

Developing HIS Infrastructure: Negotiating Tensions to Design, Implementation, and Maintenance

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PhD Thesis

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holder or the unit which grants the doctorate.

To:

my niece *Loretta Vinjero*

&

sister Chimwemwe

Build your dreams and walk paths of greatness!

Keep trying; never give up!

You can be whatever you aspire to be

God bless!

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Acronyms

BEANISH	Building Europe Africa collaborative Network for applying Information Society Technologies in Health care Sector
CDC	Centers for Disease Control and Prevention
CHAM	Christian Health Association of Malawi
CIDA	Canadian International Development Agency
CMED	Central Monitoring and Evaluation Division
DFID	Department for International Development
DHIS	District Health Information Software
DHISm	DHIS Mobile
DHO	District Health Office
EU	European Union
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HIS	Health Information System
HISP	Health Information Systems Programme
HMIS	Health Management Information System
HAS	Health Surveillance Assistant
IT	Information Technology
JICA	Japan International Cooperation Agency
MDG	Millennium Development Goal
MDHS	Malawi Demographic Health Survey
mHealth	Mobile Technology for Health
MOH	Ministry of Health
NORAD	Norwegian Agency for Development Cooperation
NSO	National Statistical Office
SIM	Subscriber Identity Module
SWAp	Sector wide Approach
TA	Technical Assistant
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WHO	World Health Organisation

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Abstract

It is often the case that efforts to implement new and advanced technologies must overlap with the maintenance of existing technology. This thesis explores conceptualization and negotiation of tensions that arise from simultaneously attending to concerns for design, implementation and maintenance of digital health infrastructure, which span multiple temporal scales. Extant literature indicates that although digital infrastructures evolve over long periods of time, their development is often reliant on short-term focused and discretely arranged project-based support arrangements. This, demands that long-term concerns for maintenance and continuity should be attended to within funded project time, together with short-term concerns relating to technology implementation. However, combining concerns that span multiple temporal scales gives rise to tensions that threaten to derail digital infrastructure development efforts. To further confound matters, recent studies suggest a dearth in theoretical and methodological frameworks, which could aid accounting and negotiating of concerns that span multiple temporal scales. In addition, there are differences in views regarding theorizing of infrastructure. Some scholars advance purely incremental approaches, where temporality is dealt with implicitly, whereas others argue that we must focus on the long-term and explicate how this affects action taking in the short-term.

The overall question for this thesis is: *How can we negotiate concerns and tensions to design, implementation and maintenance of digital health infrastructure, in the face of changing project-based support arrangements?* This question is operationalized through the questions: (i) What are conditions for integrating novel solutions into an existing socio-technical installed base? (ii) What strategies can improve implementation and maintenance capacity in the context of changing project-based support arrangements? (iii) How can we conceptually account for tensions to design, development, and maintenance of digital infrastructure?

Empirically, this study draws on introduction of mHealth solutions to extend the reach of a national digital health management information system (HMIS) in Malawi. A key goal for the efforts was investigating the possibility of replacing paper-based routine data reporting, between primary health facilities and district health offices, with mobile phone solutions. The HMIS setup in Malawi is characterised by weak public administration and dependence on loosely coordinated donor funded projects. Findings suggests that despite over a decade of HMIS strengthening activities, the Ministry of Health still lacks financial, implementation, and maintenance capacity. The multiplicity of loosely coordinated projects also complicates control of interventions, leading to duplication of efforts. On the other hand, development of persistent IT support structures is slow and painstaking, due to government bureaucracy.

This thesis makes three main contributions. *First*, the thesis advances an integrated framework that combines four existing perspectives, in order to aid conceptualization and negotiation of concerns and tensions to design, implementation, and maintenance of digital infrastructure. *Second*, the thesis suggests strategies for enhancing IT implementation and maintenance capacity, in the face of changing project-based support arrangements. *Third*, the thesis responds to calls for an ecological approach to implementation and theorizing of mHealth interventions. Papers that are part of this thesis also contribute to theory and practice.

Chapter 1: Introduction

1.1 Setting the Scene: Personal Motivation

Throughout history man has devised and used various technologies in support of everyday life, work, and adventure. Examples of innovation range from relatively simple stone tools for hunting, irrigation systems in ancient Egypt, to modern day mobile communication systems, and unmanned space exploration vehicles. This study looks at one of such innovations – mobile communication systems. At the core of this study is the application of mobile technology to support health data communication in Malawi, where the practice has traditionally been paper-based. Over the past decade, mobile technology has provided an imperative to re-envision health data communication, in infrastructure sparse contexts (Chigona et al., 2012; Asangansi et al., 2013; Shoji et al., 2012).

Despite efforts to introduce new and improved technologies, it is often the case that old and new technologies co-exist, necessitating an overlap between development and maintenance work. Usually, development and maintenance of more complex technologies, such as mobile communication systems, require mobilization of different stakeholders and supporting technologies, over time. Where deliberate efforts are not made to maintain existing technologies, they disintegrate, as people continue to be pre-occupied with development of those trending, only for such technologies to disintegrate a while later. However, even where deliberate efforts are made to mobilise contributions from multiple stakeholders, in developing and maintaining technological solutions, it is not always clear how such efforts should be approached and coordinated (Aanestad and Jensen, 2011; Karasti et al., 2010).

Over the past four years, I have had the privilege of witnessing and participating in the implementation of digital information technologies, in support of healthcare delivery and management at rural health facilities, in Malawi. Intertwined with the beauty of such an experience was the despair of witnessing some essential technologies and physical infrastructure in a state of disrepair. At one health facility, I witnessed one part of the roof getting almost completely covered with solar panels, to power electronic medical record systems, yet the facility's water supply infrastructure (bore hole, water pipes, water tank) was in a state of disrepair. The health facility also had a broken down motorcycle ambulance, a radio message system that was no longer in use, and pregnant women delivered under candle or lantern lighting. Such intermix of innovation and decay was not restricted to this one health

facility, but was evident across different health facilities I visited. The strange intermix of occurrences presented here can, to a large extent, be traced back to poorly coordinated project-centric interventions, where focus has been on meeting short-term project-centred goals. I began to ask myself: *If relatively simple, but essential, physical infrastructure such as a borehole, water pipes, and a water tank can remain in a state of disrepair, what technology, then, can stand after the enthusiasm that surrounds its introduction has waned?*

Concerns regarding how to combine technology design, implementation, use, and maintenance permeate studies on digital infrastructures (Ribes and Finholt, 2009; Karasti et al., 2010; Edwards et al., 2007; Karasti, 2014b). At the same time, literature suggests that the juxtaposition of short-term and long-term concerns pertaining to design, implementation and maintenance introduces a complex set of considerations and tensions that could derail digital infrastructure efforts (Jackson et al., 2007; Karasti and Baker, 2004; Asangansi, 2012).

1.2 Key Notions

This thesis discusses conceptualizations and negotiation of tensions that arise from pursuing short-term implementation-related and long-term concerns for maintenance and continuity, in digital health infrastructure efforts; where there is need to leverage technologies, expertise, and partnerships, across loosely coordinated project-based arrangements.

Use of the term *tension* in this thesis denotes inner striving, unrest, or imbalance from seemingly opposing forces or conflicting demands to make decisions (Kee and Browning, 2010; Carlsson and El Sawy, 2008). Among others, sources of tension in digital infrastructure include: diverging interests and end-goals among stakeholder (Ribes and Finholt, 2007); policies about funding and ideologies (Kee and Browning, 2010); pursuit of control over key parts of an installed base (Nielsen, 2006); competing concerns of the present and those for the future (Richter, 2011). “Short-term experiences of gain and loss will shape the incentive structures of individuals and institutions tasked with responding to infrastructural change. This in turn will shape the climate within which infrastructures struggle to emerge” (Edwards et al., 2007:pp 24). Considering that digital infrastructure are not an outcome of reliable maps or blueprints, tensions can become a chief site and source of infrastructural change, innovation, and learning over time (Jackson et al., 2007). For learning to take place, reliable systems for surfacing and negotiating tensions need to be put in place (ibid).

Negotiation is a broad term, which includes dialogue between stakeholders aimed at reaching an agreement or resolving differences, across a range of situations, together with related processes. Use of the term in this thesis relates to temporal negotiations. Thus, by *negotiation*, *I refer to continuous pursuit of balance between competing short-term and long-term concerns relating to design, implementation, use, and maintenance of digital infrastructure, through dynamic combination of identified short-term and long-term concerns, and deliberate action (planned or otherwise), to influence infrastructure development trajectories.*

Short-term concerns of interest to this study mainly relate to attempts at integrating and enacting newly introduced mobile technology solutions into existing socio-technical arrangements. In relation to this, I look at implementation strategy, as well as attempts at attracting adoption, to achieve growth momentum. In addition, I try to account for efforts by our implementation team and the local Ministry of Health, in trying to exert some level of control on infrastructure development trajectories, at certain points in time. Treatment of the subject of control is deemed necessary, considering that efforts to develop digital infrastructure within the context of study are shaped by distributed control to parts of the installed base, and must therefore rely on the participation of multiple independent stakeholders, with varying interests. Identified long-term concerns centre on promoting development of human and organizational arrangements to support maintenance and evolution of infrastructure solutions. In line with all this, I consider perspectives on temporality and how they aid conceptualization and negotiation of the aforementioned concerns that cover multiple time scales, and tensions that ensue from pursuing them.

Building on Karasti et al. (2010), *the short-term temporal scale is in this thesis restricted to within funded project time and is thus closely linked with the notions of project, project management and project-based organization.* Project-centred efforts are characterised by short term focus, high time pressure, and a drive to provide successful outcomes for the project at hand, to satisfy funders (Ribes and Finholt, 2009; Markus, 2004; Karasti, 2014b). Contrariwise, infrastructure development and maintenance occurs over an extended period of time (Hanseth and Lyytinen, 2010; Pollock and Williams, 2010; Monteiro et al., 2013). Thus, *the long-term temporal scale is open-ended and stretches beyond individual project life spans, covering the period within which infrastructure design, maintenance and evolution occur* (Brand, 2008; Ribes and Finholt, 2009; Karasti et al., 2010).

1.3 Empirical Problem Area

This study was mainly conducted in Malawi. The public healthcare sector in Malawi comprises four levels of operation: community, health facility, district, and national. In this setup, data reporting from community and primary health facility levels, to the district is predominantly paper-based. Previous efforts at introducing and improving the national digital health management information system (HMIS) infrastructure mostly overlooked primary health facilities, focusing on the district and national level. Although highly functional, paper-based reporting is beset with various challenges, including: (i) seasonal challenges to the transportation of report forms, as most roads in rural areas are unpaved and in poor shape during the rainy season; (ii) members of staff have to fund their travel to district health offices, in order to submit reports; (iii) transportation of report forms takes staff away from their duty stations, which are often understaffed; (iv) health facilities often send reports through ambulance drivers, with no guarantees of delivery; (v) officers at district level are burdened with data entry, before they can proceed with data analysis; (vi) work overload at district level has often resulted in poor data reporting rates, with some health programme coordinators indicating that they do not have time for data entry.

With these challenges in mind, the Ministry of Health partnered with Chancellor College, a constituent college of the University of Malawi, and the University of Oslo, in exploring whether application of mobile technology, to extend the reach of the national digital HMIS, to primary health facilities, could help circumvent challenges related to transportation of paper-based reports. Health facilities would have the possibility of submitting reports remotely, using mobile phones, to a web-based national HMIS server. In addition, it was envisaged that pushing data entry to the health facility level would ease the burden of data entry at district level, allowing staff ample time for data analysis.

Despite the appeal of mobile technology, such an undertaking could not proceed unaffected by developments within the wider HMIS setup. The intended mobile technology solutions were to build upon ongoing HMIS strengthening efforts, commissioned in 2009, aimed at upgrading the national HMIS software solution and integrating silos of programme-centric information systems. Among other things, these HMIS efforts depended on the participation of multiple health programmes, telecommunication service providers, IT consultants, and, most importantly, project-based donor support. HMIS implementations in Malawi are largely dependent on poorly coordinated donor-funded projects, which often lead to poor development of technical structures and capacity, required to manage implemented solutions

beyond initiating project-based interventions. This means that solution implementations, on-going maintenance, and evolution are a challenge. Despite more than a decade of active HMIS strengthening efforts, dating as far back as 1999, the Ministry of Health in Malawi had until the end of 2012 no in-house IT capacity to support existing health information systems (HIS), as well as the aforementioned efforts to upgrade the national HMIS software solution. Technical support for this undertaking was mostly provided by an externally funded team of IT consultants, which was loosely attached to the Ministry of Health.

As further evidence of poor maintenance capacity, key gains registered during earlier HMIS strengthening efforts that started in 1999, had significantly weakened or disintegrated before commencement of this study. For example, data review meetings which had been reported as having been institutionalised across all levels of administration (Chaulagai et al., 2005), became infrequent after the folding of a World Bank project under which they were initiated. Despite these challenges, it is evident that HMIS interventions in Malawi will for the foreseeable future require significant participation from multiple stakeholders, through project-based interventions. It is, therefore, imperative that we find ways to leverage often short-term focused project-based support arrangements in developing HIS infrastructure.

1.4 Significance of the Study

The relevance of this study goes beyond HIS and application of mobile technology in support of healthcare management (mHealth) efforts in Malawi, for at least two reasons. First, recent studies indicate that mHealth interventions largely ignore dynamics within the larger HIS context, which hides the complexity of integrating mHealth solutions into existing socio-technical setups (Braa and Nielsen, 2013). Most challenges facing mHealth are beyond mHealth itself and relate to the wider HIS setup (Leon et al., 2012). There is therefore need to take an ecological approach to the implementation of mHealth, which takes into account existing and emergent practices, technological platforms, stewardship, and organizational financial and implementation capacity (Leon et al., 2012; Braa and Nielsen, 2013). This thesis contributes towards addressing calls to account for mHealth interventions within the context of developments within the broader HIS setup.

Second, practical and conceptual challenges regarding how to leverage short-term focused project-based support arrangements in developing and maintaining digital infrastructure are not restricted to Malawi. Digital infrastructure efforts, in both developing and developed economies, are by and large driven by short-term based funding arrangements (Edwards et al.,

2013; Karasti et al., 2010; Asangansi, 2012). There is therefore an ever-present tension regarding how to register quick gains and successfully implement technological solutions, within funded project time, as well as contribute towards development of persistent organizational and human arrangements, to aid maintenance and continuity (Ribes and Finholt, 2009; Asangansi, 2012). For example, dependence on project-based arrangements has been attributed to the collapse of HIS strengthening interventions after external support has been withdrawn (Kimaro and Nhampossa, 2005; Kimaro and Nhampossa, 2007; Lucas, 2008; Tamrat and Kachnowski, 2012; Sanner et al., 2012). Nonetheless, it is expected that HIS interventions in developing economies will for the foreseeable future depend on project-based donor funding (Lippeveld, 2001), meaning long-term development and maintenance of HIS infrastructure will remain a challenge. There is, therefore, need develop implementation and maintenance capacity, to further digital infrastructure efforts.

To aid development and maintenance of digital infrastructure there are growing calls to consider short-term interventions within long-term digital infrastructure objectives (Ribes and Finholt, 2009; Edwards et al., 2013; Pollock and Williams, 2010; Karasti and Baker, 2004). The idea is to collapse boundaries between infrastructure design, implementation, and maintenance, within funded project time, in order to provide impetus towards the continuity of infrastructure efforts, beyond individual project arrangements. However, even where there is such awareness and deliberate efforts are taken, leveraging project-based arrangements to provide impetus towards realization of long-term digital infrastructure concerns, faces various practical and conceptual challenges. For example, it is challenging to align the interests and operations of project staff and infrastructure managers, who may operate according to different temporal orientations (Karasti et al., 2010).

At a conceptual level, there is acknowledgement of a dearth of theoretical and methodological frameworks that allow for the accounting and negotiation of concerns that span multiple temporal scales (Bowker et al., 2010; Karasti et al., 2010; Star, 1999):

“there is an urgent need to develop approaches, methods and tools for collaborative infrastructure development that would allow for and support different temporal orientations to ensure effective and productive collaborations” (Karasti et al., 2010: pp. 404)

In addition, accounting for varying short-term and long-term concerns that stretch the expanse of digital infrastructure goes beyond the provisions of any singular perspective:

“Infrastructure is “large” spanning time and space, but it is also “small” coming in contact with routine and everyday practice. Thus, infrastructure studies require drawing together methods that are equal to the ambitions of its phenomenon” (Bowker et al., 2010: pp. 113)

There are calls for integrated frameworks, to allow nuanced analysis of how infrastructures emerge and impact innovation processes (Edwards et al., 2013; Yoo et al., 2010).

1.5 Research Aim and Questions

This study explores conceptualization and negotiation of tensions that arise from simultaneously attending to concerns for design, implementation and maintenance of digital health infrastructure. The main question guiding the study is:

How can we negotiate concerns and tensions to design, implementation and maintenance of digital health infrastructure, in the face of changing project-based support arrangements?

A significant part of this study consisted of attempts at integrating novel mobile technology solutions for routine health data reporting into an existing installed base of paper-based and digital reporting systems. A key aspect of digital infrastructure is their modular and multi-layered character, which entails that new technological offerings are not built from scratch but on top of an installed base of existing socio-technical arrangements, with which they should integrate (Hanseth and Lyytinen, 2010; Edwards et al., 2013; Star and Ruhleder, 1996). Fitting disparate elements of infrastructure requires significant and seldom straightforward processes of adaptation and mutual adjustment of organizational and technological elements, and competing stakeholder interests (Jackson et al., 2007; Aanestad and Jensen, 2011). In light of this, the overall research question is partially addressed through the question:

1. What are conditions for integrating novel solutions into an existing socio-technical installed base?

Implementation of technological solutions is often a concern of the short-term, to be achieved within project time (Markus, 2004). Though starting within the short-term (project time), stabilization, institutionalization, and maintenance of implemented solutions often stretches beyond individual project lifespans (Markus, 2004; Ribes and Finholt, 2009). As aforementioned, continuity of digital infrastructure efforts, beyond initiating projects, demands that enabling socio-technical arrangements be pursued across loosely coordinated project-based arrangements and temporal scales (Ribes and Finholt, 2009; Karasti and Baker,

2004). In relation to this, and calls for the development of theoretical and methodological frameworks that aid conceptualization and negotiating of concerns that span multiple temporal scales, together with related tensions (see: Karasti et al., 2010; Yoo et al., 2010; Bowker et al., 2010), the overall question is further operationalised through the questions:

2. What strategies can improve implementation and maintenance capacity in the context of changing project-based support arrangements?
3. How can we conceptually account for tensions to design, development, and maintenance of digital infrastructure?

In responding to these questions, I seek to contribute to development of perspectives that inform digital infrastructure development efforts, in a manner that permits synergizing concerns that span temporal scales. I am particularly interested in the development of goal-oriented infrastructures such as health information systems, bearing in mind that different types infrastructure have different qualities (Nielsen, 2006).

1.6 Research Findings

The thesis comprises five scientific papers and a summary thereof. Following, is a list of the papers included in this thesis. The papers are also included as part of the appendices:

- 1.MANDA, T. D. & HERSTAD, J. (2015). Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices. *Information Technology & People*. **Forthcoming**
- 2.MATAVIRE, R. & MANDA, T. D. (2014). Interventions Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures. *Journal of Information Systems in Developing Countries*. 63(3). 1-17.
- 3.MANDA¹, T. D. & SANNER, T. A. (2014). The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective. *International Journal of User-Driven Healthcare (IJUDH)*. 4(1).1-16
- 4.SANNER, T. A., MANDA, T. D. & NIELSEN, P. (2014). Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation. *Journal of the Association for Information Systems*, 15 (4). 220- 243.
- 5.MANDA, T. D. (2015). Leveraging Project Arrangements in Developing Health Information Systems Infrastructure. **Under review in an international journal**

¹ This is a revised version of the paper MANDA, T. D. & SANNER, T. A. Bootstrapping Information Technology Innovations Across Organisational and Geographical Boundaries: Lessons from an mHealth Implementation in Malawi. IRIS, 2012. Akademika forlag.

Table 1-1 presents a mapping of what research question (RQ) each paper responds to

Table 1-1: Mapping of papers to research questions

Paper Title	RQ1	RQ2	RQ3
Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices	X		X
Interventions Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures	X		X
The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective	X		X
Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation	X	X	X
Leveraging Project Arrangements in Developing Health Information Systems Infrastructure	X	X	X

1.7 My Contributions

This thesis contributes to both theory and practice. *First*, the thesis advances an integrated framework that combines four methodological and theoretical perspectives in order to conceptualize and negotiate concerns that relate to infrastructure design, implementation, as well as long-term maintenance and continuity. The idea is to allow for more explicit analysis of the following concerns that span multiple temporal scales: technology and implementation design; mobilizing demand-side adoption; pursuing control where there are multiple players; enacting technology; organizing infrastructure work; institutionalizing technological solutions and participation.

Second, the thesis suggests strategies for enhancing IT implementation and maintenance capacity, in a manner that leverages agile, but short-term project-based support arrangements, and persistent, but often slow and bureaucratic government structures.

Third, the thesis contributes to discourse on mHealth by adopting an ecological view to mHealth interventions and theorizing. This is achieved by accounting for interacting heterogeneous socio-technical elements – independent stakeholders, work practices, technological solutions, etc., in the wider HIS setup. Mobile technologies are part of a whole, which is shaped by, and shapes, their application in healthcare delivery and management. Beyond the potential offered by mobile technology, much more is required to make mHealth work (Braa and Nielsen, 2013; Yu et al., 2006; Leon et al., 2012). Finally, individual papers that are part of this thesis also contribute to literature on digital infrastructures, either by proposing new theoretical perspectives or extending on existing ones.

1.8 Research Approach

The research centred on two related pilots running two DHIS Mobile solutions for routine health data reporting, between 17 health facilities and a district health office, in Lilongwe, Malawi. The pilots sought to extend the reach of the national digital HMIS solution beyond the district level, to primary health facilities. The pilots commenced during the second half of 2011 and run until the first half of 2014. Between March and April 2014 the DHIS Mobile solutions were extended to a further 29 health facilities, thereby covering all public health facilities in Lilongwe district. In addition to the DHIS Mobile pilots, the thesis also accounts for broader historical HMIS efforts in Malawi, covering the period 1999 to 2014.

1.9 Summary of the Chapter and Structure of the Thesis

In this chapter, I have presented the background and motivation upon which this thesis is built. The chapter started with a brief account of man's efforts in technology development and then progressed to discuss the necessary overlap between technology development and maintenance work. After this, it has been established that the interplay between short-term technology development efforts and concerns for long-term maintenance and continuity, result in tensions that if not well managed may derail infrastructure efforts. The chapter also presents the problem area for my research, together with an overview of concerns regarding temporality in digital infrastructure. This was, then, followed by a presentation of study aims, research questions, intended contributions, and an overview of my research approach.

The rest of this thesis is organised as follows: Chapter 2 provides a review of related extant literature, and the theoretical framework adopted in this thesis. Chapter 3 presents the empirical setting for this study, and a description of empirical cases. Chapter 4 covers research methodology. Research findings from the papers included in this thesis are presented in chapter 5. Chapter 6 discusses research findings, as well as theoretical and practical contributions, together with related implications. Chapter 7 presents concluding remarks and suggestions for further research. A list of appendices, which includes papers that are part of this thesis, follows thereafter.

Chapter 2: Theorising Digital Health Information Infrastructure

This chapter starts with a review of mHealth interventions and the need to consider such within the context of wider health information systems (HIS) efforts. Thereafter, the chapter discusses perspectives on temporality, to guide conceptualization and negotiation of concerns and tensions pertaining to design, implementation, and maintenance of infrastructure. The discussion of perspectives on temporality also highlights limitations to individual perspectives. In the end, synthesis of individual perspectives leads to proposition of a theoretical framework, which combines existing perspectives.

Over the past decade mobile technology has provided an imperative to re-envision health data collection and communication in infrastructure sparse contexts (Chigona et al., 2012; Asangansi et al., 2013; Shoji et al., 2012; Sanner et al., 2012). The application of mobile technology solutions to support healthcare delivery and management has been termed mHealth (Istepanian et al., 2004; Yu et al., 2006). Yu et al. (2006) define mHealth as *“healthcare facilitated by the convergence of mobile and desktop healthcare information systems, wireless technology and other networks such as Bluetooth and cellular networks, which is composed of people and healthcare processes that are facilitated by wireless and possibly wired connectivity, desktop and mobile healthcare applications”* (ibid: pp. 181 – my own emphasis).

Reported benefits of mHealth applications include: rapid communication of data, which shortens the time from data collection to aggregation and analysis (Leon et al., 2012); training of personnel via distance learning; improving patient access to medication via electronic prescription systems (ibid). Studies have also reported improved communication between community health workers and their supervisors, to aid care delivery (Leon et al., 2012; Manda and Herstad, 2010). Other benefits include: reduction in transcription errors, through elimination of intermediate levels of data entry; improvements in data quality, through embedded logic for data validation; and reduced data-entry workload for those charged with consolidation of reports (DeRenzi et al., 2011; Ganesan et al., 2011).

Despite the potential shown by mHealth, significant challenges remain. Much as previous studies argue that mHealth requires mobilization of heterogeneous groups of stakeholders, technologies, and work practices (Yu et al., 2006), mHealth interventions have largely ignored the broader health systems context (Leon et al., 2012; Braa and Nielsen, 2013). The

mHealth landscape is also beset with a plethora of loosely coordinated and short-term focused pilot interventions that are unable to scale - *termed pilotitis* (Labrique et al., 2013). Despite ignoring the wider health systems setup, studies indicate that most of the challenges to mHealth go beyond mHealth itself and are related to challenges in the wider health system setup (Braa and Nielsen, 2013; Aranda-Jan et al., 2014). Ignoring the wider health systems setup, therefore, hides complexities to developing digital infrastructure, resulting in a dearth in guidance on how to acquire and implement mHealth technology at scale (Leon et al., 2012). Such observations have led to growing calls for mHealth interventionists and scholars to take an ecological view to mHealth, accounting for organizational forms, work practices, interacting technological platforms, funding schemes, convergence and divergence in interests, etc., as is the case with mainstream digital infrastructure studies. Figures 2-1 and 2-2 depict frameworks suggested by Leon et al. (2012) and Braa and Nielsen (2013), to this end.

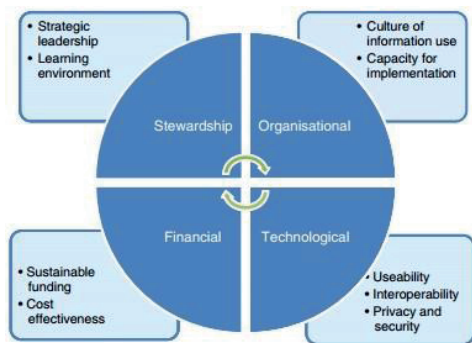


Figure 2-1: Health systems framework for decision-making about mHealth (Leon et al. 2012)

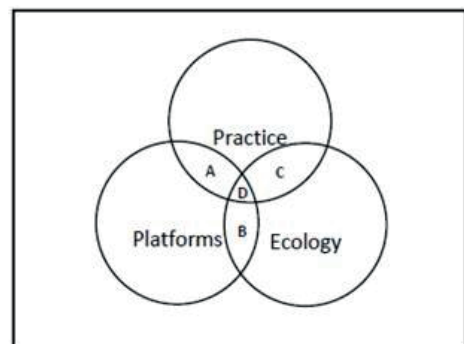


Figure 2-2: Facets for mHealth infrastructure (Braa and Nielsen 2013)

Despite some variations in the frameworks, the key message is that where mHealth solutions are meant to extend on existing HIS, there is need to leverage and contend with the above-depicted constitutive socio-technical elements. Next, I discuss concerns to infrastructure design, implementation, and maintenance.

2.1 An Overview of Concerns to Infrastructure Design, Implementation, Maintenance

Infrastructures, especially those in the making, are agonistic phenomena: imagined, produced, refined, and occasionally reassessed in a stratified and deeply conflictual field (Edwards et al., 2007). Thus, developing digital infrastructure entails negotiating competing stakeholder interests and concerns to design, implementation, use, and maintenance, which

span multiple temporal scales, together with tensions thereof (Pipek and Wulf, 2009; Pollock and Williams, 2010; Edwards et al., 2007). In part, introduction of new infrastructural technologies demands reflection on their design, regarding how to respond to both current and emergent needs (Hanseth and Lyytinen, 2010; Monteiro et al., 2013). There is also need for appropriate implementation strategies, to guide integration of novel technologies into existing socio-technical arrangements (Hanseth and Aanestad, 2003; Skorve and Aanestad, 2010). Those seeking to provide infrastructural solutions are also faced with concerns regarding how to attract use (*demand-side adoption*) (Hanseth and Aanestad, 2001; Hanseth and Lyytinen, 2010). The challenge of integrating novel technologies into an existing installed base and attracting demand-side adoption has been termed *the bootstrap problem* (Hanseth and Aanestad, 2001; Hanseth and Lyytinen, 2010), whereas that pertaining to openness to change, has been termed *the adaptability problem* (Hanseth and Lyytinen, 2010). Intertwined with concerns regarding growing demand-side adoption, are efforts to negotiate control to key parts of the installed base (*supply-side control*), so as to influence infrastructure development trajectories (Sahay et al., 2009; Jansen and Nielsen, 2005). Development of infrastructure “is always a contested process, tied as it is to questions around access, power, and the life chances of groups and individuals” (Edwards et al., 2007: pp. 38). Furthermore, long-term maintenance of infrastructure is an equally critical concern, which requires consideration early on in digital infrastructure efforts (Karasti and Baker, 2004; Ribes, 2014). Negotiation of the concerns above forms a basis for *enacting and institutionalizing* novel technologies into stable platforms that support everyday productivity (Pipek and Wulf, 2009; Fountain, 2001). Table 2-1, presents a summary of the concerns.

Table 2-1: Concerns to design, implementation, and maintenance of infrastructure

Concerns	Description
Technology and implementation design	Considerations on novel technology design, interplay with existing socio-technical installed base, and how to go about introducing new technology
Growing demand-side adoption	Attracting adoption, to achieve self-sustaining growth momentum (Hanseth and Lyytinen, 2010)
Enacting and institutionalizing technology	Transitioning experimental technologies into viable infrastructural solutions (Fountain, 2001)
Negotiating supply-side control	Pursuing control to parts of the installed base, so as to implement changes that shape infrastructure development trajectories in line with one’s interests (Nielsen, 2006)
Long-term maintenance and continuity	Promoting long-term maintenance of technological solutions and continuity of infrastructure efforts, beyond individual project arrangements (Ribes and Finholt, 2009)

The concerns above are spread across phases of digital infrastructure, and gain prominence at different points in time. It is, therefore, necessary that we consider temporality in digital infrastructure efforts, to aid accounting and negotiation of such concerns, as well as foreground the emergence of digital infrastructure (Karasti, 2014b; Pollock and Williams, 2010; Edwards et al., 2007).

2.2 Temporality in Digital Infrastructure

The ancient Greeks differentiated two kinds of time, “*kairos* (opportunity or the propitious moment) and *chronos* (eternal or ongoing time). “While the first...offers hope, the second extends warning” (Brand, 2008: pp. 9, citing Brown 1996 - Venice and Antiquity). Consideration of both aspects of time is essential, considering that time and space provide the context within which the social processes around technology implementation and use are situated, unfold, and should be explored (Sahay, 1997; Ribes and Finholt, 2009). For example, when introducing new technologies, stakeholders are, over the short-term, likely to be pre-occupied with attending to the exigencies of technology design, implementation, and growing demand side adoption, to achieve growth momentum (Aanestad and Jensen, 2011; Skorge and Aanestad, 2010). Other prevailing concerns at this stage might relate to identification of appropriate implementation strategies to minimize disruptions to existing socio-technical arrangements and accommodate emergent issues (Hanseth and Aanestad, 2001; Skorge and Aanestad, 2010; Asangansi, 2012). Successful implementation of technology is particularly a preoccupation of project-based support arrangements, where stakeholders need to demonstrate successful outcomes at the close of projects (Ribes and Finholt, 2009; Markus, 2004).

Beyond initial technology implementation, and with the passage of time, stakeholders find themselves grappling with the practical work of transitioning novel technological offerings into institutionalized solutions that support everyday productivity (Fountain, 2001; Aanestad et al., 2014). Previous studies suggest that application of technology to achieve set goals demands more than the action possibilities provided by individual technological artefacts (Pentland and Feldman, 2008). New technologies are enacted, i.e. made sense of, designed, and used through human action and the mediation of organizational and institutional arrangements (Fountain, 2001; Ackerman et al., 2012; Rose and Jones, 2005). Consequently, making novel technologies work requires ongoing changes to both novel and existing technologies and practices (Ackerman et al., 2012; Rose and Jones, 2005; Aarts et al., 2004). There might also be need to attend to breakdowns that ensue in trying to integrate novel

technologies into existing socio-technical arrangements. In the end, infrastructure work stretches across phases of infrastructure - design, implementation, maintenance, evolution - and has been discussed under different tags such as articulation work (Strauss, 1988), technology enactment (Fountain, 2001), and infrastructuring (Pipek and Wulf, 2009).

Over the long-term, usually when initiating projects have folded, maintenance and replacement of aging technology become dominant concerns (Karasti et al., 2010; Kimaro and Nhampossa, 2005). Some digital infrastructures, such as HIS need to remain in place over very long periods - the lifetimes of human beings, or the century-to-millennium scale of epidemic diseases - or risk dire consequences for knowledge and human welfare (Edwards et al., 2009). In addition, “today’s universal solution will, on some not too distant day, become tomorrow’s quaint and inflexible legacy system” (ibid: pp. 371).

Considering that digital infrastructure efforts are predominantly dependent upon short-term project-based support arrangements, there is need to combine negotiation of short-term concerns to technology design and implementation, with development of persistent arrangements that may support long-term maintenance (Kimaro and Nhampossa, 2007; Ribes and Finholt, 2009; Kimaro, 2006). Without intentional reflection on long-term concerns, we are in danger of being overwhelmed by concerns that pertain to the here-and-now, i.e. taken for granted project or implementation centred short-term temporal thinking (Karasti et al., 2010). Consequences from lack of long-term focus include development of infrastructure that is difficult to evolve (AbouZahr and Boerma, 2005) and poor development of maintenance capacity, to support implemented solutions (Kimaro and Nhampossa, 2007; Lucas, 2008; Sheikh and Braa, 2011). Combination of short-term design and implementation concerns, with those for long-term maintenance has been termed the *long now view* (Ribes and Finholt, 2009; Brand, 2008) or *infrastructure time* thinking (Karasti et al., 2010).

Although consideration of temporality in technology studies is to be encouraged, it may be challenging for at least two reasons. First, it is challenging to attain a consistent view on temporal frames as people view time from different perspectives (Sahay, 1997; Karasti et al., 2010; Karasti, 2014b). Quoting a colleague’s reflection on the definition of *now*, Brand (2008) writes: “on the stock exchange it’s today, on the Net it’s a month, in fashion it’s a season, in demographics a decade, in most companies it’s the next quarter” (: pp. 29). In the same manner, definitions on short-term and long-term temporal frames vary considerably across literature. Whereas studies on human computer interaction might define the short-

term in terms of seconds or minutes and the long-term in terms of days, weeks, and months (Dix et al., 1998), definitions of the same, might vary between a few years and several decades, among stakeholders in digital infrastructure studies (Karasti et al., 2010). Divergence in views on temporality has implications on the interpretation of technological change and long-term maintenance of digital infrastructure, especially where such processes extend beyond initiating project-based support arrangements (Markus, 2004). “Short-term experiences of gain and loss will shape the incentive structures of individuals and institutions tasked with responding to infrastructural change. This in turn will shape the climate within which infrastructures struggle to emerge” (Edwards et al., 2007: pp. 24)

Building on Karasti et al. (2010), the definition of *short-term* is in this thesis restricted to *within funded project time*. Karasti et al. (2010) term this ‘project time’. Project time as a temporal orientation “is closely linked with the notions of project, project management and project-based organization” (Karasti et al., 2010: pp. 403). Thus, project time comes to a close at the end of a project. On the other hand, the notion of *long-term* builds on the notions of ‘*infrastructure time*’ (Karasti et al., 2010) and *long now* (Ribes and Finholt, 2009; Brand, 2008), which cover multiple temporal scales (*past, present, and future*). Compared to project time, infrastructure time temporal orientation varies between being open and close ended, but favours open-endedness, stretching beyond the life spans of individual project arrangements (Karasti et al., 2010; Ribes and Finholt, 2009).

Another challenge to considering temporality in digital infrastructure efforts, especially combination of short-term and long-term concerns, is a dearth in frameworks that account for short-term implementation concerns as part of long term infrastructure objectives (Karasti et al., 2010; Pollock and Williams, 2010). Next, I review existing perspectives on temporality, along with their key points of focus and limitations.

