

DEVELOPING HEALTH INFORMATION SYSTEMS IN DEVELOPING COUNTRIES: THE FLEXIBLE STANDARDS STRATEGY¹

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Abstract

The development of appropriate integrated and scalable information systems in the health sector in developing countries has been difficult to achieve, and is likely to remain elusive in the face of continued fragmented funding of health programs, particularly related to the HIV/AIDS epidemic. In this article, we propose a strategy for developing information infrastructures in general and in particular for the health care sector in developing countries. We use complexity science to explain the challenges that need to be addressed, in particular the need for standards that can adapt to a changing health care environment, and propose the concept of flexible standards as a key element in a sustainable infrastructure development strategy. Drawing on case material

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from a number of developing countries, a case is built around the use of flexible standards as attractors, arguing that if they are well defined and simple, they will be able to adapt to the frequent changes that are experienced in the complex health environment. A number of paradoxes are highlighted as useful strategies, integrated independence being one that encourages experimentation and heterogeneity to develop and share innovative solutions while still conforming to simple standards. The article provides theoretical concepts to support standardization processes in complex systems, and to suggest an approach to implement health standards in developing country settings that is sensitive to the local context, allows change to occur through small steps, and provides a mechanism for scaling information systems.

Keywords: Health information systems, standards, complexity science, developing countries

Introduction

This article addresses the issue of strategies for developing information infrastructure *standards* in general and for the development of information systems support for the health care sector in developing countries in particular. We identify *complexity* as the main source of the challenges that such strategies need to address and propose the concept of *flexible standards* as a key element in a sustainable infrastructure development strategy. The article contributes theoretical concepts to support standardization processes in complex systems, and suggests that the complexity of a standard is determined by its constituting actor network. We describe an approach to development and implementation of health standards in developing country settings that is both sensitive to the local context and scalable across geographic and programmatic areas.

Poor health status, rampant diseases such as HIV/AIDS, and inadequate health services are seriously hampering human, social, and economic development in developing countries. Considerable efforts are currently being made by international aid and United Nations agencies to address these problems. The United Nations' millennium development goals (MDGs) (UN 2000), which target the major health problems alongside other key development issues related to poverty reduction, constitute a coordinating framework for these efforts. Appropriate health information systems (HIS) are seen as crucial in this respect (AbouZahr and Boerma 2005; WHO 2000). On the ground, however, HIS development in developing countries has proved to be difficult due to organi-

zational complexity (Gladwin et al. 2003; Jayasuriya 1999), fragmented and uncoordinated organizational structures all maintaining their own HIS (Chilundo and Aanestad 2004; Jeppsson and Okuonzi 2000), unrealistic ambitions (Heeks 2002), and more generally due to the problem of sustainability (Kimaro and Nhampossa 2005; Sahay et al. 2000).

The health care sector in a country consists of a large number of institutions ranging from small and simple health care centers up to large and technologically advanced hospitals. These institutions are managed by a number of overlapping institutional bodies, organized into geographic areas (district, province, nation), and according to vertical programs (HIV/AIDS, maternal health, vaccination) and services (primary health care, hospitals, laboratories, drug supply). Programs are influenced at the national level through various international donor organizations and the World Health Organization. While global and national health policies normally recommend local management and integration of health information from various services and programs, the current reality is very different. National health systems are typically made up of a number of relatively independent health programs and services which, in the absence of central standards, each maintain their own vertical and uncoordinated reporting systems. The lack of shared standards for data collection means that the same data are often collected and reported many times through different structures, while at the same time there are gaps where important data do not get reported. Inconsistencies in definitions and procedures create further fragmentation (Chilundo and Aanestad 2004; WHO 1994) and lack of coordination, and inefficiencies. This results in excessive data of poor quality and generally poor use of it (Sandiford et al. 1992). The *integration* (de Kadt 1989, WHO 2000) and coordination of HIS is consequently a priority that needs to be addressed.

Fragmentation of HIS is aggravated further as donor funding targets specific areas and creates new information systems which are not integrated with the existing HIS (Okuonzi and Macrae 1995). The development of relatively cheap and effective antiretroviral drugs to treat AIDS patients has led to ambitious plans to roll out treatment to millions of people in developing countries, and multibillion dollar funds are raised to implement these plans. This large-scale funding for HIV/AIDS is contributing to disintegration, leading the WHO HIV/AIDS department to state: "[1] There is an urgent need for strategic information in conjunction with the antiretroviral treatment [of AIDS patients] programmes, including the developing of monitoring and evaluation systems.... [2] Efforts should be made to integrate antiretroviral treatment into existing HIS run by governments....[3] Strengthening

existing HIS in countries can be one of the positive externalities produced by antiretroviral treatment programmes” (WHO 2003, p. 1, numbering added). Regarding standardization, [4] it is “urged that the monitoring and evaluation of ART [antiretroviral treatment] programs be simple, with data collection limited to only that information deemed to be essential for the well functioning of programmes” (WHO 2003, p. 3). However, [5] “The process of implementing ART programmes is difficult and open-ended...goals and objectives of therapy are varied and they have not yet been agreed upon” (WHO 2003, p. 4). The end result has been the development of independent and often burdensome information systems for ART.

From the above, it is obvious that an integrated health information infrastructure is important in developing countries and that such infrastructures need to be based on common standards for information sharing and exchange between information systems, programs, and institutions. We use the term information infrastructure in its broader sense, meaning the technological and human components, networks, systems, and processes that contribute to the functioning of the health information system. In developing countries in particular, access to the components of the infrastructure vary hugely between regions and geographic areas, resulting in inequities and uneven development of the infrastructure. These characteristics of information infrastructures in developing countries add to the complexity of developing integrated systems. The question is, then, what is an appropriate strategy for developing the required standards? This article suggests approaches that allow the development of specialized, but integrated, HIS, as expressed by these HIV/AIDS practitioners, through flexible standardization approaches that focus on simplicity and the essential needs for information.

At a first level, the challenge is to develop workable data standards, then, at a second level, the interface between the existing paper-based systems and the rapidly emerging computer-based infrastructure needs to be dealt with. In particular, ART programs are pushing implementation of electronic patient records that in many developing contexts, for the foreseeable future, will have to coexist with the paper-based patient record system. We will focus on the development of standards at two levels, at the technical level of software and at the service delivery level for data collection and communication. Standardization is understood in terms of the definition by De Vries (2003) as

the activity of establishing and recording a limited set of solutions to actual or potential matching problems directed at benefits for the party or parties

involved balancing their needs and intending and expecting that these solutions will be repeatedly or continuously used during a certain period by a substantial number of the parties for whom they are meant (p. 155).

The structure of this paper is as follows: In the theory and related research section, we explore complexity science as the point of departure for a framework within which to analyze and discuss standardization in the health care sector. The methodology section describes the study as a longitudinal, action research study, and explains the ontological and epistemological basis for the analysis. The empirical data are presented in the fourth section and draw mainly on material from the health information systems standardization experiences of the Health Information Systems Programme (HISP) group in South Africa, Ethiopia, and Thailand. In the discussion section, we highlight the key issues of flexible standardization in developing country contexts. The final section proposes concrete guidelines for HIS standardization.

Theory and Related Research

We present our theoretical framework and related research, based on the main concepts from the emerging field of Complexity Science, supplemented with insights and concepts from the study of complexity within the social sciences and complex technologies or socio-technical systems.

Complexity Science

Over the last couple of decades, the field of Complexity Science has emerged, primarily from the study of phenomena within physics, such as thermodynamics, and biology. Contributions are also made from studies of more social phenomena, in particular within economics, such as financial markets and the issue addressed in this article, standardization (Arthur 1994; David 1986). Complexity Science is made up of a broad range of disciplines including chaos theory and complex adaptive systems (CAS). CAS are concerned with the dynamics with which complex systems evolve through adaptation.

CAS are made up of semiautonomous agents with the inherent ability to change and adapt in response to other agents and to the environment (Holland 1995). Agents can be grouped, or aggregated into meta-agents, and these can be part of a hierarchical arrangement of levels of agents. Agents can respond

to stimuli; they behave according to a set of rules (schema). Adaptation is the process whereby individual agents and the CAS change to fit each other and their environment. Adaptation, and creativity and innovation, are seen as being optimal at “the edge of chaos” (Stacey 1996), or more generally, adaptation occurs within the zone of complexity which is located between the zone of stasis and the zone of chaos (Eoyang 1996; Wilson et al. 2001). Dooley (1996) suggests that CAS behave according to three principles: order is emergent, the system’s history is irreversible, and the system’s future is unpredictable. In particular, attention has been directed at how order within such systems is created without a “designer” but rather *emerges*, for instance, like the order among cells in an organism, molecules in a fluid or other material, a beehive—or the emergence of a standard. Central to the emergence of orders are *attractors* (i.e., a limited range of possible states within which the system stabilizes). The simplest attractor is a single point. There are also attractors with specific shapes that are called *strange attractors*, that is, “unstable spaces to which the trajectory of dynamical systems is attracted through millions of iterations” (Capra 1996). Orders emerge around attractors through various *feedback* mechanisms, and through *path-dependent* processes of many small steps that may end in *lock-in* situations (David 1986). A *de facto*, or emergent, standard, such as MS Windows or QWERTY, is a typical example of an attractor. The use of “attractors for change” is recommended when seeking to bring about changes in areas where there is only moderate certainty and agreement (Plsek and Wilson 2001).

