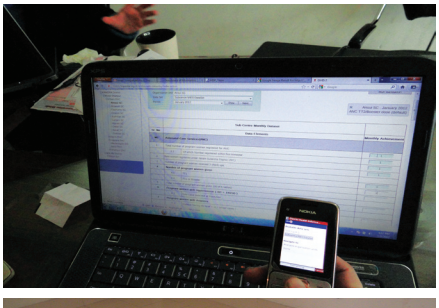
Part I

Good Design

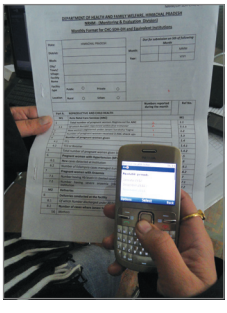
- Integrated Health Information Architectures – The Vision
- Integrated Health Information Architectures – Operationalising the Vision
- Integration and Interoperability – Standardisation is the Key
- Strategies for Scaling of Integrated Health Information Architectures



Good Design: Our World View on Architecting

This introductory section of the book presents our world view on architecting, which we see as the foundation for good design. Like a clinician who understands the different organs of the body and the principles underlying their working and inter-linkages in the context of a human body, or a building architect who knows what are the different components of a house – the bricks and mortar – and the principles on how they work, we similarly see the role of a HIS architect to understand the different components of an IHIA, and the principles underlying their working within the context of a health system. With this background, this part is comprised of 4 chapters.

The first – "Integrated Health Information Architectures – the vision" describes what our conceptualisaton of an architecture more generally, and an IHIA specifically. We emphasise our perspective of IHIA as a verb, something always in the making, rather than a finished product, a noun. A social systems perspective to understand an IHIA is a key building block of the vision. An IHIA is described over 3 levels comprising of the "social system", "application" and "data." Another key building block of the IHIA is the data warehouse, that helps to design the architecture in a scaleable manner – a fundamental prerequisite of an IHIA. As an example, we present the Health Metrics Network (HMN) concept of a data warehouse, and our point of departure of it with respect to its decentralisation and multiplicity in its reference.



The second chapter is on "Integrated Health Information Architectures: Operationalising the vision" seeks to discuss basic principles that can help to ground the vision to reality. The social systems perspective helps to emphasise a key purpose of the IHIA is to provide power to the users in terms of information for decision making. This has implications on the approach to requirements analysis, which we argue should be based on *information needs* rather than the conservative and traditionally followed approach of automating existing work process and with it incorporating the installed base of techno-institutional elements. Principles to approach this process of understanding information needs is described in relation to the three levels of the IHIA – social system, application and data – articulated in Chapter 1.

The third chapter is titled "Integration and Interoperability – Standardisation is the key", and focuses on standards which we describe as the glue that brings the different components of the IHIA together. Current debates on integration and interoperability are discussed in this chapter, and our perspectives on these two key issues are described. Standards are discussed in relation to these two concepts, again following the three level framework of IHIAs, along with general principles towards approaching standardisation. Case studies from South Africa and India are presented in this chapter to illustrate our general principles towards approaching standardisation.

The fourth chapter titled "Strategies for scaling of Integrated Health Information Architectures" concerns the fundamental characteristic of scale which architectures seek to achieve. General principles to understand the dimensions of scaling, including quantitative/qualitative or vertical/horizontal are described, along with different approaches to achieve it including those of improvisation, cultivation, and attractors. An example from Kenya is described to illustrate the potential of cloud computing on scaling, and from India to emphasise that scaling in the health sector of developing countries will necessarily involve planning for environments involving uneven infrastructures, rather than one where "one size may fit all."

1 Integrated Health Information Architectures – The Vision

'Better information, better decisions, better health' is the slogan of the Health Metrics Network (HMN). 'Global' consensus on the importance of information, combined with a likewise consensus, that current Health Information Systems (HIS) are fragmented and generally of poor quality, have contributed to the relative agreement on the need to strengthen HIS in most countries. As a result, reform of HIS is a key aspect of health restructuring agendas in most developing countries. One problem in this context, however, is that HIS has come to mean different things to varying groups of people. There are systems dealing with aggregate data around the everyday provision of services, typically referred to as 'Health Management Information Systems (HMIS)', and those that deal with patient level data in hospitals, often called 'Electronic Medical Records'. There are a variety of others dealing with specific functional areas, such as human resources, drugs and logistics, finance, inventory management, and others relating to specific diseases such as for HIV/AIDS, Tuberculosis and Malaria. Different technologies form a part of the infrastructure that is being used to support these various systems, such as stand-alone computers, networked servers, mobile phones, Personal Digital Assistants (PDAs), and so on. Taken together, we refer to these multiple systems as 'Health Information Systems'. As we move towards building bridges and standards for these different systems, and supporting infrastructures to communicate with each other, we contribute to the creation of an architecture, for systems of systems, which in this book we term as 'Integrated Health Information Architectures' abbreviated as IHIA.

Given this context of diversity and multiplicity of systems, the heart of the challenge facing policy makers, software developers, users and vendors is, 'How can we have these different systems to communicate to each other to get more integrated information?' Getting more integrated information helps managers to take more effective decisions, while data redundancies and duplications can be eliminated or minimised for the users and data providers. In this effort, international organisations like the World Health Organization (WHO), national ministries and software developers are all attempting to develop IHIAs, which represent a collection of various systems, with underlying procedures or standards that can enable 'interoperability' of data flow across these systems.

The term 'architecture' itself is not universally agreed on, and approaches to build them differ ranging from top-down blueprints to bottom-up and emerging collectives. In this chapter, we seek to provide an overview of the concept of architecture, and how we plan to use it in the context of HIS. Focusing on 'enterprise architecture' aimed at supporting health management and decision-making, we regard the 'data warehouse'

as a key integrating element. The focus is thus on management and use of information related to public health and health management, as in contrast to clinical information, which concerns individual patient care encounters. Further, our focus is on HIS, broader than the traditional HMIS, which are needed to inform decisions and management at facility, district, state and national levels. Defining architectures as 'systems of systems', we apply a social system perspective in order to better understand the social and other dynamics of systems and architectures. Finally, we describe the necessity of applying evolutionary bottom-up approaches in the development of such integrated architectures.

1.1 The Concept of Integrated Health Information Architecture

The first aim of this chapter is to present a coherent and integrated framework for HIS which we refer to as IHIA, with a focus on Use – the provision and use of data and information at all levels of the health services to support decision-making. This integrated framework includes various specialised components of the HIS, such as electronic medical records systems, laboratory systems, logistics systems and HMIS. These components need to interact by sharing data, including sending or receiving data from one or multiple systems, all according to a certain plan or design. It is within this overall design of an integrated framework that the various sub-systems and their interactions need to be 'located', assigned a role, and understood.

These various systems cannot be really understood without clarity on the supporting infrastructure, on which they are deployed and supported. For example, the rapid development of the Internet and mobile telephone infrastructures, have led to an increasing number of new HIS that were not even conceivable a few years ago. However, with these opportunities that the infrastructures provide, also comes the challenge of managing and synchronizing them. These challenges exponentially enhance the complexity of the systems, making it more and more difficult for health authorities to plan for the way forward. We argue that approaches to 'good design' within an integrated HIS framework, which can be operationalised through the concept of IHIA, represents a strategy that makes it easier to manage this increasing complexity. For example, a city planner needs architecture at different levels of detail to understand how all the various bits and pieces needed for a city to function well, should fit together and evolve. In the same way, health authorities need an architecture to understand how the various components of the HIS should work together and evolve within a flexible structure, while allowing future changes inherent in a health system to be seamlessly incorporated in the existing IHIA.

