow users at a local level to adapt the software system to suite their needs.
- The software is an aide to use of information.
- That users at all levels should be given feedback on the data that is entered into the system. Reporting must therefore be integrated with data capture and should include access to geographic information system (GIS) reports
- Reporting on routine monthly data should be restricted to small data sets to avoid overloading health workers with unnecessarily burdensome reporting responsibilities.
- The DHIS is developed as a Data Warehouse which can incorporate data from a variety of different software systems and integrate them for use by managers.

Central to the DHIS success has been its ability to be customized by health workers to the local context. Customization is required in two main areas, and these are depicted in Figure 1:

a) The organisational hierarchy – each reporting unit belongs to a parent organisation and each of these parents can belong to a higher level parent – creating a hierarchy which then usually spreads upwards towards the district health office, provincial and national ministries of health, and could include a sub-regional level. In a typical primary health care setting health facilities are grouped in a geographical area (a local municipality, or ward, or zone), and these are grouped in health district. This is important because it enables data and indicators to be aggregated to higher levels (for example out-patient attendances of individual reporting units can be aggregated to reflect all out-patient attendances in the hospital, and these can be aggregated to reflect out-patient attendances in a district or region, etc).

b) For each reporting unit, three main types of data can be collected. Data elements represent the services that are measured, for example children weighed or children fully immunized, etc. Differentiation is made between three phenomenologically different types of data elements. Routine data represents data that is collected on a routine basis (daily, weekly, monthly, annually). Survey data is data that presents a "snapshot in time" view of a specific service, collected on an ad-hoc, or infrequent basis, and usually has validity for a specific period. Semi-permanent data represents data that does not change frequently. For each of these data types, the software can be customized to represent the specific data collection needs of the user.

