DEVELOPING HEALTH INFORMATION SYSTEMS IN DEVELOPING COUNTRIES

THE FLEXIBLE STANDARDS STRATEGY

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ABSTRACT

This article addresses the issue of strategies for developing information infrastructures in general and for the development of IS 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. We begin with an overview of complexity science, and how standards to date have not addressed the needs of a changing environment. Using an action research approach in countries involved in the HISP network, we describe different contexts to demonstrate the importance of creating “attractors” to support networks of change. 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. Simple standards are important in the scaling of information systems. A number of seemingly 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 contribution that is made is to provide theoretical concepts to support standardization processes in complex systems, and to suggest an approach to implementation of health standards in developing country settings that is sensitive to the local context.

KEYWORDS:

Health information systems, standards, complexity science, developing countries.

1. INTRODUCTION

This article addresses the issue of strategies for developing information infrastructure *standards* in general and for the development of IS 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 contribution that is made is to provide theoretical concepts to support standardization processes in complex systems, and to suggest an approach to development and implementation of health standards in developing country settings that is sensitive to the local context.

Development, Health Care and Health Information Systems

Poor health status, rampant killer diseases such as HIV/AIDS and inadequate health services are seriously hampering human, social and economic developments in developing countries. Considerable efforts are currently being made by international aid and United Nations (UN) agencies to address these problems. The United Nations’ Millennium Development Goals (MDG) (UN 2000), which are targeting the major health problems alongside other key issues related to poverty reduction, constitute a coordinating framework for these efforts.

Appropriate information and Health Information Systems (HIS) are seen as crucial to strengthen the health system in developing countries (World Health Organisation 2000) and in pursuing the particular MDGs (AbouZahr and Boerma 2005). On the ground, however, HIS development in developing countries has proved to be difficult due to organisational complexity (Jayasuiriya 1999; Gladwin et al. 2003; Littlejohns, Wyatt et al. 2003), fragmented

and uncoordinated organizational structures all maintaining their own HIS (Jeppsson and Okuonzi 2000; Chilundo and Aanestad 2004), unrealistic ambitions (Heeks 2002), and more generally due to the problem of sustainability (Kimaro and Nhampossa 2005; Sahay et al. 2000). Sustainability is referring to a system that is self-sustaining and self-sufficient (Reynolds and Stinson 1993) and is, for example, used by Korpela et al. (1998) to imply that the user organization needs to identify and manage risks that threaten the long term viability of the HIS.

The health care sector in a country consists of a large number of institutions ranging from the small and simple health care centers up to the large and advanced hospitals. These institutions are managed by a number of institutional bodies, organized into geographic areas (district, province, nation), and according to certain programs (HIV/AIDS, maternal health, vaccination) and services (primary health care, hospitals, laboratories, drug supply). Programs are often influenced at the national level through various international donor organisations and the World Health Organisation (WHO). While global and national health policies normally recommend local management and integration of health information from various services and programs, the current reality is rather opposite. National health systems are typically made up of a number of relatively independent health programs and services which all maintain their own vertical and uncoordinated reporting systems. The lack of shared standards for data collection mean that the same data is often reported separately through different structures, while at the same time there might be gaps where important data does not get reported. Inconsistencies in definitions and procedures result, creating further fragmentation and lack of coordination. This results in excessive data and generally poor use of it (Sandiford, Annett et al. 1992). The problem of HIS fragmentation is well

documented (WHO 1994; Chilundo and Aanestad 2004), and *integration* of HIS is consequently a priority that needs to be addressed (de Kadt 1989, WHO 2000).

Fragmentation of HIS is aggravated even further as donor funding targeting specific areas such as the MDGs invariably are creating their own new information systems which are not integrated with the existing HIS (Okuonzi and Macrae 1995). The development of relatively cheap and effective anti-retroviral drugs to treat AIDS patients has led to ambitious plans to roll-out treatment programs to millions of people in developing countries, and multi-billion dollar funds are raised to implement these plans. This current large-scale funding for HIV/AIDS is causing further dis-integration leading the WHO HIV/AIDS department to state (WHO, 2003, our numbering): "[1] There is an urgent need for strategic information in conjunction with the anti-retroviral treatment [of AIDS patients] programmes, including the developing of monitoring and evaluation systems. .. [2] Efforts should be made to integrate anti-retroviral treatment into existing HIS run by governments. .. [3] Strengthening existing HIS in countries can be one of the positive externalities produced by anti-retroviral treatment programs." (ibid. p. 1). Regarding standardization [4] it is "urged that the monitoring and evaluation of ART programmes be simple, with data collection limited to only that information deemed to be essential for the well functioning of programmes." (ibid. 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" (ibid. p. 4).

How to address the need for specialized, while at the same time integrated HIS, as expressed by these HIV/AIDS practitioners, through flexible standardization approaches focusing on simplicity and the essential needs for information, is the focus of this article.

The uneven development of the infrastructure[1] in developing countries adds to the complexity of standardizing this infrastructure. 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, the ART programmes are pushing implementation of electronic patient records that in many developing contexts, for the foreseeable future, will have to co-exist with the paper based patient record system. This disparity in infrastructure represents a situation very different from industrialised countries, emphasising the fact that standardised technical solutions cannot easily be transferred from industrialised to developing countries.

Strategies for Standardization

From the above, it should be obvious that an integrated health information infrastructure[2] is important in developing countries and that such infrastructures needs to be based on standards for information sharing and exchange between information systems, programs, and institutions. The question is, then, what is an appropriate strategy for developing the required standards?

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[1] Infrastructure is used in its broader sense, meaning the technological and human components, networks, systems and processes that contribute to its functioning. Uneven development refers to inequities that exist between regions and geographic areas in terms of access to the components of the infrastructure

[2] Throughout the article we will use both the terms “Health Information System” (HIS) and (health) information infrastructure. We will use the first to talk about the totality of information used within the health care sector in a country or region as seen from the perspective of health care personnel (i.e. from outside), while we will use the second when we look at this “system” from inside, i.e. its components and how they are related and may be (re-) designed – in particular when issues related to standards are discussed.
Infrastructural standards are a heterogeneous group of practices that vary from practices and guidelines that guide human action, standards for data communication between hierarchical levels, to standards for software integration and hardware configurations. In this study we will focus on the standards at the technical level of software, and at the service delivery level, or standards for data collection and communication.

From the perspective of information systems (or software engineering) it is a question about information systems development strategy. Such strategies vary from top-down specification driven ones on the one hand, to bottom-up and experimental ones on the other with various models for evolutionary development in between. In general, bottom-up and experimental models address uncertainty in terms of lack of knowledge about users requirements, rapidly changing environments, etc. But such models do not scale well. When the software system increases in size, and requires frequent changes, the costs of modifications rise rapidly. In such cases top-down and specification driven models are recommended. But these models only work well when uncertainty is low (see for instance Mathiassen et al. 2000). Standardization[3], in telecommunications as well as in other areas, has followed specification driven top-down models. Such models have also been applied to the development of IS standards, for health care and many other areas – with modest success (see for instance Graham et al. 1996; Hanseth and Monteiro 1997). While such standards and the infrastructures built upon them soon became big and complex, the uncertainty regarding user needs and changing environments is also very high. This is also the case for IS standards for health care in developing countries. Accordingly, neither bottom-up strategies nor top-down strategies alone will work. The aim of this paper, then, is to demonstrate how bottom-up approaches can co-exist with top-down strategies, and how this combination can

[3] In this paper, standardization is understood in terms of the definition by De Vries (2003):
"…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).

facilitate standardization. In particular, we demonstrate how it allows an evolutionary development of a framework we call flexible standardization.