Even though complex systems may acquire persistent structures (around certain attractors), complex systems do *evolve*. The driving force behind such evolution and change is variety, the fact that the agents populating the systems are *heterogeneous* and different and that they seek to *adapt* to each other and their external environments.

Setting a new standard within this perspective means the active *creation* of an attractor. We will discuss how to do that by drawing upon some concepts from actor-network theory (ANT). Central in ANT, just like CAS, has been the emergence of order, or how actors succeed in their order-making efforts. In this context, order means widely accepted scientific theories or working technologies. ANT describes order-making as the building of socio-technical networks where elements of various kinds (technologies, humans, institutions, etc.) are translated (i.e., modified or reinterpreted) and enrolled into aligned actor-networks. Actors are also seen as heterogeneous networks (e.g., Callon 1991). Multiple actor-networks can be connected through so-called boundary objects (Star and Griesmer 1989), that is, objects which have

some meaning in common across networks and more specific meanings within individual networks.

Complexity in Health Care and Information Systems

As Complexity Science has gained momentum, its concepts and insights are increasingly picked up in other disciplines, illustrated by special issues on complexity in journals such as *Organization Science*, *Theory, Culture & Society*, and *Information Technology & People*. Complexity Science is also increasingly being applied in the area of health care organizations (e.g., Plsek and Wilson 2001), and is adopted in Information Systems and Organization/Management Studies where it is applied in a rather optimistic tone: complex systems are best managed by enabling their self-organization (see, for instance, Axelrod and Cohen 1999; Benbya and McKelvey 2006). While we agree that a new order cannot be designed and imposed on a complex system, we believe that more ambitious strategies, where a more active interventionist approach is adopted, are needed in the domain we are addressing. The HIV/AIDS pandemic together with the human resource crisis in the health sector in developing countries make it clear that there is a desperate need to bring the evolution of health care systems and their information infrastructures on a different trajectory than the current one. One way to do this, while not detracting from the ability of a complex system to evolve as a self-organizing system, is to *create an attractor* that will lead to the emergence of a new and better order. At the center of this order will be a complex system of standards, crafted and maintained as a complex adaptive system where lock-ins are avoided.

Scalability is identified as a basic requirement for successful IS development in developing countries (Sahay and Walsham 2005). Scale is referred to as the *scope of an IS* (how many users use the system), and scaling as the *expansion of the system in scope and size* (expanding the use of the system across geographical areas, as well as technical areas). Escalating complexity, increasing population and area to be covered, in particular in relation to available resources and infrastructure, make scaling a tremendous challenge in developing countries (Sahay and Walsham 2005). Scaling is also a central concern in complexity science:

Complex, adaptive systems exhibit coherence through scaling and self-similarity. Scaling is the property of complex systems in which one part of the system reproduces the same structure and patterns that appear in other parts of the system (Eoyang 1996, p. 36).

Broccoli is used as an example of scaling in a natural system as branches and subbranches have the same structure as the whole plant (Eoyang 1996). Drawing on empirical data, we will show how the development of simple standards can support the scaling process, while still encouraging diversity and experimentation (unlike the self-similarity of broccoli).

Standardization, Technology, and Creation of Attractors

Research on standardization acknowledges that the “world of standards” is rapidly changing—into a more complex one. The number of standards has increased substantially, and so have the links between them (Romer 1990; Schmidt and Werle 1998). However, complexity theory has not yet been applied explicitly beyond the concepts primarily coming out of the economic research on standardization mentioned above. Among those interested in research on standardization, consensus emerges about the growing complexity related to standards and standardization which implies that old models are not suited for current challenges. The bureaucratic models of standardization bodies make them all too slow, and various consortia models are becoming more popular (see David and Shurmer 1996; Shapiro et al. 2001). The world is changing more rapidly and standards need to be more flexible to adapt to this (Egyedi 2002; Hanseth et al. 1996). Hanseth et al. (1996) discuss two kinds of flexibility—use and change flexibility—and argue that standards need both. Change flexibility (the ability to change standards) is enabled by modularization. That means, in this context, combining simple standards with *gateways* translating between them (Hanseth 2001), not only gateways between computer-based infrastructures, but also gateways integrating paper- and computer-based infrastructures, as has proved very useful for improving the information systems in hospitals (Hanseth and Lundberg 2001). Use flexibility determines the extent to which a standard can support many different activities and tasks. Use flexibility makes it possible for users to change the practices supported by the standard without changing the standard.

This article will contribute to these strands of research by proposing a strategy for staging the emergence of new standards, and will highlight the importance of ensuring that they are an adaptive system of standards. We see this as a strategy for change within complex and self-organized systems. In particular, we see the importance of simple standards as a component to assist the process of scaling IS in health services. We now turn to an explanation of the methodology used in this research, before exploring the empirical data in detail.

Methodology

While this article draws on case material from experiences in the development and assessment of health information systems in three specific countries (South Africa, Ethiopia, and Thailand), the authors are all involved in the broader network of the Health Information Systems Programme (HISP) (Braa et al. 2004; see also www.hisp.info). As such, their experience has been gained from action research in a large number of additional developing country contexts such as Botswana, Cuba, India, Malawi, Mongolia, Tanzania, and Vietnam.

The authors, and HISP, draw on the Scandinavian action research tradition in IS development where user participation, evolutionary approaches, and prototyping are emphasized (Greenbaum and Kyng 1991). These perspectives have strongly influenced the involvement and approaches followed in IS development and standardization in the countries discussed in this article. Action research aims at generating new knowledge through taking part in the full cycle of planning, implementing, and analyzing the results from concrete interventions (Susman and Evered 1978). While action research has been the major *modus operandi* in generating the empirical data presented in this article, contextualism has been the ontological basis for the research.

Ontological Basis for the Study

Contextualism (Pettigrew 1985, 1987) emphasizes the importance of the context–content–process axis. Four key aspects of this view are highlighted, namely that the content, context, and process interact and influence one another; contextualism allows the exploration of the origins, development, and implementation of organizational change. The study of organizational change is described at the horizontal level—the *sequential interconnectedness of phenomena* across time (past, present, and future) and the vertical level (the interdependencies between the levels within and outside the organization) (Pettigrew 1985, p. 64)—and the analysis of change within the organization requires analysis at multiple levels, across time, and needs to incorporate cross-sectional categories. These aspects resonate with the approach adopted by the HISP network, which has followed a contextualist approach to information systems development, understanding and respecting historical influences (horizontal levels) as well as the vertical influences (policy implementation, reporting requirements) that have contributed to HIS development.

Pettigrew (1985) provides a description of the prerequisites for a contextualist analysis, and provides criteria for evalua-

tion of contextualist research. We have addressed these by providing evidence in the case studies of longitudinal involvement in information systems development (in the South African case study, more than 11 years), as well as depicting the role of both vertical and horizontal influences in shaping the aspects studied. The use of multiple cases allows us to reflect on the differences between the contexts, and the factors that have contributed to these differences.

Interpretive research methods (Walsham 1993) have been used to make sense of the experiences, observations, and findings of the researchers. The data analysis process can be seen as an integral component of the action research process of the HISP network. All of the authors have at various stages taken on different roles, at times assuming the role of researchers, implementers, critical analysts, or a combination of all three.

The selection of the three countries for this article is purposeful. We wanted to present success stories found in Thailand and South Africa, and Ethiopia, a country which, in terms of potential for HIS development, provided challenges in a more difficult context. The selection of this range of cases provides for interesting opportunities to contrast the contexts that contribute to information systems development.

Data Collection Methods

The authors have been involved in HIS research and development in South Africa since 1994 and in Ethiopia since 2003, as participants in the HISP project (Braa et al. 2004). Two of the authors are permanent residents in southern Africa and one in Ethiopia.

Data were drawn from a number of sources: diaries, notes and reports maintained by the researchers and students, annual reports, and statistical bulletins. Additional sources of information included in-depth interviews with key informants, focus group discussions, and informal discussions, as well as field visits and observations. Direct observation of staff at work was a major source of information as authors worked with the HISP country teams.

The data for Thailand was obtained through a study commissioned by a development aid agency. The fact that the researchers had previous knowledge of Ethiopia and South Africa, but no knowledge about Thailand, led to different approaches to the data gathering. There was a focus on the national level of the Ministry of Health, although every level of the health system (subnational, district, and facility) was visited, including a relatively extensive tour of six key offices

at national level, other HIS-related organizations outside of the health system (universities, parastatal organizations, the national statistics office), WHO, and site visits to two provinces (Nan and Nonthaburi), four districts, five hospitals, and four clinics.

