Architectural Frameworks for Developing National Health Information Systems in Low and Middle Income Countries

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***Abstract*—Consolidating currently fragmented health information systems in low and middle-income countries (LMIC) into a coherent national information system will increase operational efficiencies, improve decision-making and will lead to better health outcomes. However, engineering an enterprise information system of the scale and complexity of a national health information system (NHIS) pose unique and complex challenges in LMICs. In this paper, we review current approaches to NHIS development and discuss challenges faced by LMICs to develop their NHIS. Based on current LMIC systems we identify three stages of system evolution and propose that LMICs should follow an evolutionary, middle-out approach to NHIS development supported by appropriate architectural frameworks.**

Keywords—national health information systems, low and medium income countries, architectural frameworks, architectural approaches

I. INTRODUCTION

Information is identified, by the World Health Organization (WHO), as one of the six building blocks of a health system [1]. However, low and middle-income countries (LMICs) have generally been found to have inadequate health information systems (HIS) [2, 3]. These countries are characterized by siloed and *ad hoc* development of HIS, resulting in fragmented systems with limited interoperability and software reuse, and a plethora of small pilots that do not scale. Health information systems need to become stronger if gains in health are to be achieved and sustained [4].

A country-wide national health information system (NHIS) can be viewed as a system of heterogeneous (sub) systems, that encompasses different health information systems and applications, that span across public and private health care, different geographical levels (district, sub-national and country), and different health delivery services (primary, district, national).

A country's NHIS must provide a basic technological platform to manage and enable sharing of data, information, and knowledge across domains [4, 5]. The connectivity and knowledge management capabilities provided by an NHIS can improve the quality of health data, information, and knowledge used to support decisions at all levels and in all domains of the health sector, i.e. personal health, health care delivery, public health, and research [4, 5].

Considering the heterogeneity, scale and complexity of the NHIS it can be classified as an enterprise information system and can benefit from the work done in the design of frameworks and architectures in this area [4, 6]. However NHIS in LMICs have several characteristics that set them apart from traditional enterprise information systems. Based on our experiences working in LMICs [7-10] we aim in this paper to identify these characteristics and elaborate why novel approaches to their engineering are required. In Section II of this paper, we review approaches to NHIS engineering in various settings. In section III we propose different stages of NHIS maturity in LMICs. In section IV we suggest key considerations for the development of NHIS in LMICs and a preliminary analysis of the extent to which existing frameworks, including health specific frameworks and systems deal with this. In section V we present a recommended approach for developing NHIS in LMICs.

II. DEVELOPING NATIONAL HEALTH INFORMATION SYSTEMS

Some high-income countries have made significant strides towards building NHIS while NHIS development in LMIC has lagged behind. In this section we give an overview of NHIS initiatives in HICs and LMICs and an overview of health-specific enterprise architecture frameworks.

A. National Health Information Systems in High Income Countries

The architecture and approach to engineering NHIS is influenced largely by the structure and nature of the country's health system. There are a range of systems with unified centralized health systems like the National Health System in the United Kingdom (UK) on the one hand and decentralized and fragmented systems like that of the United States on the other [11]. Coiera [11] differentiates three approaches for NHIS development, i.e. top-down, bottom-up and middle-out.

In a *top down* approach, governance, management and implementation of the systems are centralised. Top-down approaches such as the NHS National Programme for IT (NpfIT) in the UK aim to create a single shared electronic record stored centrally, through which all healthcare providers can add or read information from others. The problems associated with these centralised, single specification approaches may include a "rip and replace" approach where systems that do not comply with national standards are replaced by compliant ones. The new compliant systems may often not fit local needs as well as the systems they replace. Furthermore, such systems are relatively inflexible in dealing with changing local requirements. The UK has since decided on a more locally-led modular approach allowing NHS organisations to introduce smaller, more manageable change, in line with their business requirements and capacity, whilst continuing with national applications already procured [12]. The UK experience shows that a political champion can usefully start the architecting process, but localised decision-making is equally important [12] and setting realistic timescales, during which conflicting interests are contested and challenges are negotiated are crucial [13].