While a village would not need much of architecture for planning, city development would definitely need one. Development of mega-cities across the developing world including India, however, illustrate how the city's architectures and development plans are inadequate in solving or even coping with the problems in a dynamically evolving city environment. This rapidly changing environment is a result of influx of people, shifting demographics, changing lifestyles and new constructions. Most people would, however, agree that without efforts to draw up architecture for how the city should develop, the situation would have been even worse. Thus, architectures should not be viewed as an end-solution, as there is no perfect architecture, but should merely be seen as an approach to manage complexity. Similarly, in the context of HIS, architecture should be regarded as a process tool, which at any point would represent the current understanding and knowledge, which by definition will be inadequate

and incomplete, and while at the same time should enable the incorporation of new developments. Our point of departure, thus, is to conceptualise architecture as a verb – a collective; designing systems not a design of systems – always in the making – rather than a noun; representing an end solution.

The concept of architecture used in this book then aims at providing a map or compass and a form of direction for 'good' design of the overall IHIA as well as the phased implementation of its various sub-systems.

1.2 What is an Architecture?

Architecture as system of systems

Architecture is formally defined by IEEE as representing the fundamental organisation of a system embodied in its components; their relationships to each other and to the environment; and the principles guiding its design and evolution. Our conceptualisation of architecture, as the organisation and evolution of a 'system of systems,' requires us to first understand the notion of a system. Very simply, a system represents a set of interacting or interdependent entities forming an integrated whole. A system can be described as set of components that are interconnected through processes of input, throughput, output and feedback. While we discuss the notion of a system in greater detail in Chapter 5; at this point, it will suffice to say, that a system is not something which exists in objective reality, but represents our conceptualisation of a certain phenomenon. For example, we may describe a hospital as a 'hospital system' because it consists of system with the characteristics of:

Input: Unwell patients entering the hospital.

Throughput: The different processes that the patient goes through in the hospital such as registration, billing, laboratory, Outpatient Department (OPD), Inpatient Department (IPD) and other more specialised ones such as blood bank and surgery.

Output: Cured patient leaving the hospital (as one of the outputs).

Feedback: This characteristic includes:

- Direct feedback: Patients' opinion on the effectiveness of the hospital services, which may, then lead to either hiring of more specialist doctors (new inputs) or better management to improve the quality of services (throughput).
- Indirect feedback: The cure rates of the hospital is considered, which, if poorer than other hospitals, would lead to changes, such as, re-defining inputs (strengthening referral process to the hospital) or throughputs (establishing a stricter control on the quality and standards of care).
- While the above depiction of a system may seem rather simplistic and linear, it is done so deliberately for understanding. In practice, each part of the system can be expanded, and social dynamics added, to create a 'rich picture' of the system. Cybernetic systems, based on feedback, are complex and full of unintended consequences shaping system behaviour, and now being studied through theories like Complex Adaptive Systems.

Building on this conceptualisation of a system, an information system represents inter-connected structures and processes, to enable the flows and use of information. In a

broad sense, the term information system is frequently used to refer to the interaction between people, processes, data and technology. The emphasis is not only on the Information and Communication Technologies (ICTs) that an organisation uses, but also, on the way in which people interact with these ICTs and use information to support their ongoing business processes. While an information system is often assumed to be computer-based, it need not always be. Like, a manual flow of information (such as the movement of a paper file in an office) involving an input, throughput and output, can also be conceptualised as an information system. In the health system of most developing countries, major part of the data is still registered and reported using paper, but they nonetheless represent (health) information systems. HIS are quite simply defined as information systems in the health sector.

1.2.1 A Social System Perspective to Health Information Systems

In the seventies and eighties, relatively in the early days of computing in organisations, computer systems were made to promise much by technologists, including the mastering of the human brain and the creation of expert systems for various domains, such as medicine and chess. Despite these promises, experiences of introducing computer-based applications in organisations were fraught with stories of failures. Surprisingly, research into understanding why computer systems did not deliver their potential led to the realisation that it was not the technology that was the primary reason. The research into failures rather revealed the reasons pertaining to the social, institutional and political conditions, such as the absence of top management support, lack of user involvement, and the centralisation of systems. This realisation starting from the eighties, contributed to the evolution of a 'social system' perspective to information systems, which emphasises the social context and its relation with the technical. One such perspective was labelled as the 'web model', (Kling and Scacchi, 1982) which described why and how large information systems tend to be tied to context through a complex web of associations. This was in opposition to a 'discrete-entity' model, representing the commonly held view that information systems are basically socially neutral technical systems.

A social systems perspective, is particularly relevant to understanding HIS in developing countries that are already situated and continue to evolve in a complex web of social, political, institutional and cultural relations, arising out of the involvement of technologies and various actors (such as international donors, ministry officials, vendors, infrastructure providers). HIS, which reflects the health system, is made-up of a number of more or less independent yet inter-linked institutions, living together in harmony and/or in conflict. Health Information Systems are made of a web of people, computers, paper, decision-making, management, procedures and institutions, with all the dynamics of a social system. Regarding HIS as being part of the social context, something much bigger and qualitatively different from the concept of a computer system or a technical system, makes it easier to understand the observed difficulties in changing or developing new systems. Changing and developing new information systems and HIS are in fact about organisational changes including organisational structures, procedures and the way people are working, which are all deeply implicated and intertwined in power relations.

Health Information Systems in developing countries comprise of many thousands of health workers, engaged in routine collecting, registering, collating, and reporting of data in a large number of formats. Data and information are analysed and used in a variety of ways by different people, to make informed decisions and to improve health

services delivery. These represent 'good' ways of applying information, which are being promoted in this book; or to only collect data to legitimate various positions, as some would claim. Since HIS are deeply embedded in the socially shaped work practices of staff in the health system, they can be seen as being barely separable from the social context of which they are a part. Seen from this perspective, HIS can be conceptualised as 'human activity systems', involving multiple activities around it, which constitute important parts of the institutional structures in organisations of the health care sector. Such routine work and repetitive activities across time and space have regularising consequences, including unintended ones for those engaged in the activities.

In this way, routine work related to information handling, represents processes of institutionalisation that are important in forming and maintaining the health institutions. While, there is a dominant tendency of institutions to constrain human action to following existing routines, the potential for change is always latent and existing, and comes to the fore through unintended consequences. As such, the argument goes that 'structure is not to be equated with constraint, but is always both constraining and enabling' (Giddens, 1984). This can be explained better in the following example in Box 1.1.

Box 1.1	Unintended consequences in mobile health project implementation in India

Unintended consequences of a mHealth system – An example from India

HISP India is involved with the implementation of a large-scale Mobile based HIS project, in a northern state of India. As part of this project, 5000 health workers have each been given mobile phones, to facilitate reporting of routine data. During the design of the application, the state first gave a list of about 150 data elements, which they wanted to be reported through SMS. They, however subsequently, expanded this list by 10 more data elements to be reported daily. The primary aim of this daily reporting from the state's perspective was to try and strengthen control of the health workers' activities, to know what they were doing on a daily basis.

However, when the implementation started, the HISP India team observed that the health workers were very resistant to the daily reporting and soon started to voice protests, including not sending both the daily and monthly reports. The matter escalated, with the 'health worker union' taking up the issue and providing written representations to the management. On exploring the reasons for this resistance, it was found that the health workers were providing particular services (relating to the daily data elements) only on a particular day of the week. They felt that this would lead to reports of non-zero numbers only on that day, while daily reports on the other days would most often show a zero. This, they felt the authorities might interpret, as them not doing their work.