2.3 Conceptualizations of Temporality in Digital Infrastructure

There are at least two streams of literature on digital infrastructure, with varying emphasis on temporality. One has its empirical roots in the evolution of the Internet, whereas the other has its foundations in the study of knowledge/e-infrastructure. The stream of literature with empirical roots in Internet studies takes a purely incremental and iterative view of digital infrastructure, with implicit treatment of temporal scales, especially the long-term. Central arguments to this stream of literature are that change has to be discovered along the way and central control mechanisms diminish significantly as infrastructures grow, meaning

infrastructure growth is void of any form of central control (Hanseth and Aanestad, 2003; Hanseth and Lyytinen, 2010; Ciborra et al., 2000; Aanestad and Jensen, 2011):

“change [in stepwise development of large comprehensive networks] is not possible to predict and specify today – it has to be discovered along the way...shared solutions will be produced as the aggregate outcome of the actions of independent actors – not an overall master plan” (Hanseth and Aanestad, 2001: pp. 2)

“Nothing has ever been sustainable, and nothing will ever be. Change is inevitable... sustainability models and frameworks will not predict the future or guarantee a sustainable project” (Ali and Bailur, 2007: pp. 12)

Suggested incremental and iterative perspectives to digital infrastructure include: *bricolage* (Ali and Bailur, 2007; Ciborra, 1992; Ciborra, 1998); *the information infrastructure theory* (Hanseth and Lyytinen, 2010), which advances constructs such as *bootstrapping* (Hanseth and Lyytinen, 2010; Hanseth and Aanestad, 2001; Hanseth and Aanestad, 2003). Bricolage argues that innovation emerges from tinkering through the combination of resources at hand (Ciborra, 1992; Ciborra, 1998). It is about accepting co-existence with the messiness of worldly routines and surprises, and leveraging the world as defined by the situation at hand, rather than setting ideal plans (Ali and Bailur, 2007; Ciborra, 1992). Beyond the argument that change has to be discovered along the way, *bootstrapping* (Hanseth and Lyytinen, 2010) advances explicit design principles to promote installed-base friendly innovation, learning, and application of lessons learned. The strategy argues for: *a judicious approach to technology and implementation design and building on the existing socio-technical installed base*. Bootstrapping also provides explicit guidelines for attracting demand-side adoption, to achieve self-sustaining growth momentum, for novel technological offerings (ibid).

On the other hand, concerns for the long-term are a central feature in knowledge/e-infrastructure studies. Perspectives in use include: *the long now of infrastructure* (Ribes and Finholt, 2009), *biography of artefacts/infrastructure* (Pollock and Williams, 2010), and *continuing design* (Karasti et al., 2010). Continuing design is a juxtaposition of the aforementioned notions ‘project time’ vs. ‘infrastructure time’ (ibid). Central to these perspectives is a need to *view short-term cycles of development and associated tactics, as phases in a longer-term biography of developments and strategies to institutionalise technology, roles and organisations* (Karasti et al., 2010; Ribes and Finholt, 2009; Pollock and Williams, 2010). Combination of short-term and long-term concerns has been termed the

long now view (Brand, 2008) or *infrastructure time* thinking (Karasti et al., 2010).

The long now view comes from realizing that “we are not the culmination of history, and we are not start-over revolutionaries; we are in the middle of civilization’s story” (Brand, 2008: pp. 31). In other words, the long-term view demands that we collapse “the realm of immediate responsibility, one in which we feel we have volition, where the consequences of our actions are obvious and surprises limited” (ibid: pp. 29) with a sense of responsibility to the future. The idea is not to control the future, but rather to give it tools to help itself. “Like a tree, civilization stands on its past” (Brand, 2008: pp. 126). It is also widely acknowledged that digital infrastructures are not built from scratch but upon some installed base (Star and Ruhleder, 1996; Monteiro et al., 2014). Regarding this, “rigorous long-view thinking makes responsibility taking inevitable because it responds to the slower, deeper feedback loops of the whole society and natural world” (Brand, 2008: pp. 118). In the order of infrastructure development, the fast layers of *project time* innovate; the slow *infrastructure time* layers stabilize. The whole combines learning and continuity. Enabling this requires mediation between the open-endedness of infrastructure and “the short-range planning inherent to work with technology and with associated short-term projects” (Karasti et al., 2010: pp. 399).

The long now perspective (Ribes and Finholt, 2009), seeks to conceptualise the problem space for digital infrastructure design, implementation and maintenance. The perspective conceptualizes an infrastructure problems space as a collection of tensions, which emerge at the intersection of scales of infrastructure work and concerns for long-term sustainability. Continuing design is a development orientation that combines short and long-term temporal scales, traditionally perceived as at odds with each other, as foundational design considerations to infrastructure development (Karasti et al., 2010). Table 2-2 provides a summary of perspectives that are central to this thesis.

Table 2-2: Summary of conceptualizations of temporality in digital infrastructure

Framework	Foundational elements	Temporal awareness
Bootstrapping	▪ Design principles: (i) technology and implementation design; (ii) pursuing demand-side adoption	Implicit treatment of temporal scales
Long now	▪ Conceptualization of infrastructure design problem space – <i>scales of infrastructure work and concerns for long-term sustainability</i> ▪ Short-term vs. long-term concerns as a tension	Long now thinking
Continuing design	▪ Short-term vs. long-term tensions as foundational elements of infrastructure design – <i>innovation points</i>	Long now thinking

Next, I discuss the perspectives bootstrapping, long now, and continuing design, which I

have applied at various stages of my research journey. In discussing these perspectives, I mainly focus on their key points of focus and associated limitations. Bricolage and the Biography of Artefacts (BoA) perspective are not discussed further, as their points of relevance to my work are covered by bootstrapping (in the case of bricolage) and the long now and continuing design perspectives (in the case of the BoA).

2.3.1 The Bootstrapping Strategy: Technology Design, Implementation and Growing Demand-side Adoption

The bootstrapping strategy recognises the importance of direct usefulness of technological solutions to target end-users, to motivate adoption. The strategy builds on a network economics perspective to conceptualise, and provide a prescriptive guide on how to transition digital infrastructure offerings from having no adopters to gaining adoptions that spur momentum for self-reinforcing growth. Network economics assumes that a proposed infrastructure gains cumulative attractiveness and self-reinforced growth through growing user adoption and demand-driven mechanisms (Hughes, 1983; Hughes, 1987). Table 2-3 provides a summary of principles advanced by bootstrapping (Hanseth and Lyytinen, 2010).

Table 2-3: Bootstrapping: technology design, implementation, growing demand-side adoption – adapted from (Hanseth and Lyytinen 2010)

Bootstrapping Principles
<ul style="list-style-type: none">▪ target IT capability to a small group▪ make IT capability simple to implement and use▪ Make IT capability directly useful without a large installed base▪ Design for one-to-many IT capabilities in contrast to all-to-all capabilities▪ Satisfy needs of the most motivated users first▪ Minimize adoption barriers▪ Expand installed base by persuasive tactics to gain momentum

By following the principles above, it is assumed that designers can aid self-sustaining growth momentum in infrastructure. However, the strategy has at least two shortfalls.

First, the bootstrapping perspective presents the view of some designer (individual or coherent group) with sufficient control to influence digital infrastructure development trajectories. In doing this, the strategy underplays the significance of the presence of multiple independent stakeholders, with competing interests, who have control over different parts of an installed base and, therefore, have a hand in the development of infrastructure (Nielsen, 2006). It should be known that the continued evolution of technological offerings demands more than their cumulative attractiveness (ibid).

Second, an exploratory perspective such as bootstrapping, which assumes that digital infrastructures progress without meaningful central control mechanisms, may lead to fragmented systems:

“If we allow exploratory, “bottom-up” and ad hoc design, how can the proliferation of fragmented and incompatible solutions be avoided? What will happen when there is no central authority with the responsibility for standardising?” (Aanestad, 2002: pp. 40)

Assumptions that change has to be discovered along the way and that digital infrastructures progress without meaningful central control mechanisms may not work well with goal-directed digital infrastructures such as HIS. HIS have a significant presence of central coordinating bodies such as health ministries or national statistical offices and are often supported by a multiplicity of independent project-based interventions that require coordination. The bootstrapping perspective could benefit from combination with perspectives that account for long-term concerns, the presence of multiple actors working on different parts of an installed base, and central organizing mechanisms. The long now (Ribes and Finholt, 2009) and continuing design (Karasti et al., 2010) may be of help in this regard.

2.3.2 The Long now Perspective: Conceptualizing the Problem-space for Digital Infrastructure Design, Implementation, Maintenance

The long now perspective conceptualizes the problem space for developing digital infrastructure as a set of tensions that emerge at the intersection of scales of infrastructure work (*enacting technology, organizing work, and institutionalizing*) and concerns for long-term sustainability (*aligning end-goals, motivating contribution* across stakeholder groups, *designing for use*) (Ribes and Finholt, 2009). Tensions can be defined as inner striving, unrest, or imbalance from seemingly opposing forces or conflicting demands to make decisions (Kee and Browning, 2010; Carlsson and El Sawy, 2008). Extant literature suggests that digital infrastructure cannot be fully realized purely on the basis of elaborate maps or blueprints (Jackson et al., 2007; Aanestad and Jensen, 2011). In the absence of such, tensions act as points of imagination, planning, and implementation of digital infrastructure, and thus can be considered as one of the chief sources of infrastructural change, innovation, growth, and learning over time (Edwards et al., 2007). Table 2-4 provides a summary of concerns and tensions advanced by Ribes and Finholt (2009).

Table 2-4: Tensions to infrastructure – adapted from (Ribes and Finholt 2009)

Concerns for sustainability	Scales of infrastructure work		
	<i>Enacting Technology</i>	<i>Organizing Work</i>	<i>Institutionalizing</i>
<i>Aligning End-goals</i>	inclusion vs. readiness	planned vs. emergent	project vs. facility
<i>Motivating Contribution</i>	research vs. production systems	development vs. maintenance	individual vs. community
<i>Designing for Use</i>	today's requirements vs. tomorrow's users	research vs. development	communities vs. constituencies

Infrastructure work is considered necessary to the negotiation of identified tensions, to aid enacting and institutionalizing of novel technologies.

Enacting Technology: Enacting technology is about accounting for the practical work of trying to make novel technology work, in the context of other existing and evolving technological arrangements, practices, and mitigating organizational arrangements (Ackerman et al., 2012; Rose and Jones, 2005; Fountain, 2001). Tensions relating to technology enactment may include: whether to develop technology with focus on users with necessary technical expertise and equipment or provide additional support to those lagging behind (*inclusion vs. readiness*); developing experimental systems, versus creation of stable resources for everyday use (*research vs. production quality systems*); addressing current user needs, but maintaining flexibility to accommodate future needs (*today's requirements vs. tomorrow's users*) (Ribes and Finholt, 2009).

Organizing Work: Humans are essentially organizing beings. Organizing is at the core of what we do, whether simple and routine or more complex and less well defined (Papa et al., 2006). As aforementioned, making technology work requires contributions from different stakeholders, with different interests and working time scales. There is also need to switch between well-articulated plans and ad-hoc actions, to address technology breakdowns or take advantage of present opportunities. In organising for change “one should expect problems to arise and prepare to resolve problems judiciously” (Papa et al., 2006: pp. 36).

Tensions relating to organizing work include: adherence to detailed plans, versus responding to emergent issues (*planned vs. emergent organisation*); pursuing balance between scientific research work and technical tasks that contribute to infrastructure development (*research vs. development*); pursuing balance between continued development of new resources and maintaining existing ones (*development vs. maintenance*) (Ribes and Finholt, 2009).

Institutionalizing: Where implemented technologies are meant to transition into stable platforms that support everyday productivity, there is often a need to develop persistent arrangements to support such. A technology is said to be institutionalized when it is integrated into users' work practices and becomes a taken-for-granted part thereof (Silva and Backhouse, 1997). Tensions relating to institutionalisation include: securing long-term financial and technical support, versus reliance on project-based resources (*project vs. facility*); pursuing own interests, versus prioritising the development of functional community infrastructure (*individual vs. community interests*); responding to the needs and interests of larger and more general users groups, against those of smaller and specialised groups (*general communities vs. specific constituencies*) (Ribes and Finholt, 2009).

Although the long now perspective aids conceptual mapping of an infrastructure development problem space, it has a couple of shortfalls. First, the perspective largely views short-term vs. long-term tensions as problematic, rather than foundational elements of infrastructure design (Karasti et al., 2010). Second, the long now perspective (Ribes and Finholt, 2009) does not provide sufficient detail on how to negotiate identified tensions and account for practices implicated in attempts to develop viable digital infrastructure solutions (Karasti et al., 2010). The notion of continuing design (Karasti et al., 2010) seeks to address these shortfalls to the long now perspective.

2.3.3 Continuing Design: Temporal Tensions as Points for Possible Innovation

As aforementioned, beyond challenges they present, tensions can also act as points of imagination, planning, and implementation of digital infrastructure. Thus they ought to be engaged constructively and should be leveraged for their contributions towards attainment of objectives to digital infrastructure under development (Edwards et al., 2007).

The notion of *continuing design* (Karasti et al., 2010) views digital infrastructure development as “an active mix of on-going—never-ending—negotiations that create an always reviewed and renewed balance among activities meeting short-term goals while addressing long-term aims and ramifications” (Karasti et al., 2010: pp. 403-404). Karasti et al. (2010) advance concepts ‘*project time*’ and ‘*infrastructure time*’ (discussed in section 2.2) to illustrate temporal tensions and the continuing work of simultaneously building and using, maintaining and redesigning infrastructure, both within and beyond individual short-term project support arrangements. Continuing design recognizes that efforts within project time can provide impetus for the infrastructure time based development orientation (ibid).

Despite its strengths continuing design (Karasti et al., 2010) shares one important limitation with other design-centred perspectives such as bootstrapping (Hanseth and Lyytinen, 2010; Hanseth and Aanestad, 2001) and long now (Ribes and Finholt, 2009) – *these frameworks do not sufficiently address the politics and power asymmetries at play in infrastructure development efforts*. Aforementioned concerns regarding infrastructure design, implementation, and maintenance are intertwined with ongoing pursuit of control to key parts of the installed base, as stakeholders attempt to influence development trajectories to suit their interests (Nielsen, 2006; Ali and Bailur, 2007; Sahay et al., 2009). Stakeholders may exert influence on infrastructure development trajectories, at certain points in time, when in control of infrastructure components such as software platforms, standards, business models, and institutionalized ways of cooperation (Yoo et al., 2010; Aanestad and Jensen, 2011; Elaluf-Calderwood et al., 2011). Although some scholars argue that those involved in the design of digital infrastructure should avoid dependence on parts they are not in control of (Hanseth and Lyytinen, 2010), this is easier said than done, considering the heterogeneity of interacting socio-technical elements in digital infrastructure undertakings. The pursuit of control among those trying to provide infrastructural solutions (the supply-side) maybe exercised at least two levels: (i) individual stakeholder groups or projects, attempting to get into positions of influence (see: Aanestad and Jensen, 2011; Nielsen, 2006); (ii) infrastructure level, where organizations charged with coordinating infrastructure efforts, seek to mobilize and organize the participation of multiple independent stakeholders (Aanestad and Jensen, 2011; Zimmerman and Finholt, 2007; Karasti and Baker, 2004). Table 2-5 provides a summary of the above reviewed perspectives, indicating their limitations.

Table 2-5: Summary of perspectives on temporality, indicating their limitations

Framework	Limitation
Bootstrapping	<ul style="list-style-type: none"> ▪ Implicit treatment of temporal scales, especially the long-term ▪ Bottom-up approach may lead to system fragmentation ▪ Weak coverage of implications of distributed control on the supply-side
Long now framework	<ul style="list-style-type: none"> ▪ Mostly views temporal tensions as problematic ▪ Does not sufficiently account for actual practices to negotiating tensions ▪ Weak coverage of implications of distributed control on the supply-side
Continuing design	<ul style="list-style-type: none"> ▪ Weak coverage of implications of distributed control on the supply-side

2.3.4 Views on Control and Participation in Digital Infrastructure Efforts

Views and responses to the exercise of control vary considerably across literature, with some scholars and practitioners adopting extreme positions. For example, in a bid to sanitize the mHealth landscape filled with a plethora of poorly coordinated interventions, the Ministry of

Health in Uganda issued a moratorium on mHealth interventions, demanding that interventions first be cleared with ministry (McCann, 2012; Mattsson and Sabuni, 2013). On the other hand, some scholars advance arguments of the inevitability of progressive weakening central control mechanisms and movement towards drift (deviation from intended objectives and control structures), as infrastructures grow (Hanseth and Lyytinen, 2010; Ciborra et al., 2000). Yet others, argue that “this pessimistic formulation runs the risk of offering a fatalistic account of the necessity of failure” (Pollock and Williams, 2010: pp. 20). This position is supported by Tjornehoj and Mathiassen (2008), who argue that control and drift are not necessarily alternative management philosophies. Rather, they are complementary and intrinsically related opposites of a dialectical relationship. In the face of such contradiction in perspectives shall we, then, go by the Spanish phrase I dearly love: *qué será será* (what will be, will be), popularised by a similarly titled song from a 1956 Alfred Hitchcock film - *The Man Who Knew Too Much*? Most certainly not, I would argue. I side with views by Pollock and Williams (2010) and Tjornehoj and Mathiassen (2008), especially when discussing goal-oriented infrastructure such as HIS, as is the case herein.

Although the pursuit of absolute control is a futile undertaking, progressive weakening of central control mechanisms and inevitable progressions towards drift (Ciborra et al., 2000) need not be accepted as a necessary feature for all kinds of digital infrastructure efforts. As aforementioned, HIS are by nature goal directed systems, which demands unified visions to achieve integrated national infrastructure. Although not all innovation processes require centralization, and need not be, the oversight of central coordinating bodies such as ministries of health might be necessary, especially where there are multiple loosely coordinated project-based arrangements. Debates around HIS fragmentation/integration are indicative of a need for some form of central control (Chaulagai et al., 2005; Kanjo et al., 2009; Galimoto, 2007; Braa and Sahay, 2012). Studies on research infrastructures recognize the significance of persistent central control mechanisms and interests (e.g. research organizations and objects) in guiding stakeholder participation and efforts around design, implementation, and maintenance of goal-directed infrastructures (Zimmerman and Finholt, 2007; Karasti et al., 2010; Ribes and Polk, 2014; Ribes, 2014). Zimmerman and Finholt (2007) discuss gateway organizations (collectives of scientific communities) as an enabler for collaborative development of large-scale research infrastructures. Gateway organizations afford collaboration across research sites, providing a platform for aligning divergent and competing goals, developing unified visions, and accessing technical expertise (ibid).

Though functional, it is necessary to point out that central control mechanisms might increase coordination overheads (Aanestad and Jensen, 2011).

Aanestad and Jensen (2011) argue for a modular (incremental) approach to mobilizing and organizing stakeholders in implementation of technological solutions. Their argument builds on the bootstrapping logic (Hanseth and Lyytinen, 2010). The idea is to cut down on coordination overheads and need for long-term commitment from multiple stakeholders, by starting small, getting grounded, and growing as technological solutions become stable. An advantage to the modular approach is that persuasive tactics may be easier to apply (ibid). Karasti et al. (2010) also recognize modularity as a way to lowering the level of temporal commitment required of stakeholders in the implementation of a universal ecological data standard. Initial grand scale implementation of the standard quickly ran into murky waters, as it required the participation of a large community of users, with varying local interests, work practices, and technological solutions. Despite the above mentioned benefits, modular/incremental approaches might suffer from short-term focus and duplication of efforts (Karasti et al., 2010; AbouZahr and Boerma, 2005; Aanestad, 2002). In light of the foregoing, I argue for a combination of modularity (Aanestad and Jensen, 2011), and participative central control mechanisms (Zimmerman and Finholt, 2007; Karasti and Baker, 2004), in mobilizing and organizing stakeholders in the design, implementation, and maintenance of infrastructure. Next, I discuss the theoretical framework advanced herein.

2.4 Theoretical Framework

This study builds on the long now perspective (Ribes and Finholt, 2009); continuing design (Karasti et al., 2010); and bootstrapping (Hanseth and Lyytinen, 2010; Hanseth and Aanestad, 2001), which have varying temporal focus, as well as emphasis and suggestions on how to negotiate tensions to infrastructure design, implementation, and maintenance. There are three principle reasons behind combination of these perspectives. The first is to allow for accounting and more explicit analysis of the following identified concerns and tensions to infrastructure design, implementation, use, and maintenance: *technology and implementation design; growing demand-side adoption; negotiating supply-side control; long-term maintenance and continuity*. Second, combination of the perspectives compensates for aforementioned limitations to individual perspectives (see table 2-5). Third, my approach, responds to calls for development of integrated theoretical and methodological frameworks, to allow for more nuanced analysis of how digital infrastructures emerge and in turn affect innovation outcomes (see: Yoo et al., 2010; Bowker et al., 2010). Table 2-6

depicts the proposed integrated framework.

Table 2-6: Proposed integrated framework

Perspective	Contribution –Foundational elements
Long now perspective	<ul style="list-style-type: none"> ▪ Conceptualization of infrastructure design problem space ▪ Mapping short-term vs. long-term concerns as tensions
Continuing design	<ul style="list-style-type: none"> ▪ The concepts of project time vs. infrastructure time, to account for negotiation of temporal tensions ▪ Treating short-term vs. long-term tensions as points for innovation
Bootstrapping	<ul style="list-style-type: none"> ▪ Explicit design principles for: (i) technology intervention design; (ii) growing demand-side adoption

In the integrated framework, the long now perspective (Ribes and Finholt, 2009) offers continuing design (Karasti et al., 2010) and bootstrapping (Hanseth and Lyytinen, 2010) conceptualization of the problem space within which choices for developing infrastructure are made. As aforementioned, the long now perspective foregrounds tensions that emerge at the intersection of scales infrastructure work (enacting technology, organizing work, and institutionalizing) and concerns for long-term sustainability (aligning end-goals, motivating contribution, designing for use). In turn, the long now perspective gains more nuanced treatment of actual practices that ensue as stakeholders continuously pursue balance between short-term and long-term concerns and tensions, through shifting priorities and combinations between short-term and long-term.

In the framework, bootstrapping (Hanseth and Lyytinen, 2010) offers the long now and continuing design perspectives explicit strategy on how to approach technology design and implementation, especially how to grow demand-side adoption, in order to achieve growth momentum. In turn, the bootstrapping perspective gains explicit temporal awareness, especially regarding treatment of long-term concerns for maintenance, from pairing with the long now and continuing design perspectives. In addition to the long now perspective's conceptualization of the problem space for developing digital infrastructure, bootstrapping may benefit from continuing design's concepts of 'project time' and 'infrastructure time', which foreground stakeholders' continuous negotiation of temporary balance between short-term and long-term concerns. That way, bootstrapping new technologies is not purely about discovering things on the go, when attending to exigencies of technology design and implementation. Rather, the long now view acts as sensitizing device prompting practitioners to consider contributing to development of persistent organizational arrangements that enhance prospects for long-term maintenance and continuity, right from the start of digital

infrastructure efforts. Thus, building for long-term maintenance becomes a concern for the here-and-now, as practitioners gain an awareness that long-term viability of digital infrastructure is not just down to cumulative attractiveness of technological solutions. The bootstrapping perspective also benefits from awareness and treatment of multiple stakeholders, with competing interests, simultaneously working on different parts of the installed base, which is offered by the long now and continuing design perspectives.

In chapter 6 (discussion and implications), I propose two further adjustments to the framework above, based on my research findings and application of the perspectives included in the framework above. The *first* adjustment proposes an additional dimension to the integrated framework above, to conceptualize dynamics regarding supply-side control. This adjustment builds on paper 4 (Sanner et al., 2014), which advances *grafting* (discussed in chapter 5), as a perspective on digital infrastructure innovation, where control on the supply-side is distributed. The notion of grafting is drawn from horticulture, where different plant stems with desirable traits are brought together and natured to form a union, which may lead to the propagation of desirable hybrids, should it hold. The notion of grafting theorizes innovation in digital infrastructure as a partly controlled process through careful alignment of resources and capacities. The perspective argues that in trying to influence both short-term and long-term infrastructure development trajectories, stakeholders: actively search for and possibly fashion opportunities to get into positions of prominence; pursue control over parts of the installed base, through forging alliances with key players; seek to retain control during early stages of implementation, but then embed that control into organizational arrangements that are likely to continue beyond their involvement, in order to influence long-term infrastructure development trajectories.

The *second* adjustment is an extension to the long now perspective (Ribes and Finholt, 2009) in the form of an additional concern for sustainability – *developing IT capacity* (Manda, 2015). This study identified poor IT capacity at both user (technology use and basic maintenance) and organizational level (implementation and maintenance) as impediments to technology implementation, use, and maintenance. Empirical findings suggest that availability and accessibility of IT capacity to aid technology, implementation, use, and maintenance warrants a separate dimension under concerns for long-term sustainability, suggested by the long now perspective (Ribes and Finholt, 2009).

Chapter 3: Research Context and Empirical Setting

This chapter presents the domain, geographical, and empirical setting for this study. The study falls within the domain of information infrastructure studies, particularly health information systems development and application of mobile technology in support of healthcare delivery and management (mHealth). Studies on information infrastructure are concerned with guiding practice and theorizing complexities that surround development and maintenance of large-scale technological offerings, which involve heterogeneous groups of stakeholders, technologies, practices, over an extended period of time. I am particularly interested in understanding the intentional shaping of health information infrastructures and how their idiosyncrasies influence development processes.

3.1 Geographical Setting

The main empirical setting for this study was Malawi, which is located in southern Africa and shares borders with Tanzania (to the North and Northeast), Zambia (to the West), and Mozambique (to the East, South and Southwest). The country is a former British colony and was known as Nyasaland, before gaining independence in 1964, and republican status in 1964. Malawi has an estimated total population of 15.91 million (UNdata, 2013) and a total land area of 118,484 Km². The country's population is mostly rural-based, with the 2008 population census indicating that 84.7 percent of the population at the time lived in rural areas (NSO, 2008). Figure 3-1 shows a map of Malawi, with district and international borders.



Figure 3-1: Map of Africa and Malawi

Malawi is sub-divided into three regions and twenty eight districts. Politically, the country was a one party state between 1964 and 1994. In June 1993 the country held a referendum on whether to maintain the one-party system of government or embrace multi-party politics. A majority of voters opted for a switch to multi-party politics. The country's first multi-party elections followed in 1994.

Despite clocking fifty years of independence in July 2014, Malawi's socio-economic indicators remain poor. In 2011 Malawi had GDP per capita of \$388.0 (a rise from \$215.0 in 2005) (UNdata, 2013). In the same year, the average proportion of dependents per household stood at 47 percent (NSO, 2012). NSO (2012) also reports that 21 percent of the population aged 15 years and above had never attended school (ibid).

As a mark of its socio-economic status, the country is significantly donor dependent, with a significant part of its yearly operational budget dependent on donor support. For example, it was expected that 40 percent of the budget for the financial year 2012-2013 was going to be met by donors. When this did not materialise, due to fallout with donors, over public finance mismanagement, and subsequent withholding of donor aid, public service delivery was negatively affected. Similar fallout with donors, between 2011 and 2012, had also plunged the country into deep economic crisis, resulting in widespread forex and fuel shortages.

3.2 Physical National Infrastructure Development

Malawi has made considerable progress towards developing its infrastructure. For example, as of 2006, the country had already met the MDG target for water, ten years before the deadline. Only four other Sub-Saharan African countries had achieved the same (Foster and Shkaratan, 2011). The country has also made significant progress on investment and institutional reforms, introducing a road fund, in order to improve its road infrastructure. In addition, Foster and Shkaratan (2011) also report that institutional reforms for the power sector were ahead of the average score for Sub-Saharan Africa.

Nonetheless, challenges remain. For example, power supply is unreliable, with power outages about three times the average levels observed in comparable countries (Foster and Shkaratan, 2011). Table 3-1 shows a comparative summary of some key indicators for power, as reported by Foster and Shkaratan (2011).

Table 3-1: Comparative summary of some key indicators for power

Indicators	Unit	Low income countries	Malawi	Middle-income countries
Access to electricity	% population	15.4	11	59.9
Urban access to electricity	% population	71	34	83.7
Rural access to electricity	% population	12	2.5	33.4
Growth access to electricity	% population/year	1.4	0.6	1.8
Power outages	Days/year	40.6	77	5.6

Challenges such as poor access to electricity (34% in urban areas and 2.5% in rural areas), and power outages favour the use of mobile phones as an enabler of access to digital content, compared to more energy intensive ICTs such as desktop and laptop computers. Owing to this, Malawi's Global System for Mobile communications (GSM) signal coverage reaches 93 percent of the population and is amongst the highest in Africa and even exceeds the average of 85 percent across middle income countries. The expansion of GSM service in the country has almost reached the limits of commercial viability (Foster and Shkaratan, 2011).

Core indicators on access to and use of ICT at household level, for the period 2010 to 2012, show that: only 8.7, 0.8, and 4 percent of households had television sets, fixed line telephones, and computers, respectively. In 2011, 36.3 percent of households had mobile phones. Figure 3-2 depicts growth trends for mobile and fixed-line telephony, and fixed (wired) broadband Internet subscriptions, per hundred people, in the period 2000 to 2012.

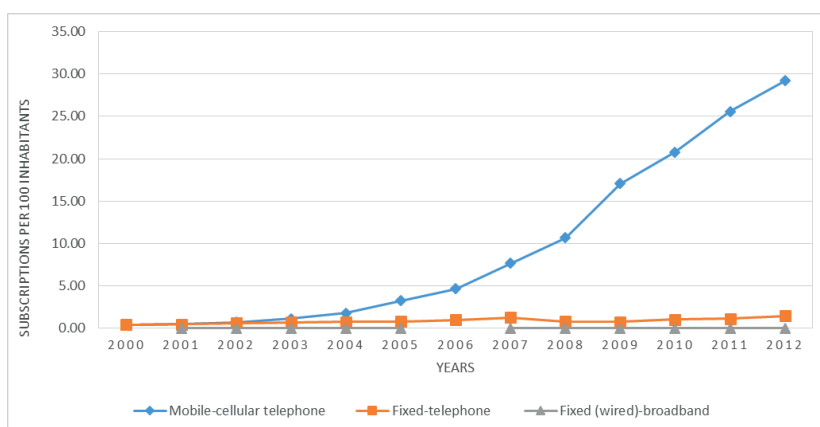


Figure 3-2: Growth trends in mobile telephony, fixed-line telephony and fixed (wired) broadband subscriptions— data source (ITU, 2013).

The mobile phone industry in Malawi continues to grow with an increasing number of mobile innovations, such as mobile banking, being introduced to the market.

3.3 Health and Healthcare

In Malawi, people access health services both within and outside the formal healthcare setup. The formal healthcare setup is a three-tier system, comprising primary, secondary and tertiary levels of care. The main health service provider in Malawi is the Ministry of Health (MoH), which owns approximately 63% of all health facilities. This is followed by The Christian Health Association of Malawi (CHAM), which owns about 26% of all health facilities. The remaining 11% is owned by private entities, local government, the military and police, and statutory corporations and companies (AHO, 2009).

Health indicators for the country are mixed, but the healthcare system is generally said to be overburdened. The healthcare system faces a critical shortage of human resources for health (Carlson et al., 2008; Republic of Malawi and Health Metrics Network, 2009). In 2009 it was reported that national doctor/population and nurse/population ratios stood at 1:53,176 and 1:2,964, respectively. This was way below WHO's recommendations for developing countries of 1 doctor per 5,000 population and 1 nurse per 1,000 population (Republic of Malawi and Health Metrics Network, 2009). Malawi's epidemiological profile is characterized by a high prevalence of communicable diseases, such as Malaria, Tuberculosis and HIV/AIDS. There is also a growing burden of non-communicable diseases such as cancers, hypertension, diabetes, and cardiovascular diseases (ibid).

Despite existing challenges, considerable gains have been registered in some areas. For example, childhood mortality levels are decreasing, with infant mortality reported at 66 deaths per 1,000 live births for the five-year period before the 2010-2011 Malawi Demographic Health Survey (MDHS) (NSO and ICF Macro, 2011). Infant mortality was at 81 deaths per 1000 live births, in the five-to-nine-year period before the survey. The number of people going for HIV testing has also increased rapidly. The 2010-2011 MDHS reported that 72 percent of women and 51 percent of men had ever been tested and received their test results.

3.4 Overview of Developments in Health Management Information Systems

The health management information system (HMIS) in Malawi has had ongoing strengthening efforts in the period 1999 to 2014, courtesy of various donor-funded projects. Some key outcomes of interventions undertaken during this period include: (i) comprehensive review of the HMIS, starting from 1999, with support from the Dutch government; (ii) commissioning of a desktop-based HMIS software solution (DHIS 1.3), in 2002; (iii) development of HIS implementation capacity, under the Building Europe Africa collaborative

Network for applying Information Society Technologies in Health care Sector (BEANISH). In addition, the World Bank supported data review and management meetings, between 2006 and 2008. In 2009, efforts were commissioned to upgrade the national HMIS software solution from the desktop-based DHIS 1.3, to a web-based server solution (DHIS2). Figure 3-3 and table 3-2 present a timeline of project-based HMIS efforts and some key outcomes, covering the above-mentioned period. Comprehensive discussion of the same follows next.

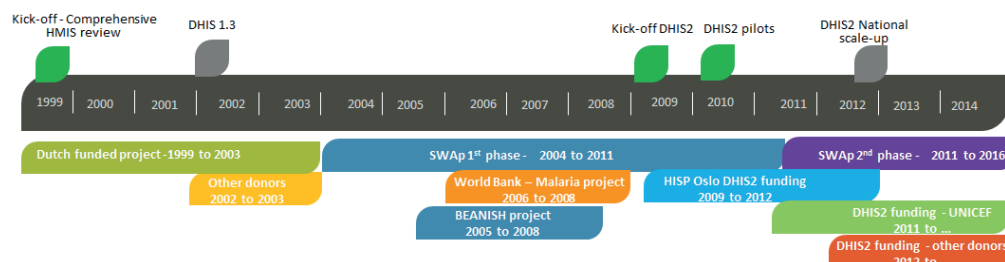


Figure 3-3: A timeline of project-based HMIS strengthening efforts – 1999 to 2014

Table 3-2: HMIS efforts and some key outcomes -1999 to 2014

Period	Key Partners	Focus/outcomes
1999 – 2002	The Dutch Government	HMIS building blocks: indicators; HMIS software solution; trainings
2002 – 2003	Multiple donors	Continuation of the efforts above
2004 -	Multiple donors –	Sector wide approach (SWAp) to health sector reform - <i>pooling together donor support</i>
2005 – 2008	BEANISH	HIS implementation capacity development
2006 – 2008	World Bank Malaria project	Data review meetings
2009 – 2012	HISP Oslo UNICEF	HMIS software solution upgrade National DHIS2 trainings
2012 – 2014	Multiple donors	Continuation of efforts from the period 2009 -2011

Figure 3-3 and table 3-2 depict both sequencing and overlaps between donor-funded HMIS strengthening efforts. The sequencing of, and overlaps in, interventions present funding and technical support opportunities, as well as coordination and continuity challenges. Next, I discuss HMIS infrastructure efforts outlined above in more detail.

3.4.1 Empirical Cases in detail: HMIS Infrastructure Efforts between 1999 and 2009

Data required to guide health service planning and management in Malawi is collected as part of routine health service delivery and through non-routine exercises, such as censuses. Staff providing care at community level, mostly Health Surveillance Assistants, report to health

facilities they are attached to. Health facilities, in turn, report to district health offices. In turn, district health offices report to the Ministry of Health headquarters. Reporting frequencies range from weekly to monthly, depending on health programme needs. At national level, the Ministry of Health's Central Monitoring and Evaluation Division (CMED) has oversight over the national HMIS and is responsible for producing quarterly and yearly comparative reports, for use by managers and other relevant stakeholders, at different levels of administration. Much as the description of data flows, thus far, paints a well streamlined structure, the situation on the ground is much more complex. There is a multiplicity of parallel reporting solutions, especially along vertical health programme lines (Kanjo et al., 2009). The HMIS landscape was even messier before 1999, during which the country kick-started the first comprehensive efforts to strengthen the national HMIS (Chaulagai et al., 2005).