In contrast, a *bottom-up* approach, as typified by the USA's approach [55], makes use of regional health information exchanges (HIE) to interconnect systems at regional level with the expectation that these regional systems will eventually aggregate to national level. This "embrace and extend" approach preserves existing systems that meet local needs and avoids the costs associated with procuring new systems and retraining staff and is more resilient to large changes, since new technologies or system designs can be adopted locally as long as they connect to the HIE. This approach does not create a single health record but allows virtual views of records, as abstracted or aggregated from regional systems. However, the bottom up approach is voluntary and can be unpredictable, without some element of central coordination. Also, interoperability between regional systems may be unnecessarily complex and it may be difficult to align these systems with national priorities and goals [11].

A third approach, the middle-out approach creates a common set of technical goals and underpinning standards to connect health providers, the IT industry and government. Recognizing the huge complexity and heterogeneity of their HIS, HICs such as Canada and Australia have adopted more of a middle-out approach by developing health architecture frameworks that focus on standards [14] and guidelines for improving the interoperability of their HIS [15-17].

In Australia, the National eHealth Transition Authority (NEHTA) was established to lead the progression of eHealth at a national level, addressing the challenges of a federated political and legal system [14, 17]. To address the varying ICT capability and maturity across the Australian health sector, the health enterprise architecture (HEA) supports both the co-existence of heterogeneous solutions, as well as different transition strategies for the different segments [18]. To balance the requirements for a long-term nationally sustainable architecture approach with the need for pragmatic individual solutions, the eHealth strategy allows various architectures to develop, within an interoperability framework (based on ISO/IEC RM-ODP [19]) and an architecture framework supported by national and international standards [14, 15]. The frameworks promote the development of a service-oriented architecture (SOA) and the use of principles included in the Open Group Architectural Framework (TOGAF) [17, 20].

Canada Health Infoway, a public not-for-profit organisation funded by the federal government, has been mandated to foster and accelerate the deployment of an interoperable electronic health record in Canada [16]. The architecture strategy is focused on the implementation of an electronic health record (EHR) infrastructure and an HIE, based on SOA principles and national standards [16]. In contrast to the Australian approach, Canada's approach is focused on national rather than regional interoperability.

In 2004 the EU agreed on an eHealth Action Plan to strengthen HIS across the European community, with the following objectives: addressing common challenges such as interoperability of health information systems electronic health records, patient identifiers and mobility of patients and health professionals; building pilots for accelerating implementation of eHealth information on, for example, health education and disease prevention as well as promoting the use of electronic health cards; working together and monitoring, benchmarking and disseminating best practices [21]. The EU's HIS is now evolving through the following action plan: A set of targets has been defined for the region; the EU Countries independently aim to evolve to these targets; progress towards achieving these targets is reviewed at defined intervals. A less formal approach has been adopted for a more federated 'organisation' where policy development is more complex. Similar to the Australian approach the EU approach supports different transition strategies at the country-level [22].

B. National Health Information Systems in Low and Middle-Income Countries

A variety of public health information systems exist in LMICs, e.g. disease surveillance systems [23], vital registration systems [2] and management information systems [24]. These systems support the management of health systems and services [25] with the primary aim of contributing to high-quality, efficient patient and population care [26]. In many cases, the systems deliver de-identified, aggregated information supporting policy-making and, in others, individual person-level data is collected. The challenge is to integrate these systems into an NHIS.

In a recent survey, many LMICs judged their HIS as inadequate or non-existent [25]. They indicated that they do not have the (financing, human, and infrastructure) resources and policies in place to implement and/or manage a HIS; and stated that they need more help with the drafting of a strategic HIS plan [25]. HIS in LMICs are characterized by significant fragmentation and duplication [27, 28], and a high dependency on external technical support [29]. The lack of systems integration inhibits operational efficiency as well as analysis

and decision-making. This is especially frustrating at the local level where data collection is still a significant burden [3, 30].