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 is presented in section four, and draws on material from the health information systems standardisation experiences of the HISP group in South Africa, Ethiopia and Thailand mainly (although some additional data from other sites is also presented). This leads us into the discussion section where highlight the key issues of flexible standardization in developing country contexts. In the final section we summarize our recommendations as concrete guidelines for HIS standardization.

2. THEORY AND RELATED RESEARCH

We will in this section present our theoretical framework and related research, which on the main concepts developed within the emerging Complexity Science field. We supplement this with insights and concepts from the study of complexity within the social sciences and complex technologies or socio-technical systems. We begin with an overview of complexity science, and in particular develop the concept of adaptation, emergent order, and the creation of attractors. These concepts are then discussed in terms of the health care system as a necessary requisite to support purposeful change. In this section we introduce the concept of scalability, arguing that we will show how simple standards can contribute to scalable systems. In the last section we discuss how standards have to date not sufficiently addressed the needs of a changing environment. This leads into a review of concepts from

large technical systems, and actor-network theory as a means to support the process of creating flexible standards as attractors – the agents of change.

COMPLEXITY SCIENCE

Over the last couple of decades the field called Complexity Science has emerged. It has emerged primarily from the study of phenomena within physics (like thermodynamics and biology). But contributions are also made from studies of more social phenomena, in particular within economy, like financial markets and the issue addressed in this article, standardization (David 1986; Arthur 1994). Complexity science is made up of a broad range of disciplines such as chaos theory and Complex Adaptive Systems (CAS). CAS are concerned with the dynamic with which complex systems evolve through adaptation and is increasingly used in organizational studies, for example in health care. CAS are made up of semi-autonomous agents with the inherent ability to change and adapt 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 the agent fits into the environment and the agent as well as the CAS undergoes change. Adaptation - and creativity and innovation – is 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; Plsek and Greenhalgh 2001; Wilson, Holt 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.

Overall, complexity science investigates systems that *adapt* and *evolve* as they *self-organize* through *time*. (Urry 2003). In particular, attention has been directed at how order within such systems are created without a "designer" but rather *emerge* like, for instance, 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 (Byrne 1998). The simplest attractor is a single point. There are also attractors with specific shapes and which are called "strange attractors," i.e. unstable spaces to which the trajectory of dynamical systems are attracted through millions of iterations" (Carpa 1996). The use of "Attractors for change" are recommended when seeking to bring about changes in areas where there is only moderate certainty and agreement (Plsek and Wilson 2001). A de-facto, or emergent, standard, like MS Windows or QWERTY, is a typical example of an attractor. Orders emerge around attractors through various *feed-back* mechanisms, and through *path-dependent* processes of many small steps that may end in *lock-in* situations (David 1986). Some steps may be crucial in the sense that they may force the process in radically different (unexpected) directions. Such points are called tipping or bifurcation points (Akerlof 1970). The existence of such points makes the evolution of complex systems *non-linear* in the sense that small changes in a system at one point in time may lead to hugely different consequences at a later point in time.

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 environment.

COMPLEXITY IN HEALTH CARE, INFORMATION SYSTEMS AND THEIR SCALABILITY

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 like Organization Science, Culture, Theory & Society and Information Technology & People – domains that include sociology and cultural studies (see for instance Urry 2003),

Complexity science is increasingly being applied in the area of health care organizations, where order is being regarded as emerging through self organising and adaptive processes rather than through central control (Plsek and Greenhalgh 2001; Tan et al. 2005). The recommended strategy to develop acceptable levels of order is to build on these self organising and adaptive properties: “To cope with escalating complexity in health care we must abandon linear models, accept unpredictability, respect (and utilise) autonomy and creativity, and respond flexibly to emerging patterns and opportunities.” (Plsek and Greenhalgh 2001, pp 628). For example, (Tan, Wen et al. 2005) locate innovation and adaptation at the “edge of chaos” and illustrate chaos as outbreaks of epidemics.

Complexity Science is also 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 Benbya et al. 2006; Axelrod and Cohen 1999). While we agree that a new order cannot be designed and imposed on a complex system, we believe that more ambitious strategies are needed in the domain we are addressing. While understaffed and under-resourced hospitals are running and thus somehow adapting to their resource-poor context, the order that has emerged through this adaptation could better be described as dis-order. The HIV/AIDS pandemic together with the human resource crisis in the health sector in many developing countries, make it clear that

there is a desperate need to bring the evolution of the health care systems and their information infrastructures in developing countries on a different trajectory to 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 centre of this order will be a complex system of standards. And this system of standards needs to be 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 (ibid.). Scaling is also central 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, pp 36). Broccoli is used as an example of scaling in a natural system as branches and sub-branches have the same structure as the whole plant (ibid.). 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).

STANDARDISATION, TECHNOLOGY, AND CREATION OF ATTRACTORS

In this section we present an argument for increased attention to flexible standards, and then draw upon research on the design or emergence of new orders, including, large technological systems within the Science and Technology Studies field, in order to explore how this might be achieved through the 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 (Brunsson and Jacobsson 2002; Romer 1990; Schmidt and Werle 1998). However, complexity theory has not yet been applied explicitly beyond the concepts coming out of primarily economic research on standardization mentioned above. Among those interested in research in standardization, there consensus seems to emerge 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 for instance Branscomb and Kahin 1996; David and Shurmer 1996; Shapiro et al. 2001). It is also acknowledged that the world is changing more rapidly and that standards need to be more flexible to adapt to this (Hanseth, Monteiro et al. 1996; Egyedi 2002). Hanseth et al. (1996) discuss to kinds of flexibility: use- and change flexibility, and argue that standards need both. Use flexibility describes the possibilities for use a standard in new ways without changing it, while change flexibility describes how easy it is to modify a standard

We aim in this article to contribute to these strands of research by proposing a strategy for staging the emergence of new standards, and to highlight the importance of ensuring that

they are a 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.

Large Technological Systems

Thomas P. Hughes' (1983) in his theory of "Large Technological Systems," describes how a technological system (which also includes humans, institutions (universities, professions' associations, etc.), documents, organizations and what he calls "legislative artifacts", or laws) evolves from an initial idea to a widely diffused infrastructure or system. As the system is growing, it gets *momentum* and develops increasingly autonomously along a certain *trajectory*. As a system gains momentum, it is normally incredibly difficult to change its trajectory. According to Hughes, such changes of trajectories only happen in case of serious crises (like the oil crises in 1973).

The different components of the system normally evolve in parallel. But sometimes one component evolves slower than the rest – it becomes a *reverse salient* that may slow down or even stop the evolution of the whole system. This might again lead to a *crisis* attracting lots of attention to the reverse salient. When a solution to the reverse salient problem is developed, this may be a radically new design which becomes an attractor evolving into a new technological system. Not all new systems emerge out of a crisis. The general pattern, however, is that a new attractor is first created as a solution to a very specific problem - for instance a reverse salient problem. The solution is then spread as its wider applicability is discovered and if it is simple and flexible enough to be adapted to new user requirements. This is opposite to how standards have been developed within telecommunication, and the still dominating view on standardization: first, specify the requirements of all users within the

domain of the standard, then specify and approve the standard, and finally implement it in terms of technological components. It is then taken for granted that the standard will be adopted. The most famous and relevant example of a technology – and its standards – that follows Hughes' model is the Internet and its services (Leiner et al. 1997; Abbate 1999). E-mail, for instance, was introduced into the Internet at a time when four computers were connected to the net – not as a general service, but just to support the maintenance and operations of the net by those responsible for the four nodes (Abbate 1999). As time passed, it was discovered that this was a very useful service and its adoption took off.