In September 1999, Malawi began a process of strengthening its HMIS after realising: (i) a lack of reliable data, coupled with poor appreciation and use of available information in health services planning and management; (ii) absence of indicators to guide data analysis; (iii) fragmentation of information systems along vertical health programme lines; (iv) poor access to centralised data, for geographically distributed stakeholders (Chaulagai et al., 2005). A comprehensive review of the national HMIS setup was, then, undertaken, between 1999 and 2002, with funding from the Dutch and the Malawi governments:

“Between 1999-2002- this was the period we had a Dutch supported project, the good thing about this project [is that] it wasn't a project on its own. It was implemented within [the] government set up. Not all project staffs were paid by the Dutch, but were using existing structures through government. It was one way of building sustainability” (manager at CMED)

The efforts were mainly focused on putting in place necessary building blocks for the national HMIS. The efforts led to the development of an indicator handbook, data collection tools, training manuals for health workers and managers, and a national health information systems policy and implementation strategy. Furthermore, a digital HMIS solution, DHIS 1.3 was implemented in January 2002, to aid routine health data storage, analysis, and presentation at district and nation level. For the first time in Malawi, the health sector had information by facility by month (Chaulagai et al., 2005). The Dutch funded project phased out in 2003.

Between 2002 and 2003 efforts were undertaken to secure support from other donors. At least nine other donor groups supported this wave of HMIS strengthening, including: “the UK

Department for International Development (DFID), United Nations Population Fund (UNFPA), United Nations Children's Fund (UNICEF), US Agency for International Development (USAID), Norwegian Agency for Development Cooperation (NORAD), Japan International Cooperation Agency (JICA), European Union (EU), World Bank, Canadian International Development Agency (CIDA), World Health Organization (WHO) “ (Chaulagai et al., 2005: pp. 377). Within the same period, 2002 to 2003, the Malawi government, with support from various donors, was also designing a sector wide approach (SWAp) to strengthening health service delivery and monitoring in Malawi. The idea behind SWAp was to harmonize donor support by channelling funds through a common basket. SWAp was rolled out in 2004 and had resources allocated for HMIS strengthening. Nonetheless, allocated resources for HMIS support were deemed inadequate, which resulted in the government approaching the World Bank for additional resources targeted at HMIS strengthening:

“In 2006 there was a World Bank project, called Malaria Booster project. HIMS needed additional resources to strengthen it, so there was an additional resource worthy \$5 million” (manager at CMED)

Under the World Bank supplementary Malaria Booster project the Ministry of Health introduced quarterly management meetings and annual performance review meetings at all levels of administration, from health facilities up to the Ministry of Health headquarters. However, due to time and administrative constraints the ministry was unable to utilize all the allocated \$5 million, by the time this project phased out in 2008. After the project phased out it became difficult to adequately fund the review meetings: “activities at zone level and district level are there, but when it comes to funding, it is not enough” (manager at CMED).

Between 2005 and 2008 the Ministry of Health's HMIS efforts also received support from a multi-national Building Europe Africa collaborative Network for applying ICT in Health care Sector (BEANISH) project. In Malawi, BEANISH was a partnership between the Health Information Systems Programme (HISP), based at the University of Oslo, and the College of Medicine, a constituent college of the University of Malawi. BEANISH contributed to the development of IT expertise that would prove vital for the next wave of HMIS strengthening in Malawi that commenced in 2009, which I discuss in the next subsection.

Over the years various donors have come to the aid of the Ministry of Health, by funding data reviews and other operations in districts where they operate. Even so, available support has often been inadequate to sustain gains registered as part of the efforts that started in 1999 (see:

Kanjo et al., 2009; Galimoto, 2007). For example, despite active efforts to foster collaboration amongst stakeholders, parallel vertical programme-specific information systems still persist (Kanjo et al., 2009; Galimoto, 2007). In addition, until the end of 2012, the Ministry of Health lacked IT expertise to manage implemented HMIS solutions. Existing health information systems policy documents and guidelines had also become dated and therefore inadequate to guide ongoing HMIS strengthening efforts, including utilisation of emerging technologies, in areas such mHealth. Health facilities also hardly received feedback from district health offices, on submitted reports. In addition, the use of DHIS 1.3, a desktop system, as the national HMIS software solution, had over the years made decentralisation of data access challenging. A new wave of HMIS strengthening efforts commenced in 2009.

3.5 A Shift from DHIS 1.3 to DHIS2: Period 2009 to 2014

In 2009, the Ministry of Health, through the Central Monitoring and Evaluation Division (CMED) and with funding from HISP Oslo, began efforts to upgrade the national HMIS software solution. This wave of HMIS efforts was intent on aligning the national HMIS setup to objectives of the efforts that began in 1999. Key processes included: (i) replacing DHIS 1.3, with DHIS2, an Internet server-based solution; (ii) pursuing integration of parallel health information systems, with DHIS2 as the overarching national health data warehouse; (iii) decentralizing access to routine health data across administrative levels; and (iv) building IT capacity to enhance end-user support and maintenance of existing solutions.

At this time, CMED did not have necessary IT capacity to support the shift from DHIS 1.3 to DHIS2. Consequently, a team of three IT experts (henceforth referred to as DHIS2 coordinators) was constituted, to provide required technical support. The team's leader had previously been part of the afore-mentioned BEANISH project. Between 2009 and the end of 2012 the DHIS2 coordinators were mainly resident in Blantyre, a city at least 300km from Lilongwe, Malawi's capital, where CMED was located. They operated from the Malawi College of Medicine, where the national DHIS2 server was also hosted. Principal responsibilities of the DHIS2 coordinators included setup and management of national DHIS2 server instances; facilitation of discussions amongst stakeholders, such as vertical health programme managers, regarding report forms to be included in DHIS2. The DHIS2 coordinators were also responsible for the facilitation of DHIS2 trainings across all districts in Malawi; upgrading local area networks at district health offices; and end-user support.

Between 2009 and mid-2012, progress on the efforts to migrate from DHIS 1.3 to DHIS2 remained slow, mainly due to financial and logistical difficulties. At first, there was a plan to run six DHIS2 pilots across six districts, but only two were ever run, in 2010. The pilot strategy was to have local DHIS2 servers at district level that would synchronise with the online national server. I followed one DHIS2 pilot in Lilongwe district, which collapsed after no more than six months. When the local DHIS2 server installation crashed, technical support was not immediately available to rectify the problem. It proved difficult to facilitate travel for the DHIS2 coordinators, who were based in a city 300km away, due to prevailing fuel shortages across the country. This was after the country had fallen out with key donors and donor aid had been withdrawn.

3.6 A New Lease of Life for the National DHIS 2 Scale-up Efforts (2012 -2013)

Between 2009 and the first half of 2012 CMED was involved in negotiations with various donors, for possible financing of the migration to DHIS2. The negotiations resulted in financial commitments from donors, including: UNICEF, UNFPA, and USAID. A challenge that emerged from this process was that donors were only committed to supporting operations in districts where they had on-going operations. A direct consequence of this was that certain districts had the support of multiple donors when others had no support at all. In 2012, HISP Oslo indicated that it had funds available to support districts which were yet to secure funding. However, this funding was only available between July and December 2012, in line with financial requirements from their funders. This meant implementation activities funded by HISP Oslo had to progress quickly, in line with the duration of the available funding.

Midway through 2012 funding and logistical arrangements for the migration were in place. Following this, trainings for assistant statisticians, responsible for HMIS at district level, were arranged. Upon completing their training, the assistant statisticians were to act as DHIS2 trainers at district level, with support from the DHIS2 coordinators. Training for this group was conducted at the beginning of August 2012. This was, then, followed by a series of trainings at district level, which run until January 2013. Trainings at district level mainly targeted programme coordinators. From January 2013, CMED prioritized strengthening of local area networks and Internet connectivity at district level, to enhance utilisation of the online national DHIS2 server solution. Mobile Internet modems were purchased to provide district health offices with reliable Internet connectivity. Efforts were also on-going to migrate

data from parallel programme-centred legacy systems to the national DHIS2 solution. The DHIS2 coordinators were an invaluable part of these efforts.

3.7 Employment Arrangements for DHIS2 coordinators

Between 2009 and the end of 2012, salaries and operations of the DHIS2 coordinators were funded with support from HISP Oslo. The level of funding depended on HISP Oslo's ability to source necessary funding, which resulted in dry spells during which there was no funding to cover salaries for DHIS2 coordinators.

Between January and May 2013 funding to cover salaries for DHIS2 coordinators was intermittent, which significantly affected their availability to provide necessary technical support. This was a critical stabilization period for national DHIS2 implementation efforts, as indicated in the previous sub-section. Between May and December 2013 salaries for two DHIS2 coordinators were provided with support from the International Training and Education Center for Health (I-TECH). From January 2014 funding was made available under a cooperate agreement between the Ministry of Health and the Centers for Disease Control and Prevention (CDC), to engage the two coordinators until June of the same year. However, by this time one of them had left. CMED, therefore, sought to use the available funding to engage the remaining DHIS2 coordinator until the end of 2014.

The principal reason behind engaging staff on contract was a lack of established positions for IT experts within CMED. Although CMED was actively working towards establishing the positions there were concerns on whether DHIS coordinators could be maintained under the civil service pay structure: "when we create the positions we might not sustain them, because what they are getting now is equal to the salary of a Principal Secretary" (manager, 2014). Principal Secretaries are the highest ranking tenured government officers at ministry level.

In sum, the above-presented HMIS infrastructure development efforts, especially DHIS2 efforts and dependence on donor-funded projects, formed a basis upon which DHIS Mobile (DHISm) pilots were built. Developments around DHIS2 were particularly significant as DHISm was an extension of DHIS2 HMIS efforts.

3.8 DHIS Mobile Pilots in Lilongwe, Malawi

Between August 2011 and 2014, I was involved in the design, implementation, and management of DHIS Mobile (DHISm) pilots and scale-up. For the period 2011 and February 2014 the pilots covered 17 health facilities, across two health areas (Kabudula and Area 25),

under Lilongwe District Health Office. Kabudula had nine subordinate health facilities, all of which were rural based. On the other hand, Area 25 had a total of eight health facilities taking part in the pilots. Unlike Kabudula, Area 25 had a rural-urban blend in the distribution of health facilities. As stated in chapter 1, a key goal for the pilots was extending the reach of the digital HMIS, i.e. DHIS2, beyond the district level, through leveraging mobile technology solutions (see figure 3-4). It was envisaged that the use of mobile technology solutions would contribute towards alleviating challenges related to the transportation of paper forms. Two DHISm solutions, one Internet-browser-based and the other based on J2ME clients, installed on end-users phones were piloted, with one solution for each health area. The DHISm solutions were extended to an additional 29 public health facilities, within Lilongwe, between March and April 2014, thereby covering all public health facilities in the district.

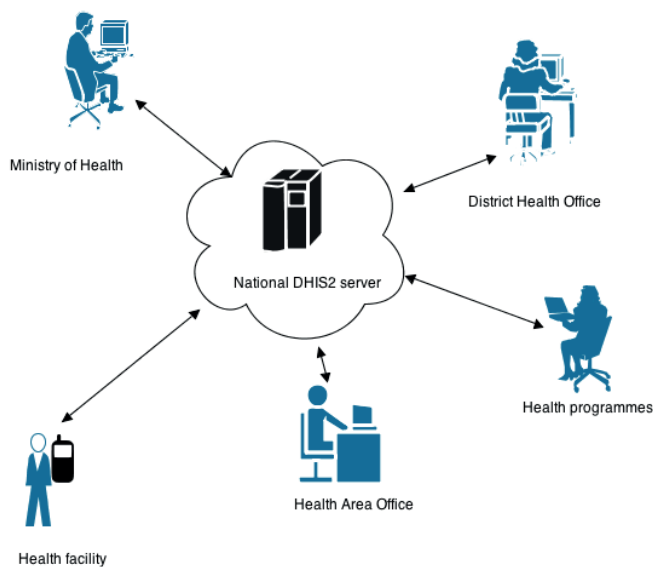


Figure 3-4: DHIS2 and DHISm setup

Design, implementation and running of DHISm pilots in Malawi involved different geographically distributed stakeholders, across organizational and national boundaries (see figure 3-5). The DHISm pilots were part of a larger action research mHealth project, MobiHealth, based at the University of Oslo, in Norway. MobiHealth provided the bulk of funding for DHISm pilots in Malawi, and also coordinated DHISm software development. DHISm software development was done by developers based in Norway and Vietnam. The DHISm implementation team in Malawi (henceforth referred to as DHISm implementers) comprised me and five other researchers. Of the five researchers, two were master students

from the University of Malawi, two were PhD students from the University of Oslo, and one was a PhD student from the Norwegian University of Science and Technology, but based at the University of Oslo. Key partners in Malawi included the Ministry of Health's Central Monitoring and Evaluation Division (CMED), Lilongwe District Health Office, the DHIS2 coordinators, participating health areas, together with subordinate health facilities, and a mobile service operator. Figure 3-5 depicts the spread key stakeholders to the DHISm pilots.

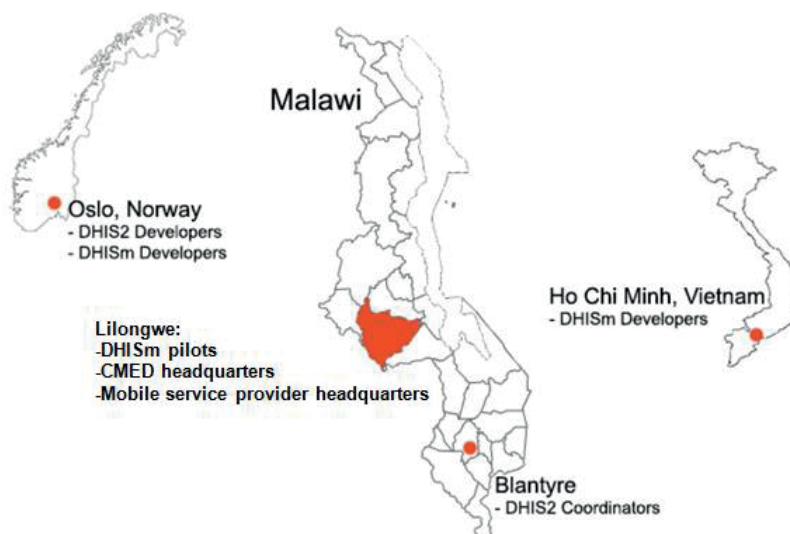


Figure 3-5: Geographical distribution of stakeholders in DHISm pilots

The main target user group for DHISm were statistical clerks, a cadre responsible for data management at health facility level. Where statistical clerks were not available, other members of staff serving a similar function, in most cases clinicians and health surveillance assistants, were given phones. The DHISm pilots started with supporting two report forms: HMIS-15 and Integrated Disease Surveillance and Response (IDSR) monthly report. HMIS-15 is a summary report covering health service delivery across different health programmes. The IDSR report covers data on epidemic prone diseases and diseases targeted for eradication. Support for IDSR was however discontinued within the first few months of piloting, due to a persistent software bug in DHISm that affected rendering of the form on mobile phones. The IDSR programme had also maintained a parallel reporting software solution. Support for IDSR was resumed between March and April 2014 after DHIS2 became the channel for IDRS data reporting. During the same period, DHISm coverage was also extended. A more detailed discussion on planning, roll-out, and changes to the DHISm pilots follows in the next chapter.

Chapter 4: Research Methodology

At an epistemological level, this study builds of the interpretive perspective, which regards knowledge as constructed, subjective, and contested (Walsham, 2006). Findings discussed herein are thus influenced by views of study participants; my experiences in interacting with various stakeholders, involved with HIS in Malawi and elsewhere; participation in various forums constituted to coordinate HIS infrastructure efforts in Malawi.

This study adopted a pluralist action research methodology (Chiasson et al., 2009), employing action research as the dominant strategy, supported by case study research (Walsham, 1995) and grounded theory (Glaser and Strauss, 1967; Glaser, 1978). Mingers (2001) advances five types of multi-method research design: *sequential* where approaches are employed in sequence, with results from one feeding into the other; *parallel* where approaches are carried out in parallel, with results feeding into each other; *dominant* where one research strategy is employed as the main approach, but is supplemented by others; *multi-methodology* which is a custom combination of approaches embodying different paradigms; *multilevel* where research is conducted simultaneously at different levels of an organization, using different approaches. Figure 4-1 depicts the pluralist action research design as employed in this study.

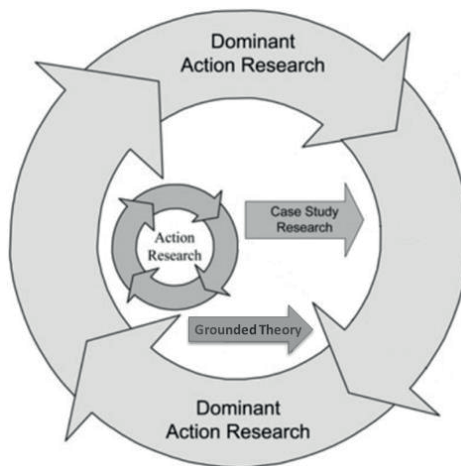


Figure 4-1: A dominant approach to pluralist action research – adapted from Chiasson et al. (2009)

Literature suggests that pluralist practices of mixing types, activities, and methods might be necessary, for the researcher to gain richer and more reliable results (Mingers, 2001;

Mathiassen, 2002; Chiasson et al., 2009). Research is not a discrete event, but rather a process with different phases and goals (design, intervention, and understanding) (Mathiassen, 2002; Vidgen and Braa, 1997), meaning different approaches may be more suited to parts of such (Mingers, 2001; Iversen et al., 2004; Mathiassen, 2002). For example, although reflection is a core tenet of action research, it is often unclear how the reflective process should be approached, and how theories are cyclically developed during the course of action research (Baskerville and Pries-Heje, 1999). Consequently, the practice of action research remains somewhat enigmatic, as there are relatively few exemplars available, and little direct guidance on how-to-do action research (McKay and Marshall, 2001).

In this study, the action research approach was adopted as studying application of mobile technology, to extend the reach of the national digital HMIS solution in Malawi, would not have been possible without the implementation of desired mobile technology solutions. At the time, the country had no mobile technology solutions in place, for routine health data reporting, within the national HMIS setup. Related to this, in adopting an action research approach, I was going to contribute towards addressing aforementioned logistical challenges that beset paper-based routine health data reporting. Adopting an action research approach was, therefore in line with my study objectives due to its dual imperative for research and real-world problem-solving (see: McKay and Marshall, 2001). In combining problem-solving and research, the approach enhances the practical relevance of information systems research within society, and provides a relevant platform for careful study of interventions, to contribute to knowledge (Davison et al., 2004; Baskerville and Myers, 2004). Such an involved approach to research also allows in-depth access to people, issues, and data (Walsham, 2006). In addition, the action research approach afforded me flexibility to explore emergent issues and opportunities in my research. Infrastructure innovation is subject to both planned action and emergent issues, which requires a methodological choice that accommodates exploration of emerging phenomena.

Although in the strictest sense the researcher is an observer in case study research, but an active participant in action research (De Vreede, 1995), extant literature suggests that the two approaches can be successfully combined (Chiasson et al., 2009; Mingers, 2001; Mathiassen, 2002). Since action research combines pure research (observing) with action (participation) (McKay and Marshall, 2001; Cavaye, 1996), it possible to apply case research as part of the evaluation/reflection, and specification of learning components within and action research cycle. Case research can be applied at various stages of knowledge construction, using various

methods (Cavaye, 1996). Action and case study research also share fundamental aspects, such as use of the case method: (i) studying a phenomena in its natural context; (ii) considering qualitative evidence as valid; (iii) studying phenomena at one or multiple sites; (iv) focusing on the questions “how?” and “why?”, although action research has an additional focus on “how to?” (Cavaye, 1996; Davison, 1998). In addition, both action and case research approaches are pluralist approaches that afford mixed research designs (Cavaye, 1996; Iversen et al., 2004; Mathiassen, 2002; Vidgen and Braa, 1997). Iversen and Mathiassen (2003) and Iversen et al. (2004) serve as examples of the application action and case study research within a dominant action research program.

Case study research and grounded theory were applied to foreground parts of the phenomena under study, in trying to examine and explain research questions that arose from the use of action research. For example, case study research was applied to aid reflection regarding the interplay between introduced mobile technology solutions, existing artefacts (paper, desktop computer solutions, etc.) and work practices, in a multi-stage undertaking such as data reporting (see: Manda and Herstad, 2015). Case studies afford investigation and description of relationships that exist in reality, thereby providing a platform for explaining phenomena and theory construction (Cavaye, 1996; Davison, 1998). Applied in this way, case study research was used to generate understanding of practice, thereby providing a platform upon which to base further action. At the end of my studies, case study research was also applied to take a summative look at the whole research processes focusing on continuing adjustment of technology and related organizational arrangements. Extant literature provides precedence in case studies of action research projects (Chiasson et al., 2009; Iversen and Mathiassen, 2003).

The grounded theory approach was mainly employed to systematically characterise day-to-day breakdowns within the mobile phone solution pilots under study; practical actions taken to resolve the breakdowns; and what breakdowns and required practical work revealed about the potential for long-term sustainability (Matavire and Manda, 2014). Grounded theory defines units of analysis, and ways of coding data, which may provide action research studies with a rigorous theory development technique (Baskerville and Pries-Heje, 1999). In addition, grounded theory units of analysis and coding afford integration with action research, across its process stages, in permitting alternation between data collection, analysis, theory building, and comparison with reality (ibid). In my case, application of grounded theory and case research helped with reflection, knowledge construction, and dissemination of knowledge

through foregrounding parts of the many activities and phenomena of possible interest, within the larger action research setup.

However, it should be noted that beyond the rationale presented above, the mixing of research approaches was in part pragmatic and opportunistic. Being involved in a project with three other PhD students, two of whom are co-authors for papers 2 (Matavire and Manda, 2014), 3 (Manda and Sanner, 2014), and 4 (Sanner et al., 2014), required a pragmatic balance between research goals and approaches, preferred by each individual. For example, during data collection and development of paper 2 (Matavire and Manda, 2014), our approach was more biased towards grounded theory as that was core to the first author's research approach. Nonetheless, the approach added to my repertoire of research skills. The disciplined approach to research also benefited later parts of my research (data collection, analysis). The case study research was, in part, a pragmatic choice for reflecting on and disseminating findings where the action research cycle was not going to be discussed in its entirety. Colleagues and reviewers often expressed reservations at labelling the methodology of a paper as action research, where the structuring of a paper did not explicitly discuss all stages of the action research cycle. Aside from such critique, it would have been counterproductive to bring on board the whole baggage of action research, where it was not going to inform the discussion of findings. Next, I discuss the DHISm action research component in detail.

4.1 Action Research Component in Detail

The action research process was shaped by interests to study implementation of DHISm in a context with existing HMIS socio-technical solutions, ongoing DHIS2 implementation, and complexities arising from the participation of multiple stakeholders (target users, managers, solution providers, donors, etc.). The research design was also influenced by an interest to study implications of technology and implementation design choices and potential for managing unintended outcomes, learning by doing, and scaling, i.e. extending the number of participating health facilities and reporting forms covered. Our team was also interested in studying possibilities and challenges for enhancing feedback on reported data, between health facilities and the district health office, and building implementation and maintenance related IT capacity across administrative levels.

4.1.1 Diagnosis, Action Planning and First Cycle of Action

Preparations for DHISm started in August 2011, but picked in September of the same year and extended until February and March 2012 when DHISm pilots were rolled out, in

Kabudula and Area 25 health areas, respectively. Between August and the end of October 2011, I was in Oslo, Norway, where detailed discussions on pilot design were held with colleagues from the MobiHealth project, at the University of Oslo, of which the DHISm pilots in Malawi were part. A comprehensive project level meeting was held in October 2011, covering issues such as: what phones to use for the pilots, where to buy the phones, what phenomena to focus on during the pilots, and design of data collection tools. Parallel to activities in Oslo, two master students, from the University of Malawi, who were part of the DHISm implementation team, were consulting with the Ministry of Health's Central Monitoring and Evaluation Division (CMED) and Lilongwe District Health Office (DHO). The idea was to engage CMED and Lilongwe DHO early on in the pilot efforts. The students were also tasked with profiling target health facilities to help our team understand: the state of existing infrastructure; data collection and persistence at health facility level; paper-based data reporting practices; and how Lilongwe DHO provided feedback to health facilities.

Consultations with CMED and Lilongwe DHO, as well as colleagues in Oslo continued between November and December 2011, when I was back in Malawi. During this period, focus was placed on finalizing the scope of the pilots, i.e. which health areas to cover first, and what report forms to support. During the same period, a post-paid mobile-subscription contract, for the DHISm pilots, was negotiated with one mobile service operator. A post-paid arrangement was preferred to ease the burden of subscription management as our team would only deal with the mobile service provider, who would in turn transfer airtime to end-users. Our team was also interested in mobile Internet data usage summaries, for research purposes. This facility was only available to post-paid customers. During the same period, our DHISm implementation team also conducted further visits to target health facilities, to document the afore-mentioned issues of interest. In continuing with preparations for DHISm pilots, twenty Nokia C2-00 phones were purchased from India. The choice to purchase phones from India was cost-related. The phones cost \$50 in India and \$85 in Malawi. The Nokia C2-00 was chosen due to its fit with what we required of a phone within its price category: (i) long battery life; (ii) support for General Packet Radio Service (GPRS); (iii) support for two SIM cards, to accommodate end-users' personal cards and those provided as part of the pilots.

In November 2011 a decision was reached, in consultation with MobiHealth, CMED, and Lilongwe DHO, to pilot DHISm in the aforementioned-mentioned two health areas (Kabudula and Area 25), starting with two report forms. Trainings and rollout for DHISm were scheduled for December 2011, but only one training session was conducted, under Kabudula

health area, after the Nokia C2-00 phones we had purchased did not work in Malawi. A new set of phones, Nokia C1-01, was purchased from Malawi and Norway, between January and February 2012. Another round of DHISm trainings and rollout followed in February 2012 (for Kabudula) and March 2012 (for Area 25). During the preparatory period for DHISm pilots our team also revised plans on what DHIS2 server to utilise for the pilots. The initial plan was to utilize the national DHIS2 production server, but a demonstration DHIS2 server was used instead, until June 2013. Despite CMED consenting to the use of the production server, as early as 2011, access was yet to be granted by DHIS2 coordinators.

4.1.2 Evaluations and Resulting Actions

After rollout, seven DHISm review meetings were held: two in May 2012, one in August 2012, two in January 2013, and two in December 2013. The review meeting in August 2012 was held as part of an international MobiHealth workshop in Vietnam. All other review meetings were held in individual health areas, in Malawi, in collaboration with participating health facilities. For the review meetings in Malawi, all participating health facilities were invited to meetings within their health area. The only exception was one review meeting for Area 25 health area, held in December 2013, where only two officers at health area level were present. Of the two, one was a statistical clerk and the other an Assistant Environmental Health Officer. The Assistant Environmental Health Officer was responsible for following up on all participating health facilities, under the Area 25 health area.

Review meetings provided an opportunity for end-users to tell their experiences and suggest changes to the pilots. The DHISm implementation team also used the review meetings as an avenue for providing end-users with feedback regarding data reporting and communicating planned changes. At the start of each review meeting, our team would outline the agenda for the meeting. After that, we would have a round where each participant would give an account of their experiences with DHISm. Thereafter, we would have open discussions on what had emerged as topics of great interest.

During review meetings held in January 2013, participants were informed of a planned change from the post-paid mobile subscription arrangement in use, to a pre-paid one, starting from February of the same year. During these meetings we provided participants in the DHISm pilots with new pre-paid SIM cards. The change in subscription arrangements was necessitated by sustained challenges we had experienced with the post-paid arrangement. Among other things: (i) end-user phone accounts were not getting consistently updated with

call credit, as per agreement with the mobile service provider. With the post-paid arrangement end-users could not top-up call credit by themselves; (ii) end-users were unable to resolve queries with the mobile service operator without our team's involvement, as I was the account manager; (iii) the mobile service operator was unable to cap voice calls, after end-users had exhausted an allocated monthly call credit, resulting in cost overruns on our part.

During the review meetings, we would also brainstorm on various issues of concern, such as who was to fund the replacement of phone batteries and what report forms had to be added to DHISm pilots. Such discussions led to the expansion of report forms supported under DHISm pilots, in June 2013. End-users had indicated that unless all available reports were supported, it would not be possible to do away with paper-based reporting. In the same month, DHISm pilots were also migrated from the demonstration server, used since inception of the pilots, to the national DHIS2 production server.

Apart from review meetings, observations, end-user support, ad-hoc meetings with participants in the pilots or other key stakeholders such as Lilongwe DHO, CMED, DHIS2 coordinators, and the mobile service operator we used for the pilots, acted as important points for reflection. For example, acknowledgement by the mobile service operator that they could not effectively cap voice calls under the post-paid mobile subscription arrangement, as was required, partly influenced the switch to a pre-paid arrangement.

4.1.3 DHISm Scale-up to all Public Health Facilities in Lilongwe

In the second half of 2013, our implementation team began to actively work on extending coverage of DHISm. Action planning for the scale-up included: brainstorming with MobiHealth team members in Oslo, regarding expansions of both the number of supported health facilities and report forms; purchase of 31 phones; and consultations with CMED and Lilongwe DHO, on the planned scale-up. These discussions also touched on possible transfer of financial responsibility for DHISm to Lilongwe DHO, starting from July 2014, to which the district health office agreed. Figures 4-2 and 4-3 show me and a colleague setting up a new set of phones for the DHISm scale-up. This was in November 2013, in Oslo, Norway.



Figure 4-2: Unpacking phones for DHISm scale-up



Figure 4-3: Testing phones for DHISm scale-up

DHISm solutions were extended to the whole of Lilongwe, between March and April 2014, covering an additional twenty nine health facilities. The number of supported routine data reports was also extended. CMED took a leading role in the scale-up process, together with a technical assistant, recruited under the DHISm pilots. Lilongwe DHO also took an active part in the DHISm scale-up, where they emphasised that health facilities were expected to use DHISm as a primary means for data reporting. Funding for this phase was provided by the MobiHealth project. The funding covered costs for the purchase of 31 Nokia Asha 206 phones from Norway, training, purchase of Internet dongles for health area offices, monthly call credit subsidies for participating health facilities, and end-user support. As of April 2014, DHISm had been extended to all public primary health facilities in Lilongwe district. Figure 4-4 depicts a timeline of Key events under the DHISm pilots.

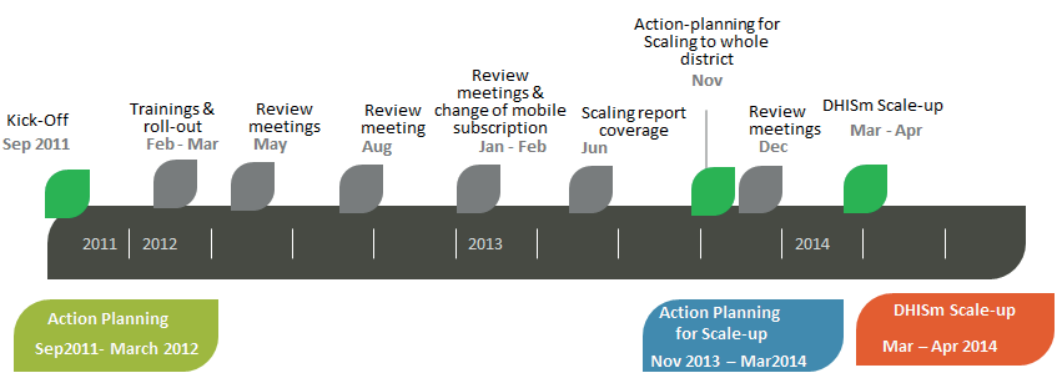


Figure 4-4: a timeline of key events under the DHISm pilots

4.2 Data Collection

Data for the study were mainly collected between September 2011 and April 2014. During this period, a total of 524 days were spent in Malawi (see table 4-1).

Table 4-1: Days spent in Malawi

Period	Number of days
1 st January 2011 - 23 rd April 2011	113
2 nd November 2011 - 21 st November 2011	19
27 th November 2011 - 22 nd May 2012	178
31 st May 2012 - 28 th June 2012	29
16 th September 2012 – 24 th January 2013	131
1 st December 2013 – 23 rd January 2014	54
Total number of days	524

Fieldwork in Malawi was for the most part interleaved with stays in Oslo, Norway, and travel for conferences and other personal and professional engagements, to a lesser extent. Whilst away from Malawi, I maintained contact with the health areas participating in the DHISm pilots. I also maintained contact with key informants at Lilongwe DHO and CMED. Data were, therefore, collected when I was in and out of Malawi.

A combination of techniques and data sources were utilised in collecting data for this study. Data were collected using interviews, focus group discussions, observations, SMS collaborations with end-users, meetings with management at district level, consultations with CMED, meetings with staff from the mobile service operator, and document reviews. Interviews and focus group discussions were audio-recorded, where informants had consented to this. I also maintained journals for data persistence and to record reflections on my work.

Informants included users of DHISm and other personnel working at health facility level, across the first seventeen health facilities that were part of DHISm pilots, before the scale-up efforts; assistant statisticians (HMIS officers) at district and national level; management at Lilongwe DHO; management at CMED; DHIS2 coordinators. DHISm users and other informants at health facility level included: statistical clerks, health surveillance assistants, nurses, clinicians, and environmental health officers. Table 4-2 presents a summary of informants in the study.

Table 4-2: Informants in Malawi

Informant(s)	Organization (level)	Key responsibilities
Deputy Director	MoH Headquarters (CMED)	Overseeing the HMIS function
Managers at district level	Lilongwe District Health Office	Overseeing operations at district level
managers and other focal personnel at health area level	Kabudula and Area 25 health areas	overseeing operations at health area level; following up on health facilities in DHISm pilots
Assistant statistician	MoH Headquarters (CMED)	HMIS at national level
Assistant statisticians	Lilongwe District Health Office	HMIS at district level
HMIS focal persons at health facility level	health facilities	Health service delivery HMIS at sub-district level
DHIS2 Coordinators	University of Malawi's College of Medicine/CMED	Coordinating national DHIS2 implementation
Technical Assistant responsible for DHISm pilots	MoH Headquarters (CMED)	Coordinating DHISm pilots and end-user support; engaging with other stakeholders
HIS researchers	University of Malawi, University of Oslo	HIS research; providing technical advice to CMED on HIS implementation

The informants were involved to varying degrees over the course of this study.

4.2.1 Interviews

A total of 35 interviews (see table 4-3) were conducted as part of the study, with some informants being interviewed multiple times. Interviews were predominantly conducted at informants' duty stations, such as offices and health facilities. Interviews were also conducted on the side-lines of events such as trainings and workshops. Occasionally, I also interviewed people over the phone, especially when away from Malawi.

Table 4-3: a summary of interviews

Year	2011	2012	2013	2014
Number of interviews	10	13	6	6

The interviews covered a wide range of topics including: state of existing infrastructures; data reporting practices; feedback on reported data, between health facilities and the local district health office; implementation plans and progress on DHIS2 and DHISm; arrangements for end-user support; and end-user experiences, for both DHISm and DHIS2. Interviews conducted in 2011 and the first quarter of 2012 mainly fed into the planning phase for DHISm

pilots. Other topics of interest included: state of existing technologies, such as water supply systems, motorcycle ambulances, and radio message systems used to coordinate patient referrals. Between the second quarter of 2012 and April 2013 focus was mostly placed on following progress on DHIS2 and DHISm implementation efforts, from the perspective of DHIS2 coordinators, CMED, Lilongwe DHO, and participating health areas. Interviews were also used to gather end-user experiences and innovations to cope with challenges they faced.

4.2.2 Focus Group Discussions

A total of fourteen focus group discussions were conducted as part of this study. Three focus group discussions were conducted as part of three DHISm trainings, between December 2011 and March 2012. Six focus group discussions were conducted as part of DHISm review meetings held in May 2012, August 2012, January 2013, and December 2013. Two focus group discussions were also conducted with personnel working at health facility and community level. The two focus group discussions were mostly focused on the organization of service delivery at health facility and community levels; data collection and reporting practices; availability of resources such as stationery; challenges faced by personnel in going about their work. One focus group discussion was held as part of a DHIS2 training workshop in Mchinji, a district to the West of Lilongwe, where DHISm pilots were running. I attended the DHIS2 training in Mchinji to experience DHIS2 implementation issues, such as capacity building, setup at district level, and paper-based data reporting practices, in a different district. The goal was investigate whether challenges observed in Lilongwe were evident elsewhere. In December 2013, I facilitated two focus group discussions focusing on implementation strategies and opportunities and challenges of partnerships between government and non-governmental organizations. The focus group discussions were held as part of an international DHIS2 training academy held in Malawi. A range of participants from both ministries of health and non-governmental organizations from seven countries (Haiti, Ethiopia, Kenya, Malawi, Rwanda, Uganda, and Zambia) took part in the discussions. Figures 4-5 through 4-7 show participants to some of the focus group discussions and training sessions mentioned here.