The significant progress made by HICs in developing their NHIS is partly due to huge financial investments [31]. Countries like Canada, Australia, the UK and USA have spent between 2.6 and 38 billion USD on their individual NHIS programs [32-34]. In contrast, it is estimated that between 1.25 and 2 billion USD (almost 50% of which is sponsored by global donors) is spent each year on different aspects of health information systems in LMICs [2]. Most of the investment is spent in a fragmented, duplicative and uncoordinated manner [2], mostly due to the lack of HIS policy [25], planning [35], local ownership and leadership [36], urgency and political commitment to address the problems with HIS [37]. This level of funding may be difficult to sustain in a weak economy [38], so countries may increasingly have to make future investments from constrained national budgets, competing with other priorities, including poverty reduction [39] and supporting health service delivery [1].

However, there are other challenges equally as inhibiting as a lack of funding. Specialized technical ICT and managerial skills [3, 36], adequately skilled healthcare workforce [31] and computer literacy is limited and made worse by a brain drain especially in rural areas [40]. Keeping qualified HIS specialists with the low salary schemes at the Ministry of Public Health remains a challenge [25].

The limited health information systems infrastructure is unevenly distributed between rural and urban areas [4] [41], with a large proportion of the LMIC population living in remote areas that are disconnected [31]. This poses a particular challenge when developing HIS for uniform implementation in a country [10] and is one of the reasons that the many 'pilot projects' [42] do not provide sustainable large-scale benefits [29].

Many LMICs also do not have a systematic approach to high-level information system design at national level. System components are implemented often on an ad hoc, piecemeal basis, with little regard to what has been done before [43], by foreign software developers and designed to solve specific problems [4]. Varying levels of maturity [8], constantly changing health systems, non-standard data formats, applications and processes [44] make interoperability and data integration difficult to achieve [41].

Despite these limitations, many innovative solutions are being developed in and for LMICs. Success stories include the District Health Information System (DHIS) [45, 46] and Open Medical Record System (OpenMRS) [9, 10, 28, 47], both of which are reaching enterprise scale in several LMICs. An open health information exchange (OpenHIE) has also recently been implemented in Rwanda [7] . Some countries are attempting to consolidate and expand their current health information systems into coherent and integrated NHIS. For example Ghana, Rwanda and South Africa, are actively planning and implementing an eHealth strategy and/or enterprise architecture [23] [39,40,42], including artifacts such as standards, interoperability, national registries, health information exchanges and data warehouses [23].

The Ghana Health Service has designed and implemented a health EA that includes plans to enable a comprehensive transformation of its health information systems [48]. This includes a high initial investment of human, infrastructure and capital resources.

The South African National Department of Health has formulated an eHealth strategy for South Africa [49, 50] which aims to address pragmatic concerns such as affordability and sustainability, benefits realisation and standards, through an incremental approach [50]. The eHealth strategy is required to be aligned with the national Government Wide Enterprise Architecture [51] that uses frameworks such as TOGAF [20] and the Zachman Framework [52].

C. *Health Enterprise Architectural Frameworks for NHIS*

Several health-specific enterprise architecture frameworks have been developed to assist countries develop and enhance their HIS. The Health Metric Network (HMN) framework, (version 2) provides a vision for an HIS, a phased approach to achieve the vision and a detailed process for developing an health information architecture [39]. The main objective of this framework is to enable consistent and accurate reporting of health information at the global level.

More recently, ISODTR14639 [22][51] provides a model that distinguishes the types of components of an eHealth architecture (unlike the Zachman framework that facilitates the organisation of architecture models) and a health-specific maturity model which may be useful to LMICs in determining their immediate priorities in an NHIS development initiative including which components to focus on first in a maturity model [22].