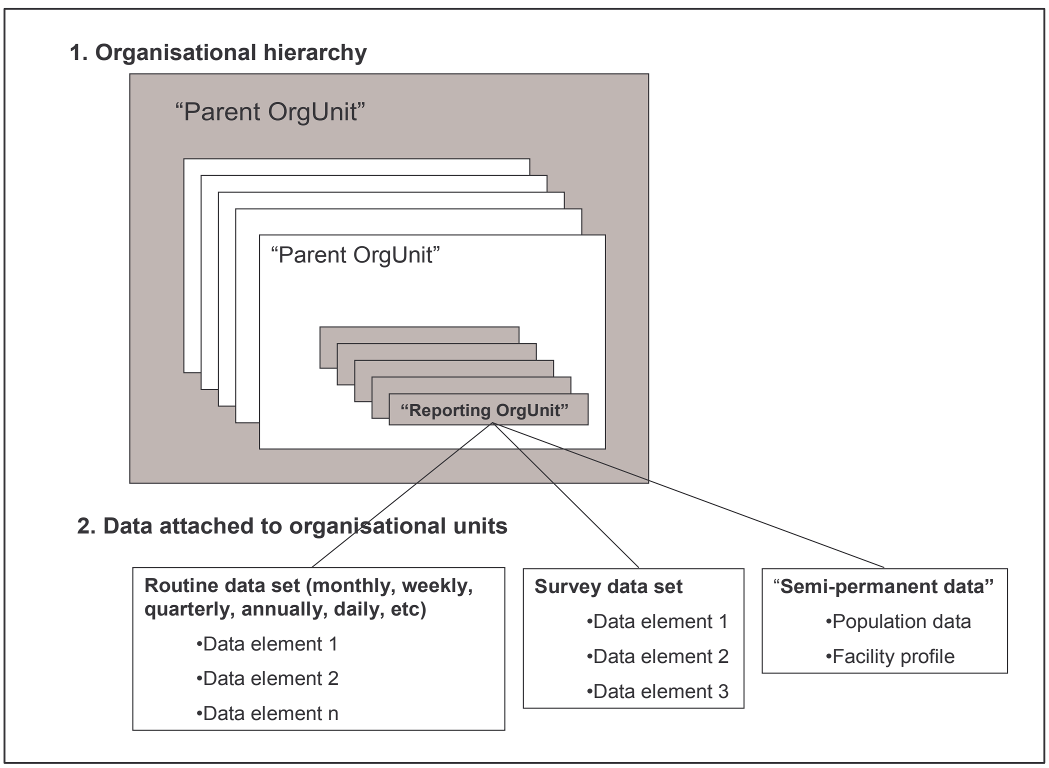


Figure 1: Aspects of the DHIS which require customization

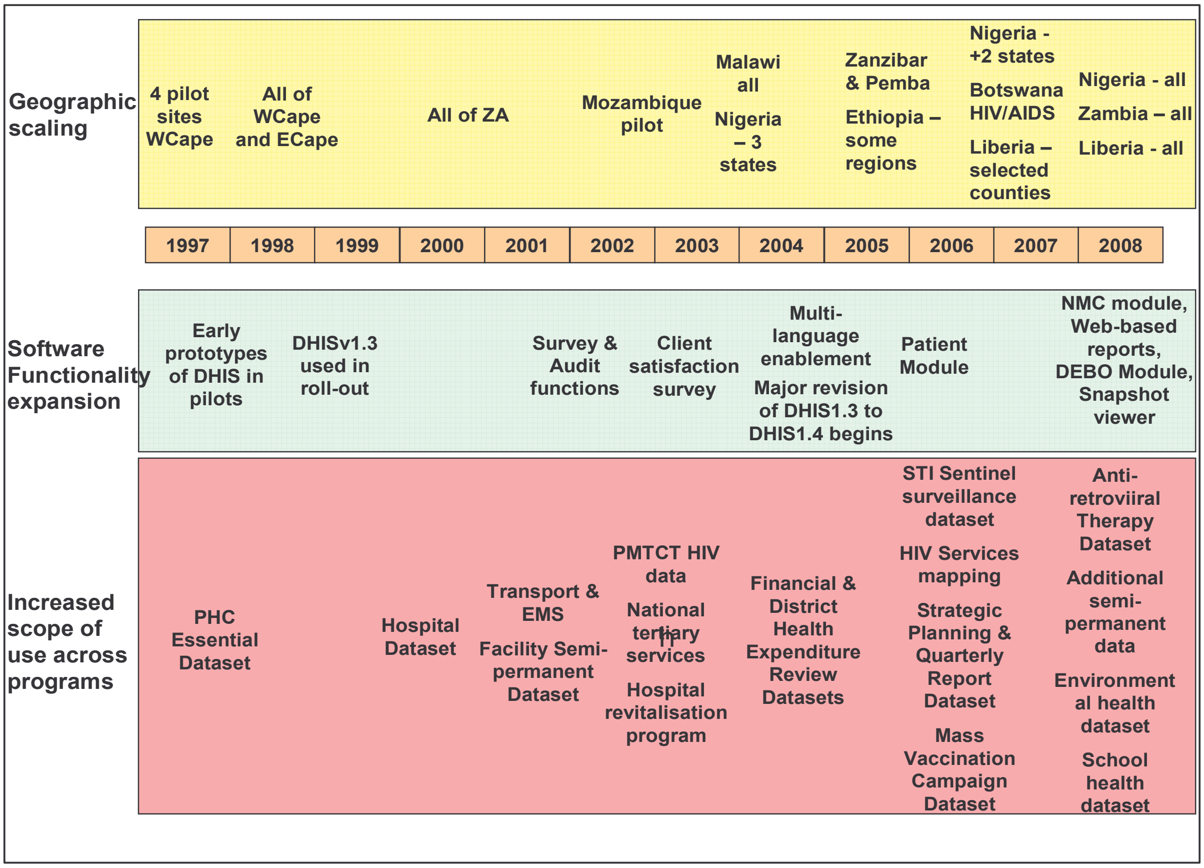


Figure 2: Three Domains of health information systems development

b) Evolution of the DHIS in response to user needs

Figure 2 details the development of the DHIS software (functionality expansion). The process of developing the DHIS software has happened in parallel to the geographic scaling of the system across South Africa and a number of other countries (the process of some of these implementations are discussed below and in (Chilundo, 2004; Chilundo & Aanestad, 2004; Mavimbe, Braa, & Bjune, 2005)), and as an iterative process fed by the expansion of users as the scope of the system (the incorporation of additional program data into the DHIS) was scaled. The improvements in software capacity (e.g. improvements in the ability of MS Excel pivot tables to handle increasing volumes of data between versions 2000 and 2003, and similar improvements in MS Access functionality) have fortuitously paralleled the expansion in the volume of data in the DHIS database.

It is interesting to reflect on the iterative nature of the feedback loops and interchanges that has accompanied the DHIS development. For instance, enabling survey and audit functionality in the software allowed the addition of data from a paper-based client satisfaction tool in the DHIS. Similarly, the addition of the patient module (the result of a specific request from a hospital department in Malawi – see later), resulted in the expansion of scope of program data in the DHIS to include notifiable medical conditions module in South Africa, and the Integrated Disease Surveillance Reporting System in Zambia.

While in general the use of the software in South Africa has driven the demand for additional functionality, there are notable instances when additional functionality has been added to address demands for use of the DHIS software outside of South Africa, namely:

- The Mozambiquean team tired of rewriting new releases of the program in Portuguese and pushed for the creation of a “multi-language conversion” table that would effect the translation of key terms into languages other than English – this is triggered by a change in the Windows ® language settings. Currently, supported languages include Spanish (Cuba), Portuguese (Mozambique), Mongolian, Russian, and Chinese. Efforts are underway to complete the translation into Swahili (Tanzania), Telugu (Andra Pradesh, India), Kannada (Karnataka, India).

- The use of the DHIS in Ethiopia resulted in some University of Oslo students developing the DEBO Software for tracking patients receiving HIV/AIDS Anti-Retroviral Therapy. Subsequently, this has been further developed and refined by a team of developers in South Africa, and has recently been released as a module of the DHIS.
- In 2007, the HISP-SA team was requested to assist in revising the software for the HMIS in Zambia. The installed system had a useful functionality which tracked the data completeness for certain data elements. This functionality was at the time not available in the DHIS, but was subsequently added as the "snapshot viewer" functionality to address this need.
- In Kenya, a team at the International Organisation for Migration (IOM) adapted the system to enable their centers to capture the specificities of HIV care and counseling as well as pre-departure medical examinations. They did this without any face to face meetings, only email guidance and support from the software development team in South Africa. Their requests for support helped to improve the functional integration between the patient module and the core module of the DHIS.

In South Africa, an important factor that has contributed to the drive for the seamless integration of datasets (for example primary health care (PHC) data, Hospital data, Environmental Health data, financial data and survey data) has come from the National Department of Health (DoH) who implemented a system of Quarterly Reporting on selected indicators. Initially, the process of reporting for this was a manual process of collating data from different sources, including various DHISv1.3 databases, and legacy systems such as the HR and financial management systems (Phase 1 of Figure 3). With the development of DHISv1.4, it was possible to integrate various separate DHISv1.3 databases into a single database in version DHISv1.4 (Phase 2 of Figure 3), and to create a dataset that represented the elements of the QRS report (Phase 3 of Figure 3).