Case Study: The HISP Experience

This case study focuses on efforts to develop standards and information infrastructures in the HISP project. Emphasis is on South Africa where the HISP project started and where the most significant results have been achieved. We will focus first on the development of a new standard as the creation of an attractor, and second on how this standard evolved into a complex adaptive system of standards. Next we will briefly present experiences from other countries where HISP also has been involved in order to contextualize the experience from South Africa by illustrating variety among countries and the broad range of issues and challenges that need to be addressed. Then we present the case of Ethiopia, a vast and poor country. Finally, we will present successful standardization efforts in Thailand, a country where HISP has not been involved, but which demonstrates useful experiences for the proposed approach. Table 1 presents statistical profiles of all three countries.

South Africa

During the apartheid era in South Africa, health services were fragmented into 17 different services, separated according to race and the system of “homelands” for black South Africans. This resulted in extreme inequity between populations and racial groups in health services provision and health status. The health information reporting systems and the data standards used were equally fragmented and incompatible. With the advent of democracy, “everybody” expected “everything” to change—including the health care system. Equity in health services provision and health status has, therefore, been a major political target in post-apartheid South Africa. In order to measure and monitor the extent to which equity is achieved, and to pinpoint areas where more resources and efforts are needed, a standardized system for collecting health data from the whole country and covering all population groups is seen as a necessity. This has to be achieved in a context where extremes in terms of access to information communication technologies exist. In the urban centers the infrastructure is well developed, while in the rural areas many hospitals and health centers lack a reliable electricity supply and passable roads, let alone access to the Internet (Day and Gray 2005).

Table 1. Country Profile (Statistics from UNDP 2003)

| | South Africa | Thailand | Ethiopia |
|--|---------------------|-----------------|-----------------|
| Population | 45.8 million | 62 million | 68.6 million |
| Area (sq. km) | 1.2 million | 513 thousand | 1.1 million |
| Life Expectancy at birth (years) | 45.7 | 69.3 | 42 |
| Fertility rate | 2.8 | 1.8 | 5.6 |
| Prevalence of HIV (% of population aged 15-49) | 15.6 | 1.5 | 4.4 |
| Maternal mortality rate (per 100,000 births) | 150* | 44 | 870 |
| Infant mortality rate (per 1,000 live births) | 53 | 23 | 112.0 |
| Under 5 mortality rate (per 1,000 children) | 66 | 26 | 169.0 |
| Human development index rank | 111 | 74 | 169 |
| Gross national income per capita (US \$) | 2,750 | 2,190 | 90 |

*Data from Day and Gray (2005).

The process of standardization of health data has been a key aspect of the process of reforming the HIS, and the health system itself. However, achieving agreement on the standards has not been an easy process as is described in detail below.

The Creation of an Attractor

What became the HISP project started in 1994 as a small collaborative research project between the University of Cape Town, the University of Western Cape, and a Norwegian Ph.D. student. The aim was to provide health care workers within a poor township in Cape Town (Mitchell's Plain) with basic information to deliver better health services to the local population (see Braa and Hedberg 2002). At the same time, several projects were initiated to address the problem of HIS fragmentation. It was soon realized that the development of a set of tools for local clinics and districts needed to be coordinated with activities at higher (provincial) levels, in particular regarding data standards. In this case, the *data standard* was a uniform set of data elements (a data set) with clear definitions, reported on by facilities, and which sensitively reflected the provision of health services. In order to reach consensus on data sets, widespread negotiation and consultation with different health programs and services were carried out in the Western Cape Province, and in May 1997, a first experimental minimal data set was implemented in all clinics in the two HISP pilot districts. In parallel with the negotiations on data sets, HISP developed a desktop database application, the District Health Information Software (DHIS), for managing the data sets. DHIS was first developed as a typical action research experiment using rapid prototyping to

support the implementation of data standards in the pilot sites. Later, as the user base increased, the development of the DHIS has turned into an ongoing evolutionary software development project where experiments and prototyping are limited to selected sites before new versions are released to all users (see Braa and Hedberg 2002).

In the negotiations about minimal data sets, it was difficult to get a real breakthrough because different programs had different needs. In addition, since the health facilities belonged to different authorities, it was difficult to get agreement to implement similar standards for data collection in their respective facilities. In the Cape Town area, for example, health services were organized either under the municipality (for citizens of the former "official" South Africa) or under the Regional Services Council, (for the peri-urban black townships). In order to address equity, information systems obviously had to be implemented across these structures. These problems were addressed by arguing, on the one hand, that since "it is not possible to agree on everything, we should agree on a basic minimum," and on the other hand, that everybody will continue to have the freedom to collect the additional data they wanted. This principle was encapsulated as a *hierarchy of standards*, and has been essential in arriving at basic consensus during the standardization process in South Africa (see Figure 1).

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

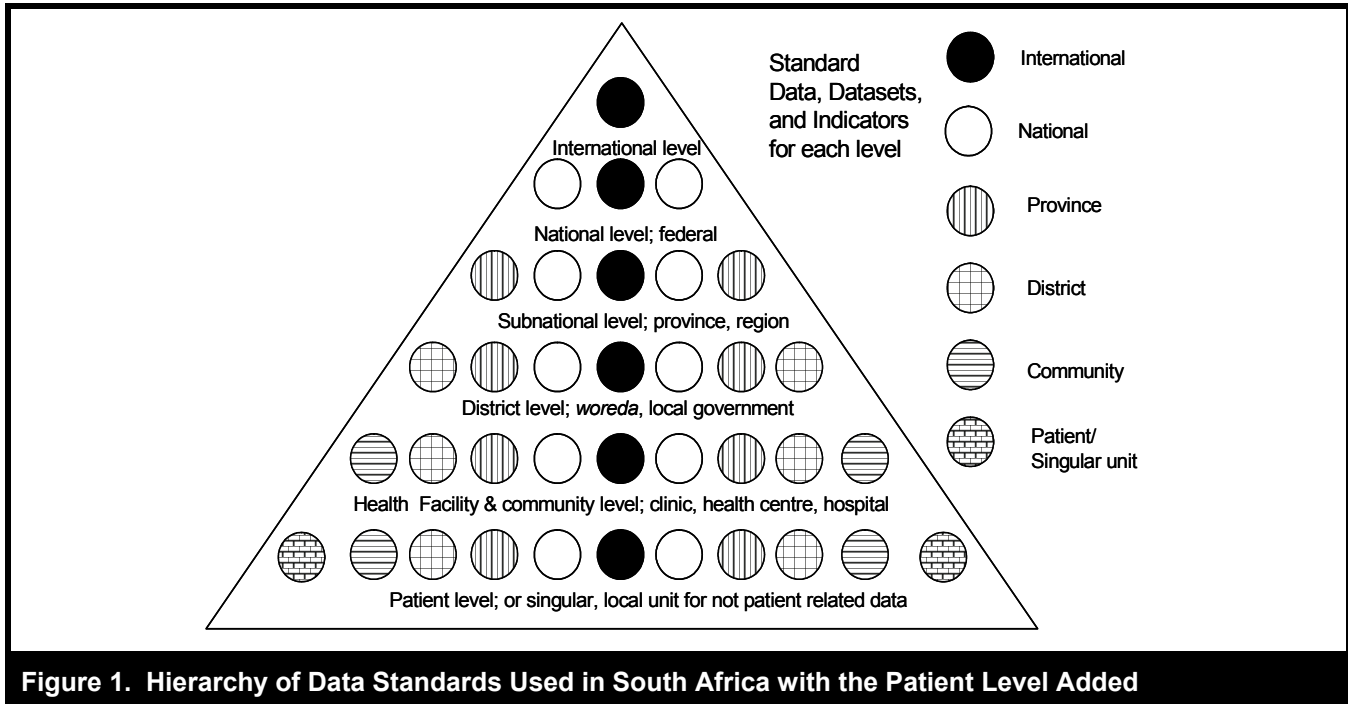


Figure 1. Hierarchy of Data Standards Used in South Africa with the Patient Level Added

First, it was the first time uniform data had been collected across the different health services in the province, and, second, the implementation was supported by the DHIS application which provided a coherent platform for data entry and processing, and presentation of data, as well as the ability to easily accommodate the changes brought about by the restructuring of health services in post-apartheid South Africa. Where previously the segregation practices resulted in separate information systems, the DHIS provided a complete data set on the desktops of both managers and health workers. In addition, the philosophy behind the development of the DHIS software, which emphasized the empowerment of users at a local level to use information to manage their health services, was coherent with that of empowering disadvantaged people in the “new” South Africa.