Since the effectiveness of the entire mobile initiative was getting jeopardised by this ongoing protest, the state did away with daily reporting and switched to a weekly one. This is now planned to be merged with the monthly report.

This example illustrates how institutions seek to reinforce existing structures, in this case, related to control. However, humans always have the potential and capability to act otherwise, which leads to the creation of 'unintended consequences'. Structures, thus, have the capabilities to both constrain and enable human action.

A social systems approach emphasises the inherent 'messiness' of things, and our state of incomplete knowledge, which makes HIS difficult to control. Technically too, new features tend to get added as extensions or changes of something already there, in the installed base. As the installed base grows, it becomes increasingly difficult to build systems from scratch and to implement substantial changes. If we combine the concept of HIS being part of information structures, with the concept of the very same systems being, in fact, social systems, it becomes clear that the installed base itself, is made up of a web of social systems. Social systems, made-up of social dynamics and politics, as they are, have considerable resistance to change, which explains why it has proven difficult to change HIS in countries; including developing new standard reporting formats, and building new systems from scratch.

1.2.2 Information Usage – For Decision-making or Power-making

Assumptions of rational decision-making seen to lie at the heart of Western progress, are characterised by the following principles:

- Better information helps make better decisions.
- Principles and logics of decision-making can be universally applied.
- Decision-makers are knowledgeable about all possible choices available.
- Choices are made, with the objective of maximising economic gains and efficiencies.

These assumptions of rationality have been shown through history of not being followed in practice and used often as a façade for how decisions are actually made. Going back to the Bay of Pigs, where fear was the key; to the very recent example of the decision of the US and UK to invade Iraq based on the argument of the presence of weapons of mass destruction. History has emphatically shown that information was intentionally misrepresented and manipulated based on political, economic and power-based compulsions to suit the needs of the US and UK governments. In family businesses, run in countries like India, the need to favour family members is often the guiding principle in making decisions rather than those of rationality. Power, fear, risk, incomplete knowledge, social dependencies and unintended consequences are all conditions that take us away from notions of economic rationality and encourage the adoption of a social systems approach, to understand the 'local rationalities' of how information is actually used. While we may make plans to demonstrate rationality, action is always situated and contingent.

Rationality assumptions have also inspired approaches to design and implement information systems, including HIS. Again, like the examples provided above, HIS have usage far beyond the rationale and best practice aims, for example, of improved health service delivery or creating universal coverage. Health Information Systems as social systems, cautions us that information may be used in many ways within a dynamic social context, not necessarily in line with a rational world view. For example, information may be used as part of a power struggle, or it may not be used at all.

Drawing from organisation research, information has been described to be used as 'signal and symbol', for which the following four different explanations have been provided (Feldman and March 1981):

Firstly, organisations provide incentives for gathering extra information, which are buried in conventional rules for organising, and the division of labour between information gathering and information. For example, it is generally agreed that much more data is reported than what would rationally be regarded as needed. In India, this fact was acknowledged in 2008, when the reporting requirements from the sub-district facilities were reduced by nearly 90%. The typical situation is, however, that when new data is needed, new forms are introduced without coordinating with the old, or without abolishing the old forms. As a consequence, multiple partly overlapping forms, providing a lot of irrelevant information are in use at the same time. Difficulties in changing the systems are due to inertias in the social system and the differences in perspective on information between information gatherers, reporters, and information users. Very often, for example, reported information is seen being used by the management, to control the workers; thus, ensuring the job is being done and vice versa (workers see data reports in order to confirm the work they have completed).

Secondly, much of the information in organisations is gathered and treated under a surveillance rather than decision supporting mode. The contemporary ideal of using information for decision-making, as part of rational management requires a proactive attitude to information and the information system. Particular targets need to be identified (for example, increase distribution of condoms to target groups), then specific indicators need to be defined, and routines for getting quality data that are used to calculate these indicators need to be ensured, (rates of condoms distributed by target group, data on target groups, data on condoms distributed to target groups), and finally, action needs to be taken according to how these indicators are developing over time. Contrary to this action-oriented modus, the typical use of information is to only act 'when something is wrong'. Thus, in order to avoid negative attention from superiors, the incentive is to make sure that the reports are not 'rocking the boat'.

Thirdly, much of the information in organisations is subject to strategic misrepresentations, for example, using information only after decisions are taken to legitimise them and selecting the information that support these decisions. A commonly held view is, that people in position often 'lie with statistics' by misinterpretations and by hiding and using information in opportunistic ways. During the controversy, on whether HIV led to AIDS in South Africa, both President Mbeki and those opposing him, used mortality statistics to prove their respective views, but with different interpretations. There are always "good" organisational reasons for "bad" record keeping.

Fourthly, information use symbolises a commitment to rational choice. In the contemporary world, politicians, managers and other decision makers need to show that their decisions are based on information, even though the information is used for other reasons. Information used only for the sake of appearance, represents only a symbol of rational decision-making.

A social systems inspired analysis of HIS, in most developing countries, will reveal that many routines of data collection and reporting that have been established at one point in time, for some purpose, still continue to be reproduced as a legacy, even though their purpose is no longer evident. An interesting anecdote narrated to us from India, was the example of a state still reporting on tobacco dispatches, a system set-up during British colonial rule to facilitate the dispatch of resources. While today, the

purpose was not there and no one used the information, the reporting structure was surprisingly difficult to abolish. A social systems perspective helps to understand that these reporting routines only help to reproduce and confirm existing social structures of the health workers through these reports, indicating they are doing their job and the management acknowledging the same through receiving the reports. The unintended consequences of the reporting system; reproducing the social structure, becomes the main purpose of the system, by dynamically providing the institutional glue. Changing this practice is not a trivial task as it would mean disrupting the existing power relations. An approach to change would need to first and foremost acknowledge this duality of the HIS, as a 'generator' of 'social order' as well as provider of information. We provide another example of unintended consequences of reporting, from South Africa. (See Box 1.2 and Figure 1.1)

Box 1.2 Unintended consequences of change: Example from South Africa

In the Day Hospital in Mitchell's Plain district, South Africa, the manager wanted to replace the data collection forms used in the wards with simple tally sheets (see Figure 1.1). While the old form included patient folder numbers and other scribbles, not used afterwards; the new tally sheet intentionally included only what was regarded useful information. The two forms (see next page) represented roughly the same amount of work carried out in the injection room on a particular day in 1995 and 1996, respectively. The old form had 59 entries, whereas the new form had 66. The health workers initially refused to use the tally sheet, because they felt that an anonymous tick did not reflect the amount of work it represented. The reporting system was, thus, seen as a way to legitimate their work. The old form contained text and figures representing real patients. Furthermore, it looked much 'busier' than the tick sheet, and it gave a certain personal touch in relation to each activity performed. The old form, therefore, represented a 'personalisation' of work, where a particular health worker dealt with particular patients. This was not seen as being represented by a tick in the new 'anonymous' form. In other words, the unintended consequences of the data reporting system, to confirm and re-enforce social contracts and existing power structures, were as important as the intended purposes of the system, to report on activities in the injection room. These dynamics needed to be understood in the social context, as the health system in South Africa was undergoing changes at the time, and many health workers feared losing their jobs. As they felt the new reporting forms did not sufficiently acknowledge the amount of work they did, they saw it as a threat to their job security. This example illustrates the way all reporting forms, data standards and procedures have similar origins of being embedded in daily reporting routines and work practices.