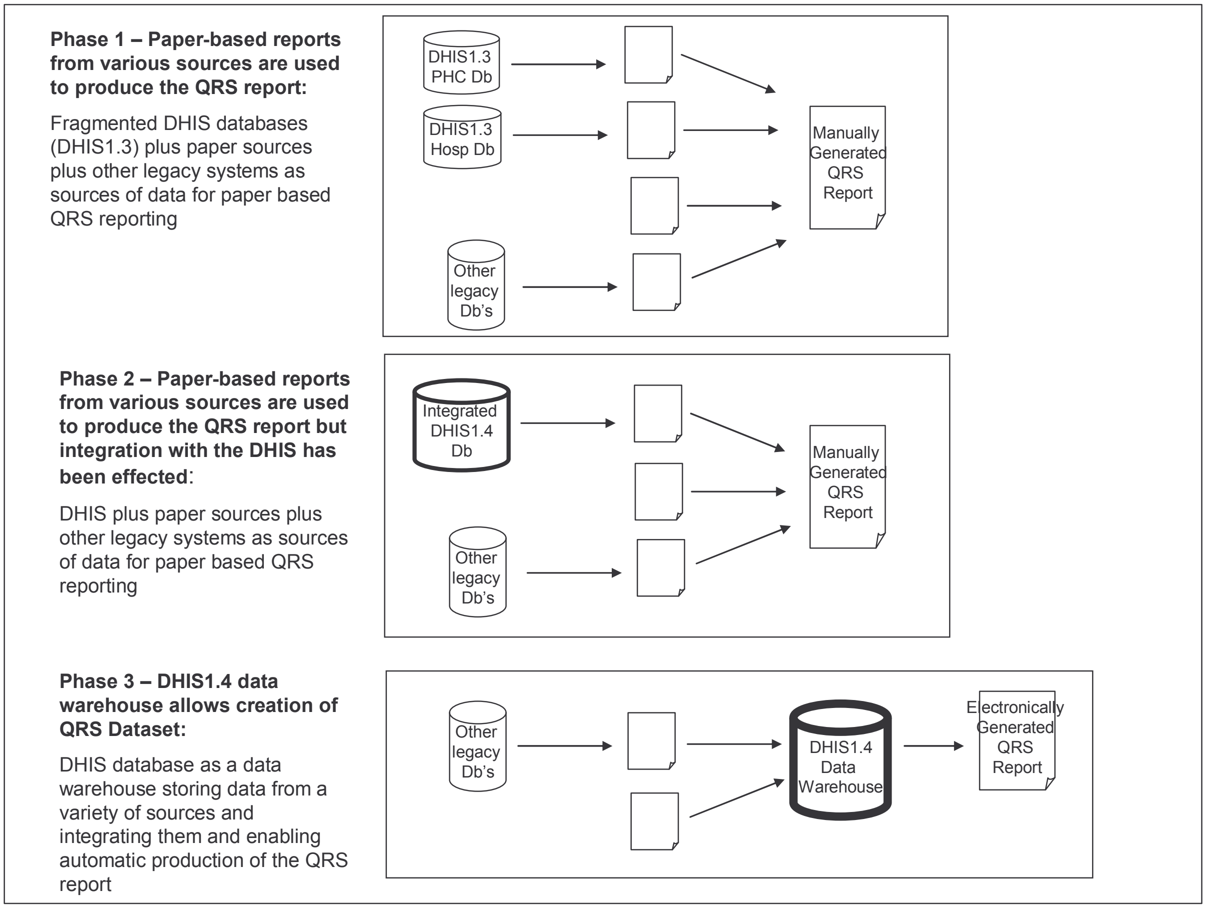


Figure 3: The evolution of an integrated HIS in a phased manner

While the DHIS was always envisaged as a data warehouse, its efficiency in fulfilling this role has improved through the functionality introduced in DHISv1.4. In this version, data elements are grouped in datasets. A dataset is a data input construct which usually represents a form that contains data to be captured. Data elements may belong to more than one dataset. For example, the data element "Total Live Births" can belong to the PHC Dataset that captures data related to PHC services, as well as the Hospital dataset being a dataset that reflects the services provided in a hospital. A hospital might have to provide a report to the PHC management on the PHC services it provides, as well as a report for Hospital Management. While the data for these two reports might be sourced from different units within a hospital, the reports might contain the same data elements. The integration of hospital and PHC databases has resulted in improved data accuracy because only a single value can be stored against the common data elements, thus ensuring that reporting through two different forms is coherent. This degree of integration, and the demand for the QRS report, has forced an evaluation of the overlap between different data sources and data element definitions. It was found that various reports used different names for essentially the same data, reported different values, and generally led to confusion when planning and budgeting for services. A re-alignment of naming conventions and reporting formats has resulted. Changes in the DHIS have therefore resulted in a simplification of processes through the integration of various data sources, but in another sense it represents an increase in complexity from the point of view of a complex database which integrates and manages data from various sources to produce a single report. As the complexity of the underlying database grows, if the additional functionality is to be utilized, users are required to have a deeper understanding of the system. The implications of this are discussed in the next section.

An important feature of this development has been the evolutionary development of the software (which, as mentioned earlier, has been an iterative cycle fed by the geographic scaling and expansion of scope of use of the software) over a 10 year period. This is the “bazaar” style of development that Raymond (1999) describes in his description of the FOSS movement, and which is sharply contrasted to that of the typical “cathedral” development style of most proprietary health software. The success in one geographic area, and with a limited scope, has resulted in a drive for additional functionality, and so the bazaar gradually grows into a bigger assembly of more closely integrated bazaars, thereby strengthening its role.

The development of the “bazaar” can be partly attributed to the software acting as an “attractor”(Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007). The attractor consisted of two related components, and these allowed the scaling of HIS across the two domains (the geographic domain, and the functional scope). One component of the “attractor” was the identification of a minimal dataset (i.e. a limited scope of program data). The DHIS as a coherent software application that easily supported data capture, analysis and reporting, while also being flexible to accommodate changes over time was the second component. Together, these created a strong “attractor”. The “attractor” was appealing to use, and encouraged others to also utilize the same standards. As more data came to be incorporated, and integrated (with the transition from DHISv1.3 to DHISv1.4), the system became even more attractive to managers who were required to report on a wide range of data. Figure 4 illustrates the increase in activities measured (data records in the database) while the number of patient encounters leveled off after the initial scaling (1999-2002).

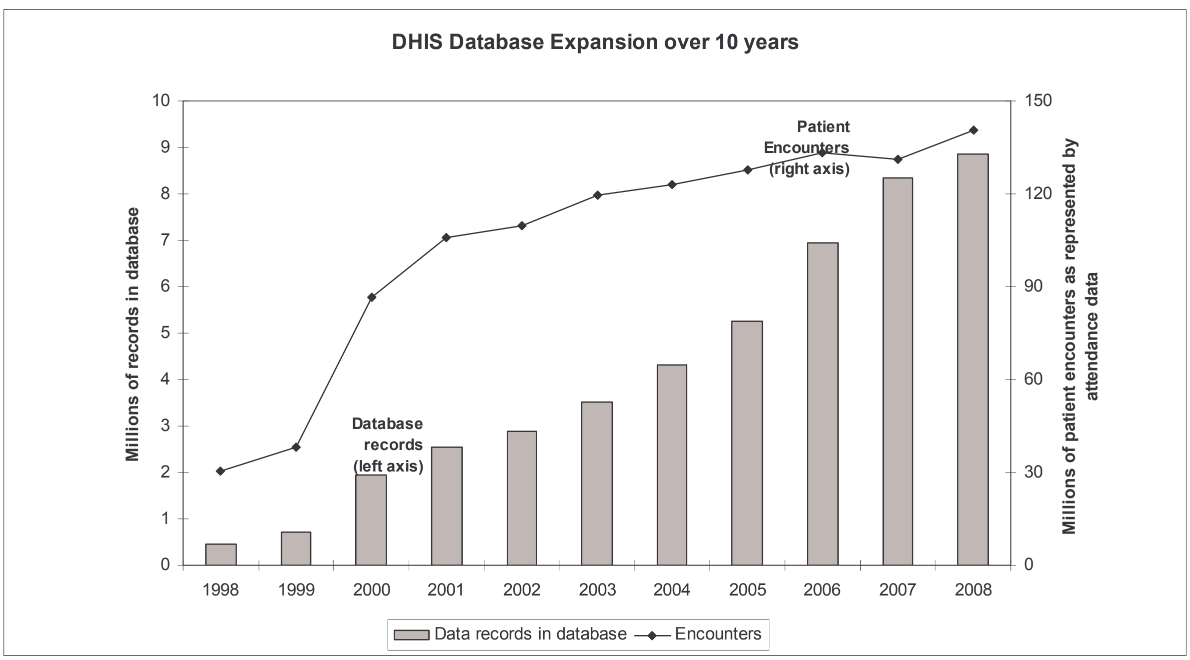


Figure 4: DHIS Database Expansion over 10 years

3.2 Human Resource Capacity Building

We address the challenge of building capacity in health workers through first describing how skills were developed in the anesthetic department of a large, academic hospital in Malawi. The department developed a simple form for the collection of anesthetic related data and utilized anesthesia clinical assistants (CA's) to capture the data in the DHIS. This process was important because it not only developed computer skills in the staff, it also expanded their understanding about information systems and allowed the department to gather data specifically related to their services. This enabled them to also assess the quality of care being provided, and in fact to effect changes to improve the quality of care. We then use this example to describe the emergence of a new cadre of health worker, the health information systems practitioner. Lastly, mechanisms for support of this cadre, and for ongoing human resource development are discussed.

a) Developing Capacity to Manage the DHIS in Africa

During one of the early co-ordination meetings for the development of a hospital management information system in a large hospital in Malawi in 2005, a representative from the anesthesia department was asked whether they had been "effectively using" the computer which had been donated to them. The reply was that they had been capturing data, but were having trouble analyzing it. A review of their data revealed a MS Excel worksheet, with multiple columns, some of which contained mixed data (e.g. age and sex combined (e.g. 40M as representing a 40 year old male patient), or diagnosis and outcome were combined in complicated ways). The spreadsheet was reformatted into columns containing uniform data by using advanced MS Excel commands, and a pivot table was developed for data analysis.