Figure 4-5: DHISm review area 25 - 2013



Figure 4-6: Meeting HSAs at Ukwe health centre



Figure 4-7: DHIS2 workshop - Mchinji district health office, November 2011

4.2.3 Observations

Observations also formed an important part of this study, allowing me to document: work practices; road conditions and transportation challenges in rural areas; resource disparities across health facilities; technology implementation and innovation; disintegration of legacy technologies; and a multiplicity of non-governmental organizations carrying out interventions. Figures 4-8 through 4-11 depict health workers readying their bicycles, the most common means for transportation in rural areas; an existing radio message system once used for coordinating patient referrals; a pole that once supported fixed telephone lines; and a waterlogged unpaved road. Figures 4-12 through 4-15 capture: (i) technology innovation in the form of an electronic medical records (EMR) system and solar panels; (ii) technology breakdown and disintegration - a broken down motorcycle ambulance and water supply infrastructure; (iii) technology change: replacement of the broken down borehole pump.



Figure 4-8: Bicycles - a common means for transportation in rural areas



Figure 4-9: Radio message system for previously coordinating patient referrals



Figure 4-10: Pole with cut fixed phone lines



Figure 4-11: Waterlogged unpaved road -rainy season, March 2012



Figure 4-12: A researcher and a health worker working on an EMR solution



Figure 4-13: Broken-down motorcycle ambulance and solar panels for EMR systems



Figure 4-14: A broken down water supply system



Figure 4-15: A new borehole pump to replace the one in figure 4-14

The health facility captured in figures 4-12 through 4-15 is illustrative of the multiplicity of technologies and stakeholder groups present at health facility level. The health facility was taking part in two separate pilots, DHISm and another pilot on the above-depicted EMR system. The EMR pilot was part of a collaborative effort between the University of Oslo and Baobab Health Trust, a local non-governmental organization specializing in EMR systems development and implementation. The motorcycle ambulance was provided by a different set of donors. Replacement of the broken down water pump (figures 4-14 and 4-15) was the work of yet another non-governmental organization. An interesting development with the water supply system at the health facility captured above is that the non-governmental organization that replaced the faulty borehole pump did not consider the broken water pipe and water tank. There were also no clear plans regarding long-term maintenance of the new borehole pump. Nonetheless, the health facility was pleased to have a working borehole pump.

4.2.4 mHealth Malawi Forum meetings and International DHIS2 workshops

Participation in international DHIS2 workshops provided me with opportunities to take part in wider discourse on DHIS2 and DHISm implementation efforts. Over the course of this study, I participated in five international DHIS2 workshops and two release meetings.

In addition to DHIS2 and DHISm workshops, stakeholder consultative meetings in Malawi, under the umbrella of mHealth Malawi forum afforded me an opportunity to observe and contribute to discourse aimed at shaping the mHealth landscape in Malawi. The mHealth Malawi forum is a grouping of different non-governmental organizations doing mHealth in Malawi, in partnership with CMED, which co-chairs the forum. Among other things, the

grouping was formed to foster collaboration between stakeholders, map the mHealth landscape in Malawi, and draw-up guidelines for future mHealth initiatives. Over the duration of this study I participated in two mHealth Malawi forum meetings. Being a member of the group, I also had access to minutes from meetings I was not been part of, and various other documents authored by the group, such as research agenda and a concept note on possible engagement with mobile service providers.

4.2.5 Document Reviews

Various documents (scientific publications, policy documents, reports, etc.) were reviewed to get a broader picture of contemporary and historical HMIS efforts in Malawi (see table 4-4).

Table 4-4: Key documents reviewed

DHIS 2 Quarterly Supervision Report – October (MoH, 2013a)
Health Information Systems Strategic Plan 2011 – 2016 (MoH, 2013b)
Situation Analysis of the Ministry of Health's Central monitoring and Evaluation Department in Malawi (Bhana, 2013)
Minutes of from mHealth Malawi forum meetings
Feasibility and Acceptability of DHIS2 Mobile M&E App: A Field Assessment in Nsanje, Malawi (Pérez and Munyenyembe, 2013)
Health Information Systems Assessment Report: Malawi (Republic of Malawi and Health Metrics Network, 2009)
Health Information System National Policy and Strategy (MoH, 2003b)
Development of the Health Management Information System in Malawi 1999 - 2003: Overview of Achievements and the Way Forward (MoH, 2003a)
Integration of Health Information Systems: Case Study from Malawi (Galimoto, 2007)
Towards Harmonisation of Health Information Systems in Malawi: Challenges and Prospects (Kanjor et al., 2009)
The Malawi National eHealth Strategy 2011 – 2016 - version 5 (MoH, 2014)
Monthly progress reports authored by a technical assistant employed under DHISm

Reviewed documentation covers HMIS *efforts* and *plans* for the period 1999 to 2016.

4.3 Data Analysis

The thesis draws upon the five papers included herein, in line with the research questions and objectives outlined in chapter 1. My approach to data analysis is predominantly abductive (Dubois and Gadde, 2002), drawing on both theory and practice. The evolution of my theoretical ideas has also benefited from numerous exchanges with colleagues, supervisors, and reviewers.

Data analysis for this research is based on the premise that developing digital infrastructure entails negotiating tensions that arise from competing concerns to design, implementation, use, and maintenance, which span multiple temporal scales (Pipek and Wulf, 2009; Pollock and Williams, 2010; Edwards et al., 2007). Although tensions manifest in different ways through scales of infrastructure: enacting technology, organizing work, institutionalizing (Ribes and Finholt, 2009), my analysis of empirical material is largely anchored as a temporal tension – short-term (project time) vs long-term (infrastructure time). This choice is driven by: (i) observation of practices on the ground; (ii) experiences from DHISm pilots, where our team grappled with the exigencies of technology implementation and efforts to enhance prospects for institutionalization and maintenance of the solutions beyond our involvement; (iii) extant literature on digital infrastructures, where the spread of concerns across temporal scales is recognized as a temporal tension (Kee and Browning, 2010; Ribes and Finholt, 2007; Edwards et al., 2007).

As stated in the problem statement (see section 1.3), and presentation on HMIS interventions covering the period 1999 to 2014 (sections 3.4 to 3.7), interventions in Malawi are dependent on discretely organized donor funded projects. In part, this has negatively affected collaboration in the short-term and continuity of efforts beyond initiating donor funded projects. As mentioned earlier, persistent lack of IT capacity and continued weakening of HMIS strengthening initiatives over time suggest a predominance of short-term project time thinking and inclination towards continuous development of technological solutions, rather than consideration of how short-term projects can provide impetus for long-term HIS infrastructure efforts. During the course of this study, The Ministry of Health expressed concerns for continuity beyond individual projects, and sought to institutionalize collaboration across projects, to develop persistent digital health infrastructure. At the same time, some projects prioritized own short-term project-centric interests, to suit reporting requirements from external funders. Others were only interested in demonstrating the feasibility of technological solution, making it clear that they would not support long-term maintenance. These developments form the basis for my interest in the short-term vs long-term temporal tension. Short-term experiences of gain and loss shape the climate within which infrastructures struggle to emerge (Edwards et al., 2007).

The long now perspective (Ribes and Finholt, 2009) serves as an overarching organizing lens, where empirical material is analysed in line with the scales of infrastructure: enacting technology, organizing work, and institutionalizing. Analysis of empirical material through

these scales aids reflection on efforts in line with introduction of DHISm solutions and trying to promote their institutionalization and continuity. Beyond DHISm, the long now perspective acts as a sensitizing lens, in my analysis of historical HIS interventions in Malawi.

Enacting technology is a broad term, but my interests in regard to enacting technology are operationalised through the following concerns that are of central interest to this study: (i) *technology and implementation design*; (ii) *growing demand-side adoption*, to achieve growth momentum; (iii) *negotiating control to parts of the installed base*, to influence infrastructure development trajectories (*supply-side control*); (iv) related *practical work in attempting to integrate novel solutions in an existing installed base*. In doing this, focus was placed on: implementation work around DHISm and DHIS2; existing socio-technical setup (artefacts in use and data reporting practices); technology use; breakdowns and their nature; end-user and organizational IT capacity.

In regard to institutionalizing, focus has been on efforts to institutionalize ongoing collaboration and implemented technologies, as well as concerns for long-term maintenance and continuity. Factors under consideration include: presence/absence and significance of control mechanisms for guiding stakeholder participation, and conditions that contribute to poor development of IT capacity for maintenance of technological solutions. Regarding the latter, I focused on how weak public administration and bureaucracy, coupled with the temporary nature of project support arrangements, impact development of IT capacity. At the next level, I, then, attempted to synthesise strategies on how to leverage short-term project arrangements and persistent, but slow and bureaucratic government structures in developing IT capacity (*in response to research question 2*). Formulation of suggested strategies has benefitted from the *long now* (Ribes and Finholt, 2009) and continuing design *-infrastructure time thinking* perspectives (Karasti et al., 2010), which prompt long-term focus.

It is worth mentioning that the scales: enacting technology, organizing work, and institutionalizing are not mutually exclusive, but overlap. In this regard, the scale *organizing work* mainly plays out as a consideration of *how* enacting technology and attempts at institutionalizing technological solutions and digital infrastructure efforts progress. Issues of focus include: decisions and actions taken - pre-planned or emergent; structures for providing end-user support; mobilization and organization of independent stakeholders – centralized vs bottom-up strategies; organization of development and maintenance activities.

Together with the long now perspective (Ribes and Finholt, 2009), the following perspectives were drawn upon quite significantly in the analysis of empirical material: continuing design (Karasti et al., 2010); bootstrapping (Hanseth and Lyytinen, 2010; Hanseth and Aanestad, 2001); grafting (Sanner et al., 2014). Bootstrapping was adopted early on in the research process and informed formulation and evaluation of implementation design, attempts at integrating DHISm into the existing HIS installed base, attempts at trying to mobilize demand-side adoption, and complexities of working in a context with multiple independent stakeholders (Manda and Sanner, 2014). Continuing design was adopted later in the study to strengthen the temporal considerations offered by the long now perspective, as well as explication of attempts at negotiating observed tensions. The grafting perspective (Sanner et al., 2014) grew out of this study and has been applied to sensitize discussions regarding *negotiation of control to parts of the installed base*, by multiple independent stakeholders, seeking to influence infrastructure development trajectories.

In the end (responding to research question 3), I try to highlight limitations in individual perspectives and how we may attain better conceptual analysis, of observed phenomena, by combining the theoretical perspectives I draw upon. In responding to question 3, I also propose an extension to the long now perspective, an undertaking that is informed by both theory and practice. Firstly, data were analysed based on scales of infrastructure work and concerns for sustainability advanced by Ribes and Finholt (2009). Second, analysis of empirical material identified *developing IT capacity* as a key concern for sustainability, which needed to be added to the long now perspective. A more thorough treatment of this subject follows in the findings and discussion chapters.

4.4 Reflections on the Research Design, Process and Challenges Faced

Initially, the plan for DHISm pilots was to cover all primary health facilities in the participating district, Lilongwe, right from the start. However, implementation plans were revised, favouring an incremental approach, to enhance learning by doing and to minimize the impact of possible unintended outcomes, from the introduction of DHISm. Revision of implementation plans was informed by bootstrapping strategy, which advocates for a judicial approach to implementation (Hanseth and Lyytinen, 2010).

After the revision of implementation plans, it was envisaged that scaling of DHISm solutions, to all health facilities in Lilongwe, would be completed midway through 2012, to enhance prospects for institutionalization. Literature suggests that scaling is critical to

institutionalization of novel solutions (Sanner et al., 2012; Braa et al., 2004). However, as aforementioned (see section 4.1.3), we were only able to scale the solutions between March and April 2014. Attempts at stabilizing DHISm across the first 17 health facilities took longer than expected. There were also challenges in securing funding for the scale-up efforts. In addition, slow progress in DHIS2 implementation efforts affected relevance of DHISm. Since DHISm was building on DHIS2 implementation efforts, it was never going to gain wider acceptance without DHIS2 stabilizing.

As a consequence of delays in scaling the DHISm solutions, I was unable to reflect on the dynamics surrounding the scale-up process in this thesis, as was initially intended. At the time scaling of DHISm solutions picked, I was drawing towards the end of my study program. The DHISm scale-up process has given rise to new partnerships and central players beyond our pilot project. At the time of writing the thesis, time was also ripe to replace the initial set of mobile phones used in the DHISm pilots. Such developments would have added depth to theorizing of institutionalizing, maintenance and possible continuity of DHISm efforts beyond the initiating project-based arrangement. These developments will be discussed as part of future research.

Bounding of the research scope was also influenced by fragmentation of health information solutions on the ground, along program lines. As aforementioned (see section 3.8), we initially supported reporting for the Integrated Disease Surveillance Programme (IDSR), but withdrew the support, partly because the IDSR programme had maintained a parallel software solution. Efforts regarding DHISm support for IDSR, are not discussed further in this thesis.

Our team's interest in studying possibilities and challenges for enhancing feedback on reported data, between health facilities and the district health office, did not progress beyond documentation of challenges in existing feedback structures. This was mainly due to prioritization of limited available human resources toward stabilizing DHISm and supporting DHIS2 implementation efforts. Two colleagues from Malawi are now looking into issues regarding feedback, one for his PhD studies, and the other as part of his MSc. Informatics research component.

Beyond the aforementioned challenges, action research can be full of action that at times threatens to derail the research component. Malawi experienced heavy fuel shortages between 2011 and 2012, a critical period in DHISm and DHIS2 implementation efforts. During this period I, together with my colleagues in DHISm pilot efforts, spent a considerable amount of

our time fuel hunting, just so we could make field trips. At times we spent entire days, and parts of some nights, hunting for fuel. It was also challenging to hold face-to-face meetings with key stakeholders to DHISm and DHIS2 efforts, such as DHIS2 coordinators, who were resident in a city 300 km away. Sometimes, face-to-face meeting were necessary to iron out sticky issues. Figures 4-16 and 4-17 show some fuel queues from December 2011, when we were making preparations to roll-out DHISm pilots.



Figure 4-16: Fuel queues, December 2011 Figure 4-17: Fuel queues, December 2011

Despite the obvious challenges, there were positives to be found in this otherwise unpleasant experience. The time we spent in fuel queues provided me and my colleagues with an opportunity to discuss and reflect on empirical material we had gathered, as well as actions we had taken as part of DHISm and DHIS2 efforts. Thus, fuel queues provided an unexpected avenue for initial data analysis and theorizing.

4.5 Reflections on my Involvement with DHISm and DHIS2 in Malawi

During the study, I assumed multiple roles, which came with different opportunities, competing priorities and expectations from various stakeholders I interacted with. Key roles I assumed include: being the project lead for DHISm, action-researcher, and PhD student.

Acting as a project lead and action-researcher opened doors for me to access key stakeholders and influence DHISm-related activities. For example, acting as the project lead afforded me participation in negotiations on pilot design, implementation, management, and evaluation. As the project lead, I was also responsible for: recruitment of two Malawian master students who were involved with DHISm; making arrangements for accommodation, visas (where necessary), and transportation for my colleagues based at the University of Oslo, during their field visits to Malawi. Other key responsibilities were: securing ethical clearance for our research; purchase of phones used in the pilots; and managing the post-paid mobile subscription account for DHISm. Responsibilities associated with managing the post-paid account comprised: settling bills, replacing failed SIM cards, and following up on end-user

queries. Finally, I was involved in the recruitment of an IT expert (technical assistant) to support DHISm and DHIS2 efforts in Malawi. The recruitment was done in consultation with the Ministry of Health's Central Monitoring and Evaluation Division (CMED), with funding from the MobiHealth. During this process, I was mainly responsible for negotiating funding with MobiHealth and drawing up terms of reference for engaging the IT expert.

As an action researcher, I participated in DHISm and DHIS2 collaborative spaces (workshops, mHealth Malawi forum, etc.), all of which have gone a long way in informing this study, beyond views provided by informants. I was also involved in development of DHISm training materials, facilitation of DHISm trainings and review meetings, end-user support, and training participating health area offices on DHIS2. Together with a colleague based at the University of Oslo we provided basic DHIS2 training to Kabudula health area, in March 2012 (see figures 4-18 and 4-19). The trainings concentrated on data entry and generation of reporting rate summaries. During the visit to Kabudula, we also assisted the health area office with anti-virus software and computer virus cleaning.

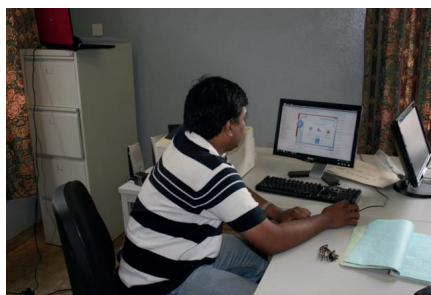


Figure 4-18: Installing anti-virus software at Kabudula health area office



Figure 4-19: Basic DHIS2 training at Kabudula

At the time, we could not provide similar training to the Area 25 health area office, as their computer had been taken to the district health office for virus cleaning. Getting the health areas more involved in DHISm was considered vital, as they had jurisdiction over health facilities taking part in the DHISm pilots.

In regard to the national DHIS2 implementation, my involvement was emergent and less formalised. Nonetheless, I was involved in providing technical advice to CMED, planning and review of implementation efforts, negotiating funding with HISP Oslo, drawing up terms of reference for DHIS2 coordinators, and supporting Lilongwe DHO. In 2012, I collaborated with CMED and DHIS2 coordinators in exporting legacy data from DHIS 1.3 to DHIS2. This

was done to facilitate Lilongwe DHO's migration from DHIS 1.3 to DHIS2. Over the course of the DHISm pilots, I was also responsible for facilitating mobile Internet subscription for the assistant statistician responsible for the HMIS function at Lilongwe DHO. This support was ad-hoc and meant to cover occasional delays in renewal of subscription, under an ongoing arrangement supported by a different donor

As aforementioned, the roles I assumed came with different competing expectations, from various stakeholders I interacted with. For example, being an action-researcher, student, and project lead meant I had to divide my time between managing day-to-day implementation activities (users support, addressing breakdowns, etc.) with writing research papers, attending research conferences, and attending courses in Oslo, Norway. Balancing coursework and implementation-related activities was quite challenging, especially during the first part of the DHISm pilots, when the pilots were mainly supported by me and fellow graduate students. During this phase, it was particularly challenging to provide timely end-user support, when our team was back in school. Delays in providing support were frustrating to users, which pushed our team to work hard towards engagement of the aforementioned IT expert, who was to support DHISm and DHIS2 implementations.

In acting as a project lead there were expectations from the MobiHealth project that I would have profound influence on the DHISm pilots in Malawi. However, at times it was challenging to influence aspects of participants' work, such as collaboration and timeliness in data reporting. Routine data reporting is an age-old institutional process with set governance procedures. All the same, encountered challenges were in part addressed through constant engagement with health facilities and aforementioned collaboration with relevant authorities, such health area offices, Lilongwe DHO and CMED.

4.6 Study Limitations

Action research requires a delicate balance between deep engagement in an ongoing intervention and maintaining critical distance from one's actions, in order to evaluate one's immersion, involvement, an influence on unfolding phenomena. At certain points in time, especially during the first year of piloting, the practicalities of trying to make implemented DHISm solutions work, made it challenging to maintain critical distance from the work I was involved in. In addition, I have conducted first person action research, which involves research self-reporting. Self-reporting is at risk of over-modesty and self-praise (Walsham,

1995). These challenges were in part mitigated through working in a collaborative research project.

At times, familiarity with the context of study made certain occurrences too familiar and obvious to be considered relevant empirical material. For example, on the day of the first training session for DHISm, there was a power blackout at the health facility where we were supposed to conduct the training. Furthermore, mobile connectivity within the area was down, because the generator powering the tower/mast, for the mobile operator we had subscribed to, had run out of diesel. This was not too surprising an occurrence for me, until my colleagues who were not from Malawi expressed their surprise. It is only after my colleagues' expression of surprise that I began to consider such occurrences as possible material to inform discussions of breakdowns affecting DHISm. Having 'fresh sets of eyes', from outside Malawi, helped in pointing out relevant events that I would have otherwise passed on. It is therefore possible that I have not considered other relevant, but seemingly familiar and trivial occurrences that could have further informed this study.

Empirical material gathered as part of the DHISm and DHIS2 interventions in Malawi could also be analysed from multiple other perspectives than those presented in this thesis. This limitation is in part addressed through collaborative work with colleagues, which is not part of this thesis (see: Purkayastha et al., 2013). In addition, DHISm and DHIS2 developments contribute towards the work of the other graduate students (Sanner, 2015; Purkayastha, 2015) with whom I collaborated on parts of this research, in Malawi. Such work provides alternative analyses to those presented herein, and also covers empirical material that is not covered in my work. Sanner (2015) draws on literature on digital infrastructure, but also relates his work with ICT4D literature on sustainability. In addition, he draws on empirical material from implementations in India. Purkayastha (2015) presents a taxonomy of classification of activities (architecture, governance, praxis) that shape the evolution of digital infrastructure. He argues that dividing the complexity of activities and their effects, leads to more nuanced studies of how digital infrastructures evolve, through observation of which activities have stabilizing or destabilizing effects on the digital infrastructure in question. In addition to the taxonomy of digital infrastructure activities, Purkayastha (2015) also engages with discourse on evolutionary process of software development; evaluation criteria for mHealth solution implementations; Big Data. Empirically, he draws on cases from Malawi, India, Kenya, and North Korea, covering both patient level and routine aggregate health information systems.

The insights provided in this thesis could also be further strengthen through engagement with literature other than that on digital infrastructure. The reader will find suggestions to this end in section 7.1, which suggests directions for further research.

4.7 Ethical Considerations

This study was cleared with the national research ethics committee in Malawi. In addition, the Ministry of Health's Central Monitoring and Evaluation Division (CMED), which oversees the national HMIS, were involved through the different phases of the DHISm pilots. Lilongwe district health office, as well as participating health areas and health facilities were also consulted at different phases of the study. Appendix 6 depicts an initial approval letter for the study. Where discussions with informants were audio recorded, this was done with their consent. Verbal consent was sought. Pictures used in this thesis were also taken with the consent of informants.

Chapter 5: Findings

This chapter is divided into two main sections. The first, presents findings from individual papers that are part of the thesis. The second, then, presents a summary of the findings in light of how each paper contributes towards answering the research questions posed in this thesis.

5.1 List of Papers and Findings from Individual Papers

Following, is a list of the five papers that are included as part of this thesis:

- 1.MANDA, T. D. & HERSTAD, J. (2015). Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices. *Information Technology & People*. **Forthcoming**
- 2.MATAVIRE, R. & MANDA, T. D. (2014). Interventions Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures. *Journal of Information Systems in Developing Countries*. 63 (3). 1-17.
- 3.MANDA, T. D. & SANNER, T. A. (2014). The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective. *International Journal of User-Driven Healthcare (IJUDH)*. 4(1). 1-16.
- 4.SANNER, T. A., MANDA, T. D. & NIELSEN, P. (2014). Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation. *Journal of the Association for Information Systems*, 15(4). 220-243.
- 5.MANDA, T. D. (2015). Leveraging Project Arrangements in Developing Health Information Systems Infrastructure. **Under review in an international journal**

From the list of co-authored papers above, I was the first author for papers 1 (Manda and Herstad, 2015) and 3 (Manda and Sanner, 2014), and second author for papers 2 (Matavire and Manda, 2014) and 4 (Sanner et al., 2014). I participated in data collection for all the papers. Following, are details on how the various authors contributed towards paper writing:

Paper 1: Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices

Author involvement during paper writing:

My role: I took the leading role in framing the overall focus of the paper. I also developed an initial draft of the paper before co-opting the second author. After submission of the manuscript, I was also responsible for corresponding with journal editors.

Jo Herstad: Took part in subsequent rounds of data analysis for the paper. We held several rounds of meetings to discuss ideas in the paper and reviewers' comments

Paper 2: Interventions Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures

Author involvement during paper writing:

This paper is a revision of an earlier paper (Matavire and Manda, 2013) submitted to the 12th IFIP 9.4 conference, held in Ocho Rios, Jamaica in May 2013.

Rangarirai Matavire: Was responsible for framing the overall focus of the paper, i.e. the need to, and importance of, discussing breakdowns and articulation work. We had several rounds of discussion to tease out ideas for the paper and sharpen its focus. Rangarirai was also the corresponding author during the review process for the paper.

My role: I was involved in data analysis for the paper, both alone and in collaboration with the first author. I also took turns with Rangarirai in writing versions of the paper. We also worked together in responding to reviewers' comments.

Paper 3: The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective

Fieldwork: Data collection for the paper was undertaken together with the second author

Author involvement during paper writing:

This paper is a revision of an initial paper (Manda and Sanner, 2012) submitted to the 35th IRIS seminar, held in Sigtuna, Sweden, in August 2012.

My role: I was responsible for the overall framing of the paper's focus, and also acted as the corresponding author for the paper. I also took a leading role in the writing of the paper, but with ongoing collaboration on data analysis with the second author.

Terje Sanner: Terje contributed towards data analysis, starting from when we were doing fieldwork. He also contributed to parts of actual paper writing.

Paper 4: Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation

Author involvement during paper writing:

The paper expands on ideas presented in the precursor to paper 3 (Manda and Sanner, 2012).

Terje Sanner: Came up with the initial conceptual framework for the paper, i.e. the notion of grafting and possible application to digital infrastructure development. He was also the corresponding author for the paper, during the review process.

My role: this paper built on the aforementioned paper (Manda and Sanner, 2012), where I was the lead author. During the development of paper 4, I took an active role in both data analysis and actual writing, taking turns with the first author. Data analysis was either done with the other authors or alone (with notes, then, shared with the others).

Petter Nielsen: Although he did not take part in actual data collection, Petter's experience proved invaluable during data analysis and the extended period over which this paper was developed. Petter contributed invaluablely in reviewing the work done by myself and Terje, through questioning our assumptions and motivations.

Next, I present a summary of key findings from the papers above.

5.1.1 Paper 1 - Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices.

This paper is situated within the broader debate on theorizing technological artefacts. The paper discusses conditions at play in attempts to integrate novel mobile technology solutions (DHISm), into an existing installed base where data reporting has traditionally been paper-based. Findings reported in the paper suggest at least five considerations that are necessary in the introduction of novel technologies: (i) immediate benefits that new technologies will offer target users; (ii) how new and existing technologies will be mobilized, in the context of supported work practices; (iii) ways to mitigate possible undermining of existing structures of communication and authority, resulting from adoption of network technologies such as DHISm; (iv) need for comprehensive coverage of report forms, to increase the relevance of implemented DHISm solutions; (v) growing demands for coordination, when attempting to extend coverage of mobile technology solutions across fragmented systems.

In regard to offering users immediate benefits, the paper indicates that DHISm solutions allow for remote data communication, between health facilities and an overseeing district health office. In doing this, DHISm solutions extended digitization of routine health data from the district, to the health facility level. Thus, DHISm offers a way to circumvent identified challenges pertaining to paper-based reporting such as: (i) difficulties in transporting reports over poor road infrastructure; (ii) health personnel having to leave their duty stations and use

their own money, in order to submit reports at the district health office; (iii) an increased data entry burden placed on staff working at district level, tasked with digitizing data from subordinate facilities; (iv) late delivery and occasional loss of reports sent through third parties such as ambulance drivers. Further to this, DHISm provides staff with immediate feedback on report delivery, as they can access submitted reports. It has usually been difficult confirm the delivery status of reports sent through third parties.

Beyond capabilities of DHISm, the paper argues that novelty and innovation are to be found in the situated intermingling of new and old technologies and practices. Thus, it is necessary to consider the idiosyncrasies of various stages to data reporting (*compilation, transportation, digitization, delivery, feedback*) and how available technologies (*paper, mobile phones, desktop computers*, etc.) render themselves to supporting human action, at each stage of data reporting, as well as a collective. For example, the predominance of paper tools in collecting service data, as well as the multiplicity of registers and groups of people involved in report compilation, means paper cannot be easily done away with. In addition, paper (A3 and A4 size registers and report forms) seems better suited to supporting group collaboration and information visibility at a distance, which are critical during report compilation, compared to mobile phones with small screen sizes. However, beyond report compilation, transportation of paper-based reports becomes cumbersome, hence the relevance of implemented mobile phone solutions. At district level, work practices are possibly better-supported by use of computers and laptops, due to the vast quantities of data handled and required computing power. The paper uses the construct of technology enactment (Boudreau and Robey, 2005) to evaluate coexistence between new, mobile-based practices, and existing paper-based ones. On the other hand, the notion of affordances (Gibson, 1979) is drawn upon to illustrate implications of the idiosyncrasies of different artefacts that are implicated in data reporting.

Regarding existing structures of communication and authority, the paper suggests that these might be challenged through allowing health facilities to directly submit data into a central server, thereby leapfrogging stakeholders who serve as gatekeepers in the paper-based system. Adoption of DHISm also places increased demand for better Internet connectivity than was previously the case, with paper-based data reporting and the use of desktop DHIS 1.3 solutions. The paper suggests that side-lining of authorities across levels of administration, who play important organizational roles such as signing-off reports, checking for data quality, and monitoring data reporting by subordinate health facilities, would have undermined the

legitimacy of DHISm. In realization of this, identified gatekeepers at health area and district level were provided with Internet modems, so they could follow data reporting.

As an extension of the above-stated, the paper suggests that adoption of mobile phone solutions calls for better communication and delivery of feedback on reported data between district health offices and health facilities, to compensate for reduced face-to-face meetings associated with paper-based reporting. If care is not taken, the use of implemented mobile phone solutions might conquer physical distance, but widen the communication gap between health facilities, health area offices and district health offices.

Finally, the paper foregrounds the necessity of supporting all available reports at facility level, in order to do away with paper-based reporting. Where some other reports are not supported under DHISm, members of staff still have to travel to the district office or send their reports through third parties. At the same time, the paper suggests that supporting all available reports is challenging, due to fragmentation of HIS along health programmes. Although it is commonly the case that members of staff working at health facility level are responsible for multiple reports, across health programs, reports are handled through parallel health programme-specific software solutions, beyond the health facility level.

5.1.2 Paper 2 - Interventions Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures

This paper considers the sustainability of DHISm in light of activities that occur in the pilot stage. Discussions in the paper mainly centre on the day-to-day breakdowns that occur during the pilot phase, their nature, what they reveal, and how their resolution relates to project goals. In going about this discussion, the paper argues that the micro-processes of domesticating mobile technology for a local setting are related to the broader context, implicating individuals, settings and resources far removed from the sites of implementation.

The paper argues that breakdowns reveal tensions in technology design, implementation strategy, and organisational context, thereby offering opportunities for action to sustain an intervention. Opportunity is an often overlooked aspect shaping the evolution of technology, yet it is implicit in challenges faced. At a basic level, breakdowns might lead to workarounds so that services resume. At a more advanced level, they provided opportunities for pursuing institutional rearrangements that address immediate and long-term concerns for sustainability.

The paper, then, draws on the notion of articulation work (Strauss, 1988; Star and Strauss, 1999) to discuss practical work undertaken to correct breakdowns. According to Star (1991) as referenced by Star and Strauss (1999), p. 10, ‘*articulation work*’ is work that “*gets things back ‘on track’ in the face of the unexpected, and modifies action to accommodate unanticipated contingencies*”. It refers to “*the specifics of putting together tasks, task sequences, task clusters -even aligning larger units such as lines of work and subprojects- in the service of workflow*” (Strauss, 1988, p. 164). From empirical material considered, the paper identifies two categories of articulation work: *technological and human*. These categories of articulation work are further analysed into different dimensions, based on the levels of organizational involvement required to perform them: (i) localised (to individual users or organizational levels); (ii) multiple levels within a single organization; (iii) and multiple levels across organizational boundaries.

The paper argues that where interventions are part of a larger infrastructure setup, as DHISm is, networking across organizational levels and organizational boundaries might be necessary, in order to resolve breakdowns. For DHISm, articulation work that required collaboration across multiple levels included efforts to resolve: challenges with mobile phone subscription; replacement of failed SIM cards; and management of national DHIS2 servers which DHISm utilized. Findings suggest that the negotiation of breakdowns is bound to be slow where multiple stakeholders require mobilization. This is mainly due to increased coordination overheads and distribution of agency across organizational boundaries, which reduce the ability of particular stakeholders to influence the trajectory of required articulation work. The paper then observes that, in such circumstances, there might be need for preliminary work, such as development of work relationships, for required articulation work to take place.

The strategic negotiation of breakdowns across stakeholder groups is a key process in designing mobile technologies that address both immediate implementation-related and long-term concerns for sustainability. Although building stable work relationships across organizational levels takes time, it provides a basis for more sustained technical and organizational arrangements required to support implemented technologies. In line with this, the paper argues that it is through choices available and decisions made in the event of breakdowns that intervention projects can be institutionalized and possibly be sustained.

5.1.3 Paper 3 - The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective

This paper reflects on real-time application of the bootstrapping strategy (Hanseth and Aanestad, 2001; Hanseth and Lyytinen, 2010), to guide DHISm pilots design, implementation, evaluation, and application of lessons learned. Application of the bootstrapping strategy in guiding and evaluating DHISm efforts confirms bootstrapping as an effective tool for risk assessment and management, through incremental technology implementation, growth, and mobilization of stakeholders. For example, by following the bootstrapping strategy DHISm pilot efforts were preceded by efforts to understand data collection and communication practices, as well as gain buy-in from target users and key decision-makers in the Ministry of Health. Resulting from this, our implementation team was able to target DHISm at supporting important routine health data reports. In trying to understand the local installed base, our team observed that not all target users had mobile devices capable of supporting DHISm, which led to target users being given phones that could support DHISm. In addition, by following the bootstrapping strategy our team took a phased approach to implementation, which made it possible to cope with initial implementation challenges arising from poor mobile service delivery and mobile phones that did not work in the context of implementation.

On the other hand, the paper reveals that it may not always be easy to mitigate identified risks, due to competing interests and power asymmetries. DHISm and the national HMIS efforts (DHIS2 implementation) that DHISm pilots sought to leverage were reliant on the participation of multiple stakeholders, across service sectors and geographical boundaries. The DHISm pilots were funded through the MobiHealth project based at the University of Oslo, in Norway, had the Ministry of Health in Malawi as a host organisation, and relied on mobile service delivery by a commercial provider. In addition, the Ministry of Health was reliant on external consultants (DHIS2 coordinators), supported under different project arrangements, for technical support. A majority of these stakeholders, though in control of key parts of the socio-technical installed base, were not intended solution adopters. Interdependencies that ensued from the above-presented heterogeneity of stakeholders resulted in competing goals, coordination overheads, and a marked fragility in DHISm pilots, which impacted adherence to the bootstrapping strategy.

From empirical findings, it can be observed that adherence to the bootstrapping strategy was more likely when DHISm implementers had a sufficient level of influence in the execution of key decisions regarding DHISm. Adherence to the bootstrapping strategy was more

challenging where divergent stakeholder interests and participation required negotiation. For example, to suit demands of the MobiHealth project, our implementation team purchased phones outside the implementation context, without ascertaining their compatibility with the local installed base. Consequently, the first set of phones purchased did not work in Malawi, which delayed implementation work. Further to this, slow progress in DHIS2 implementation slowed down DHISm work and relevance. Since DHISm builds on DHIS2, it was always going to have limited relevance without DHIS2 becoming the mainstream HMIS solution. Table 5-1 presents a summary of factors that made adherence to bootstrapping challenging.

Table 5-1: Factors affecting adherence to the bootstrapping strategy

Challenge	Deviation from bootstrapping strategy	Contributing factors
Buying phone outside the implementation context, without ascertaining availability of support	Building on technology that had not been tested locally Lack of access to the supplier when challenged emerged	Better utilization of MobiHealth funds – pursuing a balance between local and cross-context needs
Inadequate local IT implementation capacity	Reliance on external consultants for support, resulting in: - increased coordination complexity - reduced control over implementation	Historically weak local IT implementation capacity
Reliance on external financial support from multiple donors	Increased complexity resulting from competing interests and coordination overheads	Historically weak local financial base
Reliance on another layer of implementation work – DHIS2	Having a key enabling component outside our control	DHISm builds on DHIS2
Poor mobile service delivery	Having a key enabling component outside our control	<ul style="list-style-type: none"> ▪ Mobile service delivery is an industry on its own, ▪ Limited choice of mobile operators

Findings in the paper point to limitations in bootstrapping strategy regarding implications of distributed control over key parts of the installed base, on implementers' ability to guide infrastructure development trajectories. Formulation of the bootstrapping strategy (Hanseth and Aanestad, 2001; Hanseth and Lyytinen, 2010) assumes that implementers are sufficiently positioned to influence key decisions and actions affecting an implementation.

5.1.4 Paper 4 - Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation

This paper fits within the discourse on how information infrastructures are developed, especially in regard to the negotiation of short-term and long-term concerns to infrastructure development. The paper provides analysis on an often overlooked aspect to theorizing infrastructure, i.e. how heterogeneous elements developed at different times and in different places are combined and carried forwards (or not) (Monteiro et al., 2014). The paper also discusses how multiple independent stakeholders pursue control, to influence and legitimize development trajectories of digital HIS infrastructure. The paper argues that in the face of distributed control, implementations are translated into nurturing activities performed by an increasing number of actors, with varying interests and degrees of involvement.