1.2.3 From Information Systems Back to Architecture

Seeing, IHIAs as being made up by systems and subsystems, and applying the social systems perspective, we see IHIAs as a socio-technical web, where social organisational structures, software applications and ICT infrastructures are all inter-related parts of the web. The complexity inherent in a IHIA, is undoubtedly enhanced, as the multiplicity of inter-relations is magnified as compared to an individual system.

The field of architecture is further complicated, as there are as many architecture models, as there are architects. We mainly stick to the term 'enterprise architecture', which is really not a new area in the broader IS domain, as it has been a focus of

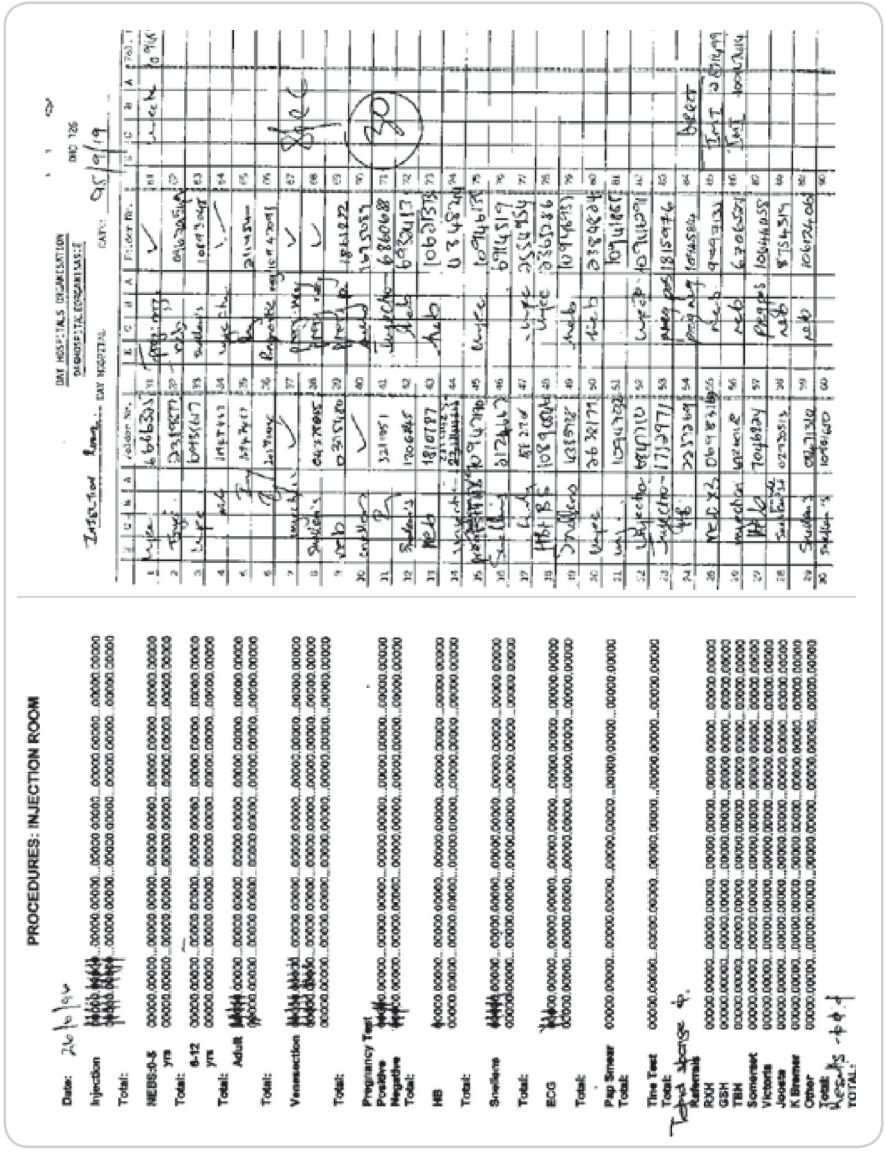


Figure 1.1 Comparison of the new tally sheet in the injection room on the left with the old reporting form on the right. Each sheet reports 66 and 59 'events', respectively. Note the columns marked 'E', 'C', 'B' and 'A' in the old form, for European, Coloured, Black and Asian patients. These columns are not in use anymore, and the space is used for marking the categories of the events reported

attention, both in research and practice, for nearly two decades now. These systems gained attention to help handle the two-fold problem of the increasing complexity of IT systems, and the increasing problem of aligning these systems with the needs of a business or an organisation. The notion of architecture was, thus, extended to include the whole enterprise as a system, which constitutes multiple sub-systems. The term 'enterprise' is derived from that of a business entity and might at first seem

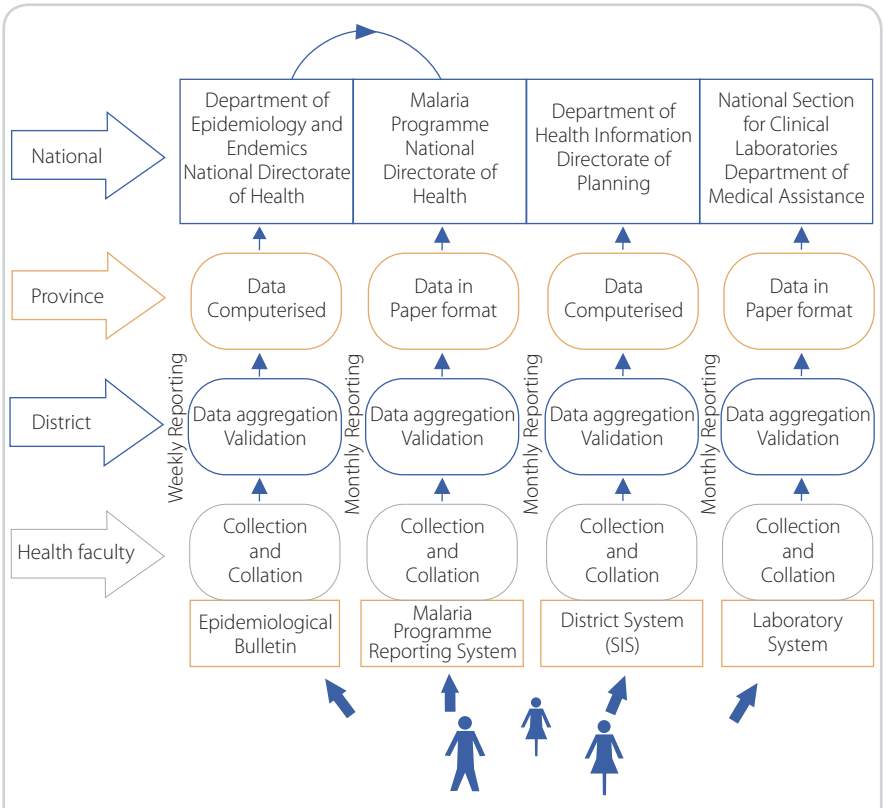
more concrete and grounded in objective realities than the term, system. At the time of business mergers, however, the term 'enterprise' was not necessarily so objective or 'physical' anymore, as the boundaries between a system and enterprise were becoming blurred, with the question of what comprises individual systems or enterprises. As for a system, one needs to define the enterprise, or in fact, a system, one tends to describe as an enterprise. We now discuss some of these issues and challenges, within the context of the health sector.

