Frugal Digital Innovation for Health Information Systems in Resource-Constrained Settings: The Case of Sierra Leone

By

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Abbreviations and Acronyms

AR: Action Research
AIDS: Acquired Immune Deficiency Syndrome
ART: Anti-Retroviral Therapy
CAR: Canonical Action Research
CDP: United Nations Committee for Development Policy
CHAI: Clinton Health Access Initiative
CHC: Community Health Centre
CHP: Community Health Post
CHW: Community Health Worker
CPM: Cyclical Process Model
DDMS: Directorate of Drugs and Medical Supplies
DHIS: District Health Information Software
DHMT: District Health Management Team
DPPI: Directorate of Planning Policy and Information
FDI: Frugal Digital Innovation
GF: Global Fund
GHSC: Global Health Supply Chain
HCT: HIV Counselling and Testing
HIS: Health Information System
HISP: Health Information System Programme
HIV: Human Immunodeficiency Virus
HMIS: Health Management Information System
ICT: Information Communication Technology
ICT4D: ICT for Development
II: Information Infrastructure
IS: Information System
LMIS: Logistics Management Information System
MCHP: Maternal and Child Health Post
M&E: Monitoring and Evaluation
MOHS: Ministry of Health and Sanitation
NACP: National AIDS Control Program
NAS: National AIDS Secretariat
NGO: Non-Governmental Organisation
ODK: Open Data Kit
PHU: Peripheral Health Unit
PMTCT: Prevention of Mother-to-Child Transmission
RCA: Researcher-Client Agreement
RRIV: Report, Request and Issue Voucher
SLPD: Sierra Leone Pharmaceutical Dashboard
TWG: Technical Working Group
WHO: World Health Organisation

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Abstract

The public health context in developing countries is challenged in its ability to adequately provide and sustain essential health information systems to support healthcare delivery and management. A problem identified in relation to the efforts in addressing this challenge is a lack of emphasis on local imperatives and resource-constrained considerations in the design and implementation of information systems. This contributes to ineffectiveness of solutions and poor sustainability capacities. On this basis, this thesis explores frugal digital innovation and its potential for addressing challenges in resource-constrained contexts. The research is motivated on the realisation that leveraging on established local systems and infrastructures can enhance resource utilisation efficiency, solutions viability, and capacity strengthening for sustainability. The public sector focus also has socio-economic development implications as scarce resources can be wasted in pursuit of non-practicable and unsustainable solutions. The research was carried out in the public health context of Sierra Leone and concerning the DHIS2 software between 2017 and 2019. The aims were first to contribute to efforts at strengthening the national health information systems infrastructure and second to advancing the scholarly knowledge in the field of information systems research. With a frugal digital innovation lens data was qualitatively collected and analysed guided by the interpretive paradigm. The findings suggest that positioning frugality at the core in digital innovations can contribute positively towards efficiency and sustainability in resource-constrained settings. As contribution to theory the thesis emphasises the mutual constitutionality of frugal innovation principles and innovation capabilities of digital technologies in a dynamic process-outcome relationship conceptualised as continuous, overlapping, and iterative. For the broader information systems field this perspective contributes to clarifying that the functional scope in digital technology-enabled innovations is extensible; innovation agency can be distributed in an ecosystem, and innovation processes and outcomes being interchangeable also means that they are not distinctly different phenomenon. Practically, a frugal digital innovation strategy is proposed to leverage existing systems, infrastructures, and resources. In this strategy, general project design principles for guiding solution architects and policy makers are proposed to; focus on addressing the prevailing user problem and contextual challenges; explore possibilities for building on established social and technological infrastructures; and consider reusing institutionalised structures. Furthermore, specific solution implementation options are proposed to include; leveraging software platform features for new solutions; scaling general IS functionalities into specific use cases, scoping domain specific systems for use in other organisational domains; and embedding new and complementary solutions into existing parent infrastructures. Beyond these, broader implications are observed in relation to research, practice, systems architecture, governance, policy, scalability, and long-term sustainability. The thesis concludes by observing that the emerging frugal digital innovation concept provides an appropriate lens for studying information systems innovation within resource-constrained settings, and for exploring solutions more suited for achieving developmental goals in public institutional contexts.

1. Introduction

In the public health sector where population-level health issues are addressed, Health Information Systems (HIS) are identified as one of the key building blocks that can contribute to efficiency and effectiveness of health services delivery and management (Berg, 2001; Lipperveld, 2001; WHO, 2010). In many developing countries, significant challenges are faced in the pursuit of efficient HIS solutions (J. Braa & Hedberg, 2002; Jacucci et al., 2006; Kimaro & Nhampossa, 2007; Mukisa et al., 2017). Resource-constraints often experienced in such contexts are identified to contribute to a situation where the environment is seen to produce new challenges but lacks the requisite corresponding resources for dealing with the new challenges (Baker & Nelson, 2005). The resource-constrained factors contributing to HIS development and implementation challenges in developing country settings are identified to permeate all levels of the public health system (J. Braa & Sahay, 2012; Heeks, 2002; Huang et al., 2017). At higher institutional levels lack of capacities, resources, and policies to support planning, development, implementation, and governance of HIS projects are identified (Kimaro & Nhampossa, 2007; Sanner et al., 2014) . On the ground in healthcare organizations there are user-related challenges due to lack of requisite infrastructures and appropriate capacity development approaches to enable effective system adoption, use, institutionalization, and support (K. Braa & Nielsen, 2015; Kimaro & Titlestad, 2008; L. C. Li et al., 2009; Roland et al., 2017).

Typically for Information Communication Technology (ICT)-based IS projects in public sector institutions of developing countries, the key operational factors are technological, institutional, and social in nature (Sahay, Nielsen, Faujdar, et al., 2018). Technological factors relate to the electronic systems, tools, software, hardware, and media that constitute the ICTs employed in the development and implementation of ISs. Institutional factors relate to the rules, structures, and norms that govern the activities of the actors involved. Social factors represent people, their environment, and issues of concern. Furthermore, these factors can be identified at organizational, country, and international contextual levels (Avgerou, 2001, 2010; Jayasuriya, 1999). At the organizational level, these include the IS users and their needs, management support structures, and availability of human and material resources. At the country level this pertains to the prevailing socio-economic development conditions such as related to health and education status, state of infrastructures, and political climate. At the international level external actors and institutions such as donor agencies, non-government organizations (NGOs), technology vendors, and technical support expertise organizations also introduce additional dynamics. All these factors contribute in forming the contextual layers and the relationships that have the ability to shape the trajectory of IS solutions development and implementation projects in different ways.

In addition to the above, many developing countries also have to rely on donor agencies and partner organizations for funding and expertise to fill up critical gaps in local resource capacities (Kimaro & Nhampossa, 2007). Although this is often seen as a welcome boost to the limited

local resource capacities, there are associated undesirable effects that contribute in the challenging situation and impacts negatively on the ability to meet local IS needs more effectively. A potential source of a negative influence in this relates to the power imbalances (Sanner et al., 2014) that can exist in donor-recipient relationships. In such situations the tendency for solutions that are designed elsewhere to be imposed on the local context can be increased (Heeks, 2006; Suchman, 2002). Indeed it is observed that ICT-based solutions that are found to work elsewhere are often transferred into other organizational contexts without due consideration for local circumstances (Avgerou, 1996; Avgerou & Walsham, 2017). Also even if arriving with the best of intentions, the literature suggest that external agencies are often interested in meeting their own short-term goals, which takes priority over long-term systems strengthening (J. Braa et al., 2004; Kimaro & Nhampossa, 2007). Thus without appropriate local approaches to counterbalance the negative externalities, problems including 'design-reality gaps' can result and consequently impact negatively on local viability and sustainability of ICT-based systems and solutions (Avgerou, 2001; Heeks, 2002; Swanson & Ramiller, 2004).

To contribute to addressing challenges faced with HIS development and implementation in developing countries settings, this thesis studies ICT-based IS innovation dynamics in the public health context of Sierra Leone. The understanding of IS innovation adopted in this thesis is based on Avgerou's (2008), description as the development and implementation of ICT-based IS solutions in organisational settings, and aimed at achieving some stated performance improvement objectives. The general motivation for embarking on this research was therefore to understand the key factors and relationships necessary in shaping efficient IS innovation processes towards effective HIS solutions for the public health sector in a developing country. This was based on the realization that despite the progress achieved in the IS field with respect to the application of ICTs for instance in health information management, reports of failure outcomes in the literature far exceed the successes (Heeks, 2006; Pankomera & van Greunen, 2018). The failure outcomes include incomplete and abandoned projects, implemented solutions that are not used or fail to produce the expected benefits, and those that are unable to scale and be sustained (Avgerou, 2008; Heeks, 2006; Huang et al., 2017).

Therefore based on Action Research (AR) (Davison et al., 2004), an IS innovation strategy and practicable solution approaches were pursued in this thesis to mitigate in the local resource-constrained situations and address needs. A major expectation in this included enhancing the potential for improving successful IS outcomes in the public health sector context of Sierra Leone and providing insights that can be useful for the developing countries context in general. The appropriateness of the IS solutions innovation strategy and approaches explored are thus examined in terms of the potential for enhancing efficiency, viability, and sustainability of solutions and outcomes. In this, efficiency is understood as avoiding waste, viability concerns solution practicability and usefulness, and sustainability is about being able to maintain the relevant systems at optimal operational levels over their useful lifetime. The research presented involved a number of field interventions in HIS development and implementation that were

carried out in the research case in Sierra Leone. The practical and immediate concern was to contribute to country-level HIS strengthening efforts that were centred on the implementation of the District Health Information Software version 2 (DHIS2). This is an open source web-based software platform used for health information management in the Sierra Leone context, and in at least 100 other developing countries across the globe (Adu-Gyamfi, Nielsen, & Sæbø, 2019; Kossi et al., 2012).

In the remainder of this chapter the research problem as well as the practical and theoretical motivations for conducting this research are introduced and elaborated on. After this, the research aims, objectives, and questions are defined. This is followed by an introduction to the empirical context and research approach, and then a summary of the research results, findings, and contributions. The chapter ends with a description of how the rest of the thesis is organized.

1.1 Research Problem

The research problem tackled in this thesis concerns the need to understand and address challenges posed by local and resource-constrained factors in the design and implementation of public sector IS innovation initiatives in developing countries contexts. Based on literature, IS research and practice is seen to be primarily driven on the assumption of universal imperatives and towards developing general knowledge and best practices regarding the exploitation of ICTs (Avgerou, 2001; Nambisan et al., 2017). Accordingly internationally-driven and a-contextual approaches and motivations dominate in many IS innovation engagements. The focus on general considerations can be linked to the fact that majority of the foundational systems such as digital platforms are developed and supported internationally, usually in developed countries (Avgerou, 2008; Heeks, 2002; Suchman, 2002). While this is important for advancing the field in general, research cautions that over-emphasis on universal attitudes to innovations can pose "risks of misguiding and frustrating local efforts to make sense and appropriate new technologies" (Avgerou, 2001, p. 44). The potential negative implications identified include for example design-reality gap problems that need to resolved in local implementation situations (Heeks, 2002). This is where for example systems designed with developed country resource mind-set are not practicable in developing countries contexts and those developed for the private sector do not suit public sector needs. Considering the peculiarities of local circumstances (Swanson & Ramiller, 2004), it is argued that approaching IS innovations based on general considerations and global motivations alone can negatively impact the effectiveness and sustainability of solutions for the public sector in developing countries.

In the public health sector context of Sierra Leone where this research was conducted attempts have been made towards improving HIS solutions development and implementation (J. Braa et al., 2010; Kossi et al., 2012). Strategies employed include translating and making global standards locally relevant and pursuing systems integration (J. Braa et al., 2007; Sæbø, 2013). But for the most part universal motivations and considerations characterize majority of the efforts where there is relatively less emphasis on ensuring long-term local viability and

effectiveness of solutions. The international interests embedded in donor funding schemes and projects that dominate the country's public health sector landscape affect the pace and direction of HIS development (J. Braa et al., 2010; Herrick & Brooks, 2018). The negative impacts thus include a slow pace of HIS development and solutions that are largely dependent on external support for operational continuity. In the broader IS innovation field, studies have emphasised the need for improving local relevance of solutions and approaches as the status quo risks creating new gaps in innovation capacities between developed and developing countries (Avgerou, 2001; Heeks, 2002; Nielsen, 2017). Particularly, strategies are needed to boost local engagements in digital technological innovations as these are identified with the potential to support addressing social and economic development concerns within resource constraints (Nielsen, 2017).

Notwithstanding, research also notes that making sense of major ICT-enabled innovations in ways that fully consider potential fit to particular circumstances of real organizations can be a daunting undertaking (Swanson & Ramiller, 2004, p. 554). Coupled with the pressure to show quick results in many development-oriented IS projects in developing countries, situations arise where achieving short-term goals takes priority over long-term systems strengthening (J. Braa et al., 2004; Kimaro & Nhampossa, 2007). This for example can put efforts, systems, and infrastructures at risk of fragmentation with undesirable consequences as the appropriate linkages between problems, contexts, and solutions are not adequately pursued (Avgerou, 2008; J. Braa et al., 2004; Heeks, 2002; Sanner et al., 2014). The associated failure outcomes are also identified to have detrimental effects on ICT for development (ICT4D) goals which form the broader aspirations in public sector IS innovation endeavours (Avgerou, 2008, 2010; Heeks, 2008, 2010). This is because the promised efficiency gains for introducing ICTs to support organizational performance improvement goals are not realized while scarce resources are also wasted in the process. Thus to be able make the most out of ICTs in the context of development (Walsham, 2017), we need to be mindful of the peculiarity of needs and factors prevailing in different organizational circumstances and pursue solutions appropriately (McLeod & Doolin, 2012; Swanson & Ramiller, 2004).

1.2 Practical Motivation

The practical motivation for the research undertaken in this thesis is taken from the recognition that despite the reported high incidence of HIS failures in developing countries some still work by meeting major goals of most stakeholders and are able to adequately support the achievement of organizational performance goals (Heeks, 2006; Krishna & Walsham, 2005). In the research context of Sierra Leone the DHIS2 which is implemented as the national Health Management Information System (HMIS) platform is identified in this relatively successful IS category in the health management setting (J. Braa et al., 2010; Kossi et al., 2012). To a large extend the DHIS2 software has achieved relative stability in terms of institutionalization and use. An understanding therefore was that the few cases of success can provide important lessons that can be drawn upon to guide further solutions exploration and improve the chances for more successful IS innovation

outcomes. For example in a study of public sector IS implementation projects in the Indian context, Krishna and Walsham (2005) identified a number of factors that were deemed to be largely responsible in the successes achieved and can be learnt from. The factors in summary included being detailed and attentive to the multiple stakeholder groups, innovative organizational structures, and the people whose concerns are being addressed in the solutions development. In addition to this the actors must have the necessary resources and the ability to persist with system implementation over a reasonable length of time, and all these should be supported by committed and knowledgeable leadership (Krishna & Walsham, 2005).

In addition to learning from successful project outcomes, it is observed that the technological systems infrastructure and resources involved can also be explored to support functional scope extensions, and used to serve needs of users in other relevant organizational domains (Nielsen & Sæbø, 2016). For instance some of the digital technologies involved such as software platforms are designed with architectural flexibilities that allow derivative solutions development and feature customizations to serve new use functions (Eck et al., 2015; Tiwana et al., 2010). Indeed the DHIS2 software on which the activities in this research are centred is identified as one such digital platform emerging in public health data management domain (J. Braa & Sahay, 2017). The architecture of DHIS2, as typical of all digital platforms (Tiwana et al., 2010), is designed with a core, generic feature offerings, and configurable complementary modules that can be customized as well as extended according local user needs.

Therefore the practical motivation behind the research presented in this thesis was based on the need and the potential for leveraging the functional extension capabilities of the DHIS2 and the resources established around it in addressing local HIS innovation challenges in the Sierra Leone context. This included exploring the opportunities offered for building on the derived local HMIS and its supporting infrastructures to support further systems development, implementation, and sustainability strengthening. The expectation was that building on established and working systems would have positive implications on how scarce resources are utilized. This for example could ensure maximum benefits extraction from the available resources and by doing improve the chances for achieving more successful HIS innovation outcomes in the local context.

1.3 Theoretical Motivation

The theoretical motivation for this research is based on the recognition that IS in developing countries are fraught with challenges that contribute to poor outcomes (Heeks, 2002). Therefore by being part of a research project focused on HIS strengthening in developing countries (J. Braa et al., 2004) and as someone who comes from a developing country I see a need to improve our understanding of the challenging situation and aid in addressing the problems. For this an opportunity is presented to contribute to an emerging field in IS research that explores a frugal mind-set to understanding the important role digital technologies can play in addressing challenges within resource constraints (Ahuja & Chan, 2016; Sahay & Walsham, 2014; Watson

et al., 2013). This innovation perspective is derived based on combining theory concepts from frugal and digital innovation studies and conceptualized as frugal digital innovation (FDI) (Ahuja, 2021; Sahay, Nielsen, Faujdar, et al., 2018). The realization that prompted this conceptualization was that traditionally innovation research treated frugal innovations and digital innovations as separate fields. Frugal innovation is about doing more with less resources with goals including affordability, simplicity, and sustainability (Bhatti & Ventresca, 2013). Digital innovation on the other hand is concerned with how different digital technologies and physical components are combined to create new products and services (Yoo et al., 2010). Digital technologies are identified to have material properties that support creation of new technical solutions and reconfiguring existing technologies to create new meanings and uses across domains and technical systems (Yoo et al., 2012).

In the frugal innovation literature the digital is mainly considered for its role as enabler of frugal innovations (Ahuja & Chan, 2014). There is a limited research emphasis on applying frugal innovation concepts to understanding digital technologies and their potential contribution to addressing development challenges, and where the digital technologies are the main innovation object of analysis (Sahay, Nielsen, Faujdar, et al., 2018). In addition, existing frugal innovation research in resource-constrained contexts tends to be driven by entrepreneurial and commercial motivations, and the potential of ICTs enabling new business opportunities (Pisoni et al., 2018). This also applies to frugal innovation studies in the healthcare sector with a focus on meeting individual and markets needs rather than public sector institutional needs (Ramdorai & Herstatt, 2015). This dearth of attention to public sector innovation needs therefore forms the basis for the FDI conceptualization, and brings into focus particular features of digital technology and their implications for IS innovations in public sector institutions with development purpose orientation. Within this perspective there is a particular emphasis on building linkages between technological or business, institutional, and social innovations towards a frugal realisation and sustainability of desired outcomes (Bhatti, 2012; Sahay, Nielsen, Faujdar, et al., 2018; Sahay & Walsham, 2014).

With my research located in a similar context where the FDI concept first emerges (Sahay, Nielsen, Faujdar, et al., 2018), I perceive a potential for contributing to improving our understanding of digital IS innovation process theorization. In this a particular emphasis is laid on applying frugal innovation principles in the development of digital technology-based IS solutions suitable for meeting needs in public and formal contexts of a developing country. With the FDI concept still in its early phase of development, how context, processes and outcomes interact and shape IS innovation towards effectively addressing local problems is yet to be deeply engaged and theorized. Towards these ends the motivation therefore is to both draw on the emerging ideas in FDI theorization to guide my research analysis and also further its development through empirical enrichment. A further motivation is that the FDI perspective can contribute in clarifying fundamental assumptions in IS innovation theorization concerning the nature of innovation process and outcome relationships, agency, and definitional boundaries. The

key assumptions that can be clarified include the understanding that innovation is a well-bounded phenomenon focused on fixed products or services, innovation agency is centralized, and innovation processes and outcomes are distinctly different phenomenon (Nambisan et al., 2017).

1.4 Research Aims, Objectives, and Questions

Based on the research problem and motivations I have presented above the broader purpose of this thesis is to contribute to improving our understanding of the technological, institutional, and social dynamics of IS development, implementation, systems strengthening, and sustainability in developing countries. This includes pursuing and elaborating FDI-based IS innovation strategy, principles, and approaches that can be used to enhance solutions viability and improve local capacities for long-term systems sustainability. The specific and immediate aim in this relates to addressing unfulfilled HIS needs and challenges faced in meeting such needs in relevant public health sector contexts. The broader and long-term expectation is that by improving knowledge on potential FDI pathways to solutions, resource-constrained public health institutions can improve their capacity for engaging with digital technologies for the IS innovations essential to improving healthcare management efficiency and service delivery effectiveness. The objectives I have defined to assist me in working towards these aims are to:

- Explore and outline the innovative potentials of digital technologies and allied resources in meeting local HIS needs
- Identify the particular properties of digital technologies that make them potentially capable of supporting frugal innovation goals in HIS development and implementation
- Establish why in resource-constrained public health settings it is important that HIS innovations are guided by FDI principles

In view of these, the research questions I have posed to guide my research investigations in this thesis consists of one main question that is broken down into two sub-questions. These are posed as follows:

1. How can frugal digital innovation help mitigate challenges to local HIS innovations and enable efficient exploration of solutions suited for addressing problems in resource-constrained settings?
    a. What are the key operationalisation considerations that can support achieving locally viable and sustainable HIS solutions?
    b. What are the implications for HIS innovation research and practice in a public health institutional context of a developing country?

1.5 Empirical Context and Research Approach

The empirical context of the research presented in this thesis is the public health context of Sierra Leone, a country located in West Africa. The United Nations 2020 economic development

review report (CDP, 2020) places Sierra Leone in the category of least developed countries. Emerging from a decade-long civil conflict from 1991 till early 2002 and a series of natural disasters afterwards, the Sierra Leone health system along with the information management systems were weak and fragmented (Barr et al., 2019). In 2008 a project was initiated to standardize, integrate and digitize aspects of the mainly paper-based HIS tools at health district and national levels (J. Braa et al., 2010). Notwithstanding the progress achieved over the years, the Sierra Leone HIS is still far from optimal as all health programs are yet to fully integrate their data reporting tools and management activities in the national HMIS platform. For example, while attention was focused on improving disease surveillance and reporting during and after the 2014 Ebola disease outbreak in the country, other areas such as HIV patient treatment management were reported to be neglected (UNAIDS, 2015). On this background I was engaged in research and practical intervention activities to contribute in broad-based collaborative and ongoing efforts to improve HIS development, implementation, and strengthening in the country. My research activities were aimed at improving solutions development, implementation, efficiency, systems availability, usefulness and long-term sustainability.

The empirical work presented in this thesis was done within the qualitative research tradition where emphasis is placed on text and text analogues rather than numbers and quantification (Myers & Avison, 2002). The overall research approach is action research where dual goals of contributing to solving problems of practical concerns to people in an immediate problematic situation and advancing scientific knowledge are pursued (Rapoport, 1970). Due to the contractual nature of the research interventions where obligations and deliverables were defined and agreed upon by the various actors involved, canonical action research principles (Davison et al., 2004) were drawn upon to guide the conduct of this research. Research data was gathered qualitatively in field notes through interviews, system design workshops, system configuration activities, training workshops, meetings, and analysis of the relevant project documentations. The research was done over a three year period from 2017 till 2019. This involved traveling back and forth between Sierra Leone where I was affiliated with the Ministry of Health and Sanitation (MOHS) and in Norway where I was enrolled as PhD candidate at University of Oslo. During the research I participated in activities related to various health programs data management and integration into the DHIS2-based HMIS platform and HIS strengthening in general for the Sierra Leone MOHS. Based on my technical expertise in DHIS2 implementation I contributed in systems designing, configuration, implementation, training, routine maintenance, and user support. The research data was analysed within the interpretive paradigm of IS research in organisations where I sought to understand how both IS and organisation influence each other in a change process (Walsham, 1993). The organisation in this case is the MOHS in Sierra Leone and the focus of my research was the processes involved in the general and specific actions engaged in as part of the country's HIS development and implementation efforts. A key strength of this research approach was the immersive, practical, and prolonged engagements opportunities offered and thus enabling my close proximity to many important events that transpired in the course of the research project. On the other hand, a major weakness is highlighted with respect to

an inability to engage in the multiple repeated cycles and iterative follow-ups expected of action research projects (Davison et al., 2004). This was mainly due to a lack of control on the trajectory of events and coupled with research time limitations in the face of drawn-out processes that characterised individual sub-stages in the action research project cycles.

This thesis and research activities conducted fall under the auspices of the Health Information Systems Programme (HISP) at University of Oslo and within its broader international support network (Adu-Gyamfi, Nielsen, & Sæbø, 2019). HISP is a global research and innovation programme supported by an international network of software developers and HIS implementers around its software, the DHIS2. The main goal of HISP is to help strengthen health systems management in developing countries through development and implementation of the DHIS2 software which is coordinated from the University of Oslo in Norway. Research activities are pursued within HISP's framework of action research (K. Braa & Nielsen, 2015). In this, participatory design approaches to HIS software development, implementation and support in developing countries contexts is particularly emphasised (J. Braa & Sahay, 2012). HISP started in the early nineties in post-apartheid South Africa (J. Braa et al., 2004) and has since pursued its commitment to participatory approaches to software development and systems implementation in supporting health ministries and organisations across countries in Africa, Asia, and Latin America. In an evolving local and global HIS landscape relevant strategies are continuously being explored in addressing persistent old problems and at the same time for meeting new demands (J. Braa & Sahay, 2012). Therefore work done in this thesis also seeks to contribute to the broader aspirations of HISP in its efforts to improve HISs in developing countries.

1.6 Overview of Research Results, Findings and Limitations

Summary of the research results and findings based on selected research papers produced during the research project and included in this thesis are presented in Table 1 below. A key message in this is that the public health management sector in developing countries is dynamic and influenced by many local and international factors. Therefore the FDIs principles implicit in the papers presented contribute a more rounded perspective for approaching and effectively addressing HIS innovation challenges likely to be faced in local and resource-constrained situations. It should however be noted that the generalisability of the findings may be limited due to the field research activities being primarily based in only one developing country context.

Table 1: Summary of the included research papers and main contributions to the findings

No.	Paper title	Result and contribution to the findings
1	**The Dynamics of a Global Health Information Systems Research and Implementation Project** Eric Adu-Gyamfi, Petter Nielsen and Johan Ivar Sæbø, Proceedings of the 17th Scandinavian Conference on Health Informatics, 12 -13 Nov 2019, Oslo Norway	**Result:** Identifies HISP as an international collaborative network of action that enables and supports HIS development and implementation in countries and internationally. **Finding:** Innovation capacities developed within an innovation ecosystem can be scalable and sustainable across local and global contexts
2	**Leveraging Software Platform Capabilities to Support HIV (ART) Treatment Adherence Management: A Case from Sierra Leone** Eric Adu-Gyamfi and Petter Nielsen, 14th IFIP WG 9.4 International Conference on Social Implications of Computers in Developing Countries, ICT4D 2017 Yogyakarta, Indonesia, May 22–24, 2017 Proceedings	**Result:** Proposes functional architecting strategy as a way to explore different user application possibilities with DHIS2 as a digital platform. **Finding:** The architectural flexibilities and features of digital platforms make them capable of supporting derivative and tailored HIS innovations
3	**Scaling Across Functional Domains: A Case of Implementing an Electronic HIV Patient Information System in Sierra Leone** Eric Adu-Gyamfi, Petter Nielsen Johan Ivar Sæbø and Zeferino Saugene, 15th IFIP WG 9.4 International Conference on Social Implications of Computers in Developing Countries, ICT4D 2019 Dar es Salaam, Tanzania, May 1–3, 2019 Proceedings	**Result:** Demonstrates the feasibility of scaling the functionality of an HIS software vertically from general to specific user application. **Finding:** Building on existing HIS systems and resources to implement differentiated functionalities has positive resource efficiency implications
4	**Merging with Installed Base Infrastructure for Information System Continuity: A Case of Resource-challenged mHealth Project in Sierra Leone** Eric Adu-Gyamfi, Electronic Journal of Information Systems in Developing Countries----Submitted	**Result:** Examines the implementation strategy of a discontinued HIS project and proposes an alternative approach. **Finding:** Merging or embedding new HIS solutions into local installed base infrastructures can be a viable approach to improving implementation continuity in resource-constrained settings

Table 1 continued:

5	**Information System Reuse: Case of Frugal Digital Innovation in the Public Health Sector in Sierra Leone** Eric Adu-Gyamfi, Petter Nielsen and Johan Ivar Sæbø, Information Systems Journal (under review)	**Result:** Demonstrates FDI through horizontal scaling of same DHIS2 functionality to support different organisational units in local public health management settings. **Finding:** Repurposing and reusing same IS and allied resources to serve multiple functional needs can contribute to efficiency and sustainability

1.7 Contributions

In this thesis both theoretical and practical contributions are offered. These are expected to contribute in improving our understanding of IS innovations and to encourage meaningful engagements with ICTs in the quest for context-appropriate, efficient, and effective HIS solutions. In the IS literature the importance of the mutual constitutionality of IS innovation and organizational change dynamics is acknowledged (Avgerou, 2008; Walsham, 1993). This applies to IS development, implementation and use processes aimed at improving organisational performance outcomes (Berg, 1999; Leonardi, 2009). From the FDI perspective this thesis contributes to the IS innovation aspect of the discourse as follows. First, within local and resource-constrained factors, it is important that the interactions involving frugal innovation principles and innovation capabilities of digital technologies are understood as mutually constitutive and in a dynamic process and outcome relationship. Second, this relationship should be conceptualized as continuous, overlapping, and iterative towards enhancing innovation efficiency and solution effectiveness. The continuous aspect of the relationship highlights the innovation potential in seeing IS system development, implementation, and usage as connected and all part of an ongoing process. The flexibilities afforded by the digital technologies involved enable overlaps in innovation processes and outcomes for innovation components interchangeability and or reusability. From this understanding process-outcome engagements should be pursued in the iterative sense and as necessary for achieving optimal state of solutions. These theory concepts when pursued together can lead to frugal innovation pathways to locally viable and sustainable solutions. The FDI conceptualisation also contributes broadly to addressing old assumptions in IS innovation conceptualization as introduced in the theory motivation section above. Based on the material flexibilities of digital technologies the functional scope and boundaries in IS innovations are not fixed as they can be contracted or extended according to needs; innovation agency can be distributed in an ecosystem of local and international actors and on technological, institutional, and social dimensions; and innovation processes and outcomes can be interchangeable and thus not distinctly different phenomenon.

In addition, an attempt is made to enrich the FDI conceptualisation with empirical examples based on practical solutions exploration attempted in the research case. From the results and findings practical IS innovation strategy for achieving short and long-term goals in resource-constrained, local, and public institutional contexts is proposed. The strategy concerns frugal exploration of solutions by leveraging established, local and working IS and the associated installed based infrastructures and systems to support new user applications. To operationalise this strategy, three general project design principles and four specific solution implementation approaches are proposed and elaborated. The principles are expected to guide solution designers, architects, managers, and policy makers involved in the design and management of HIS innovation project initiatives for resource-constrained contexts. Presented in decreasing order of priority, these are to:

a) Focus on addressing the prevailing user problem and contextual challenges to enhance local viability of solutions and long-term sustainability
b) Explore possibilities for building on established social and technological infrastructures to maximise benefits and boost efficiency gains
c) Consider reusing institutionalised structures to enhance replication of successful outcomes including performance improvements across the relevant organisational areas

The four specific FDI solution implementation approaches are proposed for consideration by IS project managers and technical solution developers engaged in solutions explorations in local problem situations. The practicability of an approach will depend on the nature of problem, the environment, and innovation affordances of the installed based infrastructure. The frugal concept of 'doing more with less' is identified as a major running theme in these approaches. These include Leveraging, Embedding, Scaling, and Scoping (LESS) in short. Thus the approaches are listed as:

1) Leveraging existing software platform modules and ecosystem capabilities where available for new solutions
2) Embedding or merging complementary IS solutions into identifiable and well established parent systems and infrastructures
3) Scaling existing IS functionality across different user dimensions for example from general health management to disease-specific health program management
4) Scoping or repurposing domain-specific IS and supporting infrastructure to cover functionality needed in different but related organisational domain

In the research case context the impacts of these contributions were seen in the joint realisation of HIS solution innovations that were deemed considerably appropriate for addressing the local needs. Through these results the efforts towards strengthening integration of the various health programs data and management activities into the national HMIS platform were substantially moved forward. The potential for long-term sustainability of the resulting solutions were also enhanced as they were largely based on established local systems and infrastructures. Therefore

policy recommendations are made in line with the project design principles proposed and in support of achieving FDI goals in resource-constrained HIS innovation projects in a developing country context as follows. First of all in the need for new IS functionalities, the existing installed base should be explored and then leveraged if determined that this in the long run would be the more frugal and sustainable option. Secondly, when setting up FDI project teams, civil servants in middle-level management positions whose availability are less likely to be affected by national politics should be identified and assigned project continuity roles. Last but not least, collaboration with other public institutions especially local Universities should be explored to serve as an avenue for local institutional knowledge development, exchange, and preservation.

1.8 Thesis Organisation

The remainder of the thesis presentation after this introductory chapter is organised as follows.

Chapter 2 covers related research and theory concepts informing my research. The literature on HIS in general and challenges and opportunities for the developing countries contexts are introduced. This includes a brief overview of IS and innovation research literature forming the larger conceptual background for my research. I look at frugal innovation and digital innovation as the relevant research streams towards my conceptual framework which is based in frugal digital innovation.

Chapter 3 describes the contexts within which my research unfolds. This involves introducing the international and local aspects of the research contexts constituted by technological, institutional, and social factors. I describe my context as a researcher shaped by HISP network activities and DHIS2-based IS development and implementation. I subsequently narrow down to the research case contexts and describe the various layers looking at the country healthcare system, the HIS and implementation status.

Chapter 4 introduces my research approach which is action research and based in qualitative traditions to researching IS in organizations. I identify the philosophical and epistemological stance subscribed, present the research case design, the action research methods employed, and show how principles from the canonical form of action research inform my research. The strengths and weaknesses of my research approach are highlighted and ethical concerns are addressed.

Chapter 5 gives a chronological account of my empirical work. This includes a phased out data collection process over a three year period and analysis of the research results and data obtained. The analysis as based on a derived FDI analytical framework is presented. Appropriate linkages are drawn between the themes identified in the analysis of the data with analytical constructs of local relevance and broader theoretical concepts.

Chapter 6 presents my research findings based on five papers included in the thesis and from the thesis broadly. I give overview of the papers in terms of their roles and how they fit into the processes involved in the events leading to the development of my research outcomes and

contributions. This includes highlighting the parts played by the papers towards addressing the research aims, objectives, and questions.

Chapter 7 discusses the research findings and how the research questions are answered in support of addressing the research problem. The key considerations and factors that inform and shape research and practical actions within the FDI framework and towards efficient and effective solutions explorations are examined. The capacity for improving local viability and sustainability of IS and outcomes in resource-constrained settings are also discussed.

Chapter 8 elaborates the research contributions and discusses the relevance specifically for HIS innovation in the resource-constrained public health context under consideration and the general IS innovation field. I also present and discuss the study implications for theory, research, solutions architecture, governance, practice, policy, and systems scalability and sustainability.

Chapter 9 concludes my thesis presentation where I reflect on the research process, recap the main highlights, and draw some conclusions. I also give additional implications of my research for advancing the still emerging FDI field I sought to contribute to in this thesis and suggest areas for future research.

Note: The research papers included in this thesis are attached individually as appendices at the end of this thesis presentation.

2. Related Research and Conceptual Framework

In this chapter I cover related research literature generally and towards the theoretical framing of this thesis. The related research literature concerns HIS development and implementation pursued in countries. Challenges and opportunities for addressing the problems in the resource-constrained public institutional contexts of developing countries are covered (J. Braa et al., 2004; Kimaro & Nhampossa, 2007; Sahay & Walsham, 2014). Innovation as concept in literature and in relation to IS research in organisational settings is defined. The purpose is to draw out the relevant concepts and principles to guide an understanding into IS innovations, challenges to innovation, and the potential mitigating role ICTs can play towards achieving efficiency and in support of social and economic development goals (Avgerou, 2010; Nielsen, 2017; Walsham, 2017). Further, a conceptual framework based on frugal and digital innovation research concepts is presented. The chapter is concluded with an elaboration of an analytical framework derived based on the FDI conceptualization and for guiding the analysis of the research presented in this thesis. Definitions of the main theory concepts are summarized in a table at the end.

2.1 Health Information Systems

Health information systems are defined as set of components and procedures organized with the main objective to generate the information needed for improving healthcare management decisions at all levels of healthcare systems (Lipperveld & Sauerborn, 2000). Of particular note, ICT-based HISs are identified with the ability to boost efficiency of healthcare systems catering to larger populations across wider geographical areas when used appropriately (Berg, 2001; Heeks, 2010). This for example includes an ability to enhance availability, accessibility, and quality of healthcare management data generated and used across organizational levels and domains (J. Braa & Sahay, 2012). The benefits include improving evidence-based decision-making to support healthcare delivery and resources management efficiency on horizontal and vertical levels across health systems (AbouZahr & Boerma, 2005; Berisha-Namani & Qehaja, 2013; J. Braa & Sahay, 2012; Lipperveld, 2001). Vertically the HIS enables information management and flow up and down the health system hierarchy to inform decisions related to general management. For instance it enables clinical data to be combined with facility level data to support community resource planning and service delivery management. Further up, the appropriate HIS can enable the combination of routine and non-routine data to enhance a country's ability to monitor, detect and respond appropriately to disease outbreaks and public health emergencies (WHO, 2010). The information produced also informs the development of policies needed to guide healthcare processes including monitoring and evaluation of health programs activities and associated social services (Alwan et al., 2016). At the horizontal levels HISs are needed to support activities in sub-organizational units and within individual health programs. This is expected to enable horizontal integration of data and interoperability of systems to inform better decisions and improve health systems efficiency. Examples of horizontal level activities supported with the HIS include logistics management, patient data management, disease surveillance and response management, and the management of human resources for health. The HIS is thus identified as one of the foundational building blocks of

every healthcare system and essential to achieving management efficiency and service delivery effectiveness (De Savigny & Adam, 2009; WHO, 2010).