This led to a discussion about the data needs for the anesthesia department, and the process by which they collected data. The result was the development of a simple form for collecting the data (it went through a number of iterations as additional data types were added), and in combination with the help of a software programmer (also a member of the HISP team), a "patient module" linked to the DHIS was developed which could capture specific patient data (the request for this type of database opportunistically coincided with the development of DHIS14 Patient Module, aspects of which incorporated some early thinking around systems for collecting patient specific data related to the tuberculosis and ARV programs). This was not an electronic patient record (EPR) in the true sense of the word. Rather, by building on the "local customization" concept of the DHIS, it allowed a person who did not have programming skills (as in the case of the principle author), but who knew the basics of database use, to set up a simple database in which the units providing services, and data elements could be customized. The "patient module" expanded the standard DHIS data collection of aggregated anonomised data to include patient specific data and text values. An export function into MS Excel created a pivot table, and both the numeric and text data could be analyzed. In this way, the department had the functionality of being able to access patient specific data (e.g. to get a complete record of the anesthetic process in a patient who died while receiving anesthesia), or numeric data. For instance, after two months of data collection an analysis of theatre utilization revealed that more than 50% of caesarian sections were being done in a facility which had less staff and less equipment than the "main" facility.

However, getting to this stage was not without its own problems. The computer that was used was outdated, and could only read a CD or a diskette. It had USB ports, but as it operated on Windows 98 getting the computer to read from a flash disk was problematic. We limped through this phase improvising, and after some months were able to upgrade it to Windows 2000, at which point it became easier to load and extract data from the computer.

Experience has taught the HISP team that this was the norm in developing country contexts, and for that reason the DHIS software has had to be maintained as a system that could function on MS Office 97, 98, and 2000 (only recently has support for MS Office 97 been dropped). If this had not been the strategy, it would not have been able to retain its relevance as a suitable system in these settings. But even despite this strategy, there was a delicate balance that had to be achieved between the software, and the capacity of the hardware. Because the software is "relatively simple" and unsophisticated in its demands from the system, it could be accommodated on a "fragile" computer, a situation that is not uncommon in Africa.

b) Emergence of a new cadre of hybrid health workers

"… people (the staff) have been central in initiating the development of the IS. This is an important aspect of the implementation process. The IS requires people to drive it, maintain it, and continue to develop it. Their motivation for involvement is based on the returns that they get from the investment that they make". (Braa et al. 2002)

The staff that captured the data in the anesthetic department were the clinical assistants (CA's), and they became computer literate through the process of capturing data. The clinical head of department facilitated tremendously by ensuring that at all times during the period, there was at least one CA who took the lead in maintaining the system. Even the clinical head of department, while clearly understanding her information needs, was not very computer literate, and had to be taught how to utilize the pivot tables – in fact, in order to reduce her frustration levels, the pivot tables were placed on a CD Rom, so that she could manipulate and adjust them, but would never be able to overwrite the CD, thus ensuring that she could abort and restart from the familiar beginning!

This case description highlights a few important issues related to building human capacity for computerized health information systems: In the case description, we see the development of a system as an interaction between the system developers (in this case the HISP-SA team), and the users. The developers of the system are not a uniform group (see Table 1) – in this case they are a heterogeneous collection of people who work together in a unique way, contributing their various skills in order to develop a functional system. Users contributed to the development of the system by saying "but can you change this so that we can do ….", and when that was accomplished, they in fact became sponsors because the system now served their purpose. Had this team not been available (as is commonly the case in developed countries), the solution would have been very different – a paper based register could have taken the place of the electronic register. But, because there were a variety of skills available, an innovative solution was developed.

Table 1: The Health Information Systems Development Team

Origin of team member	Team member	Skills base
External development team (this is the HISP implementing team)	Professional Software Developer and Head of Software Development Team	Able to envisage software development, and listens extremely well to needs of health workers, and has been able to translate this into a user friendly software program.
	Professional Software Developer	Skilled software developer, while also having good inter-personal skills, the technology orientated focus dominates.
	Medical doctor	Due to a deep understanding of DHIS and data base conceptualization, and information needs of managers, is able to bridge the medical, and informatics world, and see opportunities in both.
Internal hospital staff (Internal to the Health Department)	Head of department, and "Executive sponsor"	Medical specialist, with deep understanding of medical issues, and a vision for using data. But little understanding of how to translate medical related data to management information. Poor database management and computer literacy skills
	Clinical assistants	Medical knowledge, and growing computer literacy

The transfer of skills has not only been in terms of computer literacy. In many instances, the users have developed a more detailed understanding of the database and its functions, and how the system is arranged in the 'back-end". The transfer of skills can be depicted by viewing a spectrum with the "Pure User" at one end and the "Pure Developer" at the other. The degree of sophistication of the use of the DHIS system will depend on the degree of interaction and skills transfer that takes place between the people at the two extremes – the extent to which they shift closer towards each other through the skills transfer process. A "pure user" with little knowledge of HIS's will not be able to reprogram the DHIS, but one with a little understanding can customize the system. Someone with a greater degree of skill in the use of the DHIS can customize it for use in a variety of settings (example from Kenya IOM), and someone with far greater skills in database manipulation can effect internal structural changes. This scenario represents the new cadre of health worker that is developing – a person who is computer literate and has sufficient skills to effect changes in the computerized information system. We call this emerging cadre the health information systems practitioner (HIS practitioner). Other authors have referred to this person as an implementer (Seebregts et al., 2009), although in our assessment the implementer is closer in the spectrum to the developer than the HIS practitioner.

c) Creating local and regional networks of HIS practitioners

One of the strengths of the scaling process adopted in South Africa, Zambia (Shaw, Simoonga, Kalinda, & Muyambo, 2008), India (Sahay & Walsham, 2005) and Nigeria has been the creation of local NGO's to support and help develop HIS practitioners. The HISP-SA team has maintained a team of 8 full-time HIS practitioners since it was constituted as not-for-profit non-governmental organisation, and has recently expanded its membership to 20 full-time practitioners, in addition to up to 10 part-time consultants that are drawn in from time to time. Team membership is varied, and comprises developers, medical practitioners, nurses, environmental health practitioners, and educators. Recently younger staff with no formal post schooling education have been enrolled as part of an initiative to help develop young South Africans from disadvantaged backgrounds. Most team members are adept at least at the "simple" software customization responsibilities. However, the transfer of skills and development of capacity has not happened overnight, and is increasingly challenging as the competency of staff in the government service has increased significantly over the years, and they are therefore demanding increasingly sophisticated support. HISP-SA has to constantly weigh the odds on whether to draw new recruits from the public service (which is where a large pool of expertise lies) or to seek it outside the public service, where the pool is much smaller. A fair balance has prevailed where of the five staff that left HISP-SA since 2003, three have been employed in senior positions in the public service while of the 11 staff employed in the last year, only 2 came from the public service, and 2 from local government.