We will now move yet one level deeper into the details of how this may be carried out by means of Actor Network Theory (ANT).

Actor-Network Theory

Actor-Network Theory (ANT) addresses much of the same issues as Hughes' theory. However, ANT has focus on a more micro level and is used to describe those processes in more detail. ANT has by and large been developed and used to analyze the alignment of socio-technical networks or what we may call the "making of order in a complex world". This world has been seen as including humans and non-humans, or technological and non-technological, elements. ANT has been used in research on the negotiation of IS standards and embedding them in their local context of development and use (Bowker and Star 1999; Timmermans and Berg 1997; Hanseth and Monteiro 1997). In this sense, standardization is seen as order-making *par excellence*. In this article we will use some basic elements from ANT in developing a strategy to create attractors.

ANT describes the development and diffusion of scientific theories and technological artefacts as a process of building heterogeneous (socio-technical) networks. Central concepts in early ANT research that we will apply are closure (Law and Bijker 1992), stabilization (e.g. Bijker 1993) and enrolment and alignment (e.g. Callon 1991). Specifically, closure indicates a status where consensus emerges around a particular technology, or a standard.

An attractor (or standard), an emerging new order, can then be built, according to ANT, by enrolling and translating elements, humans and non-humans (or technological and non-technological) into aligned actor networks. The first element to be enrolled into the network is a “problem owner”. The network must be built as a solution to a problem. Later on more “problem owners,” or users, are translated and aligned with the network. Through such a process a new order gradually emerges.

We now turn to an explanation of the methodology used in this research, before exploring the empirical data in detail.

3. 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, Monteiro et al. 2004). As such their experience has been gained from action research in a large number of developing country contexts such as

Mongolia, India, Tanzania (and Zanzibar), Botswana, Cuba (Braa, Titlestad et al. 2004), Malawi, Vietnam, South Africa and Ethiopia.

The authors, as well as 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 standardisation in the countries described in this article. Action research aims at generating new knowledge through taking part in the full cycle of planning, implementing and analysing the results from concrete interventions (Susman and Evered 1978). The network of action research within HISP has made it possible to go beyond the learning in singular locations to the sharing of experience and knowledge between the various nodes and countries of the network (Braa, Monteiro et al. 2004). 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.

In this section we describe the use of contextualism as the ontological basis for the research, and the use of interpretive research methods in the analysis of data and experiences in order to gain a deeper insight into our observations. Thereafter we provide a description of the data collection methods.

Ontological basis for the study:

Contextualism (Pettigrew 1985; Pettigrew 1987) emphasises the importance of the context-content-process axis. Some of the key aspects of this view are:

- Content, context and process interact and influence one another;

- It allows the exploration of the origins, development and implementation of organisational change
- Pettigrew (1985, p. 64) describes the study of organisational change 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).
- Analysis of the change within the organization would require analysis at multiple levels, across time, and would need to incorporate cross-sectional categories.

This approach requires an in depth understanding of the research context, and in particular a focus on the “emergent, situational, and holistic features of an organicism or a process in its context” (Pettigrew 1985). This resonates with the approach adopted by the HISP network, which has followed a developmental 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 pre-requisites for a contextualist analysis, and uses this to provide criteria for evaluation of contextualist research. We have attempted to address 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 study is described taking into account the historical basis of the context (post-apartheid influences in South Africa; the drive for quality data on which to base financial allocations in Thailand), as well as factors that are likely to be an influence in the future (the

HIV/AIDS epidemic; increased access to ICT). Analysis of the processes observed acknowledges the roles played by individuals, and the power relationships in contributing to outcomes. This is done within an in-depth and contextually detailed description of the cases (especially for the South African and Ethiopian cases, although less so for the Thailand case). 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; Walsham 1995) have been used to make sense of the experiences, observations and findings of the researchers. Interpretive research aims 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) Action research, such as implementing and testing data standards and a continuous cyclic prototyping of the DHIS software (still ongoing), has been carried out in close cooperation with users at multiple levels and has been important in generating mutual learning and understanding. The data analysis process can be seen as an integral component of the action research process of the HISP network. Within this network opportunities, both formal and informal, as part of a formal research process, or as an aspect of a project implementation process, arise for discussion of numerous aspects of information systems development, which resulted in the distilling of concepts that led to the development of this research paper. All the authors have at various stages taken on different roles – at times assuming the role of researchers, implementers, critical analyst, and sometimes a combination of all three.

The selection of the three countries for this article is purposeful. We wanted to present success stories, which we found in Thailand and South Africa, and a country which, in terms of potential for HIS development, provided challenges in a difficult context (Ethiopia). As discussed above, the selection of this range of cases provides for interesting opportunities to contrast the contexts which 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, Monteiro et al. 2004). Two of the authors are permanent residents in South Africa and one in Ethiopia. In these countries an action research has been adopted to information systems development, and the longitudinal research carried out on HIS in particular South Africa, but also Ethiopia, has contributed significantly to the case study in these two countries as well as providing a comparative framework for the study in Thailand.

Apart from drawing on the day to day experience from action research, a variety of methods have been used for data collection. Data was drawn from a number of sources – diaries and notes and reports maintained by the researchers and students, annual reports, and statistical bulletins. Additional sources of information gathered during the action research approach adopted for the development of information systems 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 and in particular as members of the HISP teams worked with their country counterparts.

The data for Thailand was obtained through a study commissioned by a development aid agency. The request was to do an informal assessment of Health Information Systems in a few developing countries, one of which was Thailand. The aims were to a) identify key problem areas, b) suggest ways to address these areas, and c) to develop a formal methodology to assess and, eventually to measure progress over time in these areas. This study provided the data described in the Thailand case study. The fact that the researchers had previous knowledge of Ethiopia and South Africa, but no knowledge about Thailand, invariably led to different approaches to the data gathering. There was a focus on the national level of the ministry of health, though every level of the health system (sub-national, district and facility) was visited. A team was formed by people responsible at the national level and one of the authors, and a relatively extensive tour to 6 key offices at national level Ministry of public health was undertaken. Other HIS-related organisations outside of the health system were interviewed – universities, para-statals, the national statistics office and WHO were also contacted. In addition, 2 provinces (Nan and Nonthaburi), 4 districts, 5 hospitals and 4 PHC clinics were also visited.

[INSERT TABLE 1 ABOUT HERE]

4. CASE STUDY: THE HISP EXPERIENCE

This case study focuses on efforts made at developing standards and information infrastructures in the HISP project. Emphasis will be on South-Africa where the HISP project started and where the most significant results have been achieved. Based on the framework of complexity theory we will focus on, first, the development of a new standard as the creation of an attractor, second, 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 a broader range of issues and challenges that need to be addressed. Then we present the case of Ethiopia, a vast and poor country where HISP has been working since 2003. Lastly we will present successful standardization efforts in a country where HISP has not been involved, Thailand, but which demonstrates useful experiences for the proposed approach.

While Ethiopia is one of the worlds poorest countries, and has a poorly functioning HIS (although they have ambitious plans to strengthen this), South Africa and Thailand are mid-income countries, that have had considerable achievements in their HIS development. The profile of the countries described in the case is shown in the table below.