Challenges are identified globally with regards to HIS development, implementation, usage, and sustainability in healthcare organizations (Alwan et al., 2016; Berg, 2001; J. Braa & Hedberg, 2002; Kimaro & Nhampossa, 2007). These challenges include an inability to properly leverage opportunities offered by capacities and resources rooted in ecosystems of social, institutional, and technological relationships to improve the situation (Ali-Hassan, 2013; Lane, 2011; Msiska & Nielsen, 2018). In addition there is lack of appropriate strategies to support solutions development and implementation, which is reflected in the high rates of HIS project failures reported in the literature (Heeks, 2006). The lack of appropriate strategies is identified to impact negatively on the effectiveness of healthcare systems because the goal of producing well-functioning HISs to ultimately improve evidence-based decisions and actions are not fulfilled (Lipperveld et al., 2000; Walsham, 2020).

2.1.1 Problems and Opportunities for Advancing HIS in Developing Countries Contexts

In many developing countries appropriate health information systems are either not available or not well-functioning in terms of contributing towards improving the delivery of healthcare services (Heeks, 2006; Walsham, 2020). Problems of institutional inequalities, poorly designed technological solutions and constraints on resources are typical factors contributing to failure in the public health sector (Sood et al., 2008). Other factors are also linked to heavy reliance on external support for funding, technology, and expertise which in turn influence how the HISs are introduced and sustained in developing country contexts (Heeks, 2002; Kimaro & Nhampossa, 2007). Here it is for example identified that the pursuit of short-term goals in donor funded projects often takes priority over long-term systems strengthening. The resulting effects include inadequate local capacities and governance structures unable to support training, technical system maintenance, and further functional improvements to meet new and changing user requirements over time (J. Braa et al., 2004; Kimaro & Nhampossa, 2007).

Research efforts are made to address some of the problems associated with short-sightedness, such as aimed at addressing ‘pilotitis’ which is a phenomenon where HIS project initiatives are unable to scale beyond the pilot stage (Huang et al., 2017). There are also attempts to address a situation of uneven and partial implementation of systems that contribute to HIS and data fragmentation problems (J. Braa et al., 2004; Sahay & Walsham, 2006). Integration of systems through gateways and standards are examples of strategies proposed for addressing fragmentation problems (J. Braa et al., 2007; Hanseth & Lundberg, 2001). This involves organising the HIS solutions development and implementation into more manageable and sustainable modules such as based on health programs-specific needs, and then integrating the various systems through flexible integration approaches (Aanestad & Jensen, 2011; J. Braa et al., 2007). Still others are looking at how to resolve design-actuality gaps found when information technology solutions and software systems are designed in developed countries contexts but used in developing country contexts (Heeks, 2002). Typically these gaps have to be bridged at the

level of implementation through improvisation and local adaptation strategies (Heeks, 2002; Kimaro & Titlestad, 2008; M. Li & Nielsen, 2019). In addition to this, capacity development approaches such as through the networks of action (J. Braa et al., 2004), and community of practice arrangements (L. C. Li et al., 2009) are proposed to support in the development of the requisite local and international capacities and encourage collaboration.

Yet another avenue identified that presents opportunities for addressing HIS development and implementation is the emergence of digital technologies and software platform-based innovations (Nielsen, 2017; Tiwana et al., 2010; Yoo et al., 2010). Even though developing countries are yet to be fully engaged in digital innovation explorations, the potential for the socio-technical generativity necessary for supporting the development of locally relevant solutions is identified (Eck et al., 2015; Msiska & Nielsen, 2018). The reason is that digital technological platforms are designed with the capacity to support innovations at core of systems development and also closer to the users and the use context (Henfridsson & Bygstad, 2013; Koutsikouri et al., 2018; Plantin et al., 2018; Tiwana et al., 2010). Developed on architectural principles of flexibility and modularity, and based on functionality development strategies such as through generification (Gizaw et al., 2016; Pollock et al., 2007) digital platforms are for example able to support general use cases and particular requirements through feature customisations (Bansler & Havn, 1994). The DHIS2 software which the research in this thesis centres on has platform capabilities (J. Braa & Sahay, 2017; Roland et al., 2017) and therefore was seen as part of the opportunities presented to support further exploration of innovative ways to addressing HIS challenges faced in the context under consideration.

2.2 The Innovation Concept in Research Literature

The word “innovation” has different connotations for different people, but according to Shah et al. (2014) the modern interpretation and popularization of it in research literature is attributed to the writings of the Austrian economist Joseph Schumpeter from the 1930s (Schumpeter & Backhaus, 2003). Schumpeter defines innovation as combining in new ways existing or new resources, knowledge, equipment and other factors with a commercial purpose. He stresses that it is the commercialization of the generated new ideas that differentiates innovation from invention and where the social agents involved are entrepreneurs (Shah et al., 2014). The entrepreneur is motivated to innovate due to the need to specialize and dominate a new industry. Thus according to Utterback (1971) the innovation process goes through three phases starting with ideation, problem solving (where invention occurs), and implementation and diffusion for the economic impact which realizes the innovation. General sources of innovation are identified to include changes that may occur in industry structure, market structure, local and global demographics, human perception, model and meaning, and in the amount of knowledge in the available scientific literature (Drucker, 2014). Within this innovation can disrupt or sustain established structures and can be radical or incremental in nature and impact (Bower & Christensen, 1996; Tidd & Bessant, 2020). Disruptive innovations eventually displace established incumbents with new products or services which create new markets or redefine an industry and thus more radical

in approach. Sustaining innovations on the other hand pursue products or services improvements to meet known needs of existing customers and to reinforce the dominance of established organizations and thus incremental in nature.

With particular focus on technological innovations, Henderson and Clark (1990) observes the need to go beyond the traditional impact categorizations such as radical and incremental to include architectural innovations and the impact on core design concepts, relationships between components, and the organizational capability requirements for success. In addition to this others observe the need to view innovations in the sense of connecting new problems to new and effective solutions (Cropley & Cropley, 2015). Broad solution types are identified to include product or service, process, position, and paradigm (Tidd & Bessant, 2020). Product or service innovations are things (i.e. products/services) organizations offer; process innovation is about changing the ways in which the things are created and delivered; position innovation is the changes in the context where the things are introduced; and paradigm innovation deals with changing the mental models that frames the operations of an organization. Regardless of solution type however, a recognized need, competent people with relevant technology, and financial support are identified as fundamental requirements to engaging in innovations (Reguia, 2014). Within these factors organizations may also adopt open or closed innovation process approach (Chesbrough, 2012; Huizingh, 2011). In closed innovations the innovation process and associated intellectual assets are tightly controlled internally, usually by a firm's research and development department. On the other hand in open innovations organizations purposefully permit inflows and outflows of relevant knowledge for the purposes of accelerating internal innovation and to expand markets for innovation outputs (Chesbrough, 2012). The openness usually involves exchange of knowledge and ideas between business partners, with customers, educational and scientific actors, and public institutions. In a world becoming increasingly globalized and interconnected, it is suggested that open rather than closed innovation practices can more likely to contribute to achieving both greater business successes and general socio-economic advancement (Eppinger, 2021).

2.3 Information Systems Innovation and Prevailing Challenges

Information systems represent the tools and means by which organizations and people collect, process, store, use, and share information (Berisha-Namani & Qehaja, 2013). Therefore a major focus in IS innovation research concerns the development and implementation of ICT-based systems and the organizational change expected in connection with the introduced IS solutions (Avgerou, 2008). In the development are goals of realizing IS designs and user requirements in solution artefacts, and the subsequent system adoption and use in the target organization covers the implementation (Hedman & Lind, 2009; Krishna & Walsham, 2005; McLeod & Doolin, 2012). The organizational change involves moving towards some desired performance improvement goals which is mutually intertwined with the IS innovation process in a dynamic relationship that is not necessarily linear nor technologically deterministic (Avgerou, 2008; Leonardi, 2009; Walsham, 1993). According to Nambisan et al. (2017) there are old assumptions

in the theorisation of IS innovation processes and outcomes that need clarifying. These are observed to be based on received theories in innovation management studies that are primarily focused on addressing three main questions namely; "how do innovations form and evolve", "how should actors or entities organise for innovation", and "how does the nature of innovation and organisation of innovation interact". The assumptions that need to be challenged in relation to these questions are that 1) Innovation is a well-bounded phenomenon focused on fixed products and therefore the question of how innovations form and evolve is a well-bounded question, 2) The nature of innovation agency is centralised, and therefore actors and entities can organise for innovation, and 3) Innovation processes and outcomes are distinctly different phenomenon, and therefore there is interaction between the nature and organisation of innovation that can be explicitly theorised (Nambisan et al., 2017, pp. 244–245). An indication is made concerning how the digitization of innovation processes and outcomes offer opportunities for challenging these assumptions (Kallinikos et al., 2013; Nambisan et al., 2017; Yoo et al., 2010).

According to research major challenges to IS innovation in organisations relate to funding, expertise, and technological capability (Fonstad & Mocker, 2020; Reguia, 2014; UNCTAD, 2021). Innovation requires investments in material and human resources as part of the inputs and these must be secured and sustained over time (Henfridsson et al., 2018; Nambisan, 2018). Often innovation initiatives go through series of experimentations with different ideas over longer durations without success guarantees nor return on investments (Tidd & Bessant, 2020). For organizations faced with resource constraints but must innovate to survive or conform to emerging trends (Swanson & Ramiller, 2004) there are risks of projects abandonment due to the possibility of funds drying out quicker than estimated. This can be seen in many IS projects in public sector contexts of developing countries where short-term funding schemes usually provided by international donor agencies introduce uncertainties about the long-term continuity of projects (Kimaro & Nhampossa, 2007). In many of such instances IS innovation project initiatives often end when the initial funding cycle ends and key actors and interests change (Heeks, 2002).

Information system innovation also requires expertise and knowledge of the problem domain as well as understanding of the technological systems involved. The need for expertise span the entire IS project life cycle starting from solution conception, design, implementation, use, and maintenance (Duarte & Costa, 2012; Hedman & Lind, 2009). In essence while an IS innovation may be new in the hosting organisation it does not necessarily have to be the case in the wider ecosystems of businesses or institutions. This means that the expertise needed for engaging in the particular innovation can be available externally if not internally. In such instances, the options include developing the capacities, employing personnel with the requisite expertise or procuring the services of consultants. For a resource-constrained organization, any of the options above can be challenging due to the associated investments requirements. In the case of choosing to locally develop the needed capacities this could for example require the creation of new teams and organisational re-structuring that require time and resources (Fonstad & Mocker, 2020).

Therefore in resource-constrained settings, difficulties in securing long-term funding can serve as stumbling block to engaging in innovation endeavours.

Technological capability is another challenge identified to impede engagements in innovations. This is about capabilities in technological solution creation and the ability of the environment to provide the necessary socio-technical infrastructures to support solution operationalisation and sustainability (Fonstad & Mocker, 2020). Technological capabilities are identified to vary across countries and organisations (Archibugi & Coco, 2004; UNCTAD, 2021). With respect to IS innovation for example, the relatively matured state of infrastructures such as related to internet services and electricity supply in developed countries are identified to give the public institutions in such contexts better technological capabilities than their developing country counterparts (Sood et al., 2008). Developing technological capabilities involves funding, expertise, time, policies and institutional structures to ensure proper functioning and sustainability. Therefore due to resource-constraints and associated factors prevailing in many developing countries contexts, weak to non-existent state of technological systems infrastructures, institutional voids and constraints, and unhelpful socio-cultural practices are for example found to impede meaningful engagements in innovations (Bhatti, 2012; King et al., 1994; Sahay, Nielsen, & Aanestad, 2018).

2.3.1 The Potential for ICTs to Boost Innovation Activities in the IS Field

The rapid growth and widespread deployment of ICTs are seen to present opportunities that can be leveraged to enhance capacities for engaging in IS innovations (Barrett et al., 2015). The ability for ICTs to support digitization of innovation processes and outcomes broadens participation in solution designs and implementation, enable wider accessibility, and presents relatively low innovation entry barriers to new comers both in developed and developing countries settings (Nambisan et al., 2017; Roland et al., 2017). The innovation boosting potentials of ICTs can also be identified with respect to the different roles they can play at various stages as well as forming part of the key components in the entire IS innovation value chain (Fichman et al., 2014). Starting from the innovation planning or discovery phase, knowledge about the relevant technology informs the solution designing and together with the requisite expertise and other resources serve as part of the inputs. In the execution phase, ICTs contribute to shaping the relevant innovation processes. Open-source ICT-based platforms like the DHIS2 central in this research are for example identified with the potential to open up innovation processes to broader participation (Roland et al., 2017), while propriety counterpart systems may close up and limit participation. At the output stage ICTs are also part of the innovation results which can be in the form of products, services, or processes (Tidd & Bessant, 2020).

More importantly, it is observed that ICTs by enabling broader collaboration in IS innovations can potentially enhance the capacity to explore appropriate linkages of resources and expertise towards more effective solutions-problems pairing (Cropley & Cropley, 2015; Nambisan et al., 2017). Such capacities can be particularly relevant for addressing problems of complex and dynamic nature where contingent and situated approaches to solutions innovation are needed

(Avison & Taylor, 1997; McLeod & Doolin, 2012). Due to the prevalence of resource-constrained conditions and environmental uncertainties in developing country contexts, complex and dynamic problem circumstances are also more likely to be encountered. For such a situation IS innovation approaches must be capable of adapting to changing circumstances and evolving user needs. The potential of ICTs to support addressing challenges and towards socio-economic development objectives in resource-constrained contexts is thus recognized (Avgerou, 2010; Heeks, 2010; Walsham, 2017). Nonetheless, there is also the need to subject the efficiency enhancing capacity of ICTs especially in supporting socio-economic development objectives to critical examination due to potential distortions and obstacles to realising the intended benefits. Towards this several researchers have pondered on the relevant questions such as whether ICTs are indeed contributing to building a better world (Sahay, 2016; Walsham, 2012). This is important to ensuring that ICT-based innovations are suitable for addressing core user problems, of contextual relevance, and able to meet functional and resource efficiency goals.

2.4 Conceptual Framework

The conceptual framing of the research in this thesis is based in theory concepts derived from frugal and digital innovation studies. This was first conceptualized as frugal digital innovation where digital technologies and other resources are combined and or recombined in frugal ways to create innovative products and services to solve problems, and supported by complementary institutional and social innovations (Sahay, Nielsen, Faujdar, et al., 2018). The technological innovation in this is the creation of new technical solutions from existing digital technologies composed of hardware, software and networks. The institutional innovation is in changing existing ways of organizing and doing things, and the social innovation concerns how the solution positively affects the lives of the target beneficiaries (Bhatti, 2012; Sahay, Nielsen, Faujdar, et al., 2018; Sahay & Walsham, 2014). As indicated earlier the motivation for the FDI conceptualization emerges from the need to shift the primary focus in innovation research from entrepreneurs, the creation of new business opportunities, and the leveraging of technologies in this respect (Schumpeter & Backhaus, 2003) towards addressing public sector and development-oriented issues (Nielsen, 2017; Sahay, Nielsen, Faujdar, et al., 2018). The emphasis on the need to apply a frugal mind-set to digital technology-based IS innovation is expected to effectively contribute to addressing the associated resource-constrained challenges. This framework is therefore adopted to guide the analysis of the innovation processes and outcomes in IS solutions explorations pursued and presented in this thesis. The frugal and digital innovation concepts forming the foundational pillars in this framework are thus introduced next.

2.4.1 Frugal Innovation

Frugal innovation is defined as creating innovative products and services that are affordable with design and function simplicity, and can be sustained and maintained within limited local resource situations (Bhatti, 2012; Zeschky et al., 2011). Frugal innovation is a perspective to innovation that emphasizes doing more and better with less resources (Ahuja & Chan, 2014; Bhatti & Ventresca, 2013; Sahay & Walsham, 2014). A more generic understanding of the frugal term is

described as being sparing or economical with the use of resources in meeting legitimate user needs (Pisoni et al., 2018; Weyrauch & Herstatt, 2017). The innovation aspect implies the creation of innovative products and services with same or better performance and functionality as offered by their high cost counterparts (Bhatti, 2012; Zeschky et al., 2011). For this Bhatti et al. (2018) for example identifies that on the axis of cost and performance, innovative products and services meet the frugal criteria when they can be located in high performance and lower costs quadrant. Similarly, Weyrauch and Herstatt (2017) suggest that frugal innovations must simultaneously meet three goals of substantial cost reduction, concentration on core functionality, and optimized performance level. Having a frugal perspective is thus important because innovations in general according to Tidd and Bessant (2020) are not necessarily easy, cheap or efficient. Yet the potential for supporting addressing needs across various economic segments of populations and towards promoting social inclusivity of marginalised communities in developmental activities is recognized (Zeschky et al., 2011).

Consequently, the different types of frugal innovations are collectively described as constraint-based innovations where the majority of the studies are carried out in developing economies, with the Indian context as the most studied according to recent surveys of the literature (Agarwal et al., 2017; Pisoni et al., 2018). In the same contexts other constraint-based innovations are characterized as disruptive, grassroots, indigenous, jugaad, bricolage, base of the pyramid innovations and many more (Agarwal et al., 2017). Among these notions, the emphasis on overcoming local resource constraints in solving problems and with rapidity can best be seen in jugaad and bricolage. Jugaad is about fast, creative, and improvised way of solving problems at lower costs (Agarwal et al., 2017), and bricolage involves applying or combining resources at hand in a “make do” fashion to meet new problems and opportunities (Baker & Nelson, 2005). Further, to build on the strengths of constrained-based innovations, technological systems are identified to be important in the sense of their ability to facilitating frugal explorations of solutions (Ahuja & Chan, 2014; Lim & Fujimoto, 2019). Of particular note is the potential of digital technologies to facilitate frugal ecosystem approaches in IS solutions exploration for the purposes of meeting affordability, simplicity, and sustainability goals (Ahuja & Chan, 2016).

2.4.2 Digital Innovation

Digital innovations are innovations that leverage the potential of digital technologies (Yoo et al., 2012). Ciriello et al. (2018) elaborate three key characteristics of digital technologies and how they change the nature of innovation. The first is that once information is digitized it can be transformed, transmitted, stored, and processed by other digital devices (Yoo et al., 2010). Secondly the ability to re-program digital information makes it editable and malleable from its original state so that it can interact with external systems (Kallinikos et al., 2013). Third and lastly the need for digital technologies in the creation of other digital technologies makes it self-referential and thus enabling high scalability and distributed participation in innovation activities (de Reuver et al., 2017; Yoo et al., 2010). This is best exemplified by digital platform technologies which by serving as foundational systems can enable new and derivative

innovations through their core-complementary architectural strategy and re-configurability (Henderson & Clark, 1990; Tiwana et al., 2010).

Digital innovations have gained recent attention in IS literature largely due to the pervasiveness and relative ease of accessibility to digital technologies (Lyytinen et al., 2017; Nambisan et al., 2017). However, to be able to unleash the full potential of digital innovations there are issues identified in the IS research literature that must be addressed. For example as earlier indicated, Nambisan et al. (2017) observes the need for theorizing digital innovation processes and clarifying fundamental assumptions such as concerning definitional boundaries, agency, and relationship involving the processes of innovation and the resulting outcomes. Sahay, Nielsen, Faujdar et al. (2018) are also asking questions about what constitutes digital innovations and how they can be materialized in practice within existing local and contextual conditions. Further issues relating to digital innovation examined in the literature include the need to identify avenues by which relevant actors can be mobilized to release the potential of digital technologies by engaging their material attributes towards meaningful contribution to organizational and socio-technical generativity goals (Lane, 2011; Msiska & Nielsen, 2018). This is especially relevant for the developing country contexts because as observed, digital technologies and innovations have largely emerged from developed countries contexts (Avgerou, 2001). Developing countries are thus mostly considered as fringe participants in digital innovations and seen mainly as implementation grounds, and used as sources of insights on systems adoption for the developed countries (Barrett et al., 2015; Msiska & Nielsen, 2018). Therefore it is important that new innovation conceptualisations that promote developing countries' engagements in digital technological innovations and towards the positive materialization of their social and economic development goals are explored (Nielsen, 2017).

2.5 A Frugal Digital Innovation Analytical Framework

In making sense of activities in my research project and for interpreting my empirical data, I draw on the frugal and digital innovation concepts, and the further shaping of these concepts for addressing IS needs in the formal and public sector institutional settings. Based on the innovation concepts identified to be relevant to the goals in this research an FDI analytical lens is derived. The particular focus is to identify and understand the prevailing local problems, contextual factors, and the innovation purpose orientation for achieving desired impacts. This includes an identification of the technological, institutional, and social innovations and enablers, as well as the intersections necessary to realizing and sustaining the expected outcomes (Sahay, Nielsen, Faujdar, et al., 2018). An analytical emphasis in this concerns the need to understand the nature of the relevant digital technologies involved in terms of their ability to not only support the creation of new technical solutions but also within frugal innovation principles (Ahuja & Chan, 2014; Sahay, Nielsen, Faujdar, et al., 2018; Yoo et al., 2012). Therefore the frugal innovation principle of doing more and achieving better outcomes with fewer resources is emphasized in the analysis for the purposes of achieving efficiency gains (Bhatti & Ventresca, 2013). For this, considerations that are identified to pertain at generic stages in digital IS innovations based on

Fichman et al. (2014) are also drawn upon to guide in the analysis. These include considerations at the discovery, development, diffusion, and impact stages where the first three correspond to Schumpeter's three-stage model of invention, innovation, and diffusion (Schumpeter, 1950 cited in Fichman et al., 2014). The analytical considerations at these generic stages are mapped to conceptual and actionable components identified in the current research project and in accordance with the adopted action research approach. These are illustrated in Figure 1 below and subsequently elaborated.

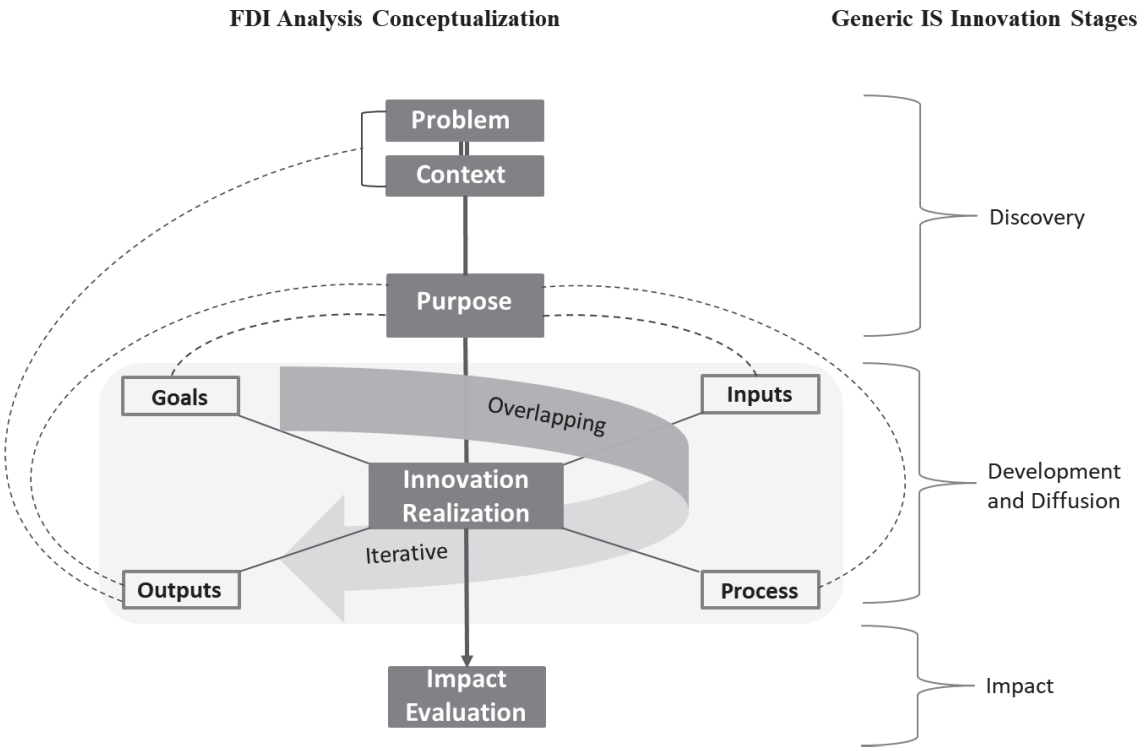


Figure 1: An FDI analytical framework in reference to generic stages in IS innovations

Understanding the Problem-Context Dynamics and the Innovation Purpose

The derived FDI analytical framework starts with defining the problem that need to be solved and the related contextual factors at play. In tandem, the purpose for the innovation is established through constructive engagements with solution beneficiaries and stakeholders, and for obtaining co-created problems and solutions narratives (Nambisan et al., 2017). This represents the diagnosis and planning phases in the action research process with consideration of factors pertaining at innovation discovery in the generic IS innovation process (Fichman et al., 2014). The focus here include a need to understand the nature of the core technological systems involved in terms of their ability to support the innovations necessary for addressing the

identified problem and in respect of frugal innovation principles (Bhatti et al., 2018) . In this framework the problem and context are taken together as mutually constitutive and interdependent components (Avgerou, 2001). Thus understanding the contextual factors should contribute better insights into the nature of problems and subsequently shape the solution designing appropriately (Avgerou, 2001; J. Braa & Sahay, 2012; Nambisan et al., 2017; Swanson & Ramiller, 2004). From these contextual considerations, factors, risks and potential mitigations to the challenges identified are mapped out. In establishing the purpose of the innovation, it is noted that the FDI conceptualization in principle is applicable to innovations with commercial and non-commercial purpose-orientation. But for the public health context under consideration the IS innovations in the long run are expected to support population healthcare improvements and towards socio-economic well-being of people. Thus the purpose of the innovations is to be understood in the non-commercial sense and the specific choices and decisions as inputs to the innovation realization are to be guided accordingly.

Innovation Realization

The innovation realization represents action taking or execution in the action research approach and corresponds to solution development and diffusion in the generic IS innovation process. This is based on four sub-stages that are identified to include the need to define the innovation goals, inputs, process, and outputs. As shown in in Figure 1 above, the innovation goals, inputs, process, and outputs must converge in support of the innovation purpose. In addition the outputs must address the IS needs and problems as well as address prevailing contextual factors for innovation viability. Based on the properties of the digital technologies involved these sub-stages are thought of as potentially overlapping and iterative (Fichman et al., 2014; Nambisan et al., 2017). Also, questions of what constitutes the digital innovation's core feature set, the potential use applications and the necessary complements must be addressed. In addition to this, barriers to solution deployment and adoption should be identified and mitigations proposed. From the FDI perspective the innovation goals must be based on short and long-term outlooks and in terms of achieving efficiency gains such as related to costs, functionality, and performance optimisation (Weyrauch & Herstatt, 2017). The necessary inputs to the innovation execution within the FDI framework must include digital and non-digital resources (Henfridsson & Bygstad, 2013; Nambisan, 2018). The appropriate level of innovation process openness (Chesbrough, 2012) necessary in terms of who can participate in what, from where and when should be determined and implemented accordingly. Lastly, the influence of the technological, institutional, and social innovation intersections in shaping system adoption, use, and support processes towards the innovation goals should be examined (Sahay, Nielsen, Faujdar, et al., 2018).

Innovation Impacts Evaluation

Finally, when the outputs from the innovation realization are put into use they are to be evaluated to ensure that they do indeed fulfil the needs of users and fit local contextual factors. Any

impediments to reaching the stated innovation goals should be resolved to maximize benefits (Fichman et al., 2014). This represents the evaluation phase in the action research process and also corresponds to the impact stage in the generic IS innovation process (Fichman et al., 2014). The evaluation covers outcomes at solution piloting, optimization, and scaling stages (Sahay & Walsham, 2006). In the FDI framework this includes evaluating the institutionalisation potential of organisational processes initiated and the ability to support the new innovations in becoming viable extensions of the established IS installed base infrastructure (Sahay, Nielsen, & Aanestad, 2018; Sanner et al., 2014). The innovation impacts are also evaluated based on the short and long term gaols and expectations. The opportunities created at the technological, institutional, and social innovation intersections are also examined based on the potential for supporting further local innovations and enhancement of long-term systems sustainability capacities. Summary definitions of the main theory concepts and terms contributing in the conceptual framing of this research are presented in Table 2.

Table 2: Definitions of the main theory concepts and terms

Theory concept	Definition	Reference literature
Innovation	Combining in new ways existing or new resources, knowledge, equipment and other factors for the successful implementation of creative ideas with a commercial purpose	(Schumpeter & Backhaus, 2003)
Digital technologies	Reprogrammable digital artefacts able to homogenize data and thus enable data storing, retrieving and sharing across digital systems	(Yoo et al., 2010)
Digital innovation	Innovations that leverage the material properties of digital technologies for re-programmability and data homogenization in creating new products and services	(Ciriello et al., 2018; Nambisan et al., 2017; Yoo et al., 2012)
Frugal	Being sparing or economical with the use of resources in meeting legitimate user needs	(Bhatti, 2012; Pisoni et al., 2018; Weyrauch & Herstatt, 2017)
Frugal innovation	Creating innovative products and services that are affordable with design and function simplicity, and can be sustained and maintained within limited local resource situations	(Bhatti, 2012; Zeschky et al., 2011)
Frugal digital innovation	Combining and re-combining different digital technologies into innovative products and services in a frugal way, along with building complementary intersections between technological, institutional, and social innovations to realising and sustaining outcomes	(Sahay, Nielsen, Faujdar, et al., 2018)

3. Research Context

In this chapter I describe the contexts that inform and shape my research activities. I identify these to be multi-layered with international and local dimensions. All these various contexts are also dynamic in nature and are produced based on historical and contingent factors. Both the international and local contexts are also constituted by technological, institutional, and social factors. My context as a researcher has three interconnected aspects and more internationally-oriented. This includes HISP which roughly defines the broader social context of my research and thus potentially shaping my research and contributions in line with the community goals and aspirations. The HISP node at University of Oslo and the larger University of Oslo constitute my academic and research institutional context. Then the DHIS2 which is the focal system of HISP activities represents part of my broader technological context. The context of the empirical case is local and also multi-layered with the relevant factors identified at country, health system, and HIS levels. The state of socio-economic development status and resulting living conditions form the local social context of the research. Below this is the healthcare system comprising of different sub-organisations, health programs, and other non-government and partner organisations representing the local institutional context. The country HIS implementation and the relevant infrastructures and actors exerting various influences on local IS projects and related activities are identified to form the local technological context. The DHIS is part of the local technological installed base infrastructure. The interrelationships between the different contextual layers and factors, and how these contributed to shaping my research activities are observed at the end.

3.1 The HISP Community Context

HISP is an international network of heterogeneous actors engaged in various activities aimed at improving health management and consequently better healthcare for individuals and populations across the world (Adu-Gyamfi, Nielsen, & Sæbø, 2019; J. Braa et al., 2004). Social development objectives related to healthcare improvements pursued through HIS research, development, and implementation by HISP forms my broader social context as a researcher and frames my research and potential contributions. It was within this social development focus and ambitions that HISP was initiated in the early 1990s to support HIS development, implementation, and related capacity building in South Africa as part of a post-Apartheid health sector reconstruction programme (J. Braa & Hedberg, 2002). HISP was established based on a collaboration between participants coming from the University of Cape Town and the University of Western Cape in South Africa, and a Norwegian PhD candidate from the University of Oslo in Norway (J. Braa et al., 2004). The founding of HISP was therefore based on research and development involving public health activists and IS developers where goals are pursued within participatory design and action research approaches (J. Braa et al., 2007). Participatory design is fundamentally user-centred with a focus on encouraging user participation in software development and implementation activities in addressing their concerns (Gregory, 2003). The action research emphasises on cyclical interventions in the research settings to accomplishing change while reflecting and learning from the change processes (Baskerville, 1999).

Today HISP is a global network constituted of independent HISP groups including for example HISP South Africa, HISP India, HISP Uganda, HISP at University of Oslo, and other Universities such as University of Dar es Salaam, and Universidade Eduardo Mondlane. The other actors in the network include but not limited to Ministries of Health, NGOs, global policy-makers, global donors, researchers, students, social entrepreneurs, individual consultants, and software developers. These form an organically growing and supportive ecosystem around the DHIS2 software where employment and professional career development opportunities are also provided. The processes and outputs from the community contribute towards social and economic development of the individuals and groups in the network as well as the participating countries. The focus of HISP however remains advancing scholarly knowledge and strengthening positive impact and sustainability of its action research interventions pursued within the public health sector and IS fields (J. Braa et al., 2004). The goals include organisational development, system design, scientific knowledge, and training (K. Braa & Nielsen, 2015). These are pursued through developing, implementing, and adapting the DHIS2 software to existing and new use-cases in local contexts. This includes improving the platform capacities of DHIS2 to interface and integrate with other systems and experimenting with new technologies. Capacity development goals are also advanced through Masters- and PhD-programmes at UiO and with partner Universities (Kaasbøll et al., 2019) and through DHIS2 Academies organized regionally and internationally. Despite the decades of HISP engagement in HIS software development and implementation and successes achieved by way of project scalability and sustainability, the work of HISP is best described as an ongoing process. This is partly due to opportunities emerging with new technological advancements, new use-cases and the continuous need to maintain and improve the DHIS2 software.

3.1.1 HISP at University of Oslo

The HISP group based at University of Oslo (HISP UiO) in Norway with which I am affiliated serves as part of the broader institutional context of my research. HISP UiO plays a core role in coordinating the HISP community and capacity building around the DHIS2 software and its implementations. The development, maintenance and innovation related to the DHIS2 software is coordinated by HISP UiO and within a distributed software development approach that enables participation of different software developers and users located in different countries across the globe (Roland et al., 2017; Titlestad et al., 2009). In connection with this, HISP UiO also manages an online community platform that supports interactions between the UiO team, ministries of health, donors, HISP-groups, system implementers, and third-party DHIS2 App developers. This online community platform is made up of a mailing list service for information dissemination, publicly accessible DHIS2source code repositories, a community forum where users can post and receive responses on issues, and an issue tracker mainly used by the software team to document, track and manage bugs, new requirements and features, and use cases. Participation in all these activities is enabled by institutionalized structures that are governed within community guidelines and protocols.

Apart from coordinating global HISP network activities, HISP UiO also provides country-level DHIS2 implementation support through technical assistance and research programme arrangements. It is through one of such arrangement that my researched project was conceived of and subsequently enabled my access to Sierra Leone's MOHS where my field research work was hosted and conducted. This was part of a collaborative HIS development and implementation support partnership arrangement involving three institutions, namely HISP UiO as the DHIS2 technical implementation support partner, the Global Fund as the funding agency, and the MOHS as the project beneficiary. The conduct of the actors in this partnership was guided by formal contractual agreements where my participation as a PhD candidate affiliated with the project was clearly indicated. Thus my research and activities were also guided within these formal institutional frameworks.

3.1.2 The DHIS2 Software Platform

The DHIS2 software, a second generation of DHIS version 1 that was started in South Africa (J. Braa & Hedberg, 2002) serves as the main software on which my research activities were centred and thus forms part of the broader technological context. The DHIS2 is a generic open-source software system with data warehousing functionalities and customizable modules for integrated health data management (J. Braa & Sahay, 2017; Sæbø et al., 2011). Activities supported include collection, storage, validation, analysis, transmission, and presentation of aggregate health data as well as patient and individual level data. Ministries of Health and NGOs in more than 100 developing countries use DHIS2 to support health management and other activities (Adu-Gyamfi, Nielsen, & Sæbø, 2019; Nicholson et al., 2019).

DHIS2 is a Java-based web application and compatible with major operating system platforms including Windows, Linux, Mac OS X and Solaris. It uses RESTful Web APIs and enables Java Scripting, CSS and HTML5 apps and is compatible with all major web browsers and runs on PostgreSQL, MySQL and H2 database systems. With a BSD licensing regime DHIS2 is made available as free and open-source with the code available and can be modified and redistributed freely. Applications such as OpenLMIS, iHRIS, OpenMRS are interoperable with DHIS2 and can also interface with third party systems and technologies including web portals, SMS and E-mail, and Geographical Information Systems (GIS) to enhance its functionality (J. Braa et al., 2010). DHIS2 mobile supports offline operations in areas with poor and fluctuating Internet connection based on HTML5, and SMS and Browser with Java-based clients. DHIS2 Android apps support offline data capture and analytic applications for data visualization and analysis.

Over time, the DHIS2 software has evolved from a single software product with a set of generic and customizable features into a software platform capable of hosting the development of different derivative software applications and service solutions (J. Braa & Sahay, 2017). As a software platform with stable core architecture and modules designed to vary (Tiwana et al., 2010) DHIS2 is able to support diverse functionalities and activities (Roland et al., 2017). This includes enabling innovations for new use cases outside the health domain such as for supporting public sector management of agricultural and educational services delivery and activities. Thus

the flexible adaptability of DHIS2 functionalities and ability to interface with other systems serve as a major factor enabling interventionary research activities where solutions can be explored while also learning from the processes to inform better subsequent actions.