Almost simultaneously to these developments in the Western Cape, the Eastern Cape Province started to develop a different dataset. The provincial government, supported by EQUITY, a large USAID funded project, had a strong interest in developing data standards. However, they lacked a software system for data processing. In October 1998, HISP presented the achievements in the Western Cape, at which time the team was approached by the EQUITY manager who asked, “Are you able to customize the DHIS, import the data from our software, and implement it in all districts in the Eastern Cape before December?” The answer proved to be “yes,” and the resulting implementation of internally uniform datasets in two

provinces was a major step forward in developing flexible standards in South Africa.

Although the two data sets differed, the important issue was that key data were comparable. For the first time, data had been uniformly collected across black and white population groups, urban and rural areas, rich and poor, in two provinces previously divided into black homelands, and “coloured” and white administrative areas. The achievement of simple, practical results in two provinces sparked interest in other provinces and at the national level. As a result, consensus was achieved over a number of years on a national standard data set (Shaw 2005).

At this stage, we can say that an attractor for a new order, a new set of standards, was created. The standards component of this attractor consists of the two data sets defined and agreed upon in the two provinces (Eastern and Western Cape). What really made these data sets an attractor was the fact that collecting, sharing, and making decisions based on these data was supported by a working software system, a software system that was in use in all districts in the Eastern Cape and in pilot districts and at the regional level in the Western Cape Province. There are multiple reasons for the emergence of this attractor, among which is the fact that despite strong opposition to reducing the reporting requirements to a minimum data set, the presence of a coherent data set, and a functional tool to analyze the data, addressed an

important need for managers. The attractor was created by enrolling users and their existing work practices, minimal data sets, a software package, and health care authorities plus some additional components into a heterogeneous but aligned actor network. This occurred in a political climate that strongly supported this change, and which drove donors and newly appointed managers in the same direction.

Making a Set of Standards an Adaptive System

The collaboration between the Western and Eastern Cape provinces initiated the countrywide standardization process which subsequently included all provinces and the national level, and the first national *essential* data set was agreed upon in June 2000. While all provinces maintain their own extended data sets, the national data set makes up the shared core which all provinces must collect and report. This data set has been revised several times since then. At each revision, the debate rages as to which data elements get included and which do not get included. Over time, additional data elements have been added, either as existing program data sets have expanded, or to accommodate new vertical programs (e.g., HIV/AIDS programs). By 2005, it was expanded to become a national indicator dataset (NIDS), reflecting the increased focus on the use of indicators, as compared to the earlier focus on data elements. The term *indicator* is used in public health to denote information, obtained from data elements, which is used to measure the extent to which health targets are met (e.g., achieve an immunization coverage [indicator] of at least 80 percent [target]).

The tension over which indicators are included in the NIDS is constantly present, and is in fact never resolved. The typical pattern in the development of the NIDS has been that new data sets for selected vertical programs are initially developed as a separate data set, and collected and collated in a separate database within the DHIS software. This allows experimentation and fine-tuning to occur, often in selected sites or specific geographic areas. Once the data elements have stabilized, the data set (or a subset) gets included in the NIDS, and becomes part of the national reporting system. This has happened with the development of a hospital data set in the Eastern Cape Province, and with the development of an Emergency Medical Rescue Service data set for the country.

The response to the HIV/AIDS pandemic has resulted in services being organized as separate vertical programs, with separate funding, which is seen as a threat to the unification of the health system. Different information systems are developed and provinces are not bound to use a specific system. Reporting is limited to the NIDS, and although the

data may be collected through different systems, extracts are generally used for inclusion in the NIDS, using the DHIS as the *de facto* national standard for data processing and collation. Data on vertical programs such as the Prevention of Mother to Child Transmission (PMTCT) is thus uniformly collected in all health facilities (in accordance with the NIDS), even though data at the patient level are managed through many different systems in various provinces and institutions.

As managers use information, and understand the meaning of the data elements and indicators, they start changing their practices and their information needs change. This is illustrated by the example in Exhibit 1.

Braa (2005) suggests that two important aspects have contributed to the flexibility of the South African approach. First, the principle of the hierarchy of standards makes it easy to absorb and implement changes over time; there is no “final” data set in the sense that changes and experimentation are encouraged. Second, the flexibility of the DHIS software makes it easy to technically manage *the ever changing national and local data sets*.

Using Gateways to Accommodate Heterogeneity

Gateways translating data standards between the reporting levels and horizontally between subsystems have been important in the successful scaling of the standards in South Africa. The gateways are of three general types: paper to paper (e.g., registers for primary registration of patient data and aggregating monthly data sets), between paper and computer, and from computer to computer. The types of gateways that are needed are changing rapidly. Electronic patient record systems are increasingly used in hospitals indicating that electronic gateways will be important in the future. Over the last 10 years, computer availability has gradually moved down the hierarchy from district offices to hospitals and some health centers (mainly in large urban centers). Increasingly the gateways between paper reports from facilities and the DHIS is also moving down the hierarchy, as facilities enter their own data directly into the software. However, this is happening at an uneven pace between rich and poor areas.

Summary of the South African Case

In a post-apartheid South Africa, an attractor was created (a uniform data set, and the DHIS software to collate and analyze the data) in response to the need for integration and

Exhibit 1. Debating the Value of Data Elements

The process of defining and redefining the data sets in South Africa did not take place overnight. It was a journey that lasted years, and involved many iterations, as different role-players became involved. In some areas, there was intense debate about the inclusion or otherwise of certain data elements. The data elements collected for the immunization program serve as a good example.

The Expanded Programme on Immunization (EPI) Directorate required reporting on nine data elements. Their information requirements were largely focused on the numbers of immunizations given, with little attention paid to the development of indicators. On the other hand, one of the district municipalities in the Eastern Cape requested that the provincial data set be revised, omitting two data elements, which they argued could be calculated from the other data elements. The reason for the change was to focus health workers on the most important data elements. The purpose of the immunization program was not to count individual immunizations, but to have 90 percent of all infants “fully immunized” by the age of 1 year, hence the request for the inclusion of the data element “fully immunized under 1 year.”

The counterargument provided by the province was that

- national required the data in a specific format, and province was not in a position to adjust this
- WHO required this data and therefore national was not in a position to change this
- the numbers of immunizations given were needed in order to determine stock levels
- the data set would be incomplete if this data was not submitted

Eventually it was resolved that the district council would carry on submitting the data required by province, and would continue to collect their new indicator (fully immunized under 1 year), but that the concerns would be raised at the national level and that the request for a process for review would be tabled. It took 3 years before the adjusted data set was accepted nationally, and occurred only after it could be demonstrated how useful the new indicator has been. Trying to introduce this data element in other countries has faced similar resistance, mainly because the WHO has not yet recognized the value of this data element.

equity. For the first time managers, had access to useful and current data. The success of this attracted more users, provinces, and health care programs. Besides the investment in the development of the technical parts of the information infrastructure, a huge investment went into training health workers in the 4,000 public health facilities spread across the 9 provinces. This contributed to the development and acceptance of the standards, and the creation of the attractors. Over time and as the process unfolded, standards (i.e., minimal data sets) could be modified and extended as needs changed. Another set of standards has developed, being the emergence of different gateways to communicate the information. During this process, the complexity of the system of standards increased, and the types of gateways in use has changed as access to infrastructure has improved. The adaptability of the system makes it easy to implement because it supports existing practices while its flexibility accommodates the transformation of practices. These practices are radically different from the practices used under the apartheid regime, which were bureaucratic, centralized, and inflexible.

Accommodating the changes in the data standards has been possible because the individual standards have been simple

and accordingly flexible. They have been simple in the technical sense that modifications have been easy to make. Just as important, they have been organizationally simple because each has been limited in functional scope, and because each actor has been free to increase this scope by adding their own additional data standards as allowed for by the hierarchy of standards. The conflicts involved have been limited. Other standards have been restricted to a limited domain (geographic area), and, accordingly, the number of actors that needed to agree on modifications has been limited. Accommodating a variety of standards within related domains has increased the breath of experiences gained and increased the speed of learning and improved the overall information infrastructure as well as the health care system.

We believe that the South African experience can be considered a best practice that others should try to adopt. But all countries are so doing so is not a trivial matter. For instance, as demonstrated by many researchers mentioned above, complex socio-technical systems and their standards usually have strong inertia. According to Hughes (1987), their trajectory can only be changed in unique circumstances—during serious crises or external shocks. The regime change in South Africa

was such a unique circumstance. In the next section we will discuss attempts at replicating this strategy in other countries, and use these experiences to propose a more generally valid recipe for best practice for IS standardization.

HISP Experiences in Other Countries

This section will briefly describe the main experiences gained in some of the other countries in which HISP has been active, in order to highlight the variety of approaches and the various challenges met when trying to get started with bottom-up standardization activities. These examples are provided in an attempt to illustrate the ways in which a bottom-up, and evolutionary, approach to standardization may be undertaken.