In Nigeria, since 2003 a team of six to eight HIS practitioners have been identified as "national consultants" and they have been supported by the "regional consultants" from HISP-SA who visit Nigeria on a regular basis. The capacity within these local teams varies across the spectrum from "pure user" to HIS practitioner – seldom have pure developers been identified in these countries.

In Zambia the lead national consultant (who is a programmer running a software development company) very quickly developed advanced DHIS skills, and together with his thorough understanding of the health system, has made him an invaluable support to the Ministry of Health. He has also been contracted as a regional consultant to Nigeria to translate an Excel spreadsheet used by the WHO Epi program into a dataset within the DHIS. We see therefore the beginnings of a process of cross-fertilization occurring between "second generation" HIS practitioners on the continent who are sharing skills and experiences amongst themselves – this is likely to escalate as communication between these teams expands, and as capacity develops.

The networks are maintained through the use of email and interactive wiki websites, sharing of publications and reports, and opportunities to study masters and PhD programs in Oslo and at universities in Africa (South Africa- University of Western cape and University of Pretoria; Mozambique – Universidade Eduardo Mondlane; Tanzania – University of Dar es Salaam; Ethiopia – University of Gondar and University of Addis Ababa). An interesting series of developments related to this has taken place in Nigeria. A young Nigerian medical doctor who is also a self-taught programmer has enrolled for a PhD with the University of Oslo. His interests lie in mobile technology and the potential use of the DHIS2 in Nigeria. He has also participated in the OpenMRS Internship program and Google "Summer of Code" initiative, and this provides some interesting possibilities for strengthening networks around HISD in Nigeria. The agreement with the HISP-Nigeria team is that while he completes his studies he would be "bonded "to the team, and would provide support to the various initiatives in Nigeria as part of his fieldwork. Similarly, a PhD student from LSE asked to be able to do some field work in the country of his birth, and has also been supporting HIS in the Northern Nigerian states, and will hopefully upon the completion of his studies continue to be involved with HISD being effected by the HISP-Nigeria team. Through these academic and institutional linkages and networks, synergistic opportunities arise for strengthening individuals and HISD in an evolutionary manner as described in the "networks of action" approach (Braa, Monteiro, & Sahay, 2004).

3.3 HIS Development and DHIS Implementation

Over the years, different approaches have been adopted for strengthening the health information systems in various countries. In South Africa, the approach has been to develop a small data set for monthly reporting, and the data collection tools to support this. These systems are all paper based, and data in the monthly reports was computerized at the district level. The "standard approach" to scaling has been to begin small in selected sites, scale to district or provincial level, and then scale across provinces to achieve national coverage. In South Africa the pilot began in 1997 and was eventually effected across the whole country by 2001 (Braa & Hedberg, 2002). Data submission rates are high (above 70% within 1 month of end of reporting period and above 90% within 3 months after end of reporting period). A similar approach was adopted in Zambia, except that the implementation began as a Provincial-wide process in one province. The implementation process was utilized as an opportunity to develop capacity in a team of trainers (comprised of provincial and district information officers, and representatives from nursing colleges who were requested by the National MoH to include the concepts of HISD in their under-graduate curricula) who then took responsibility for the implementation across the other provinces. The process was initiated in October 2007, and all provinces were using the system by November 2008. Although it is still to early to say with certainty, it appears as if data submission rates are reasonably high, but with a longer time lag from the end of reporting period. As in South Africa, the monthly reports are paper-based, and computerization generally takes place at the district level. In Liberia, a similar approach has been adopted, with government employees scaling the system beyond the initial pilot in 15 counties.

In Nigeria, the process has been significantly different, and continues to evolve. Initially, all facilities within a few local government authorities (LGA's) (typically between 15-20% of all LGA's in a state) were selected as pilot sites. Staff in facilities were trained, and monthly reports were sent from facilities to LGA level – in the past they were collated and aggregated at this level before onward transmission, but with the revision of the HIS, it was deemed important to have data disaggregated at facility level, and so the facility reports were sent onwards to the state level. It was at this level where computerization took place, mainly because computers were not available at the LGA level. Power supply at the LGA level was extremely unreliable, and it was impossible to identify a secure environment in which to store a computer. As a result between 4-6 data capturers were utilized at the state level to capture data for the whole state (Shaw, Mengiste, & Braa, 2007). After a period of 18 months, the system was expanded to include the remainder of the LGA's. While the aim was to gradually decentralize data capture to the LGA level, after 2 years of no progress it was decided to rather cluster data capture sites around a group of LGA's (called a zone), and to locate the computers in hospitals which were more likely to have staff to capture the data, to have a reliable power supply, and a reasonably secure room for the computer.

However, reporting rates remained low, and as data for an extended period of time became available, it revealed that a relatively small number of facilities actually provide health care. For instance, a review of data from Jigawa State reveals that the two busiest facilities in each LGA provide 52% of all immunization services in the state, and the 4 busiest facilities, represented 72% of all the immunization services provided[1]. Similarly, when analyzing maternity data for 2006 across 5 states, 1.6% of facilities are responsible for 52.5% of all deliveries. Given the resource constraints experienced in the Nigerian health sector, the limited support that could be provided by donors, and the low base from which health services are being developed, it became apparent that it was more effective to focus on selected facilities than on all facilities.

One approach is to focus on the busiest hospital and the busiest primary health care facility in all LGA's. Over time, implementation would then adopt the layer of "next busiest" facilities in each LGA, and so on. This is called the "prioritized sample" approach to scaling of HIS. An alternative approach is to select a cluster of facilities that are linked in a hierarchy of service provision, for example in the provision of maternal and child health services (see Figure 5). Some facilities (for example health facilities that are open 24 hours a day, 7 days a week) may provide basic ante-natal care, but not offer maternity services. Maternity services are instead provided at Basic Emergency Obstetric Care (BEOC) facilities, but these facilities would only deal with uncomplicated deliveries. Complicated deliveries requiring more specialized care would be provided at Comprehensive Emergency Obstetric Care (CEOC) facilities. The "hierarchical cluster" model provides an alternative approach to focus HIS strengthening initiatives. The intention of the existing project is to expand from one cluster to three clusters per state over a 9 month period, and to effect HISD in these clusters over the 5 year project duration. The effectiveness of this approach will only become apparent as the project unfolds.

These two approaches are not a deviation from the "all or nothing imperative" described by Braa et al 2004, p 340), but rather an experiment in approaches to scaling. Both the "prioritized sample" method, and the "hierarchical cluster" method will expand the implementation to other sites over time, and as capacity develops, so that eventually all health facilities are incorporated in the initiatives. The time taken to effect scaling is a function of the level of investment, the success in building capacity, the allocation of local resources to support the scaling efforts, and perhaps most importantly, the level of sophistication in information use that is desired.