3.2 The Sierra Leone Country Context

Sierra Leone is a country located in West Africa bounded by Guinea in the north, Liberia in the south and the Atlantic Ocean in the west. The country's population is reported to be just over 7 million per the last national census conducted in 2015[1]. According to a 2020 economic status review by the Committee for Development (CDP) of the UN (CDP, 2020) Sierra Leone is categorized as a least developed country. The CDP describes least developed countries as those within a low-income level group and confronted with severe structural impediments to sustainable development. It is also common that countries in this category experience extremely difficult situations where many pressing national needs compete for very limited available public sector resources. This is described in the literature as characteristic of resource-constrained contexts where an environment provides new challenges but lacks additional resources to meet those challenges (Baker & Nelson, 2005).

In Sierra Leone, the currently low level of socio-economic development can be traced back to several historical and recurrent events which have contributed and continue to have negative and disruptive effects. One of these was a 10 year civil war that lasted from 1991 until 2002. Another more recent incident was the Ebola disease outbreak in the country between 2014 and 2015. These events and together with perceived high levels of corruption and mismanagement of public sector resources have negatively affected all sectors of the economy. According to a development effectiveness review report by the African Development Bank[2] in 2015, about half of the population is reported to be living below the poverty line. In addition the country suffers from generally poor state of infrastructure and shortage of skilled labour. Based on data published by the World Bank[3] in 2018, life expectancy at birth in Sierra Leon was reported at 54 years and adult literacy rate was only 43%.

3.2.1 The Healthcare System

Sierra Leone has a pluralistic healthcare system where government, private sector, NGOs and faith-based organizations participate in healthcare service delivery across the country (ReBuild Consortium, 2011). Health services are delivered at primary, secondary, and tertiary levels. First line services are provided at peripheral health units (PHUs) which are sub-classified into Maternal and Child Health Posts (MCHPs) situated at villages, Community Health Posts (CHPs) at small towns, and Community Health Centres (CHCs) located at chiefdom levels. Secondary healthcare is delivered at district and non-governmental hospitals and lastly tertiary healthcare is delivered at regional levels and involving government and non-governmental hospitals.

[1] (www.statistics.sl)
[2] (afdb.org)
[3] (www.data.worldbank.org/)

The healthcare system in Sierra Leone was also severely impacted by the 10 year civil war. Other events contributing to challenges and negative impacts on the health system include a cholera outbreak in 2012, followed by the Ebola outbreak in 2014, and the damage to life and property caused by floods and mudslides in 2017 (Barr et al., 2019). During the Ebola outbreak, for example, it was reported that 6.9% of the health workforce in Sierra Leone died and the trust of communities in the healthcare system was also reduced (Mæstad & Shumbullo, 2020). The outbreak also exposed existing weaknesses in the health system linked to low availability of resources, poor coordination, and weak governance. Today the Sierra Leonean health system still faces challenges due to underfunding, high disease burden and insufficient health worker numbers, and with skewed health workforce distribution in favour of urban centres. The country health indicators are described as among the weakest in the world including high rate of maternal and under-5 mortality. Communicable diseases are identified to be the leading cause of death and morbidity in the country with malaria identified as the single biggest killer accounting for 38% of all hospital admissions (WHO, 2018).

Over the years, there have been many attempts by the MOHS and partner organizations to improve health services delivery and by extension the country health status (Herrick & Brooks, 2018). This includes the development and implementation of a National Health Strategic Development Plan (MOHS, 2017) that is expected to increase access and quality of essential health services to save lives, prevent diseases, and promote healthy living. In this, assistance from development partners is significant with technical and financial support from key actors including the WHO and other UN agencies. In addition to this, numerous local and international NGOs are providing a wide range of services and support in different areas of health service delivery through multilateral and bilateral arrangements (Barr et al., 2019).

3.2.2 Country HIS and Implementation Status

Following the civil in Sierra Leone in 2002, there were several concerted efforts that were initiated to develop the country health information systems and infrastructures. Beginning from 2006 the country was selected among a few countries to benefit from HIS development and strengthening project under the now defunct Health Metrics Network (HMN) in partnership with WHO (J. Braa et al., 2010; Kossi et al., 2012). During this period, the HIS was almost entirely paper-based therefore the HMN project focused on introducing computer-based tools into the national context from 2007 and onward. This project first targeted district level management of aggregate health data that were reported from the facilities on monthly basis. During this time HISP UiO was engaged to implement an electronic solution based on DHIS2 and also support the development of the needed local capacity for system use at national and district levels (J. Braa et al., 2010; Kossi et al., 2012; Tohouri et al., 2010).

By 2008, a national Health Management Information system (HMIS) based on DHIS2 was fully implemented across all 13 health districts at the time and at the national level. The district implementations were however deployed as standalone systems due to Internet connectivity challenges. Every month data entered into each of the district server instances would be extracted

onto portable media devices and transported to the national level for import into the national instance for analysis and reporting. At the same period a more granular data management system based on OpenMRS[4] for patient level management was also introduced by Jembi health systems[5] for HIV patient management at Connaught hospital. Jembi was part of the Open Architectures, Standards and Information Systems (OASIS) international project consortium that was collaborating with HISP UiO and others on the HMN project in Sierra Leone. Data interoperability based on SDMX-HD open standard was implemented for the OpenMRS so that it could share an aggregate of the patient-level data with the DHIS2-based HMIS (J. Braa et al., 2010).

The 2014 Ebola outbreak in the country also affected the HIS (Mæstad & Shumbullo, 2020). Data collection activities were particularly impacted at the local levels as substantial attention was focused on monitoring and reporting Ebola cases. In 2015 the HMIS at the national level also experienced total system breakdown which was attributed to human factors. An interdiction case (Public Service Commission, 2016) involving some key technical personnel at the Directorate of Planning Policy and Information (DPPI) , the unit in the MOHS responsible for all the HIS infrastructure, and resulted in the loss of the HMIS server. Consequently a new and cloud-based HMIS server had to be deployed from scratch and health programs integration processes reinitiated. With steady improvements in network connectivity over the years, the DHIS2-based HMIS is now centralized, online and fully accessible for data reporting and analysis across all the districts of the country. Yet the HIS in Sierra Leone still remains a combination of paper-based and electronic systems. For aggregate data management, data collection and collation at facility levels are predominantly paper-based. Electronic data entry usually starts from the district levels upward to the national level except in the case of the weekly-based Integrated Disease Surveillance and Response (IDSR) data reporting. The data for the IDSR is reported electronically from the facilities to districts for electronic approval and then made available for access in the HMIS at national level. In addition to this are health programs-specific electronic systems which are used for aggregate data management but are not feeding data directly into the national HMIS. This includes DHIS2 tracker piloting for HIV patient management at Connaught hospital and a laboratory information management system (LIMS) managed by the National AIDS Control Program (NACP). Others include human resource information system (HRIS), and a cluster of logistics management information system (LMIS) tools.

The national data reporting rates are considered to be satisfactory where for example; in 2017 the performance for primary healthcare facilities was measured at 98% timeliness and 80% completeness. Yet there is still room for improvements especially for hospitals which lag behind the primary healthcare facilities with 24% timeliness and 69% completeness for the same 2017 reporting year. Data reporting and integration also need to be strengthened for the various health

[4] (openmrs.org)
[5] (jembi.org)

programs including fully capturing data in communities through the work of community health workers. Addressing the data reporting and integration challenges requires the support of responsive socio-technical infrastructures and proactive management actions. In 2018 for instance, the HMIS was unavailable for two months due to server hosting subscription and related payment challenges. This seeming lapse in administrative procedures negatively affected the overall reporting performance for the year with respect to timeliness. Hence appropriate and well-coordinated governance strategies are also needed to effectively support continuous improvements in health data quality metrics and reporting at all levels of the healthcare system.

3.3 The Shaping of Research Activities by the Contexts

Within the contexts described my research activities were consequently shaped. For example the starting point of my research within the HISP network provided the international framework perspective based on best practices, knowledge, and experiences developed through decades of HIS research and implementation in countries (J. Braa et al., 2007). The lessons learnt and published from similar work in other countries and within the same Sierra Leone context at different times e.g. (J. Braa et al., 2010; Kossi et al., 2012; Sæbø et al., 2011) provided a preliminary and a tentative understanding into my research case. In addition to this, my affiliation with HISP UiO and University of Oslo where core HISP community activities are coordinated provided me the opportunity to gain a more rounded perspective of important issues that needed to be focused on. An important concern at the time was related to the need for improving local effectiveness of systems implementation and the requisite support capacities (Adu-Gyamfi, Nielsen, & Sæbø, 2019). This also included an appreciation of the general issues likely to be encountered in my research and what potential strategies could be employed in addressing problems. Examples of these were identified as hard to solve, and therefore recurrent problems with DHIS2 implementations such as related to internet connectivity challenges that require continuous explorations and strategies to effectively mitigate.

The dynamic nature of the research context based on the multiple and interrelated and constantly moving aspects however implied that developments and events were also characterized with some unpredictability and thus activities not always going as planned. Examples of changes in planned activities in relation to the research project are later described in the methodology chapter. The changes required that research activities were continuously adapted along with changing environmental conditions, actors, and interests. The nature of the country context affected the trajectory of events in the HIS development, implementation, and the related research activities. This included factors such as pertaining to national politics, onslaught of natural disasters, and funding uncertainties and thereby requiring adaptability in research activities. Thus analysis of outcomes in the research and interpretation of the findings are also shaped based on these influences at the multiple contextual levels and in view of the prevailing technological, institutional, and social dynamics.

4. Research Approach

In this chapter I present the research approach looking at the philosophical paradigm, how the research design unfolded and methods employed in the data collection and analysis. The strengths and weaknesses of the research approach are presented, and the chapter ends with ethical considerations. The research approach adopted in this thesis is action research (AR) as applied in the IS field (Baskerville, 1999). In this, AR principles proposed in canonical action research (CAR) based on Davison et al. (2004) are drawn upon. The research methods are based in the qualitative research traditions where words and representations rather than quantification are emphasised in obtaining and analysing research data. The aim in this is to understand and explain social phenomena involving people and taking into consideration the social and cultural contexts (Myers & Avison, 2002). In relation to this the analysis and interpretation of the empirical material in this thesis is guided by the interpretive paradigm as particularly applied to IS research in organisational settings (Walsham, 2006).

4.1 Paradigm and Epistemology

The interpretivist philosophical paradigm subscribed in this thesis identifies with the notion that reality is socially constructed and understood inter-subjectively (Klein & Myers, 1999). The epistemology within this paradigm is that it is only through conscious social constructions that we may gain knowledge of reality (Klein & Myers, 1999; Walsham, 1995). Therefore within the interpretivist paradigm my aim is to understand the research phenomena by the meanings assigned through language, documents, tools and other artefacts such as information systems (Walsham, 1995). Inherent in this is a focus on the full complexity of human sense-making in context as the situation emerges, meaning that dependent and independent variables are not predefined. Thus I seek to understand an emerging phenomenon involving IS in an organisational context where according to Walsham (1993) both the IS and the context are influenced by each other. In addition to this I consider the outcomes and findings from my research to be co-created based on researcher-participants interactions within the action research methodology. Hence to the extent possible multiple subjective realities and viewpoints are considered with regards to the IS innovations pursued. Although understood as co-created phenomenon there is potentially multiple interpretations of the processes and outcomes based on the actors involved and their different standpoints. These actors include system users, managers, partners and other relevant participants in the research case context.

4.2 Research Design

Since 2008 HISP has been involved in providing support for HIS implementation to the MOHS in Sierra (J. Braa et al., 2010). The support is provided through a collaborative partnership between the University of Oslo (UiO) and the MOHS and with funding support from the Global Fund (GF); a non-profit international donor organization set up to fight AIDS, Tuberculosis, and Malaria[6]. As indicated earlier my access to the project and participation in its field interventions

[6] (www.theglobalfund.org)

and research was enabled as a result of this partnership. This was arranged as PhD internship at the MOHS in Sierra Leone with the aim of providing technical DHIS2 implementation support while also using the project as the primary source of empirical data. Based on my prior involvement in DHIS2 country implementation work during my Masters studies with the same HISP UiO research team I had built adequate technical expertise and competence of practical relevance that could be of benefit to my research host. A total duration equivalent to 12 months was spent for field work in-country and was spread between the periods from June 2017 to November 2019. During this period I embarked on 4 separate field trips to Sierra Leone and was hosted at the MOHS by the DPPI and worked with the local HMIS team there.

Due to the formal, planned, and collaborative nature of activities in the research project and the potential for contributing to both practical and theoretical concerns, the research was designed to follow the AR approach (Baskerville, 1999; McIntyre, 2007; Rapoport, 1970). Therefore at the initial stages of the project the focus was on identifying the research problem that needed to be tackled and thus forming the basis of a tentative research proposal. In the adopted action-based research approach (Davison et al., 2004) this represented the problem diagnosis phase which was found to be HIS development, implementation and sustainability challenge. The practical problem focus was first narrowed down to a particular need for more efficient HIS to support HIV treatment in terms of facilitating client testing and monitoring adherence of patients undergoing antiretroviral treatment (ART). Considering the technological and financial resource limitations of the context the prudent approach was to build on the existing HMIS. The DHIS2 that is used as the HMIS software had platform capabilities and with customizable modules that could be tailored for the more granular patient level information management required in this project. Therefore working with the project implementation team we designed a solution based on the Tracker and Event Capture modules in the DHIS2 and named as ‘HIV patient tracker’. Subsequently this was implemented and analysed in one CAR (Davison et al., 2004) cycle covering problem diagnosis to solution piloting and evaluation.

After the first research cycle further implementation of the HIV patient tracker was stalled. The lack of progress was due to management changes at the national HIV program and at the MOHS in general resulting from changes in the government after the 2018 national elections. Added to this was lack of budgetary allocation for further implementation of the HIV patient tracker project. Due to this my research attention was redirected to activities involving routine implementation and strengthening of the national HMIS. This included both general and health programs-specific IS solutions innovations, implementation and integration activities. The research design at this stage followed a mix of intervention and case analysis of routine activities. Some intervention work such as integrating a logistics management information system (LMIS) data reporting functionality into the HMIS followed at least one definitive action research cycle. The other activities that were of more routine in nature related to HMIS configuration and systems strengthening which constitute the various aspects of the same research case and contributing to addressing the overall challenge of HIS development,

implementation strengthening and sustainability. The research case design and action processes are illustrated (in Figure 2) below.

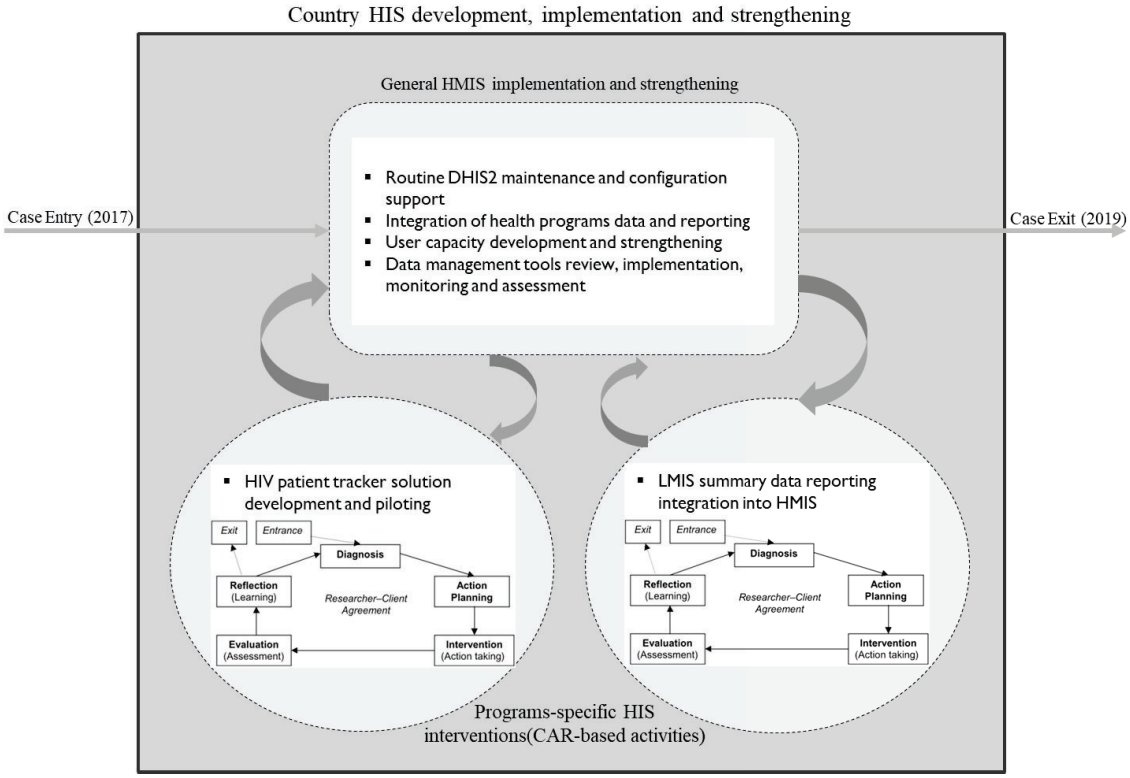
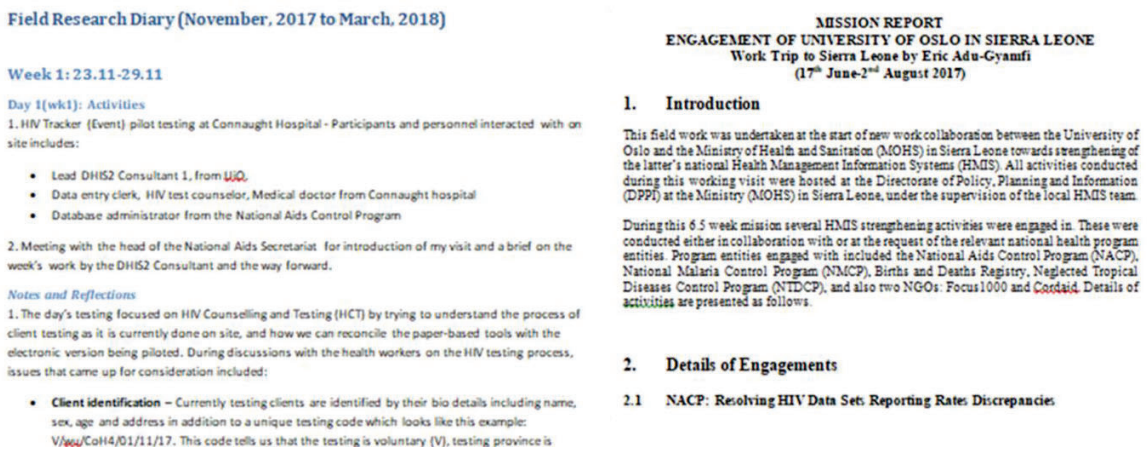


Figure 2: Defining the research project case and activities

The main data recording strategies I adopted included, taking notes, keeping a research diary and preparation of project status reports. When in the field I would take notes in meetings, workshops, discussions and in semi-structured interviews. These usually ranged from one-on-one discussions and to large group meetings, field visits, system configuration activities, and other engagements. There were times when opportunities were presented to probe further on some particular research interest with some research informants. Example of this was several semi-formal interviews I had with long-serving HMIS personnel at DPPI to understand how events had unfolded historically over the years. Some these HMIS personnel had been there from the beginning when DHIS2 was first introduced in the country and were involved in the initial activities of digitizing the paper tools, piloting and rolling out in all districts in 2008.



Field Research Diary (November, 2017 to March, 2018)

Week 1: 23.11-29.11

Day 1(wk1): Activities

1. HIV Tracker (Event) pilot testing at Connaught Hospital - Participants and personnel interacted with on site includes:

- Lead DHIS2 Consultant 1, from UiO,
- Data entry clerk, HIV test counselor, Medical doctor from Connaught hospital
- Database administrator from the National Aids Control Program

2. Meeting with the head of the National Aids Secretariat for introduction of my visit and a brief on the week's work by the DHIS2 Consultant and the way forward.

Notes and Reflections

1. The day's testing focused on HIV Counselling and Testing (HCT) by trying to understand the process of client testing as it is currently done on site, and how we can reconcile the paper-based tools with the electronic version being piloted. During discussions with the health workers on the HIV testing process, issues that came up for consideration included:

- **Client identification** – Currently testing clients are identified by their bio details including name, sex, age and address in addition to a unique testing code which looks like this example: V/aou/CoH4/01/11/17. This code tells us that the testing is voluntary (V), testing province is

MISSION REPORT
ENGAGEMENT OF UNIVERSITY OF OSLO IN SIERRA LEONE
Work Trip to Sierra Leone by Eric Adu-Gyamfi
(17th June-2nd August 2017)

1. Introduction

This field work was undertaken at the start of new work collaboration between the University of Oslo and the Ministry of Health and Sanitation (MOHS) in Sierra Leone towards strengthening of the latter's national Health Management Information Systems (HMIS). All activities conducted during this working visit were hosted at the Directorate of Policy, Planning and Information (DPPI) at the Ministry (MOHS) in Sierra Leone, under the supervision of the local HMIS team.

During this 6.5 week mission several HMIS strengthening activities were engaged in. These were conducted either in collaboration with or at the request of the relevant national health program entities. Program entities engaged with included the National Aids Control Program (NACP), National Malaria Control Program (NMCP), Births and Deaths Registry, Neglected Tropical Diseases Control Program (NTDCP), and also two NGOs: Focus1000 and Cordaid. Details of activities are presented as follows.

2. Details of Engagements

2.1 NACP: Resolving HIV Data Sets Reporting Rates Discrepancies

Figure 3: Screenshots of field research diary and status report

At the end of each day I would transfer my notes into a digital diary format describing the research activities engaged in and reflections. For a full duration of each field trip this would translate into about fourteen pages of typed notes. These would then be used to serve as guidance for further work and to inform my research problem investigation. In addition to this I prepared project status and activity reports at the conclusion of each scheduled field trip in Sierra Leone and shared with my project supervisors at UiO and the DPPI management at MOHS. Screenshot of examples of my field research diary and activity report is shown (Figure 3) above. Analysis of research data was therefore done on more routine basis to both understand project progress and to inform subsequent next steps of systems implementation such as moving from solution testing to pilot implementation in the case of the HIV patient tracker system. Further analysis was done during writing up of research papers based on the outputs from the study.

4.3 Action Research

Action research has its origins in the social sciences field where it is for example defined by Rapoport (1970) as a form of research that "aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework" (p.499). The thinking behind AR is that social processes are best understood when change is introduced into a particular social environment and the resulting effects thereof observed (Baskerville, 1999; McIntyre, 2007). Hence traditionally, AR in its various forms are identified as suited for studying and learning from organizational change processes (Baskerville & Wood-Harper, 1998), and where descriptive types of research questions may be more appropriate for guiding the investigations.

In the IS field the use of AR in scholarly investigations according to Baskerville (1999) gained popularity towards the late 90s. Its usage was seen to contribute to producing highly relevant research results. The key strength is identified in being grounded in practical action and aimed at solving immediate problems while also carefully contributing to theory (Davison et al., 2004). Nonetheless AR is also critiqued with for example a difficulty of balancing between action and

research where more often than not action gains primacy over research. Hence with a tendency where practice-oriented research projects may focus more on action and less on research AR is criticized as being just another type of consultancy work (McKay & Marshall, 2002). Therefore based on these observations I try to follow as much as possible the more rigorous AR processes identified in CAR and involves problem diagnosis, action planning, action taking, evaluation, and reflections (Baskerville, 1999; Davison et al., 2004). These processes are illustrated in Figure 4 below.

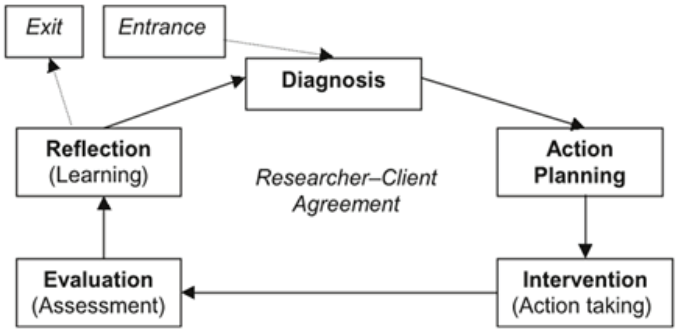


Figure 4: Typical canonical action research cycle (Davison et al. 2004)

4.3.1 Drawing from Canonical Action Research (CAR) Principles

In response to the criticisms raised against AR suggestions are offered for improving methodological rigor and enhancing the scientific merits including for example adhering to principles of the canonical form of AR (Davison et al., 2004; Susman & Evered, 1978). The 'canonical' term according to Davison et al (2004) became associated with the iterative rigorous and collaborative process-oriented model developed by Susman and Evered (1978) and became widely adopted in the social sciences and thus gained it a canonical status. In my use of the AR methodology I attempt drawing on five CAR principles as proposed by Davison et al (2004). In the table below (Table 3), I give a brief overview of the CAR principles based on Davison et al (2004, 2012) and examples of how these were applicable in this thesis.

Table 3: Description of the CAR principles and application in my research project

CAR Principle	Description	Example in this thesis
Researcher-Client Agreement (RCA)	Contains mutual guarantees for behavior between the researcher and client in the context of the project	Yearly HIS implementation support contracts were signed between MOHS and UiO
Cyclical Process Model (CPM)	Involves five stages of diagnosis, planning, action, evaluation, and reflections which the action researcher will typically follow in planning and executing the research project	One complete CAR cycle each was followed in two of the research projects (i.e. HIV patient tracker and LMIS-HMIS integration)
Theory	Theory is required in the framing of the focal problems and to guide intervention activities	Theory concepts including functional scaling and frugal digital innovation were used in framing research interventions and knowledge development
Change through action	Action is required to change the current situation based on the agreement that the actions are appropriate for the diagnosed problem	Paper-based HIV patient registers were digitized and moved into an online space for wider accessibility
Learning through reflection	Addresses implications for actions in the focal context, in similar research domains, and knowledge in the broader domain	Research papers were published during the project as outputs of the CAR cycles

The principles are in summary; researcher-client agreement (RCA), cyclical process model (CPM), theory, change through action, and learning through reflection. These principles and associated criteria are meant to be used by both researchers and reviewers to ensure and to assess rigor and relevance of CAR.

4.4 Methods

According to Orlikowski and Baroudi (1991) field studies are the most appropriate methods epistemologically for generating valid qualitative and interpretive knowledge. Within this paradigm knowledge validity is adjudged based on qualities such as credibility and authenticity of the supporting evidence, as opposed to for example verifying objectivity or replicability in a positivist paradigm (Munkvold & Bygstad, 2016). One way interpretive knowledge can be validated and was applicable in this research is through prolonged engagement in the research field (Creswell & Miller, 2000). During my reasonably prolonged fieldwork I got exposed to the plurality of perspectives from various research participants over time which helped in gaining better understanding of the study context.

In line with the interpretive field studies approach (Orlikowski & Baroudi, 1991) qualitative techniques (Silverman, 2013) were employed in gathering and analysing the research data. These

specifically included engagements in practical intervention activities, semi-structured interviews, field visits, observations, participation in meetings and discussions, analysis of relevant documentations, and photographs. Other tools included note-taking at capacity building events through on-site user training sessions and off-site workshops. The research data was then analysed hermeneutically through iterative consideration of the interdependent meaning of the various parts of the research case and the whole that they form which is the overall country HIS strengthening. For example in my case the implementation of the HIV patient tracker and LMIS data reporting integration into the HMIS could be considered as separate projects on their own but also parts of the whole country HIS development and implementation process and thus analysed accordingly. This was thus guided further within the hermeneutic circle co-principles of contextualization, interaction between researcher and researched, abstraction and generalization, dialogical reasoning, multiple interpretations, and suspicion (Klein & Myers, 1999).

4.5 Strengths and Weaknesses Perceived with the Research Approach

The perceived main strengths and weaknesses of my research approach are highlighted in this section. One of the key strengths identified is the grounding of the research in practical action with aims of contributing to solving practical problems and to theory development (Davison et al., 2004). In addition to this was the opportunity presented for engaging in the research case and staying on-site for a considerable length of time. This included the support received from local participants and their collaborative efforts in the activities that served as the basis of the empirical work. The weakness in relation to the research approach was that the canonical action research principles adopted could only be applicable to a certain degree. All aspects of the research project could not fit strictly into the CAR principles adopted although methodological diversities are also allowed within the different streams of action research approaches identified (Baskerville & Wood-Harper, 1998). For example CPM was followed as much as possible and RCA was largely arrived as deliverables in a rolling DHIS2 implementation support contract between UiO in Norway and the MOHS in Sierra Leone. This meant that local participants' interests were not so much focused on research outputs but on practical outcomes relevant for tackling their immediate problems and concerns. With this lack of research interest by the MOHS as the client organisation, the criticism that AR has a tendency to devolve into a type of consultancy work and thus affecting research rigour (Davison et al., 2004; McKay & Marshall, 2002) is identified as a weakness in this research project. However, the research publications produced are part of an attempt to mitigate this weakness and improve analytical rigour and contribution to theory. Furthermore, CAR is premised on repeated cycles and iterative follow-ups to resolving a defined and agreed upon problem specified for example in an RCA (Davison et al., 2004). But in this research project due to time limitation and lack of control on how event unfolded, two clearly distinct and definitive CAR cycles each could be reported; one for the HIV patient tracker implementation and the other for the LMIS summary data reporting integration into the HMIS. While this weakness is highlighting it is also observed that the individual stages in each of the CAR cycles involved cyclical and iterative evolutions that may be considered redundant to describe in this thesis presentation.

The qualitative interpretive field study methods used in this research are also recognized for their suitability in assisting researchers make sense of complex socio-technical processes emerging in a particular context (Orlikowski & Baroudi, 1991; Walsham, 1995). Health information systems implementation in organizational setting is also socio-technical multi-actor process and therefore best suited to be studied qualitatively. The weakness however is that being a highly contextualized and interpretive process, it is difficult to generalize the research findings more widely. Hence the knowledge proposition in this study approach also lacks predictive power and at best viewed as guidelines and principles for studying similar phenomena in similar contexts (Munkvold & Bygstad, 2016). Therefore where appropriate a mixed methods research approach may be able to address some of the weaknesses raised although this also depends on how events unfold in the particular research case context under consideration.

Additionally, observations are made with respect to the research approach adopted where action research is used in conjunction with hermeneutic circle analysis principles and technique, and within interpretivist paradigm. Primarily, the use of the hermeneutic circle principles in AR is informed by a relationship drawn based on the circular movements involved. This is in respect to the iterative nature of actions in AR and understanding gained through part-to-whole analysis in hermeneutics. In this sense AR produces results that are analysed hermeneutically to gain better understanding, and the knowledge in turn informs further actions that lead to better results (Smits, 1997). Also the qualitative methods and interpretive paradigm adopted in analysing outputs and results in this action-oriented research project provided an opportunity for deeper reflections. This involved looking at the dynamics involving social constructions in the research space, as well as understanding and leveraging the materiality of digital and non-digital ecosystem resources in solutions explorations.

4.6 Addressing Ethical Concerns and Challenges

The health sector is a sensitive area for IS research due to socio-cultural factors and also the possibility of a research coming into contact with personally identifiable data such as individual health records. In my case I have been careful in ensuring that my dealings with persons and data are within acceptable local and international framework of research ethics. In terms of data, I have largely been exposed to aggregate health data and reports that are accessible within the MOHS, by its partners such as WHO, UNAIDS, and the public at large. In the case of the HIV patient tracker implementation although the system configuration and testing were done at Connaught hospital, dummy patient data was used throughout that stage. To further secure the system against unnecessary exposure of patient information the configuration was done such that it was not possible to display the entire list of registered patients. One would have to enter a combination of patient demographic information to search for a specific patient registration in the system. Also, when it was time for piloting with real patient data the administration of the system was handed over to the NACP who had in place non-disclosure agreements to govern the conduct of their staff in terms of their handling of HIV patient information. According to NACP the non-disclosure agreement was instituted to deter negligent and deliberate disclosures of HIV

patient information due to the potential stigmatization and discrimination concerns. In fact I was informed of a prior incident of national data breach and unlawful publication of HIV patients' information. Therefore during this stage also only aggregate data that was publicly accessible was used in my research analysis and paper publication.

For my broader empirical work and during specific data collection events such as in interviews and research-focused discussions, I always explained to my informants about my status as a researcher and obtained verbal consents accordingly. The majority of my data collection events however were based on practical and participatory activities where I was not necessarily identified as a researcher. For such instances and all others I have employed anonymity and general descriptions of individuals' designations so that quotes and statements are not easily traced back to the actual persons. At the more official levels my dual status as PhD intern from the University of Oslo and also DHIS2 implementation support personnel were always clearly stated such as in contracts documents and at high-level management meetings. Hence my activities on the field were also as much as possible guided by such official designations and related expectations. Throughout my field work in Sierra Leone, I was often introduced as DPPI personnel especially when attending off-site and routine meetings and workshops as part of DPPI's delegation. In connection with such activities expenses in terms of transportation, feeding, and accommodation were borne by DPPI.

While I enjoyed good working collaboration with the local participants I also endeavoured to be circumspect and balanced in my dual goals of contributing to solving practical problems and advancing scholarly work at the same time. Towards these goals Davison et al. (2021) for example indicate that action researchers do not only have the ethical responsibility to develop competence in the domain area of the research topic but also should be able to persist with the project to its completion. The challenge here relates to exiting from an action research project that on the broader and higher levels is considered as still an ongoing process. In the face of uncompleted activities at the end of my official involvement in the case, the dilemma concerned balancing between providing continued HIS implementation support and focusing on finalising my PhD research. The strategy adopted in this situation was a gradual withdrawal from the case by focusing on completing the major pending activities while carefully avoiding taking up new major tasks. Nonetheless, minor support activities continued to be provided as necessary, and in maintaining mutually beneficial exchanges in relation to the research project.

5. Empirical Work

The empirical work in this thesis was conducted on-site in Sierra Leone and remotely from UiO in Norway as my academic institutional base. While my field work concerned a country-wide implementation of the national HISs I was primarily based at the capital Freetown in the Western Area Urban district. In addition to this I went on field research trips to Bo City in Bo district, Makeni in Bombali district, and Port Loko in Port Loko district. The map below (Figure 5) shows the locations of these four districts.

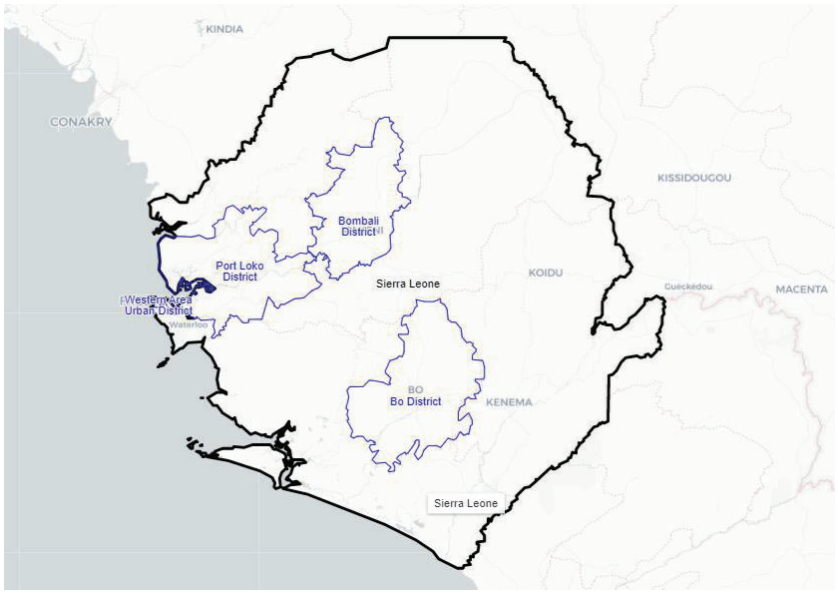


Figure 5: The four districts visited during my field research in Sierra Leone

5.1 Data Collection

The data collection process in the research case unfolded in three phases. These are covered by starting with my introduction to the research case at UiO in Norway and followed by four separate field research trips to Sierra Leone. Activities during each of the three phases are described into more details in the sections below. It should be noted that although presented in a chronological order the research and interventionary activities pursued did not unfold in a linear fashion. The research involved issues that needed to be revisited at various times and were characterised with back and forth processes involving technological, social, and institutional engagements.

5.1.1 Phase 1: Research Project Introduction, Intervention Planning and Start of Field Work

In September 2016 while in Oslo Norway and had just completed my Master's degree program, I was introduced to the possibility of participating in an AR project in HIS implementation planned to be carried out in Sierra Leone. Although there had been an ongoing support for DHIS2 implementation by HISP UiO in Sierra Leone (J. Braa et al., 2010), the work had largely focused on strengthening the HMIS in general. The current project was however, at least in the

initial stages, aimed at helping to address specifically information management challenges that were being faced with HIV case surveillance and patient management in the country. This had become an important issue to be addressed as part of national health systems recovery efforts after the Ebola disease outbreak in the country in 2014. As indicated in the previous chapter, the outbreak response moved attention away from all none Ebola related health issues and had negatively affected generally the national healthcare delivery system and particularly the HIV program (UNAIDS, 2015). Research activities at this stage focused on gathering and analysing data to inform initial diagnosis of the research problem. The empirical activities were based on available secondary data which included published research, official guideline recommendations on HIV case-based disease surveillance and treatment such as published by the World Health Organization (WHO, 2016), and other relevant country reports. This research phase was concluded with my PhD research proposal and a conference paper. Inefficiencies due to lack of integration of predominantly paper-based data management tools for HIV patient management in Sierra Leone was identified and a digital solution was proposed (Adu-Gyamfi & Nielsen, 2017).