1.2.4 IHIA – Transition from Standalone HMIS to Integrated Framework of Systems or Architecture

In the context of the health sector, there are multiple possible perspectives on how to 'circumscribe' the enterprise in question, when we discuss either a 'health system' more generally, or in a particular region/country, like the 'health system of India'. A hospital may be regarded as an enterprise or a business area, the system of district hospitals in a state, likewise, and the public health services in a state, may be regarded as an enterprise. In fact, each business area, or health services area, within the health system may be de-limited and defined as an enterprise, within an 'enterprise architecture' framework. The overall health system 'enterprise architecture', is therefore seen consisting of a number of enterprise architectures, each of them dealing with a particular business area such as drugs, logistics, management, laboratories, HIV/AIDS anti-retroviral treatment, and hospitals. Likewise, enterprises can be defined in relation to the multitude of organisational units that make-up the health system (such as dispensaries, sub centres, primary health care centres and district hospitals). Other forms of enterprise or systems can be based on service functions and logistics (laboratories, drug supply, or ambulance services), or across various administrative and managerial levels (health facility, sub-district, district, or state). Regarded as an enterprise, the health system is made up of multiple enterprises, and even enterprises of enterprises, or system of systems.

If we include everything in an enterprise-based analytical framework, how is it possible then to handle the complexity? Firstly, identifying and defining the perspective on the enterprise, the business or functional area, on which to focus. Second, by focusing on the information provided, and its use to support management within the health system. This way, we can obscure irrelevant areas, such as the various production systems. However, achieving such clarity in practice is both technically and institutionally complex, for historical reasons. A description of the multiplicity of systems relating to malaria control in Mozambique is depicted in Figure 1.2.

Traditionally, each part, sector or programme within the health sector has been developing their own information systems, tailored to serve their specific needs. The Figure 1.2 shows, how even within the same Malaria programme, there are four independent channels or systems of reporting; relating to notifiable diseases, laboratories, national HMIS and the malaria programme's own systems. These systems often are paper-based at the levels of data collection and reporting, and computerised at higher levels of the state/province or national levels. As there has been little or no coordination of these reporting systems and since most data originates from the local health services; health workers become overburdened by a plethora of reporting formats to fill in and report on every month. There are overlaps and inconsistencies between these reporting formats and the way data elements are named and defined,



Source: Chilundo B, Aansted M. Negotiating multiple rationalities in the process of integrating the information systems of disease specific programmes, *EJISDC* 2004;20(2):1-28.

Figure 1.2 Multiple reporting systems for Malaria in Mozambique

resulting in the reporting of the same data several times in different formats, and sometimes in different ways under multiple names. Quality of data and efficiency of the systems are adversely affected, leading to a vicious cycle of data not been used, because of its poor quality. And the less it is used, the more the quality suffers.

1.2.5 Architecture to Support Decision-making and Management

Fragmentation and lack of coordination of HIS have been identified by various researchers and also managers, as the major problem shaping their use and utility. Each health service, health programme, project or initiative tends to organise their own reporting systems, often oblivious of what already exists, whether the data they require is already being collected under any other programme or a different name? Given that the main problems are fragmentation and lack of integration, how can then, a separate but still fragmented design and architectures for each of the sub-systems improve the situation? The simple answer is that separate architectures for each sub-system will not necessarily lead to integration between the sub-systems. A general problem with information system design methodologies, which are based on mapping current work-flows and information handling practices, which is to some

extent needed, is that they tend to focus on and conserve current practices and therefore do not necessarily enable innovation, that is support new ways to do the work, which new technologies necessarily enable. Therefore, what is needed is, to first, take the perspective of the whole and overall health system as a point of departure, and second, replicate this perspective at each level of the health services; from the national and state levels to the levels of district, sub-district, and health facilities. What is common for each administrative level is the need for information to inform decision-making and to support management. Key indicators and information more generally related to public health and health management at the particular level in question, is in contrast to clinical information related to individual patients. This information by definition needs to encompass at least the scope of management and decision-making, meaning that key information from all sub-areas are needed. While the national and state levels will mostly deal with policy-making and evaluation, the district is responsible for the operational management of health services delivery, including vertical health programmes in the district. This requires more of monitoring than evaluation related information. For example, while at the national level, one needs to know the overall state of immunisation coverage, to be able to evaluate the effectiveness of the immunisation programme; at the district level, one needs more detailed monitoring information such as information related to drop outs and vaccine supply and so on. Further, these services are implemented and delivered by various health facilities in the district. Translating this into the language of 'enterprise architecture', we may say that each business area identified for the architecture is that of management, co-ordination and decision-making. An IHIA should then be designed to meet these cross-cutting information needs.

The rapid developments of Internet and mobile infrastructure have led to new computerised and mobile-based information systems that have been planned for and implemented. The worry is, of course, that the current process of computerisation only replicates the former situation of fragmentation and poor co-ordination, though not casting it in stone, but wiring it up in the computer infrastructure. To guard against this, we propose an approach to design, based on information use. At all levels of management, for supporting processes of co-ordination and decision-making, key information is needed. This support could be leveraged from various data sources, including routine data collection, and other relevant areas; for example, from the census data and population based surveys of health status and utilisation of services. The approach to focus on information use, shares the generic characteristic of information for decision support across all administrative levels based on available and relevant data sources. This provides for the foundation, and a replication of design processes, both vertically (across administrative levels) and horizontally (across programmes at different levels) to establish the systems of systems – or in our words the 'IHIAs'.

In Table 1.1, we present as an example from India, the various data sources that could help in providing inputs to a IHIA.

1.3 Constructing IHIAs – The Data Warehouse Approach

Data Warehouse – Defining the Term

We have discussed how the architecture approach to design can help in developing an integrated and efficient roadmap for the way forward. In this section, to operationalise

Table 1.1 Various data sources to a IHIAs in India

Sl. No.	*Source Name*	*Data*	*Examples of Use – information*	*URL*
1.	Census of India (conducted every ten years)	Demographic information	• Trends in demographic, population density. • Social status and living conditions of different population groups.	http://www.censusindia.gov.in/
2.	Sample registration system (conducted every six months)	Vital statistics	• Birth rate and death rate. • Expected trends in population growth. • Fertility and mortality indicators.	http://www.censusindia.gov.in/
3.	National family health survey (multi-round survey, conducted every five years, latest 2005-06)	Vital statistics and utilisation rates, social health statistics	• Fertility rates. • Infant and child mortality status. • Family planning practices. • Status of nutrition and anaemia in women and children. • Reproductive and child health practices. • Health service utilisation rates and quality of health.	http://www.nfhsindia.org/
4.	District level household survey (2 surveys conducted yet, latest by 2002-04)	District level demographic and vital statistics, mortality and morbidity statistics	• Coverage of ANC and immunisation. • Extent of safe deliveries and contraceptive prevalence. • Awareness about RTI/STI/HIV/AIDS. • Utilisation of government health services and users' satisfaction.	http://mohfw.nic.in/dlhs_2002.htm
5.	Central Bureau of Health Intelligence (complies all information annually)	Health profile of India	• Socio-economic information. • Disease wise morbidity and mortality. • Expenditure and financing in health. • Health infrastructure information.	http://www.cbhidghs.nic.in/
6.	Bulletin on rural health statistics in India (updates information based on quarterly reports from all states)	Rural demographic profile	• Demographic trends in villages. • Death and birth rates.	http://mohfw.nic.in
7.	National Rural Health Mission	Rural health profile	• Trends in rural health, mortality, morbidity, service utilisation.	http://mohfw.nic in/nrhm.htm
8.	Other facility surveys at state or districts (for example, DRDA) or sub-districts (for example, Panchayat) levels	Demographic profile	Various health related information	Can be obtained from local governments office

this approach to design, we introduce the concept of a 'data warehouse'. In the information systems domain, this concept is not novel and emerged during the eighties and nineties from the earlier work on 'systems for decision-making', and even earlier in the seventies from the domain of expert systems. Interestingly, the term HMIS emerged in the late eighties and early nineties as a specific health-variety type of a 'system for decision-making'. This concept came in use when there were intensive efforts, more generally in the business world of the West, to introduce systems to support management's decision-making in organisations. Addressing private sector companies, the selling point was to provide decision support to the management with key data 'at the touch of a button' from across relevant data sources, such as currency rates, updated sales statistics from the company, stock market, oil prices, and so on. In health, a similar approach; for example, in a hospital would have been to provide key indicators on patient flows, by wards and diagnosis, finances, resource utilisation (staff, drugs, equipment), which is what we will advocate in this book. At that time, however, the typical clinical perspective dominated, and efforts were more directed towards supporting clinicians' decision-making in line with the diagnostic expert system approach. Within the public health systems in decision-making, the concept was still rather alien.