The paper proposes *grafting* as a sensitizing lens to guide infrastructure development and theorizing. In the paper grafting is defined as “*a process whereby organizational goal-oriented information system innovations (e.g., mobile phone-based reporting from sub-district health facilities) merge with and extend existing socio-technical arrangements (e.g., HMIS in Malawi) so that the parts continue to grow*” (Sanner et al., 2014: pp. 235). The grafting perspective argues that digital infrastructure innovation is not just down to the mechanics of network economics, as is suggested by the bootstrapping perspective (Hanseth and Lyytinen, 2010). Rather, grafting highlights fragility and tensions inherent in attempts to integrate novel technologies into existing installed base, where there is need for contributions from loosely coordinated stakeholders, who control important parts of the of the installed based, but do not necessarily have to adopt proposed technological solutions. In line with this, the paper argues that a significant amount of domain and context-specific knowledge and much sensitive and well-targeted practical work is needed to facilitate the mutual adaptation of newly introduced technological components and local constituencies. The paper, then, argues that with such insights, we are better placed to answer questions such as: *why do so many attempts at implementing relevant, even strategically crucial, information systems fail to take hold?*

The paper conceptualizes the pursuit for control as taking place at least two levels. First, at the highest level, the Ministry of Health faces the challenges of coordinating and facilitating collaboration between loosely coordinated interventions, because it lacks comprehensive knowledge on who is doing what and where. From the position of the ministry, this challenge is being negotiated through introduction of a control point (Elaluf-Calderwood et al., 2011) for the mobile technology-oriented interventions – *the mobile health task force (mHealth-*

Malawi Forum). The forum comprises stakeholders from different government departments, non-governmental organisations, donors, and the University of Malawi. Second, the pursuit of control takes place at the level individual projects or stakeholder groups, such as DHISm implementation. Here, implementation teams seek to gain access to parts of the installed base under the control of others, and to shape digital infrastructure development trajectories to suit their interests.

The paper suggests alliance building as a necessary step for implementers to access services and technical platforms under the control of others. The paper also points out that alliance building might be contentious and protracted, requiring implementation teams to adopt temporary arrangements that permit implementation work to proceed in the meantime. In the case of DHISm, the implementation team had to utilize a demonstration server, instead of the planned national DHIS2 production server, for at least one and a half years, due to protracted negotiations with the team managing the servers.

The paper also suggests that implementation teams may fashion opportunities to get into positions of prominence, by supporting related ongoing initiatives. The DHISm team supported DHIS2 implementation activities, in order to warm up relations with key stakeholders and induce necessary momentum in otherwise slow-moving DHIS2 efforts.

Another key concern with grafting is focus beyond exigencies of initial implementation efforts and progressing from external dependencies, such as project-based funding and IT support arrangements, to local nurturing of infrastructure development efforts. The empirical context for this study is one in which public administration is weak and non-governmental organizations and donors play an important role. The paper suggests drawing up of terms of reference for long-term engagement of IT technical assistants (TAs) in collaboration with the local Ministry of Health, coupled with recruitment of TAs, as a way of promoting more sustained local nurturing and maintenance of digital HIS infrastructure.

In sum, the grafting perspective conceptualizes digital infrastructure innovation as involving pursuing and relinquishing control through: (i) alliance building; (ii) actively searching for and possibly fashioning opportunities to get into positions of prominence; (iii) transferring the embodiment of control from individuals into institutional arrangements that can survive individuals and specific project arrangements; (iv) transitioning between adoption of temporary arrangements within the short-term, to kick-start implementation efforts or address

breakdowns, and development of persistent arrangements that facilitate institutionalization and continuity of implemented technologies (Sanner et al., 2014).

5.1.5 Paper 5 - Leveraging Project Arrangements in Developing Health Information Systems Infrastructure

Beyond findings relating to aforementioned stakeholder interdependencies in DHISm and DHIS2 implementations, the paper presents: (i) a mapping of tensions to digital infrastructure development; (ii) approaches to negotiating identified tensions to aid coordination across project-based interventions, in order to enhance technology implementation and continuity of digital infrastructure efforts. Drawing on the long now perspective (Ribes and Finholt, 2009), the paper take a longitudinal look at tensions emanating from design, implementation, and maintenance of digital HMIS infrastructure in Malawi, in the period 1999 to 2014.

The paper identifies the following as key issues contributing to weakening of HMIS strengthening efforts in Malawi: (i) poor funding arrangements; (ii) lack of end-user IT capacity for use and maintenance of technological solutions; (iii) poor organizational IT support structures, within the Ministry of Health, to support technology implementation, and maintenance; (iii) dependence on loosely coordinated short-term donor funded projects for long-term infrastructure development.

Key identified areas for developing end-user IT capacity and organizational IT support structures include: use of mobile Internet; use of computers; low level computer repairs; and establishment of a technical help desk and technical team, to manage technology implementation and maintenance. Regarding these concerns, the paper observes a tension concerning the extent to which end-users can draw upon own expertise in using technology and negotiating breakdowns, against development of organizational structures for end-user support (*end-user action vs. end-user support*). A tension is also observed regarding how to mobilize required technical support, in a context where support structures are often restricted to within project boundaries (*fragmented vs. shared IT support*). The paper also observes a tension between engaging IT experts on short-term, but agile, project-based arrangements, against long-term recruitment on tenure, which is subject to slow bureaucratic processes (*project flexibility vs. bureaucratic discipline*). To promote synergy between short-term project arrangements and sustained government-based tenured arrangements, the paper supports institution of *centrally coordinated participative forums*, to promote collaboration, formulation of common visions, and pooling of resources such as funding and IT capacity.

In considering IT capacity development and related tensions, the paper proposes an additional concern for long-term sustainability, to the long now framework (Ribes and Finholt, 2009) – *developing IT capacity*, together with the above-presented tensions (see table 5-2).

Table 5-2: Rendition of the long now framework as informed by this study

Concerns for sustainability	for	Scales of II work					
		Enacting Technology		Organising Work		Institutionalisation	
Aligning End-goals		Inclusion Vs. Readiness		Planned	Vs.	Project Vs. facility	
				Emergent			
Motivating Contribution		Research Systems	Vs. Production	Research Maintenance	Vs.	Individual Community	Vs.
Designing for Use		Today's Vs. Tomorrow's Users	Requirements	Research Development	Vs.	Communities Constituencies	Vs.
Developing capacity	IT	<i>End-user action vs. end-user support</i>		<i>fragmented shared IT support</i>	vs.	<i>Project flexibility vs. bureaucratic discipline</i>	

The concerns - developing of IT capacity - relates to those proposed by Ribes and Fihnolt (2009) in multiple ways. First, without the right level of competence at both individual and organizational level it is challenging to take advantage of otherwise useful technological offerings and maintain them over time. Second, developing necessary IT capacity, across project-specific arrangements, requires *mobilizing contribution*, and *aligning end-goals*, across stakeholder groups.

From the tensions presented in table 5-2, the paper identifies the tension arising from trying to build infrastructure based on project-centric arrangements and pursuing sustained institutional structures, to ensure continuity beyond individual projects (*Project Vs. facility*), as the most dominant. All HMIS strengthening initiatives that form the basis for this study, covering the period 1999-2014 (DHIS1.3, DHIS2, DHISm, etc.) have been considerably reliant on project-based funding and technical support arrangements. Consequently, *all the other tensions observed play out within the project vs. facility tension*. In regard to approaches for negotiating identified tensions, the paper adopts a position that: (i) tensions, though potentially problematic, should be considered as possible points for innovation: This is achieved through application of the notion of continued design, which is a juxtaposition of the temporal tension ‘*project time*’ vs. *infrastructure time*’ (Karasti et al., 2010). Continuing design (ibid) highlights temporal tensions and practices implicated in trying to address short-term exigencies to implementation, whilst trying to provide impetus towards long-term concerns for technology maintenance and evolution, within funded project time.

5.2 Summary of Findings

The summary of findings presented here is guided by reflections on how the various papers contribute towards answering the overall research question and its sub-questions:

How can we negotiate concerns and tensions to design, implementation and maintenance of digital health infrastructure, in the face of changing project-based support arrangements?

Key short-term concerns include attending to conflicting needs and priorities of different stakeholders and addressing immediate implementation-related challenges: integrating introduced solutions into existing socio-technical setup (artefacts, data reporting practices, etc.); addressing breakdowns; developing technology use-related IT capacity; providing day-to-day user support. Long-term concerns mainly relate to building persistent organizational arrangements that can promote maintenance and continuity of implemented DHISm and DHIS2 solutions through: persistent IT support structures, temporal coordination of multiple independent project-based arrangements. These issues are reflected through the questions:

1. What are conditions for integrating novel solutions into an existing socio-technical installed base?
2. What strategies can improve implementation and maintenance capacity in the context of changing project-based support arrangements?
3. How can we conceptually account for tensions to design, development, and maintenance of digital infrastructure?

Tables 5-3 and 5-4 summarise how each paper contributes towards answering the research questions. Table 5-3 presents a mapping of *what* question each paper responds to, whereas table 5-4 details *how* each paper contributes towards answering the research questions.

Table 5-3: Mapping of papers to research questions

Paper Title	RQ1	RQ2	RQ3
Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices	X		X
Interventions Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures	X		X
The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective	X		X
Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation	X	X	X
Leveraging Project Arrangements in Developing Health Information Systems Infrastructure	X	X	X

Table 5-4: Summary of how papers contribute towards answering research questions

Paper Title	Contribution to thesis research questions
Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices	<u>Question 1:</u> The paper looks at how technology implementation should consider idiosyncrasies of a technology being introduced, existing work practices and artefacts, and how these components are mobilized in trying to create new socio-technical hybrids
Interventions Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures	<p><u>Question 1:</u> The paper discusses implementation-related issues within the short-term (nature of breakdowns and articulation work), as well as what they reveal about long-term sustainability.</p> <p>The paper argues that constant adaptation of human and technical resources is necessary for the continued use of introduced technology</p> <p><u>Question 3:</u> the paper provides conceptual analysis of articulation work that is required to negotiate different kinds of breakdowns</p>
The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective	<p><u>Question 1:</u> The paper discusses how introduced mobile technology solutions relate to practices and demands around data reporting.</p> <p>The paper highlights tensions inherent in multi-stakeholders undertakings – their enabling nature and contribution towards heightened potential for failure.</p> <p><u>Question 3:</u> The paper discusses <i>bootstrapping</i>, an incremental implementation strategy to addressing immediate implementation related concerns. It also indicates possible limitation to application of such a design-based the strategy, which overlooks power asymmetries among stakeholders</p>
Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation	<p><u>Question 1:</u> The paper highlights tensions from pursuing concerns that span short and long temporal scales, and continued attempts at attaining balance between short-term and long-term concerns</p> <p><u>Question 2:</u> the paper discusses attempts to leverage short-term project-based support arrangements and persistent organizational structures, to provide and develop IT capacity for technology implementation and maintenance</p> <p><u>Question 3:</u> The paper suggests <i>grafting</i> as a perspective for analysing and guiding digital infrastructure efforts, in a way that pays attention to distributed control of the installed base and power asymmetries between stakeholders.</p>
Leveraging Project Arrangements in Developing Health Information Systems Infrastructure	<p><u>Question 1:</u> The paper maps tensions that characterize the problem space within which health infrastructure design choices are made (DHIS1.3, DHIS2, DHISm)</p> <p><u>Question 2:</u> the paper discusses attempts to leverage short-term project-based support arrangements and persistent organizational structures, to provide and develop IT capacity for technology implementation and maintenance</p> <p><u>Question 3:</u> The paper extends the long now perspective, by proposing an additional concern for sustainability – Developing IT capacity</p>

Chapter 6: Discussion and Implications

In this chapter, I discuss the research findings presented in the previous chapter. Following this, I present a summary of contributions to theory and practice.

6.1 Responding to question 1: Conditions for Introducing and Enacting Novel Solutions

The first question guiding this study is: *What are conditions for integrating novel solutions into an existing socio-technical installed base?*

In responding to this question, I seek to contribute to discourse on digital infrastructure, especially regarding negotiating the bootstrap problem (Hanseth and Lyytinen, 2010) and enacting of technological solutions (Boudreau and Robey, 2005; Fountain, 2001). Through the papers that are part of this thesis, I underscore the importance of considering idiosyncrasies of the installed base and novel technological offerings. The rationale behind is that doing so helps with identification of what parts of the installed base to keep and leverage, and those that need changing. My papers, contemplate *technology* and *implementation design*, as well as *negotiation of control* to parts of the installed base, in negotiating technology adoption, breakdowns, and undesired outcomes of technology implementation.

6.1.1 Technology and Implementation Strategy Design

All papers that are part of this thesis underscore the importance of *designing technology for immediate usefulness* and *involving target users and key decision makers*, across levels of administration, to *secure buy-in* for DHISm. This is exemplified by continued engagement with health facilities (users of DHISm), as well as managers from the district health office and the Ministry of Health headquarters, who are key decision makers. Buy-in from managers was considered essential for the legitimacy and long-term institutionalization of DHISm. Previous studies have also suggested designing for usefulness and involvement of target users and other key stakeholders, as necessary conditions to enhancing adoption of new technological solutions, to gain growth momentum (Grisot et al., 2014; Skorge and Aanestad, 2010).

Beyond securing stakeholder buy-in, this thesis posits the necessity of considering proposed technologies within an ecology of: (i) *the nature of practices to be supported*, such as routine health data reporting; (ii) *how people collaborate in going about their work*; (iii) *related demands on supporting technological artefacts*; (iv) *collectives of technological artefact that*

require mobilization (Manda and Herstad, 2015; Manda and Sanner, 2014). New technologies are made sense of and enacted in the context of evolving interactions with an existing installed base (Fountain, 2001), meaning innovation is to be found in simultaneous enactment of new and existing technologies and practices (Boudreau and Robey, 2005; Manda and Herstad, 2015; Aanestad et al., 2014). Consideration of the above-mentioned facets may be useful in deciding on what artefacts are more suited at supporting what parts of multi-stage tasks such as routine health data reporting, which comprises *report compilation, transportation, digitization, and feedback*. Each of these stages has varying demands for supporting technological artefacts.

Resulting from consideration the aforementioned aspects, our team was able to recognize a need to leverage existing paper tools to support compilation of reports. Paper is commonly used to manage data during service delivery and seems better suited at supporting local collaborative compilation of reports. On the other hand, utilization of DHISm to replace physical transportation of paper forms places DHISm in a space where its usefulness is demonstrable and accepted by stakeholders concerned. This way of introducing and enacting new technological solutions corresponds to calls by previous studies for installed base friendly strategies, i.e. *incrementally build on the installed base*, whilst offering immediate benefits to intended users (Hanseth and Aanestad, 2003; Hanseth and Lyytinen, 2010).

Continuing in the same manner of minimizing contradiction of the installed base, I have tried to emphasise the necessity of paying attention to *how new technological solutions such as DHISm challenge existing social relations*. Demands for better Internet connectivity after adoption of DHISm and potential for challenging structures of authority, through isolating key gate-keepers, call for consideration of ways to bring key stakeholders along. Previous studies, suggest that *consideration of the interests of key stakeholders* as a useful condition for integrating new technology into an existing socio-technical installed base (Grisot et al., 2014). In addition, in a context where feedback on reported data has traditionally been poor, adoption of DHISm could also have the unwanted effect of eroding communication between health facilities and district health offices, which could compromise data quality. Previous studies suggest that outcomes of technology supported change are paradoxical and non-linear, requiring continued adjustments in both technology and practice (Arnold, 2003; Jarvenpaa and Lang, 2005; Jamison et al., 2013; Aanestad et al., 2014; Boudreau and Robey, 2005).

The empirical case also suggests that the existing installed base might be weak, requiring *strengthening of the installed base, to facilitate technology implementation and enactment*. In the context of DHISm, this is exemplified by: (i) purchase of phones for health facilities; (ii) end-user training, to facilitate technology use; (iii) subsidies regarding mobile phone subscription; (iv) improving Internet connectivity for key stakeholders. Ribes and Finholt (2009) also reflect on the challenge of trying to provide infrastructural services to users with varied technical expertise and equipment under the tension *inclusion vs. readiness*. Negotiation of this tension, through the actions above, complies with calls by the bootstrapping and continuing design perspectives, to minimize barriers to adoption (Hanseth and Aanestad, 2001; Hanseth and Lyytinen, 2010; Karasti et al., 2010).

Even where the best of attempts are made in initial technology design and implementation, breakdowns are bound to occur (Matavire and Manda, 2014; Strauss, 1988; Aanestad, 2002). This study's findings suggests a need for practical work, which might require *mobilization of resources* local to the point of breakdown, or distributed across organizational and geographical boundaries (Matavire and Manda, 2014). Ribes and Finholt (2009) reflect on continuous efforts to organizing infrastructure work - *negotiating balance between planned and emergent infrastructure work* - under the tension *planned vs. emergent work*. Negotiation of this tension is reflected upon by the continuing design perspective (Karasti et al., 2010) and other studies, which underscore the necessity of ongoing practical work to enhance enacting and integration of novel technology into an existing installed base (Pipek and Wulf, 2009; Skorve and Aanestad, 2010). Where there is need to respond to breakdowns, presented findings suggest *flexibility to change, in implementation strategy*, as an important condition. Adoption of incremental and flexible implementation strategies such as bootstrapping and continuing design, may provide room for learning and negotiating effects of unforeseen circumstances when introducing and enacting novel technologies (Manda and Sanner, 2014; Manda, 2015).

Beyond prescriptions of design strategies such as bootstrapping (Hanseth and Lyytinen, 2010) and continuing design (Karasti et al., 2010), reviewed empirical material, foregrounds power asymmetries, especially emanating from control to key parts of the installed base and financial resources, as critical to attempts at introducing and enacting new technology.

6.1.2 Negotiating Control on the Supply-side of Digital Infrastructure

It may not always be possible to address the bootstrap problem, solely on the basis of following design principle prescribed by design strategies such as bootstrapping (Hanseth and Lyytinen, 2010) and continuing design (Karasti et al., 2010). *Successful integration of novel technologies into an existing installed base goes beyond the mechanics of networks economics or frugal technology design* (Sanner et al., 2014; Manda, 2015). Previous studies underscore the importance of control to parts of the installed base, arguing that those in control of such are able to influence infrastructure development trajectories to suit their interest (Nielsen, 2006; Elaluf-Calderwood et al., 2011). Considering, the multiplicity of interacting technical elements and stakeholders, it is not always possible to only build on parts of an installed under one's control. In the case of DHISm implementation efforts, this is exemplified by dependence on a mobile service provider (for mobile services), DHIS coordinators (for server-side services), and multiple donors (for DHIS2 and DHISm funding). Such distribution of dependencies results in a marked fragility to implementation efforts, which may result in the collapse of digital infrastructure efforts should critical relations fail (Manda and Sanner, 2014). This thesis suggests *alliance building, with key stakeholders* such as DHIS coordinators, as a necessary condition to accessing the services of others and parts of the installed base under their control (Manda, 2015; Sanner et al., 2014). Where it is not possible to build alliances with key stakeholders, early on in implementation efforts, it might be necessary to *adopt evolving temporary technological arrangements, to allow implementation efforts to proceed*. In the case of DHISm, this is exemplified by changes in mobile subscription arrangements and adoption of a DHIS2 demonstration server, instead of the planned production server, when negotiations regarding access to the production server protracted (Manda and Sanner, 2014; Sanner et al., 2014).

Another important aspect to developing digital infrastructure is opportunity, meaning it is not always possible to only build on stable platforms, as argued by Hanseth and Lyytinen (2010). Waiting (or not) for the maturation of target platforms to leverage may spell the difference between being at the centre or periphery of infrastructure development efforts. In the case of DHISm, trying to build upon interest in mobile technology to support routine health data reporting meant leveraging DHIS2 implementation efforts that were still unfolding. At times, the instability of DHIS2 delayed DHISm work. Here there is an important *dialectic between opportunity and installed base stability*, in attempting to introduce novel technologies. In negotiating this dialectic it might be necessary to *fashion opportunities that create momentum*

in the progress of efforts, implementers seek to leverage. In the context of this study, this is exemplified by the DHISm implementation team's efforts to support DHIS2 implementation efforts (Sanner et al., 2014). It should be noted however, that heterogeneity and geographical distribution of influential stakeholder groups, might make it difficult to induce momentum in parts of the installed base under the control of others.

Informed by the context of study – Malawi – where public administration is weak and there is a multiplicity of loosely coordinated interventions, I also argue for the *pairing of bottom-up approaches such as bootstrapping (Hanseth and Lyytinen, 2010) with central, but participative, control mechanisms as a necessary condition for organizing contemporary efforts across groups of independent stakeholders and promoting continuity of efforts* when introducing, and attempting to institutionalize new technological solutions. Bottom-up approaches and central control mechanisms need not be seen as polar opposites, but complementary and intrinsically related opposites of a dialectical relationship.

Bottom-up approaches reduce the level of temporal commitment required of stakeholders and coordination overheads, which central control mechanisms are prone to, through modular recruitment of participating stakeholders (Aanestad and Jensen, 2011; Grisot et al., 2014). Bottom-up approaches also allow for more flexibility regarding organizing interventions, as and when funding opportunities arise, as can be evidenced from HMIS interventions in Malawi. Bottom-up approaches also make it possible to decentralise more specific project-level implementation details to project teams. It has already been established that seeking to control the expanse of activities in developing digital infrastructure across heterogeneous stakeholders is a futile undertaking (Ciborra et al., 2000; Aanestad and Jensen, 2011; Edwards et al., 2007). At the same time, extant literature and this study's finds suggest that in the absence of high-level control structures, bottom-up and incremental strategies such as bootstrapping are prone to short-term focus and fragmentation of infrastructure efforts (AbouZahr and Boerma, 2005; Aanestad, 2002).

Central control structures provide a platform for aligning divergent and competing goals, developing unified visions, pooling together like interventions, and accessing technical expertise (Zimmerman and Finholt, 2007). The interdependence between bottom-up approaches and central control mechanisms can be evidenced from developments in Malawi, where project teams decide on modalities relating to project-specific interventions, but central control structures such as the mHealth Malawi forum and DHIS2 implementers' meetings are

actively used to foster collaboration, formulation of common visions, and continuity of efforts beyond individual project arrangements. The organizing function of central control mechanisms is recognized by scholars studying e-infrastructures (Zimmerman and Finholt, 2007; Karasti et al., 2010; Ribes and Polk, 2014; Karasti and Baker, 2004). Thus, we cannot accept the argument for progressive diminishing of central control mechanisms (Ciborra et al., 2000) as necessary for all kinds of digital infrastructure, especially goal driven digital health infrastructure. Although no single group of actors is entirely in control of changes to digital infrastructure, it is also not the case that “*the trajectory of change is ... without any central control*” (see: Jansen and Nielsen, 2005: pp. 77).

Findings from this study also underscore the importance of contributing towards *development of local capacity and organizational structures to further digital infrastructure work*. This may be necessary where digital infrastructure efforts are dependent on short-term project support arrangements. Previous studies suggest that making considerations for sustainability, and starting to develop necessary structures and capacity for maintenance as necessary conditions for promoting institutionalization, maintenance, and continuity of introduced technological solutions (Kimaro and Nhampossa, 2005; Kimaro and Nhampossa, 2007; Ribes and Finholt, 2009; Lucas, 2008). Next, I reflect on strategies for developing implementation and maintenance capacity, in a context where the local Ministry of Health has poor IT capacity and is dependent on short-term project-based support arrangements.

6.2 Responding to Question 2: Institutionalizing Development of Implementation and Maintenance Capacity

The second question guiding this study is: *What strategies can improve implementation and maintenance capacity in the context of changing project-based support arrangements?*

Extant literature acknowledges that project-based arrangements are usually focused on near-term objectives, such as putting in place working technology within funded project time, at the expense of prolonged change processes and long-term maintenance (Markus, 2004; Kimaro and Nhampossa, 2005). Prevailing poor implementation and maintenance capacity, within the Ministry of Health, in Malawi, is in part a result of dependence on discretely arranged project-based interventions. To correct the persistent lack of implementation and maintenance IT capacity, and enhance prospects for institutionalization of novel technological solutions and ongoing digital infrastructure efforts, it is necessary that the Ministry of Health maintains an awareness of long-term objectives for HIS infrastructure development. In other words, the Ministry of Health should *think ‘infrastructure time’* (Karasti et al., 2010) and

account for short-term interventions as part of long-term biographies of digital infrastructure development (see: Pollock and Williams, 2010). Infrastructure time thinking anticipates consequences for future systems, and related responsibilities pertaining to growth, use, maintenance, modification, migration, and redesign (Karasti et al., 2010). With this way of thinking, short-term project based arrangements can be used to provide impetus for sustainable HIS infrastructure development. Looking at historical HIS efforts, conceptual awareness associated with infrastructure time thinking could have minimized short-term project-centric thinking in earlier failed HMIS efforts, such as the World Bank funded data review meetings, which faltered after project support was withdrawn (see section 3.4.1). For contemporary efforts, the Ministry of Health could utilize forums such as the mHealth Malawi forum and DHIS2 implementers meetings, to deliberate development of required IT capacity. Such forums could also be used to tackle challenges regarding resource allocation asymmetries and fragmentation of IT resources across projects.

Within the short-term, establishment of IT positions within the Central Monitoring and Evaluation Division (CMED) of the Ministry of Health, which is subject to painfully slow government bureaucracy, could be augmented with project-based IT support arrangements. This is in line with arguments from the continuing design perspective, which calls for augmenting long-term protracted processes, with temporary arrangements, to provide momentum in infrastructure efforts (Karasti et al., 2010). Engagement of a technical assistants (TA) to support DHISm and DHIS2 implementations, as part of this study, serves as an example of such an approach. Engagement of DHIS2 coordinators under changing project-based arrangements over time (HISP Oslo, I-TECH, CDC), is yet another example. Project-based support arrangements may also be necessary for long-term engagement TAs:

“when we create the positions we might not sustain them, because what they are getting now is equal to the salary of a Principal Secretary [highest ranking tenured civil servants at ministry level]” (manager, 2014).

Despite the above-mentioned benefits, recruitment of TAs with support from projects can be challenging. For example, it is critical that TAs engaged under such arrangements should work under the oversight of CMED, and with clear terms of reference. In the absence of such, there is a potential risk of side-lining CMED, if TAs deal directly with external funders. In the absence of clear protocols for reporting, the suggested hybrid arrangement might also put a strain on TAs, where there is need to report to both CMED and external funders. Another challenge with dependence on project-based arrangements for technical support is that they

are discretely arranged as and when funding is available, which may lead to periods with no funding to cover operations of TAs, as was evidenced in DHIS2 implementation efforts (see section 3.7). The study also documents periods of lean funding due to fall outs with donors (see sections 3.1; 3.5; and 4.2.7). Having established positions within CMED could provide a basis for drawing on government resources, to help offset the severity of such shocks.

Besides engagement of TAs, CMED could, over the long-term, also benefit from vibrant local organizations such as the newly established HISP Malawi, which is focused on providing HIS related IT support and capacity development. Such arrangements have proved beneficial and resilient elsewhere (Titlestad et al., 2009; Kimaro, 2006). Table 6-1 provides a summary of strategies on how CMED can enhance required IT capacity.

Table 6-1: Strategies for enhancing implementation and maintenance capacity

Principle	Actualizing
Embrace infrastructure thinking:	<ul style="list-style-type: none"> - addressing short-term project goals, as part of long-term goals for growth, maintenance, redesign - Engaging donors and other relevant stakeholders through existing coordination forums
Reduce shocks from intermittent project-based funding	<ul style="list-style-type: none"> - Reducing dependence on individual projects - Establishing IT positions within CMED
Adopt a hybrid approach to developing IT capacity: <i>Balancing project flexibility with slow government bureaucracy</i>	Augmenting slow government bureaucratic process of establishing IT positions with project-based support arrangements, within the short-term
Institutionalize engagement of technical assistants	<ul style="list-style-type: none"> - Having clear terms of reference for engaging technical assistants (TAs) - Having clear reporting structures for TAs
Work towards retention of tenured technical assistants	Augmenting government pay structure with project-based funding, where necessary, but with reduced dependence on discrete project-based financing
Build progressive IT support arrangements	Promoting development of and collaboration with local organizations with specialised IT capacity such as HISP Malawi

The idea behind the strategies above is not just to present a utopian laundry list of possible things to be done. Rather, the recommendations are meant to sensitize forward thinking and continued evaluation of efforts regarding development of implementation and maintenance capacity. A significant amount of practical work and alliance building with key stakeholders is necessary in order to actualize the recommendations above. Where local ministries of health face persistent financial and technical constraints, there might be need to have in place

hybrid funding arrangements, where resources are drawn from multiple partners (Kimaro, 2006). Next, I discuss how we can conceptually account for tensions to design, development, and maintenance of digital infrastructure.

6.3 Responding to Question 3: Conceptually Accounting for Tensions to Design, Implementation and Maintenance

The discussion in this section responds to the question: *How can we conceptually account for tensions to design, development, and maintenance of digital infrastructure?*

In responding to this question, I reflect on how existing perspectives inform accounting and negotiation of observed concerns and tensions to design, development, and maintenance of digital health infrastructure, within the context of study. It is in negotiating observed concerns and tensions that novel solutions are enacted and institutionalized to form viable infrastructural solutions. The discussion, mainly builds on the perspectives: bootstrapping (Hanseth and Lyytinen, 2010), continuing design (Karasti et al., 2010); the long now (Ribes and Finholt, 2009); grafting (Sanner et al., 2014). The discussion highlights strengths and limitations to these perspectives and how their combination may help address shortfalls in individual perspectives. The goal is to contribute towards discourse on developing frameworks that allow for more explicit and nuanced accounting of the emergence of digital infrastructure. At present, there is a dearth in frameworks that aid conceptualization of digital infrastructure (Tilson et al., 2010), especially negotiation of concerns that span multiple temporal scales, and related tensions (Karasti et al., 2010; Pollock and Williams, 2010). In addition, explicit accounting of concerns and tensions to digital infrastructure goes beyond stipulations of any singular perspective (Yoo et al., 2010).

Preceding discussions and presented empirical evidence suggest that attempts at enacting and institutionalizing novel solutions such as DHISm, necessitates negotiation of multiple concerns. Key concerns identified include: (i) *technology and implementation design*; (i) *growing demand-side adoption*, to achieve growth momentum; (iii) *negotiating control to parts of the installed base*, to influence infrastructure development trajectories (*supply-side control*); (iv) *long-term maintenance and continuity*. This range of concerns and related tensions seem inherent to digital infrastructure efforts, as can be evidenced from previous studies (Pipek and Wulf, 2009; Nielsen, 2006; Aanestad et al., 2014; Grisot et al., 2014; Karasti, 2014a; Sahay et al., 2009). The availability of appropriate frameworks to guide attempts to negotiate this range of concerns and related tensions is particularly critical to

digital infrastructure efforts that dependent on short-term and discretely arranged project support arrangements, as is the case in Malawi.

6.3.1 Technology and Implementation Design

In responding to question 1, I have argued in favour of *judicious designs* and *incremental development upon the installed base*, as ascribed by bootstrapping and continuing design (Karasti et al., 2010; Hanseth and Lyytinen, 2010; Aanestad and Jensen, 2011). Following conceptualizations by these perspectives provides room for learning and negotiation of breakdowns. For example, As previously discussed (Manda and Sanner, 2014), real-time application of the bootstrapping strategy provided our implementation team flexibility to adjust implementation strategy, negotiate breakdowns, and apply lessons learned from implementation work. At the same time, in I have also argued that application of bootstrapping has shown that the strategy might be lacking in guiding efforts where implementers have no control over key parts of the installed base, due to the presence of multiple stakeholders, with competing interests (Manda and Sanner, 2014; Sanner et al., 2014). Previous formulations of the strategy are from the perspective of a single/coherent group of stakeholders driving technology implementation and adoption. However, it is possible to have multiple loosely coordinated ‘bootstrappers’ working on different parts of an infrastructure, with little or no overlap in their day-to-day activities, as seen in DHIS2 and DHISm efforts. In addition to these limitations, bootstrapping’s implicit treatment of temporal scales might also compromise conceptualization of tensions that ensue in trying to attend to short-term exigencies to technology implementation, whilst trying to build persistent arrangements to support maintenance. Attending to both implementation challenges and development of IT capacity for maintenance, beyond our team’s involvement was key to DHISm efforts. Empirical material also suggests that, historically, continuity of HMIS efforts in Malawi has suffered from lack of long-term orientation. Bootstrapping could, then, benefit from pairing with continuing design (Karasti et al., 2010) and related concepts of *project time vs infrastructure*, which highlight temporal tensions, in project supported efforts. Continuing design (Karasti et al., 2010) also recognises a multiplicity of stakeholders working on different parts of the installed base, and suggests modalities for negotiating this (ibid).

6.3.2 Pursuing Demand-side Adoption

Presented findings also underscore the importance of technology adoption by target end-users, as a basis for successful integration of new technologies such as DHISm into the installed base of routine health data reporting. This is a common concern across the perspectives under

discussion here, which suggests *designing technology for immediate usefulness* (Hanseth and Lyytinen, 2010; Sanner et al., 2014; Karasti et al., 2010; Ribes and Lee, 2010). Nonetheless, of all these perspectives the bootstrapping strategy suggests more explicit principles on how to grow demand-side adoption (see table 6-2).

Table 6-2: Enhancing demand side adoption (Hanseth and Lyytinen, 2010)

Bootstrapping Principles
<ul style="list-style-type: none"> ▪ Target IT capability to a small group ▪ Make IT capability simple to implement and use ▪ Make IT capability directly useful without a large installed base ▪ Design for one-to-many IT capabilities in contrast to all-to-all capabilities ▪ Satisfy needs of the most motivated users first ▪ Minimize adoption barriers ▪ Expand installed base by persuasive tactics to gain momentum

In responding to question one, I have pointed out that growing adoption is not only subject to the mechanics of network economics (Hughes, 1987), as assumed by bootstrapping strategy. Implementers’ lack of control to key parts of the installed base might constrain their ability to continually respond to user demands and hence grow infrastructure. Thus, growing demand-side adoption is subject to both mechanics of network economics and distribution of control to key part of the installed base. This suggest a need to pair principles provided by the bootstrapping strategy and continuing design (Karasti et al., 2010), with considerations on how to negotiate control on the supply-side of digital infrastructure as suggested in the grafting perspective (Sanner et al., 2014). Grafting conceptualizes digital infrastructure innovation as involving pursuing and relinquishing control, to influence infrastructure development trajectories, through: (i) alliance building; (ii) actively searching for and possibly fashioning opportunities to get into positions of prominence; (iii) transferring the embodiment of control from individuals into institutional arrangements that can survive the involvement of individuals and specific projects; (iv) transitioning between adoption of temporary arrangements within the short-term, *to kick-start implementation efforts or address breakdowns*, and adoption of persistent arrangements that *facilitate institutionalization and continuity of implemented technologies* (Sanner et al., 2014). Previous studies also suggest that control over key parts of an installed base impacts stakeholders’ ability to put in place desired infrastructural solutions, considering that infrastructure is political and contested (Jansen and Nielsen, 2005; Elaluf-Calderwood et al., 2011; Tilson et al., 2010).

6.3.3 Enacting and Institutionalizing Technology

Building infrastructure entails ongoing practical work (Pipek and Wulf, 2009; Aanestad et al., 2014). Although initial technology implementation is likely to take place within funded project time, the work of enacting and institutionalising technology is likely to continue beyond individual project-based arrangements. This can be evidenced from DHIS2 and DHISm efforts, as well as other historical HMIS strengthening efforts in Malawi, in the period 1999 to 2014. Consequently, it would be helpful to have perspectives that conceptualize ongoing negotiation of tensions from combining short-term implementation concerns and the protracted work of enacting and institutionalizing technology. The long now (Ribes and Finholt, 2009) and continuing design (Karasti et al., 2010) perspectives could act as appropriate sensitizing lens to this end. The long now perspective offers a basis for conceptualizing dimensions infrastructure work (*enacting technology, organising work, institutionalizing*), concerns for sustainability (*aligning end-goals, motivating contribution, designing for use*), and related *tensions* (Ribes and Finholt, 2009; Richter, 2011). Beyond this, paper 5 (Manda, 2015) highlights limitations to the long now perspective, in that other than guiding categorization of infrastructure work and related tensions, it is limited in accounting for and explicating actual practices implicated in negotiating identified tensions. This position is also advanced by Karasti et al. (2010). This is where pairing of the long now and continuing design comes in handy – see paper 5 (Manda, 2015). For example, use of the *concepts project time vs infrastructure time* (Karasti et al., 2010) foregrounds the tension of responding to issues of here-and-now, such as attending to breakdowns, and putting in place persistent technical support arrangements, through drawing up terms of reference for recruiting technical assistants (TAs) and recruiting TAs. Earlier on, I advanced an argument on how conceptual awareness associated with the continuing design perspective could have benefited earlier HMIS strengthening efforts, which began to fail after the withdrawal of initial project-based support (see section 6.2). The long now could also be paired with bootstrapping or the grafting perspective, as there are some overlaps between these perspectives.