The Health Informatics Service Architecture (HISA), a European standard (ISO-EN 12967) [53, 54], may be used to define an architecture enabling openness, integration and interoperability amongst healthcare information systems through a unified, open architecture based on a middleware layer [53].

The Generic Component Model (GCM)[6], has been developed and applied to several health issues [55]. Although not specific to health, RM-ODP has generally also been applied in a health setting [19] as has TOGAF [48, 56] and elements of the Zachman framework [57].

II. Evolution of NHIS in LMICs

Based on our experiences working in LMICs [7-10], we observe the following general evolution of NHIS in LMICs through three different stages of maturity.

A. *Stage 1*

The first stage of NHIS development is usually aimed at directly supporting public health management and policy-making. It typically includes systems such as vital registration, aggregated data reporting and various management information systems (logistics and supply-chain, facility mapping, data warehousing etc.). Individual patient records

are mostly paper-based and aggregate data is manually captured at the point of care.

An example of such a Stage 1 system is the District Health Information System (DHIS), which provides a national data dictionary or repository of indicators and is implemented widely in a number of LMICs [58].

B. Stage 2

The second stage of NHIS development in LMICs is often characterized by greater emphasis on systems based on individuals, including patient record HIS for specific diseases or health services, e.g. HIV, tuberculosis, maternal and child health. At this stage, there is little or no interoperability between systems. Although there may be some automated reporting and/or aggregated data export. Aggregate data is often collected separately for systems from stage 1.

An example of a Stage 2 NHIS is the Open Medical Record System (OpenMRS) [9, 47, 59] which is currently being implemented nationally in some countries, e.g. Rwanda and Kenya. In preparation for its potential role in a NHIS, OpenMRS is being supplemented with initiatives such as the Maternal Concept Laboratory1, which aims to harmonize concepts across multiple implementations of OpenMRS, in this case in the area of maternal and child health. Similarly, in South Africa, eKapa is being implemented, nationally, for HIV/AIDS information management as part of a tiered architecture [60]. At this stage, a government sponsored eHealth unit or an external coordinator may be established to assist with national coordination of these implementations.

C. Stage 3

The third stage is characterized by greater emphasis on data integration and interoperability. In this stage, it is possible to realize some integration of individual patient records across point of care systems, with automatic feeds into aggregate data systems, for national reporting, monitoring and policy-making, resulting in greater data reuse. Interoperability and adoption of data standards are key concerns at this stage [61].

An example of a Stage 3 NHIS is the Rwanda Health Information Exchange (RHIE) [7] that is implementing a national standards-based HIE to improve interoperability between health applications, initially for maternal and child health with plans for other domains.

Most LMIC NHIS are between stages one and two with some countries striving to achieve stage three. Given these circumstances, it seems that the approach to NHIS in LMICs should include policies, frameworks and technical architectures that serve to improve interoperability of systems as opposed to complete integration of systems.

III. Engineering NHIS for LMICs

A. Key considerations

Drawing from our own experiences in designing and deploying NHIS in developing African countries [7, 8], and previous experiences of others in LMICs [46, 62] and HIC [11, 63] we highlight the following key considerations for engineering effective NHIS in LMICs.

1) Resourcing and organisational complexity, unstable long term funding

National government health funding for HIS is limited. In some cases, and depending on the structure of the health system, implementation decisions and budgets may be delegated to sub-national and/or district structures with consequent tension between national HIS policy, direction and control, and local implementation, requirements and procurement. This is further compounded by the fact that in many LMICs up to half the HIS budget originates from donor organisations [2]. This results in multiple funding sources with different agendas and interests, viewpoints, procurement and technology preferences, and changing perspectives on the purpose, role and benefits of deploying HIS. Associated with this is the short-term nature of the funding. Donor funds are usually geared for specific projects over relatively short time periods. Long term government funding for HIS usually fluctuates and must compete with other health care priorities in an already overstretched health system. Political and social goals compete with cost saving and optimization imperatives [62]. Even when funding is available, specialised IT skills might not be readily available to optimize technology choices and maximize investments.