The critique of these approaches is that it they do not immediately address equity issues which are so important in health service delivery. However, our experience suggests that these approaches should be viewed as a mechanism for effectively scaling health information system development, and that equity issues can be addressed through alternative approaches, such as the use of population of facility surveys that target a broader range of health facilities or communities, and identification of sentinel sites that collect additional data to unearth inequities that require attention.

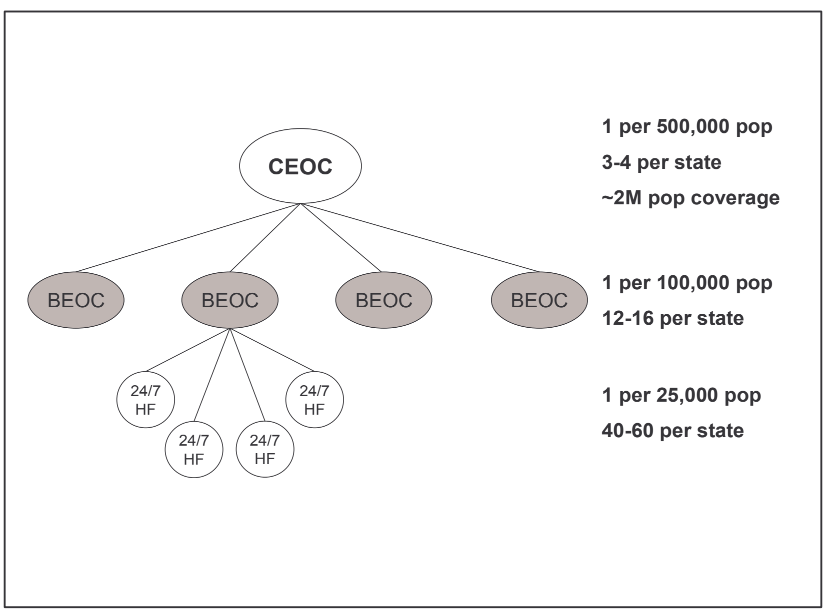


Figure 3: The Hierarchical Cluster Approach

	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08			
1. Rollout of tools		1. NW + West				1. Ea, So, +Ce	1. Lu, No, + Lus				
2. Data returned using new tools			2. NW + West								
3. DHIS Foundation course					3. NW + West			3. Ea + Ce	3. So + Lus		
4. DHIS Advanced										4. Copper	4. NW + Ce
5. Use of information (Curric 3)										5. Copper	5. NW + Ce

Figure 4: Integrated HMIS Roll-out in Zambia as a Phased Process

4. ANALYSIS AND DISCUSSION

Our analysis first focuses on the geographic scaling of HIS and the scaling of the scope of use of the software. We explore the way in which the scaling across these domains influence and interact with one another, and how scaling in one area affects scaling in the other. Thereafter we analyze the factors that have contributed to sustainable HISD in Africa.

4.1 Software Development in Support of Scaling across two domains

This chapter has described the scaling process across two "domains". The most obvious is the scaling across the geographic domain. Different approaches have been used to accommodate local circumstances and resource availability. Scaling across the geographic domain is probably the most complex scaling process because it must take into consideration the structural requirements for the effective functioning of the HIS (including the software component), and access to resources must be considered – like power supply and internet access, secure and safe storage space for hardware, access to computers, paper, and printers). Because the pace at which access to ICT (for example the internet, or computers) is gained is erratic and relatively unpredictable a wide range of tools (from paper based systems to simple computerized systems, more complex computerized systems and an emergent internet based system) continues to be maintained so that HIS can be easily (and seamlessly) scaled from paper-based systems to computerized systems over time.

Other factors like human resource capacity of staff to absorb the revised HIS (capacity both in terms of numbers and level of education) must also be considered. These are the factors that will ultimately influence the process that will be used to effect the scaling of the system. This is clearly reflected in the unique approach to scaling the HIS adopted in Nigeria with the "hierarchical cluster" approach. It suggests an interesting balance between the imperative to cover all health facilities while also prioritizing selected facilities as a first phase to scaling across the rest of the geographic area.

The second domain in which we have seen scaling occur has been in relation to the scaling of the scope of use of the software across health domains (PHC, hospital data, survey data, disease surveillance, etc). The scaling across the geographic dimension has taken place at the same time as the scaling in scope, but in reality, while geographic scaling is being implemented, the scope of the version that is being scaled has been held static. In other words, the focus during geographic scaling has been on data for a specific domain, and even if the scope was extended as new software modules became available, these were only really introduced and utilized once the geographic scaling process had stabilized to some extent. For example, in Zambia the scaling across the whole country involved the use of the DHISv1.4 for data capture and data analysis, and even these two components were introduced and taught separately as part of a phased approach to the scaling across the country (Figure 6 shows how different aspects of the revised HMIS system were scaled in a phased approach). While the scaling process was being undertaken, we were customizing the notifiable medical conditions module in the Zambian database, with the intention that this would be introduced at a later stage as an additional module. Once the system has been introduced, and basic training has been completed, it is much easier to introduce additional modules (expand the scope) because the users are already familiar with the basic configuration.

The HISP approach to development and scaling integrated information systems (in the sense of systems that support a broad base of data across a wide scope (or range of programs)) is in stark contrast to the single-disease systems (single program systems) being advocated across Africa for HIV/AIDS information systems. While this could be considered as a first step to scaling of HIS, these systems often become an end in themselves, which result in fragmented and duplicative reporting systems and which detract from the capacity to focus resources on a single integrated system.

4.2 Developing sustainable systems in Africa

While our experience over the last 10 years is relatively short, we believe that there is sufficient evidence to suggest that the HISD that has taken place has not been the result only of the availability of only software or information processing capacity. A better way of describing the development of sustainable information systems would be as a continuously evolving balance between information systems development, human capacity development and scaling approaches. The "glue" holding these components together is the information system and its use. Building on Braa, et al (2007) we have described the information system as flexible, in a variety of ways. Combining paper-based systems, with computerized systems and internet systems through common standards provides a flexibility to seamlessly integrate information from the periphery (where often computers do not exist) to the centre (where internet access may be available). The modularization of these components allows them to respond dynamically to the changing access to ICT that characterizes development in Africa. The information systems are also flexible in the sense that they can accommodate change (minor changes that might take place with the health system in response to new diseases and threats), and can be adapted in significant ways to be utilized outside of the traditional health care sector, such as its use in by IOM in Kenya. The availability of a range of software tools is another important aspect of the systems flexibility and ability to accommodate the range of contexts found in Africa.

A factor in making the system an "attractor" has been its ability to effect integration between fragmented systems. While initially it did this by bringing PHC program data together in a single database, along with survey and "semi-permanent data", this was later expanded by the increased internal functionality available in DHISv1.4. Ironically, the more information systems are fragmented by single-disease reporting systems, the more attractive the concept of the DHIS as a data warehouse becomes to managers who are required to report on a range of services drawn from different reports.