6.3.4 Extending the Long now Perspective: Adding a Dimension on Developing IT Capacity

As mentioned in the previous sub-section, the long-now perspective (Ribes and Finholt, 2009) goes a long way in conceptualizing practical infrastructure work and concerns for sustainability. Despite this, I am of the view that the perspective could benefit from an additional concern for sustainability – *developing IT capacity*, as suggested in paper 5 (Manda, 2015) and depicted in table 6-3.

Table 6-3: Extending the long now perspective

Concerns for sustainability	End-goals	Scales of II work			
		Enacting Technology	Organising Work	Institutionalizing	
Aligning	End-goals	Inclusion Vs. Readiness	Planned Vs. Emergent	Project Vs. facility	
Motivating		Research Vs. Production	Research Vs. Maintenance	Individual Vs. Community	
Contributing		Today's Vs. Requirements	Research Vs. Development	Communities Vs. Constituencies	
Designing for Use		Today's Vs. Tomorrow's Users			
Developing Capacity	IT	<i>End-user action vs. end-user support</i>	<i>Fragmented vs. shared IT support</i>	<i>Project flexibility vs. bureaucratic discipline</i>	

The proposed extension to the long now perspective might enhance its applicability to contexts with sparse IT capacity, such as Malawi. Other studies underscore the significance of developing IT capacity at both user and organizational level, to aid technology adoption, use, maintenance, and evolution (Kimaro, 2006; Lucas, 2008).

So far in this section, I have pointed at aspects of digital health infrastructure efforts documented herein and application of the following perspectives in theorizing the same: bootstrapping (Hanseth and Lyytinen, 2010), continuing design (Karasti et al., 2010); the long now (Ribes and Finholt, 2009); grafting (Sanner et al., 2014). I have also endeavoured to highlight limitations to individual perspectives, and possibilities for combining the perspectives. Next, I conclude this section by summarizing how the perspectives can be combined. In doing this, I advance a framework that combines aspects of the perspectives above, in relation to the question: *How can we conceptually account for tensions to design, development, and maintenance of digital infrastructure?*

6.4 Towards Integrated Perspectives for Theorizing Digital Infrastructure Efforts

The perspectives reviewed can be combined, with the extended long now perspective providing a foundation for conceptualizing the digital infrastructure problem space and temporal tensions. Continuing design, then, goes a step further in highlighting and explicating temporal tensions, through the concepts *project time vs infrastructure time*, which arise from attending to concerns that span multiple temporal scales, within funded project time. These concepts are particularly useful in deliberating digital infrastructure efforts in the context of loosely coordinated and discretely arranged interventions, as is the case in Malawi. This view is complemented by bootstrapping and grafting, which also seek to conceptualise how digital

infrastructures emerge, be it with some differences in emphasis. Bootstrapping provides more explicit design principles on how to grow demand-side adoption. In turn, it gains explicit treatment of temporal scales, and concepts on how to conceptualize temporal tensions, through pairing with the long now and continuing design perspectives. Grafting provides conceptualization of implications of power asymmetries, distributed control to parts of the installed base, and the pursuit of control for such. The subject of control is under theorised or not covered in bootstrapping, continuing design and the long now perspectives. Table 6-4 presents a summary of how the perspectives can be combined.

Table 6-4: Proposed integrated framework

Perspective	Contributes	Gains
Long now	Conceptualization of infrastructure design problem space – dimensions of <i>infrastructure work and concerns for long-term sustainability</i>	More nuanced strategies and explicit accounting of practices in enacting and institutionalizing technology Conceptualization of pursuit for control on the supply-side
Continuing design	<ul style="list-style-type: none"> Concepts: <i>project time vs. infrastructure time</i> Treatment of short-term vs. long-term tensions as points for innovation 	<ul style="list-style-type: none"> Conceptualization of pursuit for control on the supply-side Additional principles from bootstrapping
Grafting	<ul style="list-style-type: none"> Foregrounding power asymmetries pursuit of control distributed among stakeholders 	Conceptualization of problem space for digital infrastructure – <i>dimensions of infrastructure work and concerns for long-term sustainability</i>
Bootstrapping	<ul style="list-style-type: none"> Explicit design principles for: (i) technology intervention design; (ii) pursuing demand-side adoption 	<ul style="list-style-type: none"> Implicit treatment of temporal issues, especially the long-term Conceptualization of pursuit for control on the supply-side

Next, table 6-5 depicts the proposed integrated framework, which draws aspects from bootstrapping (Hanseth and Lyytinen, 2010), continuing design (Karasti et al., 2010); the long now (Ribes and Finholt, 2009); grafting (Sanner et al., 2014).

Table 6-5: Proposed integrated framework for digital infrastructure

Concerns/Tensions	Principles/concepts	Basis
Scales of infrastructure work	enacting technology; organizing work; institutionalizing	Long now (Ribes and Finholt, 2009)
Concerns for sustainability	aligning end-goals; motivating contribution; designing for use; developing IT capacity	All four perspectives; Empirical findings (Manda, 2015)
Explicating temporal tensions	project time vs. infrastructure time development, maintenance and redesign in mind	Continuing design (Karasti et al., 2010)
demand-side adoption	<ul style="list-style-type: none"> ▪ target IT capability to a small group ▪ make IT capability simple to implement and use ▪ make IT capability directly useful without a large installed base ▪ design for one-to-many IT capabilities in contrast to all-to-all capabilities ▪ satisfy needs of the most motivated users first ▪ minimize adoption barriers ▪ expand installed base by persuasive tactics to gain momentum 	Bootstrapping (Hanseth and Lyytinen, 2010)
Supply-side control	<ul style="list-style-type: none"> ▪ building alliances ▪ searching for and fashion opportunities to get into positions of prominence ▪ transferring control from individuals into institutional arrangements – long-term continuity ▪ transitioning between temporary and persistent arrangements, to accommodate short-term and long-term concerns 	Grafting (Sanner et al., 2014)

The relevance of this framework has been portrayed through application of its parts in the preceding discussions, thought this chapter. The proposed combination of perspectives might lessen biases resulting from application of singular perspectives, thereby contributing towards addressing the dearth in frameworks that aid nuanced conceptualization of how digital infrastructures emerge (Pollock and Williams, 2010; Karasti et al., 2010; Yoo et al., 2010):

“Infrastructure is “large” spanning time and space, but it is also “small” coming in contact with routine and everyday practice. Thus, infrastructure studies require drawing together methods that are equal to the ambitions of its phenomenon” (Bowker et al., 2010: pp. 113)

“there is an urgent need to develop approaches, methods and tools for collaborative infrastructure development that would allow for and support different temporal orientations to ensure effective and productive collaborations” ([Karasti et al., 2010: pp. 404](#))

It is hoped that the framework advanced herein goes some way in addressing concerns raised in the quotes above. Next, I conclude this thesis by presenting a summary of theoretical and practical contributions made herein.

6.5 Summary of Contributions and Implications to Theory and Practices

This thesis makes the three contributions to theory and practice. *First*, the thesis contributes towards conceptualization of concerns and tensions to design, implementation, and maintenance of digital infrastructure, whose negotiation aids enacting and institutionalizing of novel solutions. *Second*, the thesis contributes to discourse on mHealth, through consideration of how dynamics within the larger HIS context, interplay with mHealth interventions. *Third*, the thesis suggests strategies for enhancing IT implementation and maintenance capacity, in the face of changing project-based support arrangements. The papers that are part of this thesis also contribute to literature, either by extending on existing perspectives or proposing new perspectives on theorizing digital infrastructure.

6.5.1 Theoretical Contribution – Conceptualizing Concerns and Tensions to Digital Infrastructure

The thesis advances a framework that draws on existing perspectives on temporality, to inform theorizing of concerns and tensions to digital infrastructure design, implementation and maintenance. The thesis applies the perspectives: bootstrapping (Hanseth and Lyytinen, 2010); long now (Ribes and Finholt, 2009); continuing design (Karasti et al., 2010); grafting (Sanner et al., 2014). The perspectives are applied to guide conceptualization and possible negotiation of concerns and tensions relevant to this study: *technology and implementation design; growing demand-side adoption; enacting and institutionalizing technology; negotiating supply-side control; long-term maintenance and continuity*. Through this analysis, the thesis identifies that individual perspectives are suited to informing parts of observed phenomena, but may also benefits from combination with other perspectives. The framework advanced allows for analysis of the above-mentioned concerns that span multiple temporal scales. It combines incremental and long-term views to digital HIS infrastructure development, to accommodate emergent nature of digital infrastructure, as well as implications of long-term concerns on actions in the here-and-now. The proposed framework responds to the call for an

analytical shift from a ‘discrete systems’ to an ‘infrastructural’ perspective and the need to explore long-term biographies rather than isolated moments and sites of change (Pollock and Williams, 2010; Karasti et al., 2010), which demands a combination of methodological tools and approaches (Yoo et al., 2010; Bowker et al., 2010). Aside from responding to the above expressed concerns for frameworks to further our understanding of digital infrastructure, the framework proposed in this thesis could be of relevance to concerns and questions posed or reflected upon by previous studies on digital infrastructure design: *how different elements developed across time and space, are combined and natured* (Monteiro et al., 2014; Hanseth and Lyytinen, 2010); *conditions necessary for digital infrastructure growth and evolution* (Grisot et al., 2014); *activities that span before-use-design and design-in-use of infrastructure* (Pipek and Wulf, 2009); *how to transition novel IT offerings into viable infrastructures* (Hanseth and Lyytinen, 2010).

6.5.2 Theoretical Contribution – Contributions to mHealth Literature

In considering mHealth interventions within the context of larger HIS efforts, this thesis contributes to mHealth literature in highlighting the complexity of introducing such solutions and attempting to integrate them into existing socio-technical installed bases. In doing this, the thesis highlights possible solutions to addressing challenges encountered. Previous research suggests that mHealth interventions largely ignore dynamics within larger existing HIS setups, to their own detriment, as a majority of challenges facing mHealth go beyond mHealth itself (Leon et al., 2012). There is need to take into account work practices; heterogeneous artefacts in use; technological platforms; financial, implementation, and maintenance capacity (Braa and Nielsen, 2013; Leon et al., 2012). This thesis, then, contributes towards the emerging discourse on taking an ecological perspective, which embraces and deliberates the above-mentioned elements in designing, implementing, and maintaining of mHealth solutions.

6.5.3 Practical Contribution: Strategies on how to enhance and institutionalize implementation and maintenance capacity

The thesis advances strategies on how to develop implementation and maintenance capacity where efforts to develop digital health management information systems must build on agile, but short-term project-based support arrangements, and slow and bureaucratic government structures. The thesis advances six principles in relation to this: (i) embrace long now (infrastructure time) thinking; (ii) reduce shocks from intermittent project-based funding,

through mobilizing long-term government support; (iii) adopt a hybrid approach to developing IT capacity - balancing project flexibility with slow government bureaucracy; (iv) institutionalize engagement of technical assistants, who are often engaged on project-based arrangements; (v) working towards retention of tenured technical assistants; (vi) building progressive IT support arrangements, through collaboration with, and establishment of, organizations focused on providing and developing specialised HIS-related IT capacity.

Through consideration of the importance of IT capacity in guiding implementation, use, and maintenance of digital infrastructure, the thesis also extends on the long now perspective, proposing an additional concern for sustainability – *developing IT capacity*. The propositions made herein, could enhance prospect for long-term maintenance and continuity of infrastructure, as previous studies point at maintenance as a challenge in digital health infrastructure (Kimaro, 2006; Pollock and Williams, 2010; Sheikh and Braa, 2011).

Chapter 7: Conclusion

This thesis contributes to discourse on temporality in digital infrastructure, covering activities at enacting and institutionalizing technology, as well as organizing infrastructure work. The thesis suggests a framework that combines existing perspectives on temporality in infrastructure, to aid conceptualization and negotiation of concerns and tensions to design, implementation, use, and maintenance of digital infrastructure. Literature suggests that although digital infrastructures, such as HIS, unfold over extended periods of time and are meant for long-term use, their development is reliant on project support arrangements (Ribes and Finholt, 2009; Edwards et al., 2007; Kimaro and Nhampossa, 2005). However, project-based arrangements are less focused on long-term change processes, such as maintenance and redesign of infrastructure. Rather, they are often short-term focused and aim at demonstrating successful implementation of technology at the end of funded project time (Karasti et al., 2010; Markus, 2004). The mismatch between the extended periods over which digital infrastructures unfold and are meant to be used, and inherent short-term thinking associated with project-based support arrangements poses several challenges to digital infrastructure efforts. First, it leads to piecemeal development of infrastructure, which results in solutions that are difficult to evolve and do not respond to changing user needs (AbouZahr and Boerma, 2005). Second, it may be challenging to develop capacity for maintenance of implemented technology, which weakens prospects for institutionalizing novel solutions (Karasti et al., 2010; Kimaro, 2006). To address such challenges, there are calls to blur boundaries between design, implementation, use, and maintenance of digital infrastructure (Ribes and Finholt, 2009; Karasti et al., 2010; Edwards et al., 2013; Pollock and Williams, 2010; Blomberg and Karasti, 2013). The idea is to prompt long-term thinking by accounting for short-term interventions as part of long-term processes.

Despite efforts to encourage long-term thinking, recent studies indicate a lack of frameworks that guide conceptualization and negotiation of concerns and tensions to design, implementation, and maintenance of infrastructure, which span multiple temporal scales (Bowker et al., 2010; Pollock and Williams, 2010). Other scholars have also called for a combination of perspectives, arguing that the expanse of concerns in digital infrastructure goes beyond the provisions of any singular perspective (Bowker et al., 2010; Yoo et al., 2010; Pollock and Williams, 2010).

The thesis also discusses conditions to enacting and integrating novel mobile technology solutions into an existing installed base of routine health data reporting. The thesis deliberates the interplay between novel mobile technology solutions, the existing installed base of existing practices and artefacts in use, as well as efforts of multiple stakeholders, with often competing interests. Recent studies indicate a lack of concrete analysis on how heterogeneous elements of digital infrastructure (developed at different times and places) are combined and carried forwards (or not) (Monteiro et al., 2014). In discussing mHealth interventions in light of dynamics within the larger HIS context, the thesis also contributes towards addressing calls for an ecological approach to mHealth, which accounts for interacting heterogeneous practices, artefacts, stakeholders, and other organizational support structures, within mHealth interventions (see: Leon et al., 2012; Braa and Nielsen, 2013).

The thesis also suggests strategies on how to develop IT implementation and maintenance capacity. This is meant to guide HIS infrastructure efforts in the context of loosely coordinated project-based support arrangements and slow, bureaucratic, government structures, which make long-term engagement of IT experts challenging. Although development of such strategies is based on empirical findings from Malawi, the strategies could be of relevance elsewhere. Studies from other African countries indicate challenges in trying to build capacity for maintenance in the context of weak public administration and reliance on donor funded project support arrangements (Kimaro and Nhampossa, 2005; Kimaro, 2006; Kimaro and Nhampossa, 2007).

7.1 Further Research

Further research is necessary to test applicability of the theoretical framework advanced herein, in a different empirical setup. It would be interesting to look at what concerns from those discussed herein are dominant across contexts and what the resultant impact would be regarding application of the conceptual framework on digital infrastructure advanced herein.

Following up on the interest in long-term maintenance and continuity of digital infrastructure beyond initiating project-based arrangements, it is necessary that the mHealth initiatives discussed herein be studied for an extended period of time.

Going forward, the insights provided in this study could be strengthened further, by pairing the theoretical lens discussed herein, with concepts from institutional theory, especially the institutional logics perspective (Thornton and Ocasio, 2008; Thornton et al., 2012) and the capability approach (Sen, 1999).

7.1.1 Possible Insights for Institutional Theory – Institutional Logics

The thesis brackets deep institutional relations, power for example, and logics that guide the workings of government agencies such as the Ministry of Health, as well as how donors relate with government agencies and amongst themselves. In discussing attempts at institutionalizing technological solutions and the participation of independent stakeholders, I lean more towards the practical and organizing aspects of achieving such. I do not discuss in great detail historical institutional motivations that shape prevailing project-based funding infrastructure. Rather, I focus on how we may build long-term digital infrastructure given prevailing funding infrastructure. We are likely to achieve more insights to guide both the practice and theory of developing digital infrastructure, through unpacking deep sitting and possibly changing institutional logics that shape intra and inter organizational stakeholder relations, material practices, and funding infrastructure, to impact development of digital infrastructure. Unlike the case with a majority of previous studies, it is necessary that concepts from institutional theory, such as institutional logics, be applied in combination with those from extant literature on digital infrastructure.

The institutional logics perspective combines macro-historical structures, agency, and multi-level processes (society, inter-organizational, organizational, individuals), in explaining how institutions, which form the basis guiding how organizations and individuals operate, enable and constrain decisions and action (Thornton et al., 2012). Institutional logics can be defined as “the socially constructed, historical patterns of cultural symbols and material practices, including assumptions, values, and beliefs, by which individuals and organizations provide meaning to their daily activity, organize time and space, and reproduce their lives and experiences” (Thornton et al., 2012:pp 2). Thus, Institutional logics provide the formal and informal rules of action, interaction, and interpretation that guide and constrain decision makers in accomplishing organizational tasks (Ocasio, 1997).

Recent studies are indicative of the relevance of the institutional logics lens in studying HIS (Asangansi, 2014; Asangansi, 2012; Sanner and Sæbø, 2014; Sahay et al., 2010; Currie and Guah, 2007). In analysing HMIS implementations in Nigeria, Asangansi (2014) argues that the capitalist market institution “cascades down and is expressed as a tendency for HMIS project funders to calculate return on investment and be more interested in manageable short term projects ...rather than long-term broad system commitments” (ibid :pp. 26). In a similar vein, Sanner and Sæbø (2014) argues that years of donor focus on short-term impact-centred project evaluations, have resulted in projects progressively paying out high per diems, to

attract participation and demonstrate impact. Over time, this practice has created expectations for pay among target user groups, for them to support project work, resulting in a self-reinforcing dynamic between per diems and participation, which threatens realization of long-term objectives for digital infrastructure. On the basis of their study, Sanner and Sæbø (2014) contend that capacity building and sustainability challenges are not easily resolved within the scope of a single project, but should be considered within the dynamics of the broader institutional landscape and development interventions. Sahay et al. (2010) apply the institutional logics perspective to elucidate challenges and possibilities for change in HMIS implementation, stemming from contradictory institutional logics. Focusing on HMIS efforts in Tajikistan, their narrative centres on interplay between policies of existing institutions left behind by Soviet legacy which favoured a centralized planning model, and propositions by consultants, introducing computer-based HMIS that pushed for local decision-making through a decentralized system for collecting, processing, and analysing primary healthcare data.

In sum, consideration of institutional logics elucidates opportunities and challenges for constructing explanations, narratives and vocabularies of practice to navigate or modify established motivations, relations and practices, and possibly create new ones (Asangansi, 2014).

7.1.2 Strengthening Human Infrastructure: Possible Insights from the Capability Approach

Beyond the discussions in this thesis, further research might want to consider a broader and detailed analysis of longitudinal developments regarding human infrastructure - *the people, organizations, and networks required to prototype, integrate, harden, and nurture infrastructural solutions* (Lee et al., 2006) – through the lens of the *capability approach* (Sen, 1999; Sen, 1990). HMIS interventions in Malawi and similar resource constrained countries are generally tagged as “*HMIS strengthening*” (which has connotations of a developmental agenda), yet the continued fragility of registered gains beyond initiating project interventions, suggests a challenge beyond the short-term vs long-term tensions, resulting from prevailing funding infrastructure. Beyond attempts at trying to provide novel ways of communicating health data, there seems to be a general disregard of developing digital infrastructure in a manner that builds organizational and individuals’ capabilities, to self-determine what solutions best address their needs, as well as how implemented solutions should be maintained, nurtured, or be replaced.

The capability approach affords an evaluation of the interplay between human agency and institutional arrangements (Zheng, 2009). The approach considers what people are effectively able to do and to be (“doings and beings”) – termed functionings - as constitutive elements of living and it relates the evaluation of the quality of life to the assessment of the capability to function (Sen, 1990). The capability of a person is seen as a combination of various different functionings (a “functioning n-tuple”) he or she can achieve. Included items may vary from elementary functionings such as escaping morbidity and mortality, to complex functionings such as achieving self-respect and actively taking part in the life of a community (ibid).

Scholars have applied the capability approach in investigating the impact of technological solutions on target user groups, providing a framework of thought to locate technological adoption in the bigger context of development, as means rather than ends (see: Kleine, 2010; Zheng, 2009; Zheng, 2007). In considering the capability approach we may be able to reflect on questions such as: (i) What conditions enable or restrict the “agency” of ICT adopters?; (ii) What are the needs and aspirations of potential ICT adopters? (Zheng, 2009). In the end, in looking at broader aspects of human infrastructure and prevailing institutional arrangements, we can inform policy and practice, to avoid occurrences where supposed HMIS strengthening efforts keep going in circles, chasing the same objectives, yet not achieving desired objectives regarding enhancing human capabilities (desired beings and functionings). The capability approach has also been paired with the institutional perspective, to operationalize it in theorizing ICT (Bass et al., 2013).

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Appendices

Appendix 1: Paper 1

MANDA, T. D. & HERSTAD, J. (2015). Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-Based Data Reporting Practices. *Information Technology & People*. **Forthcoming**

Enacting Technology: Accounting for the Interplay between mHealth Solutions and Existing Paper-based Data Reporting Practices

Introduction

The implementation of ICTs to support healthcare delivery and management in sub-Saharan Africa has often been hampered by poor communication and electricity infrastructure, lack of resources, and insufficient political commitment and support (Bukachi and Pakenham-Walsh, 2007). At the same time, the need for effective communication infrastructure to support generally under-served rural populations is getting even stronger. Although negotiation of the above-mentioned challenges requires a combination of approaches, mobile telephony seems better suited to overcoming challenges pertaining to poor telecommunications and electricity infrastructure (Bukachi and Pakenham-Walsh, 2007; Shoji et al., 2012). Based on these qualities and its ubiquity, mobile telephony, provides an imperative to re-envision health data collection and communication in rural areas (Chigona et al., 2012; Sanner et al., 2012; Shoji et al., 2012; Asangansi et al., 2013).

Previous studies on technology use demonstrate that application of technology to achieve set goals demands more than action possibilities afforded by individual technological artefacts (Pentland and Feldman, 2008). There is need for ongoing adjustments to technology and practice, within a changing context of use (Aarts et al., 2004; Ackerman et al., 2012). In the case of mobile technology, it matters how mobile devices can be used together with other resources (pen and paper, etc.) as individuals often draw on a wide range of resources when trying to accomplish something (Jones and Marsden, 2006). Within organizations, individuals' work tasks demand different resources, are part of a larger system of tasks, and their accomplishment is dependent upon connections and relationships with other tasks (Gasser, 1986). Consequently, *new technologies are enacted*, i.e. made sense of, designed, and used through human action and the mediation of organizational and institutional arrangements (Fountain, 2001: pp. 12; Rose and Jones, 2005; Ackerman et al., 2012). Thus, designing artefacts whilst hoping for patterns of action is fallacious (Pentland and Feldman, 2008). Technologies can be enacted in unanticipated ways, some of which are undesirable and paradoxical (Arnold, 2003; Jarvenpaa and Lang, 2005; Jamison et al., 2013). In light of such dynamics, various researchers have called for the theorization of ICTs to enable an understanding of critical implications associated with their use by individuals and society (see: Monteiro and Hanseth, 1995; Orlikowski and Iacono, 2001; Sein and Harindranath, 2004).

Although positions on how to theorize human-technology interplay vary considerably, the core idea that concerns us here is that by privileging either the technology or the social, we lose sight of their situated intermingling. However, in studying the situated intermingling of technology we must do so without overlooking the particularities of interacting elements (Orlikowski, 2005; Rose and Jones, 2005). Various technologies have different affordances, i.e. possibilities for action available to humans (Gibson, 1979: pp. 127), which allow particular technologies to be implicated in human action in unique ways from other

technologies. For example, “no amount of translation will turn a toaster into a cell phone” (Pentland and Feldman, 2008: pp. 243).

The goal for this paper is to contribute to the debate on theorizing of artefacts and their enactment, realizing “what is ‘novel’ about ‘new’ organizational practices are not the ‘new’ practices themselves, but the way they interact with traditional organization practices” (Dunford et al., 2007: pp. 39). Empirically, we draw upon implementation and enactment of mobile phone-based tools for routine health data reporting, between health facilities and a district health office, in Malawi. In Malawi, data reporting between health facilities and district health offices has traditionally been paper-based. Although highly functional, paper-based reporting is beset with challenges pertaining to transportation of paper-based reports. Transportation of paper reports is particularly challenging for rural health facilities where roads are unpaved and in poor condition during the rainy season. Options for transportation are also very limited, resulting in health facilities sending in reports using whatever means is available (ambulance drivers, patients, etc.). In such a setup, it is not uncommon for reports to go missing or remain undelivered for months. Although at first glance it appears that mobile phone solutions are best placed to correct these challenges, through enabling remote communication of data, their operationalization requires significant practical work. Pen and paper cannot be easily done away with. Pen and paper have traditionally been at the heart of data collection during service delivery and related aggregation. Consequently, it is certain that implemented mobile phone solutions and paper-based tools and practices will coexist for some time to come.

In line with the above-stated goal, our narrative centres on emergent outcomes of the situated intermix between humans, mobile phone-based and paper-based solutions, across different stages of data reporting: compilation, transportation, digitization, delivery of feedback. Often, studies on mobile technology largely dwell on capabilities of mobile devices as if that is all that matters (Braa and Nielsen, 2013). Our guiding question is: how do mobile phone solutions interplay with existing paper-centric tools and practices in routine health data reporting?

By accounting for the above-mentioned factors we are better placed to account for what parts of the existing socio-technical setup need to be maintained and those that are problematic and require modification. Where technology-supported changes are required, it is possible to better determine where and how to introduce new artefacts. There is also an opportunity to discover exciting, but often overlooked ways in which implemented technologies fit the use case at hand, and can be theorized. For example, in this paper we see that contrary to the general focus on mobile phones as tools for supporting people on the move, their relevance might actually be found in reducing people’s mobility. Such is especially the case where mobile phones are used to replace physical transportation of reports.

The rest of this paper is organized as follows: the next section presents a review of related studies and the theoretical approach adopted for this paper. This is followed by a presentation

of the research methodology employed. Thereafter, the empirical findings are presented and discussed. Finally concluding remarks are provided.

Related literature

In this section, we review literature on mobility, technological affordances, and technology enactment.

Mobile Phones and Mobility

Oxford dictionaries define mobility as “the ability to move or be moved freely and easily” (Oxford Dictionaries, 2013). In information systems, the concept of mobility has been applied in studying the mobility of individuals and technological artefacts, especially in relation to implications of their interaction (Luff and Heath, 1998; Kristoffersen and Ljungberg, 1999). Although various artefacts, such as desktop computers can be moved, mobile technologies are categorized as those specifically designed to support use, whilst on the move (Weilenmann, 2003). Previous studies have focused on: how to provide individuals on the move with access to remote resources (Kristoffersen and Ljungberg, 1999) and local collaboration and mobility (Luff and Heath, 1998; Kristoffersen and Ljungberg, 1999). Scholars have also studied situations where people move as the activity occurs (‘truly mobile work’) (Weilenmann, 2003) and collaboration in everyday life (Weilenmann, 2003; Jarvenpaa and Lang, 2005). Weilenmann (2003) provides a categorization of studies on mobility based on core concerns addressed (see table 1).

Table 1: Views on Mobility – Adapted from (Weilenmann, 2003: pp. 23)

Beyond the above-depicted categorizations scholars need to be more concerned about what categories or issues of mobility, i.e. physical movement or positioning, are relevant for the actors, involved in the activity in focus (Weilenmann, 2003).

Affordance

Gibson (1979) defines affordance as a relationship between an animal and its environment. He states that “ the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill.” (Gibson, 1979: pp. 127). Three fundamental properties of affordance include: (i) an affordance exists relative to the action capabilities of a particular actor. For example, a horizontal, flat, extended, and rigid surface (relative to the weight and size of an animal) affords support; (ii) the existence of an affordance is independent of the actor’s ability to perceive it; (iii) an affordance does not change as the needs and goals of the actor change (Gibson, 1979; McGrenere and Ho, 2000).

Over the years, the concept of affordances has been widely applied in design studies, especially human computer interaction (HCI). Application of the concept in this field has been noted to varied and erroneous in some cases (McGrenere and Ho, 2000). For example, the definition of affordances by Norman (Norman, 2002) deviates from Gibson’s. Norman has however clarified that what he intended to advance was the notion of perceived affordances (Norman, 1999). McGrenere and Ho (2000) argue that returning to a definition close to that of

Gibson's would solidify the concept. In this paper we build on the definition provided by Gibson.

Paper: Its affordances and limitations

Organizational work practices have often evolved hand in with the use of paper (Newman and Wellner, 1992; Sellen and Harper, 2003). Paper has been very much at the centre of collaborative work due to its affordances. First, its use can be easily interwoven with other activities. Second, paper allows for easy direct marking, viewing of information at a glance, and flexibility in spatial layout, to draw attention to particular pieces of information (Sellen and Harper, 2003). Third, paper can provide large, inexpensive, high-resolution display surfaces (Guimbretière, 2003). In addition, paper is a primary means of capturing information for most people, due to its portability, tangibility, ubiquity, and familiarity (Newman and Wellner, 1992; Stifelman, 1996; Guimbretière, 2003).

On the flipside, paper is a static medium that is difficult to edit, search or index, is expensive to duplicate and distribute, and is expensive to archive (Guimbretière, 2003). Although well suited to collocated interaction, paper cannot support instantaneous remote communication (DeRenzi et al., 2011; Ganesan et al., 2011). It is down to such limitations that mobile technologies such as mobile phones have increasingly become integrated into people's business and social lives.

Mobile Phones: Affordances, application in healthcare, and limitations

The application of mobile technology to healthcare is commonly referred to as mHealth (Istepanian et al., 2004). Mobile phones have been widely applied in mHealth due to their ubiquity and suitability to areas with generally poor electricity infrastructure (Shozi et al., 2012). In addition, compared to paper, mobile phone applications can support instantaneous remote data communication (DeRenzi et al., 2011; Ganesan et al., 2011). The use of mobile phones to send data to remote servers may also reduce: transportation costs, the number of data entry stages and related transcription errors, and data-entry workload for those charged with consolidation of reports (DeRenzi et al., 2011; Ganesan et al., 2011). Furthermore, mobile phone applications for data collection may have logic for data validation embedded, to enhance data quality (DeRenzi et al., 2011).

However, just as with paper, the application of mobile phones solutions is not unproblematic. Known challenges include: small screen sizes and inconvenient text input, even for devices with QWERT keyboards (Shudong and Higgins, 2006). Maintenance and operation of handsets can also be challenging, due to end-users' lack of familiarity with electronic data submission (DeRenzi et al., 2011; Ganesan et al., 2012). Often, there are also difficulties in leveraging fragmented software platforms, due to the increased overhead of coordination and communication (DeRenzi et al., 2011). The sharing of phones, where need be, may also be problematic. Mobile phones are personal devices by design and also in how they render themselves to use (Jones and Marsden, 2006; Ballard, 2007). Compared to paper, mobile phones are more cumbersome at supporting tasks such as note taking (Jones and Marsden, 2006). Finally, while pen and paper do without electricity, mobile phones require electricity

for charging batteries. Considering the affordances and limitations of both paper and mobile phones, we argue that it is worthwhile using the technologies in a complementary manner, to support work practices.

Technology enactment and organisational change

It is expected that organizations will continue to change as new generations of information technology emerge. However, the engagement between technology and organizations is not unidirectional, where only technology shapes organizations. Rather, information technology and organizations engage dialogically, with each affecting and transforming the other in an emergent fashion (Jones, 1999; Robey and Boudreau, 1999; Fountain, 2001; Aarts et al., 2004). Beyond technological capabilities, technology supported organizational change requires people who are willing to utilize technology in particular ways. There is also need for new processes, behaviours, and rules on how things are done (Fountain, 2001; Markus, 2004). In the end, technology enactment is a combination of technology design and implementation together with stakeholders' perception and reflective use of technology within given socio-material conditions which are both context and outcomes of this interaction (Fountain, 2001; Orlikowski, 2005; Rose and Jones, 2005). Activities undertaken in enacting technology can be considered as bridge building between experimental and production systems or design intents and user requirements (Ribes and Finholt, 2009).

People can individually or collaboratively enact technologies in different ways, which produce novel and unanticipated consequences (Boudreau and Robey, 2005). Resulting from this, the ability of information technologies to enable radical change may be limited if information technologies are enacted in ways that were unintended (Boudreau and Robey, 2005; Pentland and Feldman, 2008; Ackerman et al., 2012). Technology, in turn, may shape human action, as well as organizations and institutions to better conform to its logic (Fountain, 2001; Rose and Jones, 2005). Overall, outcomes of such interplay are not sequential and direct, but complex, emergent, and with unpredictable (Fountain, 2001; Arnold, 2003; Jarvenpaa and Lang, 2005; Rose and Jones, 2005).

Approaching Theorizing of Technology Enactment

Theoretical understanding of technology enactment is important in order to understand how particular technologies are implicated in organizational change (Fountain, 2001; Markus, 2004; Rose and Jones, 2005; Jamison et al., 2013). Theorization of technology enactments should account for: (i) *properties* of human and material agency; (ii) the socio-technical *conditions* for human-technology interaction, which are both context and outcomes of such interaction (Rose and Jones, 2005); (iii) the *process* of human-technology interaction over time, as mediated by existing and emergent socio-technical context (Fountain, 2001; Rose and Jones, 2005). Figure 1 depicts a framework for analysing situated human-technology interaction, based on these three elements.

Figure 1: Human-Technology Interaction – Adapted from (Rose and Jones, 2005)

Here, technology is viewed as “an ingredient in a more complex process of social change, in which forces for transformation are frequently offset by forces of persistence” (Robey and Boudreau, 1999: pp. 182). Thus, technology can simultaneously support the forces of either persistence or transformation (ibid). Being open to such irony allows access, through empirical observation, to the reconstitutive qualities of technology, rather than technology’s instrumental qualities (Robey and Boudreau, 1999; Arnold, 2003).

Accounting for the factors depicted in figure 1 permits understanding of: (i) the influence of both legacy systems and a decision maker’s perception of challenges relating to existing legacy systems; (ii) the influence of both decision makers and new information technologies on the trajectory of the organization; (iii) “the emergent process of the implementation, as organization members struggle to adapt the new system to their individual purposes, and use the opportunities it presents to further their own interests” (Rose and Jones, 2005: pp. 32); (iv) new sets of organizational situations and possibilities brought about by the combined influence of technological solutions and their human stakeholders (ibid). In addition, understanding of technological paradoxes may help in the development of solutions that offer a more balanced user experience (Jarvenpaa and Lang, 2005).

Methodology

This paper is based on a case study of two related pilots exploring the possibility of using mobile phone solutions to support routine health data reporting, between primary health facilities and a district health office, in Malawi. The formal healthcare setup is a three-tier system, comprising primary, secondary and tertiary levels of care. The primary level comprises primary health facilities and community-based preventive and curative health services delivery. In this setup, community level services are provided under the supervision of health facilities. Health facilities report to district health offices, which in turn report to zone health offices and the Ministry of Health headquarters. Reporting frequencies range from weekly to quarterly, depending on health programme specifications. Data reporting between health facilities and district health offices has traditionally been paper-based. Previous efforts to implement digital health management information systems mainly targeted the district level and up. The study reported herein, was conducted under the Lilongwe District Health Office, across seventeen health facilities, which fall under two health area offices. Health area offices are an administrative level between district health offices and health facilities and are unique to Lilongwe. One of the participating health areas had all its health facilities located in rural areas, where roads are unpaved and prone to poor mobility during the rainy season. The other health area had a rural-urban blend, in the distribution of health facilities.

The two pilots discussed herein are based on DHIS Mobile (henceforth referred to as DHISm) and run on Nokia C1-01 feature phones. DHISm is an integral module of DHIS 2, a server-side solution for aggregate data management and analysis. DHISm provides functionality supporting the use of mobile devices for data communication with DHIS 2. Of the two pilots, one runs a phone browser optimized DHISm solution, and the other a J2ME client application installed on end-users’ phones.