2) Distributed autonomy, heterogeneity a feature, not a problem

The fragmentation of systems in LMICs cannot be seen in isolation from the environments in which these systems exist. Indeed, the environment which embodies diverse agendas from local and national governments, donors and vendors also contributes to the fragmented nature of HIS. For example, the various reporting systems are technically heterogeneous (in terms of application, platform, protocols and language), in relation to the reporting requirements of the diverse funding mechanisms (government, donor agencies, universities, international organisations, and local municipalities), and with respect to institutional grounding (central ministries, district administration, local health clinics, vertical programs) [62]. There are multiple organisational and political units of autonomy. Physicians have strong autonomy and inform decision making from the bottom up, while organisational entities, such as national, provincial/state, district and facility structures inform decision making from the top down. These multiple decision making points for adoption and use of health information technology result in HIS systems and applications that are naturally and fundamentally heterogeneous.

3) Dynamism and changing requirements

The health system continuously evolves, driven by political, social and changing health priorities, with a constant balancing of limited resources. An effective NHIS that supports and improves health care delivery must be resilient to change, to support current and future priorities of the health system. Multiple spheres of control, continuously shifting health priorities, health delivery mechanisms and erratic funding are

[1] http://www.maternalconceptlab.com

all key drivers of change in an NHIS. Health practitioners may be initially cautious of new IT systems, but as they become more familiar with and incorporate IT into their work routines, they will drive specific extensions and enhancements to the system. New information technologies, e.g. mobile devices, medical devices and sensors, will emerge resulting in new applications, while others will be decommissioned in line with changing priorities. In this way NHIS must not only deal with improvements and expansion, but also to application removal and contraction.

B. Architecture frameworks to support NHIS engineering

Based on the considerations identified above, we now describe key requirements for architectural frameworks to support NHIS development in LMICs, and provide a preliminary analysis on the extent to which existing architecture frameworks can deal with these.

1) Coordinated Approach – dealing with organisational complexity

Strong and committed strategic/business and IT leadership, which is often lacking in LMICs, is required to implement an architectural approach to NHIS development. The eHealth leadership must provide a coherent framework, which embodies the strategy, and coordinates countrywide NHIS development.

The eHealth Strategy toolkit, developed by WHO, can guide the development of the country-specific National eHealth strategy [64].

The Massachusetts Institute of Technology, Center for Information Systems Research (MIT CISR) [65] can play an important role in guiding the development and implementation of policies to sustain long-term plans and reducing risks, especially of uncoordinated spending.

A target state architecture, of the type recommended by TOGAF together with real-world examples, like those implemented in Canada and Australia, along with the transparency provided by a catalogue of architectural artefacts will ensure that solutions are designed more adequately for the environment to which it will be deployed, giving due consideration for how the solution could scale in the future.

Roles and responsibilities must be clearly understood if the coordinated approach is to be effective. Frameworks, like TOGAF and PEAF (Pragmatic Enterprise Architecture Framework) [66], define the roles involved in the EA process. A more detailed evaluation of the roles suggested by each of the frameworks will enable the selection of appropriate roles for LMICs that will facilitate an agile management approach.

The ability to segment the architecture, allowing each segment to develop independently, with interoperability between segments is particularly important in LMICs where the maturity of systems vary so vastly across the enterprise. Managing a segmented architecture requires strong business leadership and a high level of collaboration which is a challenge in LMICs. The Federal Enterprise Architecture Framework (FEAF) [67] is of particular interest because of its application in a governmental environment. The framework promotes local ownership and leadership within segments at various levels of the enterprise and at the same time facilitates collaboration across the segments.

2) Collaborative/Systems Approach – dealing with autonomy and heterogeneity

The current landscape of NHIS development in LMICs is characterized by siloed development, involving multiple agencies including both governmental and non-governmental organisations. Substantial collaboration is required to drive the development of holistic solutions and promote reuse.