[INSERT TABLE 2 ABOUT HERE]

THE SOUTH AFRICAN CASE

During apartheid era in South Africa, the health services were extremely fragmented according to race, and the system of 'homelands' for black South Africans. This resulted in extreme inequity in health services provision and health status between populations and racial groups. The reporting systems and the data standards used were equally fragmented and incompatible. With the advent of democracy, there was an atmosphere where "everybody" expected "everything" to change – not the least 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 to what extent this target is being achieved, and to pinpoint areas where more resources and efforts are needed, a standardised system for collecting and comparing health related data from all over the 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 ICT's exist. While in the urban centres the infrastructure is well developed, in the rural areas of the Eastern Cape and Limpopo Provinces, many hospitals and health centres lack access to internet and even a reliable electricity supply, and even the roads may be impassable during the rainy season (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 and is described in detail below.

[INSERT FIGURE 1 ABOUT HERE]

The creation of an attractor

What became the HISP project started in 1994 as a small collaborative research project between researchers at the Universities of Cape Town, Western Cape and a Norwegian Ph.D. student interested in doing action research in developing countries building on Scandinavia experiences in action research and participatory design. The aim of the first (small) project was to provide health care workers within a poor township in Cape Town (Mitchell's Plain) with computer support so they could 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. However, HISP and others soon realized that the development of a tool for local clinics and districts needed to be coordinated with activities at higher (provincial) levels, in particular regarding data standards". In order to reach consensus on a "minimal" data set, 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 the clinics in two of the HISP pilot sites. In parallel with the negotiations on data sets, HISP developed a desktop database application, called District Health Information Software (DHIS), for managing various data sets. DHIS was first developed as a typical action research experiment using rapid prototyping and aiming at supporting the implementation of data standards in the pilot sites. Later, as the user base has increased drastically, the development of DHIS has turned into a (still) 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).

It was difficult to get a real break-through in the negotiations about minimal data sets because

1) it was difficult to get consensus between health programs on what data should be included and what should be excluded, and

2) 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 organised 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, on the one hand, arguing 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 in the standardisation process in South Africa (see figure 2).

Finally then, agreement was reached to implement the minimum data set of 47 data that had been piloted and revised in the HISP pilot sites uniformly in all health facilities in the Western Cape Province from January 1998. Once implemented, this data set quickly became a success, basically for two reasons:

1) it was the first time uniform data had been collected across the disparate health services in the province, and

[INSERT FIGURE 2 ABOUT HERE]

2) 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 the post-apartheid South Africa. Where previously the scattered data that existed were hard to obtain, now at a sudden better and complete data sets were available at the desktops of managers and health workers once it was reported and captured. The philosophy behind the development of the flexibility of the DHIS software emphasized the empowerment of users at a local level to use information to manage their health services - a philosophy 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 developed a different essential dataset. EQUITY, a large USAID funded project had a strong interest in developing data standards and was funding this initiative. However, they lacked a software system to accommodate the data processing. In October 1998 HISP arranged a large workshop in Cape Town to present the achievements so far in the Western Cape. After the workshop the HISP team was approached by the EQUITY manager who asked: “Are you able to customise the DHIS, import the data from our software and implement it in all districts in the Eastern Cape before the holiday season in December?” The answer proved to be “yes,” and the resulting implementation of internally uniform datasets in two provinces was regarded as a major step forward.

Although the two data sets differed, the important issue was that key data was essentially the same, and for the first time had been uniformly collected across black and white

population groups, urban and rural areas, rich and poor, and in two provinces, which had previously been divided into black homelands, and coloured and white administrative areas. The achievement of practical results in two provinces sparked interest in other provinces and at national level, and consensus was achieved over a number of years on a national standard dataset (Shaw 200).

At this stage we can say that an attractor for a new order, a new set of standards, was created. The (technical) standards component of this attractor consists of the two data sets defined and agreed upon in the two provinces (Eastern and Western Cape). But what made these data sets really 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 regional level in the Western Cape province. We can also see that this attractor emerged as such, not primarily because "everybody" agreed that the data sets satisfied their requirements, but because they were used and helped users do their job better. The standards aimed at supporting the creation of a "brand new" South-Africa, but to get started they had to support the "old." We will discuss later on how they also enabled the transformation from the "old" towards the "new." The attractor was created by enrolling users and their existing work practices, minimal data sets, a software package, and health care authorities plus some more components into an heterogeneous but aligned actor network.

Making a Set of Standards an *Adaptive* System

The collaboration between Western and Eastern Cape initiated the countrywide standardization process which subsequently included all provinces and the national level, and the first national "essential" dataset was agreed upon in June of 2000. While all

provinces are maintaining their own extended data sets, the national data set makes up the shared core which all provinces are collecting and reporting. 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 programme data sets have expanded, or to accommodate new vertical programmes (as with the HIV/AIDS programmes). It has now (2005) been expanded to become an "National Indicator Dataset" (NIDS), reflecting the increased focus on the use of indicators[4] (as compared to the earlier focus on data elements). Since each indicator is composed of data elements (a numerator and a denominator), the indicator list is easily translated into an essential data set. The tension between 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 datasets for selected vertical programmes initially get to be developed as a separate dataset, and collected and collated in a separate data base within the DHIS software. This allows experimentation and fine tuning to occur, often in selected sites or specific geographic areas. Once the development of these data elements has stabilised, the whole dataset, 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 dataset in the Eastern Cape Province, and with the development of an Emergency Medical Rescue Service dataset for the country.

[4] The term indicator is used in public health to denote information used to measure to what extent health targets are met (e.g. immunize at least 80% of infants in a particular area) and to monitor for example disease patterns (e.g. prevalence and incidence of TB in a population group over time). An indicator (percentage children immunised for example) is calculated from data elements.

The health services responses to HIV/AIDS pandemic has resulted in the services being organised as separate vertical programs, with separate funding. This is seen as a threat to the process of unifying the health system. Different information systems are being developed, and provinces are not bound to utilise 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, which utilises the DHIS as the de facto national standard for data processing and collation. Data on vertical programs such as the 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 following example from the South African experience:

[INSERT BOX 1 ABOUT HERE]

Gateways translating data standards between the reporting levels as well as horizontally between sub-systems have been important in the successful scaling of the standards in South Africa. The gateways are of three general types; computer to computer, between paper and computer, and from paper to paper. Examples of the latter are registers for primary registration of patient data which includes procedures for aggregating the required monthly data sets. While the computer-paper gateways include users, GUI as well as procedures and paper tools, computer-computer gateways have so far mostly been between DHIS applications. However, electronic patient record systems are increasingly being used in hospitals in some provinces and for tuberculosis (TB) and AIDS patients, indicating that

“electronic” gateways will be important in the future. One such gateway is currently existing between the DHIS and the electronic TB patient register. Over the last ten years we have seen computer availability gradually moving down the hierarchy from district offices to hospitals and even some health centres (mainly in large urban centres like Cape Town and Johannesburg). This means that the gateways between paper reports from facilities and the DHIS is also moving down the hierarchy, and increasingly facilities enter their own data into the software. However, this is happening at an uneven pace between rich and poor areas.