Between June and August 2017 I embarked on my first field research trip to Sierra Leone. This was my introductory visit, and was planned to be relatively short and in a sense to serve as a toe dipping exercise into my PhD field work. This however by good fortune turned out to coincide with many empirically relevant activities including projects that were just starting to be rolled out. Project and research activities during this visit centred around aggregate data forms configuration in DHIS2 and participation in training workshops organized independently by Focus1000[7] in Freetown and then later in Makeni on facility digital data reporting system pilot, Cordaid[8] in Bo on data quality, and DPPI in Freetown on DHIS2 user introduction for the Malaria program. Details of the major activities are provided below.

HMIS Aggregate Data Management and Quality Strengthening Activities

The NGOs; Focus1000 and Cordaid were part of 'the Saving Life Project' a consortium that was funded by the UK government through DFID UK[9] as part of Sierra Leone's public health emergency recovery effort after the Ebola outbreak. In that partnership arrangement, Focus1000's responsibility was to support improvements in health aggregate data collection and reporting from health facility to district levels. Cordaid's responsibility was to strengthen data quality management by building capacities in the district health management teams (DHMT) for data verification, triangulation and analysis. Consequently I was invited to participate in a week-long data quality training workshop for all DHMTs organized by Cordaid and DPPI in Bo during which I was asked to give a presentation on DHIS2 features that can be used to support data quality assurance.

[7] (www.focus1000.org)
[8] (www.cordaid.org)
[9] (www.dfid.gov.uk)

Facility-level Aggregate Digital Data Reporting Project

Focus1000 as part of its responsibility to support facility aggregate data collection and reporting initiated implementation of an electronic and facility-based mobile data collection and reporting solution on behalf of DPPI during this period of my visit. This was expected to address some of the challenges associated with the paper-based data reporting system which were mainly logistical in nature especially with respect to travelling long distances just to deliver reports to the district office every month. The attendant costs include fuel for motor bikes, risks to personnel, risks to the paper forms in terms of potential loss or damage, and health worker time lost to traveling. The Focus1000 solution therefore was to enable health facility workers to record and transmit aggregate data remotely to the districts and into the HMIS. The solution consisted of tablets provisioned with internet and based on open data kit (ODK)[10] and ONA XLSForm[11] templates. The ODK was installed on Android mobile devices while the ONA served as a mediating server system between the ODK and DHIS2. From health facilities data was transmitted to the ONA server, validated by the district team and then pushed to DHIS2 through an electronically integrated web interface. The system solution configuration showing the different setups at facility, district and national levels as well as upstream health data reporting and downstream configuration data flow is illustrated in Figure 6 below.

During this weeklong activity I participated in the pilot training preparation session in Freetown and later in the pilot initiation and training on site in Makeni (See figure 6). I also had the opportunity to interact with the solution consultant from Bluesquare[12], an organization based in Belgium, as well as Focus1000 personnel and trainees.

[10] (www.opendatakit.org)
[11] (www.ona.io)
[12] (www.bluesquare.com)

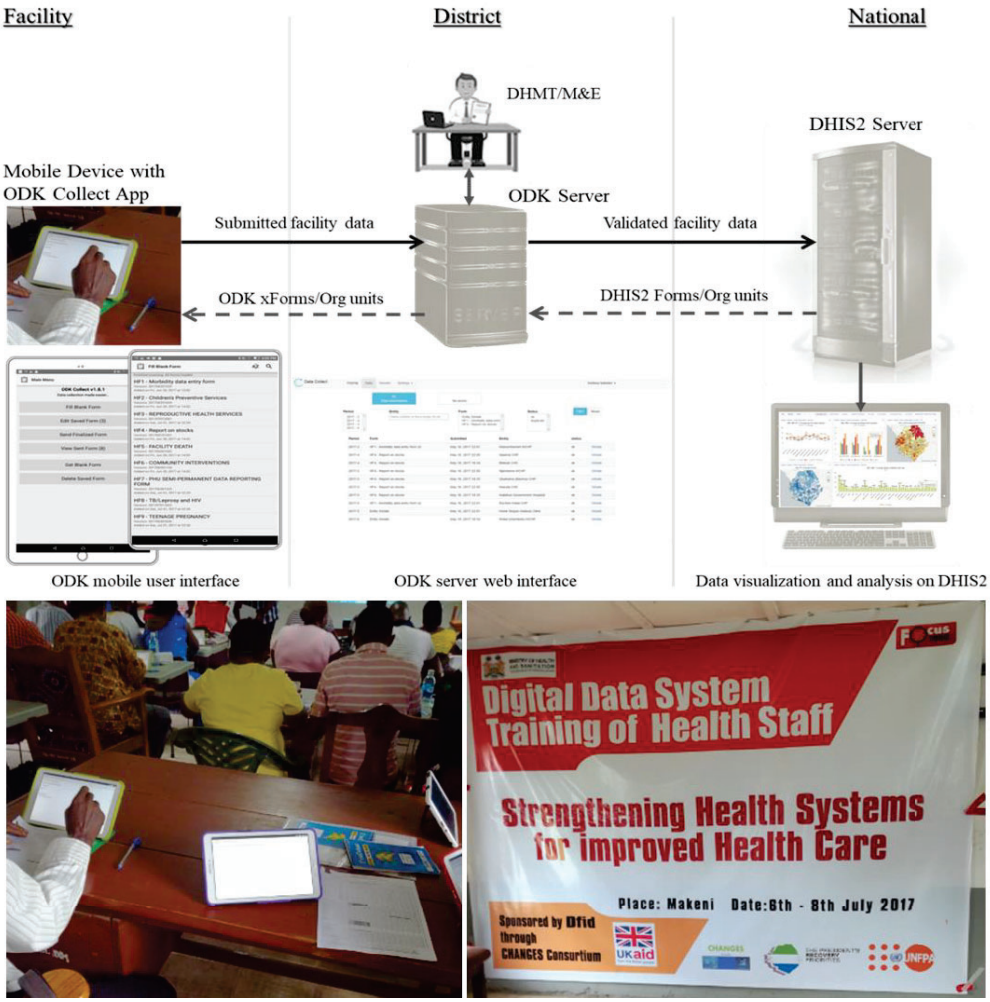


Figure 6: Facility digital data reporting system, pilot launch and facility health workers training workshop held in Makeni in the Bombali district

HIV Patient Tracker Implementation: Preliminary System Design in Oslo and Testing in Freetown

After returning to Oslo from my trip to Sierra Leone a team of HIS researchers and implementers from HISP UiO in October 2017 visited Sierra Leone to gather requirements and finalize initiation plans for the start of the HIV patient tracker project implementation. In Sierra Leone, they met with the primary project stakeholders which included DPPI, NACP, the National Aids Secretariat (NAS), and visited 3 hospitals in Freetown (Connaught, Ola During, Princess Christian Maternity-PCMH). At the hospitals they interacted with HIV counsellors, ART nurses, medical doctors, and reviewed existing data management tools as part of system implementation requirements gathering. Upon their return to Oslo in November, a weeklong system implementation planning and solution design workshop was held in which I participated. They shared their findings from the trip along with system experts presenting experiences from similar projects that were being implemented in Palestine, South Sudan, and Uganda to inform the

current solution design. A preliminary system design was produced (Figure 7) and a DHIS2 test server instance was set up for system configuration and testing. The solution was also discussed in an online session with WHO representative team in Geneva to solicit their feedback in terms of meeting their guideline recommendations on HIV program management (WHO, 2016). The need for feedback from WHO was because the solution design was also part of an effort to produce DHIS2 standard configuration packages for WHO such that countries could adopt and implement (Poppe et al., 2017).

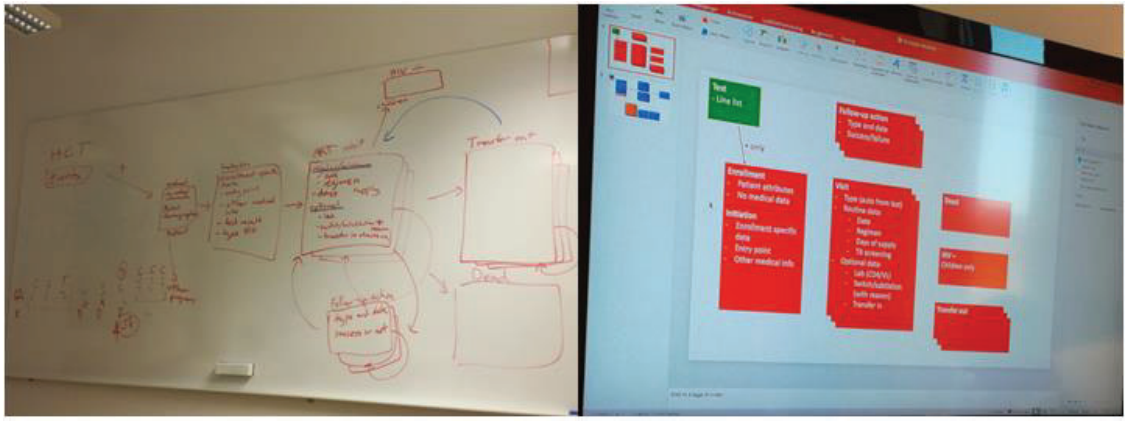


Figure 7: HIV Patient Tracker design workshop held in Oslo, Norway (November 2017)

Later the same month, I went back to Sierra Leone for further field work in connection with the HIV patient tracker project initiation. The selected site for system configuration and testing was the HIV clinic at Connaught hospital located in the heart of the capital Freetown (See Figure 7). This on-site system customization activity was led by a DHIS2 consultant from UiO, with participation of NACP representative in charge of the program's database management, a medical doctor, and a data entry clerk. I participated in the customization activities where HIV counselling and treatment (HCT) and ART paper registers were digitized using two software modules; Event Capture and Tracker Capture in the DHIS2. After this the solution was presented to three clinical staffs and the NACP representative (i.e. the program database manager) for their feedback. The system user testing was done with two tablet devices that were provided by UiO and provisioned with Google Chrome browser. Internet connectivity was obtained through a wireless network router located in the Doctor's office where we digitized the paper registers (See Figure 8). I then prepared a user guide each for the two program modules (i.e. HCT and ART) and shared with the users and afterwards remained in-country to provide technical support.

The summary description of this first phase of the research was a mix of planned intervention work and routine HIS strengthening activities. The intervention work involved digitization of the HIV program registers and online testing with dummy data at Connaught hospital. The routine activities involved events which contribute to understanding more broadly the dynamics of the HIS implementation and strengthening in the research context.

Figure 8: Digitizing the HIV Registers at Connaught hospital in Freetown, Sierra Leone in November 2017-(In the photo: JM and I working from Connaught hospital)

5.1.2 Phase 2: Second Round of Field Work and Data Collection – 2018

My field work continued in 2018 from January till March. Data collection activities centred on further work on the HIV patient tracker implementation, initiation of work to integrate LMIS data reporting into HMIS which was planned in late 2017, and integration of other health programs' data into the HMIS. Detailed descriptions of activities are presented as follows:

HIV Patient Tracker System Testing and Pilot Initiation

Still focusing on the HIV patient tracker system implementation I made three visits to Connaught hospital with the NACP personnel overseeing the project to follow-up on the solution testing. Through interactions with the doctors, counsellors and nurses at the clinic the challenges were related to system features that needed to be improved. These included increasing the number of tablet devices as well as the need to explore offline system usage capability as there were problems with reliable internet service provision. It was for example reported that the wireless internet at the doctors' office that was being used for the system testing was experiencing frequent outages due to equipment failure and funding challenges for internet service subscription. In March 2018, a first project implementation update meeting was held at the office NAS involving 23 participants from NAS, NACP, NGOs, and partners (See Figure 9). At this meeting I presented the solution design and the issues pertaining to the ongoing testing at Connaught hospital.

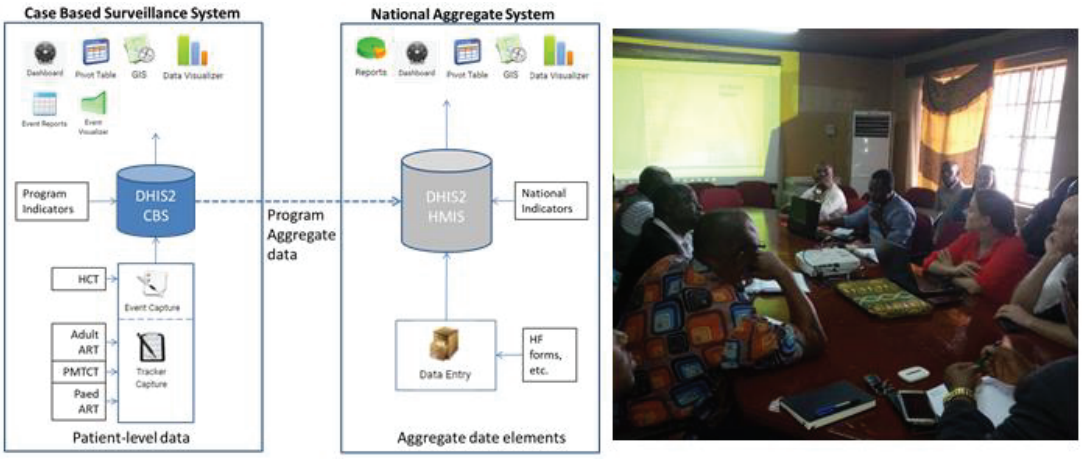


Figure 9: Presenting the HIV Patient Tracker solution design and implementation update at NAS in Freetown (In the photo: myself and HIV program and partner organizations representatives)

After the project status briefing, together with the NACP project representative we visited two other hospitals, Ola During and PCMH as part of feasibility assessment for expanding the system testing to include these facilities. Ola During hospital serves paediatric (children) HIV clients while PCMH provides prevention of mother to child transmission (PMTCT) services to pregnant mothers. The aim was to explore inclusion of the paediatric and PMTCT services in the system testing which had only focused on adult ART services. Through semi-structured interviews we interacted with seven clinical staffs stationed at four different sections of the hospitals and involved in HIV testing and ART management. I collected data through notes and photographs of paper tools used for patient management. In May 2018, when I had left the country a member of our UiO project team visited and provided on-site refresher training for the users at Connaught hospital and then initiated system piloting with real patient data. This was followed by a second system implementation update meeting with 19 participants from NAS, NACP, DPPI, NGOs, and partners. Further pilot scale up feasibility assessment report based on visits to eight additional health facilities and interaction with 40 clinical staffs was also presented. Research activities relating to the HIV patient tracker implementation formed one complete CAR cycle and this is summarized in Table 4 below.

Table 4: One Complete CAR Cycle involving the HIV Patient Tracker Implementation

CAR Phase	Activity	Output
1. Problem diagnosis	○ Introduction to the research problem and meetings with my PhD supervisors to define the scope of work. ○ Review of relevant research literature and project related documentations to inform the problem diagnosis. ○ System requirements discovery field trip to Sierra Leone	- The research problem was defined as lack of centralized and widely accessible patient HIS for the HIV program. - Conference paper was presented at 2017 IFIP WG 9.4 on the state of the HIV patient management in Sierra Leone, and proposed a digital solution - HIV patient IS implementation support contract was signed between UiO and MOHS as part of RCA
2. Action planning	○ Solution design conceptualization, customization and implementation planning with roles assignment in Oslo, Norway	- Preliminary solution design and configuration specifications based on DHIS2 Event and Tracker capture was proposed - System implementation plan with roles and responsibilities and infrastructure needs were defined
3. Action taking	○ Setting up of testing platform and production server ○ System customization and testing at Connaught hospital and user documentation development ○ Training of users and initiating system piloting with real patient data	- HIV registers were customized in DHIS2 for testing - Two system user guides; one for each system module (Event and Tracker capture) were prepared and delivered to the users at Connaught hospital - Production DHIS2 instance was set up with dashboard reports for monitoring aggregate patient data entries
4. Evaluation	○ System design, testing, and project implementation review meeting and reporting ○ Solution pilot implementation and review meeting and reporting ○ Pilot scale-up feasibility assessment at additional health facilities	- Improved data quality in the pilot phase compared to the aggregate reporting system in the same period - Proposed system pilot implementation scale-up plan
5. Reflection	○ Writing up and reflecting on the work done, the practical results and the research findings	- Conference paper was presented at the 2019 IFIP WG 9.4 on the successful scaling of HIS functionality from general to specific use case

Initiation of Work on LMIS and Other Health Programs Data Integration into the HMIS

In addition to the HIV patient tracker pilot testing there were other more general HMIS strengthening activities I got involved in. The empirical work involved participation in workshops, meetings, and discussions. This included a two-day national consultative workshop that was held in Makeni in January 2018 to discuss feasibility and implementation roadmap for integrating LMIS data into the HMIS. This was organized by DPPI and the Directorate of Drugs and Medical Supplies (DDMS) which is in charge of health logistics management under the MOHS. In attendance were over 100 participants and stakeholders including MOHS directors, program managers, district health management teams, medical doctors, pharmacists, M&E

personnel, and partner organizations representatives. At this meeting a vision of integrated and harmonized national HMIS and LMIS platforms was defined. Major project activities and intermediate steps towards achieving key milestones with timelines and responsibility matrix were also identified spanning from January 2018 till June 2019. A broader LMIS and HMIS integration envisioned was to start with incorporating logistics data summary reporting called RRIV (Report, Request, and Issue Voucher) into DHIS2 which is used as the HMIS software. At this workshop I also presented a DHIS2 solution prototype I had developed for the RRIV data reporting to demonstrate project feasibility. In addition to this there were many presentations, breakout sessions, and informal exchanges which presented many opportunities to engage in research data gathering.

Additional activities contributing generally to the case during this phase also included participating in monthly national monitoring and evaluation (M&E) and HIS technical working group meetings organized by DPPI. I attended three such meetings during this period. There was also a workshop held by Focus1000 to review progress of the mobile data collection project piloting that was initiated during my first field visit to Sierra Leone in June 2017. The performance of the pilot was deemed satisfactory based on the project team's assessment as data reporting rates saw significant improvements compared to the legacy paper-based reporting system. Further, I also engaged in HMIS aggregate form review sessions for NACP, Nutrition, Community health workers (CHW), and participated in DHIS2 training sessions organised by DPPI. The main highlights of this research phase in terms of planned intervention work were pilot initiation of the HIV patient tracker and initiation of work on the LMIS data reporting integration into the HMIS.

5.1.3 Phase 3: Final Field Work and Data Collection – 2019

In January 2019, I returned to Sierra Leone for further field work and stayed until April the same year. Research activities again focused on the HIV patient tracker implementation and general HMIS and related activities. The LMIS (RRIV) data integration into DHIS2 was also significantly advanced during this field work. Research activities involved participation in meetings, workshops and system configuration activities. Details of activities engaged in are described as follows:

HIV Patient Tracker Pilot Follow-up

The HIV patient tracker piloting at Connaught hospital was found to be faced with challenges due to project organization, the technology, and funding. Hence in the first week of my visit I met with the NACP project coordinator to draft a work plan of activities that would cover the period of my visit with the main highlight focusing on addressing the pilot challenges at Connaught and then scaling up of the piloting to include more health facilities. The proposed plan was discussed with the NACP program manager, the Director General of the National Aids Secretariat (NAS) and later in a general meeting with the wider HIV program and their consultants. The activity plan was also submitted to DPPI so that it would be factored into the overarching country HIS strengthening work plan and systems integration roadmap for the

MOHS. Previously the plan was to extend the system piloting to some selected health facilities located in the Western Area districts. Pilot feasibility assessment had already being carried out at eight facilities during the previous year and requirements for computer devices and internet connectivity had been documented. However due to resource availability challenges and lack of clarity on project funding the program decided to reprioritize district hospitals for the pilot expansion phase. They had provided internet services and computer devices to their personnel at district hospitals and saw it prudent to utilize these to also support the Tracker implementation.

But before proceeding with the new work plan, the Tracker solution had to be presented once again in a general meeting with the NACP program as some of the new management team members including the program manager, the ART coordinator, HIV Doctors at Connaught hospital, and program consultants were not familiar with the purpose or the importance of the system. With the local NACP Tracker project coordinator we presented a brief historical background to the project, the solution architecture, modules and functionalities, and implementation progress. We tried to clarify the importance of the system in terms of how it can support care givers to improve HIV patient management and monitoring. From programmatic point of view we highlighted the potential for the solution to improve quality of data reporting and analysis. Again another meeting was held at a later date to demonstrate the solution to program coordinators and consultants for them to have practical appreciation of the system functionalities.

During yet another general meeting at NACP the HIV counselling and testing coordinator at Connaught provided a situation update and challenges that have stalled the ongoing Tracker piloting at the clinic. The main challenges were lack of internet connectivity and inadequate number of mobile devices which posed difficulties for continuous system access and use. These were the same issues that had been identified previously but had not been adequately addressed. On the organizational side the coordinator also explained that previous care delivery set up of a patient being attended by different caregivers sequentially coupled with the inadequate number of devices made it difficult to use the system. Patients were seen starting from the reception, counselling, testing, doctor examination, ART enrolment, and drug dispensing. As a result the clinic had been reorganized to improve service work flow and also support use of the tracker system going forward. Still another challenge was raised concerning the need for continuous user training due to high staff turnover. It was for example observed that majority of the clinical staff at the time was not familiar with the Tracker system as they were newly employed.

In the weeks following the project update meeting, together with the NACP Tracker project coordinator we paid four separate visits to Connaught hospital in connection with the piloting of the Tracker system. During the first visit we were taken through the new care delivery set up at the clinic and at the same time conducted needs assessment for strengthening the system piloting. With the new setup, there were two adjacent rooms for counselling and testing, three separate dispensary rooms, and 1 room for lab. Based on this at least five tablet devices were needed at the various care points. Also to improve internet accessibility at least two mobile internet

modems were required. Alternatively it was also suggested that wireless routers/repeaters could be installed to extend the existing Wi-Fi internet signal from the doctor's office to serve the entire clinic. From there we also visited the national HIV lab (Viral Load Measurement Lab) at Lakka. We went there to assess a new IT infrastructure being rolled out for the HIV program's laboratory information management system (LIMS) and the possibility of leveraging the resources there to also support the Tracker system implementation.

On the second visit to Connaught we met with representatives of an international NGO called King's College London's Sierra Leone Partnership (hereby referred to as Kings SL) stationed at the hospital and providing healthcare delivery assistance (Herrick & Brooks, 2018). Kings SL had stepped in to support the Tracker piloting with internet modems, service subscription and IT personnel and needed some clarifications on system design and further requirements to enable efficient resource utilization at the clinic. Based on this meeting Kings SL, the resident HIV doctor, and the NACP Tracker project coordinator agreed that we conduct refresher training for the HIV counsellors and ART nurses of whom some were new at the clinic and to the Tracker system. Thus on subsequent visits we conducted two separate hands-on training sessions for the clinical staff with a representative of Kings Sierra Leone also in attendance (See Figure 10). Further, a request was sent by NACP to DPPI for the release of tablet devices to support the pilot scale up. DPPI made available three of these tablet devices for use at Connaught but could not release more devices for long-term use by the HIV program due to other usage plans. Subsequently in a meeting with Global Fund (GF) the HIV program was tasked to cost the Tracker pilot scale-up implementation including purchase of mobile devices and submit a budget for consideration. A proposed budget covering 73 sites was then submitted to the GF team for the pilot expansion funding consideration and 25 facilities were prioritized based on ART case-load.

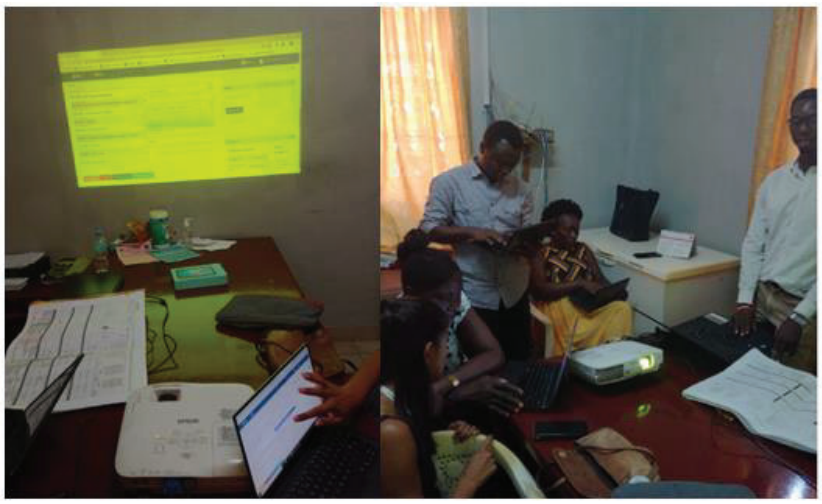


Figure 10: DHIS2 user training with HIV healthcare personnel at Connaught hospital

LMIS Data Reporting Integration into HMIS: Configuration Finalization and Pilot Initiation

As part of the ongoing activities to integrate the RRIV forms into the HMIS this phase of my field work involved the customization of 27 forms in total in the DHIS2. This work was an expansion on a prototype earlier developed and presented at a joint LMIS-HMIS integration workshop that was held in Makeni in January of 2018. The 27 forms break down into nine distinct forms for each of the nine different logistics health programs reporting a set of RRIV data. The forms are further differentiated by the three different levels of care based on health facility types which are 1) *Hospitals* 2) *CHC (Community Health Centres)* and 3) *MCHP-CHP (Maternal and Community Health Posts)*. At each level of care (or facility type) the lists of health commodities supplied vary accordingly hence the need for three different data sets for every program. On every form (see e.g. Figure 11 below) there are eight data entry columns namely: Opening Balance(A), Quantity Received(B), Losses/Adjustments(C), Quantity Dispense(D), Closing Balance(E), Days Out of Stock(F), Maximum Stock Quantity(G), and Quantity Needed(H). The inputs in fields G and H were made to calculate automatically based on defined formulas. All the forms have similar interface and same layout as the DDMS paper form with the aim of facilitating ease of data entry.

DPPI together with DDMS held a two-day DHIS2 user training workshop for pilot initiation of the project which was attended by logistic management personnel from the districts and central levels. This was supported by partner organizations such as the President's Malaria Initiative (PMI) and Clinton Health Access Initiative (CHAI). The forms were revised in the DHIS2 based on modification request submitted by CHAI on behalf of DDMS. In March 2019, pilot use of the DHIS2 RRIV forms was launched by DDMS in four districts (Bo, Bombali, Port Loko, and Kenema). The users were able to complete monthly data entries within the existing HMIS reporting deadline of the 15th day of the month for the previous month's data. By November 2019, the DHIS2 solution pilot had been extended to cover 13 out of the then 14 health administrative districts of the country.

Three different evaluation exercises were conducted during the pilot period. Two were one-off assessment activities while the last one was a routine monitoring and evaluation process. Right after initiating the piloting a USAID global health supply chain (GHSC) program[13] conducted an LMIS systems review and assessment on behalf of the National Malaria Control Program (NMCP). The purpose of the GHSC assessment was to improve LMIS reporting for Malaria commodities by looking at data flow and integration, key performance indicators, gaps in standard operating procedures, and the pilot LMIS data (i.e. RRIV) integration into DHIS2. The GHSC assessment team met with key stakeholders at central levels including myself and in the four districts that were piloting the solution. Findings from the assessment relevant to the DHIS2 solution pilot are summarized as strengths and weakness. The main strength of the solution was highlighted as being able to help in improving data entry time due to a friendly user interface and

[13] (www.ghsupplychain.org)

closely modelled after the paper forms. A major weakness was identified as lack of data validation features as this can have negative implications for effective data quality monitoring.

The second evaluation was part of a broader country level HMIS assessment exercise conducted by a team comprised of HISP group members based at the University of Oslo in Norway and HISP West and Central Africa. I was included in the assessment team. During this exercise we met with the DDMS team and the various health programs participating in the DHIS2 RRIV data integration project. Generally, the stakeholders found the data entry functionality of the solution to be satisfactory but needed further feature improvements such as needed for data validation, analysis and reports visualization. A document containing a list of all improvement requests was received and shared with DPPI for further action. Some of these feature improvements would also address many of the weaknesses that were identified during the GHSC assessment. In addition to this was the more routine pilot monitoring and performance evaluation conducted by the LMIS TWG. From the time the pilot was initiated the TWG had been following up and addressing challenges such as related to internet service provision, data reporting timeliness and completeness, data quality, and general system usability support. For example the team's monthly pilot data analysis showed that the overall average reporting rate for the pilot period remained above 80% which is an improvement from a performance of 70% and below with the previously fragmented system of data reporting. In Table 5 below I present a summary of the LMIS data integration into DHIS2 as one full CAR cycle.

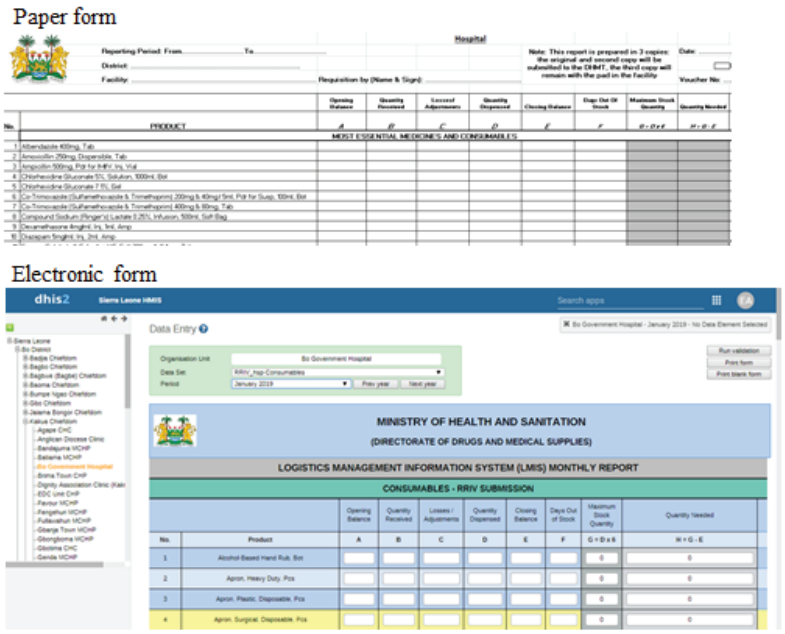


Figure 11: RRIV (LMIS) data reporting forms customization in DHIS2

Table 5: CAR cycle for LMIS-HMIS integration

Stage	Activity	Output
Problem Diagnosis	○ Review of the relevant project documentation including integration concept note and learning from prior case context engagements	- Problem identified as lack of common LMIS data reporting system and a single reporting interface to be based in the HMIS proposed as a solution
Action Planning	○ 2 project kick-off meetings in Freetown and 2-day national consultative workshop in Makeni	- Project activities agreed to be part of DHIS2 support contract as form of an RCA. Configured DHIS 2 solution prototype and integration roadmap agreed by project stakeholders
Action Taking	○ 7 LMIS-HMIS integration meetings and several informal discussions. Solution configuration in DHIS2, user training workshop, and piloting	- 27 LMIS (RRIV) data reporting forms configured in DHIS2 and pilot initiated in 4 districts of the country
Evaluation	○ Solution and pilot evaluation conducted separately by USAID's global health supply chain (GHSC) program, local HMIS/LMIS team, and HMIS assessment team from UiO	- GHSC assessment reported their findings as strengths and weaknesses of solution for the Malaria health program. Pilot and data quality evaluation results were produced by the local HMIS/ LMIS team. Suggestions for solution improvement were captured in the UiO country HMIS assessment report for MOHS
Specifying Learning	○ Field report dissemination and analysis, and writing up a research paper based on the findings.	- A research paper conceptualizing the project as frugal digital innovation in public health context was submitted to a journal

5.1.4 Summary of Research Activities, Data Collection Events and Estimation of Time Spent

Presented here to conclude the data collection section is a summary of the research project activities I engaged in during the various phases of the project in a chronological order from 2017 to 2019 (in Tables 6, 7, and 8). I also estimate my research effort in terms of time spent on the research project and related data collection events both on-site and remotely to be about 62 weeks (15.5 months). The empirical work conducted over the course of the research project mainly centred around the following activity areas: 1) the overarching national HIS strengthening and related routine activities, 2) HIV patient tracker implementation for the national aids control program, 3) developing LMIS data reporting integration functionality in the HMIS for the logistics department, and 4) following implementation of the facility digital (mobile) data reporting system. Within these processes the data produced were captured as researcher field notes, memos, meeting minutes, project reports, and software artefacts from configuration activities. Data collection techniques and frequency are summarized in Table 9.

Table 6: 2017 summaries of research activities

Research Phase and Period	Place	Research Project Activity Participation	Estimated Input in Time	Data Collection Event
Research project scope definition in Norway and 1st and 2nd field trips to Sierra Leone (**2017**, June to Dec)	Oslo (**Norway**)	-Project scope definition -Review and analysis of HISP UiO team's Sierra Leone field visit reports on HIV and TB programs HIS improvement needs -HIV patient tracker design and implementation planning	4 weeks	- 2 meetings with project advisors - 1 field trip debriefing meeting - 1 system design workshop with HISP experts
	Freetown-Bo-Makeni (**Sierra Leone**)	-Digitization of HIV registers at Connaught hospital, - System configuration debriefing with DPPI, NACP and NAS - System testing follow up at Connaught hospital	2 weeks	- 3 stakeholder debriefing meetings on the HIV patient tracker - Interactions with HIV doctor, nurses, data entry clerk and NACP personnel
		-Revision of NACP facilities and data set assignments in DHIS2 -Data collection forms modifications in DHIS2 for Malaria, Births and Deaths Registration and Neglected Tropical Diseases -DHIS2 data quality training for district M&Es and data entry clerks organized by DPPI/Cordaid in Bo -DHIS2 user training for NMCP organized by DPPI in Freetown -Training and pilot initiation of facilities digital data reporting tool by Focus1000 in Freetown and in Makeni	8 weeks	- 4 meetings/ discussions with health programs on aggregate forms revisions and configuration - 4 training workshops - 4 semi-structured interviews/ discussions with health workers, a system consultant, NGO personnel and management team member

Table 7: 2018 summaries of research activities

Research Phase and Period	Place	Research Project Activity Participation	Estimated Input in Time	Data Collection Event
HIV patient tracker implementation and HMIS strengthening (**2018**)	Freetown-Bo-Makeni (**Sierra Leone**)	-Designing and authoring of 2 user guides for the HIV patient tracker modules (HTC, ART) and following up on system testing at Connaught hospital -1st HIV patient tracker implementation update meeting with stakeholders in Freetown -HIV patient tracker testing expansion feasibility assessment at Ola During and PCMH hospitals	4 weeks	-2 HIV tracker user guides authoring - 3 system testing follow-up visits at Connaught hospital - 1 implementation update meeting - 7 semi-structured interviews with hospital health workers
		-Data collection forms configuration and changes in DHIS2 for NACP, Nutrition, Community health worker program and DDMS -Scorecard tool and indicators validation training for district M&Es organized by Cordaid in Bo -LMIS(RRIV) form prototyping, integration workshop in Makeni , and actual 27 forms customization in DHIS2 -National M&E and HIS technical working group meetings in Freetown -Facilities digital data reporting pilot review workshop in Freetown -DHIS2 data use training for national and district M&Es and DHOs in Freetown organized by DPPI, HISP UiO and HISP South Africa	8 weeks	- 6 meetings/ discussions on forms configuration in DHIS2 - 2 training workshops - 3 M&E and HIS technical working group meetings - 1 pilot review workshop
	Oslo (**Norway**)	-Following remotely the HIV patient tracker pilot initiation, pilot expansion feasibility assessment, and 2nd project implementation update meetings -Project update debriefing and pilot progress presentation to HISP UiO team in Oslo -Research engagement on the global HISP research and DHIS2 implementation programme	8 weeks	- 1 Project update meeting in Oslo - Review and analysis of reports from 2nd HIV tracker project update - 5 semi-structured interviews with global HISP participants and DHIS2 software developer at UiO

Table 8: 2019 summaries of research activities

Research Phase and Period	Place	Research Project Activity Participation	Estimated Input in Time	Data Collection Event
LMIS (RRIV) pilot initiation, HMIS strengthening, and country DHIS2(HMIS) implementation status assessment (**2019**)	Freetown-Bo-Port Lokko (**Sierra Leone**)	-HIV forms org units assignment revision in DHIS2 and tracker user refresher training at Connaught -LMIS (RRIV) forms revision in DHIS2 and pilot initiation training organized by DPPI and DDMS for districts held in Freetown -WHO immunization (EPI) configuration package installation requirements and integration planning -WHO data quality app training for district health officers by DPPI -DHIS2 population data integrity checks with WHO country personnel and data from Statistics Sierra Leone -Preliminary DHIS2 integration requirements analysis for IMAM program by UNICEF/Nutrition -HMIS tools/indicators harmonization workshop organized by DPPI in Bo -Designed and customization of new DHIS2 data collection forms for the Neglected Tropical Diseases Control Program(NTDCP) -TB programs forms revision and modifications in DHIS2 DHIS2 user training for all TB data operators organized by DPPI in Bo -In-country HMIS implementation assessment	16 weeks	-3 meetings with the HIV program -2 HIV tracker refresher user trainings -1 DHIS2 user training workshop for the logistics department -2 EPI stakeholder meetings -1 WHO data quality app training workshop -4 meetings with DPPI management -5 LMIS-HMIS integration meetings -1 meeting on IMAM integration -1 meeting on new NTDCP forms integration -1 meeting with TB program -1 DHIS2 training workshop for TB program -2 semi-structured interviews with DPPI M&E officers -4 pre and post assessment meetings -22 HMIS assessment interviews at national levels and in 2 districts
	Oslo (**Norway**)	-HMIS forms revision and configuration in DHIS2 (6 forms) -Writing of the HMIS assessment report with the assessment team	12 weeks	-Forms analysis and configuration -Analysis of assessment findings

Table 9: Breakdown of the Main Data Collection Events and Methods Used

Project Activity	Meeting/ Discussion	Interview/ Visit	Workshop/ Training	System Configuration Activities
HIV Tracker Implementation	12	11	4	3
LMIS(RRIV)-DHIS2 Integration	9	1	2	28
General HMIS strengthening	23	4	6	11
Facility-based digital data reporting	2	4	3	
Country HMIS Implementation Assessment	4	22		
Broader HISP related activities	3	5	4	
Sub-totals	**53**	**47**	**19**	**42**

5.2 Data analysis

In line with the qualitative traditions and interpretive paradigm adopted in this thesis my research data was analysed as text and text analogue. The textual data is based on notes compiled from interviews, discussions, workshops, meetings, photographs, and from project related documentations. Software artefacts resulting from the research activities are also captured as text analogue and analysed. In addition to this is data drawn from published work on HIS development and implementation research generally and reports in relation to the specific case context under consideration e.g. (J. Braa et al., 2010; Sæbø et al., 2011; UNAIDS, 2015). Experiences shared by HISP members who have been involved in the study context also provided a historical background and perspective on potential issues to be mindful of during my field work. As action-based field research, the analysis also generally followed the iterative and cyclical processes in line with CAR (Davison et al., 2004). This included routine data analysis to inform action and the more theoretically focused analysis done such as during the writing of research articles as outputs from the research project. The data analysis process involved considering how the various interdependent parts of the research project contributed into forming a coherent conceptual whole towards addressing my research questions. This data analysis approach can be located within the hermeneutic circle framework (Klein & Myers, 1999). Hermeneutical analysis involves making sense of textual data constructed based on interaction with people and their cultural and historical contexts (Rapport, 2005; Van Manen, 2016). Summary applicability of these principles in analysing my research data is presented as follows:

The fundamental principle of the hermeneutic circle: suggests that human understanding is achieved through iterating between considering the interdependent meaning of parts and the whole that they form (Klein & Myers, 1999). The relevance of this principle was found in the multiple, dynamic and interdependent aspects of my research case where for example my work constantly shifted between focusing on the broader HIS strengthening and the different but complementary sub-processes involved as described in the research design (refer to Figure 2 above). Thus in a sense, I followed the lead of the research case in terms of where actions were required. The related sub-principles of the hermeneutic circle were also applicable in this

research. This starts with the principle of contextualisation through critical reflection on the social and historical background forming the research setting. In my case, the research is set in a developing country context which socio-economically is often identified to suffer human and material resource-constrained challenges. This includes the history of an ongoing HIS implementation process for over a decade (J. Braa et al., 2010). These among others therefore informed the need to position the analysis within social, political, cultural and technical considerations that directly and indirectly impact on the local context. The principle of interaction between researcher and subjects was used in reflecting on data construction through interactive processes. My research by being action-based enabled participant interactions as the main source of empirical data. The CAR cycle and principles (Davison et al., 2004) such as establishing RCA infrastructure with deliverables required that I worked with both local and international project actors. This also means that the possibility for multiple interpretations of events was acknowledged, and due to possible biases and distortions some level of suspicion and sensitivity accordingly applied to the examination of the various informant narratives. Finally in applying theory concepts to data and towards abstraction and generalization, dialogical reasoning was necessary in resolving potential contradictions between my preconceptions and the findings. Within these I present the data analysis next based on my proposed analytical framework for understanding and addressing public sector IS needs from the FDI perspective.