HMN is a good starting point for HIS development at country level. Its pragmatic high-level methodology is aligned with the TOGAF Architecture Development Method (ADM) and may be generally applied to health systems strengthening. Such an implementation will provide a common collaboration point across countries so they may learn from each other, as well as leverage off HMN resources available across the world. Furthermore, implementation of the framework may provide valuable information that may assist in prioritizing further HIS development efforts, as well as assist in addressing LMICs public health issues.

MIT CISR's IT Engagement Model could facilitate collaboration and alignment across the many disease-specific programmes without completely disrupting those programmes at the outset, essentially promoting ownership and leadership at the programme level, while still ensuring a systems approach to NHIS development. It could also facilitate more opportunities to address reuse of components and interoperability issues. The EU approach, though somewhat ad hoc, seems to be aligned with such an approach and has already fostered a level of collaboration amongst its stakeholders. It may be useful to adopt this approach to initiate country and inter-country level discussions. Then, to speed up progress of a specific change more uniformly across a wider cross-section of systems, a more formal method may be applied.

The Zachman framework [68] can be used to integrate the different EA methodologies used in siloed programmes into a consolidated view and to facilitate descriptions and comparisons of different frameworks in different LMICS, to capture usage experiences and patterns and to facilitate reuse.

3) An Evolutionary Approach – dealing with dynamism

An architecture approach to LMIC NHIS development must consider the low levels of skills, limited infrastructure and financial resources. An incremental approach allows these countries to balance and better manage these scarce resources by starting NHIS development in a simple manner then evolving to more sophisticated models.

The ISODTR14639 maturity model supports such a pragmatic approach to developing an NHIS by starting with the development of the basic and essential components first and then building on that platform in stages. Given that resources are limited, the maturity model can be used to prioritise the allocation of these resources, and allow LMICs to take initial steps towards developing an eHealth system

without committing to large upfront investments, typically required in HIC settings.

Tailored applications of the TOGAF ADM have been used successfully by HICs such as Canada and Australia and LMICs such as Tanzania [56]. The challenge of a constantly shifting health system and priorities is another major hurdle in designing NHIS. An architecture development process, such as the TOGAF ADM, can facilitate the development of HIS in smaller units or work, giving priority to specific areas of need with the limited resources available at a given time. This makes the development effort affordable and sustainable.

One of the benefits of using frameworks that also support a mature enterprise is that a less mature enterprise gets the benefit of starting an architecture initiative in a simple manner, with the opportunity to evolve to a more sophisticated model without having to migrate to a new framework every time it evolves to a greater level of maturity. The initial investment in up-skilling and modelling is an investment in the future of the architecture development programme, addressing the LMICs requirement for a sustainable, affordable, pragmatic, effective approach, grounded in best practice.

4) Interoperability over integration

An NHIS must essentially promote coherence and cooperation between subsystems and applications without compromising local autonomy. From a technical perspective, support is required for interoperability over systems integration. Interoperability is thus an overarching concern and goal of the NHIS at the enterprise level.

The RM-ODP and HISA frameworks can play a key role in improving the interoperability between systems participating in an NHIS. Elements from the high-level system architecture design, standards catalogue and interoperability framework, developed by HICs like Australia and Canada can serve as starting points for an LMIC architecture. The actual standards and guidelines recommended by the frameworks will likely differ significantly between HICs and LMICs, but the purpose and structure of the frameworks is shared.

IV. DISCUSSION

General enterprise architecture frameworks show significant variability in terms of scope and approach. They can individually facilitate specific improvements in HIS in low resource settings. However, no single framework addresses all the concerns with HIS development completely. One approach is to use of a blend of existing methods that address the specific challenges of a setting [69].