A data warehouse, which on the data input side, is loosely defined as a database which contains and manages data of different types from varying sources; and which on the data output side, is designed to process and present the data and provide a multiplicity of users with data, which is tailored for their specific needs. Simply put, it represents a 'warehouse of data' (database), compiled from different sources, with the tools for analysis and presentation, to support specific user needs. A data warehouse for health management will more generally contain, aggregate data and indicators from various production or transaction systems, for medical records, human resources, logistics, finances and laboratory. While the HMIS, as a concept, could be understood as a standalone system, the data warehouse typically represents a core database component of a framework of integrated systems. The sources of data for both, the data warehouse as well as the traditional HMIS, could be paper based. But where the HMIS would typically be represented by their own specific paper forms, the data warehouse would include data captured from a range of paper forms, also belonging to other health programmes, and thus, could be regarded as a shared resource to programmes and units contributing the information.

As an example of a data warehouse, the DHIS2, is currently being used for HMIS data in various states in India, and is slowly being expanded to include other data sources and integrate with other health programmes. The important difference from the concept of HMIS is that the data warehouse is more explicitly understood as being linked to different data sources, meaning that, in our context, the data warehouse is capable of importing aggregate data generated from patient records in hospitals or data from a human resource management system. The input to the DHIS2 can be captured directly or imported using different technologies such as from a mobile phone, a file to be imported from another system, or data captured directly from paper based data collection tools.

We may say that the development of these concepts had come full circle, when the HMN in Geneva, made from 2005, the concept of data warehouse; the centre piece in their technical framework. A simultaneous trend being, the increasing discredits of the term HMIS, due to its inherent problems of poor data quality and evidently poor use of

information. HMN chose to use the term 'data repository' instead of 'data warehouse', in order not to intimidate health authorities who may not understand. Despite their focus on analysis, presentation and use of data, which is evident from the HMN framework and concept, they use the term 'data warehouse' or 'data repository', instead of the more modern term 'business intelligence' (BI). Why? Probably for the same reason we do here, to emphasise the dual focus, integrating different data sources (core of the data warehouse concept) as well as, optimal analysis and use of data (where integrated access to data is a current key problem). In chapter 6, we apply the BI perspective and further develop the output side of the data warehouse further.

The District Health Information System – An Example of a Data Warehouse

In this book, we use the development and application of the DHIS application in India and in many other countries, particularly in South Africa, to describe and discuss the gradual development of an IHIA; from a standalone HMIS to an integrated framework of interoperable information systems. The DHIS represents an instantiation of a data warehouse and a framework within which an IHIA can evolve. We first provide a brief description of the DHIS. A more detailed description is provided in Chapter 6.

What is the DHIS?

The DHIS is a software application for collection, validation, analysis, and presentation of aggregate statistical data; tailored (but not limited) to integrated health information management activities. It is designed to serve as a district-based country data warehouse, to address both local and national needs. DHIS is a generic tool rather than a pre-configured database application, with an open metadata model and a flexible user interface, which allows the user to design the contents of a specific information system without the need for programming. DHIS development has evolved over two versions. The first – DHIS1 – was developed in 1997 by HISP in South Africa, on MS Access, a platform selected because it was at that time the de facto standard in South Africa. The second – DHIS2 – is a modular web-based software package, built with free and open source Java frameworks, developed since 2004 and coordinated by the University of Oslo. The DHIS2 builds on the version 1 data model, and has over time created various enhancements towards making it a full-fledged data warehouse for statistical, aggregate, and anonymous data. The first prototype of DHIS2 was implemented in Kerala in 2006, and has been through numerous cycles of further development, since. It is now implemented in many states in India and various other countries in Asia and Africa.

On the data input side: DHIS can manage and integrate multiple datasets from different sources and types of data, including related to different health programmes and health services, population census, financial data, health and demographic survey data, human resources data, drug and logistics data, and so on. Data can be extracted and imported from varying electronic data sources (for example, a medical records database) directly to the DHIS by mobile telephones, captured from paper reports using online or offline web and the Internet – or using standalone desktop computer and e-mail attachments or memory sticks for reporting.

On the data output side: DHIS can combine, analyse and correlate data across datasets – and institutional boundaries; calculate indicators and present them in time series and/or across units, by comparing performance of facilities; evaluate quality

and significance of data using 'expert rules'. DHIS provides analysed data to the users according to their needs for management, decision-making, monitoring and evaluation, and health services provision. A variety of tools are used for dissemination and presentation of data; maps and Geographical Information Systems (GIS), charts, tables and pivot tables, using on-line (web) or off-line (desktop-warehouse) modes. Given the limitation in Internet connectivity in developing countries, the DHIS2 includes an automatically generating tool for downloading off-line data repository application using Excel pivot tables as a means for presentation.

On the throughput side: In the currently popular language of BI, the data input part is typically referred to as data warehouse, while the data output part is referred to as BI, because the 'metadata' design of this part of the DHIS and similar applications, is based on the elicitation and implementation of the 'business' knowledge and logic used for running and managing a business, or a health service, in our case, hence 'intelligence'. The definition of indicators, such as, immunisation coverage or infant mortality rate, the knowledge of how to validate data in relation to these indicators, and how to interpret and apply them, represent typical examples of this BI inscribed in and supported by DHIS.

We are endorsing the focus on information analysis and use, inherent in the term BI, but we are using the term 'data warehouse' to cover the input components of the data warehouse because we regard the process, or the verb 'data warehousing'; designing and developing the integrated HIS, as being integral to the building of the IHIA. The relevant institutions, organisations, departments and units are identified, and their information needs, by way of datasets and indicators, are defined. Typically, one starts with a sub-set of both participating departments and their datasets, and expands gradually, as institutions and users learn what works and what does not. The data flow, which is the data flowing back and forth from the various departments that are being integrated and gradually expanded by the DHIS data warehouse, are, in fact, instantiations of the enterprise architecture. Conversely, by depicting the data flows in the organisation or health system, the underlying structures and architecture, or lack, thereof, are being drawn up.

We illustrate the close relationship between the development of the enterprise architecture and the DHIS as a data warehouse, with an example from South Africa. In South Africa during apartheid, the health services as well as their HIS were extremely fragmented and there were no existing local democratic government structures. The new ANC government started out in 1994 to 'make right the wrongs of apartheid'. Establishing a system of strong decentralised health districts was regarded as a key intervention in order to both integrate health services and to empower the communities. Integration of information and information systems were regarded important in this process. In Figure 1.3a, which is from the ANC Strategic Plan for HIS, 1994, the data flows at the left depicts the 'past', lack of local control and access to their own information, and one sees that all data flows are going out of the districts with no feedback. We would not call it an 'architecture', but, in fact, it is the conscious architecture of apartheid. The disenfranchised community was purposively kept ignorant of local integrated managerial structures, including access to their own information. It is therefore 'architecture' by design, the enterprise architecture of apartheid. The vision of the decentralised democratic structures of the new South Africa, the 'future', or in our language, the enterprise architecture of the new district structure (Figure 1.3b). Here, all data flows are passing through the district information office and data warehouse, for local analysis and use.