Summary of the South African Case

We have here seen that the attractor that was created attracted more users, provinces, and health care programmes. During this process some standards (i.e. minimal data sets) were modified and extended and new ones were developed in parallel with gateways linking them. The standards were implemented in an infrastructure based on paper and physical transport as well as computer. During this process the complexity of the system of standards. This system has stayed adaptive in the sense that it has grown – but more important: it has easily been adapted to changing needs. This has been achieved 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. But just as important: they have been organizationally simple because each have 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, and, accordingly, the number of actors that needed to agree on modifications has been limited. The system of standard has also turned out to be adaptive because the variety of standards within related domains has increased the breath of experiences gained, and, accordingly, the speed of

learning and improvement of the overall infrastructure as well as the health care system. Lastly, the adaptability of the system also makes it easy to adopt for users because it supports existing practices at the same time as its flexibility enable the transformation of these practices.

We believe that the South-Africa experience can be considered a “best practice” that others should try to adopt. But all countries are different – 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 (1984), their trajectory can only be changed in unique circumstances – during serious crises or external chocks. The regime change in South-Africa was such a unique circumstance. We will in the next discuss attempts at replicating this strategy in other countries to work out a more generally valid recipe for “best practice” for IS standardization.

HISP EXPERIENCES IN OTHER COUNTRIES

We 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 (Braa et al. 2001). The achievements have been modest in terms of adopted standards, and implementation and testing in individual provinces has been fraught with problems. What we see as one of the main reasons for this is the fact that the health care sector in Mozambique, as the rest of the public sector, is

centralized and does not allow for different solutions in different provinces. Consent from the national level is necessary in order to pilot solutions, and if this is not obtained, innovation is constrained.

In India HISP is established in two states, and in the state of Andhra Pradesh significant results have been achieved. The achievements however reflect the fact that HIS and health in general is in India organized in vertical programmes with little horizontal collaboration and integration. HISP has managed to work and develop standards within one large health program (family health and welfare), but coordination amongst other programmes and hospital services have been difficult to achieve.

Vietnam has a similar fragmented structure with little integration between the programme 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: indicators used to measure progress towards the UN'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, health programs developed their own 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 ministry, all programme managers agreed to establish one shared HIS by combining the sub systems. 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 national

level could then gain access to all data in the “data warehouse”, including their own. This system is piloted in 4 districts. As a next step inconsistencies within and between the data sets are to be addressed, and standardization will be tried achieved through a piecewise harmonization of the various data sets.

These experiences further illustrate how the creation of an attractor allows a standard to emerge. It is not always easy to do this. Experimentation and innovation at a local level are central in developing appropriate solutions before they are scaled up. What is common, however, for all these cases is that the attractor is created as a solution to a very specific problem or objective. When this problem is solved, what “naturally” comes next is addressed.

The experiences from Mozambique show that in centralized system, starting a standardization process through local, small scale experiments is difficult if one is unable to convince (translate and enrol) 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 State level)) started at the top. However, these activities have also followed a bottom-up strategy in the sense that one single issue was addressed (MDG in Vietnam, pooling data in Botswana, etc.), and an attractor was created by translating and enrolling human and non-human actors into a growing actor-network. When the initial problem was solved, the activities expanded. In addition, problem solving was addressed by developing a pilot solution in a defined area, before it was scaled up.

We will now look a bit deeper at one country, Ethiopia, to provide some richer illustrations of challenges and opportunities involved in the creation of an attractor that will become a new standard in a country where existing structures are not shaken up by radical change as occurred in South-Africa.

THE ETHIOPIAN CASE

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* (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. In order to bring development to all parts of the country, the government has recently embarked on an ambitious project to network all regions and *woredas* using a combination of fibre, microwave, wireless and satellite technologies, while at the same time the mobile network is expanding rapidly.

The Current Situation and Federal Strategies

The overall HIS in Ethiopia is poorly developed. Formats for data collection have evolved over time as a result of decrees from vertical programme 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 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, with the health sector as a targeted area. The general assumption is that this will require one all-encompassing standardized system. As one key actor at the federal MoH said (2005): “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 items to be collected, while others have used the centrally defined template and have added additional forms. In this way each Regions have developed their own distinct system of formats and procedures for collecting, analysing, using and reporting data internally in the Regions and from the Regions 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 co-ordination between programmes, 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 the next paragraph we highlight some of these problems in a description of a federal workshop with participants from 4 Regions.

[INSERT BOX 2 ABOUT HERE]

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.

We will now turn to HISP's experience in experimental and bottom-up oriented standardization efforts in three regions of Ethiopia. In this we first explore the successful standardisation process in Addis Ababa Region, followed by two other regions (Oromia and Benishangul-Gumuz) who are included because they emphasise the vastness of the challenge to develop a unified HIS in Ethiopia, and the uneven development between and within the regions in terms of infrastructures.

Addis Ababa Region

HISP initiated activities in Ethiopia in early 2003. Initial approaches to federal level were rejected on the ground that development and implementation of HIS would be carried out by their own experts, and that currently the ministry's priority was the development of a national strategy for HMIS. Subsequently the Addis Ababa Health Bureau (AAHB), which has the autonomy to plan and execute its own development programmes and manage its own problems accepted a proposal to utilize the DHIS software, mainly because the AAHB had serious difficulties with the existing paper-based HIS.

The HISP group, based at the Addis Ababa University, developed a DHIS prototype in parallel with a systematization of the rather complex collection of datasets. The prototype demonstrated inconsistencies and problems in the current reporting formats. While many such inconsistencies had been known but not acted upon previously, the process of

computerization made these problems more transparent and triggered action. A workshop in March 2004, attended by health workers and managers from the Health Bureau, sub-cities, facilities, and some participants from MOH, demonstrated the prototype and findings. The health bureau decided on a city-wide project and formed a committee to develop new standards and reporting formats. Sub-groups reviewed the forms from each program area and over the next two months all data formats were revised and a set of uniform reporting formats were agreed upon and compiled in a book.

After having agreed on integrated data sets, the database for capturing and managing these data was finalized, computers were purchased and the DHIS installed. Training and facilitation followed and the project hired a technician to provide support across all sites. During 2004-5 the information system was implemented in the 5 city-hospitals and 23 larger health centres. Three city-wide workshops were conducted during the following year, each one resulting in a range of modifications. In July 2005 the workshop assessed the results of the first full year of data reporting. 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.

[INSERT FIGURE 3 ABOUT HERE]

Oromia Region:

The Oromia Region is the largest and most populous region in Ethiopia. It comprises one third of the total surface area (bigger than Italy) and a population of 25 million and 1458 public & private health facilities. The HIS reform process started after some key actors from the Oromia Health Bureau participated in a HISP workshop in Addis Ababa. The major challenges in Oromia are the vastness of the region; the poor infrastructure and the lack of human capacity. While drawing on the experience in Adis Ababa 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 emphasises horizontal extension across zones, before gradually reaching “down” to the woreda level (vertical extension).

Benishangul-Gumuz Region:

The Benishangul-Gumuz Region stretches 2000 kilometres along the borders of Sudan, is populated by several smaller ethnic groups, and is one of the poorest regions in Ethiopia. Here the HIS relies on a paper based system of reporting up to the regional level for most zones (see figure 4), and to the zonal level for the zonal office in the regional capital Assosa (Mengiste 2005). This reflects the need to accommodate different processes in the development of the HIS, in response to the uneven access to computers and human resource capacity.