Findings presented herein are largely centred on stages and practices regarding one report, HMIS-15, which captures data across a range of healthcare services and other matters of concern. In addition, practices around other reports such as the integrated disease surveillance and response (IDSR) programme are drawn upon. At the start of this study, HMIS-15 data was maintained using DHIS 1.3, a desktop software solution, used at district and Ministry of Health levels. However, efforts were underway to migrate to DHIS 2. Participants in the pilots comprised a heterogeneous group of personnel stationed at different administrative levels, right from health facilities to the Ministry of Health headquarters. This grouping included: clinical officers, health surveillance assistants, statistical clerks, statisticians responsible for HMIS-15 and IDSR, managers at health area, district, and ministry level. Phones were only provided to staff at health facility level, responsible for targeted reports.

The case study strategy fits our study because it supports explorative investigations of interactions between information technology-related innovations and organizational contexts (Benbasat et al., 1987; Darke et al., 1998). The approach allows in-depth, multi-faceted explorations of complex issues in their real-life settings, and development of thick descriptions of phenomena, to aid theorizing (Walsham, 1995; Darke et al., 1998; Crowe et al., 2011). This is because the case study approach “lends itself well to capturing information on more explanatory 'how', 'what' and 'why' questions, such as 'how is the intervention being implemented and received on the ground?’” (Crowe et al., 2011: pp 4). Theorizing of human-technology interaction herein makes significant use of thick descriptions to uplift particularities of artefacts, work practices, and context. Furthermore, the approach allows us to make sense of other peoples interpretations of implemented technologies.

Data collection

Data were collected through semi-structured interviews, focus group discussions, document analyses, informal charts with different stakeholders, and as part of technical support rendered to end-users. Semi-structured interviews were conducted to get: (i) baseline data on paper-based data reporting practices; (ii) perspectives of managers and end-users on the planned pilots; (iii) experiences of end-users and managers regarding the pilots. Categories of users interviewed included the above-mentioned members of staff working at health facility level; a district nursing officer; three technical assistants supporting DHIS 2 and DHISm pilots; one statistician and the deputy director working under the Central Monitoring and Evaluation Division (CMED) of the Ministry of Health (MoH).

Table 2. Key informants in Malawi

Focus group discussions were conducted as part of four training sessions, three of which were on the DHISm solutions under pilot and the other on DHIS 2 in general. Four more focus group discussions were conducted as part of DHISm review meetings, within participating health areas. Participants in focus group discussions mainly included the above-mentioned staff working at health facility, health area office, and district health offices levels. Paper-based registers and report forms were the main sources of documentation reviewed for this

study. In addition, publications on health management information systems in Malawi (Chaulagai et al., 2005; Hamre and Kaasbøll, 2008; Kanjo et al., 2009) were reviewed.

Data Analysis

Data were analysed by following activities undertaken at various stages of data reporting: compilation, transportation, digitization, and delivery of feedback. In doing this, we considered how affordances (Gibson, 1979) of artefacts such as mobile phone solutions, paper, and desktop computers, affected their application in support of on-going activities. For example, the compilation of an HMIS-15, discussed in the next section, built on paper reports from different departments. In analysing report compilation we therefore considered whether, given their small screen sizes, available mobile phones could support collaborative practices around report compilation better than A3-sized paper registers and A4-sized report forms. With regard to remote data communication we considered action possibilities afforded by paper and mobile phone solutions. Our data analysis also draws upon the concepts of technology enactment (Fountain, 2001; Rose and Jones, 2005), mobility (Luff and Heath, 1998; Weilenmann, 2003). The concept of mobility has been employed to demonstrate situations where the use of paper and mobile phones is relevant, as well as the manner in which implemented mobile phone solutions are used.

Findings

The HMIS-15 report captures data on multiple aspects of health service delivery and management (see figure 2), including: family planning, child health, Tuberculosis, medical supplies, finance, physical facilities, management and supervision, admissions, inpatient deaths, community health activities, and human resources at work. These services are spread across service departments.

Figure 2: An extract of the HMIS-15 reporting form

Based on the multiplicity of service departments involved, data that feeds into the HMIS-15 report are spread across different paper registers.

HMIS-15 Report Compilation

Compilation of the HMIS-15 report demands collaboration across service departments. The conversation presented below exemplifies an HMIS-15 report compilation process. The transcript is a translation from a phone interview between the first author and a Statistical Clerk at one health facility. The interview was mostly conducted in Chichewa, a local language.

- Author 1: I wanted to know: how is compilation of the HMIS-15 form done at your health facility?
- Respondent: [You mean] the way we do it?
- Author 1: Yes
- Respondent: First, we compile other reports. I have to compile [the] HTC (HIV testing and counselling) [report], compile [the] antenatal [report], compile [the] maternity [report], and also compile totals for OPD (Outpatient department)...
- Author 1: Ok

- Respondent: Data for each section, be it HTC, antenatal [care], OPD, or MCH (Maternal and Child Health) is available at that point. That is when one can compile the HMIS-15 [report]. Otherwise, one cannot compile the HMIS-15 report without these other reports
- Author 1: Ok. So, are you responsible for compiling all those reports you have made mention of?
- Respondent: Yes, except for family planning, obstetrics, HTC, plus MCH. These are done by the focal persons. But, I do the following reports myself: maternity, antenatal [care], and OPD
- Author 1: How do you liaise with the focal persons, until such a point when you are done preparing the HMIS-15 report, do you just send them the reporting form or you work together?
- Respondent: No, it's team work. I go to everyone and politely ask them to compile their reports on time, so that we can send the reports. I tell this to the people responsible for family planning, HTC, and everyone else. Meanwhile, I work on other things [reports]. When everyone has compiled their reports, data is then extracted onto the HMIS-15 [report], after which the report is completed. After it [the HMIS-15 report] has been completed, it is handed over to the officer in-charge for approval. After he has given his approval, the report is sent to the district health office
- Author 1: With regard to extracting data from other reports onto the HMIS-15 report, are you solely responsible for that or you give the HMIS-15 report form to others for them to fill in required data, or they just pass you their forms for you to get the data yourself?
- Respondent: No, the HMIS-15 report [form] is not circulated across all these departments. They all send me their reports, after which I transfer the required data onto the HMIS-15 [report form]
- Author 1: Ok. So, how many registers do you use when compiling the HMIS-15 report, is it one or several?
- Respondent: There are a lot of registers. For example, to complete the section on maternal services two registers are used – an antenatal register and a maternity register. When one has those two, then, it is possible to fill in [data for] that block. There are other registers also; family planning, for example...

The conversation above demonstrates the collaborative nature of HMIS-15 report compilation, which requires mobilization of different stakeholders, across service departments, and paper registers and forms. Once finalised, the report has to be signed off by an officer in charge, before submission to the District Health office, with copies submitted to health area offices. Officers either transport reports themselves or send them through other people (patients, ambulance drivers, etc.).

Concerns with Paper-based Reporting

Our empirical investigation identified five main challenges with paper-based reporting. First, transportation of paper-based is increasingly difficult during the rainy season, as most roads are unpaved. Second, members of staff indicated that they are expected to finance trips to the district health office (DHO), for report submission. Third, staff at rural health facilities also indicated that a round trip to town, where the DHO is located takes an entire day. Another challenge is that although ambulance drivers are considered a convenient means for sending reports to the DHO, there have been cases where reports remained undelivered for months. Finally, handling data entry for all health facilities is burdensome for assistant statisticians

working at district level. The conversation below exemplifies some of these challenges, with transportation of reports coming out as a major challenge. The conversation is an extract of a focus group discussion regarding transportation of paper reports between health facilities and Lilongwe DHO. The discussion took place in March 2012. The conversation centred on IDSR reporting, but officers responsible for HMIS-15 reporting were party to the discussion and expressed similar sentiments.

Facilitator 1: Does anyone not do reports every month?

IDSR Officer: Yeah, there are some facilities who probably, we are thinking that maybe they, have just closed the facility [and he laughs a bit]. In other words, maybe they have just closed the IDSR. For example, to mention Health-facility-X; Health-facility-X...I haven't seen a report since November [2011], if not September [2011]. I don't know what the reason is; I don't know why they don't send reports. Yes, Health-facility-X you are here; where do you send your reports now?

All: [Everyone laughs]

IDSR Officer: Anyway, I was trying to respond to the question that: "is there anybody who does not report for two or three months?" Yeah, there are health facilities [that] do [not]...

Health-facility-X: I think you should also give me time [to speak]. Yeah, we do send the reports, but the problem is communication breakdown, because sometimes we do give the reports to the ambulance drivers. So, on the way I don't know what happens. But we have [copies of] the reports and we have been sending the reports since October 2011

IDSR Officer: It is just unfortunate that this [sending of reports through ambulance drivers] is probably the best means of sending reports to the district, but we send [the reports, through] people who do not know the importance of the reports...I remember last time when one of the drivers had an accident people discovered that he had a pile of reports from various health facilities of Chileka [Health Area], not being delivered to the DHO for months. It was discovered after three months, the reports were just [left] in the car. So, it's just [an] unfortunate [situation]. We might blame each other, but maybe the channel of communication we use is not correct. So probably the methodology you are trying to bring in...will lessen some other problems.

Facilitator 2: But when you guys send the reports, maybe to the IDSR officer, he is here, does he give the feedback that he has received the reports?

Staff from

No!

health facilities:

IDSR Officer: The feedback we give is that we haven't received the reports.

Facilitator 2: There is a big [resounding] no!

Staff from

Everyone laughs

health facilities:

IDSR Officer: Nobody can say yes. It's true, we haven't given any feedback. But we presume that when we are silent it means their report has reached us. But when we haven't received it, we try to follow up, [telling them] we haven't received your reports from such [and] such a month, to such [and] such a month...

Facilitator 2: But to them the silence meant that you have received [the reports], not so?

Staff from health facilities: Yes! [Followed by some laughter]

The transcript above foregrounds challenges such as unreliability of ambulance drivers a means for transporting reports, and poor feedback on reported data.

Mobile Phones and DHIS Mobile (DHISm) Solutions in Use

With DHISm, existing practices around data collection and report compilation have been maintained. The DHISm solutions are drawn upon after paper-based HMIS-15 reports have been signed off, as a replacement of physical transportation of paper reports. With DHISm, staff may connect to a remote DHIS 2 server and submit their reports. The use of DHISm solutions extends the reach of the digital national health management information system solution to health facilities. Reducing the need for travel allows members of staff to attend to other key duties at own duty stations. Health facilities in Malawi are often under-staffed, especially in the rural areas. In addition, implementation of the aforementioned DHISm solutions is worthwhile, as previous interventions on digital health information systems targeted district health offices and the Ministry of Health headquarters. Even in a few cases where electronic medical record systems have been implemented at health facility level, data reporting to the district remains paper-based. Use of DHISm at facility level reduces the need for data entry at district level.

In addition, with DHISm solutions, persistence of reported data is visible to staff who send in reports. Staff can review entered data stored on the national DHIS 2 server. Thus, members of staff have confirmation that their data is centrally stored and remotely accessible. Furthermore, DHISm solutions provide health facilities with automated data validation checks available on the nation DHIS 2 server.

Not a Bed of Roses: The Flip-side of Mobile Phone Supported Data Reporting

Data reporting between health facilities and district level has traditionally been paper-based, meaning certain communication practices and structures centre on the movement of paper. For example, all reports from health facilities to district health offices have to go through designated officers such as program coordinators and assistant statisticians, for entry into software solutions. All HMIS-15 reports go through an assistant statistician at district level. Earlier studies also indicate that officers at district health office level play an important gate-keeping role, especially in crosschecking data quality (Hamre and Kaasbøll, 2008).

Up until late 2012 HMIS-15 data was entered into DHIS version 1.3, before export files were forwarded to the Ministry of Health headquarters. With paper-based reporting and usage of DHIS 1.3 at district level, the district health office could get by with poor Internet connectivity. For example, the office housing the assistant statistician, handling HMIS-15 reporting, had no Internet connectivity. The officer would use colleagues' offices, when forwarding reports to the Ministry of Health headquarters. Adoption of DHIS 2 and DHISm solutions creates a need for reliable Internet connectivity at district and health area level, to keep key stakeholders in the loop of things. At the start of the DHISm pilots the two health area offices taking part in the pilots also had no dedicated Internet connectivity or access to the DHIS 2 Server.

After noting the aforementioned challenges, we provided the assistant statistician and participating health area offices with USB Internet modems (dongles). In addition, we

provided basic DHIS 2 training to health area offices. The training mainly focused on data entry and generation of reporting rate summaries. The rationale behind such efforts was to allow health area offices monitor data reporting by subordinate health facilities, as well as enter own data on the national DHIS 2 server. Both health area offices already had computers.

Apart from the above-mentioned challenges, DHISm users have to forgo some flexibility associated with paper:

“let us take HTC [HIV Testing and Counselling], for example...suppose the test kits are out of stock and you just write 0 [for the number of tests conducted during the month]...the person getting the report might have some questions [when trying to make sense of the 0]:...[they would ask] ‘is it that people didn’t do their work, or what?’...But with the manual [paper-based] report we are able to write 0 and also append a reason for the zero, such as ‘test kits were out of stock’. But on the phone we just write 0...possibly, you could design the form in such a way that we are able to write something [notes] instead of just writing a zero” (Statistical Clerk, 2013)

The quote above highlights the importance of differences between paper and mobile phone applications, in supporting existing practices such as appending notes to explain data.

The Nokia C1-01 phones in use also have a limited area for information display (128 x 160 pixels, 1.8 inches), compared to A3-sized (11.69 x 16.53 inches) paper registers, or A4-sized (8.27 x 11.69 inches) report forms. Figure 3 provides some contrast between an A4 HMIS-15 form and a Nokia C1-01 phone.

Figure 3: Page from an A4-sized HMIS-15 report form and a Nokia C1-01 phone

Another concern raised by end-users regards the need to support all available report forms: “involvement with other programmes [whose reports are currently not supported] forces one to still travel to the district [health office]” (Health Surveillance Assistant, 2013).

Though a necessity, supporting all available report forms is challenging. Although at health facility level members of staff are often responsible for multiple reports, giving an impression of integrated health systems, the situation on the ground is far more complicated. Beyond the health facility level, reports are handled through parallel health programme-specific software solutions. For example, for the most part of this study the aforementioned IDSR Programme had a parallel standalone software solution. Fragmentation of information systems along vertical programmes has been a long standing issue in Malawi (Kanjio et al., 2009). Consequently, considerable efforts will be required to comprehensively support available report forms.

Discussion

In this section, we draw upon studies on organizational change and the following concepts to elucidate empirical findings: technology enactment (Gasser, 1986; Fountain, 2001; Rose and Jones, 2005; Dunford et al., 2007), affordance (Gibson, 1979), and mobility (Luff and Heath, 1998; Kristoffersen and Ljungberg, 1999; Weilenmann, 2003). The discussion responds to the question: how do mobile phone solutions interplay with existing paper-centric tools and

practices in routine health data reporting? The discussion is organised around various stages of data reporting: compilation, transportation, digitization, and delivery of feedback, in that order. We reflect on the demands of these activities and how implemented mobile phone solutions shape and are shaped by existing sociotechnical setup. At the end, we tie together our reflections in relation to related studies.

Compilation and Transportation of Reports by Health Facilities

Our finding demonstrate that compilation and sending of reports such as the HMIS-15 brings together requirements for local and remote mobility (Luff and Heath, 1998; Weilenmann, 2003). Local mobility is necessary to coordinate HMIS-15 report compilation, as data for the report is drawn from different departments, paper registers, and paper-based report forms. Considering that persistence of service data and compilation of reports that feed into the HMIS-15 report is centred on the use of paper, it is rather difficult to do away with paper during report compilation. Actually, it is not necessary to do away with paper at the moment. In addition, the large A3 and A4 paper sizes for registers and report forms afford information visibility at a glance (Sellen and Harper, 2003), for collaborating partners. The Nokia C1-01 mobile phones which have 1.8 inch displays cannot afford collaborators similar information visibility. It would be unreasonable and cumbersome to have people squeeze around a Nokia C1-01. Previous studies have also observed that the small size of mobile devices can be a significant constraint if collaboration has to be centred on the mobile device (Luff and Heath, 1998; Shudong and Higgins, 2006).

In introducing new technological solutions it is necessary to determine what parts of the socio-technical setup need to be maintained and those that are problematic and require modification. Considering that report compilation takes place within the confine of a health facility, one could argue that the affordances of paper suffice. Paper artefacts ably support micro (Sellen and Harper, 2003) and local mobility (Luff and Heath, 1998) which are necessary in collocated report compilation. Although mobile phones may also support local and micro mobility, they do not afford collaborating members of staff action possibilities such as viewing of information at a glance. Further to this, paper registers and report forms are to a larger extent socially accepted as shared resources, whilst mobile phones are rather more personalised. Personalization of mobile phones is also acknowledged in extant literature (Jones and Marsden, 2006; Ballard, 2007). The introduction of mobile phone solutions in our empirical case pushes a highly personalised artefact into a shared space. Additional work is therefore required to make implemented mobile phone solutions an integral part of existing practices around report compilation.

The use of paper-based reporting forms also better supports organizational processes such as report verification and signing-off, by senior officers at health facility level. Such processes would be difficult to support using only mobile phones, which in most cases are in the custody of junior officers. The immediate and prolonged implication of this is that implemented mobile phones solutions can only feature as data communication tools, in the time being. This demonstrates that the existing context is not just there to be acted upon, but also shapes the application of technology (Robey and Boudreau, 1999; Fountain, 2001). However, beyond report compilation, implemented mobile phone solutions provide a convenient way for communicating data. Mobile phones afford instantaneous remote data communication in ways paper cannot (DeRenzi et al., 2011; Ganesan et al., 2011). Implemented mobile phone solutions lower the need for individuals to travel between distributed places, i.e. remote mobility (Kristoffersen and Ljungberg, 1999), for purposes of

HMIS-15 report submission. Thus, use of mobile phone solutions circumnavigates identified challenges, arising from poor road conditions and unreliability of third parties in transporting paper reports. It suffices to support local mobility, using paper, and provide for remote connectivity, using mobile phones. This way of using mobile phone solutions is close to stationary use of desktop or laptop computers. Nonetheless, the prevalent under-development of electricity infrastructure and necessary competence regarding the use of computers, at health facility level, makes mobiles phones more suitable. Mobile phones are more ubiquitous, have lower demands for power, and hence are better suited to supporting HIS in rural contexts (Bukachi and Pakenham-Walsh, 2007; Chigona et al., 2012; Shoji et al., 2012). These factors rather than supporting users one the move are what make mobiles phones useful in the case presented herein.

Implemented mobile phone solutions also gain relevance in providing staff at health facility level with functionality for reviewing submitted reports. This in part addresses uncertainties regarding the delivery status of reports, as is the case with paper-based reporting. The extract from a focus group discussion on data reporting, presented earlier, demonstrates a serious breakdown in data reporting, arising from poor feedback on 'submitted' report. The officer from the district claimed that one health facility had not been reporting for months, but the health facility claimed that they had been sending in their reports through ambulance drivers. In this case, the paper-based reporting setup did not provide a way to ascertain who was in the right. With the implemented mobile phone solutions the national server provides a ready point of reference, to resolve such concerns. Beyond this, availability of data validation at report submission time, and bypassing of district health offices as an intermediate data entry stage can significantly lower transcription errors. This is in line with findings from earlier studies (see: DeRenzi et al., 2011). The use of mobile phones in this case also alters existing data reporting practices in that digitization of data is shifting to the health facility level.

Digitization and Feedback: Changing Roles and Relations across Administrative Levels

Having health facilities directly submit data into the national DHIS 2 server alters the significance of certain roles. For example, the assistant statistician at district health office level can no longer function as a gatekeeper through whose desks reports must pass, before digitization. The work of concerned stakeholders at health area and district health office levels now shifts more towards monitoring of data reporting and provision of feedback on reported data. However, as mentioned in the case presentation, this shift demands better Internet connectivity, in order to keep key stakeholders in the loop, than was previously required with paper-based data reporting and the use of desktop DHIS 1.3 solutions. Without such, mobile phones will be termed a leapfrog technology not only for enabling users skip fixed-line technologies (Heeks and Jagun, 2007; The Economist, 2008), but also key stakeholders at health area and district health office levels. That the end result of this leapfrog would be disastrous requires no further emphasis. Previous studies have demonstrated the importance assistant statisticians, working at district level, in promoting data quality (Hamre and Kaasbøll, 2008). Figures 4 and 5 depict how the use of DHISm tools for data reporting alters existing communication channels and roles.

Figure 4: paper-based reporting

Figure 5: DHISm supported reporting

Due to the above depicted alterations in communication patterns, adoption of mobile phone solutions calls for even better forms of communication between district health offices and

health facilities, than has traditionally been the case. For example, there is need to compensate for reduced face-to-face meetings associated with paper-based reporting, through enhanced delivery of feedback on reported data. If care is not taken, the use of implemented mobile phone solutions might conquer physical distance, but widen the communication gap between health facilities, health area offices and district health offices. Bellotti and Bly (1996) state that visual and auditory accessibility enables awareness of things people would otherwise miss on, which in turn might prompt spontaneous communication. Findings by Hamre and Kaasbøll (2008) also suggest that face-to-face meetings can be motivational for healthcare personnel. However, although challenges pertaining to poor provision of feedback have been known for some time (Chaulagai et al., 2005; Hamre and Kaasbøll, 2008) they still persist. Bellotti and Bly (1996) also argue that “if our aim is to support a range of group work, including distributed collaboration; we must design for mobility and not against it” (Bellotti and Bly, 1996: pp. 216). Their use of the term mobility refers to movement of people between distributed places. We do not necessarily agree with this argument, as, in our empirical case, there is a clear need to do away with physical travel for the purposes of report delivery. However, we find their argument relevant in creating awareness that the relevance of mobile phone solutions, within work contexts, is found in the multiplicity of interacting technologies and people.

In the case study presented here, remote submission of health data through mobile phones also benefits from the use of desktop computers and laptops, at district level. The vast quantities of data dealt with at district level and the computing power required cannot be ably supported by the use of mobile phones or paper. It is only natural to make use of available computer hardware. In the end, realising the potential of mobile technology solutions to support local and remote collaboration requires a heterogeneous combination of technologies, both old and new (Luff and Heath, 1998; Jones and Marsden, 2006; Bukachi and Pakenham-Walsh, 2007).

Tying things together: Enactment of technology across collectives

The empirical case demonstrates that the combination of report compilation and delivery involves intricate interdependences between groups of artefacts and individuals, at different administrative levels. This corresponds to findings from earlier studies that, within organizations, individuals’ work tasks are part of a larger system of tasks and their accomplishment requires mobilization of multiple resources (Gasser, 1986). We could liken the various artefacts (registers, paper forms, mobile phone tools, etc.) mobilized to playing cards in a deck, each with unique affordances and roles, but also dependent upon the rest, for the task at hand. In card games, cards are drawn upon based on their unique characteristics (numbers, types, and colour) and resultant affordances, but not in a way that is unconnected to cards already drawn, rules at play, and intentions of card players. When played, cards shape the progression of the card game, and so this dynamic continues. In the same way, the idiosyncrasies and affordances of paper-based tools, mobile phones solutions mean that individual artefacts are best suited to parts of the reporting process. At the next level, it is in the mobilization of their combined affordances, by individuals and groups at different levels of organization, that data reporting as a whole is accomplished. Thus, it would be naive to over emphasize the potential of mobile phone solutions, at the expense of everything else that matters. This corresponds to the observations by Pentland and Feldman (2008) that well designed artefacts do not necessarily give rise to new organisational routines. Organisational routines involve coordination between multiple individuals playing out smaller parts of larger organisational routines. As has been demonstrated in our findings, the enactment of implemented mobile phone solutions is intertwined with utilization of paper-based tools at

health facility level, as well as desktop computers and Internet connectivity at higher administrative levels. These dynamics fit in with arguments that novel technologies are made sense of within a context of continuous interplay with humans and existing socio-technical arrangements, where each element, though still retaining uniqueness, is a part of the whole (Fountain, 2001; Aarts et al., 2004; Rose and Jones, 2005).

From the case, it is also evident that implemented mobile phone solutions are without much significance in the absence of a comprehensive coverage of reports health facilities must send to district health offices. Every unsupported report necessitates travel to the district health office. However, it is equally evident from the findings that each additional report form increases the level of complexity, due to an increase in the number of stakeholders and parallel information systems that require mobilization. It can be challenging to leverage fragmented software platforms, due to the increased overhead of coordination and communication (DeRenzi et al., 2011). Addressing such complexity goes beyond the capabilities of end-users and demands action taking by solution implementers and administrators. Taking such steps echoes observations by Ribes and Finholt (2009) that activities undertaken by solution implementers in transitioning experimental technologies into production systems are very much part of technology enactment. Considering the dynamics discussed thus far and building on Dunford et al. (2007), it is not farfetched to argue that in the case presented here innovation is not to be found in the sole act of implementing the said mobile phone solutions. Rather, what is innovative is the collective enactment of existing paper-based tools and practices, mobile phone solutions, and available desktop computer solutions.

Conclusion

The paper responds to the question: how do mobile phone solutions interplay with existing paper-centric tools and practices in routine health data reporting? Available evidence suggests that organization will continue to change with continued evolution of ICTs. In line with this, the application of ICTs such as mobile phones and related solutions offer significant transformative opportunities to enhance healthcare management, by extending the reach of digital health information systems (HMIS) to rural areas. In extending the reach of HMIS, mobile phone solutions allow for remote data communication and data validation checks, thereby addressing challenges concerning transportation and digitization of paper-forms.

The paper demonstrates that implemented mobile phone solutions occupy a unique place that neither paper nor desktop computer solutions can ably occupy. However, our findings demonstrate that effective utilization of implemented mobile phone solutions requires adjustments on the part of new and existing technologies and work practices. The paper substantiates this line of argument by providing an account of how idiosyncrasies of data reporting practices, paper, mobile phone, and desktop solutions shape application of new technology. In considering particularities of work practices, context of use, and affordances of the above-mentioned technological artefacts, we see that various artefacts are suited to different stages of data reporting: compilation, transportation, digitization, feedback. For example, paper renders itself well to supporting local mobility and collaboration during report compilation, compared to mobile phones with small screen sizes. Beyond this, transportation of paper report forms is problematic due to poor transport infrastructure. Mobile phone

solutions, then, provide a way of circumventing transportation challenges, through affording instantaneous remote data communication. At the next level of administration, existing desktop computer solutions are more suited to handling larger quantities of data. This emerging socio-technical hybrid also alters existing patterns of report submission, which requires mobilization of different groups of people across levels of organization, to prevent marginalization key stakeholders. In the end, report compilation and communication unfolds guided by use of paper, age-old paper-centric practices, and demands of local collaboration, challenges of transporting paper reports, and affordances of paper, desktop, and mobile phone solutions in use. Such interaction is continuously evolving.

In paying attention to the above-mentioned factors we observed that contrary to the general focus on mobile phones as tools for supporting people on the move, their relevance might actually be found in reducing people's mobility between distributed places. In our case study mobile phone solutions are mainly drawn upon to replace physical transportation of paper-based reports.

Above all, we argue that simultaneous enactment of old and new technologies is necessary in order to make implemented mobile phone solutions work. What is novel and exciting in the case presented herein is the collective mobilization of the aforementioned interacting elements, in a way that recognizes their uniqueness and interdependence. In addition, we recognize that the participation of end-users, administrators, and technology implementers is necessary in order to make available technologies work. This is what might result in ICT supported organizational change. In other words, novelty and innovation are to be found in the intermingling of new and old technologies and practices (Dunford et al., 2007). The reflections on coexistence between novel and established practices, provided herein, are seldom reflected upon in studies on innovation in mHealth (see: Leon et al., 2012; Braa and Nielsen, 2013).

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Table 1: Views on Mobility – Adapted from (Weilenmann, 2003: pp. 23)

	Study focus	Concepts in use
1	The movement of artefacts around a small at-hand domain	micro-mobility
2	The movement of people within a local area such as an office	wandering / local mobility
3	The movement of people between sites of work (in a vehicle)	travelling
4	Working away from the home-base	visiting / remote mobility /remoteness
5	Working while in motion away from the home base	truly mobile work
6	Collaboration in everyday life (Weilenmann, 2003)	mobile technology use in general / social dimensions of using mobile technology on the move

Table 2. Key informants in Malawi

Informant(s)	Organization (level)	Key responsibilities
Deputy Director	MoH Headquarters - CMED	Oversight over the national HMIS function
Assistant statistician	MoH Headquarters- CMED	HMIS report consolidation at national level
Technical assistants supporting DHIS 2 and DHISm	MoH Headquarters- CMED and University of Malawi's College of Medicine	Coordinating DHIS 2 and DHISm implementations
HMIS and IDSR Officers	District Health Office	Coordinating HMIS and IDSR reporting with health facilities
HMIS focal persons	Health facilities	Health service delivery, HMIS reporting function at facility level
Officers in-charge	Health Area Offices	Health service delivery, Administrative oversight

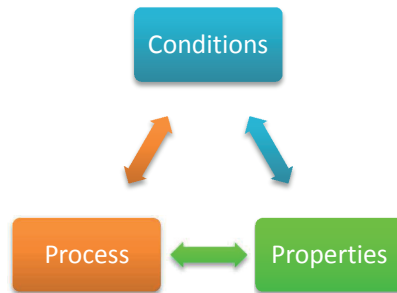


Figure 1: Human-Technology Interaction – Adapted from (Rose and Jones, 2005)

Maternal Services		Finance	
39	Number of pregnant women starting antenatal care during their first trimester	56	Total income from cost sharing
40	Total number of new antenatal attendees	Physical Facilities	
40	Total antenatal visits	17	Do you have functioning water supply system?
41	Number of deliveries attended by skilled health personnel	17	Do you have functioning communication system
42	Number of women obstetric complications treated at obstetric care facility	17	Do you have functioning water supply system? Electricity and communication system? (Y/N)
43	Number of caesarean sections	Management and Supervision	
44	Total number of live births	13	Is the health center committee functional? (Y/N)
44	Number of babies born with weight less than 2500g	15	Were you supervised by DHMT members using the integrated supervision checklist? (Y/N)
45	Number of abortion complications treated	New Cases (OPD plus Inpatient)	
46	Number of eclampsia cases treated	27	Sexually transmitted infections-new cases
47	Number of postpartum haemorrhage (PPH) cases treated	29	Syphilis in pregnancy
48	Number of sepsis cases treated	31	HIV confirmed positive (15-19 years) new cases
49	Number of pregnant women treated for severe anaemia	37	Opportunistic infections-new cases
51	Number of newborn treated for complications	58	Acute respiratory infections-new cases (U5)
52	Number of postpartum care within 2 weeks of delivery	60	Diarrhoea non-bloody- new cases (under5)
Family Planning		64	Malnutrition – new case (under 5)
53a	Number of persons receiving 3 months supply of condoms	69	Malaria - new cases (under 5)
b	Number of persons receiving 3 months supply of oral pills	70	Malaria - new cases (5 & over)
c	Number of persons receiving Depo-Provera	78	Neonatal tetanus-confirmed new cases
d	Number of persons receiving Norplant	79	Cholera - confirmed new cases
e	Number of persons receiving IUCD		
f	Number of persons receiving sterilisation method of FP		

Figure 2: An extract of the HMIS-15 reporting form

HMIS-15 report form page showing various sections: Maternal Services, Family Planning, Physical Facilities, Management and Supervision, and New Cases (OPD plus Inpatient). A Nokia C1-01 phone is placed over the form.

Maternal Services		Finance	
39	Number of pregnant women starting antenatal care during their first trimester	56	Total income from cost sharing
40	Total number of new antenatal visits		
41	Number of deliveries attended by personnel		
42	Number of women obstetrically treated at obstetric care facility		
43	Number of caesarean sections		
44	Total number of live births		
45	Number of babies born with weight < 2500g		
46	Number of abortion complications		
47	Number of eclampsia cases		
48	Number of postpartum haemorrhage cases treated		
49	Number of sepsis cases treated		
50	Number of pregnant women treated for severe anaemia		
51	Number of newborn treated for complications		
52	Number of postpartum care within 2 weeks of delivery		

Family Planning	
53a	Number of persons receiving 3 months supply of condoms
b	Number of persons receiving 3 months supply of oral pills
c	Number of persons receiving Depo-Provera
d	Number of persons receiving Norplant
e	Number of persons receiving IUCD
f	Number of persons receiving sterilisation

Physical Facilities	
57	Do you have functioning water supply system?
58	Do you have functioning communication system
59	Do you have functioning water supply system? Electricity and communication system? (Y/N)

Management and Supervision	
60	Is the health center committee functional? (Y/N)
61	Were you supervised by DHMT members using the integrated supervision checklist? (Y/N)

New Cases (OPD plus Inpatient)	
62	Sexually transmitted infections-new cases
63	Syphilis in pregnancy
64	HIV confirmed positive (15-19 years) new cases
65	Opportunistic infections-new cases
66	Acute respiratory infections-new cases (ARI)
67	Diarrhoea non-bloody-new cases (under 5)
68	Malnutrition - new case (under 5)
69	Malaria - new cases (under 5)
70	Malaria - new cases (5 & over) XDR
71	Neonatal tetanus-confirmed new cases
72	Cholera - confirmed new

Figure 3: Page from an A4-sized HMIS-15 report form and a Nokia C1-01 phone

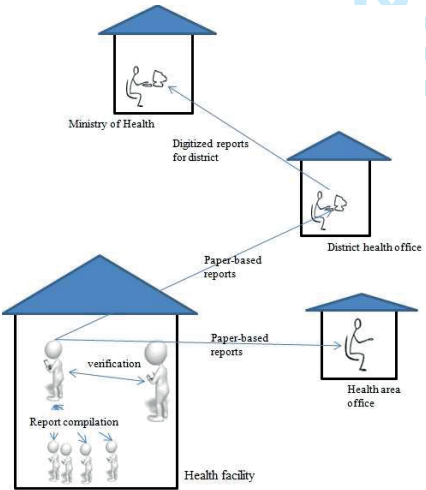


Figure 4: paper-based reporting

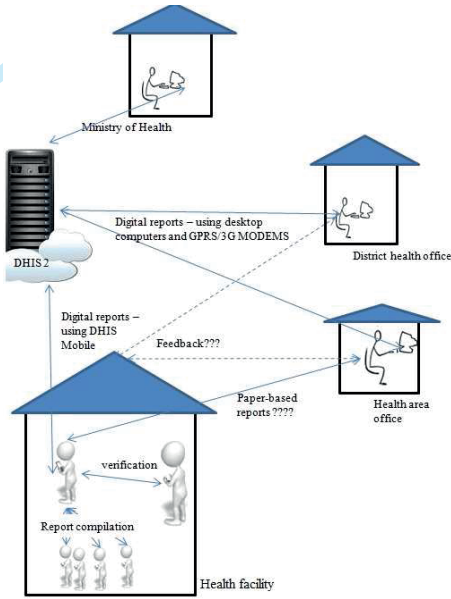


Figure 5: DHISm supported reporting

Appendix 2: Paper 2

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INTERVENTION BREAKDOWNS AS OCCASIONS FOR ARTICULATING MOBILE HEALTH INFORMATION INFRASTRUCTURES

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ABSTRACT

This study investigates a mobile health project launched in Malawi and considers its sustainability in light of activities that occur in the pilot stage. It has been said that most projects of this nature fail during piloting hence it is pertinent to review the activities in this early stage. The study follows a grounded theory inspired research approach and is focused on the day to day breakdowns that occur in the pilot, what they reveal, and how the resolutions relate to the project's goals. It is found that when breakdowns occur, an articulation process to sustain the intervention becomes visible. Breakdowns can reveal tensions in the technical design and organisational context thereby offering opportunities for action in order that an intervention is sustained. The ensuing activity, for analytical purposes, is termed articulation work, and its variety and limitations are explained. In this study we discover two categories of articulation work, technological and human. Further to this, we argue that these two categories of articulation work can be further analysed into different dimensions, based on the levels of organizational involvement required to resolve them: (i) localised; (ii) multiple levels within a single organization; (iii) and multiple levels inter-organizational.

KEYWORDS: breakdowns, articulation work, sustainability, developing nations, intervention, grounded theory, information infrastructures, mobile health

1. INTRODUCTION

There is a global drive to improve the Health Information Systems (HIS) of developing nations as it is recognised that they have a critical role to play in the provision of primary healthcare services (Braa, 2004). The initiatives are driven by the persistent concerns that current systems are collecting irrelevant information, the quality of data gathered is poor, there is duplication of efforts due to fragmentation, data is not received in a timely manner, and the information gathered is not used for decision making (Chaulagai et al., 2005; Lippeveld et al., 2000). However, designing and implementing health information systems to address these and other issues is a complex task. Numerous reasons have been given for this, such as the failure to change underlying organisational structures (Sahay et al., 2010; Silva and Hirschheim, 2007), a mismatch between adopted approaches and context (Cho et al., 2008; Puri et al., 2004) and the challenges of harnessing activities across networks of stakeholders with their diverging interests (Braa, 2004). In an effort to address these constraints, mobile technologies are espoused to have capabilities suited to the low resource contexts of developing countries (Sanner et al., 2012).