The value offered by the health-specific frameworks is that they have been practically and successfully applied in strengthening HIS. However, some are not complete and not all health architecture frameworks are developed specifically for LMICs and may require some adaptation. For example, HMN prescribes system resources, which are not always available in resource constrained environments with unevenly distributed infrastructure [10]. Plans for version 3 of the HMN framework provide guidelines for how African countries could actually achieve these goals, particularly given the current status of their HIS, human resources and general technical infrastructure [4, 10].

Country-specific health architecture frameworks have mainly been implemented in HICs. The value offered by these frameworks is that they have been practically and successfully implemented in strengthening HIS. However, they cannot be adopted in totality in resource-constrained LMICs. The architecture frameworks used by HICs generally require large investments of capital to develop and maintain. Their elaboration also depends on a high level and availability of management and technical expertise. They also have reliable and powerful communications and electrical infrastructure. Furthermore, while public HIS, including preventive, curative and programmatic approaches to health service delivery are a priority for LMICs, HIC architecture frameworks are designed to maintain and develop HIS with a greater focus on individual, curative, clinical care. Specific techniques and models from HICs can, however, be useful in LMICs if tailored to LMIC-specific requirements, implicitly tailored to the nature and structure of the countries health system. While lessons learnt are invaluable, complete reuse in other settings is debatable.

We identify the following key lessons learnt from HIC that are applicable to LMICs:

The lead responsibility of the NHIS must lie with the government, usually the Ministry of Health (MOH), under the leadership of a single organisation that must take control and responsibility for the overall NHIS architecture, in collaboration with advisory bodies involving e.g. professional associations and patient representatives [70]. An eHealth strategy and tangible, achievable plans must be developed and continuously assessed in terms of the benefits of the investments and the challenges encountered [70].

A national HIS policy, including a sustainable and adequate budget, staffing and expertise; clear rules and regulations on data collection, security, processing and use, is essential [25]. Adoption of selected standards is necessary to ensure the safety and quality of the information on which HIS are based. In advanced environments it is possible to use electronic health record (EHR) systems connected to a health information exchange (HIE), using unique patient identifiers to link clinical data across different care settings and unique provider and facility identifiers to support the authorisation processes [70].

While these components may be commonly useful to HICs and LMICs, the implementation of these components must be tailored to a specific LMIC environment. For example, the HIE has already been practically implemented in several LMICS and HICs, such as Rwanda [7] and Canada (HIAL) [16], but each is based on an architecture which is appropriate for the country in which it is implemented.

While many HICs have implemented NHIS architectures based on patient-centric solutions such as electronic health records and self-service portals [21], LMICs are still focusing on public health issues while simultaneously trying to introduce more person-centric technologies [22]. Given the

resource constraints in LMIC, it is unlikely that their NHIS will reach the technological sophistication of those in HICs, although they may well be more appropriate for the LMIC setting. However, it is also possible that new and possibly simpler and more streamlined technical paradigms will emerge from low resource settings, such as systems based more on mobile technology.

The middle out approach [11] for NHIS engineering, similar to the Australian NHIS, appears to be more suited to LMICs, when compared with top down and bottom up approaches. A middle out approach is already being used for the NHIS in Rwanda, which has implemented a central Health Information Exchange and established a single government sponsored entity tasked with standards and policy regulation and enforcement [7].

V. CONCLUSION

LMICs are complex environments for engineering national health information systems. While lessons may be learnt from NHIS development in HICs, these approaches may not be appropriate in their entirety for LMICs, due to differences in the socio-political and economic landscapes. In this paper, we described the current state of NHIS in LMICs and classified systems into three distinct stages of maturity. Given the nature and evolution of NHIS in LMICs, we propose that the middle-out approach is more appropriate than the top-down and bottom-up approaches for building NHIS in LMICs. Furthermore, we explored key challenges and considerations for engineering effective NHIS in LMICs, and translated these into requirements for architectural framework support. A comprehensive and rigorous analysis of the issues and challenges around engineering NHIS in LMICS is still to emerge. This work is an initial step towards achieving this.

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