Lastly, but perhaps most important, is the incremental "bazaar" type development of the system in response to user demands. This has ensured that the system is rooted in the needs of workers in the "South", rather than being a "cathedral" that is designed and developed in the "North" and transposed and implanted on users in the south. It has also been a practical way of developing software where funding has had to be secured through small projects, each of which could only fund a small component of the system, not dissimilar from the growth of a bazaar in a typical down-town African village. Software development costs are reduced because the users are also the "testers", and they help to find and communicate bugs through internet links, thus increasing ownership, albeit also accompanied by frustration at the existence of bugs.

Utilizing the FOSS philosophy of freely sharing not only software products, but also training materials, and manuals has probably also contributed significantly to the spread of the software in Africa. Maybe not because of the significantly lower costs associated with this type of technology, but rather because the philosophy resonates with the spirit of "ubuntu"[2] that is so prevalent in Africa. Within the HISP network this approach is increasingly becoming a selling point, especially as it denotes an approach that does not seek to create dependence on outside support.

The prototyping approach that has as its aim the empowerment of local users is important in converting users to become advocates for the system. The result has been that the HISP network has seldom initiated a HISD project on the basis of the systems specifications and what it portends to do – rather it has been through a process of small-scale, bottom-up start-up, which has scaled because the processes and procedures that have been developed have spoken for themselves. This is where the systems development process has interacted with the scaling process in an iterative manner. The initial scaling of a system across one area (Copperbelt province in Zambia for instance) has been followed by repeated waves of increasingly sophisticated additions to the system. This 'developmental' approach to ISD recognizes that capacity to absorb new processes and procedures, and to institutionalize them takes time. If the new systems are too complex or radical, then it is likely that they will be rejected as inappropriate, but small changes that build towards a bigger vision has a much better chance of being accepted. As discussed earlier, recognizing that the scaling process is encapsulated within a bigger developmental process, allows certain aspects of the HIS to be held static, while the scaling takes effect. There is no need to "implement everything all at once" (as is so often the call by eager donors or officials), when the capacity to absorb and institutionalize it all at once is limited. Hence, it is acceptable to incrementally increase the range of programs that are incorporated by the system, or to expand the modules of the system, once the initial scaling has been effected. This allows the systems and processes to grow in synch with the increased capacity of users.

Utilizing the "hierarchical cluster" approach to scaling of HIS is perhaps the most interesting aspect to monitor over time. It is interesting because HISD is being effected in tandem with other health systems strengthening initiatives. Together they may create a critical mass that is more successful at producing quality information for program monitoring than HIS strengthening efforts on their own have done. In this example the network approach to development of HIS (Braa, Monteiro, & Sahay, 2004) is further expanded to include program managers. This is not an insignificant issue, especially as the referral patterns within the cluster run parallel to and will hopefully support the vertical and horizontal diffusion of HIS strengthening efforts. In addition, the expanded network of users is an important factor in countering the political impulsiveness and vested interests of decision makers in much of Africa.

While the HIS may be the glue around which the systems and procedures are developed, it is the people that make the information system work. The recognition of a special cadre of health worker called the HIS practitioner, who has a range of IT skills to complement knowledge of the health sector is important because it helps to define the specific skills that need to be developed to help these individuals address their daily tasks. Since the publication of the article by Braa et al (2004), a number of developments have taken place. The HISP-SA node has become significantly stronger, and has extended its influence through longitudinal support to HIS development in Nigeria, Liberia, Zambia and Namibia. The model developed by the HISP-SA team of a three pronged partnership with academia, local non-governmental organisations and government continues to be tested and developed in Nigeria and Zambia. The 'networks of action" are therefore shifting from being Oslo-centric to a more Afro-centric pattern, made increasingly interesting by the sharing of HIS-practitioners amongst themselves.

5. CONCLUDING REMARKS

Over the 10 years of HIS development we have seen a range of responses to the development of HIS. In some countries the take-up has been slow, and probably related to the low base from which systems are being developed, the insecure funding environment that is reflected by low levels of commitment and erratic government spending, and the general lack of access to resources. This is in contrast to the situation in Zambia where there has been a long history of HIS development, and where a revision of the software and accompanying processes was able to be effected in a relatively short space of time. Public health officials actively supported the process, and contributed from their own resources to compliment donor funding. Similarly, in Liberia there has been active involvement by public health officials and a commitment to scale the system beyond the initial pilot in 4 counties. In South Africa the HISD effort has been funded by national and increasingly provincial and local government and is largely independent of donor funding. Ongoing research is needed to explore how different approaches can scale more quickly while still being effective in terms of their outcomes.

In addition, while we have acknowledged the existence of systems and processes focused on a narrow disease priority which result in fragmented information systems, further research is needed to explore how these systems can be merged with existing information flows to strengthen the overall HIS.

To conclude, perhaps the best way to summarize the experience of the HISP network to date is to suggest that developing scalable and sustainable health information systems requires adherence to five key approaches, namely:

- Health information system (not only the software) should be flexible so as to be able to adapt to the constantly changing environment;
- The utilization of a participatory prototyping approach to HISD helps to secure adoption and use of the system while also reducing development costs;
- Adherence to the FOSS philosophy of sharing and sharing alike is easily internalized in the African culture of 'ubuntu';
- Health information systems should seek to integrate systems and procedures rather than fragment them;
- The utilization of broad-based "networks of action" incorporating local non-governmental organisations, government, and academia both locally and abroad appear to be succeeding especially in the creation of a cadre of HIS practitioner.

These approaches appear to lay the building blocks for sustainable HISD in complex contexts which are beyond the control of any single individual.

ENDNOTES

1. Source: DHIS data for Jigawa as at Nov 2008.
2. Ubuntu" means "a person is a person through (other) persons" (umuntu ngumuntu ngabantu)

REFERENCES

Benbya, H., & McKelvey, B. (2006). Toward a Complexity Theory of Information Systems Development. *Information Technology and People, 19*(1), 12-34.

Bergqvist, J., Dahlberg, P., & Ljungberg, F. (2002). Scalability through Cultivation - designing IT support for co-ordination work. Retrieved 13 November, 2006, from http://citeseer.ist.psu.edu/cache/papers/cs/23947/http:zSzzSzwww.dahlberg.se zSzpubzSzmaster.pdf/scalability-through-cultivation-designing.pdf

Bjerknes, G., Ehn, P., & Kyng, M. (Eds.). (1987). *Computers and Democracy - A Scandinavian Challenge*. Avebury, Aldershot.

Boerma, T. (2005). WHO News - Getting the numbers right. *Bulletin of the World Health Organisation, 83*(8), 567-568.

Braa, J., Hanseth, O., Heywood, A., Mohammed, W., & Shaw, V. (2007). Developing Health Information Systems in Developing Countries - the flexible standards strategy. *MIS Quarterly, 31 Special Issue*

Braa, J., & Hedberg, C. (2000). *Developing District-based Health Care Information Systems: The South African Experience.* Paper presented at the IRIS 23.