5.2.1 Applying the Derived FDI Analytical Framework

With the conceptual analytical framework derived in chapter two of this thesis the data gathered from both practical and empirical activities in my research project were analysed and interpreted. The overall problem was identified as unmet IS user functionality needs within a public and resource-constrained institutional setting and the need to tackle this from an FDI perspective. Important system functionalities needed were identified to be non-existent in some cases, and or non-optimal and non-sustainable in others. These were found to negatively impact on organizational performance. The context of the innovation was identified to be socio-technical and multi-layered in nature where there is a high-level general country context described as development-challenged. This translates into constraints on resources at the public health institutional level. At the individual organizational levels there are factors related to non-optimal technological infrastructures and lack of necessary institutional, social, and technological support arrangements. It was therefore agreed by the relevant stakeholders that well-functioning and context-appropriate systems were needed. For this the project team consisting of local and international participants identified that some established and relatively well-functioning installed-base systems in the local context like the DHIS2 can be leveraged to support the further systems functionalities and improvements needed. The next was to determine the purpose of the research project which was identified on two levels based on my understanding of the case. On the first level the purpose of the innovation was about addressing the immediate practical concerns of users by providing the needed IS functionalities to support organizational performance improvement objectives. It is noted that as this takes place in the public non-commercial institutional setting general public interest and socio-economic development

purposes are to be served. The understanding was that supporting efficiency of public healthcare delivery efforts with appropriate HIS solutions can contribute to improving the health conditions and thus the socio-economic well-being of the people concerned. The second level purpose was that through this problem-solving endeavour we can gain a deeper understanding into IS innovation processes which involve systems development, implementation, and use. This also should contribute to the enhancement of the requisite local capacities for supporting systems viability and subsequent sustainability in the resource-constrained settings under consideration.

With the problem, context, and purpose understood, individual research project activities were analysed and within the proposed solutions innovation sub-stages in the framework. This action-oriented aspect of the framework begins with identifying the innovation goals in the various specific project engagements. For example based on an immediate need for functional systems and to strengthen local support capacities, efficiency and long-term systems sustainability were defined as the general innovation goals. Essentially this applied in all the different projects engagements for the short to medium terms and being able to sustain the viability of solutions and outcomes for the long term. This also included achieving efficiency with respect to meeting system functionality requirements within constraints of time, funding, and expertise. These were analysed within the frugal innovation defining criteria of substantial costs reduction, essential functionality focus, and performance optimisation (Weyrauch & Herstatt, 2017). The substantial cost reduction was analysed in terms how much of the existing systems and resources could be reused and thus avoiding additional costs associated with new systems introduction. The reuse of the DHIS2 software and surrounding infrastructures was one instance of meeting this stipulation. With users knowing the specific IS functionalities they were lacking the solution development process was able to be focused on addressing the essential needs, and thus this also leading to optimising system and eventual organisational performance goals.

The material inputs to the solutions innovation were identified and analysed on technological, institutional, and social dimensions (Sahay, Nielsen, Faujdar, et al., 2018). The technological innovation input was an ICT installed base consisting of the DHIS2 software and resources including technical support expertise that was accessible both locally and remotely as necessary. The institutional innovation enablers were found in the flexibility of existing institutions and being accommodative to new organizational processes with potential for institutionalization. An example of this was the technical working group that was set up consisting of actors from different organizations to collaborate on projects. This also included availability of the requisite support from the relevant management personnel at the various institutional levels. The social innovation input was in the networks of people and the trust and good working relationships built over the long periods of HIS development and implementation in the local context. Through this for example both the local and international actors were able to mutually manage and navigate socio-cultural differences and complexities for project progress. The inputs are therefore identified as digital and non-digital resources fed into an open and participatory innovation process with emphasis on local leadership in shaping both the innovation process and outcomes

accordingly. In this the innovation processes were also analysed based on how the choices made contributed to building the requisite local capacities to enable the support that would be required for long-term system use and towards institutionalization. In this case innovation initiatives were pursued through locally-situated approaches where for example DHIS2 expertise was made available on site and worked with users in solutions innovation activities. In connection with this, several training workshops were organized to help in appropriately equipping the users. The innovation outputs therefore marked the end of the innovation realization iteration and in this case the outputs were in the form of software product artefacts and services. The outputs included paper forms and registers transformed into digital artefacts and deployed online for expanded access and use across wider geographical areas (e.g. Figure 11 above). The many routine and one-off systems configuration and support work were also part of the digital technology-enabled innovation services output. In all these the innovation outputs were analysed to ascertain that they do indeed address the prevailing problems, suite functional and contextual requirements, and supportive of the innovation goals. Where necessary and within project capacity, remedial actions were taken to resolve system shortcomings to ensure maximum benefit extraction.

Lastly the immediate and long term impact expectations of the innovation projects were evaluated. In the short-term we expected to see organizational change in the form of performance improvements in the health information management processes and thus potentially contributing to better health service delivery outcomes. In the case of LMIS data reporting integration into the HMIS for example there were appreciable improvements in data reporting completeness and timeliness. The efficiency gains enabled by this newly introduced technological solutions and the subsequent institutionalization potential to sustain the benefits were also examined. In the context of ICT4D research the expected long-term impact is ultimately socio-economic development (Heeks, 2008). Similarly in this research project the long-term social impact is about improving the health status of the beneficiary population. Enhancing the capacities of healthcare workers with efficient IS solutions is seen as contributing towards achieving this ultimate end goal. However a deeper evaluation of the long-term impacts is beyond the scope and analytical focus in this thesis due to time limitations. Summary of the research and data analysis based on the FDI analytical framework and results are presented in Table 10 below.

Table 10: Summary of analysis and results based on the proposed FDI analytical framework

FDI Analysis Stage	Analysis Result
Problem	Unfulfilled IS user functionality needs related to public health data and service delivery management
Context	Resource-constrained, multi-layered, and dynamic context with high environmental uncertainties
Purpose	Public non-commercial and socio-economic development purpose-orientation
Innovation Realization	Goals: Efficiency and sustainability enhancements Inputs: Digital and non-digital resources Process: Open and participatory approach Outputs: Software product and service artefacts
Expected Impact	Organizational performance, public health services delivery, and population health status improvements

5.2.2 Identifying Themes and Linking Data to Concepts

Within the hermeneutic circle analysis van Manen's 'selective or highlighting technique' to data analysis (Rapport, 2005; Van Manen, 2016) was used in identifying key themes in the research data. These were then linked to constructs and concepts informing the research, and shaping the interpretation of the findings and the contributions. The technique involves searching for structures of experience which are descriptions or sentences in the text highlighting recurring themes, incongruities and puzzles in the data. In my case these included data pointers highlighting the challenge of HIS development, implementation, and sustainability more directly. One expression gleaned in official documents such as in contracts, strategy documents, and in meeting minutes was "health information system strengthening". This is derived from broader health systems strengthening efforts initiated by the MOHS as part of HIS recovery and improvement processes. I identify this expression as a structure within which the project stakeholders experienced and made sense of this multifaceted phenomenon of systems development and implementation, and strengthening usefulness and sustainability. For instance during my very first field trip in Sierra Leone, a senior management personnel remarked that they would like University of Oslo to assist in building a HMIS that is more resilient to failure. More specifically, to build a system with the capacity to mitigate unauthorized human actions that can result in severe system failures such as permanent loss of system database and access to server infrastructure.

Therefore from the structure of experience four thematic areas based on the analysis of the data are identified as essential to addressing the research problem and questions. Linkages are then made to analytical constructs of local relevance based on local strategic aspirations for HIS development such as outlined in national policy and strategy documents e.g. (MOHS, 2017). Broader conceptual linkages are made to position and show the relevance of the analysis within the FDI framework and the broader IS research field contexts.

Table 11: Themes, constructs and concepts in the data analysis

Thematic area of analysis	**Relevant local analysis construct**	**Broader conceptual positioning**
General HIS development, implementation and strengthening is continuous multilateral process	A unified HIS architecture and governance structures is necessary for broad participation	Open participation, coordination and organizational collaboration (J. Braa et al., 2004; Constantinides & Barrett, 2014)
Health programs data management integration can contribute to directly strengthening the HMIS	Data management policies are required to guide individual health programs data management and reporting practices	Systems standardisation and integration flexibility (J. Braa et al., 2007)
Strengthening health programs-specific HIS and complementary systems could potentially feed back into strengthening the HMIS	Interoperability framework is needed for systems integration and data sharing across health programs	Modularity and loose coupling integration among multiple but complementary systems (Aanestad & Jensen, 2011; Henfridsson & Bygstad, 2013)
Expanding the scope and reach of the HMIS infrastructure could improve its further institutionalisation and usefulness	Socio-technical flexibility of systems is required in enabling functionality scaling across organisational domains for efficiency gains	Leveraging innovations at the intersections of technology, society and institutions (Bhatti, 2012; Sahay, Nielsen, Faujdar, et al., 2018; Walsham, 2006)

These contribute to informing and shaping my interpretation of the data and to drawing practical and conceptual implications in relation to the research outcomes and findings. Table 11 above summarizes these themes, constructs and concepts identified, and the linkages.

6. Findings

In this chapter I present my research findings based on five research papers I have included in this thesis and based on additional findings during the research process. These papers were written as part of the outputs from my research project and within the broader HISP context. The papers contribute towards meeting the research aim and objectives of this thesis as well as addressing the research questions. First I give summary presentation of the papers and point out how each forms part and fit into the groundwork towards the innovation strategy, approaches, and processes pursued in this thesis. This is followed by showcasing summary findings emerging from the papers and from the analysis of the broader research case in terms of how they contribute to addressing the questions posed for guiding the research investigations presented in this thesis.

6.1 Presentation of the Research Papers

Paper 1: The Dynamics of a Global Health Information Systems Research and Implementation Project

Eric Adu-Gyamfi, Petter Nielsen and Johan Ivar Sæbø, Proceedings of the 17th Scandinavian Conference on Health Informatics, 12 -13 Nov 2019, Oslo Norway

This paper sets the larger international context of my research work and also introduces the research foundations I sought to build on, be guided by and contribute to advancing. The paper looks at the history, current status, future outlook and general dynamics of HISP and DHIS2 in terms of research, software development activities, and HIS implementation in developing countries. It traces the beginnings of HISP and DHIS2 in the early 1990s in post-Apartheid South Africa where as part of the then government's reconstruction plans, efforts were made to decentralize management of the healthcare system and also improve equitable access to healthcare services in the country (African National Congress et al., 1994).

The aim of this paper was to examine the factors underlying the global success of HISP and DHIS2, looking at the organization, the software itself, and stakeholders influencing the scaling and long-term sustainability of the project. Research data was drawn from the research material produced within the HISP network, related IS research, our own experiences as HIS researchers at HISP UiO and involvement in DHIS2 implementation projects. The methods used included analysis of data obtained from project documentations, semi-structured interviews with key informants, and from participation in workshops, meetings and conferences.

The conceptual highlights in the paper are the action-oriented, open and participatory design approaches which frame the activities of HISP including DHIS2 software development and implementation in countries (J. Braa & Sahay, 2012). These have roots in the Scandinavian traditions of action research where there is particular emphasis on user-driven and participatory processes (Gregory, 2003) which in this case are enabled by the DHIS2 software. The software is designed to be adaptable for meeting changing user needs, and able to integrate with other

technologies, and available infrastructure. Beyond this we also looked at other broader issues such as donor funding support and local acceptance of the project. On this particular issue a software developer at UiO for example observed in an interview that "donor interest in DHIS2 is largely driven by its acceptance and adoption by countries' ministries of health".

The conclusion that was arrived at in the paper was that HISP and DHIS2 through scalable and sustainable approaches can be described as a global success story in terms of HIS research and implementation. However we also observe that the future requires careful strategies to ensure continued relevance. This includes strategies such as pursuing project and software platform stability, growth, and increased community participation. For the set objectives in this thesis the findings in this paper also demonstrate the crucial role digital technologies have and continue to play in the development and implementation of HIS in developing countries contexts.

Paper 2: Leveraging Software Platform Capabilities to Support HIV (ART) Treatment Adherence Management: A Case from Sierra Leone

Eric Adu-Gyamfi and Petter Nielsen, 14th IFIP WG 9.4 International Conference on Social Implications of Computers in Developing Countries, ICT4D 2017 Yogyakarta, Indonesia, May 22–24, 2017 Proceedings

With HISP as the reference point for my research this paper explores the possibilities for building on the DHIS2 software to contribute to solving local HIS implementation challenges. The particular case dealt with challenges that were identified with the management of HIV patient treatment programs in the public health context of Sierra Leone. Following the 2014 Ebola outbreak in the country a UNAIDS report (UNAIDS, 2015) identified that some of the progress made with respect to HIS patient treatment programs had eroded due to weakened treatment adherence monitoring capacities. The information management aspect of the HIV treatment program was found to be fragmented due to multiplicities of tools which lacked integration capacities. Therefore writing this paper at the planning stage of my field work we took a more explorative approach by drawing on the broader HIS integration research literature and within HISP research generally and concerning the specific case context. The paper also serves introductory role to the research project planned as longitudinal action research to address the identified problem and as such covered the problem diagnosis and solution proposal phase in the AR cycle (Davison et al., 2004).

The study is approached within the conceptual framing of digital platforms (Tiwana et al., 2010) and the capabilities afforded for pursuing derivative and more integrative HIS solutions development. The DHIS2 software has evolved over the years into a type of digital innovation platform (Bonina et al., 2021) and is able to support derivative solutions development and innovations in the public health IS space (Roland et al., 2017). This is also conceptualized as functional architecting with potential practical strategies including charting, encroaching and connecting (Nielsen & Sæbø, 2016). Thus the main argument advanced in this paper was that the emerging platform phenomena presents opportunities for developing ICT-based IS solutions to

better support healthcare delivery and management. For the particular case of HIV patient management and treatment adherence monitoring, we realized that the focus in the literature was more on the individual effectiveness of existing tools and less on the possibilities of combining several tools to achieve integrative view of the process and data (Lima et al., 2016). Further, we identified the paucity of attempts to develop these more integrative solutions and which should be geared towards meeting needs in particular contexts of developing countries where human and material resources are often constrained. On that account and by learning from the HISP experience (J. Braa et al., 2004) we proposed a solution based on the free open-source, customizable, and community-supported DHIS2 software. Moreover, the DHIS2 was already being implemented in the case context for the more general health information management needs of the country.

The relevance of the findings in this paper for the thesis broadly is in highlighting the facilitating role digital artefacts like software platforms can play in IS implementation processes in low resource contexts. Platforms through their core and complementary design architecture and modularity principles can be described as foundational technologies. These are also designed with pre-packaged functionalities for general use and can be reconfigured or tailored to particular user and contextual requirements as well as connect and interface with other technologies (Tiwana et al., 2010). With relatively lower entry barriers including costs, the important take away from this paper for the thesis is that leveraging software platform capabilities also has frugal digital innovation potentials.

Paper 3: Scaling Across Functional Domains: A Case of Implementing an Electronic HIV Patient Information System in Sierra Leone

Eric Adu-Gyamfi, Petter Nielsen Johan Ivar Sæbø and Zeferino Saugene, 15th IFIP WG 9.4 International Conference on Social Implications of Computers in Developing Countries, ICT4D 2019 Dar es Salaam, Tanzania, May 1–3, 2019 Proceedings

This paper takes a more practical perspective to addressing HIS implementation challenges identified in the research case context. We explore the concept of scaling of IS functionalities horizontally by expanding size, coverage or scope in the same or different setting, and vertically in terms of penetration or depth the health system hierarchy (Sahay et al., 2013; Sahay & Walsham, 2006) Within this conceptual framework we operationalize the functional architecting strategy of charting (Nielsen & Sæbø, 2016). Charting is a strategy based on extending an existing software component with additional functionality to cover an unmet functional need, in a new and typically adjacent domain. Consequently we conceptualize our solution approach as scaling across functional domains.

In this project we customized two software modules (i.e. Event and Tracker capture) in the DHIS2 software platform to implement requirements for supporting electronic management and adherence monitoring of HIV patients undergoing ART treatment in Sierra Leone. The customized Event capture module was used for managing HIV client testing and counselling and

the Tracker capture was used for ART enrolment and treatment management including adherence monitoring. We tested and piloted the solution in the largest HIV clinic in the country in terms of patient numbers located at Connaught hospital in the capital Freetown. The clinic caters for about 4000 out of a total of 20,000 registered patients countrywide. The strategy to achieving this was based on building on the existing DHIS2 and surrounding infrastructures such as server hosting and support arrangements as well available technical expertise to implement the new solution as a form of scaling. Through this approach additional cost associated with setting up new technological solutions and establishing needed supporting structures were avoided. Apart from addressing an unmet functional need in an adjacent organizational domain, the expectation was also that improving data management at the more granular level of the health management hierarchy would feed back into improving the aggregate data quality in the general HMIS.

Beyond practically contribution to tackling IS development and implementation problems in the thesis context, the findings from this paper highlight the need for both technological flexibility and organizational collaboration in realizing IS functionality scaling and moving towards achieving intended efficiency gains. This is based on sharing the view with Sahay and Walsham (2006) that, scaling incorporates complexity comprising of heterogeneous network of technical systems, across geographies, technical expertise, data and databases, and socio-cultural practices including politics. Therefore, these complexities should be acknowledged and managed as part of the IS functionality scaling process to enhance project success.

Paper 4: Merging with Installed Base Infrastructure for Information System Continuity: A Case of Resource-challenged mHealth Project in Sierra Leone
Eric Adu-Gyamfi, EJISDC-----Submitted

This paper presents a learning opportunity for reflecting on the potential IS continuity challenges that can be faced when established installed base systems and capacities are not fully leveraged to support new solutions implementation. The study is thus conceptualised within the perspective of understanding local installed based capacities leveraging potentials to enhancing viability of new HIS solutions implementation (Hanseth, 2010; Sanner et al., 2014). In this paper, digital mobile HIS project implementation case was examined retrospectively. The study covers the period from initiation to piloting, the ensuing halt in further system implementation activities, and the factors contributing in the lack of continuity. This project was initiated in 2017 as part of health systems recovery and strengthening efforts that was named the “Saving Life Project” consortium in Sierra Leone and funded by the UK government through its DFID UK program. This was meant to serve a complementary role to the national HMIS by supporting electronic data collection and reporting from health facilities to district levels. The existing manual process of delivering paper reports from the facilities to districts every month for electronic entry into the national HMIS was identified with inefficiencies and risks to personnel and the paper reports. Accordingly, an electronic system was seen to have the potential to mitigate the logistical challenges and safety concerns while also improving the quality of data reporting. After more

than a year of successful piloting on a national scale and with relatively better data reporting performance than the legacy paper-based system, the project was suspended due to donor funding problems.

Consequently I propose in this paper that the implementation discontinuity could have been mitigated if the solution and supporting infrastructures were merged or fully embedded into the existing installed base. In the implementation context there were locally established and adequately supported systems such as the DHIS2 that could have been explored for providing end-to-end solution innovation instead of introducing new technologies. The new system for example came along with parallel organizational and support arrangements that could be not sustained when the external funding ceased. Pertinent to the objectives in this thesis, the findings from the paper lead to the conclusion that in resource-constrained settings and characterized with funding uncertainties, HIS solutions that serve complementary functionalities should be embedded or merged with the established installed base infrastructures. The rationale in this is that this could help improve the overall systems sustainability by creating a positive feedback loop (Henfridsson & Bygstad, 2013) with new project resources feeding into strengthening the existing capacity base and in turn benefiting from the enhanced stability of the installed base. This also has prudent resource reuse implications and can positively support progress towards socio-economic development objectives pursued by leveraging the efficiency enhancing potentials of ICTs.

Paper 5: Information System Reuse: Case of Frugal Digital Innovation in the Public Health Sector in Sierra Leone

Eric Adu-Gyamfi, Petter Nielsen and Johan Ivar Sæbø, *Information Systems Journal* (under review)

In this paper we engaged in practical intervention in the study context to address IS functionality need fulfilment related to health logistics data management. The work involved extending the aggregate data management functionality of the HMIS in Sierra Leone to meet a similar functional need in the logistics management domain. We describe this solution approach as information system reuse and conceptualized within the frugal digital innovation framework (Sahay, Nielsen, Faujdar, et al., 2018). We recognized that HMIS and Logistic Management System (LMIS) are important complementary components in healthcare services management. However as a common practice, the two systems are often housed in separate organizations and managed accordingly from the national all the way to the facility levels (SIAPS, 2014). This separation was also the practice in our case. With the LMIS lagging behind the HMIS in terms of summary data reporting rates performance we embarked on extending the functionality of the HMIS to support performance improvements in the LMIS domain.

The decision to pursue a reuse of the HMIS in this case was arrived at by the key project stakeholders realizing that the HMIS was more widely accessible across the country and relatively was performing better in terms of data reporting rates compared to the LMIS.

Therefore with our role as technical system implementers in the project, we proposed and subsequently customized the aggregate data management functionality in DHIS2 (i.e. the HMIS software) to also cater for the LMIS data summaries reporting requirements. The solution consolidates the LMIS summary reporting that was previously spread across three software tools (i.e. Channel, SLPD, and mSupply) in the LMIS domain. The solution was subsequently tested and piloted in four districts of the country and reported better data reporting rates performance as compared to the previous multi-system LMIS solution. We discuss the solution development and implementation approach as a promising frugal digital innovation for the public health sector in a developing country context.

For the aims and objectives in this thesis the findings from the paper demonstrates the relevance and feasibility of applying the frugal digital innovation concept to solving IS functionality needs and addressing resource-constrained challenges in public health management contexts. The value proposition is that in the midst of resource constraints often experienced in public institutions of developing countries reusing existing resources to address unmet needs should be explored. This can serve as an option for achieving more and potentially better outcomes with fewer resources (Bhatti & Ventresca, 2013). Furthermore, in order to fully realize the potential benefits of this approach, emphasis is placed on the need to create and leverage intersections between the technological, institutional, and social innovations emerging in the project context to improve sustainability (Sahay, Nielsen, Faujdar, et al., 2018). In our case we found these FDI intersections to include flexibility and improvisation between the institutional and technological, open and participatory design processes between the technological and social, and collaboration avenues between the social and institutional innovation dimensions.

6.2 Summary of the Papers and Roles in the Research Process

In this section I summarize the papers presented above (in the Table 12 below) in terms of their roles in the build-up of the FDI research process and contributions in terms of addressing the research questions posed to guide the investigations into the research problem. The presentation follows the AR process stages and the contributions of the papers are indicated based on relevance at each of the stages as well as the research questions addressed. These and other findings from the research project are discussed afterwards in the next chapter.

Table 12: Summary of the included papers and role in the build-up of FDI processes for local HIS solutions innovation

The FDI research process	Role and contribution of the papers	Research question addressed
Problem diagnosis and background framing	(Paper 1) Evolutionary processes responsible for the generativity of the broader HISP and DHIS2 project are foregrounded. On this background in-country problems of institutional disparities, lack of requisite technological solutions and resources constraints related to HIS innovations are identified and tackled.	Main research question
	(Papers 2, 4 & 5) Fragmentation of systems and efforts, and inadequate emphasis on local considerations in IS innovations are diagnosed as problems that need to be solved within the resource-constrained context under consideration.	Research sub-question (a)
Discovery and planning	(Paper 1) Evidence of emerging new use cases of DHIS2 within and beyond the health domain support feasibility of user-driven local innovation efforts (Paper 2 & 5) Platform capacities of the DHIS2 including the ability to support functionality scaling is identified as innovation enabler. Programmability and reusability of the ICTs involved set the premise for pursuing efficiency goals through installed base systems and resources leveraging	Main research question & sub-question (a)
Action and evaluation	(Papers 2, 3&4) Vertical scaling of HIS functionality and resources from general to specific use cases is actualised and evaluated. Capacities needed for the established installed base to support further innovations and in a frugal way are identified. (Paper 5) Horizontal scaling or scoping of DHIS2 functionality and HMIS resources for use in distinct but complementary organisational areas is operationalised. The potential for addressing resource-constrained challenges posed to successful HIS innovations is demonstrated.	Main research question & sub-question (b)

Table 12 continued:

Reflection and learning	(Paper 1, 2&3) Open and participatory approaches are identified as important to scalability and sustainability of HISP, DHIS2, and local HIS innovations. (Paper 4) HIS innovations that are not grounded in and aligned with established local infrastructures and support systems can be at risk of suffering continuity and sustainability problems	Research sub-question (a)
	(Paper 5) Applying FDI perspective to HIS innovations in public institutional contexts of developing countries has both local and broader research and policy implications	Research sub-question (b)

7. Discussion

In this chapter I discuss the research findings in relation to the efforts made towards resolving the core research problem defined and investigated in the thesis. The research objectives are revisited to ascertain the level of accomplishment and relevance. Attempts are made to answer the research questions that were posed to guide the empirical investigations in the research project with individual contributions and roles of the included papers in the research process explained into more details. Other findings from the research case in general are also discussed. Further, the effectiveness of the research approach and the solutions strategy adopted in terms of dealing with the prevailing problems and challenges are examined. The potential implications for supporting the achievement of IS innovation goals and expectations are then discussed with respect to the particular research case under consideration and resource-constrained settings generally.

7.1 Emphasising Local and Resource-Constrained Imperatives in IS innovations

To recall, the research problem in this thesis was defined as lack of emphasis on addressing challenges posed by local and resource-constrained factors in the design and implementation of IS innovations meant for solving problems in public health contexts of developing countries. The main challenges were identified broadly to relate to inadequate funding, shortage of expertise, and weak to non-existent technological capabilities in countries (Fonstad & Mocker, 2020; Reguia, 2014; UNCTAD, 2021). The lack of appropriate strategies for dealing with the challenges in the research problem context was found to contribute in innovation inefficiencies, poor local viability and sustainability of solutions, and thus resulting in high rates of failure outcomes. However, opportunities could be found on technological, institutional, and social innovation dimensions that when properly harnessed can support improvements in frugal solutions exploration and towards effectively addressing local problems.

The claim concerning the importance of the research problem was rationalised based on two premises. The first is that the pace and development of the core of IS technologies and innovations are dictated and supported in the more resource-ready contexts of developed countries. As a result, the processes associated with the introduction, adoption, and diffusion of solutions based on these systems is also seen to be guided by general principles and international best-practice considerations. The second premise is based on observing that the ability of organisations and actors to effectively engage in innovations is largely dependent on the availability and accessibility to the requisite resources. Yet, the availability of these resources are found to vary across countries and contexts where for example public sector organisations in developed countries seem to be relatively better positioned regarding access to funding, expertise, and technological capabilities compared to their counterparts in developing countries (Archibugi & Coco, 2004; UNCTAD, 2021). In the face of the problem and challenges identified, the main argument therefore being advanced in this thesis is that the development of core IS technologies such as software platforms may continue to be influenced and supported internationally due to resource availability reasons. However, the design, development, and

implementation of derivative innovations in close proximity to users in developing countries contexts must be informed and shaped by local and resource-constrained considerations. This is the basis of the FDI conceptualisation adopted in the HIS solutions explorations embarked on in this thesis and aimed at improving IS innovation outcomes in the public sector contexts of developing countries.

Within the same resource-constrained contexts of developing countries, others have focused on software development activities and characterised similar solution approaches as part of innovations in the fringes of platform ecosystems enabled by socio-technical generativity (Msiska & Nielsen, 2018). In more broader theoretical terms, the concept of cultivation is also explored in Information Infrastructure (II) research within the IS field (Hanseth, 2010; Sanner et al., 2014). These can be argued to corroborate the FDI perspective by drawing strategic linkages based on commonality of goals pursued such as the need to start from an installed base, design simple and cheap solutions through bootstrapping and modularity strategies, and for immediate usefulness by a defined target user group (Aanestad & Jensen, 2011; Hanseth, 2010). A point of departure however can be identified with for example the concept of installed base cultivation in II innovation (Hanseth, 2010). This seems to imply a much slower organic process (Grisot et al., 2014) that cannot be easily intervened and fast-tracked in dealing with problems of urgent nature and within contextual uncertainties. In this respect and in the view of this thesis FDI is seen to afford the innovation agility and rapidity necessary for addressing problems within time and resource constraints, and thus was appropriately explored in the current research case context.

Therefore in the efforts towards resolving the research problem, the results and findings lead to the suggestion that technological innovations and associated organizational practices should not be adopted or transferred wholesale simply because they worked elsewhere or align with industry and international best-practices and standards. For the purposes of enhancing successful outcomes innovation initiatives in developing country contexts should be approached with the aim of achieving local, simple, targeted, and incremental gains. Studies in the broader innovation field also advocate similar motivations (Aanestad et al., 2014; Bhatti & Ventresca, 2013; Senyard et al., 2014). The emphasis here however is again based on the recognition that many developing cannot afford the funding, time, and infrastructures in large scale and long-term research and development (R&D) approaches typical in developed countries contexts (Aanestad & Jensen, 2011; Avison & Taylor, 1997; Sood et al., 2008). The different innovation circumstances prevailing in developed and developing country settings and between public and private sector goals should be acknowledged. While R&D approach to IS innovation with clear delineation between processes and outcomes may work in laboratory settings, a dynamic approach may be more suitable in the messy real-world problem situations in organizations. While resource-intensive and drawn-out institutional processes may be supported in developed country settings, these may be impracticable for speedy resolution of problems in developing countries contexts.

7.2 Innovation Enablers of the Local Installed Base Infrastructure

The first objective in this research was to inquire into the properties of digital technological installed base systems and resources and the role they can play in facilitating local IS innovations. In the HIS solutions exploration, key innovation enablers of the local installed base were seen to correspond to innovation enabling traits of the DHIS2 and allied digital technologies identified as platform enabling distributed participation and combinatorial solutions development. The local installed base infrastructure in this research comprised of the DHIS2 as the main digital platform technology, and the allied resources included a server infrastructure, network services, computer devices, people, institutions, and support arrangements. These served as the platform ecosystem that both prompted and informed new solutions conception and enabled exploration of viable innovation possibilities. In the IS literature, this capacity of the digital technologies and ecosystem resources to serve as foundational systems on which new solutions can be built or enable new meaning attributions in previously unanticipated ways is conceptualized as socio-technical generativity (Eck et al., 2015; Lane, 2011; Lyytinen et al., 2017; Msiska & Nielsen, 2018; Yoo et al., 2012). In this research, generativity was critical to the technological innovation successes based on reasonably matured DHIS2 software platform modules that could be utilized in multiple ways for solving local problems. This for example enabled the solution innovation that was needed to support individual patient data management requirements in the HIV health program (Paper 3). A sufficiently widespread and accessible internet service through the local country's mobile telecom networks, and the availability of the requisite user terminal devices enabled solutions deployment success. The institutional and social arrangements were also adequately accommodative of the innovation processes.

Therefore the second innovation enabling role played by the installed base infrastructure was in serving as a collaborative platform supporting a broad-based participation of actors and stakeholders in the HIS innovation activities. The DHIS2 played a key role in this by virtue of its being web-based and online system around which core innovation activities were centred. By this it was able to support the necessary system design and implementation processes with the participation of actors who were more or less spread internationally. This is identified in part of the large-scale participatory design approaches the DHIS2 platform is able to support within the broader HISP network (Roland et al., 2017). In the current research for example, technical support was able to be delivered remotely, and system designs, configurations, and problem fixes also be tested and verified by system owners through the same medium. Within the country, issues related to system use could be reported from all user locations and promptly addressed remotely without the need for travelling long distances as would be the case with standalone and offline systems deployment. The ability to provide remote and online support and guidance through this means also contributed in the local capacity development process. Other digital avenues that were instrumental in this included the use of E-mails and internet-based chat applications such as Skype, Zoom, and WhatsApp to support interactions and information dissemination among the relevant stakeholders.

Third and lastly the installed base infrastructure was found to be capable in supporting frugal innovation approaches to solutions explorations. The flexible properties of digital technologies in terms of their ability to be re-programmed and re-combined with other technologies and resources enabled high resource reusability. This for instance enabled the tailoring flexibilities necessary for effectively addressing local system and user requirements. The ability for the established digital technology based-IS and infrastructure to be used in multiple and different ways helped in achieving efficiency and thus FDI goals. Going forward, the capacity for further frugal innovation exploration and sustainability is observed. This includes the capacity for enabling solution-problem pairing possibilities and with rapidity in re-combining and repurposing existing systems and resources for efficiency gains.

7.3 The Mutual Innovation Shaping Potentials of the Frugal and the Digital in FDI

The last two research objectives in this thesis were set based on a need to understand and maximise the mutual shaping potentials of frugal and digital innovations principles in IS solutions explorations and towards the realisation of FDI goals. The main frugal innovation principle was thus identified as the need to achieve more benefits and better outcomes with fewer resources at hand or accessible in the problem context. More specifically this stipulates that frugal innovation activities should be focused on reducing costs, meeting essential user functionality needs, and improving overall performance concerning innovation processes and outcomes. This principle was followed in this research by seeking to leverage the existing installed base of technological systems, established institutional arrangements, technical expertise, and supportive socio-cultural practices built around local HIS development and implementation in the research context. For the digital innovation aspect, the rapid and near ubiquitous availability of ICTs and the enabled digitisation of innovation processes and outcomes was found to support productivity of engagements in the IS innovation exploration. In this the particularly flexible properties of digital technologies including combinability, programmability, and reusability were identified and explored accordingly. Other relevant digital technological capabilities such as enabling modularity, interoperability or integration, and scalability of solutions were also explored. In the initial stages of the current research project, generative capacities perceived with the DHIS2 as the core digital platform technology served as the foundation for solutions conception and design options exploration (Paper 2). As the research progressed, the potential to reuse the existing DHIS2 and HMIS resources such as server infrastructure and technical expertise was realised in the solutions pursued for the HIV program (Paper 3) and the LMIS organisation department (Paper 5). These reusability property guided by the architectural modularity principle underlying the design of the DHIS2 digital platform was fundamental to the frugal realisation of the innovations pursued.