HISP has been active in Mozambique since 1998. The achievements have been modest in terms of standards being adopted. Implementation and testing in individual provinces has been fraught with problems. One of the main reasons is that the health care sector in Mozambique, as in the rest of the public sector, is highly centralized and HISP members have not been able to convince the central health authorities to provide strong support for a more experimental approach.

In India, HISP is established in two states, and in the state of Andhra Pradesh significant results have been achieved. HIS and health in general in India is organized in vertical programs with little horizontal collaboration and integration. HISP has managed to develop standards within the Health and Family Welfare program, a large program that includes vertical programs such as family planning, immunization, etc. Coordination among other programs and hospital services has been difficult to achieve.

Vietnam has a similar fragmented structure with little integration between program silos. Here it has nevertheless been possible to agree on the development of a shared data set for all data and indicators for one very specific purpose: to measure progress toward the United Nation's millennium development goals. This approach will eventually motivate a minimum data set approach similar to the one in South Africa, although more limited.

In Botswana, because of a dysfunctional official HIS, each health program developed their own independent standards and systems. This created problems because only the "rich" programs managed to develop internally good systems, and there was no coordination between program-specific standards. In 2005, under strong managerial leadership in the health ministry, all program managers agreed to establish one shared HIS by combining the different subsystems. Since all

data passes through the districts, the decision was to capture and include all program-specific data sets in one data warehouse, using the DHIS, at the district level. Programs at the national level could then gain access to all data in the data warehouse, including their own. This system is being piloted in four districts. As a next step, inconsistencies within and between the data sets are to be addressed, and standardization will be achieved through a piecemeal harmonization of the various data sets. This approach is in contrast to that adopted in South Africa, where a *minimalist* data set approach was adopted. In this case, a *maximalist* approach has been adopted as a strategy to include all stakeholders by capturing all data across all programs in the shared data warehouse, with a view to streamlining and reducing it at a later stage. Since the essential data is included as subsets of the full data sets, the essential data will, as in South Africa, be made available to all user groups.

These experiences illustrate the importance of an attractor which allows a standard to emerge, and the fact that it is not always easy to do this. They also illustrate different ways in which an attractor may be created, although the common pattern is the creation of an attractor as a solution to a very specific problem or objective. Once the initial problem is solved, the process of developing the information system moves naturally forward, to address the next problem, the attractor gaining momentum and support, and becoming an increasingly important factor in the process.

The experiences from Mozambique show that in centralized systems, starting a standardization process through local, small-scale experiments is difficult if one is unable to convince (translate and enroll) central authorities. The positive experiences gained in other countries were obtained through close collaboration with central authorities. So while the activities in South Africa started at the bottom of the system (clinics in townships, then province, and finally reaching the national level), in other countries (Botswana, India at the state level) they started at the top. However, in these countries, activities have also followed a bottom-up strategy in the sense that a single, limited issue was addressed (MDGs in Vietnam, pooling data in Botswana, etc.), in a pilot site (before being scaled up), and an attractor was created by translating and enrolling human and nonhuman actors into a growing actor-network.

We will now explore more deeply HISP experiences in Ethiopia to provide some richer illustrations of challenges and opportunities involved in the creation of an attractor that becomes a new standard in a country where existing structures are not shaken up by radical change as occurred in South Africa.

Ethiopia

Ethiopia is a federal republic, consisting of 11 relatively independent regions with borders drawn along widely accepted ethno-linguistic lines. The regions are divided into zones, which are divided into *woredas* (district, the basic administrative unit in Ethiopia; there are 580 in all). Ethiopia is, even more than most developing countries, characterized by stark contrasts and uneven development between rich and poor and urban and rural areas, as well as between the capital and the rest of the country.

The overall HIS in Ethiopia is poorly developed. Formats for data collection have evolved over time as a result of decrees from the Ministry of Health (MoH) and from vertical program managers and agencies. When new reporting formats have been issued, the old often continue to be used since they are “owned” by a different agency, causing inconsistencies and duplication. The information unit at the MoH has tried to create some order by issuing an overall compilation of required formats, but these efforts have not improved the situation.

The government has recently initiated a fast-track implementation of e-governance solutions supported by a project to network all *woredas* in the country, with the health sector as one targeted area. The general assumption is that this will require one all-encompassing standardized system. As one key actor at the federal level said, “We want to give the contract to one company who will then be responsible for everything, regardless of the costs.” This approach by a central ministry is consistent with that found in many other countries, and is in contrast to the South African case, and in the experimental, bottom-up approach described for three regions in Ethiopia (see below).

In an attempt to overcome the rigidity of the federal forms, different methods have been used at a regional level to collect region-specific information. Some regions have printed revised versions of the centrally defined forms to which they have added the additional data items to be collected, while others have used the centrally defined template and have added additional forms. In this way, each region has developed its own distinct system of formats and procedures for collecting, analyzing, using, and reporting data internally within the region and from the region to the federal level. The *de facto* data standards at each level are thus defined by the unsystematic array of “hard-coded” paper forms that are actually in use. It is very difficult to change these standards for a number of reasons, including the lack of coordination between programs, the absence of a strong vision for an integrated information system, and the difficulties in accessing

and communicating with all parts of this vast country, particularly the more remote rural areas. In Exhibit 2 we highlight some of these problems in a description of a federal workshop with participants from four regions.

The problems highlighted demonstrate the top-down and all-inclusive approach to standardization common among ministries and central agencies. It also demonstrates the enormous variety and heterogeneity of needs, interests, and opinions among stakeholders, and accordingly the challenges involved in implementing such an approach.

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

The HISP group, based at Addis Ababa University, developed a DHIS software prototype in parallel with a systematization of the rather complex datasets. The prototype demonstrated inconsistencies and problems in the current reporting formats. While such inconsistencies had been known but not acted upon previously, the process of computerization made these problems more transparent and triggered action. The prototype and findings were demonstrated at a workshop in March 2004, attended by health workers and managers from the Health Bureau, sub-cities, facilities, and some participants from MoH. The health bureau decided on a city-wide project and formed a committee to develop new standards and reporting formats. Subgroups reviewed the forms from each program area and over the next 2 months all data formats were revised and a set of uniform reporting formats were agreed upon and compiled in a book.

Having agreed on integrated data sets, the database for capturing and managing this data was finalized, computers were purchased, and the DHIS installed. Training and facilitation followed and a technician provided support across all sites. During 2004-2005, the information system was implemented in the 11 sub-cities, 5 city hospitals, and 23 larger health centers. Three city-wide workshops were conducted, each resulting in a range of modifications. In July 2005, the results of the first full year of data reporting were assessed at a workshop. The achievements were regarded as significant and, as a result, new programs such as pharmacies and drugs now wanted to be included in the “unification” and standardization process. Another area in which significant progress has been

Exhibit 2. The Difficult Process of Gaining Agreement on a Uniform Integrated Dataset

A 3 day federal workshop was convened (July 2004) to address the key information needs of the health services. The idea was to present a minimal indicator/data set that would provide a basis for developing the information system. This was meant to represent the *information needs* of a variety of programs, and would serve as the *standard* for reporting in the region. However, the workshop did not agree on the suggested data set for a number of reasons.

1. Most participants, who were representing the range of vertical programs and services, didn't find "their" data in the proposed data set. They all wanted the data for their vertical program to be included in the dataset, but this would have violated the minimalist approach that was perceived to be the correct avenue to follow. The proposal lacked a conceptual framework in which such additional information needs could be accommodated, and thus the participants found the proposed data set was far too limited.
2. The workshop arrived at a consensus on the need to reduce the number of data elements, but not on where or how much to cut. Said one speaker, "Reporting diagnosed diseases on the ICD format represents the major burden. Since the facilities are not able to diagnose correctly using these codes, this reporting format needs to be reduced drastically." Another responded that "reporting diseases using ICD is required internationally."
3. Agreement was also not reached on which areas to include in the standardization process: "The HIV/AIDS pandemic will have impact on the entire health system in Ethiopia and it is crucial that the reporting of HIV/AIDS data is included in the federal system" (federal level HIV/AIDS coordinator). To this, someone responded, "The federal data standards we are discussing here should be what is common for the 3500 health facilities in Ethiopia. The HIV/AIDS programs are so far only implemented in a few places. We cannot ask facilities to report on activities in which they are not involved. Besides, HIV/AIDS requires much more data than we can include here, and should therefore not be included but rather be part of a separate system."
4. The necessity of having one standard system (one set of paper forms, one software system) was emphasized by a few speakers, whereas others strongly opposed this and stated that the regions as well as the programs needed to be able to develop according to their own needs, but within the federal framework of data standards. There was, however, no shared understanding at the workshop as to how to best balance these opposite positions
5. The problem of being able to accommodate changes in an information system was raised by several participants: "We are all the time being given new reporting requirements by the federal level. I am sure this will continue in the future. So what do we do when we have our new federal formats? Are they also going to be changed all the time? And how will that be possible?"

made is in the implementation of the ART program for HIV/AIDS patients. In a recent development (2006), two HISP team members together with two doctors have developed and implemented a simple but effective, free and open source electronic patient record system in the ART clinics of two hospitals. The reporting requirements for ART patients are complex. It is a requirement that statistics provide the outcome (regimen effectiveness) for every monthly cohort of new ART patients, which is increasingly difficult to manage in a paper based system as each cohort needs to be monitored from their starting date. By providing these reports at the "touch of a button," the system gained instant success and within 2 months of its implementation has been requested by four additional regions; an attractor is being created.