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., & Reinert, E. S. (1995). Technology Transfer vs. Technological Learning: IT infrastructure and health care in developing countries. *Information Technology for Development, 6*(1), 15-23.

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

Chilundo, B. (2004). *Integrating Information Systems of Disease-Specific Health Programmes in Low Income Countries.* University of Oslo, Oslo, Norway.

Chilundo, B., & Aanestad, M. (2004). 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), 1-28.

Ciborra, C. (2000). *From Control to Drift - the Dynamics of Corporate Information Infrastructures*: Oxford University Press.

Davis, G. B. (1982). Strategies for Information Requirements Determination. *IBM Systems Journal, 21*(1), 4-31.

Elden, M., & Chisholm, R. F. (1993). Emerging Varieties of Action Research - Introduction to the Special Issue. *Human Relations, 46*(2), 121-142.

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

Greenbaum, J., & Kyng, M. (Eds.). (1991). *Design at Work:Cooperative design of computer systems*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Greenbaum, J., & Madsen, K. (1993). Small Changes: Starting a Participatory Design Process by Giving Participants a Voice. In D. Schuler & A. Namioka (Eds.), *Participatory Design: Principles and Practices*. Hillside, N.J.: Lawrence Erlbaum Associates.

Hanseth, O., & Braa, K. (2000). Globalization and "Risk Society". In C. Ciborra (Ed.), *From Control to Drift - the Dynamics of Corporate Information Infrastructures* (pp. 41-55). Oxford: Oxford University Press.

Jacucci, E., Hanseth, O., & Lyytinen, K. (2006). Introduction - taking complexity seriously in IS research. *Information Technology and People, 19*(1), 5-11.

Jayasuriya, R. (1999). Managing Health Information Systems for Health Services in a Developing Country: a case study using a contextualist framework. *International Journal of Information Management, 19*, 335-349.
Korpela, M., Soriyan, H. A., Olufokunbi, K. C., Onayade, A. A., Davies-Adetugbo, A., & Adesanmi, D. (1998). Community Participation in Health Informatics in Africa: An Experiment in Tripartite Partnership in Ile-Ife, Nigeria. *Computer Supported Cooperative Work (CSCW), 7*(3 - 4), 339-358.
Madon, S., Reinhard, N., Roode, D., & Walsham, G. (2009). Digital inclusion projects in developing countries: Processes of institutionalization. *Information Technology for Development, 15*(2), 95-107.
Mash, B., & Mohammed, H. (2000). Participatory development of a minimum dataset for the Khayelitsha District. *South African Medical Journal, 90*(10), 1024-1030.
Mavimbe, J. C., Braa, J., & Bjune, G. (2005). Assessing immunization data quality from routine reports in Mozambique. *BMC Public Health, %*(108).
Odedra, M. (1992). Is Information Technology Really Being Transferred to the African Countries? In S. Bhatnagar & G. Cyranek (Eds.), *Technology Transfer for Development: The prospects and Limits of Information Technology* (pp. 47-58). New Delhi: Tata MC Graw Hill.
Odedra, M. (1993). Sub-Saharan Africa: A Technoligical Desert. *Communications of the ACM, 36*(2).
Odedra, M. (1994). The Role of International Organisations in Technology Transfer. *Journal of Third World Science, Technology and Development Forum, 12*.
Pan American Health Organization. (1999). *Setting up Healthcare Services Information Systems: A Guide for Requirement Analysis, Application Specification, and Procurement.* Washington, D.C.: Pan American Health Organization.
Ramanathan, J. (2005). Fractal Architecture for the Adaptive Complex Enterprise. *Communications of the ACM, 48*(5), 51-57.
Raymond, E. S. (1999). *The Cathedral and the Bazaar*. Sebastopol, California: O'Reilly.
Rohde, J., Shaw, V., Hedberg, C., Stoops, N., Venter, S., Venter, K., et al. (2008). Information for Primary Health Care. In P. Barron & J. Roma-Reardon (Eds.), *South African Health Review 2008* (pp. 423). Durban: Health Systems Trust.
Rolland, K., & Monteiro, E. (2002). Balancing the Local and the Global in Infrastructural Information System. *The Information Society, 18*, 87-100.
Sahay, S., Monteiro, E., & Aanestad, M. (2009). Configurable Politics and Asymmetric Integration: Health e-Infrastructures in India. *Journal of the Association for Information Systems, 10*(5), 399-414.
Sahay, S., & Walsham, G. (2005, 26-28 May 2005). *Scaling of Health Information Systems in India: Challenges and Approaches.* Paper presented at the International Federation for Information Processing Working Group 9.4 Conference, Abuja, Nigeria.
Sandberg, A. (Ed.). (1979). *Computers Dividing Man and Work*. Stockholm, Sweden: Arbeitslivcentrum.
Sandiford, P., Annett, H., & Cibulskis, R. E. (1992). What can Information Systems do for Primary Health Care? An International Perspective. *Social Science and Medicine, 34*(10), 1077-1087.

Seebregts, C., Mamlin, B., Biondich, P., Fraser, H., Wolfe, B., Jazayeri, d., et al. (2009). The OpenMRS Implementers Network. *International Journal of Medical Informatics*(Forthcoming), 10.

Shaw, V., Mengiste, S., & Braa, J. (2007). *Scaling of health information systems in Nigeria and Ethiopia - Considering the options.* Paper presented at the IFIP 9.4 9th International Conference on Social Implications of Computers in Developing Countries, Sao Paulo, Brazil.

Shaw, V., Simoonga, C., Kalinda, P., & Muyambo, S. (2008, 7-9 May 2008). *Using Communities of Practice as a Lens for Understanding Adoption of ICT.* Paper presented at the IST-Africa Conference 2008 Windhoek, Namibia.

Shibuya, K., Scheele, S., & Boerma, T. (2005). Health statistics: time to get serious. *Bulletin of the World Health Organisation, 83*(10), 722.

Siika, A. M., Rotich, J. K., Simiyu, C. J., Kigotho, E. M., Smith, F. E., Sidle, J. E., et al. (2005). An electronic medical record system for ambulatory care of HIV-infected patients in Kenya. *International Journal of Medical Informatics, 74*(5), 345-355.

Silva, L. (2007). Institutionalization does not occur by decree: Institutional obstacles in implementing a land administration system in a developing country. *Information Technology for Development, 13*(1), 27-48.

Tan, J., Wen, H. J., & Awad, N. (2005). Health Care and Services Delivery Systems as Complex Adaptive Systems. *Communications of the ACM, 48*(5), 36-44.

The Lancet Editorial. (2009). Europe's aid to sub-saharan Africa: better results needed. *The Lancet, 373*(9662), 434.

Walsham, G., & Sahay, S. (1999). GIS for District-Level Administration in India: Problems and Opportunities. *MIS Quarterly, 23*(1), 39-66.