Further on in the research process, it became apparent that a partial application of FDI principles in digital HIS solutions innovation in resource-constrained contexts can have negative consequences on project continuity. In this case in Paper four for example, the principle of interoperability was respected by way of integrating the facility level mobile data collection tool

and the HMIS for health and system configuration data exchange. However, by setting up separate technological infrastructure and organisational support systems parallel to the installed base, the capacity for long-term local sustainability was weakened. This was so because the sustainability of the project was made dependent on the continued availability of additional and external resources and support. As a result when external funding ceased the project was also discontinued. Therefore it is important that the mutuality of relationship involving the frugal and the digital in FDI and the ability for shaping digital innovation processes in support of local sustainability are recognised and explored for efficiency maximisation. The instrumental nature of the digital in this is emphasised in the sense of the multiplicity of roles it can play in IS innovations by forming part of the inputs, processes, and outcomes and thereby contributing to the ability to achieve FDI goals. Consequently it is argued that FDI principles derived based on combining and applying frugal and digital innovation principles should guide HIS innovations endeavours within resource constraints. Three of such guiding principles are proposed and discussed in the next chapter as part of the contributions from this current research project.

7.4 FDIs Realisation and Mitigation of Challenges in Local HIS Innovations

The main research question that was used to guide the empirical investigations in this thesis was "*how can frugal digital innovation help mitigate challenges to local HIS innovations and enable efficient exploration of solutions suited for addressing problems in resource-constrained settings?"* To investigate this research question it was important that frugal digital innovation and its constitution were understood based on literature and within the context of the current research. From the research findings a composite understanding of FDI is thus obtained as moulding of digital technologies and ecosystem resources into new and innovative solutions in respect of frugal innovation principles, and supported by complimentary innovations on institutional and social dimensions. Approaching HIS innovations from this perspective is thus deemed as a more holistic path to addressing problems because of the particular emphasis placed on the need to build synergies between systems, resources, and capacities to improve local sustainability. This differentiates FDI from the broad concept of frugal innovation which does not necessarily involve digital technologies or inherently focused on local sustainability. The FDI perspective advanced in this thesis also goes beyond the mere digitization of ISs and the affordability and simplicity expectations emphasised in frugal innovations. The distinguishing characteristic is the emphasis on identifying or building complementary innovations necessary for enhancing local viability and sustainability. The result is then a network of innovations on the technological, institutional, and social dimensions and additional innovation possibilities that emerge from these intersections. These are presented and discussed looking at the potentials for mitigating challenges posed to efficiently engaging in HIS innovations in local and resource-constrained contexts.

7.4.1 Technological Innovation

Within the FDI framework, technological innovation are seen as new technical solutions created from existing digital technologies (Sahay, Nielsen, Faujdar, et al., 2018). In this research the

major technological innovations realized as covered in the included papers are the HIV patient tracker solution (Paper 3) and the LMIS summary data reporting management system (Paper 5). These were all based on and off existing resources and infrastructures surrounding the national DHIS2-based HMIS. In addition to these, further technological innovation possibilities were identified due to the openness of processes and the flexible design architectures of the digital technological systems involved. In the LMIS example, the design openness of the technological innovation, flexibility of the underlying technical infrastructures, and participatory implementation processes enabled other actors to improve upon the original solution post implementation. This included a reconfiguration of the DHIS2 forms to enable additional data analytic and reports visualisation capabilities. In the case of Paper four, a recommendation was made for the challenged implementation of the health facility-based mobile data collection tool to be supported and fully incorporated into the HMIS technological installed base infrastructure to mitigate the project continuity challenges and enhance long-term sustainability. The established technological infrastructure to be used in this respect was identified to comprise of the DHIS2 software and supporting technological systems.

7.4.2 Institutional Innovation

Institutional innovation involves changing existing ways of organizing and doing things (Bhatti, 2012; Sahay, Nielsen, Faujdar, et al., 2018). The institutional innovations in the research project could be seen at two levels of the project organisation. At the higher institutional level this involved a kind of triple helix collaboration (Etzkowitz, 2003) involving the MOHS as beneficiary government institution, university-based technical support service partner which is HISP UiO, and with funding support provided by an international donor agency, the Global Fund. This collaborative arrangement was not necessarily novel in the research context, but the particular focus on health program-specific HIS development such as involving the HIV patient tracker was new. Previously the attention had been more on general HMIS development and implementation. This new focus therefore expanded the scope of the institutional collaboration and participants to for example include the National Aids Secretariat (NAS). This is a semi-autonomous government entity outside of the MOHS but oversees and coordinates policies, resource mobilization, and all activities related to combating HIV and AIDS in the country.

At the organizational level, using common technological infrastructure to serve needs in different sub-organizational units resulted in new ways of local collaboration. For instance DPPI, the department responsible for the HMIS worked with the National Aids Control Program (NACP) on the implementation of the HIV Patient tracker system. For the incorporation of the LMIS summary reporting functionality into the HMIS a joint technical working group was established by DPPI and DDMS to oversee implementation activities. This collaboration was towards strengthening the position of DHIS2 as a common data reporting platform system in the local context and was cascaded down to the district levels. Through this an opportunity was created where user expertise and resources could be shared among general HMIS and health programs-specific users of DHIS2-based HIS innovations and thereby improving efficiency. In Paper five

for instance common data reporting timeliness instituted across the health and logistics domain contributed to user processes alignment. This also enhanced the capacity for the integrated data management and analysis essential for supporting evidence-based decisions concerning health services delivery and resources management.

7.4.3 Social Innovation

Social innovation in FDI concerns how the solution positively affects the lives of the target beneficiaries (Bhatti, 2012; Sahay, Nielsen, Faujdar, et al., 2018; Sahay & Walsham, 2014). In this research the social innovations are identified at the level of system users, managers, and actors participating in the HIS strengthening activities. This is partly due to a research design focused on addressing immediate needs of health workers. At this level a social capital (Ali-Hassan, 2013) built through a long collaboration on HIS development and implementation in the country was identified and leveraged in support of the FDI goals. This represents resources and assets rooted in a network of social relations comprising individual actors and groups around for the DHIS2 software platform. With this as a common reference point key project stakeholders were able to understand and appreciate the value in exploring the existing system and resource reuse scenarios proposed (e.g. paper 4 and 5). This represented change of mind-set in a context where due to the often short term goals and interests associated with donor-funded projects new technological introductions would normally be the considered option especially if proven to have worked elsewhere. The resource reuse perspective therefore facilitated the social mobilization necessary for releasing the required innovation potentials. An example of this was my own participation as a PhD intern affiliated with the research project case base on an innovative HISP approach to providing less costly technical support services through action research. While the use of PhD students in providing technical DHIS2 implementation support is not an unusual practice in HISP projects (Kaasbøll et al., 2019), this has not been recognized for its frugal innovation potentials. This is in comparison to a high cost alternative of procuring the on-site services of a professional consultant for the same duration.

The reality of impacts of the perceived social innovations beyond the immediate organizational situation to the wider social context such as at patient levels are however only inferred and extrapolated at this stage. This is due to a research design that was not based on direct engagements with patients and clients of the healthcare system. The understanding therefore is that benefits accrued in the healthcare system as a result of improving management capacities can potentially translate into better service delivery for patients and clients of the public health system. This for instance includes having timely and accurate health logistics data to inform procurement and distribution of commodities to where they are needed for efficient and effective patient care (Paper 5). In the case of the HIV Tracker (Paper 3), enhancing care worker access to patient treatment information through a centralized database solution can allow patient mobility for socio-economic reasons while still being connected to care. The digital technology-based solution also can improve patient data privacy and confidentiality as access to patient information can now be centrally regulated.

7.5 Practical Considerations for Enhancing Local Innovation Viability and Sustainability

In this research project, several factors were identified to impact the HIS innovation processes and activities engaged. In the face of the resource constraints and the contextual peculiarities a careful consideration of choices as inputs to the innovation processes were critical to achieving project goals as well as improving solution viability and sustainability capacities. The foregrounding of these factors contributes towards addressing my first research sub-question (a) i.e.; *"What are the key operationalisation considerations that can support achieving locally viable and sustainable HIS solutions?"* Following the three FDI dimensions (Sahay, Nielsen, Faujdar, et al., 2018), the considerations found are categorized in relation to the technological, institutional, and social factors prevailing in the multi-layered contexts. For the technological dimension the key consideration relates to the availability of generic, flexible and extensible technological infrastructure. In this research the DHIS2 was identified as the core of the technological installed base and was also relatively well-established in the Sierra Leone public health management context. This enabled pre-packaged system functionality adaptations as well as combination with complement technologies to adequately address local system and user requirements. In this, the architectural flexibility and openness of system design enabled the innovations necessary for enhancing local viability of the solutions.

For the institutional dimension, local organizational structures, work practices and partner support arrangements have to be reasonably malleable in terms adapting to environmental changes and project requirements. This is needed to allow the emergence of locally appropriate process improvisations and to explore the potential for institutionalisation of new practices. For example based on such institutional malleability in the current research case context new avenues of collaboration were initiated and sustained between DPPI, DDMS, and partners in the project involving LMIS summary reporting incorporation into the HMIS (Paper 5). This was specifically pursued through joint technical working group meetings and activities at the national level. In the districts, collaboration between LMIS and HMIS personnel was made possible due to having a common reporting system interface. Additionally, DHIS2 support arrangement already in place for the HMIS could flexibly incorporate major aspects of the technical support needs in relation to the newly implemented LMIS reporting functionality. Through this flexible institutional arrangement between the MOHS and HISP, the capacity for long-term systems sustainability was enhanced.

The considerations on the social dimension included the ability to adopt open and participatory approaches in solutions innovation and implementation for the purpose of improving local acceptance of solutions. This required that appropriate strategies were employed to motivate user participation and local leadership in the innovation processes in addressing the needs identified. In the case involving the HIV patient tracker for example (Paper 3), a local and middle-level management personnel was motivated to play a project champion role and this largely contributed in maintaining stakeholders interests in the HIS solution. An important consideration in connection with this is that, the interests of the major stakeholders should be adequately

aligned and the key actors should have the capacity to commit to agreed project plans, decisions, and responsibilities. This can then enhance the focus on the ultimate project goal, which in this case is strengthening HISs to support improvement in healthcare services delivery and consequently better health and well-being of people. Towards this, it is also important that the necessary political, management, and partner support can be secured to improve accessibility to the requisite resources toward project implementation success. I summarize these considerations according to the FDI dimensions in Table 13 below.

Table 13: Summary of factors that enhanced viability of the local HIS innovation processes

Factor grouping by FDI dimension	**Impact on the HIS innovation process**	**Findings in the thesis**
Technological		
Available generative technological installed base infrastructure	Facilitating functional adaptations and support for new functional innovations	Same DHIS2 infrastructure supported the HIV patient tracker project and the LMIS reporting functionality in the HMIS
Flexible software architectures, open systems design, and open innovation processes	Supportive of system learning, and enabling further innovations	Open-source DHIS2 software platform and global support community are open and accessible to everyone
Institutional		
Malleable institutional processes, practices and support structures	Allowing local process improvisations and towards institutionalization of new practices	Single DHIS2 support agreement was used to cover both the HMIS and the new LMIS reporting functionality
Access to local or remote support expertise based on needs	Enabling a situated approach to addressing user needs and with promptness	Availability of DHIS2 implementers both on-site in Sierra Leone and accessible remotely from Oslo
Social		
Participatory implementation process and motivated users	Encouraging user participation, learning, and local leadership	Emphasised on participatory approaches and locally-driven HIS strengthening activities
Aligned interests of the relevant stakeholders and commitment to project roadmap and goals	Enhancing project goal focus and continuity support	Interests of relevant stakeholders were adequately aligned on projects. This included both user organizations and donor agencies.

7.6 Significance of FDI for Public Sector HIS Innovations in a Developing Country Context

Ultimately innovations in the public sector contexts are expected to produce the gains that can lead to the positive materialization of social and economic development goals (Bhatti & Ventresca, 2013; Nielsen, 2017). Consequently the motivations for embarking on the research presented in this thesis included a need to understand the factors and relationships that contribute in this respect. The FDI exploration was thus based on the understanding that there was a potential for enhancing efficiency, viability, and sustainability of solutions and systems. Efficiency was pursued through prudent use of available resources and by avoiding waste in the innovation process. Solutions were designed through participatory approaches so that local user needs could be properly met to enhance viability. The emphasis on mitigating local resource constraints and contextual challenges was also aimed at strengthening the local sustainability capacities. Highlighting the significance of these contributes to addressing my second research sub-question (b) i.e. *"What are the implications for HIS innovation research and practice in a public health institutional context of a developing country?"*

Based on the research results and findings, FDI have implications for appropriately supporting conceptualisation of research problems and the exploration of practical solutions within resource constraints. For the public and formal institutional settings of developing countries, the argument is that prior IS innovation conceptualisation by treating the frugal and the digital as separate phenomena did not enable maximisation of the expected benefit potentials. The integrated conceptual view proposed within FDI therefore presents opportunities that can be utilised to improve problem conceptualisation and gain deeper insights of the issues that need to be solved. Within this, an opportunity is provided to encourage local IS innovation initiatives where the relevant actors themselves can identify and mobilise resources and capacities to support in the solutions exploration. In the extant IS literature this can be seen as part of bottom-up strategies that are found to contribute to successful outcomes in mostly large scale and open-ended IS innovation projects in more structured contexts e.g. (Aanestad et al., 2014; Grisot et al., 2014). However in the multi-layered and normally unstable contexts of public sector innovations in developing countries, the FDI framework is seen to provide a more integrative framework for dealing with problems. This involves seeking to combine and balance bottom-up approaches with top-down considerations to enable the flexibility necessary to maximise benefits and in achieving innovation efficiency and solution effectiveness.

In addition, the frugal innovation concept of doing more and better with fewer resources and for more people is identified with the potential that can contribute to general socio-economic development of a people. For instance it is identified that engagements in inclusive socio-economic development activities can be improved by enabling participation of low-income producers and consumers in the innovation value chain (Knorringa et al., 2016). In the formal public sector context of a developing country this includes the potential for improvisation in addressing institutional voids and in overcoming constraints that are often found to hinder

economic productivity. For HIS innovations new solutions can be explored based on the available resources, existing structures and socio-cultural practices to save time, costs, and reduce new institutionalisation processes. The public health management landscape in a developing country such as in Sierra Leone is influenced by various local and external factors. The local factors in addition to resource-constraints in this case were found to include changes introduced by national and organisational management politics. Others include shifting priorities due to changing disease burdens and the need to respond to disease outbreaks and environmental emergencies. The external factors emanate from the need to fulfil interests and expectations that come with the numerous donor funding schemes that are critical to the optimal functioning of the national health system. Then there is the need to be able to implement international standards and best-practices such as stipulated by the WHO for routine health programs management, campaigns, and in responding to pandemics. Meeting these needs require HIS infrastructures that are able to support flexible systems functionality and scope adaptation within relatively shorter periods. With an added emphasis on the innovation capabilities of digital technologies in FDI, a major implication is observed in this respect in terms of the potential for supporting low-cost, collaborative, and locally-relevant engagements in HIS innovation explorations. More FDI implications in relation to solutions architecture, policy, and governance issues for public sector IS innovation in developing countries settings are discussed along with the research contributions in the next chapter.

8. Contributions and Implications

In this chapter I start with an overview of what I see as my contributions to IS innovation research and practice for the specific resource-constrained and public institutional context of developing country under consideration. These are based on the results and findings obtained from the empirical work and HIS solutions innovation activities engaged in the research project. Furthermore an IS innovation strategy employed in the research project together with general solution design principles and specific implementation approaches that were found to be supportive of the FDI goals pursued are presented. The implications of what these research contributions mean for the emerging FDI and broader IS innovation fields are then discussed. In this I particularly dwell on the potential impact on systems architecture, project governance, policy, practice, scalability, and long-term sustainability.

8.1 Theoretical Contributions

This thesis contributes theoretically to the discourse on ICT-based IS innovation research where both an IS and its implementation in organisations are conceptualised as mutually constitutive process shaped by multiple factors and considerations at different levels (Avgerou, 2008; Berg, 1999; Leonardi, 2009; Walsham, 1993). From the FDI standpoint a contribution is made to the conceptualisation of the IS innovation aspect in this discourse. This thesis first identifies a mutual constitutionality of frugal innovation principles and innovation capabilities of digital technologies that need to be emphasised and understood in terms of the potential for shaping a dynamic innovation process and outcome relationship. In other words in FDI, digital innovation activities must be guided by frugal innovation principles while the innovation capabilities of digital technologies must be explored in support of frugal innovation goals. Thus secondly the relationship between innovation processes and outcomes should be conceptualised and explored within a continuous, overlapping, and iterative framework towards enhancing innovation efficiency and solution effectiveness. Within this framework, the activities involving IS development, implementation, and usage in organizations are understood as an always ongoing process where attempts are made to continuously perceive and leverage latent generativity capabilities of the installed base infrastructure. This FDI perspective is in support of the notion explored in Leonardi (2009) that in IS innovations in organisational settings, there is a blurring of the lines and boundaries in terms of where systems development and implementation end, and usage and further innovation begin. The flexibility of the digital technological artefacts involved introduces overlaps in the innovation process and enables interchangeability and reusability of innovation components such that outcomes in prior innovations can serve as inputs and enablers in new innovation activities. The innovation process-outcome dynamics in this should be approached in the iterative sense and with the aim of achieving optimal state of solutions. This requires continuous evaluation of the innovation outputs in terms of suitability in addressing user problems and meeting the stated innovation goals and purposes. Therefore all these concepts when pursued together can contribute to potentially frugal innovation pathways to viable and sustainable IS solutions in resource-constrained contexts.

Furthermore the above FDI conceptualization also presents an opportunity to contribute in clarifying three old assumptions in the theorization of the relationship between IS innovation processes and outcomes, and definitional boundaries (Nambisan et al., 2017). First of all, being able to expand the functional scope and boundaries of exiting IS and infrastructure to support new innovation processes and outcomes in this thesis challenges the assumption that innovation is a well-bounded phenomenon focused on fixed products or services. This points to the fact that boundaries in IS innovation can be contracted or extended according to needs and goals. Secondly the innovation activities in this thesis involved actors that were based locally and internationally and with innovation agency identified on technological, institutional, and social dimensions. Within this framework the various actors and entities could indeed organise for the innovation but this was not based on the centrality of innovation agency but rather due to it being distributed and collaborative in nature. Thirdly, it is recognised that there is an interaction between the nature and organisation of innovation. However with the state of digital technological artefacts understood to be always in a flux and to the point of processes and outcomes being potentially interchangeable, these interactions cannot be theorised as distinctly separate phenomenon but rather as mutually constitutive.

8.2 Practical Contributions

Practically, the FDI case examples presented in this thesis demonstrate the viability of the theoretical contributions elaborated above. From the results and findings in the empirical case the practical contribution of this thesis includes an IS innovation strategy proposed for supporting the achievement of short and long-term goals in FDI projects. The strategy elaborates relevant considerations and viable options for leveraging existing systems and resources to support FDI activities and goals. To operationalize this strategy, three general FDI project design principles and four specific solution implementation approaches are proposed. The strategy, principles, and approaches are presented into more details as follows.

8.2.1 The FDI-based HIS Innovation Strategy

One of the goals in this thesis was to find an HIS innovation strategy that could be considered more appropriate for addressing needs in resource-constrained settings. The argument for framing local HIS solution innovations for public health institutions in developing countries within the FDI conceptualization is made based mainly on the resources constraints and uncertainties prevalent in such contexts. An analysis of the research and findings in connection with this goal yielded an FDI-based HIS innovation strategy. The strategy describes frugal solutions exploration by leveraging existing digital systems, ecosystem resources, and infrastructures to serve unfulfilled IS functionality needs in a local organisational context. The key considerations include availability of funding, expertise, and the level of technological capability. The strategic options for maximising results include the development of new solutions on top of the existing infrastructures, integration of different technological systems, and functionality incorporation of other systems into a relatively well established local IS infrastructure. Similar concepts in the extant IS literature are explored in digital platform and II

innovation studies (Gawer & Cusumano, 2014; Hanseth, 2010; Koutsikouri et al., 2018). However the argument in this FDI strategy presentation is that the majority of the concepts explored in these related strategies can be seen to be more suited for addressing issues that pertain at the core of platforms or II development and evolution. The FDI strategy therefore proposed in this thesis is recommended for exploring innovations away from the core of software development and closer to end user contexts such as explored in studies focusing on developing countries (Msiska & Nielsen, 2018; Nielsen & Sæbø, 2016).

8.2.2 FDI Project Design Principles

Within the FDI analytical framework adopted the proposed innovation strategy was devised through reflecting on the practical IS solution innovation processes in the different intervention activities engaged in the research case. From the learnings obtained, general guiding principles are derived to be applied in designing FDI projects to enhance suitability for addressing problems in the resource-constrained public sector institutional setting. These are proposed for guiding solution designers, architects, managers, and policy makers involved in the design and management of local IS innovation project initiatives. Presented in a decreasing priority order of consideration, the first principle indicates the need to:

> Focus on addressing the prevailing user problem and contextual challenges to enhance local viability of solutions and long-term sustainability

The importance of this design principle is highlighted in relation to the innovation flexibility afforded by digital technologies. Such affordances such as ease of programmability can lead to needless use of time and resources on extraneous 'nice to have' features rather than focusing on providing absolutely essential system functionalities. The emphasis is therefore necessary so that solution designers and implementers are mindful of the facts and specifics of problem-context dynamics and addressing the challenges accordingly. In the broader IS innovation literature a similar notion highlights the need to focus on real and specific problems of users for producing immediate usefulness as part of a bootstrapping strategy in II innovation (Grisot et al., 2014; Hanseth, 2010). The difference here is that within II, functionalities can be developed in anticipation of enrolling targeted user groups in the future. However in FDI the users are already known and their needs together with the local and resource capacity considerations serve as the driving force in the innovation process. This is exemplified in this research project where the HIS functionality needs such as in the case of the HIV tracker and the LMIS reporting in the HMIS were identified by the users themselves and subsequently they worked with system developers and implementers in the solutions realisation. Next, the second principle proposes for solution designers to:

> Explore possibilities for building on established social and technological infrastructures to maximize benefits and boost efficiency gains

This is to highlight the need for a frugal mind-set and to focus on how to maximise benefits from the resources present in the local innovation context. This requires knowledge about the existing infrastructure in terms of the core functionalities and features that can be leveraged or built on to save time and costs. The emphasis to explore building on or off established social practices and working technological systems is to improve rapidity and efficiency in the solutions exploration. Thus exploring what may be considered as half-ready solutions by adapting generic features of software platforms can contribute toward these goals. Within resource-constrained innovation studies, this principle can be seen in the functional architecting strategy of charting, connecting, and encroaching based on the generative capacities of software platforms (Nielsen & Sæbø, 2016). Charting is explored for new user cases; connecting for integrating with other systems; and encroaching for incorporating functionality of other ISs. The relevance of this guiding principle is also motivated on the understanding that derivative innovations can also benefit from the growth momentum and positive network externalities of the established infrastructures (Hanseth, 2010). The third and last innovation strategy design principle proposed is to:

> Consider reusing institutionalised structures to enhance replication of successful outcomes including performance improvements across the relevant organizational domains.

This principle is rationalised based on the observation that developing the support infrastructures necessary for new IS solutions to perform satisfactorily and as part of new institutionalization process can be tedious and unduly protracted. Therefore where the systems involved are not vastly different in terms of operational requirements and goals, reuse of the institutionalized structures and arrangements should be considered. This can be seen as a frugal means to addressing institutional voids and constraints. Utilising the same institutional structures and support arrangements in different but allied functional units can improve the capacity to replicate desirable performance outcomes across multiple organisational areas. For example in the thesis the use of same DHIS2 support arrangement for the HMIS was used to support the LMIS data reporting functionality development (Paper 5). Furthermore in the DHIS2, LMIS data reporting timeliness was aligned with existing HMIS data reporting timeliness due to the proven practicality of the latter for balancing between data entry workload and leaving adequate time for quality monitoring and follow-ups.

8.2.3 Practicable FDI Solution Implementation Approaches to Doing More with Less

The operationalisation of the FDI strategy proposed and guided by the general project design principles was pursued in the various case examples in this research project. From this, four innovation realisation approaches that were found suitable for addressing needs in resource-constrained public health contexts are presented as part of the practical contributions. These are proposed for consideration by IS project managers and technical solution developers engaged in solutions explorations in local problem situations. The approaches are identified to include Leveraging, Embedding, Scaling, and Scoping (LESS) in short to emphasise the frugal principle of doing more with *less* (Bhatti & Ventresca, 2013). The approaches are to be pursued

individually or in combination depending on the problem situation and the capabilities of the installed based infrastructure. These are elaborated as follows:

1) Leveraging software platform modules and ecosystem capabilities where available for new solutions: Software platforms by virtue of their architectural design flexibilities can support derivative product and service innovations. This was the idea explored in Paper two (Adu-Gyamfi & Nielsen, 2017) and later realised in Paper three i.e Adu-Gyamfi, Nielsen, Sæbø and Saugene (2019). The technical features of digital platforms together with network of users, software developers, and associated support communities formed an ecosystem with capabilities that could be leveraged in developing and implementing the required solution. In DHIS2, the open-source approach to its development further allowed these platform and ecosystem capabilities to be localized. This means that unlike proprietary software platforms once DHIS2 is implemented in particular settings both its code-base and software modules can be modified and customized to suit contextual needs without affecting other deployments in other locations. For this the necessary expertise can also be sourced locally or from the wider HISP community to assist in tailoring or developing the functionalities required. In this research for example, we were able to successfully tailor DHIS2 platform software modules (i.e. Event Capture and Tracker Capture) in accordance with local and international standards such as required for managing HIV treatment programs (WHO, 2016). The frugality of this approach is argued on the basis that the software platform and its ecosystem resources are already established in the local context and can be tailored and reused as needed.

2) Embedding or merging complementary IS solutions into identifiable and well established parent systems and infrastructures: In the health information management domain there are often more targeted IS solutions that can be deployed as standalone systems and or serve as complements to more general and high-level management systems. Mobile technology and network-based health management solutions collectively referred to as mHealth (Labrique et al., 2013; Mechael, 2009) fall in this category of complementary systems. For example facility level mobile data collection tool and patient-level HIS can be made to feed data aggregates into an HMIS system through electronically integrated interfaces. The purposes for exploring this approach can include a need to improve data quality while also reducing data entry workload on health workers. In such instances it is possible for the complementary solution to be embedded in or merged into the existing parent system and infrastructures to enhance overall systems continuity capacities. In this thesis for instance it is argued that although the HIV patient tracker solution (paper 3) suffered scalability stagnation it nonetheless endured due to it being embedded into the established local HMIS infrastructure. Based on this it is suggested that the facility-level mobile data collection project (paper 4) could have continued if its technological and organisational infrastructures were fully embedded or merged with infrastructures of the parent system it was meant to complement.

3) Scaling existing IS functionality across different user dimensions, for example from general health management to disease-specific health program management: Scaling describes a process

where a system is expanded in size to accommodate more users or to cover wider geographical area (Sahay & Walsham, 2006). This usually involves expanding same system functionality in the same or across different contexts (Sahay et al., 2013; Shaw et al., 2007). In adding to this, it is proposed here that a system that is already deployed and in use can be scaled through functional adaptation to cover user needs in adjoining but different organisational areas and usages. An example of this approach in the current research project was in scaling functionality of a system implemented to manage aggregate health data (i.e. HMIS) into supporting patient-level data management (paper 3). The management expectation for this approach was that improving quality at the more granular data management level should in turn contribute to improvements at the aggregate management level. Through this use of the same technological system across adjoining organizational domains, internal resources could be reused to support system use and local sustainability. The frugality of this approach is in the saving of time and maintenance costs that would normally accompany hybrid multi-vendor systems and new technological solutions.

4) Scoping or repurposing domain-specific IS and supporting infrastructure to cover functionality needed in different but related organizational domain: Country-level health management involves different types of organizational units playing unique but complementary roles that collectively enable a proper functioning of health systems and services. Normally the different sub-organizational units also have specific ISs that are used to support their individual operations. Examples of these are the HMIS used for managing healthcare-related data and the LMIS used for managing logistics data. While such systems can be made to interoperate and share data as necessary through various integration approaches, in the context of resource-constraints keeping integrated interfaces functional and up-to-date can be challenging and at worst unsustainable. With this consideration one system can be made to serve needs across multiple and distinct organizational areas. This can be achieved by scoping or repurposing an existing functionality on the relatively well established and better performing system and by so doing encroach on the domain of another IS by incorporating and taking over some of its functionality. The repurposing of HMIS aggregate data management functionality to support similarly needed functionality in the LMIS organization demonstrates this approach (paper 5). In this case the functional scope and boundary of the HMIS was expanded along with the relevant support infrastructures.

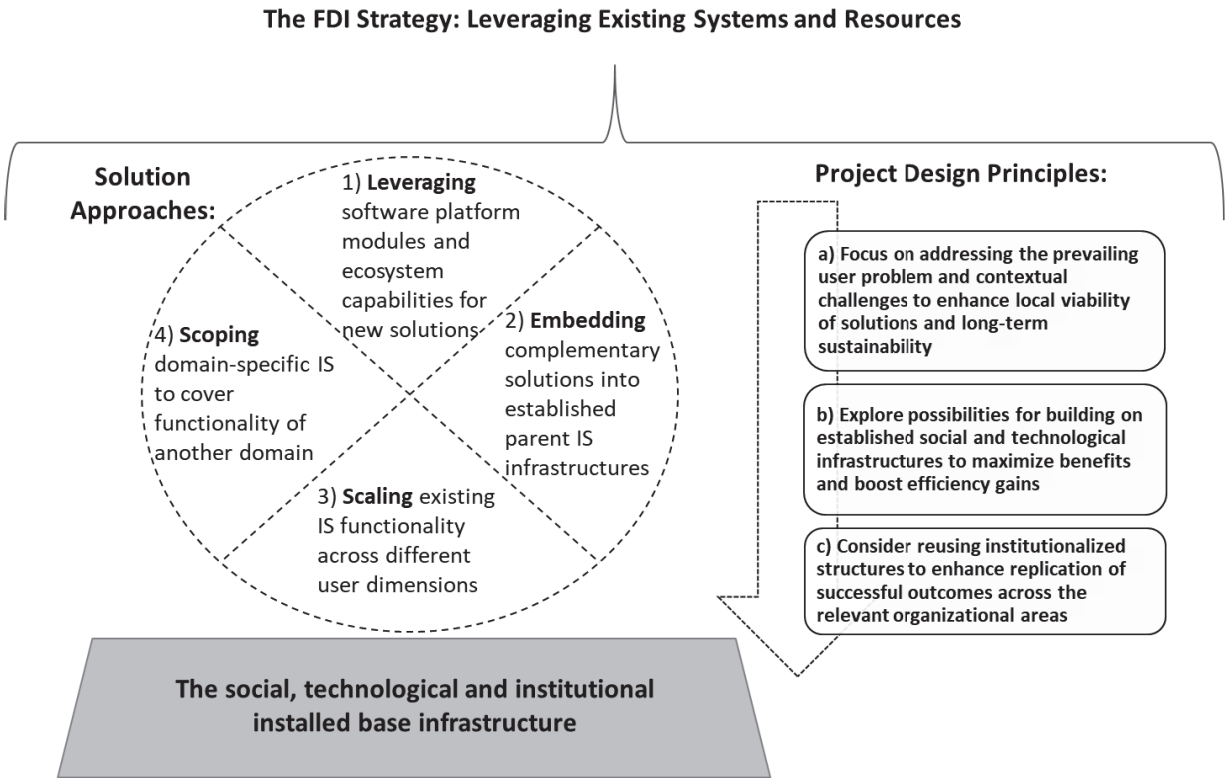


Figure 12: The proposed FDI strategy, project design principles and practicable approaches

By way of summarizing the linkages between the FDI-based innovation strategy, design principles, and practicable innovation actualization approaches are also illustrated in Figure 12 above. In the next section I draw implications for research, theory, practice and policy.

8.3 Implications of the Findings and Contributions

From the findings and contributions presented and discussed, I draw implications for research and practice. In this research, adopting a social development purpose-orientation was important in shaping the innovation processes. This together with the focus on one country context, on digital technological capabilities to support local IS innovations in frugal ways, and the interpretive paradigm adopted imply that the generalizability of the results and findings is limited. However the FDI strategy, project design principles, and practicable solution approaches should have wider applicability beyond the individual research case especially in similarly resource-constrained contexts. Also the FDI goals by being based on frugal and digital innovation principles should be relevant in innovations with commercial, private, or public socio-economic development interests. These should also apply in both developed and developing country settings where the main goal is to achieve more and better outcomes with fewer resource inputs.

Within the FDI framework it is also important to clarify the relevance of certain inherited conceptual attributes from the frugal and digital innovation research fields. For example, it can

be said that the understanding of digital innovation as innovations based on the material properties and capabilities of digital technologies is quite settled (Ciriello et al., 2018; Nambisan et al., 2017; Yoo et al., 2010). On the other hand the frugal innovation concept can be seen as still evolving due to its broader association with constraint-based innovations (Agarwal et al., 2017). Constrained-based innovations however may or may not involve digital technologies and are not necessarily pursued in formal institutional settings. So for FDI where digital technologies are central in the innovation processes and formal public institutional context is the main focus (Sahay, Nielsen, Faujdar, et al., 2018), the understanding of frugal innovation needs to be properly contextualized. As part of addressing this issue, a criteria-based definition based on Weyrauch and Herstatt (2017) can help sharpen our understanding of frugal innovation. The stipulation that frugal innovation must simultaneously meet three criteria of concentration on core user functionality, substantial cost-reduction, and optimized performance levels helps contextualizes and grounds a proper understanding of frugal innovation within the FDI framework. Following this introduction I discuss further implications with respect to systems architecture, governance, practice, policy, scalability, and long-term sustainability.

8.3.1 Systems Architecture and Governance

A system's architecture defines the formal patterns that link its structural and functional components. The nature of systems architecture and impact on governance and evolution is an important topic in both IS and general innovation research, and thus also has relevant implications for the FDI field. For example in the frugal innovation literature Lim and Fujimoto (2019) identify product architecture simplification strategy along modular-integral spectrum of functional, structural, and relational with cost and performance implications. Functional simplification focuses on system performance optimisation, and therefore the resulting architecture can be modular or integral. In structural simplification many functions are mapped to fewer structural components as cost saving strategy. This can lead to integral solutions architecture with potential negative impact on system performance. Lastly, in relational simplification, the density of interrelationships between functions and structural components are reduced to improve architectural modularity and thus performance optimisation.

The corresponding considerations in digital innovation can be seen in terms of strategies explored in managing systemic risks and control issues with respect to the architectural options in IS innovations (Hanseth & Bygstad, 2012). In this, loosely coupled systems are more modular and support control and management decentralization while tightly coupled systems are integral and therefore can lead to risks and control centralisation (Aanestad & Jensen, 2011; Henfridsson & Bygstad, 2013). With the contribution in this thesis emphasizing on innovation exploration based on leveraging existing systems, this could result in tightly coupled and highly integrated solutions architecture posing risks to systems availability and resilience due to the centralisation of control and related risks. On the other hand, the benefits of having a homogenous technological infrastructure include reduction in maintenance and evolution costs due to systems vendor management and support services consolidation. Additionally by serving data

management needs of multiple and complementary organizational units with one IS technological infrastructure the potential for achieving integrated data management is enhanced. In this research project, the potential for enhancing integrated health system's data management was seen with using same DHIS2 and server infrastructure to support both HMIS and LMIS summary data reporting (Paper 5).

8.3.2 Policy and Practice

Beyond digital technologies enabling new IS solution innovations, the nature of institutional policies and concerning project organizational setups are identified to have constraining and facilitating effects on local innovation capacities. As part of mitigating the potential negative effects, appropriate policies can be designed and implemented to support FDI goals. The policies can for example be used to guide activities of the multiple actors and, interests that are often associated with IS development projects in the public sector contexts of developing countries. Especially in the need for new HIS solutions, the existing IS installed base and allied resources should be explored and implementations pursued if that is the more frugal and sustainable option for the long-term. In the thematic analysis of this research, appropriate local constructs to support effective policy formulations were also identified to include defining a unified HIS architecture and governance strategy to guide broad-based participation and collaboration. Such policies could further be broken down to the health programs level for guiding individual project implementations as well as data management and reporting practices. At the central level this requires establishment of interoperability frameworks that are capable of supporting the necessary systems integration and data reporting standard requirements across the relevant organizational domains. Practically, this could contribute to improving health programs-specific HIS development and data management practices that would in turn contribute to strengthening the general HMIS performance.

Additionally and for the purpose of enhancing continuity of solutions implementation, policies concerning project organization and team setups could emphasize local leadership. Particularly project implementation steering role assignments could consider personnel whose continued involvement are less likely to be affected by national and high level managerial politics. For example a policy could be instituted to empower suitable civil servants in mid-level management positions to take up key local project implementation lead roles. This can be a frugal alternative to securing relatively expensive and short-term services of external consultants. In addition to this, more enduring public institutions such as local universities can be partnered with to serve different support functions and also contribute to local capacity building. Such collaborations can be used to preserve local institutional knowledge by for example attaching student to projects in internship programs. These can also lead to the production and dissemination of project reports and relevant academic knowledge to contribute in the advancement of FDI research and practice in the public sector context of developing countries.