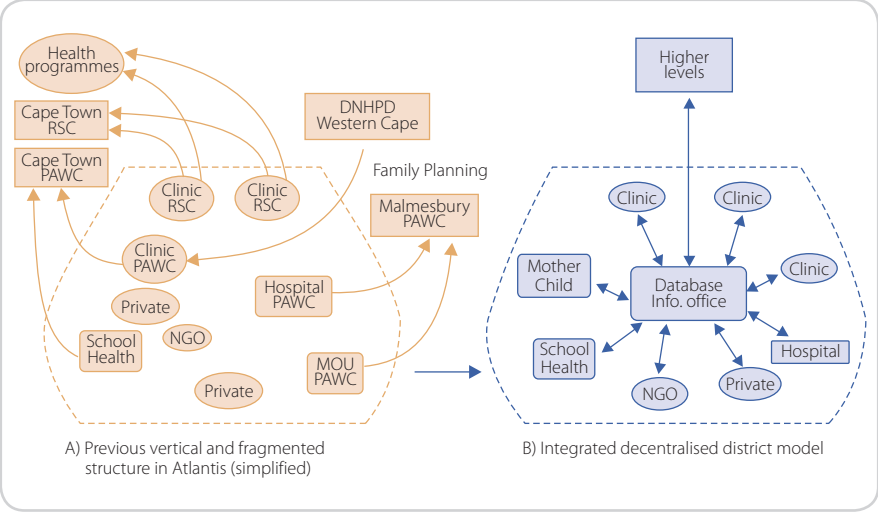


Figure 1.3 Information flows during apartheid and as they were envisioned in post-apartheid South Africa by 1994

However, only in 1997, when the DHIS was implemented together with a new unified data standard, was this vision of an enterprise architecture instantiated, or made real. Before its actual implementation, the process dragged on for years without much result. After having implemented the first version of the data standard and the DHIS, that is the architecture; however, the actors learnt that it was both useful and achievable. The architecture started to grow; new institutions joined in, datasets were added and extended – a process that continues to this day, 2012. Following the first prototype implementation of the DHIS in 1997, the vision of the Figure 1.3 was further developed, depicted in Figure 1.4. Here the design of what we call today, enterprise architecture for management and health services delivery at the district level, was drawn up, gradually implemented and enhanced through cycles of new versions of the DHIS, representing cycles of instantiations of the architecture.

This vision which South Africa articulated in 1994-97, has largely been achieved today and is what many countries are now undertaking, fifteen years on, with varying degrees of success. The important characteristic of this vision is its focus on the district level, and that all data passing through it enables integration with positive implications on data quality and information utilisation. Similar processes of integration need to be replicated at all levels of the health administration hierarchy. This is the crux of the design challenge of a IHIA. The lesson we draw is that, enterprise architecture, given the complex organisational and social structures and the degree of uncertainty, can only become real through its practical instantiations, and from there, it grows through a cyclic process of learning. That is, the continuous process of developing the enterprise architecture needs to be triggered, through concrete instantiations on the ground. Top-down blueprints of architecture with limited practical grounding, attempting 'big bang implementations', has little to no chance of succeeding.

After having discussed the key principles of a data warehouse, and illustrated, through the DHIS and its application, we discuss the HMN perspective on the data warehouse.

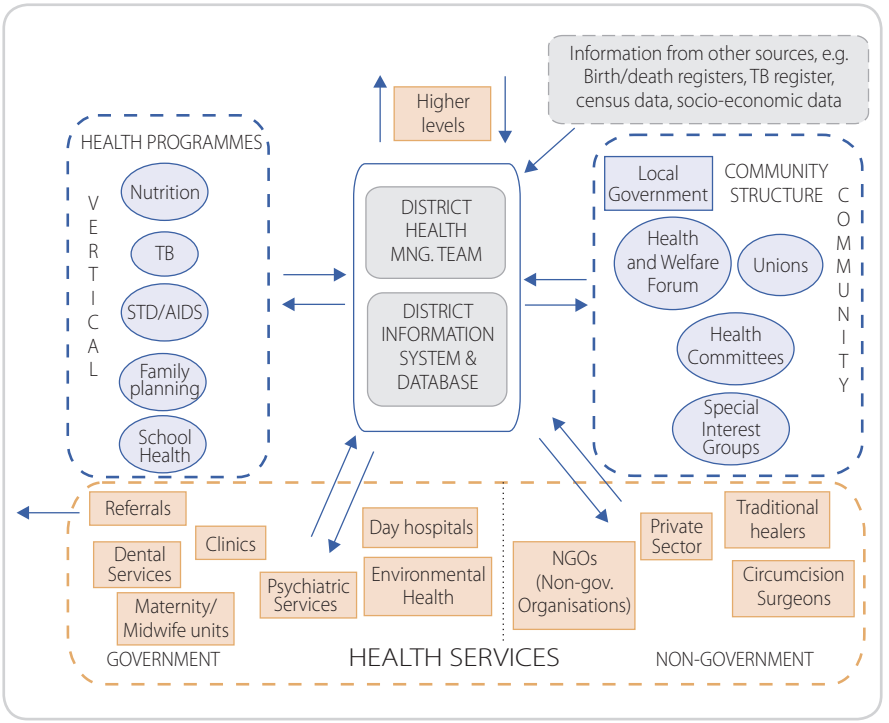


Figure 1.4 The data warehouse architecture. Vision and design of integrated health information management at district level, from South Africa, 1995

1.3.1 The HMN Concept of National Data Warehouse

The launch of the HMN in 2005, as an agency under the WHO, provided global leadership as well as a consensus-based strategy for the development of a national HIS. Consensus was that, countries should strive for interoperable subsystems within a national framework, where aggregated data from the sub-systems are integrated and made available in a national data repository. HMN initially used the term 'data warehouse', but subsequently changed it to 'data repository', in order not to intimidate users, who were oblivious to the fact that a data warehouse could easily be described as a database. Interoperability between systems is seen as a key feature of a data warehouse, as it helps to provide a pivotal component which enables the integration of data between the different subsystems. The linkage between a human resource management system and a medical records system, for example, is carried out indirectly when both systems export their data to the data warehouse, which will combine the data and calculate the rate of patients treated, per category of staff in hospitals. In Figure 1.5, a schematic description of the HMN data warehouse approach is provided.

The above framework leads us to identifying various data sources, summarised in Table 1.2. The data sources are divided into health services based (for example, medical records) and population-based (for example, census data).