[INSERT FIGURE 4 ABOUT HERE]

Summary of Ethiopia

In these three regions we see how a federal structure with independent regions facilitates variety, innovation, and regional standards– in our view a required for successful health care infrastructure standardization and development - even if the government has decided to go for a centralized top-down strategy. The cases highlight the extreme heterogeneity found in developing countries such as Ethiopia regarding user needs, human resources as well as basic infrastructures required by a computer based information infrastructure. Robust,

flexible, and scalable approaches where paper and computer based information infrastructures smoothly interoperate and where the computer based gradually can replace the paper based are needed in contexts like this.

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 and compared this to the “best practice” presented above as a validation.

THE THAILAND CASE

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 ICT infrastructure which reaches all districts. Data on individual patients is captured electronically in most health facilities, and standard datasets are submitted upwards 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% in 1990 to 1.3% in 2004, with the number of new infections reducing from 43.000 to fewer than 20.000 per annum. 80,000 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 quality of data in order to justify the decentralised 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 (NHSO) 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 decentralised to the province level. The CUPs are provided with ICT network access and computers as part of their payment.

The direct link between payment to the CUPs and data on the services rendered has given great attention to the quality and timeliness of data from the HIS. Two sets of standard national data are identified; one is covering community services and is made up of 18 sub-sets including immunisation, family planning, disease surveillance, chronic diseases etc., the other is covering hospital services and consist of 12 sub-sets including inpatients, outpatients, patient payment, referral etc. Each of these 18+12 sub data sets 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. Numerous different software applications for a variety of purposes have been developed in the provinces.

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 like Bangkok and rural areas. While freedom for local innovation enable more advanced provinces to develop solutions according to their potential, less advanced provinces are benefiting from sharing software solutions developed in other provinces. Standards are regularly revised through an ongoing HIS development program that has broad participation from all 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 build 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 also for others. Based on user experiences and new needs discovered, the infrastructure and standards have been extended and modified – it has evolved as a Complex Adaptive System.

5. DISCUSSION

The aim of this article is to work out a strategy for developing IS standards in order to improve the HIS in developing countries. Interpreting the outcomes of the action research project reported by means of complexity theories we propose a strategy whose two main components are, first, create an *attractor* that may emerge as a new standard and evolve into a system of standards, second, the individual standards should be crafted in a way making the whole complex system of standards an *adaptive* one. Furthermore, the proposed

strategy is based on two principles which we call *flexible standards*, and *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 will discuss each of these five issues, starting with issue of complexity.

Complexity and developing countries

Heterogeneity, as illustrated through the uneven development of economy and infrastructure between and within regions in Ethiopia, is a key characteristic of developing countries. One particular requirement to the HIS standardization in question is to achieve full data coverage within an area (district, province, country), which has been termed the dilemma of “all or nothing” (Braa et al. 2004) 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. This problem area can be analysed within the framework of *scaling* as referring both to the scope and “size” to be covered, and to the process with which this scope is being covered (Sahay and Walsham 2005). The infrastructures built in the HISP project have turned out to be scalable within the requirements that have been addressed. Data standards may, if kept minimal by focusing on the “must know” data, have proven to be scalable even in the poorest contexts. The infrastructures have been modified and extended when needed. Gateways, in particular between paper and computer, have been important tools for scaling the overall infrastructure by linking its technically incompatible parts.

We conclude that the uneven development and heterogeneity contribute significantly to making scaling of infrastructures difficult in developing countries. Furthermore, we also

conclude that for scaling of HIS to succeed in developing countries, the data layer and not the technical layers needs to be in focus.

Creating attractors

HISP started out with experimental development of data standards and software together with users in a few pilot sites which soon brought the project into activities aiming at developing data sets for larger areas. The real “take-off” came when the project could offer users a simple software application to support a minimum data set that would be implemented in the Western Cape Province. At this point we can say that an attractor was created. What was then regarded as success in one province, led another province to be enrolled, the attractor gained momentum, and gradually the entire country got enrolled. This attractor can be seen as an actor-network consisting of the project members, the computers and the DHIS software, the minimal data set, the group of people defining the data set, and the users using the system. All are important, but, maybe most important are the users. What made this actor-network an attractor that attracted more users was the fact that a number of users were already using it. When more users were attracted, this generated positive feedback making the attractor even more attractive.

In the other countries where attractors have successfully been created, this has happened by pursuing a strategy to rally resources in a resource constrained environment around the solution to a single problem (making existing data available to users in Botswana, generation of indicators related to UN’s Millennium Development Goals in Vietnam, supporting the payment system in Thailand, etc.). The successful solutions consisting of software and data sets have been as simple as possible so that the solutions have been inexpensive to implement, easy to learn to use, and supported experimental development strategies. When

users used the solutions, this proved that the systems were working properly seen both from an organizational and technical perspective. A working solution which is giving benefits is indeed powerful in the sense of attracting more users and other stakeholders.

The cases presented above demonstrate how this strategy might be adopted with success in various contexts. In principle, one can start anywhere in the health sector and develop a working solution supporting any work tasks. However, the cases as well as literature on HIS (AbouZahr and Borma 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 the key priorities of the health services in the particular country. 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 next. 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 ambitions in their aim at developing uniform standards. This represents a dilemma, a tension which in all likelihood will never be totally resolved, but will have to be managed. In South Africa this tension between local need for flexibility and the central need for control has been eased and managed through the application of the principle of the hierarchy of standards (figure 2), which dynamically combine flexibility as a *right* and adherence to the standards of the level above as a *duty*.

Standards as Complex Adaptive Systems

As mentioned above, standards easily arrive at lock-in states. They are better characterized by their persistence against change than their capabilities to adapt to their changing environment - the persistence of QWERTY for more than hundred years being a paradigm

example. A national HIS needs many interdependent standards – a complex system of standards. But since each standard may be in a lock-in state, the whole system will be that as well - a system of standards can easily turn out to be best characterized as a Complex NON-Adaptive System. However, it is of crucial importance to craft standards and their relations so that they emerge as a Complex *Adaptive* System that adapts 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.

Standards need to be flexible for several reasons. In the phase when an attractor is created, a standard needs to be flexible in order to allow for experimental development of the standard itself and the software implementing it, to arrive at satisfactory solutions for the users. Furthermore, individual standards should be scalable both in terms of serving the needs and being adopted by more users, and in the sense that they may be extended or modified to address the needs of new users.

Standards also need to be flexible so they can be adapted to the heterogeneous user requirements and resources and underlying infrastructures available in developing countries due to uneven development. Finally, flexibility is important to enable the variety as a basis for evolutionary improvement of the system of standards. Variety is seen as the “driving force” behind evolution in complex systems in general. Similarly, in our case, variety of standards increases experimentation, the range of experiences gained and accordingly possibilities for learning and finding improved alternatives to existing ones.

Flexible standards

Two forms of flexibility can be identified: use and change flexibility (Hanseth et al. 1996) The degree of use flexibility determines the extent to which a standard can support many different activities and tasks, the possibilities for users to change the practices the standard supports without changing the standard. Change flexibility determines how easy it is to change the standards when required. A standard's total flexibility is the sum of these two. And flexible standards need both kinds.

Use flexibility is supported by the "need to know" principle where one tries to get "maximum information out of minimum data." i.e. when new needs are identified, one try as hard as possible to satisfy those by combining existing data before new elements are introduced into the standards. In South-Africa, as illustrated by the use of ANC indicators (box 1), this principle has been pursued through the focus on essential data and indicator sets which also have enabled an incremental change process where work practices have been gradually improved without necessarily changing the initial data sets, but rather by gradually extending them as new needs arise. The idea of achieving use flexibility by means of minimum data can also be expressed as a principle in the same style as others*: rich information from minimum data,* a principle which is a corollary to "flexible standardization."