8.3.3 Scalability and Sustainability

Scalability in the frugal innovation literature is understood as a product's ability to scale in terms of sales while sustainability is about meeting green market objectives, such as using ecologically sustainable resources in the innovation process (Albert, 2019). For digital innovations on the other hand, scalability is concerned with the ability for a system to expand in size, capacity, functional scope, and in terms of number of users (Adu-Gyamfi, Nielsen, Sæbø, et al., 2019; Sahay et al., 2013). Sustainability of digital innovations is also understood as being able to maintain or sustain a system at optimum level of operation over its useful lifetime. In IS innovation research, although systems are expected to scale and be sustainable it can be observed these are not always the primary focus. More often frugal or digital innovations are driven by the need to solve immediate and pressing problems through improvisation or combining resources at hand in a make-do fashion. These motivations for example can be seen in jugaad and bricolage (Ciborra, 1992; Radjou et al., 2012; Senyard et al., 2014). In such cases the material inputs to the innovation process may also be highly localized to the extent that they cannot be easily found and replicated in other contexts. For the emerging FDI field, solutions scalability and subsequent sustainability are also important issues that have to be part of the key considerations in designing and pursuing the appropriate innovations. This implies that the technological solution and the supporting social and organizational structures also have to be designed with flexibilities that allow them to scale along with the digital technological solutions. This includes designing solutions with simplified architectures that can be scaled, maintained, and sustained within available capacities.

9. Conclusion

This chapter concludes my thesis presentation. A recap of the research problem and thoughts on how the research investigations contribute a resolution are presented. The empirical activities enabling the investigative process are reflected upon. The chapter ends with summary of the conclusions, and with suggestions made for future research. The suggestions are based on the aims and objectives pursued and the results obtained in this thesis project.

9.1 Recap of Research Problem and Resolution

In this thesis an attempt was made to address persistent challenges found to be associated with efforts in meeting IS needs in public health institutional and resource-constrained contexts of developing countries. A lack of emphasis on local and resource-constrained considerations in the design and implementation of IS innovation projects was identified as a problem contributing to solutions ineffectiveness and unsustainability. The factors were identified at organisational, national, and international levels with technological, institutional, and social dimensions. In addition, the relevant IS innovation projects were seen to be more often driven by external interests to the point where achieving short-term goals often takes priority over long-term systems strengthening and local sustainability. Also in spite of the heavy external funding and support of international donor agencies and partner organisations the expected IS development progress is not realised. Therefore in contributing towards a problem resolution, the need to emphasise local imperatives in IS innovation projects meant to serve public sector needs and social development interests was proposed. Pursuing this called for an appropriate IS innovation conceptualisation to support in identifying and leveraging the innovation potentials that exist in relationships involving IS technologies, and contextual factors for solutions.

The appropriate IS innovation strategy was conceived within the FDI framework (Sahay, Nielsen, Faujdar, et al., 2018). Within this framework, the central role of digital technologies in innovation inputs, processes, outcomes, and the potential to enable frugal innovation pathways to solutions were identified. In addition, the importance of applying frugal innovation concepts to shaping digital innovation processes was emphasised as important for success. Furthermore, opportunities emerging at intersections of technological, institutional, and social innovations were identified and leveraged to enhance the sustainability of the FDI outcomes. The ultimate purpose in this particular context of health was found as the need to improve health services delivery and management towards socio-economic well-being of people. Within the FDI analytical framework it was understood that the goals and purposes in an innovation project whether commercial, private or public and non-commercial should be clearly understood to guide the entire innovation process life cycle. This includes decisions and actions that must go into the innovation realisation phase. The innovation outputs should then be evaluated in terms of potential for achieving short and long term FDI goals, supporting organizational performance improvement, and paving the way towards institutionalisation. Over time the expected social development impact from using the implemented solutions should also be assessed.

9.2 Reflecting on the Empirical Case and Relevance

The empirical background to this thesis was action research based on participating in HIS development, implementation, and strengthening in the public health management context of

Sierra Leone. The dynamic, relational, and multi-layered nature of contexts produced by historical and contingent factors have contributed to an HIS infrastructure that needed strengthening. This was expected to contribute in various ways to performance improvements in healthcare delivery and management. Consequently interventions were pursued at general country HIS level and health programs-specific HIS levels. The interventions together with empirical work based in qualitative methods of data collection and analysis yielded various outcomes with a mix of successes and setbacks. This nonetheless contributed a more holistic and qualitative understanding of the challenges and opportunities to advancing IS innovation research and practice from an interpretivist researcher standpoint (Walsham, 1993). For instance two IS innovation projects were able to scale nationwide but one was considered successful and the other was considered a failure. The findings were that the successful solution was fully embedded into the existing installed base infrastructure while the failed solution was deployed and supported on separate and parallel infrastructure. However, the determination of success or failure was not only based on the ability for achieving resource efficiency but also the viability and long-term sustainability based on local resource capacities.

The relevance and suitability of the empirical case for FDI exploration are reflected on. This is based on identifying certain case characteristics that may be considered unique to innovations situated in developing countries contexts and therefore requiring less mainstream approaches. These were found to include a high prevalence of environmental uncertainties and resource-constrained factors relating to funding, expertise and technological capability. This was also informed by the urgency with which problems were required to be resolved in meeting goals. In the Sierra Leone case politics at national and project organisational levels were also found to contribute in environmental uncertainties. Additionally, funding for projects were seen to be reasonably accessible but with no long-term guarantees, the requisite local expertise capacity was not adequate and needed boosting, the still maturing national infrastructures prompted solution innovativeness, and projects were seen to be time-bound. On the positive aspect the installed base infrastructure consisting of technological, institutional, and social systems and structures were found to be reasonably malleable in supporting process improvisations and activities involving systems functionality adaptations. These characteristics of the empirical case and the formal institutional innovation settings were therefore found as suitable conditions and can serve as an adequate basis for justifying the action research approach to the FDI strategy exploration pursued in this research project.

9.3 Summary of Conclusions and Suggestion for Future Research

With the results and findings obtained from the research project, a number of conclusions arrived are hereby summarised. The main conclusion is that the emerging FDI conceptualization provides a promising analytical lens for studying IS innovation within resource constraints, and for guiding the exploration of solutions more suited for meeting ICT4D goals. This is partly due to the particular focus on addressing local HIS needs within formal and public institutional settings. The public health management context in a developing country like Sierra Leone is

dynamic and influenced by many local and international factors. This therefore requires an innovation mind-set and strategies that are capable of supporting rapid and frugal adaptations of flexible HIS installed base infrastructures and resources in meeting changing user and health management requirements. The FDI conceptualisation, strategy, principles, and approaches are seen to have the potential to facilitate the achievements of such goals. In addition to this, there is a mutually constitutive relationship identified to involve frugal innovation principles and innovation capabilities of digital technologies that should be emphasised in shaping innovation processes and outcomes towards maximising benefits. For the purposes of efficiency it is important that this relationship is conceptualised and approached as continuous, iterative, and overlapping. The centrality of digital technologies within this FDI conceptualisation is identified to contribute in challenging old assumptions in broader IS innovation theorisation. This is achieved by clarifying that innovation boundaries are extensible, innovation agency can be distributed within project ecosystem network, and the possible interchangeability of components in the innovation life cycle means that processes and outcomes are not strictly distinct phenomena. Additionally the FDI-based solution strategy proposed by leveraging on existing systems and resources can contribute to potentially frugal pathways to solution exploration and enhance local sustainability capacities.

Further, it was observed during this research that there are considerations on technological, institutional, and social dimensions that do indeed impact on the success of FDI project initiatives. These include available and continuously generative socio-technical installed base infrastructures, flexible and adaptable institutional arrangements, supportive organizational and cultural practices, aligned stakeholders interests, and commitments from management, donors, and relevant political actors. In the case of this research enablers identified on the technological dimension served as the starting point for the FDI solutions exploration. The institutional and social innovation enablers were perceived and leveraged as the research unfolded. While this may be different in other research contexts it is important that all three innovation aspects are perceived albeit can be in different degrees and stages of development. For example while the technological innovations were more perceptible in this research, the institutional innovations were largely identified as early stage organizational process improvisations to collaborate on projects. The actual institutionalisation of these processes and long-term impact on innovation sustainability could not be assessed due to research time limitations and therefore can be a focus of future research investigations. Additionally there is a need to revisit FDI implementations to evaluate the extent to which the social development goals envisioned in such projects are being achieved. Again due to design and time limitations in the current research the reality of the expected social development benefit could not be evaluated. This can also be pursued in future research investigations where the analysis is based on the perspectives of the end-beneficiary groups such as patients in this case of HIS-focused innovations. These can then contribute to obtaining more holistic insights covering the entire FDI value chain proposition from discovery, development, diffusion, to usage and impact evaluation. Notwithstanding, the research outcomes in this thesis are presented as a way of contributing to the further development of the still

emerging FDI conceptualisation and to improving the prospects for more successful IS outcomes in resource-constrained public sector contexts of developing countries.

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Appendices

The Included Papers:

I

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The Dynamics of a Global Health Information Systems Research and Implementation Project

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Abstract

The Health Information Systems Programme (HISP) is a sustainable and scalable research project enabling and supporting health information systems implementation in more than 100 developing countries. In this paper, we present the historical roots, the status, and discuss the future of HISP and its software (DHIS2). We also reflect on factors contributing to the project's global success and find the open and participatory approaches to HISP and DHIS2 software development, and implementation in countries as key. For the future, we discuss strategies to stabilise as well as grow the HISP and DHIS2 community into a sustainable ecosystem.

Keywords

HISP, DHIS2, health information systems implementation, participatory action research, open-source software.

1 INTRODUCTION

Health information systems (HIS) are designed to manage different kinds of healthcare-related data and are one of the foundational building blocks of every health system [1]. These information systems (IS) enable data generation, collection, analysis, communication and use for decision-making at individual, facility, population, and public health surveillance levels [2]. While individual-level data serve as the basis for clinical decisions, facility aggregates and administrative data enable community-level resources planning and service delivery. The health service data, when combined with non-routine data such as household surveys, support population-level decision-making, and data from all sources combined enhance a country's ability to monitor, detect and respond appropriately to public health emergencies.

In many developing countries, appropriate and well-functioning HISs are either not available or fail to scale or be sustained [3]. Problems of institutional disparities, lack of proper technological solutions and constraints on resources in the public health sector are typical factors contributing to failure. In this context, we present the Health Information Systems Programme (HISP) and the District Health Information System (DHIS) software as a global success story in terms of being a sustainable and scalable project providing and supporting the implementation of HIS in developing countries. As a large-scale longitudinal international action research programme coordinated from the University of Oslo (UiO), HISP has engaged in the development and implementation of the DHIS software for more than two decades. The DHIS2 (second generation DHIS since 2005) is a generic open-source software system with data warehousing functionalities and customizable modules for integrated health data management[4]. Ministries of Health and Non-Governmental Organizations (NGO) in more than 100 developing countries are using DHIS2, covering an estimated 2.28 billion people (www.dhis2.org/inaction).

In this paper, we explain the historical roots, the status, as well as discuss what we see as the future of HISP and DHIS2. As participants in HISP at the University of Oslo, we provide an insider view of the organisation, its software and software innovation approaches, the research and education component, capacity building strategies, sources of funding, and the broader global community dynamics.

This paper is a retrospective study on activities the authors have participated in. As action researchers, we have carried out HIS strengthening activities through HISP totalling over 30 years. Data collection methods used for this particular paper include analysis of published HISP research and related IS literature, project documentation, semi-structured interviews, and own notes and memos based on our direct involvement in DHIS2 implementation projects. We aim in this paper to contribute by providing a detailed description of HISP and DHIS2. In addition to this, we offer relevant reflections on the factors contributing to the scalability and sustainability of this project. Accordingly, we have organised the paper as follows. First, we trace the early stages of HISP and DHIS2 and describe the key events and enablers in the establishment phase. Next, we describe the status and evolution of the project over the years, related to the organisation and the software. We provide an outlook on what we see as the future for the project and then discuss the community dynamics and what we see as accounting for the successes achieved so far. We conclude with our reflections on the future.

2 THE EARLY STAGES

2.1 The Organization and the Software

As part of the political processes of change in post-apartheid South Africa in 1994, strategic management teams were set-up to develop plans for the reconstruction of the health sector in different provinces [5]. With the government's priority to establish an integrated and decentralised health system, a district-based health system supported by a district health management information system was identified as a key element [6]. In 1995, the

HIS subcommittee for the Western Cape Province which included HISP founding members proposed to develop a district-based health information system. HISP started through this initiative and based on action research in two 'coloured' townships created during apartheid [7].

HISP was set up as a collaborative project involving the University of Cape Town, the University of Western Cape and a Norwegian PhD candidate from the University of Oslo (UiO). The initial aim was to contribute to addressing the information management challenges of the then highly centralized and extremely fragmented health system in South Africa. The strategy adopted to achieve this aim was through tools and data standardisation, development of essential datasets and a software application to support its implementation. This strategy led to the development of the first District Health Information Software (DHIS) prototype based on Visual Basic and Microsoft Access. The development team was located at the University of Western Cape (UWC) and consisted of two core software developers and a group of HISP members acting as mediators between users and the developers[8]. After testing and piloting in three districts in the Cape Town area, they scaled the system to the entire Western Cape Province by 1998 [7]. By 2001, the Department of Health in South Africa adopted DHIS, and associated HISP standardisation strategies. They further implemented it as the national standard in all districts of the country.

From the start, the project invested significant resources in building expertise in HIS in the countries where DHIS was implemented. In South Africa, formal DHIS training courses were made part of UWC's master in public health. The training received from UWC was cascaded down to the provinces by the trainees, and through this, nearly 2000 health workers were trained [7]. With success in South Africa, HISP pursued similar initiatives in other countries, including India and Mozambique. As the project expanded, challenges emerged with the two-person software development team and software architecture not suited for distributed development. Even if open source, DHIS used the Microsoft Access database and thus required full MS Windows and MS Office stack. The standalone installation of DHIS at each health facility, requiring a large maintenance team travelling around to keep all installations functional, virus-free and up-to-date was also challenging. To address these challenges and at the same time try to bridge software development and user context gaps, parallel development of a DHIS version 2 (DHIS2) started at the University of Oslo in 2005 [9]. Developed as open-source software and with client-server architecture, DHIS2 supports distributed software development, broad user participation and centralised maintenance.

2.2 Research, Capacity Building and Growth

Founded on research and development HISP was a synergetic collaboration between public health activists in the post-apartheid South Africa, and information system developers coming from the Scandinavian tradition of participatory design and action research (AR) [10]. Participatory design emphasises user participation [11] and AR has its basis in cyclical interventions in the research settings to accomplish change while reflecting and learning from the change processes [12]. In Mozambique, with funding from the Norwegian Council of Universities' Committee for Development Research and Education, HISP, the Universidade Eduardo Mondlane (UEM) and the Ministry of Health partnered up to pilot DHIS in 3 districts in 1999 [7]. A group of PhD candidates from Mozambique enrolled at UiO was the driving force in this implementation. They led user engagements in system customisation, training and translation to Portuguese. This university-based model [13] of HISP and DHIS capacity building was later replicated in India, Tanzania, Ethiopia, Malawi, Sri Lanka, and Bangladesh, and has resulted in more than 500 Master and 55 PhDs from HISP countries graduated and more are at various stages of completion.

Another institution for training is DHIS2 Academies established in 2011. Based on periodic regional gatherings and training of DHIS2 users, the Academies offer practical sessions on topics ranging from system development, implementation, maintenance, and system use. More than 4800 participants have attended the 87 Academies arranged so far. Since 2017, an online Academy is also offering free and self-paced courses on the fundamentals of DHIS2. Additionally, DHIS2 experts and community members from around the world, including implementers, developers, ministry representatives, technical partners, and donors meet in Oslo every year to share experiences on DHIS2 implementations at the DHIS2 Annual Conference (formally Experts Academy) since 2012.

In 2006 DHIS2 was first implemented in the state of Kerala in India after which it rapidly became the preferred option to the earlier DHIS [14]. The rapid global spread of mobile Internet at the time was a key factor in this. For example, in 2010, the Ministry of Health in Kenya decided to implement an online DHIS2 server [15]. Due to uncertainties regarding internet coverage and doubts regarding whether its 200 districts could use an online system, the decision was to go for a hybrid approach with one central online server for online offices supplemented by standalone installations where the Internet was not available. An offline data entry feature based on HTML5 was also developed to deal with cases of fluctuating internet connectivity. Such a centralised approach introduces common failure points and related risks to system availability. However, the advantages of improved data access and reporting timeliness inspired countries like Ghana, Uganda, and Rwanda to follow suit with their online national deployment of DHIS2[16].

2.3 Funding Sources

In the beginning, the funding of HISP came from the Norwegian agency for development cooperation (Norad), the University of Oslo, the Norwegian research council, the Norwegian university council, donors and the governments in the countries where DHIS was implemented. Early HISP activities in South Africa and Malawi, for example, received funding and support from EQUITY/USAID and Dutch AID [7]. The financing of the activities at UiO came through research programmes, PhD- and Master-scholarships, support for establishing Master programmes in developing countries, salaries of Faculty members and direct implementation support.

Master students and PhD-candidates developed the DHIS2 software and piloted it at the beginning. Over time, the funding from Norad evolved into core funding for professional system developers [14].

Other agencies including PEPFAR, the Global Fund, UNICEF, GAVI, CDC, USAID, WHO, and Bill and Melinda Gates Foundation have also funded HISP and DHIS2 activities through various arrangements [17] [18] [19]. For example, since 2015, PEPFAR is funding the development of DHIS2 software features to support particular requirements they have related to their use of DHIS2 as their internal reporting system. When implemented, these features are also available to all other DHIS2 users. Another organisation using DHIS2 for reporting in their program countries is Médecins Sans Frontières (MSF). With their focus on using mobile devices for reporting, MSF is providing particular funding for the DHIS2 mobile solution. Another source of funding is regional organisations such as EMRO (East Mediterranean Regional Office, WHO), supporting regional implementations of DHIS2.

3 THE PRESENT STATUS

3.1 The Current HISP and DHIS2 Community

HISP is today a global network constituted of Independent HISP groups (like HISP South Africa, HISP India and HISP Uganda), Universities (like University of Dar es Salaam and Universidade Eduardo Mondlane), Ministries of Health, NGOs, global policy-makers, global donors, researchers, students, social entrepreneurs, individual consultants, and more. Together, they play different, but complementary roles, and form an organically growing ecosystem around the DHIS2 software with new roles developing and shifting between the different actors.

HISP UiO, which coordinates the development of DHIS2, is now also a professionalised software development organisation. Other core actors in this global ecosystem around DHIS2 implementations are the HISP groups with established and sustainable local expertise in developing countries (Bangladesh, India, Malawi, Mozambique, Nigeria, Rwanda, South Africa, Sri Lanka, Tanzania, Uganda, Vietnam, West and Central Africa region, and Colombia). They support the implementation of DHIS2 in their countries and regions based on their domain knowledge, technical and implementation expertise and experience. Their efforts include training of users at different levels, system implementation, maintenance, integration with other systems and software development of extensions and apps. They also contribute by arranging regional DHIS2 academies and share knowledge with other entities through, e.g. the DHIS2 annual conference.

3.2 The Research Component

HISP is a large-scale and international action research project with actors including Universities, Ministries of Health, NGOs, global donors, researchers, students and many others [20]. The focus of HISP is knowledge development and the impact and sustainability of its AR interventions [7]. These are mainly pursued within the public health IS space of developing countries and with diverse AR goals [21] including organisational development, system design, scientific knowledge, and training [20]. Practical research activities involve experimenting with new technologies, adapting the DHIS2 software to new use-cases in local contexts, improving the platform capacities of DHIS2 (including interfaces and ease of integration), capacity building approaches, institutionalising the use of the system and evaluations of its impacts. The foundation of HISP research is the spread of these best practices for enhancing the long-term sustainability of outcomes [7].

The growth of the community has allowed diversification and specialisation in research, implementation, capacity building and software development. Designated software developers, product managers and project coordinators at UiO, for example, are not necessarily directly involved in academic research. Still, implementation and software innovation projects typically include different roles.

3.3 DHIS2 Software

The DHIS2 software has evolved from a tool for collection, storage, validation, analysis, and presentation of aggregate health data to also support patient management and individual records. It is a platform that Ministries of Health rely on for monitoring and evaluating the health services and health status of the population. Capacity strengthening and platform development fuel the participatory action research core of this project. It enables local innovations necessary to ensure relevant systems for the users today, and flexible enough to meet the new and changing requirements of tomorrow, such as emerging patient-based use cases (e.g. [22]) and others in agriculture, education, e-government and logistics management (see www.dhis2.org/user-stories).

DHIS2 is a Java-based web application and runs on multiple platforms including Windows, Linux, Mac OS X and Solaris. It's rich RESTful Web APIs, enable Java Scripting, CSS and HTML5 apps and by using the W3C standard compatible with all major web browsers. DHIS2 runs on PostgreSQL, MySQL and H2 database systems and with minor development efforts, DHIS2 can run on any mainstream relational database. Using the BSD license makes DHIS2 free and open-source with its code available to be used modified and redistributed freely. It interoperates with other relevant applications such as OpenLMIS, iHRIS, OpenMRS [23] and the World Health Organization (WHO) tools in the public health domain [24]. DHIS2 interfaces with third party web portals and technologies, including SMS, E-mail, and Geographical Information Systems (GIS) to enhance its functionality. The software user interface and meta-data are internationalised and currently available in English, French, Spanish, Portuguese, Hindi, Vietnamese, Chinese and Norwegian. DHIS2 mobile supports offline operations in areas with a poor and fluctuating Internet connection, based on HTML5, SMS and Browser and Java-based clients. DHIS2 Android apps support offline data capture, including a Dashboard app for data visualization.

3.4 Community Support and Coordination

Since the inception of DHIS2, UiO has played a core role in coordinating the community and the capacity building around the software and its implementations. The core DHIS2 software development expertise and activities are located at UiO with some of the software development

efforts delegated to experts in the HISP groups. The platform architecture [25] of DHIS2 is supporting this distribution. The professional software team consists of more than 30 developers located at UiO and in Vietnam, Spain, the US and the Netherlands. It is organized into frontend and backend teams headed a lead developer with the management and coordination of these teams located at UiO while the developers are distributed. Another essential element of HISP is providing implementation support to strengthen local capacity. Global, regional and UiO implementation support are available and work with the different groups on activities including capacity building, defining requirements, managing the community (Discourse) platform (www.community.dhis2.org), organising academies, creating training material, training in academies, and more.

An online community platform supports the interaction between the UiO team, ministries of health, donors, HISP-groups, implementers, third-party developers, and so on. The platform includes mailing lists, source code repositories, a forum, and an issue tracker. The Discourse platform, now acting as both a forum platform and mailing list, is the primary tool used to communicate publicly within the community. Another core tool mainly used by the software team to document, track and manage issues (bugs, new requirements and features, use cases, etc.) is Jira (www. jira.dhis2.org). Beyond the software team, any user on Jira can view, create and participate in discussions regarding features, requirements and bug reports. Users can also follow the progress of issues solving, and see an overview of planned future changes to the software. Software developers are also using a source code repository based on GitHub. The repository stores the source code of projects, providing version control of the software code and making the project openly available.

3.5 The Current Funding Landscape

Today's funding of HISP comes from international and national organisations related to the development of the DHIS2 software and country support in terms of implementation and capacity building. The funding landscape has changed over the years. For example, Norad, the Global Fund and PEPFAR entered into a joint agreement to coordinate funding and leverage investments in 2012 [17]. Through this agreement, Norad continues to support UiO's core funding needs, including the management team, software development, and in-country implementation support. The Global Fund support for core resources are applied to in-country services only. PEPFAR supports their targeted reporting needs in their DHIS2 implementation (i.e. DATIM) being used in more than 50 countries and this funding also feeds into the generic core of DHIS2 features available for all. UiO is also supporting the project by supporting the contribution from faculty members. UNICEF and the World Health Organization (WHO) are also supporting the core resources at UiO as well as particular initiatives[24].

4 THE FUTURE OUTLOOK

4.1 Stability and Growth of the DHIS2 Platform

The sustenance of DHIS2, its growing number of new and more mature implementations, the human capacity supporting it and the wider HISP community will require further investments. One of the strategies pursued by UiO to prepare for the future is the positioning of DHIS2 as a digital global public good in which each community member can contribute in its growth and evolution [18] [26] [27]. Some inherent tensions with this approach relate to the funding of public goods. As public goods allow unrestricted use, sustainability will depend on 'voluntary' and continuous support from core funders. The tension here is a need to balance between serving those who can pay for functionality and those who cannot. Another tension is between developing globally relevant and generic software and serving the particular needs of a specific user. Another tension relates to the adoption of DHIS2 in domains other than health, such as education and e-government. While the primary goal of HISP is to support the health system, there is a need to strike a balance between focus and stability on the one hand and innovation on the other to maintain an acceptable quality of the core platform [19].

Improving DHIS2 stability and performance presupposes a generic and reasonably open core platform to enable increased community participation [28]. A purer platform approach, strictly separating generic core services, boundary objects such as Web APIs, and apps will be necessary to allow stability and diversity in a demanding community. [29]. Towards this, further *control devolution* [30] may be required to delegate even more platform and app development activities away from UiO to others in the community. This will enable app development by developers closer to the users and thus better suited to drive locally relevant innovation. Open and standardised interfaces must also be continuously updated to allow for interoperability with third-party systems where necessary.

Additionally, system performance at implementation and use need to be improved. These will require well-defined system deployment specifications and guides for proper configuration and use of DHIS2 features. The emerging individual events and patient-level use cases, and the traditional aggregate data management functionalities need to be continuously improved. Considering that internet connectivity is a challenge in many DHIS2 country implementations, more attention is required to strengthen offline usage of core functionalities for data entry, tracker, reporting and analytics.

4.2 Research, Learning and Long-term Capacity

With maturing DHIS2 software platform and implementations, new research topics also emerge. For example, there is an increasing need to go beyond how to create functioning systems. Key research themes in this respect relate to assuring high-quality data collection and a better understanding of how to improve and strengthen information use and better decisions based on HIS. A side effect of the global success of the project is that DHIS2 is becoming increasingly generic. Together with the increasing number of users, the distance between the users and the developers is increasing. We need to revisit the participatory design and action research approaches that spurred the initial success of HISP in this novel context. Further, there is a continuous need to evaluate the success and impact of DHIS2 implementations, especially for ministries of health in DHIS2 implementation countries

who are the primary user base. A DHIS2 developer at UiO, for example, observes, "… donor interest in DHIS2 is largely driven by its acceptance and adoption by countries' ministries of health". The strategy must, therefore, include a relevant DHIS2, tailored and country-specific guidance, and capacity building programs. Further development and institutionalisation of country support teams are required. Where HISP nodes and University partnerships exist, these too must be leveraged to support in-country capacity development.

5 DISCUSSION

HISP and DHIS2 have sustained over two decades based on the vision to build the capacity necessary for developing countries to govern their HISs in a sustainable way and by so doing strengthen their health services. A key factor contributing to sustainability is the adaptability and the resilience of HISP and DHIS2. The project has always been *open*, at least for those accepting the principles of openness and outputs in global public goods, for innovations and prototyping in new directions, and for new community members to join, support, influence, change and contribute to the further development.

Where some projects fail (or stagnate for years before starting again) and some financing sources dry out, HISP pursues new projects in new places or with other use-cases and explores new sources of financing. This *flexible and pragmatic* approach shows as a successful approach in the context of development where there is a need for a long-term commitment, while funding typically comes in bursts as parts of time-bound projects. The funding of HISP activities at UiO thus has a long history of balancing incremental donor needs and incremental requirements with product development, market development activities, and academic goals.

Aside from funding, political empowerment of local stakeholders in health and practical learning through hands-on participation, i.e. participatory design approaches [31] are key to the success of HISP. In South Africa, these principles resonated with the government's policy of health systems decentralisation. In countries with more rigid centralisation of health systems organising, top-down engagements for political buy-in are complemented with bottom-up strategies for system learning [31]. Learning through hands-on participation also helps to develop local capacity and contributed to project acceptance at the early stages. During the expansion phase of HISP when the traditional participatory design approach based on the experience in South Africa became impracticable, new approaches were explored. For example, the *networks of action* approach [7], [20] was used to provide the needed implementation support across multiple pilot projects in different countries. When proved successful, this approach was further expanded in a distributed participatory approach along with the introduction of the fully open-source and web-based DHIS2 software [9] [31].

The HISP community has shown the ability to adapt DHIS2 to changing user needs, technologies and available infrastructure. The earlier and at the time standalone, offline and non-web based version is now entirely replaced with a centralised, integrated, and online version (i.e. DHIS2). Design flexibility, extensibility, and modularity enable its customisation to fit various use-case requirements. While these factors and others are driving the adoption and growth of DHIS2 across continents, some challenges still need to be addressed. An immediate example is platform governance, which involves incentivising participation and at the same time balancing control within an ecosystem of independent app developers and the core development team at UiO [27].

In terms of research and education, HISP is pursuing new research themes towards quality assurance and data use. The country implementations of DHIS2 also continue to serve as projects where researchers within HISP contribute practically to system implementation while learning and sharing knowledge obtained from the processes.

6 REFLECTIONS

Maturing over 20 years, HISP is now active in more than 100 developing countries and has scaled to achieve global success. The success lies in sustainable and scalable software and a thriving community. The community supports the development and implementation of HISs used in the management and prevention of diseases and pandemics. The factors (see Table 1) that have accounted for success include project openness and participatory approaches for relevance, appropriateness, and innovation such as going online for scale and sustainability and scoping into other use-case domains. While the changing contexts of implementations and funding uncertainties make future events in the network difficult to predict, HISP must remain committed to open participatory approaches [31] and focus on balancing stability with growth towards sustainability.

Table 1 Summary of Factors Contributing to Success.

The early stages:
Open, participatory design approaches
Funding and political support
Focusing on the health domain
Shifting to online and mobile at the right moment in time
The present status:
In-country, regional and global capacity building
Career building, research and community support
Matured APIs for interfacing with other systems
Generic and flexible system expanding into new areas
Platformisation; allowing content and app development outside UiO: WHO, NGOs, private entities
The future outlook:
A sustainable ecosystem with new business models and funding schemes
Balanced focus on stability and growth
Global public good positioning for broad participation
Perhaps some tough choices about focusing on the core and towards 'control devolution'

7 REFERENCES

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II

Paper 2

Leveraging Software Platform Capabilities to Support HIV (ART) Treatment Adherence Management: A Case from Sierra Leone

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Abstract. Research on antiretroviral therapy (ART) programs reveal that HIV positive patients who adhere to treatment substantially improve their life expectancy and lower the risk of progression to full-blown AIDS. While there is a significant body of research in the medical and social science fields on ART adherence, Information Systems (IS) research has paid little attention to this subject. Especially lacking is research on how Information and Communication Technology (ICT) based solutions can be developed to better support ART adherence programs. We argue in this paper that software platforms offer capabilities that can be leveraged to address more effectively the information management challenges associated with ART adherence programs. The motivation for this paper is taken from a broader action research project planned to be carried out to support an ART adherence program in Sierra Leone.

Keywords: HIV · Software platforms · ART adherence · Health information systems · Ecosystems · Integration · DHIS2

1 Introduction

Studies reveal that higher ART adherence levels in HIV-positive patients lead to improved patient survival outcomes [1–6]. Still, research also shows that many intervention programs only manage to achieve very modest improvements in patient adherence [6]. Factors identified to contribute to this are broadly categorized as socio-cultural, technological, attitudinal, and economic in nature [7–12]. But also a major concern in the literature is that the "*inability to monitor adherence may ultimately undermine efforts to treat HIV/AIDS in high-burden areas*" ([13], p. 78). Addressed in this paper then is how we can tackle this problem from an Information Systems (IS) research point of view by exploring solutions which can effectively support ART adherence programs particularly in developing countries.

According to clinicians the effectiveness of antiretroviral (ARV) drugs for treating HIV[1] disease depends on strict adherence to stipulated usage guidelines. The World

[1] HIV/AIDS: Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome. Retrieved October 22, 2016 from http://www.who.int/mediacentre/factsheets/fs360/en/.

J. Choudrie et al. (Eds.): ICT4D 2017, IFIP AICT 504, pp. 35–46, 2017.
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Health Organization's (WHO) guideline documentation[2] for example outlines a three-level program for administering ARV drugs to HIV positive patients, described briefly as follows: a new patient starts on first-level treatment regimen, is monitored for at least 6 to 12 months, and then switched to second and third-level regimen respectively when treatment failure is detected. Differences in patient demographics including age groupings, pregnancy status in women, and the prevalence of other co-morbidities such as tuberculosis (TB) also introduce variations into the ARV drug administration protocols. These guidelines and other information requirements (e.g. for managing HIV opportunistic infections) increase the complexities of patient monitoring hence the need for appropriate information systems. Therefore, this paper proposes information systems solutions that can support effectively the management of HIV treatment and related activities. The aim is towards enhancing health worker ability to monitor patient adherence to HIV (ART) treatment. The expectation is that the appropriate information system is able to support individual patient management activities. For instance including the ability to schedule patient hospital appointments, send automatic reminders to patient on upcoming events like drug refill, notify caregivers when necessary and enhance their capacity to carry out patient follow-up activities. Developing such solutions requires the integration of software systems, technological devices, data from health programs, and alignment of local information management practices around HIV treatment. Such system once developed will give a more holistic view of patient treatment data as well as improve caregivers' visibility of the treatment process. In pursuit of the proposed system we argue that software platforms provide capabilities which can be leveraged. The advantages offered include their ability to support the development of relatively cheaper, quicker and highly customizable solutions to meet adherence management needs especially in resource-constrained settings.

This paper introduces a broader research project motivated by an urgent need to restore and improve survival outcomes in HIV positive patients. These are patients enrolled into ART treatment programs within a challenged health context of Sierra Leone, still recovering from the Ebola disease outbreak. It was reported that the pandemic nature of the Ebola outbreak diverted attention and resources from HIV treatment activities resulting in increased deaths among HIV-positive patients. With attention shifted back to HIV as the Ebola subsides, areas identified as requiring immediate attention include; expanding patient access to antiretroviral (ARV) drugs, providing adequate clinical care, and improving ART adherence monitoring. In this paper we attempt to contribute to the efforts aimed at improving ART adherence monitoring. We approach this by investigating the development of appropriate information systems solutions to support adherence monitoring. The study draws extensively from HIS integration work within an international action research program known as Health Information Systems Program (HISP) [19]. Field intervention work is currently at an advanced stage of planning waiting for commencement in Sierra Leone. This paper contributes to HIS integration research by highlighting the capabilities of emerging software platforms, and how they can enable the development of ICT-based

[2] WHO | Consolidated guidelines on the use of antiretroviral drugs for treating and preventing HIV infection, 2016. Retrieved October 22, 2016, from http://www.who.int/hiv/pub/arv/arv-2016/en/.

solutions to help improve the management of ART adherence in resource-constrained settings. The emergence of District Health Information Systems 2 (DHIS2) as a software platform within the HIS field is discussed as an example of the opportunity presented to pursue the development of such solutions. The remainder of the paper is organized as follows: First, background literature review of concepts informing the study is presented. After this the research approach is described with a brief description of the problem diagnosis and the proposed solution. This is then followed with discussion and conclusion.

2 Background Literature

2.1 ART Adherence Monitoring

According to Amico et al. [6] ART adherence has gained wider recognition as a critical health promotion behavior for HIV- positive patients undergoing treatment. However there are still uncertainties about how higher levels of treatment adherence may be initiated and sustained especially in larger populations over longer periods [13, 33]. Because many of these studies are conducted on short-term basis with few patients, the long-term viability of adherence monitoring strategies are still unclear. Reported average study duration is about 20 weeks with an average sample size of about 56.7 participants [13, 34]. The ability to monitor large scale ART adherence programs especially within public health sectors of developing countries still require further exploration. This need is clearly articulated by Amico et al.: *the demanding nature of ART regimens underscores the need for more strategic and multifaceted interventions that extend beyond the typical patient-provider interaction or ad hoc clinic discussions* ([6], p. 285). Furthermore, research indicates that the scaling up of ART adherence programs to cover larger populations increases the complexities of monitoring the adherence - health outcome dynamics [35]. It is also stated that currently there is no established "gold standard" for measuring or reporting adherence outcomes [13]. The various methods used in monitoring ART adherence such as patient self-reporting, patient attendance at scheduled visits, pill counts, electronic bottle monitors, pharmacy records, and others are also identified as not effective for all conditions [6, 13]. Moreover, as the treatment of HIV transitions from acute to chronic disease [5] the long-term use of ART will require more strategic solutions that are responsive to the changing dynamics of adherence management in different settings [38].

2.2 ICT in ART Adherence Management

The potential for ICT-based tools to support ART adherence activities has been examined in intervention studies and systematic literature reviews [14–18, 39]. The advantages of ICTs are identified as their potential for interaction, collaboration, low cost, and use in areas with limited human and material resources [14]. Technological devices like mobile phones can facilitate the ability of health workers for example to track and follow-up patients to provide them with the necessary care. Some specific functions performed with ICT tools in managing ART adherence include reminding patients to take their drugs

through phone calls, SMS messages, and pager devices [15–18]. Other devices such as medication events monitoring systems (MEMS) are used to remotely monitor patient-pillbox interactions to help determine medication adherence [38].

Despite these benefits there are challenges that need to be addressed if the full potential of ICT in the area of ART adherence management can be realized. For example the medication events monitoring systems (MEMS), which although efficient at monitoring pillbox events is regarded to be expensive technology [38], and as such may not scale in financially constrained settings. Other web-based solutions used for encouraging medication adherence through the use of social media and similar resource intensive technologies [39] may also not be suitable in some resource-limited conditions. Another dimension also worthy of consideration is the socio-economic and demographic differences in patients which could impact usability of certain technological solutions. But more importantly there are calls to look beyond current solutions which seem to be narrowly focused on the use of single technologies for more comprehensive approaches [6, 13, 14, 39]. Such standalone and mostly ad-hoc solutions may not for instance suit public health contexts for the long-term use. Due to information and process overlaps that often exist between different health programs, more integrative and sustainable solutions will be required to reduce information systems fragmentation typical in such contexts [22].