We see thus that in Addis Ababa, the electronic infrastructure reaches down to all administrative units, hospitals, and health centers, and even to electronic records for HIV/AIDS patients. This is in sharp contrast to the situation in other regions. The standards and database solution created in Addis Ababa have created strong interest in other regions and Addis Ababa University has signed agreements to undertake similar projects with four additional regions; an attractor is being created here as well.

In the Oromia Region, the HIS reform process started after some key actors from the Oromia Health Bureau participated in the workshop in Addis Ababa. This region is the largest and most populous region in Ethiopia. It comprises one-third

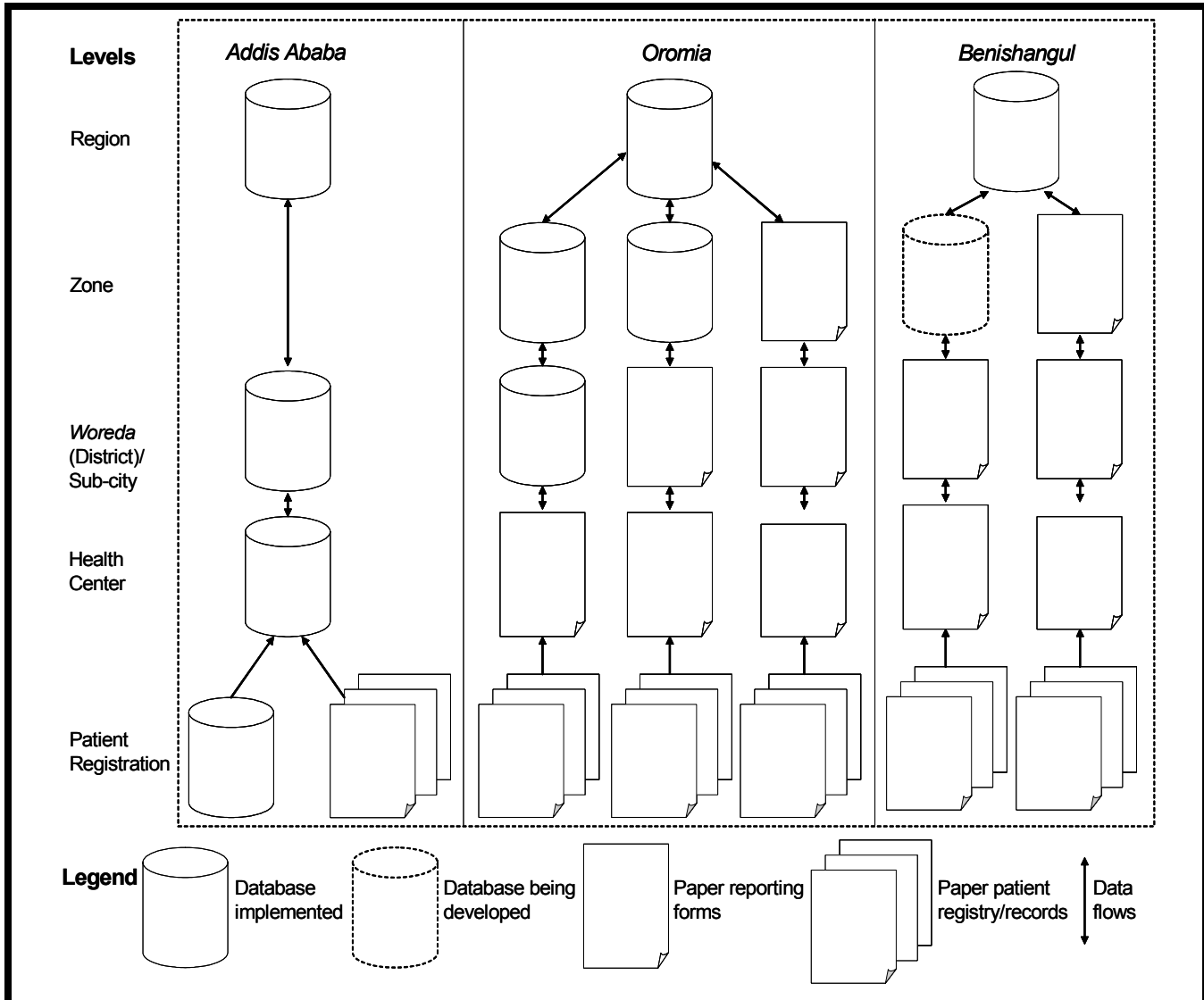


Figure 2. Uneven Development of HIS Infrastructure Across Regions in Ethiopia (Simplified)

of the total surface area (bigger than Italy) with a population of 25 million and 1,458 public and private health facilities. The major challenges in Oromia are the vastness of the region, the poor infrastructure, and the lack of human capacity. While drawing on the Addis Ababa experience in terms of the database development, the implementation process in this region varies across the zones. In two zones, training on computer basics and the use of DHIS application has been provided and the database application has been implemented in some *woredas*. In the remaining zones, the plan is to first train all zonal offices in the use of the DHIS database before extending to the *woredas*, which are in the deep rural areas. This strategy thus emphasizes horizontal extension across

zones, before gradually reaching down to the *woreda* level (vertical extension).

In the Benishangul-Gumuz Region, one of the poorest regions, stretching 2,000 kilometers along the borders of Sudan, and populated by several smaller ethnic groups, the HIS relies on a paper-based system of reporting up to the regional level for most zones (Mengiste 2005). Figure 2 highlights the two important issues that emerge from this case: first, the use of gateways at different levels of the hierarchy, and the level of the gateway being influenced by access to technology; and second, the different types of gateway in use, again depending on access to technology.

In these three regions, we see how a federal structure with independent regions facilitates variety, innovation, and regional standards—in our view a requirement for successful health care infrastructure standardization and development. It is, however, necessary, as in South Africa, to develop shared core national essential data sets in order to enable monitoring of, for example, health status and health services delivery across all regions and *woredas* in this vast country. The cases highlight the extreme heterogeneity found in developing countries such as Ethiopia regarding user needs and human resources as well as the basic infrastructures required by a computer-based information infrastructure. The difference in the implementation processes between regions reflects the need to accommodate the unevenness between regions. Robust, flexible, and scalable approaches, where paper- and computer-based information infrastructures smoothly interoperate and where the computer-based systems gradually replace the paper based ones, are needed in contexts like this.

In the case of both the general HIS standardization and the specialized solution for ART patients, we see that an attractor has been created in Addis Ababa and thereafter spread to other regions, thus showing a similar pattern to the early phases of the standardization in South Africa. Furthermore, in both cases we see a bottom-up initiative that is increasingly getting involved in national-level negotiations as the spread of standards between regions needs to be compatible with national policy. Despite initial conflicts related to the role of regional bottom-up initiatives in the national standardization process, an agreement has been reached between the HISP group and the MoH to cooperate in the national task force to develop national HIS standards. In the case of the ART solution, however, future developments are less certain as there are multiple international and national actors involved—and significant funds.

We will now look briefly at experiences from a country that has not been involved in the HISP project and which successfully built an information infrastructure for health. The process used here will be contrasted to that used in the best practice case presented above.

Thailand

Thailand has a population of 64 million people and is divided into 75 provinces and 795 districts. The HIS in Thailand may be regarded as a best practice among mid-income countries and uses an extensive information and communication technology infrastructure that reaches all districts. Data on individual patients is captured electronically in most health

facilities and standard data sets are submitted upward through the system to the central level, from where feedback and key information for the management of the health services is accessible through the web (www.phdb.moph.go.th). The health system works well, as indicated by the HIV/AIDS situation. HIV prevalence has dropped from 4 percent in 1990 to 1.3 percent in 2004, with the number of new infections reducing from 43,000 to fewer than 20,000 per annum. Eighty thousand people are on ARV therapy, for under \$300 per year.

According to the 1997 constitution, every Thai has the right to health care. From the inception of the universal coverage scheme in 2001, there was a tremendous push to improve data quality in order to justify the decentralized distribution of funds based on capitation costs (paid per capita) for prevention and health promotion and for direct costs for hospital and high cost patient care. The National Health Insurance Scheme has established a system of contracting units (CUPs) in each district, consisting of a hospital and their network of clinics, which are then paid for the services they are rendering according to the data submitted. The actual payment, quality control, and accounting are decentralized to the province level. The CUPs are provided with ICT network access and computers as part of their payment.