Change flexibility (and scalability) is achieved through the classical principle of *modularization*. This principle is found to be 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, i.e. *gateways*, between them.

What makes a standard simple (or complex) is, of course, its technical complexity in terms of number of data elements. But the complexity of a standard is 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 using the standard, standardization bodies involved, etc – and the links of various kinds between all these. Simplicity and flexibility might 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. For example, this can be done by adding additional data elements for a province to the core national data set in South Africa. That will decrease the technical complexity of the standards, but, maybe more important, 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. In addition, it is also important to apply the modularization principle so that the technical standard and the use practices it supports are as separate as possible.

Standards should be modularized horizontally and vertically. *Vertical modularization* corresponds to traditional layering in software engineering where one layer offers services to the one above. Separate standards will be defined at each layer. This principle is beautifully demonstrated by the 7 layer OSI protocol model, or as simplified in the layered internet model in figure 5.

[INSERT FIGURE 5 ABOUT HERE]

In our case, the separation of the data layer from the rest have found to be important in order to identify the data that can be collected in the various health care institutions and

transferred by available infrastructural services (electronic in some areas, physical in others), and which may be used to produce the information needed at various managerial levels.

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.* In the computer communication community gateways have been regarded as an anomaly – something you need when you have failed to achieving a shared standard (see, for instance, Stefferud, 1994).

In South-Africa gateways were developed and used to translate between standards at different levels in the hierarchy. In the case of the DHIS, this is a computer based gateway between two computer based information infrastructures. But in South-Africa, as well as in all developing countries, the uneven development makes a uniform computer based infrastructure across the whole health sector totally unrealistic. Accordingly, a national infrastructure supporting smooth information exchange requires smooth integration between the paper and computer based sub-infrastructures respectively. That makes gateways linking paper and computer crucial. And the infrastructure that has been built so far includes numerous such gateways. Such a gateway is a hybrid object (Latour 1993) consisting of a human and a software package.

Gateways enable the definition of simple standards. They also make the system of standards more adaptive because individual standards may be changed without having to change other standards,. As an increasing number of health centres and clinics are getting

computers, the paper-computer gateway is moving down the hierarchy, but in an uneven pace between rich and poor areas.

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.” And 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 centre of the efforts presented in this article to enable smother coordination and control of organizational processes and health care delivery. But integration may cause less independence – and less flexibility. This dilemma was formulated by practitioners at the workshop in Ethiopia as the choice between “one system that fits all” and multiple systems adapted to the needs of individual health programs. Integration is often perceived as “one system” both in terms of data and software. 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 have emerged through the interaction between and within the sub-systems 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 and linearity, the emerging standards and HIS-processes have arrived through conscious design efforts, although by a very heterogenic network of designers. In the South African case, a large IS development project that has evolved over more than ten 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. In a multilayered CAS, components such as the group of designers and implementers also make up a CAS.

The strategy described here, is not just a strategy for standards development, it is also a strategy for radical change of complex systems. This interpretation of the strategy can be summarized by the following principle: *radical change through small steps.*

CONCLUSION

This article addresses the issue of strategies for developing information infrastructures in general and for the development of IS 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. Two issues related to complexity are of particular importance, and which are specific for developing countries. First, the uneven development between rich urban and poor rural areas, and the extreme differences regarding health service and the organization of their delivery and the basic infrastructures available (electricity, computers, skilled work force, telecommunication, etc.) on the one hand, and, secondly, the important role played by vertical programmes (like HIV/AIDS programmes) funded and partly managed by international donor organizations in increasing complexity and HIS fragmentation.

Our strategy contains two main steps. First, create an attractor by building an actor network where the following elements are enrolled and aligned: a simple software solution supporting

a specific problem that matters for specific user groups and make sure the solution is implemented in the user organization in a way giving the users some benefits (i.e. the solution must support existing work practices); make the attractor/standard more attractive by make more users use it; and add more standards and modify the existing ones as use and the number of users expands. The second step is to make and keep the emerging system of standards an adaptive one by exploiting heterogeneity: allow for multiplicity of standards as illustrated by the hierarchy of standards; make the standards simple – technically as well as organizationally; develop gateways to translate between standards and link sub-infrastructures; and modify the standards as requirements change.

In addition, our strategy contains a number of principles that should be followed to contribute to the evolution of a system of standards by maintaining a number of principles – each of them in line with the idea that the order of complex systems evolve and maintain "order at the edge of chaos." These principles are:

- *Flexible Standards*. Standards should be flexible – both regarding use and change. They should be use-flexible - users should be able to change their practices as much as possible without changing the standards. But standards do need to be changes. Accordingly each standard should be as simple as possible so that it is easy to modify. Use flexibility may be achieved by following the following principle (which is a corollary to this one)
- *Rich information from minimal data.* A focus on "must know" rather than "nice to know" as illustrated by the emphasis on indicators and minimal essential data set approach help making the standards simple, at the same time a focus on identifying data that may be used for several purposes and trying to utilize exiting data for new

purposes rather than adding new ones, stimulate transformation and improvement of work practices without changing the standards.

- *Integrated Independence*: The infrastructure will emerge as an integrated system. At the same time, the components should be coupled as loosely as possible to enable the different components (standards and sub-infrastructures) to be modified independently in order to make the whole system adaptive and easiest possible to improve.

We also see this strategy as a theoretical contribution in being based of a combination of Complexity Science and Actor-Network Theory that forms a strategy for radical change of complex self-organized systems from within. This last contribution can be formulated as a fourth principle in the same style as those above:

- *Radical change through small steps:* Radical change is often an aim when introducing IT solutions into organizations. And radical change is indeed what is needed in the health care sector (as well as others) in developing countries. In the days of BPR the recommendation then was to design the new organization and its ICT solutions together. That does not work in the world of complex systems. Accordingly, new solutions, including standards, need first 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. This may be achieved by following the strategy and principles described above.

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TABLES AND FIGURES

Ministry of Health			Para-statals	Universities	Inter national
National	Subnational	District			
25	18	27	12	2	5

Table 1: Number and site of interviews conducted in Thailand Case Study data

Country profile	**South Africa**	**Thailand**	**Ethiopia**
Population	45.8 million	62 million	68.6 million
Area (sq. km)	1.2 million	513.1 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[5]	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

Table 2. Country profile (statistics from UNDP and World Bank 2003)

[5] Data from Day and Gray (2005).