2.3 HIS Integration Strategies

Information systems integration is identified as a socio-technical process involving different actors [24]. Within healthcare, integration strategies must take *"the users' needs of the HIS, the purpose of the systems, and the wider organizational perspectives […] and relate those to goals of better efficiency, effectiveness, and co-ordination in organizations"* ([20], p. 59). This has also been described as a negotiation process [23] involving technological systems, people, organizations, and cultural practices working toward achieving a more integrated view of information to facilitate decision-making and care delivery. Integration strategies should therefore be able to accommodate changes to the system implementation process [22]. Examples of these include *modular implementation strategies* [28] and *loose coupling integration* strategies [29]. These are also important for preserving evolutionary independence and modular maintainability of the systems involved.

Also depending on the information needs dictating the integration or *interoperability*[3] of a set of systems and actors, the underlying integration processes could be pursued either at the *horizontal* or *vertical* levels of the organization [20]. Vertical level integration supports bottom-up flow of usually aggregate data between levels of the administrative hierarchies for higher-level management decision-making. Horizontal level integration on the other hand supports lower-level routine care delivery activities

[3] In healthcare, **interoperability** is the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged. Retrieved November 29, 2016, from http://www.himss.org/library/interoperability-standards/what-is-interoperability.

enabled by a single point of access to more granular data from multiple sources. These can include patient data from wards, specialties, and data from other sources like pharmacies and logistics. The horizontal integration approach is therefore suitable for achieving integration objectives proposed in this paper. This could be enabled by ICT platforms capable of supporting the integration of software systems, technological devices, different health programs data and local practices.

2.4 Software Platforms and HIS Integration

Platforms are foundation technologies upon which complementary products, technologies, or services can be developed [26]. Functionalities provided by platforms allow multiple parties to work together to address common problems [26]. Potential benefits offered by platforms include cost and time savings on product development, which can be achieved through half-ready solutions and platform components reusability. They also facilitate the development of highly varied derivative products and services and enable higher levels of products and services customization to meet diverse user requirements [25]. Platforms, by enabling interactions among different sets of actors often result in ecosystems of solutions comprising of human actors, software systems and services working together towards common goals [26]. Examples of software platforms which have contributed to the development of many useful derivative software products and services include Google Android, Apple iOS, Microsoft Windows, and many more (see [26]). The capabilities offered by software platforms can therefore be seen as an avenue through which new healthcare related information systems solutions could be explored.

In the HIS field, the District Health Information Systems 2 (DHIS2) is presented as an example of an emerging software platform (see: www.dhis2.org/technology). Nielsen and Sæbø [30] conceptualize aspects of the platform evolution of DHIS2 as *functional architecting*. Following a number of user adoptions involving the DHIS2 tracker (a software module which runs on top of the DHIS2 platform), they describe three architectural strategies involved in extending DHIS2's platform functionality into different use domains. These are elaborated as *charting*, *encroaching*, and *connecting*. Charting extends a system's platform capability into another domain to fulfil unmet functional needs, encroaching offers alternatives to existing solutions in the domain, and connecting integrates with systems where each has clearly defined roles in the domain. With this conceptualization they demonstrate that software platforms emergence offer opportunities for advancing HIS integration work.

3 Research Approach

This paper introduces a longitudinal action research project planned to span several years. Using a canonical action research methodology [31] several cycles of research iterations involving *problem diagnosis*, *action planning*, *intervention* (action taking), *evaluation* (assessment), and *reflection* (learning) are planned to be executed. The research work done so far covers the first iteration of problem diagnosis and action

planning. This is informed by an ongoing conversation between HISP UiO team and project partners in Sierra Leone. From this the research objectives have been identified and the initial requirements for the proposed solution have been analyzed. Additional data about the problem context has been gathered from sources like the *National AIDS Progress Response Report*[4] for 2014 and other relevant documentations. DHIS2 platform documentation including the implementers guide (see: www.dhis2.org/documentation) have been instrumental in planning the solution implementation roadmap. Also experiences have been drawn from similar HISP projects including a recent DHIS2 tracker implementation for a national malaria control program in Zimbabwe [40], in which one of the authors of this paper participated. In Sierra Leone, HISP UiO's involvement in health information system strengthening through the implementation of DHIS2 since 2008 [21] have also served as the groundwork in the build up to this current research. The next phase of this research process will focus on initiating planned field intervention activities at the research site.

3.1 Problem Diagnosis and Solution Description

The research problem is diagnosed as high fragmentation of information systems currently used for managing the HIV treatment program. The fragmentation is identified as: (1) the information systems used in managing the ART programs have been deployed as standalone systems and spread across localities in HIV clinics. And the lack of a common information platform makes patients monitoring challenging across localities, and (2) the information systems for managing HIV related health programs such as prevention of mother-to-child-transmission (PMTCT) for HIV pregnant women have been implemented as 'silo' systems. This lack of communication between systems also affect efficient delivery of care to patients who may be enrolled into other health programs which need to be managed together with HIV treatment. These problems have contributed to making adherence monitoring challenging, and impacting negatively on the effectiveness of the ART program.

A solution based on a software module on the DHIS2 platform known as tracker capture, is hereby proposed to address the identified challenges. The tracker capture module utilizes the DHIS2 platform's data warehousing functionalities to enable enrollment, management, and tracking of patients in specific health programs (see: www.dhis2.org/individual-data-records). With this approach the currently fragmented systems will be absorbed onto one instance of the tracker capture hosted on the DHIS2 platform. End users at the health facility level will then be able to access the centralized system via web-enabled devices such as computers and smartphones through the internet. Allied health programs like malaria and TB can also be deployed as separate instances on the same platform and configured to share data into the HIV system. Data sharing is also possible between third party systems through interoperable interfaces supported by the DHIS2 platform. With this, a more holistic view of patient data can be achieved for effective monitoring and treatment adherence promotion. It will also

[4] Sierra Leone National AIDS Response Progress Report 2014. Retrieved October 8, 2016, from http://www.unaids.org/sites/default/files/country/documents/SLE_narrative_report_2015.pdf.

improve health worker mobility through the DHIS2 tracker capture App available for deployment on Android-based devices.

3.2 Challenges with Managing ART Adherence and Why DHIS2

Complexities of ART treatment regimen and guidelines pose major information management challenges for care providers [6]. To manage patient adherence effectively requires continuous monitoring of multiplicity of events associated with the treatment process. These include for example the ability to access the right information to determine what ART regimen a patient is eligible for. While undergoing treatment a patient's progress have to be monitored continuously to inform subsequent actions. Other events such as viral load and CD4 count measurements, diet restrictions, drug resistance and side effects, and many other HIV associated complications also have to be monitored. This puts a huge information management burden on care providers instead of having more time for patient care. With current unavailability of more efficient information management tools the effects of ART adherence programs have been reported as generally weak, and underpowered [6, 34]. Also in adherence promotion, activities like patient education, treatment tracking and provision of follow-up services by health workers require the support of ICT tools. And lacking these tools can hamper their ability to effectively conduct adherence monitoring. In the contexts of developing countries under consideration, the viability of the needed supporting ICT tools will depend on factors such as systems availability, accessibility, and flexibility. This is where the DHIS2 platform is seen as a more viable solution. It is currently available and being used at various levels of health information management in 47 developing countries including the one under study (see: www.dhis2.org/inaction). The main strength of DHIS2 is its strong support base of researchers, system developers, system implementers, and users. This international support network is actively engaged in the continuous development of the DHIS2 platform and modules to meet the changing needs of health information management [19]. The platform has generic functionalities that can readily be customized to suit the requirements of the particular context. In the particular case of ART adherence management, platform modules such as the tracker capture and event capture can be used to manage patient information and related treatment events. DHIS2 also integrates internet technologies, SMS services, and Geographical Information Systems (GIS) which can support patient follow-up activities in the communities for adherence promotion purposes. One caution though, is that because DHIS2 was traditionally developed for aggregate data its security regime is currently less developed. Hence extra measures should be taken to safeguard data privacy when dealing with patient level data.

4 Discussion

Looking at the literature, the majority of the available studies are conducted as clinical trials with the primary aim of promoting ART adherence in HIV-positive patients. These studies do not necessarily focus on the ICT tools themselves involved in the

intervention activities. Where ICT tools are the focus of analysis it is mostly about what activities they were used to perform [e.g. in 14–18] or assessing their effectiveness in systematic literature reviews such as in de Lima et al. [14] and Muessig et al. [39]. But generally speaking, studies on how more appropriate technological tools may be developed are still lacking. There is a need to take into account particular contextual needs, including resource limitation concerns such as lack of local expertise and financial resources and relatively poor state of technological infrastructures to support such activities. In recent times however, access to ICT services has improved considerably in many developing countries due to the proliferation of mobile telecommunication networks. This together with emerging technologies like software platforms and associated services in the health domain, now makes it more feasible to implement more effective ICT solutions to address information management challenges identified with ART adherence programs.

In this paper we emphasize leveraging the capabilities of software platforms due to several potential benefits that can be gained. The most fundamental capabilities software platforms offer are based on their architectural design principles The *platform* aspect which is *the extensible codebase that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate* ([25], p. 675) is designed to be stable. The other aspect, a complementary set of *modules* is designed to vary. A module is *an add-on software subsystem that connects to the platform to add functionality to it (ibid)*. Benefits that can be gained from this include providing a foundation on which information system solutions can be grounded in the context of adoption. This can contribute to local institutionalization and participation in the systems development processes. The current ad-hoc and off-the-shelf use of technologies do not provide the mechanisms necessary for enabling local participation. Implementing a platform upon which solutions can be developed and or tailored [36] can help generate local knowledge bases around such tools to ensure their long-term sustainability. Also important to long-term sustainability is the ability of platforms to interface with other systems to enable interoperability. In the context of HIV treatment this ability to share data across different systems is critical for treatment effectiveness due to complexities associated with ART regimens [6]. Platforms can enable different technological solutions to be pooled together for rapid innovations and experimentation to address the changing dynamics and information needs involved in ART treatment. This can also contribute to research by encouraging ART adherence studies to examine the effectiveness of combining different technological tools rather focusing on single technologies as is common currently.

With free and open-source software platforms like DHIS2, an added benefit in the context of developing countries is the lower economic barrier to entry. Liberal licensing regimes such as *Berkeley Source Distribution* (BSD)[5] license for DHIS2 for example, contribute to expanding access to platform services. Under such arrangements users have the freedom to use, share, change, or improve the platform and complementary services without the licensing overheads often associated with proprietary systems. Additionally

[5] BSD license definition. (2005). Retrieved November 25, 2016, from http://www.linfo.org/bsdlicense.html.

platforms enable integration of services such as SMS, email, internet, maps, etc. to support development of innovative solutions, for example to support geo-spatial disease surveillance activities. Platforms like the DHIS2 also provide data warehousing and data analytic functionalities which can be helpful in addressing difficulties with monitoring and measuring adherence programs efficacy [38]. Also designed into platforms are security mechanisms for safeguarding data privacy. This is particularly important because loss of patient privacy, confidentiality, or secrecy can lead to HIV patient stigmatization with negative consequence on ART adherence [14, 37].

Finally, concerning lack of local capacity or expertise for platform or module development and maintenance in developing countries, platform governance mechanisms [27] provide strategies to address such challenges. This is done through global community collaborations where responsibilities for development and maintenance are shared among platform owners, module developers, and users. This collaborative approach is especially characteristic of open-source software projects like the DHIS2 (see for example: www.dhis2.org/contact). Within such global communities, different types of expertise are available to provide assistance when needed [32].

5 Conclusion

The main idea explored in this paper is that the software platform phenomenon emerging in the health information systems domain presents new opportunities to develop ICT-based solutions to better support healthcare management. The specific area within healthcare management focused on in this paper is HIV treatment and ART adherence monitoring for HIV-positive patients. Current research studies involving the use of ICT in ART adherence programs tend to focus narrowly on the use of specific technologies such as mobile phones. There also seem to be a lack of studies exploring how to design or develop ICT solutions specifically for supporting ART adherence programs. We therefore call for more studies to focus on the technological solutions themselves involved in ART adherence management and monitoring. This means more IS research practitioners have to recognize the need to adequately engage in addressing this research problem. This can be pursued through the development of new ICT based solutions or innovative use of existing technologies. Proposed in this paper is a more integrated solution based on DHIS2 platform to integrate technological and non-technological actors, and processes to support ART adherence monitoring activities for the case of Sierra Leone. To improve chances of success the paper proposes the use of suitable IS integration strategies in the problem context. These are flexible implementation processes that are adaptable to role negotiations among the actors involved. Through the use of concepts and strategies discussed, this paper argues for the opportunities software platforms offer and how their capabilities can be leveraged to develop more effective and locally relevant solutions. Going forward we hope to begin work on planned field intervention activities to investigate further the viability of the solution proposed.

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III

Paper 3

Scaling Across Functional Domains: A Case of Implementing an Electronic HIV Patient Information System in Sierra Leone

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Abstract. With adherence to treatment, HIV positives can live a normal life. Accordingly, investments are made and health systems are expanded to reach those at risk in developing countries, where HIV is reported to be most endemic. At the same time, many developing countries still rely heavily on paper-based tools which are found to be inefficient when large numbers of patients are involved and of limited use to support follow ups and assure adherence to treatment. In this paper, as we move from an existing paper base and to a digital and online information management system, we focus on improving our understanding of how to use an existing system made for collecting, aggregating and presenting population based routine data to support individual follow-up of HIV positives and their adherence to treatment. We approach this through an action research project in Sierra Leone where we have piloted a HIV patient information management system. We contribute insights on health information system scaling with emphasis on building on existing systems in developing new functionalities rather than introducing entirely new systems. Within this approach we observe the need for technological flexibility and organizational collaboration in utilizing existing resources for efficiency gains.

Keywords: HIV/AIDS · Patient information management system · UNAIDS 90-90-90 · Health information systems · Scaling · IS functionality · Electronic system implementation · DHIS2 · Flexibility · Organizational collaboration

1 Introduction

Essential components of HIV (human immunodeficiency virus) treatment are diagnosis, linkage to care, retention in care, adherence to antiretroviral therapy (ART), and viral suppression [1]. In line with this the Joint United Nations Programme on HIV/AIDS (UNAIDS) sets the 90-90-90 goal to help end the AIDS (Acquired Immune Deficiency Syndrome) epidemic by the year 2030 [2]. It outlines that by the year 2020,

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90% of all people living with HIV will know their HIV status, 90% of all people with diagnosed HIV infection will receive sustained antiretroviral therapy and 90% of all people receiving antiretroviral therapy will have viral suppression. However, recent UNAIDS data [3] show that many developing countries are underperforming with respect to meeting these targets. Available data for Sierra Leone for example show only 35% of people living with HIV know their status and out of that only 26% are on treatment. No data was reported for patients on ART who are virally suppressed (ibid).

HIV care expansion strategies towards the UNAIDS 90-90-90 goal tend to pay attention to issues of availability of clinical resources, funding, and logistics supply such as antiretroviral (ARV) drugs (e.g. [4]) which are used in ART programs. But also of equal importance is the development and implementation of the appropriate information management systems for treating HIV as a chronic condition [5, 6]. Such systems potentially ensure correct patient identification during care encounters and linkage to care, and facilitate patient follow-up over time for retention and treatment adherence. From a health monitoring and planning point of view, information management systems are also required to produce the information needed for efficient resource allocation and for scale-up of treatment programs to cover more patients across wider geographical areas. Similarly, appropriate information systems (IS) can help substantiate more accurately the measurement of progress towards the 90-90-90 goals. Based on these and identified inefficiencies of paper systems especially when dealing with large number of patients [7], the World Health Organization (WHO) for example recommends a progressive transition from paper to electronic patient IS starting with high-burden sites [8]. Yet paper-based systems are heavily relied on in many developing countries including Sierra Leone. This is in spite of many information communication technology (ICT) based solutions previously explored in the literature [9]. A common approach in developing countries' setting is the use of electronic medical record (EMR) software, such as OpenMRS (www.openmrs.org) [7, 10–12]. However, this approach too is found to be problematic due to architectural complexities, and high cost of adoption and maintenance of EMR systems [11, 13]. Thus within resource-limited settings, the continuous system adjustments needed for the changing dynamics of HIV treatment in particular becomes more challenging.

So to sum up, HIV treatment programs in developing countries are faced with resources availability challenges including lack of adequate funding, and human and material resources. This can also be seen in the lack of appropriate information management solutions. Prior attempts at implementing more efficient ICT-based IS solutions to support patient management too have largely failed to be sustained or be developed further due to resource limitations. Hence taking a different approach we explore in this study the application of an existing system made for collecting, aggregating and presenting population based routine data to also support individual level HIV case based management. With this approach we seek to utilize as much as possible resources already existing in the case context to minimize system implementation and subsequent maintenance costs, and thus potentially enhancing long-term system sustainability. Our conceptual framework is drawn from literature on health information systems (HIS) scaling in developing countries, where *scaling* involves expanding the size, scope, depth and functionality of an IS [14–16]. Combining this with functional architecting concepts and strategies for scaling functional architecture

of software systems [17] we introduce what we call *scaling across functional domains*. We define this as the building of new and differentiated functionalities for previously uncharted domains, starting from an existing install base. This is demonstrated through our case where we have scaled from aggregate health data management system functionality into individual level HIV client management functionality in Sierra Leone. Specific functions covered with the new system functionality are HIV counselling and testing (HCT), ART management and adherence monitoring.

While we find this proposed dimension to HIS functionality scaling to be particularly relevant within resource-limited contexts, how to approach this in practice is lacking in the literature. Therefore our research question is *how to scale functionality of HIS installed base to serve unmet functional need in an adjacent domain.* From this we contribute empirical insights on how to extend ICT-based IS functionality from one functional domain to another. At the same time we identify key enabling conditions to include technological flexibility and collaboration among the various domain organizations involved. The study follows an action research (AR) project covering designing, piloting, and evaluating an electronic HIV patient information management system. This paper gives an account of the first AR cycle reporting from a single pilot site about to be expanded to cover more health facilities. The solution, named HIV Patient Tracker, is built on the existing national health management information system (HMIS) and based on the DHIS2 software platform (see: www.dhis2.org). In the remainder of the paper we describe details of the research project. First we introduce the conceptual framework. After this the research methods are described together with data collection and analysis strategies. This is followed by solution description, presentation of findings, discussions and concluding remarks.

2 The Conceptual Framework

Scaling of health information systems is analyzed in the literature on mainly horizontal and vertical dimensions [14–16]. Horizontal is in terms of size, coverage or scope, and functionality of the HIS in the same or different setting, and vertical in terms of penetration or depth of the HIS across the health system hierarchy. Within these dimensions, issues of complexity, learning, and adaptations are also analyzed against a backdrop of local and global contexts [18]. For example based on experience from implementing a HIS in primary health care in India, Sahay and Walsham [14] observe that IS scaling is an important issue in the context of globalization. They show how information systems expand within and across contexts and problematize what is scaled as complexity, and conceptualized complexity as a heterogeneous network of geography, numbers, technical systems, data and databases, system expertise, and socio-technical practices including politics (ibid).

With a more particular focus on software components, Nielsen and Sæbø [17] discuss how multiple actors are strategically configuring and re-configuring independent software components to serve functional needs when different systems are integrated. They conceptualize this as functional architecting and identify three different strategies; charting, encroaching and connecting. Charting is a strategy based on extending an existing software component with additional functionality to cover an

unmet functional need, in a new and typically adjacent domain. The encroaching strategy is also about extending into a new domain, but where a different system is already offering the functionality. Thus, encroaching is about grabbing the functional role of another software component by duplication, competition or substitution. Where encroaching is about competition, the connection strategy is about coordinating and negotiating the functional role and responsibility of complementary software based in different domains. Turning to the larger literature, scaling of systems functionalities is also seen to occur across dimensions and within local and global contexts. However the focus and approach has predominantly followed a 'replication' logic of sameness of functionalities within and across settings [18].

In this paper, we will use the concept of scaling as our lens to discuss our findings related to how the paper based information system was changed and how the new HIV-system was implemented as an extension of the existing HMIS infrastructure. We term this as scaling across functional domains, which is an attempt at expanding on the functional scaling dimension beyond just replicating same system functionality, to the building of new functionalities for different and typically adjacent domains starting from an existing install base. In our case this can also be viewed as moving an IS into a *new* domain where the move will also potentially strengthen the parts (i.e. the aggregate and population based functionality) that remain in the *old* domain. The installed base which currently serves the old domain and is our starting point consists of the HMIS software, surrounding socio-technical infrastructures, system expertise and other support structures.

3 Methods

Under a broader action research project of the Health Information Systems Program (HISP, see www.hisp.uio.no) at the University of Oslo in Norway this study was initiated. HISP engages in health information systems design, development and implementation in developing countries [19]. The AR cycle [20] of *problem diagnosis, action planning, action taking, evaluating*, and *specifying learning* was followed. This approach was chosen as the research was prompted on a request by Global Fund (www.theglobalfund.org/en/) and the Ministry of Health and Sanitation (MOHS) of Sierra Leone to extend the functionality of the existing HMIS platform into a patient level information management system for the HIV program. This study also follows up the research project as earlier proposed in Adu-Gyamfi and Nielsen [21]. The project is funded by the Global Fund with the MOHS as the owner, and the University of Oslo (UiO) as the implementing partner. Other local stakeholders are the National HIV/AIDS Secretariat (NAS) in Sierra Leone, which has the strategic responsibility for the HIV/AIDS program in the country, the National HIV/AIDS Control Program (NACP) which is the program implementing agency and owner of the HIV patient information management system being implemented, and the Directorate for Planning Policy and Information (DPPI) which is responsible for the ministry's entire information systems infrastructure including the HMIS system.

An interpretive paradigm of IS research is used in this study [22]. Research data was collected and analyzed through qualitative means [23]. Data collection methods

included participating in system conceptualization, setup and customization workshops, on-site visits, meetings, discussions, semi-structured interviews, email conversations, review of relevant documentations, and user training sessions. The empirical work spans a period of about 9 months between September 2017 and May 2018. All four authors were involved in the field work at various times but the first author stayed longer in the field (about 6 months in total) to collect more data while following up on the project implementation.

3.1 Data Collection and Analysis

The research team engaged with NAS, NACP and DPPI in meetings and discussions to understand and define the problem. The problem was defined as a lack of efficient, centralized and widely accessible information management system for the HIV program. Three selected HIV clinics were then visited to ascertain the problem scope. At all three clinics visited semi-structured interviews and discussions were conducted involving a total of 15 HIV counselors and ART nurses, 2 HIV medical doctors, and 1 electronic data entry clerk. Paper registers for HIV testing, ART, and aggregate reporting were also reviewed. These helped in identifying prevailing resource challenges, work processes and end-user requirements. After this, we held a weeklong system conceptualization workshop in Norway with DHIS2 developers and system consultants. Workshop activities included system design and customization planning, and learning from experts involved in similar ongoing projects in other developing countries. Later in the workshop we had a conference call with WHO representatives in Geneva for their feedback on the preliminary system design with respect to the WHO guideline recommendations [8]. This was also significant because our work informs early efforts to making a WHO reference configuration of DHIS2 for case based HIV information management (see e.g. [24]). We then embarked on a field trip to Sierra Leone to finalize the solution customization. Once on site, the HIV program personnel also reviewed the proposed solution and gave their inputs for further customization.

The next set of activities involved preparing training materials, developing system user guides, training of users and subsequently testing of the system at one clinic in the capital city. The test clinic has the highest case-load of ART patients in the country, which is about 4000 out of the 20000 registered patients countrywide. Challenges encountered during the system testing mainly related to internet service availability, which was resolved by the HIV program management. Two months into testing a first review meeting was held where we presented the system solution and progress on the implementation to 23 participants from NACP, NAS, DPPI and partner organizations. In May 2018, the system testing was ended and piloting with real-life patient data started. Program indicators were defined so the data entries could be supervised by the program management. We then conducted pilot expansion feasibility assessment for 8 more HIV clinics, and the findings together with preliminary results from the ongoing piloting were shared in a second project update meeting with 18 participants in attendance. This marked the end of the first AR cycle as we withdrew from the site to reflect on the results and prepare for the next cycle expected to focus on expanding the pilot to cover more HIV clinics. By end of September 2018 about 4200 HCT

registrations and close to 400 ART patient enrollments had been recorded on the new system for the pilot site.

Data collection and analysis strategies employed during this research included daily field notes compilation and reflection in the form of a research diary. Both the research problem and data were analyzed and tackled iteratively through consideration of *the interdependent meaning of parts and the whole that they form* [23]. This informed subsequent data collection and analysis by identifying emerging themes and patterns. Further analysis was also prompted against the extant research literature to foreground issues of HIS scaling in developing countries and help position our research contribution in the broader context of HIS research and practice. This was facilitated through the chosen conceptual framework.

4 System Description

The resulting HIV patient tracker solution infrastructure consists of a DHIS2 server instance deployed on cloud-based server which is accessible via internet. This is deployed as a separate DHIS2 server instance different from the existing HMIS instance, with own database, server address, and user access policies due to sensitivities associated with HIV patient data. A secured link is to be established for automatic aggregate data transfer to the HMIS server. The design of the HIV case based surveillance (CBS) system and how it connects with the national aggregate HMIS server is shown in Fig. 1. Two software modules of the DHIS2 platform namely Event Capture and Tracker Capture were customized for managing HIV client related services provided at HIV clinics which are HIV counselling and testing and ART services. The Event Capture is used for capturing data on counselling and testing including capturing Tuberculosis (TB) screening and testing information. The Tracker Capture module is

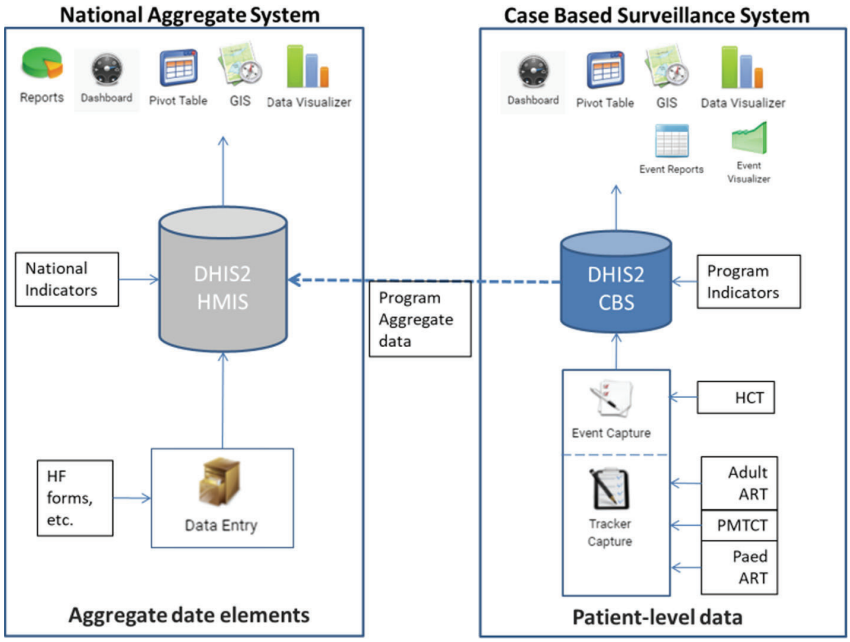

Fig. 1. Design of the existing national aggregate system and the new HIV system

used for managing adult ART, PMTCT, and Pediatric ART services. It consists of an *enrollment register* followed by four program stage registers in order of *initiation*, *visit*, *follow-up*, and *exit*. Additional features are included to enable scheduling of ART patient care events in advance, view events that are open, due, or in the future, and missed events which need to be followed up. All two modules were modelled according to local requirements and in line with WHO guideline recommendations on person-centered HIV patient monitoring and case surveillance [8]. The CBS system also inherits the reporting functionalities of the aggregate system plus its own individual events reporting functionalities.

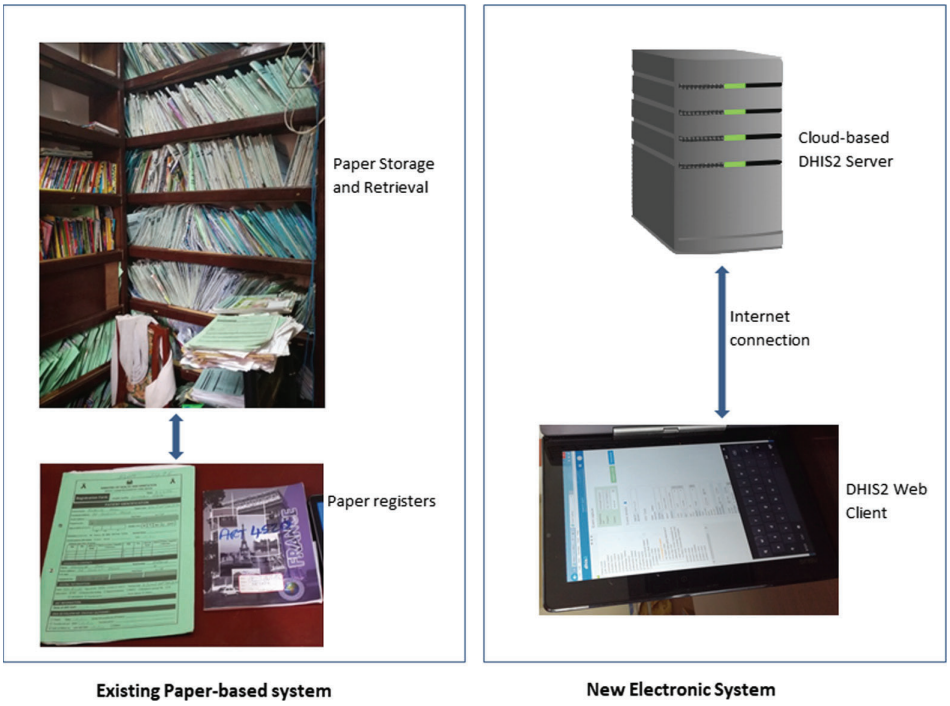

Fig. 2. Paper vs. Electronic system for HCT and ART Management at the HIV clinic.

The new HIV patient tracker setup alongside the existing paper-based system is also shown above in Fig. 2. For now the two setups are running in parallel while the new electronic system is gradually integrated into the routine care delivery processes.

5 Findings

During the research we found the HIV service workflows across the clinics visited to be generally identical and adhering to WHO guidelines to a large extent. Testing for HIV is offered as a routine service, notably for tuberculosis patients (as co-infection is common) and all pregnant women, as well as in some other programs. If the test is positive, the patient is enrolled in ART. Treatment consists of a mix of various drugs, which may be changed over time due to adverse effects or less efficacy. Patients on ART thus regularly come to a health facility to measure the effect of treatment and to

get a new supply of medicines. CD4 count and degree of viral load suppression are also measured (CD4 count is used to monitor response to ART, and viral load is suppressed at a level where the disease is chronic but not deadly and risk of passing the virus on to others is limited). Special programs target pregnant women to prevent transmission to the unborn child, and there are also special child programs where nutritional status is included in addition to ART management. Due to these different treatment configurations, an information system needs to cater for both larger populations for irregular testing, and a smaller population on life-long treatment with scheduled visits. Key challenges relate to duplication of records and patients who default on ART. One area contributing is patient movements across facilities and service points without accompanying paper trail. This point was reiterated by the HIV program manager explaining that "*a client can default and even be reported as lost to follow up at one facility, while taking treatment in another facility"*. This also affects ART enrollment data credibility and has implications for efficient resource planning and allocation.

Gauging from the national list of facilities offering HIV services it can be said that care is reasonably well distributed across the country. However shortage of skilled health workers coupled with the inefficient paper-based information management system pose challenges for efficient service delivery. The paper systems by nature cannot support automation of tasks needed for effective patient monitoring, such as automatically scheduling patient visits and follow-ups with auto-reminders. The many associated manual processes also consume time and attention which should have been given to patient care. In addition, with increasing complexities and size of data, relying on paper tools alone makes it difficult to detect and correct data quality problems. In fact the ongoing system piloting has revealed discrepancies between data aggregates from the HIV patient tracker and that of the paper-based tools which feed into the HMIS. Furthermore as we plan to increase the coverage of the solution to include more health facilities the need for unique patient identification system has been expressed. This is required to facilitate ART patients' follow-ups and also minimize incidence of multiple registrations.

Lastly, on the system implementation, we find team flexibility necessary in adapting plans and system choices, and aligning multiple stakeholder interests and resources towards project goals. The state of local infrastructure should also be taken into consideration. For example while it would have been possible to deploy the patient IS solution on a local server infrastructure, an existing offshore cloud server was used. Although this option was to guarantee higher system availability due to generally unstable electricity supply in the country, the downside is that without internet connectivity the system cannot be used. Hence an offline usability feature of the DHIS2 system should be explored further.

6 Discussions

Our discussion of the findings so far in our project relate to three main points; the characteristics of the technology that made this scaling possible, the benefits of the installed base related to the specific technology, and the need for organizational collaboration to grow in a sustainable way.

First, our case is one of proven, though limited, success. The DHIS2 was successfully scaled to cater for the recommended WHO guidelines on case based management [8], while allowing customization to suit current work practices in the Sierra Leone hospital. Preliminary results point to quick adoption by staff at the hospital, and potentially improved aggregate data quality compared to the paper-based reporting structure. On the technology side, this can be attributed to the design and architecture of the DHIS2 itself. Having gone through a decade of *generification* [25], it can now be applied for a wide range of use cases, especially applied to management of aggregate and patient data in the health sector. The generic nature of the software also means it needs to be customized and configured before it can be used, and can be considered as half-ready product [26]. The possibilities for customization are great, giving it the flexibility needed to first accommodate the WHO guidelines, and when there were requests for additional data to be collected in Sierra Leone, this could be added on the fly. While the tracker and event functionalities have been applied for HIV management in other countries, Sierra Leone was the first place it was adapted specifically building on the WHO guidelines [8].

Second, the intended approach was to build on the installed base to limit the amount of technologies needing support. In our case the answer to this is inconclusive, as there has been limited interaction so far between the owners of the HIV patient IS and the owners of the HMIS. However, there are also some obvious efficiency gains. There has been no introduction of new technology, and the cloud server used for the HMIS was partitioned to serve also the HIV system. There is an in-country person who can assist in maintaining both. There is also a strong base of local level staff in districts that routinely use DHIS2, which will provide a local support structure for future national roll out of the HIV system. Indeed an important aspect would be to grow the total user base, of both administrators and end-users, which will mitigate some of the known challenges of staff turnover and political changes. As the users of the different systems are different, the growing of both will limit the risk of losing key capacity related to the technology. Integration of information systems is another key challenge in the field [27], which has not been explicitly covered in this paper. However, using the same technology across two functional domains this integration is achieved by default. As the case based HIV system covers more health clinics, aggregate statistics derived from it can supplant the manual reporting of the same data to the HMIS. An added benefit of this will be fewer manual aggregation and data entry steps, improving data quality. Building on the installed base does not only have potential benefits for the new system introduced, but also strengthens the existing system it is built upon.

Thirdly, as the discussion above points to, while increasing the capacity of one technology to support several systems has potential benefits, it needs to be coupled with corresponding growth in organizational cooperation [28]. The benefits of increased user base, increased scope for specialization, and mutual support between user groups can only be achieved if the system owners (the organizations) enable and promote this. If this is not achieved, we have two organizations using the technology independently, building their own capacities irrespective of their complementarities, and independently facing the same challenges to implementation and sustainability. At the moment, there is only limited collaboration between DPPI and NACP. While DPPI have made available hardware for the pilot (tablets) and assigned their staff at the

hospital to support the entry of backlog data, a closer collaboration between DPPI and NACP needs to be fostered, so that they can pool resources for common requirements such as server maintenance, hardware procurement, and end-user training.

Theoretically, we have in this paper approached the complexity of scaling by focusing on functional architecting [17]. Our case is an illustrative example of charting, in terms of the HMIS system being extended with additional functionality to cover an unmet functional need related to HIV treatment. As shown, with the flexible DHIS2 software the WHO guidelines could be adopted and additional local requirements from Sierra Leone implemented. While Nielsen and Sæbø [17] primarily focus on different approaches to strategically positioning of different software components, we have in this paper highlighted how scaling functional architecture also depends on coordination and cooperation at the organizational level. We also emphasize building on the installed base so as to maximize efficient utilization of existing resources. But to release the full potential of this strategy the social, technical and political complexities of the context of scaling must also be taken into consideration [14, 15].

7 Conclusion

In our research we sought to investigate how we can scale an existing IS across two domains. We approached this through building on the existing Sierra Leone HMIS to cater for case based HIV management also. HMIS and case-based management represent different domains of care and information management. Where HMIS is routine reporting and analysis of aggregate data for general health management, the HIV system is focusing on continuous individual case-based management. We chose this approach because the alternative of introducing a new information system based on a different technology will require creating all the institutional and organizational structures needed for sustaining the solution. By instead building on a technology already present and supported in the MOHS, we aimed with this choice of architecture to reducing the costs and complexities related to the implementation and further development. Flexibility of the installed base technology enabled its functionality to be scaled for the different use case. Cooperation between the owners of the two systems (domains) though currently limited was vital. Additionally, implementation team flexibility helped achieved practicable and potentially more sustainable solution with the prevailing resource situation. In future research fostering of deeper collaboration between the owners of two systems for long-term project sustainability will be investigated further.

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