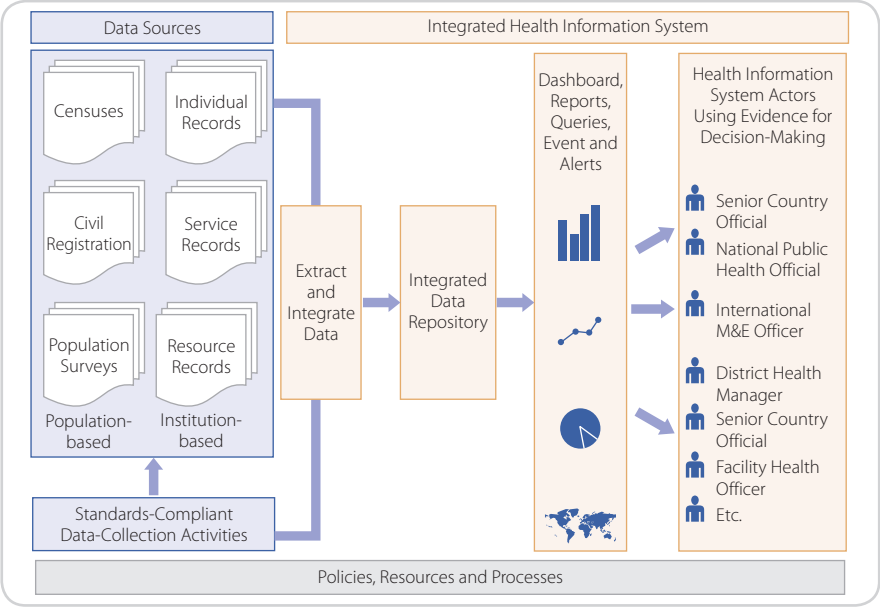


Figure 1.5 The HMN data warehouse concept

Table 1.2 The six data sources as defined by HMN

Principal data source categories for the National Data Warehouse	
Health services based data sources	
Individual records	All name based client and patient records, from register books for out-patients, or ANC (Antenatal Care) clients, to the registration and tracking of all pregnant women and Medical Record Systems in hospitals. The data warehouse imports and aggregates data from these primary data sources.
Resource records	Taken to mean that all other sources of health services data and records, ensures quality, availability and logistics of all inputs, in areas of human resources, drugs, health facilities and their services, laboratories, financial systems – budget /expenditures.
Service records	Includes data and records from across sectors like environmental health, insurance, police, and occupational health.
Population-based data sources	
Census data	Population census is the primary source for the size of population, geographical distribution, target population for interventions, plus data on social and economic conditions.
Civil registration	Compulsory registration on birth, death and marriages provides both legal documents and important data sources in many countries. In many developing countries, such registration systems are relatively poor.
Population surveys	In developing countries, where civil registration is poor, health and demographic surveys are the most important source of population health status. For example, for HIV status, child and maternal mortality.

1.4 Our Point of Departure – Generalised and Decentralised HIAs

The HMN approach, to a national data warehouse or a 'data repository', as they term it, is all encompassing, since it does include all the principally relevant data sources in one data warehouse; thus, representing an ideal situation, where critical data can be technically and institutionally managed, in one national database. The point of departure taken in this book is that, within a national health system, there may be multiple data warehouses where there is more than one type or collection of datasets in each of the warehouses. A national data warehouse for aggregate hospital data, for example, may keep detailed data by sub-hospital level (e.g. wards) and/or by diagnosed diseases using ICD10 while only exporting summary data by hospital to the overall national data warehouse. We agree, however, in the HMN approach of a main national data warehouse framework, although we suggest changing its centralist emphasis, by labelling it a district-based data warehouse approach. In fact, we would argue that each administrative level of the health sector should have a data warehouse for their key information. The data managed by the national level data warehouse, will be a sub-set of this national framework of 'district-based data warehouses'. This design view is not changed by the fact that countries have a central web-based data warehouse. The lower administrative levels such as at the district would still have their 'views', as their data with lower levels requires more and granular data, than the higher levels. The district data warehouse, therefore, contains more detailed data than the national level 'view'.

It is our perspective that each administrative level will need a database, containing its key data, required for management. For example, in a hospital, the data warehouse for management will include aggregate data and indicator data, on patient flow, outcome by wards, services, diseases and patient groups; financial data, data on resources, laboratories and so on. This provides management indicators, for example, bed occupancy and average length of stay. We label such databases, focusing on management data, as 'data warehouses', even at local levels, such as in a hospital or district. It is therefore vital to release the 'data warehouse' concept, and its exclusive, all-encompassing, ideal features to turn it into a practical tool, for the stepwise development, targeting first the low-hanging fruit, and then gradually 'climbing higher up the tree'. This approach resonates with the decentralised 'district based' systems, advocated by WHO, since the Alma Ata declaration, which represented a 'bottom-up' evolutionary alternative to the 'top-down' national approach.

Incremental Development of the Enterprise Architecture

In this book, we build upon the HMN framework, which helps to provide an overall architecture, context and with it tangible goals for national HIS development; and to design an architecture, which can include a multiplicity of data warehouses, with processes of interoperability in-built to facilitate the flow of data. This book, however, advocates a practical and more incremental approach to its design, development and implementation which is contrary to a comprehensive and a more all-encompassing one. For example, the first version of the data warehouse enterprise architecture in a country, like India, would typically start out from the existing systems of routine data, the HMIS would then gradually expand, by adding more data and datasets, like we described in the case of DHIS, in South Africa. First, for example, census data is added, then, data on resources in the health facilities, infrastructure, human resources, surveys and so forth, in an evolutionary approach. This step-by-step approach to building

the data warehouse architecture implies that the 'final' architecture is not there at the outset, not even as a finished design on paper; the architecture will always be in the making. In fact, the verb architecting or 'data warehousing' may be more useful to capture the essence of the architecture or the data warehouse as being always in the making.

Over time, users and institutions will learn more about the ICT based systems and their potentials and challenges, leading to changes in requirements and expectations. At the same time, it is important to keep in mind that, health systems, programmes, priorities, technology and infrastructures are ever-evolving, and precipitates ongoing transitions in requirements and potentials. Thus, in this ever-changing context, future requirements and predictions for systems development will always be characterised by a certain level of uncertainty, making incremental learning approaches necessary. That is, to start the systems development with what is achievable, learn from it and gradually expand, as users are maturing and infrastructure, technology and technical solutions are improving. 'Agile systems development', is a modern term for such approaches that are gaining popularity. Prototyping in system development has been used for decades, and is among the better used agile approaches. The incremental and ongoing approach to DHIS development represents a perspective, labelled arguably as agile architecting, with its emphasis on the need for flexibility, improvisation, responsiveness, and user participation in the evolutionary making of the architecture.

Summary

Key concepts that can be taken from this chapter are summarised below:

1. Fragmentation and lack of co-ordination of HIS, is generally agreed to be the major problem, facing the similarly agreed objective of providing quality information to improve decision-making in the health sector. Furthermore, thanks to the efforts from HMN during 2005-2010, it is now 'globally' agreed that actors in health in a country or in a state, need to work together within an integrated framework for information management and use.
2. The strategy to approach the problem of institutional and information-wise fragmentation is within the integrated and co-operative design of HIS, which we label as 'enterprise architecture or IHIA,' which could in a simple way be defined as an approach to 'good design'.
3. The central approach in designing such architecture is to focus on information use for management, which then becomes the common theme across the various enterprises and systems, that comprise the health system.
4. We have, in line with HMN, advocated the need for making the data warehouse, a central component of the architecture. Furthermore, we have also advocated the need for an evolutionary, agile and participatory approach to the development of an architecture, which should not be regarded as a fixed or final product, as it will always be in the making and to be further improved. As users and institutions learn, health challenges changes, new requirements emerge and technologies develop, 'good design' or better architecture will always be something envisioned for 'tomorrow'.

5. Overall, we advocate a social systems perspective, that is the need to regard information systems – and architectures – as being a product of social dynamics, work processes and procedures as well as technical components. Seen from this perspective of a 'web', it becomes natural to understand that social inertia makes changes slower to implement, than if they had been mere technical systems.
6. The DHIS is described as an example of an instantiation of the architecture, which helps provide a framework for an architecture to evolve.

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