Two sets of standard national data are identified: one covers community services and is made up of 18 subsets including immunization, family planning, disease surveillance, chronic diseases, etc.; the other covers hospital services and consist of 12 subsets including inpatients, outpatients, patient payment, referral, etc. Each of these 30 data subsets are specified as a file format to be sent to the national level as e-mail attachments.

Health facilities use various software applications for the primary capture of data and report electronically to the CUPs using Internet or USB memory sticks. Feedback from the central level and access to information is generally web-based, but numerous paper-based reports are also produced. As more and more districts get adequate web access, interchange of data and information between local and central levels is increasingly robust and scaleable. As long as the provinces report the required standard data sets and files, the provinces are free to collect and process the additional information they need and can use the software of their choice.

While standard software applications have been distributed to the CUPs for collating and transmitting the standard data files, a variety of other software applications have been developed in the provinces in order to pursue their particular information needs. Infrastructure and socio-economic conditions differ

between provinces and between cities such as Bangkok and the rural areas. While freedom for local innovation enables more advanced provinces to develop solutions according to their potential, less advanced provinces benefit from sharing software solutions developed in other provinces. Standards are regularly revised through an ongoing HIS development program that has broad participation from all of the main role players in the process.

We see the approach to standardization followed in the implementation of this highly successful information infrastructure as basically the same as the one in South Africa. The first version of the standard and the infrastructure was built in order to solve one very specific problem: the model for financing the health services. The data required for this purpose turned out to be useful for other purposes as well. Based on user experiences and new needs, the infrastructure and standards have been extended and modified; it has evolved as a complex adaptive system.

Discussion

The aim of this article is to suggest a strategy for developing flexible IS standards to improve the HIS in developing countries. Using complexity theories to interpret the outcomes of the action research project, we propose a strategy whose two main components are to create an *attractor* that emerges as a new standard and which evolves into a system of standards, and second, to suggest that the individual standards must be crafted in a manner which allows the whole complex system of standards to be *adaptive* to the local context. Furthermore, the strategy is based on two principles, which we call the *principle of flexible standards*, and the *principle of integrated independence*. This strategy, we argue, while being rather general, is of particular importance when addressing the complexity caused by the uneven development of infrastructure in developing countries. We illustrate how this approach is supported by obtaining rich information from minimal data, how radical change can be achieved through taking small steps, and how gateways and a focus on data standards (as opposed to technical standards) are the important components when aiming at scaling national HIS in developing countries.

Creating Attractors

The real take-off for the South African pilot project came about when users were offered a simple software application to support a minimum data set. At this point, an attractor was created, which, through its success, enrolled additional users.

In the other countries where attractors have successfully been created, this has happened by pursuing a strategy to rally scarce resources around solving a single specific, but large problem, shared by many. In Addis Ababa the problem was a fragmented HIS, and the solution was to standardize the data sets by solving incompatibilities and overlaps, establishing a uniform infrastructure to collate data, and presenting information in the form of indicators. A similar solution in Botswana made data available to users by establishing a DHIS data warehouse at the district level. The successful solutions, consisting of software and data sets, have been successful because they have been simple (easy to adopt; accommodate changes with ease) and have supported experimental development strategies. When users adopt the solutions, it demonstrates that systems are working properly seen both from an organizational and technical perspective. A working solution providing benefits is indeed powerful in the sense that it attracts more users and other stakeholders. This is illustrated by the instant success of the simple solution to manage ART for HIV/AIDS patients in Addis Ababa.

The cases demonstrate how this strategy might be adopted with success in different contexts. In principle, one can initiate a top-down or a bottom-up approach and develop a solution in support of work tasks, provided user needs are addressed. However, the cases as well as literature on HIS (AbouZahr and Boerma 2005; Shaw 2005) have shown that in order to attract interest from both local and national actors, it is important to start with a focus on key priorities of the health services. The starting points (i.e., the initial problem being addressed) will largely determine the next steps to be taken, and which actors should be enrolled. HIS standards have national importance and the role and involvement of health authorities will always be significant. However, as we have illustrated above, governments in developing (as well as developed) countries may easily become too ambitious in their aim at developing uniform standards. In South Africa, this tension between local need for flexibility and the need for central control has been managed through the application of the hierarchy of standards (Figure 1), which dynamically combine flexibility as a *right* and adherence to the standards of the level above as a *duty* (Jacucci et al. 2006). This is discussed below as the *principle of integrated independence*.

The Principle of Flexible Standards

A national HIS needs many interdependent standards—a complex system of standards. Individual standards easily arrive at lock-in states, which may result in the whole system being locked-in, a complex *non*-adaptive system. However, it is important to craft standards and their relations so that

they emerge as a complex *adaptive* system that can adapt to a changing environment and thereby contribute to the sustainability of the HIS. That can only be achieved if the individual standards adapt to the changing environment and each other, which can only be achieved if the standards themselves are flexible.

What makes a standard simple (or complex) is partially its technical complexity in terms of the number of elements. But the complexity of a standard is also determined by its constituting actor network (i.e., the data elements, the user practices supported, the technological components implementing the standards, the people and organizations responsible for maintaining these components, the users of the standard, standardization bodies involved, etc.) and the links of various kinds between all of these actors. Simplicity and flexibility can be achieved by making these actor networks small and simple. That is partly achieved by defining independent standards for different use domains and geographical areas, and partly by limiting their functional scope. This mechanism decreases the technical complexity of the standards but, more importantly, it also decreases the organizational complexity in terms of the use practices that need to be analyzed and the organizational complexity required to involve all stakeholders.

Two forms of flexibility can be identified: use and change flexibility (Hanseth et al. 1996). A standard's total flexibility is the sum of these two. *Use flexibility* refers to the ability to use a standard in a number of different environments, or for a number of different purposes. The "need to know" principle, which emphasizes the importance of collecting essential information rather than "nice to know" information, is an example of how use flexibility helps to get maximum information out of minimum data, that is, using existing data elements in new combinations to address new information needs, rather than adding new data elements or reporting formats into the standard (see Exhibit 1). *Change flexibility* (and scalability) is achieved through the classical principle of *modularization*. This principle is crucial across all engineering disciplines; it should be no surprise that it also applies to standards. Rather than one complex standard covering everything one should make several small and *simple* standards and define simple interfaces—*gateways*—between them. The DHIS software has become popular and gained momentum primarily because of its change flexibility. Data elements and indicators are handled as individual components (records) and may be added, deleted, and edited by the user. The software also allows the data collection tools to be customized to the need of the individual reporting unit, such as a hospital or health center. These functionalities have made it possible to focus on the standardization process of the

individual data elements, allowing for differences between provinces and use areas. In contrast, in other countries, as for example India, it has proven very difficult to change the paper formats which are often "gazetted" and appear to be cast in stone.

Standards should be modularized horizontally and vertically. *Vertical modularization* corresponds to traditional layering in software engineering where one layer offers services to the layer above. Separate standards are defined at each layer. This principle is beautifully demonstrated by the seven-layer open systems interconnection (OSI) protocol model. In our case, the separation of the data layer from the rest (the technical layers) has been found to be extremely important in order to, on the one hand, identify the data that can be collected in the various health care institutions and, on the other hand, transfer this data by available infrastructural services (electronic in some areas, physical in others).

Horizontal modularization means that rather than going for one "universal" standard for a domain, one makes several standards—one for each part of the domain—and interfaces are defined between them. The classical interface between standards is a *gateway*, a piece of software that links together different sub-infrastructures into an integrated one, by translating between data representations, formats, and protocols. In the computer communication community, gateways have been regarded as an anomaly, something you need when you have failed to achieve a shared standard (see, for instance, Stefferud 1994). In our view, gateways are just as important as standards in order to build and maintain flexible and successful infrastructures. We use the concept of gateways in a broader meaning, seeing them as boundary objects between actor-networks (Bowker and Star 1999; Star and Griesmer 1989). Gateways, then, also include *objects* that link and translate between paper based and electronic infrastructures, or between incompatible electronic infrastructures. The objects representing such gateways will be hybrids (Latour 1993), composed of humans, procedures, computers, and specialized software.

The typical gateway in the cases of South Africa and Ethiopia is between paper and computers. This gateway consists of a number of procedures for collating the paper forms received from the paper-based infrastructure and translating them to the required electronic format so that it can be transmitted in the electronic infrastructure. Gateways also include the procedures for analyzing the data and producing different reports (i.e., from computer back to paper and the paper-based infrastructure), feedback to those who collect the data, and other stakeholders. The paper-computer gateways take many forms and are rather complex in terms of people, procedures, and the paper- and computer-based tools involved.