Figure 1. Provinces in South Africa

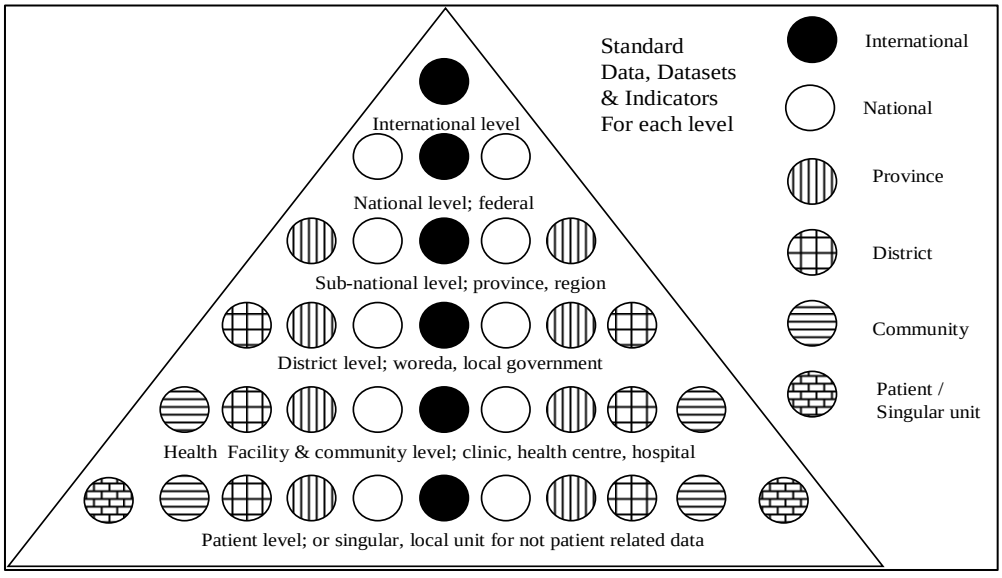

Figure 2: The hierarchy of standards for data elements used in South Africa

Figure 3: Regions in Ethiopia

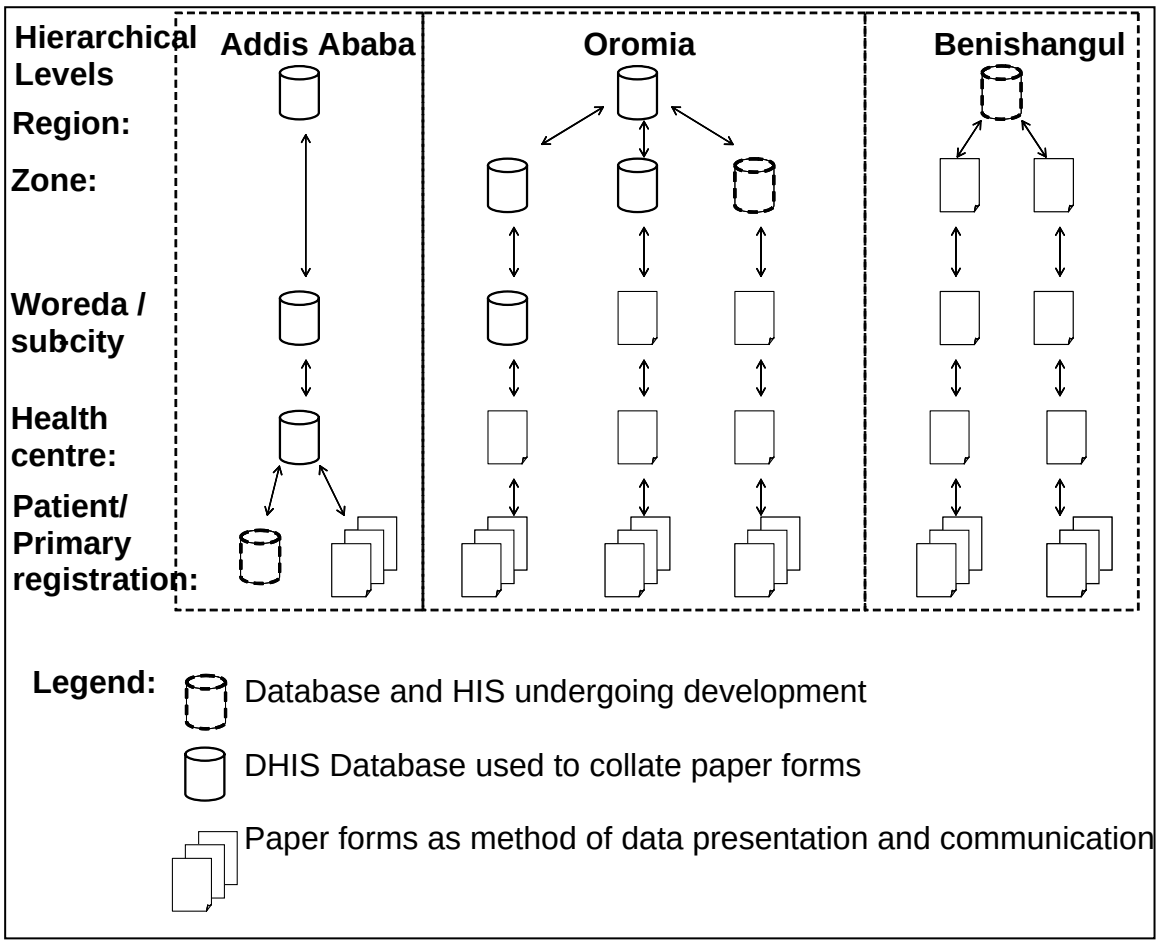

Figure 4 : Uneven development of HIS across three regions

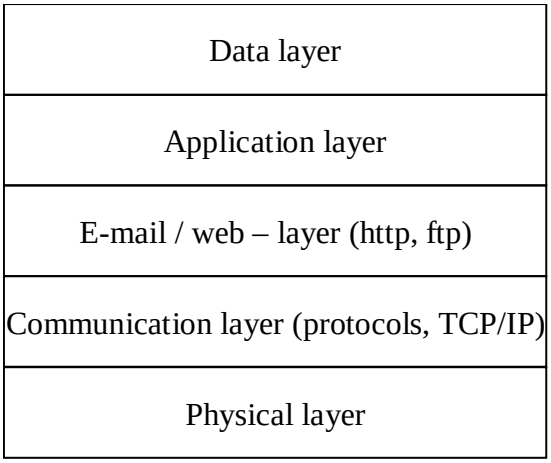

Figure 5: Layered model of information infrastructures; four technical layers and one (logical) data layer.

One example that highlights how improved services influenced the development of the data set hinges on the data elements collected for ante-natal services. Two of the ante-natal indicators were:

- Ante-natal coverage (the percentage of the expected pregnant women attending the services for their first ante-natal visit)
- Average ante-natal visits per ante-natal client (first and follow-up ante-natal visit per first ante-natal attenders)

The Ukahlamba district found that they had a very high ante-natal coverage rate (112% (due to influx of cross-border patients) for the Ukahlamba District Jan – Dec 2000) (Data source: DHIS data 2000, for Ukahlamba District), and that as they had an average ante-natal visits per ante-natal client of three, it was apparent that the pregnant population was able to access their 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 twenty weeks of pregnancy, and if necessary (their gut feeling was that a very low percentage actually accessed services in the first trimester) increase this percentage. Hence the indicator “First ante-natal visit within first 20 weeks of pregnancy” was introduced. This required the existing data element “First ante-natal visit” to be split to become:

- First antenatal visit within first 20 weeks of pregnancy
- First antenatal visit after 20 weeks of pregnancy.

The DHIS software was able to accommodate these changes at the district level, while the sum of these two indicators contributed to the national level indicator of total “First ante-natal visit”. The standard at the national level is thus adhered to, while the need for greater detail at the local level is accommodated. At the same time, local initiatives like this contributes to an increased understanding of the usefulness of data elements at the national level, and in other provinces, and it contributes to the evolution of the data set (standards) over time.

Box 1. Evolution of Indicators Based on Improvement in Service Delivery

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 programmes, 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:

a) 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 programme" 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 by far too limited.
b) 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". While another responded that "reporting diseases using ICD is required internationally….., "
c) Agreement was also not reached on which areas to include in the standardisation 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 programmes 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".
d) The necessity of having one standard system (one set of paper forms, one software system) was emphasised 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.
e) 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?"

Box 2. Workshop participants' views