Another gateway is that between electronic systems, the electronic record systems for HIV/AIDS patients and the DHIS in Addis Ababa being a typical example. In this case, the relevant patient-related data elements are mapped to the corresponding DHIS standards. The HIV/AIDS data is translated into aggregated monthly data and provided in a format appropriate for import into the DHIS. Similar gateways are in use in all districts in Thailand; in South Africa similar gateways exist between the tuberculosis control program data and the DHIS. These will become increasingly important in the next few years, particularly in relation to HIV/AIDS patients.

Without gateways we are trapped. We need to develop infrastructures based on single, universal standards, but in countries like Ethiopia this is impossible. In most other cases, universal standards are beyond our capacity or will be totally inflexible if built. Establishing a fragmented infrastructure composed of a range of small ones which are not connected is not a viable option. An appropriate blend of standards and gateways allows infrastructures to evolve by maintaining order at the edge of chaos.

The Principle of Integrated Independence

According to Kumar and van Hillegersberg (2000, p. 23), “Integration has been the Holy Grail of MIS since the early days of computing in organizations.” With the diffusion of the Internet and other computer communication technologies, tighter and more integration has been enabled—and demanded. Improved integration of information systems is also at the center of the efforts presented in this article to enable smoother coordination and control of organizational processes and health care delivery. But integration may cause less independence—and less flexibility. The case of South Africa demonstrates that both integration and independence of data standards have been achieved between provinces (i.e., geographical areas) and health programs (i.e., functional areas). A sort of integrated independence has emerged through the interaction between and within different 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 or linearity, the standards developed through the HIS-processes have been developed through conscious design efforts, although by a very heterogeneous network of designers. In the South African case, a

large information systems development project that has evolved over more than 10 years, the loose and flexible coupling between the evolving variety of designers and owners of the (sub)systems, such as the national level, provinces, health programs and the HISP group, is a significant feature.

We now summarize three key aspects that are linked to this strategy, namely rich information from minimal data, enabling radical change through small steps, and effective scaling of health information systems in a complex environment.

Rich Information from Minimal Data

Flexible standards must, we have argued, be simple and easy to change and at the same time support a wide range of work practices. One of the outcomes of applying this approach to the data set standard is the finding that we can get rich information from minimal data. A focus on the must-know rather than nice-to-know information, as illustrated by the emphasis on indicators and the minimal essential data set, can be extremely powerful in that it allows a simple, well-chosen data element to be used for several purposes. In addition, existing data can often be used for new purposes by innovation in the development of indicators, rather than adding new ones. These initiatives can stimulate transformation and improvement of work practices without changing the standards.

Developing a minimal dataset can best be achieved by means of the bottom-up approach to standardization, in combination (of course) with top-down implementation of best practices in new areas and micro-macro consultation and learning. As shown in the South Africa case, that means that a very simple draft data set is implemented. Based on user experience, one can develop it so that a wide range of work practices are supported without extending it or with minimal extensions. The data set is then extended only when this is absolutely necessary. The traditional top-down approach to standardization usually leads to huge sets of data where “need to have” has not been separated from “nice to have” data. And while these data sets have a huge array of data, often only a small portion of the data is actually used meaningfully, negating the purpose of having a large data set in the first place. Even if, as is described in the Botswana case, a shared data warehouse is developed, the long-term strategy is to integrate data sets and to make the essential data from each data set available to everybody. By making the availability of both useless and useful data transparent, the process toward the reduction of each data set by emphasizing “need to have” is initiated.

Radical Change Through Small Steps

The strategies described in the cases are not just for standards development, but also for radical change of complex systems whether these are systems of standards, infrastructures, health care systems, or others. This interpretation of the strategy allows one to achieve *radical change through small steps*.

Radical change is often an aim when introducing IT solutions into organizations. In the days of business process reengineering, the recommendation was to design the new organization and its ICT solutions together. That did not work in industrialized countries, and it will not work in developing countries, because it does not work in the world of complex systems. Accordingly, new solutions, including standards, need to be designed so that they support existing practices and then these practices can be modified incrementally. The standards need to be modified in parallel with the changes in practice, by following the strategy and principles described above.

We have seen this approach used in the development of data standards (the minimum data set in South Africa), and in the development of the DHIS software. What emerges through the analysis of this practice is the use of gateways as a mechanism to effect changes in small steps that are appropriate and synchronous with the process of infrastructure development. The use of gateways is thus in reality a set of procedural standards that accommodates change in small steps, but which can bring about radical change.

The change is radical in the sense that it brings about possibilities, and new ways of doing things, which previous practices, and particularly the BPR (business process reengineering) style processes did not achieve. The advantage of this approach is that it is sensitive to the needs of a complex adaptive system, and allows the systems to interact and adapt as the changes are introduced.

Scaling Information Systems in Developing Countries

Heterogeneity, as illustrated through the uneven development of economy and infrastructure between and within regions, is a key characteristic of developing countries. One particularly important requirement that we address through HIS standardization is to achieve full data coverage within an area (district, province, country). This has been termed the dilemma of “all or nothing” (Braa et al. 2004), and is important when, for example, the aim is to address equity across population groups in South Africa, or to implement the “health for all” insurance

scheme in Thailand. As discussed earlier, this problem area can be analyzed within the framework of *scaling*. Using the self-similarity between branches and subbranches of a broccoli as a metaphor, CAS sees scaling as the replication of the similar in a network (Eoyang 1996). However, it is in this latter perspective that the scaling of IS in developing countries provides a stark contrast to the typical industrialized country where the “similar” infrastructure is relatively evenly distributed. We demonstrated how in Ethiopia, the HIS had to scale differently in the various regions.

We can summarize our experience in suggesting that there are two important strategies that need to be followed in order to scale information systems in this context. First, focus on data standards and information rather than on technical standards. The focus in South Africa and Addis Ababa on essential data and indicator sets is the case in point here. Second, accept that there will always be technically incompatible subsystems. Make them compatible in terms of data by building gateways between them. Scaling HIS in, for example, Ethiopia is along one axis about replicating data standards and information handling procedures throughout the hierarchy of health services covering the country. While technical standards cannot be uniformly replicated across the uneven heterogeneous infrastructure, data standards can be replicated. From a standards perspective, the focus needs to be on the content/message rather than the container/messenger. However, along another axis, scaling of HIS in Ethiopia is about *replicating*—establishing and maintaining—effective and seamless data flows which are appropriate throughout the country. The use of gateways helps us achieve this.

Conclusion

Many developing countries are currently engaged in strengthening their national HIS. This trend is reinforced by the launch in 2005 of the Health Metrics Network, a global initiative to support such efforts, and which is supported by WHO, the European Union, and a number of international agencies (<http://www.who.int/healthmetrics>). The challenge of coping with fragmentation, multiple data sources, and lack of standards is regarded as a key issue. An important contribution of this article is to provide a strategy to standardize HIS and information infrastructures which are appropriate for the context of developing countries.

In proposing a strategy for the development of information infrastructures for the health care sector, two issues related to complexity are of particular importance, and both are specific for developing countries. First, there is uneven development

between rich urban and poor rural areas, characterized by the extreme differences in health service delivery and the availability of basic infrastructure. Second, there is the important role played by vertical programs (like HIV/AIDS programs), funded and partly managed by international donor organizations, in increasing complexity and HIS fragmentation.

Our strategy contains two main aspects. First, *create an attractor* by building an actor network. In our cases, we describe how the use of a simple set of data standards (in South Africa), a data warehouse (in Botswana), and a software program that made the data available to all user groups addressed a problem for a specific group of health workers. The creation of attractors enrolled and aligned a user group by providing the users with benefits (i.e., the solution must support existing work practices), and the standards were able to accommodate changes as the user base expanded. The cases also show that creating attractors in national priority areas, such as equity in South Africa and the universal coverage scheme in Thailand, are powerful attractors to drive change at the national level. Similar attractors are required at a global level to address workable solutions in the information systems arena to support initiatives to combat the HIV/AIDS epidemic and the attainment of the MDGs.

The second aspect is to ensure that the emerging *system of standards remain adaptive*, a complex adaptive set of standards. This is done through a number of mechanisms, including paying attention to use and change (modularization) flexibility, and the use of gateways to link different components/standards. Scaling of standards in developing countries is enabled by flexible gateways between both computers and paper-based systems and between different computer-based systems and by emphasizing the data standards rather than the technical standards.

The limitations of this study relate to the fact that the principles discussed, and the proposed strategy, have emerged as reflections on processes in the various countries in which HISP has operated. The applicability of these concepts needs to be tested outside the HISP network, and in different contexts, and as an explicit approach to strengthening information systems. The case studies used here reflect mainly on initiatives in strengthening public health services; space limitations have restricted detailing experiences in for example hospital information systems. Aspects requiring further research thus relate to the explicit use of these approaches as components of interventions in new contexts, and a reflection on how these principles can be applied, or differ, in hospital contexts, and in contexts outside of the health sector.

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