Mobile technologies have proliferated globally, with developing nations demonstrating exceptionally high adoption and growth rates (Sanner et al., 2012). The mobile device is useful for transcending the spatial and temporal limitations imposed by rural settings in poor countries. Healthcare delivery systems in these nations are thereby concerned with the increasing usage of this technology to ease the challenges they face (Asangansi et al., 2013; Chigona et al., 2012; Sanner et al., 2012; Shoji et al., 2012). However, as highlighted by Arnold (2003), mobile technology can behave in paradoxical ways which are not anticipated when it is introduced in organisational contexts. This evident paradox is

characterised as a mythological god called Janus who was cursed with looking forward and backwards at the same time. In our case, mobile technology was introduced with the goal of minimising the challenges of health work in situations of resource limitation, yet the maintenance of mobile technology is challenging in rural and under-developed urban locations where poverty is rampant. With such interventions, there is the risk that "*work routines are often destroyed and replaced with much less flexible and more expensive solutions*" (Berg, 1999, p. 96). In the broader context of human development, wherein health care provision is implicated, Escobar (2011) contends that the countries to which development aid is directed often have limited participation and control in rationalising the interventions. He concludes therefore that these interventions might themselves be implicated in the increase of poverty.

This study describes one such intervention in Malawi that was meant to extend the reach of the public health information system through the design and implementation of mobile technology based tools. It demonstrates how the micro-processes of domesticating mobile technology for the local setting are related to the broader context, implicating individuals, settings and resources far removed from the sites of implementation. We utilise the concept of 'information infrastructure' (Hanseth and Lyytinen, 2010) to illuminate the range of challenges and breakdowns that occur in implementing the technology. We further describe and categorise the articulation work that is undertaken to keep the project afloat and seek to surface the meaning of these activities for the sustainability of intervention. Through the use of these concepts we capture the broader socio-technical context of design and implementation of the system. Opportunity is an often overlooked aspect shaping the evolution of technology, yet it is implicit in the challenges that are faced. The study therefore conceptualises breakdowns, and the opportunities for articulation work that emerge along with the structural constraints determining the type of activities possible. More specifically, the study offers a multi-layered approach to discussing the nature of breakdowns, i.e. human or technical; levels of organization at which they might occur, and related implications on required articulation work and strategies to negotiate them.

1.1 Related Work

Given the tendency in IS research to overly focus on the potential of mobile technology, recent studies have called for a more holistic approach to mobile health implementation management, citing implementation failures, especially in relation to attempted scale-up efforts (Braa and Nielsen, 2013). Studies in large scale information systems have also narrowly focussed on the implementation aspects of technology separately from design (Pollock and Williams, 2008). Pollock and Williams (2008) bemoan the prevalence of what they term flat ethnographic studies, which seek to explain technology by looking only at the context of use at the expense of the broader socio-technical context in which they are embedded. To address these concerns, this study is conducted by researchers who engage with the varied breath of stakeholders in a technology implementation, from its designers to its users, across organisational and national boundaries, including its global context. The work contributes towards building an understanding on developing mobile systems meant to scale across multiple sites in different nations. It is also suited to address Pozzebon and Pinsonneault (2005, p. 125), who in discussing the implementation of generic software packages assert that the "*nature of the process by which global and local are negotiated is still poorly understood*". This persistent challenge necessitates the usage of a more encompassing socio-technical perspective, particularly the information infrastructural lens (Hanseth and Lyytinen, 2010), which is not common within the discourse on mobile healthcare technologies. In our study, we make the particular connection between articulation

work and the processes through which generic software comes to work across contexts and in local settings.

The study also pays attention to the peculiar context of Malawi, a developing nation facing unique challenges, thereby contributing to the broader discourse on IT and human development. Malawi is considered amongst the least developed nations, with a population growth rate that occurs in the foreground of a constrained infrastructural base. It consequently ranks poorly on global health indicators such as infant mortality rate and life expectancy. The health information system is highly fragmented thereby affecting the quality of the data that is used to make essential health decisions (Kanjo, 2012). Furthermore, while work in information systems has scarcely focussed on theoretical contributions, and has relied on existing concepts from sociology and other cognate disciplines, often in a descriptive manner (Matavire and Brown, 2011), our study makes a grounded theoretical contribution which is practically relevant to the context of research. In the following section, we proceed by providing a background of the theoretical concepts utilised in our research. After that, an outline of the chosen research method is given, including the analytical procedures used. A description of the case is then provided, followed by findings leading into the conclusion.

1.2 Breakdowns, Information Infrastructures and Articulation Work

Breakdowns in technology projects offer unique opportunities for understanding the context in which they are employed (Fischer, 2004). They also increase the visibility of stakeholders in an intervention and constitute interesting and overlooked sites of local innovation that may support acts of sustaining, extending and tailoring, as well as repurposing extant infrastructure (Jackson et al., 2012; Rosner et al., 2013). Breakdowns raise important questions about the fit and transformational role of a technology within an organisation. They become *"the basis for a much more detailed understanding of the relational nature of infrastructure"* (Star, 1999, p. 382). This means that breakdowns of technology can be useful in understanding the infrastructural context of their application. Infrastructure here is considered as information infrastructure, which is a socio-technical system of IT capabilities existing amongst stakeholders, including users and designers (Hanseth and Lyytinen, 2010). Since technological capabilities are constantly changing and stakeholders participation is fluid over time, an information infrastructure is also considered as evolving (Hanseth and Lyytinen, 2010). In the context of developing nations, the evolution of IT capabilities is not continuous but is punctuated by short periods of significant change with long periods of relative stasis (Njihia and Merali, 2013; Silva and Hirschheim, 2007). To explain the inability of a health systems intervention to be sustained, Silva and Hirschheim (2007) also note the importance of changing the underlying deep structures of organisations. In attempting to understand the underlying structures of systems, it is important to note that a defining feature of an information infrastructure is its invisibility, except during breakdown (Star, 1999).

Breakdowns are not a phenomenon that is unique to projects in under-developed contexts. According to Strauss (1988), p. 172, *"all projects have the potential for breakdown and repair; moreover, some degree of monitoring and rectifying of the fitting together of work is likely to be occurring at every phase of a project and at various levels of project organization"*. What is unique therefore, are the idiosyncrasies of the context within which health information systems interventions occur (Puri et al., 2004); particularly in regards to issues that have been associated with under-development, that is the low literacy rates and poor access to electricity such as obtains in the case of Malawi. Breakdowns in the flow of activity are known, across differing philosophical traditions, to have the capability of revealing the nature of the world around, particularly the resources essential to the performance of a task (Jackson et al., 2012; Koschmann et al., 1998). A consideration of resources is elemental to the development of systems within the context of developing

nations, even as that might be, as in this case, constructed through a socio-technical lens. Looking at breakdowns in interventions has the benefit of allowing the analyst to look not only at the technology, but also at the activity for which the technology is implicated (Koschmann et al., 1998). When breakdowns occur, re-alignment of tasks, resources and agents is important in getting the project back on track (Baker and Millerand, 2007). This re-alignment can be in the form of “*making do*” or “*workarounds*” to get the project work to continue, or can be an occasion for “*institutional rearrangements*” (Strauss, 1988). Breakdowns emerge as an opportunity for building networks in the project’s ecology (Mark, 2012). The management of breakdowns occurs through negotiation (Strauss, 1985). We demonstrate that, it is through choices available and decisions made in the event of breakdowns that intervention projects can be institutionalized in developing countries. In particular, we find articulation work being a dominant and approachable strategy for resolving breakdowns.

In the context of approaches that users adopt in stabilising technology within their context we find concepts like bricolage, improvisation and articulation work (Ciborra, 2002; Humphry, 2011). Bricolage is a concept that illustrates the collage created by users when they utilise seemingly useless bits and pieces of artefacts in their context to enable them to engage in routine work (Ciborra, 2002). The concept has been used to describe user activities in the appropriation of health technologies (Braa and Hedberg, 2002). In comparison, improvisation, while related to bricolage tends toward the consideration of activities that sustain routines in the face of the isolated and unexpected. Articulation work, on the other hand, is work that is usually unaccounted for in organisations yet it is critical to ongoing project activities. The concept refers to those tasks that are undertaken to facilitate the co-ordination of work. An important character of articulation work, in comparison to other concepts used in explaining the boundaries of information systems like bricolage and improvisation (Ciborra, 2002), is how it demonstrates the limited control that actors have in enacting routines within their context (Humphry, 2011). Articulation work, given its relationship to breakdowns, can be conspicuous since it brings a situation to visibility when re-alignment is possible or obstructive if no clear solution is available (Koschmann et al., 1998). In the service of workflow, the work of articulation is often assigned to specific organizational units, yet it is sometimes the case that these tasks are performed by people whose role is not primarily the maintenance of a technology, such as its users. Articulation work is also represented as invisible work since it is not visible except in instances of breakdown (Suchman, 1995). According to Star (1991) as referenced by Star and Strauss (1999), p. 10, ‘*articulation work*’ is work that “*gets things back ‘on track’ in the face of the unexpected, and modifies action to accommodate unanticipated contingencies*”. It refers to “*the specifics of putting together tasks, task sequences, task clusters -even aligning larger units such as lines of work and subprojects- in the service of workflow*” (Strauss, 1988, p. 164). Articulation work is a “*critical factor in information infrastructure building projects that involve multiple and diverse communities*” (Baker and Millerand, 2007). Infrastructure often requires articulation work to enable its continued functioning, as it contributes toward maintenance and transformation of novel technological offerings into quality systems that support everyday productivity (Bowker et al., 2010; Ribes and Finholt, 2009).

In our review of literature, particularly in the domain of health information systems, we have not found a study that elaborates the complex relationships between breakdowns, articulation work and information infrastructures. In the following section, we elaborate on the research method chosen for this study, provide an analytical case description, elaborate the findings and offer our analysis and discussion, rounding off with what it means for further work in the concluding section.

2. RESEARCH METHOD

2.1 Research Approach

Primarily, the research is inspired by Grounded Theory Methodology (GTM) (Glaser, 1978; Glaser and Strauss, 1967). GTM is an inductive research methodology that gives primacy to empirical material by seeking to let the theory emerge and the data proverbially '*speak for itself*' (Alvesson and Skoldberg, 2009). Over time, the methodology has evolved into two distinct approaches, given the divergent paths taken by its originators. It has hence been a subject of contention, even within the information systems discipline (Matavire and Brown, 2011). Epistemologically, this research is interpretive and the researchers sought to obtain meaning from observations made in the data (Klein and Myers, 1999). GTM is rich in techniques for data analysis applicable to the social sciences and has been widely applied in interpretive information systems research (Matavire and Brown, 2011). Following GTM inspired techniques, preliminary concepts codifying the data were generated. Explanatory concepts were considered from a parallel literature review and integrated into the analysis. The usage of existing concepts to explain phenomenon in a grounded theory study is not in conflict with its original tenets (Glaser and Strauss, 1967). The reflexive usage of grounded theory methodology, without full adoption, is also widespread in social science research (Alvesson and Skoldberg, 2009). It is also a common approach within the Information Systems discipline (Matavire and Brown, 2011). The particular techniques from Grounded Theory Methodology (GTM) used were open coding, selective coding, theoretical coding and memoing with the overarching technique of constant comparative analysis applied. Open coding is the line by line analysis of documents like field notes, interview transcripts and recordings to identify categories in the data. Selective coding is the inclusion and exclusion of codes to enable theoretical focus. Theoretical coding is the integration of categories into sound concepts through making the relationships between them explicit (Matavire and Brown, 2011). Constant comparative analysis refers to comparing instances of concepts to others found within the data and literature in order to discover their dimensions or properties. Memos were also written to explore ideas which illuminated the empirical occurrences. It is important to highlight that the usage of grounded theory was merely analytical due to the constraints of applying the full methodology to a study of an ongoing action research project, where different actors work together despite the diversity of their research approaches. The analytical usage of grounded theory is common in information systems research (Matavire and Brown, 2011).

2.2 Data Collection and Analysis

While the mobile health system was piloted in Malawi starting from December 2011, this particular paper is developed from data jointly collected in the follow up stage with reflections on earlier activities. The second author has also been involved in the day-to-day running of the project from its inception. Field work was performed by both authors, within the context of a research pilot project, from April 2012 to May 2012 in a period of 6 weeks. Additional data was collected from interactions through to November 2012, making the span on data collection 8 months. The predominant qualitative data collection methods were observation, individual and focus group interviews. Email and SMS conversations highlighting the challenges of the project from its onset were also analyzed along with bug reports and processes for their resolution. Interviews with key personnel were also conducted. Five full day focus groups were organized in this period, with participants consisting of Statisticians, Health Surveillance Assistants, Statistical Clerks, Village Clinic Officers and Health Officers. Health Surveillance Assistants are responsible for collecting information within the community. Due to technical reasons, four focus groups have been considered in this analysis as shown in Table 1, below. Initial rigor in open coding generated a multitude of

concepts by “*running the data open*”, however in later field notes, the approach was less open as concepts like articulation work were explored further. A literature review was undertaken to theoretically elaborate the codes. Focus groups helped to understand the challenges that the workers faced in their activities, mobile health technology usage, and on how the devices could be extended to support other aspects of their work. Field notes were the primary strategy for collecting the data and emergent ideas were pursued. Some interviews were also audio-recorded, with the permission of informants. Memos were used to reflect on observations, interview and theoretical ideas.

Table 1: Focus Group Participants

Focus Group	Health Facility Type	# of Participants	Designation
Group 1	Ministry of Health Headquarters	3	HMIS Management
Group 2	Health Centre	11	Health Surveillance Assistants (HSAs), Senior HSA, Statistical Clerk, Village Clinic Officers
Group 3	Health Centre	3	Health Officer, HSAs
Group 4	Health Area (A unit administering a collection of health centres)	2	Senior HSA, HAS

Some of the collected data was loaded into QSR-NVivo, a qualitative data analysis software which is compatible with grounded theory research (Hutchison et al., 2010). In particular, field notes and interview notes were loaded into QSR-NVivo, and open coded for categories. Memos were taken when ideas about the data came through discussion among authors and were also linked to the relevant categories in the software. It is through these discussions that the issue of articulation work was found to have strong explanatory power as pertaining to the issues arising and the desired outcome of the work, which is institutionalization of mobile technology in a healthcare setting. Detailed memos were also developed outside the software through an incremental memo sorting process as theoretical ideas were integrated with the discussion. QSR-NVivo was therefore not used extensively.

3. CASE DESCRIPTION

3.1 Initial Organisation

This study was concerned with a mobile HIS pilot project initiated in Malawi to support the capturing of routine indicator data at health facilities administered by the Ministry of Health. At the time of the pilot, the ministry was engaged with the Health Information Systems Program (HISP), for which the authors are members, to facilitate migration from the standalone desktop based information system, DHIS 1.3, to the web based DHIS2. Data collection was done on paper registers at the level of health facilities, and these were sent for collation into DHIS 1.3 at the district level and further sent in electronic format to the national level. Numerous challenges therefore existed in sending data from the facilities by paper, particularly in the cases of rural health facilities where transport is scarce and road infrastructure is poor. It is in this context that the case for mobile data capturing at the level of health facilities was proposed, particularly since the DHIS2 software had mobile functionality integrated into it.

Work on the pilot started in late 2011, where strategies were formulated pertaining to how the hoped-for nationwide rollout would proceed. Discussions were held amongst key

members of the project team and relevant officials from the Ministry of Health, particularly members of the Central Monitoring and Evaluation Division (CMED). The project entailed the deployment of DHIS Mobile; a suite of mobile device based aggregate data capturing tools that utilize different technologies including internet browsers, Java (J2ME), and SMS. The J2ME mobile client runs on Java enabled phones and could be configured to use either SMS or internet traffic. The pilot in Malawi was undertaken for the J2ME and browser based DHIS Mobile solutions in 17 health facilities that fell under two of five health areas in Lilongwe district. Lilongwe city is the capital of Malawi, and the district encompasses some rural areas. The mobile J2ME and browser solutions in this case required GPRS connectivity to support data transfer between users and an online server. A monthly facility and a weekly disease surveillance report were chosen for the pilot. 20 Nokia C2-00 mobile phones were acquired from India based on a notable price difference in acquiring the devices from Malawi. Training was agreed for two representatives from each facility, where a requirement for at least one of them to be a statistical data clerk was made. Statistical clerks are employees of the Ministry of Health in Malawi whose responsibility is the management of health facility data. It was noted later that some facilities had no statistical clerks, and chose to fill the vacancy from the pool of Health Surveillance Assistants (HSAs) assigned to health facility catchment areas. In another instance, a data entry clerk who had been trained on the mobile technology had left the health facility, and no one had replaced him. This mobility was not an unusual scenario and often the health facilities responsible for supervising the work of HSAs can choose a replacement amongst them. The statistical clerk position was usually filled by school leavers, while the HSAs underwent additional training. A post-paid contractual arrangement was entered into with a mobile provider in order to ensure central bill payment and to permit cost analysis, specifically pertaining to data usage in line with research objectives. However, it was always envisioned that the project aimed at addressing real challenges experienced at health facilities and its sustainability was a stated and motivating goal.

3.2 Breakdowns

3.2.1 *Mobile Device and Server Configuration*

As the organisation and functionality of the intervention emerged, configuring mobile devices for the mobile network was initiated. This included the purchase of SIM cards, applying internet connectivity settings, creating data entry forms, installing the J2ME client, creating user names, and testing. It is during this early stage that the conceptualised intervention started to face problems, initially that the India acquired phones were not compatible with the host mobile network. The devices could not be configured for data packet access using configuration files from the service provider. Technical discussions ensued where a range of specialists were engaged to configure the devices to work in Malawi. This was not fruitful because of the persistence of the device and network conflict. A decision was made to acquire a different local model of devices which had been confirmed to be configurable within this context. While this was ongoing, training had to be re-scheduled, to the chagrin of participants. Configuration of the online server instance to be used for the pilots progressed much slower than expected, as efforts depended to a significant extent on a resource team, resident in Blantyre, some 300 km away. Coordinating tasks with the team proved to be more challenging than anticipated. Face-to-face meetings with the system administrators were difficult to arrange which was exacerbated by prevailing nationwide fuel shortages at the time of implementation.

3.2.2 Mobile Service Provider Interactions

Earlier in the project, a post-paid subscriptions package with the mobile service provider had been selected. Insomuch as this arrangement permitted central administration of phone subscriptions and access to data usage summaries for research, it posed some challenges. With post-paid subscriptions, the available package meant that voice calls had to be capped to avoid excessive bills. This limited the capacity of phone users. With pre-paid subscriptions the phone users would have had the option of purchasing additional phone credit from numerous sale points. Furthermore, issues with ‘packed up’ SIM cards or call service unavailability arose for some users. The chosen service provider also delayed in refreshing call credit at the beginning of each month. The challenges proved difficult to resolve because of the organisational setup within the provider. The contact persons were service personnel who depended on their colleagues in the provider’s IT department to resolve the pilot project’s technical concerns. There was limited direct contact with the IT personnel, which made it challenging to resolve critical technical issues. Interactions with the contact persons revealed that they lacked authority to push for resolutions from the provider. For instance, at one point the mobile provider contact had to call an IT person and ask for an explanation as to why it had taken long to cap voice calls as agreed. The request was refused, yet the issue was subsequently resolved; after five months of piloting had elapsed.

3.2.3 Mobile Application Usage for Data Entry

The conversation below, between one of the authors and a participant enrolled in the pilot, demonstrates some of these challenges:

UserX: “My number is ... am unable to SMS, make or receive calls” (17 October 2012)

UserX: “Just want to remind you about my issue...my number is ...Am unable to SMS, make or receive calls” (18 October 2012)

Author: “I have presented the issue to [mobile service provider]. I am waiting for their feedback” (18 October 2012)

UserX: “Evening, the [mobile service provider] people have not rectified my problem...unable to call or SMS...pliz assist”(5 November 2012)

All the messages from UserX were forwarded to our contact person, for action. Such challenges could be minimised with the use of pre-paid cards as they can be acquired from vendors countrywide. Modalities to switch from post-paid mode of subscription to pre-paid were initiated. A sticky point is the management of the allocation of Internet data bundles for participants. The mobile service operator had no service that allowed subscribers to share data bundles. There was a need to push call credit to the devices which recipients needed to manually convert to data bundles. Another challenge is that the cheaper data bundles targeted, had limited validity periods, a day in most cases. There were ongoing negotiations for a solution with the mobile service provider. While longer term strategies to resolve these problems are preferred, it is also important to highlight an occasion where users articulated a resolution. The pilot was also designed to compare usability between the J2ME and browser based clients in low resource settings. All participants were trained in the use of the browser based solution while a group from one Health Area received additional training in the use of the J2ME client. During the process of data entry in the latter group, when the J2ME client experienced connectivity problems, some participants shifted to the browser based application. This is important since it creates the possibility to install multiple clients on user devices such that they can shift from one to another to resolve breakdowns.

3.2.4 Ministry of Health Project Coordination

As previously noted, piloting was started in a period during which the Ministry of Health was attempting to migrate from a desktop-based DHIS1.3 to the internet and central server based

DHIS2 solution. The pilot project was utilising an online national DHIS2 server, but the Ministry of Health Central Monitoring and Evaluation Division (CMED), which was at the centre of the proposed migration efforts, was yet to shift from DHIS1.3. There was no seamless metadata, data element and indicator export functionality between DHIS1.3 and DHIS2. The implication of this is that all district health offices in Malawi, including our pilot district were required to send their data to CMED in a DHIS 1.3 compliant format. Although CMED intended to move to DHIS2, they lacked financial and technical capacity to push the migration forward. For example, the Ministry of Health Headquarters had a single IT officer in their hierarchy, whose focus was not on the national health information system. It was found that the bureaucracy in applying for the creation of a new IT position in the Ministry hampered the efforts. Therefore, migration of data from DHIS1.3 to DHIS2 was dependent on the DHIS team in another city. Financial support for the migration was dependent on multiple implementation partners, with their own timelines and organisational arrangements to adhere to. Each external donor agency or parallel program had its own organisational priorities, which did not uniformly represent the problems on the ground. For instance, in one scenario, 18 districts had multiple donors willing to support ongoing HIS efforts, whilst the other 10 districts had none at all. Donor organisations only operated within certain districts that they had targeted to achieve the greatest impact according to their internal organisational goals. Thus, while the goal is integration of data processes, spatial fragmentation still persists due to uneven distribution of HIS resources. To counter such challenges, some working groups were put in place by the Ministry of Health and its partners. For example, a Monitoring and Evaluation (M and E) Technical Working Group was mandated to establish appropriate standards for integration. Within the working group, a mHealth forum with the membership of the various organisations running mobile interventions in the health sector of Malawi was established after the pilot was started. It is through this forum that key questions about the sustainability of projects could be negotiated. For instance, a key concern that arises in the design of technology for health is, if it works, *“who is going to pay for it?”* The mobile devices need airtime to be enabled for data access on a regular basis and it was therefore anticipated that negotiations with mobile providers can occur at the level of the Technical Working Group.

3.2.5 Global Development and Local Requirements

At the time of implementation, the DHIS Mobile platform used was rapidly evolving to support varying requirements from the parent project's multiple implementations in various countries. This introduced instabilities in the platform. For example, at one point, in upgrading to a newer DHIS2 server instance, it was discovered that compatibility with a mobile J2ME reporting client supported by the previous version had been lost. This was temporarily resolved by backwardly synchronising server instance releases with available mobile client releases, which was satisfactory. This scenario presented shows an instance where the issues in Malawi were similar to those in other locales, hence the speedy resolution. DHIS Mobile software was developed by an international team of software developers, with most core developers resident in Vietnam and some key project leaders, responsible for coordinating developer tasks, based in Norway. It was therefore challenging to adequately relay localised software requirements between the implementation team in Malawi and the global team in Vietnam and Norway. In cases where urgent resolution of bugs was needed, given the limited technical skills in the ministry, local workarounds would likely address the problems timeously. There existed communication challenges in forwarding local requirements to the global development team and coordinating their resolution. A member of the global team aptly characterised this through the remark: *“to be honest we didn't understand the request until now”*; months later.

3.2.6 District Office System Access

In the case of mobile HIS data entry, data is transmitted from mobile devices into the central server. This is problematic for data quality as all the intervening checks necessitated through the paper-based system are leapfrogged by the mobile technology and central server architecture. In DHIS1.3, data was entered in a database on the local machine at the district level, archived, and sent via email to the health statistics office at the national level. In one instance, a participant at the district office, would enter the data offline after receiving the paper reports, store the file archive on a memory stick, and go to an adjacent office block where an internet connection existed to send the data. Internet connectivity related challenges were also experienced at national level in attempting to retrieve these files. With mobile data entry at facility level, it is important for the district offices and the national level to have stable internet connection in order that they may verify and confirm the entered data. Furthermore, health workers at the facility level also needed mechanisms through which they could access reports on the submitted data in order to improve on its quality. During the pilot, data dongles were provided, a situation which required manual monthly airtime top up. Besides from this, the participant officer also continued to receive paper reports from facilities that were not part of our pilots, for entry into the DHIS 1.3 system. A district officer therefore had to reconcile the data entered onto the online DHIS2 server, using mobile phones, with the data in DHIS1.3, before sending data for the district to the national level in the archive format. This was an inconvenience which was expressed clearly as an untenable situation. At the time of writing this paper, the situation had improved after CMED and most districts in Malawi, including Lilongwe had shifted from DHIS 1.3 to DHIS2. The shift made it easier for the district participating in the DHIS Mobile pilots to manage data reporting through a combination of paper-based registers and DHIS Mobile-supported reporting, as now all data was maintained under one central server.

4. ANALYSIS AND DISCUSSION

It is realized that the basis for the pilot to be permitted within the Ministry of Health of Malawi was to attempt to address the numerous challenges encountered in the flow and proper use of data in line with local and global requirements. Malawi is considered as a least developed nation, a measure which demonstrates its marginality in the provision of basic services like education and healthcare to its people. Hence simply put, it is breakdowns in the healthcare delivery infrastructure that permit this innovation process to occur in Malawi. Our own intervention, centred on the DHIS Mobile technology, was geared towards addressing the challenges posed in monitoring health indicators from across the country. We saw in this research that though technology typologies might assist in the conceptualization of solutions for developing nations as described by Sanner et al. (2012), technology fit and sustainability can only be the result of a continuous articulation process within the context. This articulation work is conspicuous where users find their own solutions to the challenges, and obtrusive where unsustainable mechanisms are enacted to solve the challenges. Such mechanisms, in this case, manifest in donor dependency to resolve problems. We find that chosen solutions interacting with persistent structures in the intervention can result in breakdowns. This also means that the choices that are also made in the event of breakdowns have a similar causal and conditional impact on future failures and successes as they affect the problem and decision space.

4.1 Breakdowns and their Articulation

In Table 2 below, we see situations where breakdowns occurred in the intervention, and how they were resolved. The goal was to eventually have a design which was robust and could operate within Malawi, with aligned external dependencies. In this study we discover two

categories of articulation work, technological and human. Technological articulation pertains to technical work that is done to ensure the work of mobile data entry gets back on track. Human articulation pertains to the work of formation of temporal networks of action among actors to address breakdowns. We also see the challenges of designing mobile HMIS technology for developing countries, with Malawi categorised as least developed (UN, 2011). The systems designed in global domains, face challenges that are understood in event of localised breakdowns. Articulation work is used as a strategy to overcome these challenges. However, it is recognised that articulation work is not enough to sustain interventions, even what is here termed human articulation. In the research context we see the peculiar case of the formation of the mHealth forum, which we argue is articulation work, in the form of organisational rearrangement. Kanjo et al. (2009) who also conducted their study on the HIS in Malawi recognise that stakeholder buy-in alone was not enough to get a system to be institutionalised, and therefore recommend that flexible standardisation is key to HIS success. However, it is important to realise that such institution wide approaches require higher level negotiation processes which are relatively inaccessible to many m-health initiatives. This research recognises and considers the essence and possibility of a multi-level approach to institutionalisation.

Table 2: Breakdowns and their Articulation

Breakdown	Articulation Work	
	Technological Articulation	Human Articulation:
Failed mobile device and server configuration	Phones hurriedly replaced, and the pilot training affected.	Negotiations with network operator and project sponsors led to a realisation that the local mobile provider involvement should start early.
Limited mobile services from provider as we deal with marketing agent.	Mobile data capping remained problematic. Usage trends and alternative packages were analyzed in the billing statements so as to determine future re-arrangements.	More strategic partnerships with local mobile provider could provide leverage in negotiating packages.
Failed SIM cards.	SIMs collected from mobile service operator and delivered individually to remote facilities. Mobile software configurations reapplied and tested.	Negotiations on SIM ownership to provide incentive for mobile device maintenance among users.
Missing mobile system Functionality	Making do with the available features while awaiting changes.	Engagements with the global team to consider requirements from case and improve responsiveness to local concerns.
Limited system access from District Health Office	Manual dongle top up. Assistant statistician needed to enter data from new system into old.	Negotiations for full migration from legacy system to new system.
Mobile client application failures	Users chose browser client when J2ME client failed.	Negotiating the building of redundancy into the intervention by training users on multiple

		clients.
Erratic internet connectivity in Central health statistics office.	Awaiting connectivity solutions proposed by different stakeholders.	Advocating to stakeholders for a sustainable solution. Developing resident capacity to manage implemented solutions and provide support to users.
Delays in attending to user queries by mobile service provider	Making do with current limited services.	Frequent follow ups on queries raised with provider. Lobbying with other organisations doing mHealth, through the Malawi mHealth forum, for a unified voice to gain more bargaining power.

From the case presentation and Table 2, above, it is evident that resolution of local technology breakdowns can be achieved at individual level, across different levels within an organization, and across organizational boundaries (within or across countries). However, where interventions are part of a larger infrastructure setup it is often the case that networking across organizational levels and across organizations is necessary to resolve breakdowns. In this study, articulation work that requires collaboration across multiple levels includes efforts to resolve: mobile telephony subscription; replacement of failed SIM cards; migration from DHIS 1.3 to DHIS2; DHIS2 server configuration; and failed attempts mobile device configuration, for the set of phones purchased in India. Consequently, the two identified categories of articulation work, technological and human, can also be analysed from other dimensions based on the levels of organizational involvement required to resolve them: (i) localised (individual or location where breakdown occurs; single point of end-user support) ; (ii) multiple levels within single organization (multi-level and intra-organizational); (iii) and multiple levels cross-organizations (multi-level and inter-organizational).

A challenge is found in motivating local and global stakeholders into more structured and sustainable inter-organisational arrangements. A significance of the multi-dimensional analysis of articulation work presented above is that it may help interventionists anticipate the amount of effort and coordination required to address breakdowns in a mobile health project. Coupled with an obvious need for coordination that emerges when multiple stakeholders require mobilization to address breakdowns is the issue of jurisdiction. Particular stakeholders tasked with the resolution of breakdowns might not be in a position to influence the trajectory of required articulation work across organizational boundaries. When this occurs, there might be need for preliminary work, such as development of work relationships, to take place in order for required articulation work relating to identified breakdowns to take place. However, building stable work relationships across organizational levels takes time. The DHIS Mobile pilots could have benefited from such an analysis in dealings with the mobile service provider, where resolution of issues agreed upon with points of contact depended on other IT personnel the project team was hardly in contact with. Implications of buying mobile phones outside the context of implementation, under which the DHIS Mobile project team could not readily access the vendors, when problems emerged, could also have been weighed more carefully. Going forward, such an analysis also creates an opportunity for those implementing mobile health systems to anticipate the amount of work introduced in negotiating the development of more sustainable organizational arrangements that can outlive current intervention activities.

Meanwhile, articulation work remained as the dominant strategy to keep the intervention afloat. Infrastructure work frequently entails ongoing articulation work to permit continued functioning (Bowker et al., 2010). Quite often, failures in information systems

projects in developing countries are due to limitations in technological and human infrastructure (Heeks, 2002; Manda and Sanner, 2012; Semaan and Mark, 2011). In our work, we demonstrate through an ongoing project the low level strategies that are employed to resolve these challenges, and we find articulation work occurring technologically and organisationally. By analysing our research in this manner, we also see the possibility for breakdowns being used as opportunities for the building of both technological and human infrastructure. We also see the challenges that can arise if breakdowns are tackled in isolation, as similar challenges exist in other projects within the context of developing nations.

It is critical that efforts to develop necessary technical and human infrastructure take on board key stakeholders and also look beyond individual project arrangements. It has been noted that project-centric interventions often collapse when interventions end (Lehmann and Sanders, 2007; Sanner et al., 2012). However, unlike individual project arrangements, which are often short-term, infrastructures evolve over long periods of time. This necessitates the presence of more persistent individual and organizational arrangements to transition novel solution offerings into stable technologies that support productivity (Ribes and Finholt, 2009). It is against this background that key players within the Malawi HIS landscape, such as the Ministry of Health (through CMED) and the team coordinating the shift from DHIS 1.3 to DHIS2 had been engaged from the onset. At the same time, engagement of multiple stakeholders, especially across organizational boundaries, must be approached with caution, as this can introduce significant coordination overheads, which may slow down the resolution of breakdowns. All the same, the strategic negotiation of breakdowns across stakeholder groups is a key process in designing mobile technologies that address both immediate and long term concerns for sustainability (Mark, 2012; Ribes and Finholt, 2009).

5. CONCLUSION

This study demonstrates that mobile intervention in developing countries entails the development of local work routines at multiple organisational and interorganisational levels to support the introduced technology. In some cases, this is done with the resources embedded in the context, while in others users have to rely on the continued support from the interventionists. In either case, we see that sustainability of intervention is an evolutionary process which entails the constant adaptation of human and technical resources necessary for the continued use of introduced technology. Given the limited infrastructure in the context of this study, articulation work is employed to keep the project ongoing and it takes on the peculiar form that provides suggestion to the sustainability of the intervention. Two varieties of articulation work are discussed in this work, which are human and technical. Participants employ technical and human resources in the environment based on their local knowledge to sustain the work. The organisational structure is altered in that new connections are sought when breakdowns occur. This is illustrated in the human articulation aspects where diverse interactions are employed to address a breakdown. In technical articulation, we see problematic parts being replaced and rearranged by participants to enable the intervention to continue. In this context, we realise that rigid systems will be expensive and not easily integrated into the contexts as users will not be able to recover from breakdowns resulting in failure.

Breakdowns can manifest at various levels within the organizational hierarchy, or manifest across organizations shaping an implementation. In our case, this includes stakeholders within the Ministry of Health, users, implementation partners, the mobile service provider, the project support team in Malawi, and the global development partners. Breakdowns can be localised, such as those within the Ministry of Health, or manifest in cross-organisational relations. The latter is evidenced in how breakdowns within our mobile

service provider, with regard to addressing issues impacted the pilots, showing the boundaries of articulation. The varied nature and extent of breakdowns has an implication on the type of articulation work required to resolve them. For example, breakdowns requiring the mobile service provider to cooperate are much harder to resolve considering that they are beyond control thereby temporally becoming external contingencies. We also find that breakdowns are occasions to alter the organisational and technological structure of the project as evidenced in the formation of the mHealth forum.

In future work, we aim to continue to develop a theoretical framework that is useful in the design of mobile HMIS solutions. From our analysis we see that designing for articulation is a useful strategy for developing HIS in developing nations. Our work also enables us to consider the role and timing of strategies that can be employed to improve outcomes in information infrastructure interventions, such as the the long-now of information infrastructure design (Bowker et al., 2010; Ribes and Finholt, 2007, 2009) The long-now perspective is concerned with building information infrastructures to address present and emergent demands, with an emphasis on decisions taken early on in the intervention as having consequences for the sustainability of the intervention. In paying attention to the relevance of the totality of socio-technical arrangements, which lead to breakdowns or their resolution, this paper underscores the importance of the information ecology (Nardi and O'Day, 2000) within which mobile HMIS solutions are constructed. Our work also points to the inter-organisational character of localised interventions. They demonstrate how the local can be intricately tied into activities that occur across organisational and national boundaries. Understanding the nature and sustainability of such relationships is a key aspect in ensuring sustainability. It was recognised that interorganisational relations have a key role in enabling nations to develop suitable technologies for development (Njihia and Merali, 2013). The study also raises question about the approaches that are suitable for investigating technologies in complex organisational settings such as that which is illustrated in the case. It is important to adopt approaches that illuminate the multiple levels of the phenomenon and the varied relations that are implicated in developing technologies for low resource contexts. Grounded theory methodology has the character of following the data from the setting closely, with fitting categories for explanation. The role of literature in such studies is often contested, however we demonstrate in this work that the adoption of the principles of the methodological approach is not in conflict with existing theoretical concepts. However, the difficulty of adhering to the methodological tenets of GTM means its application, particularly within the broader context of an action research project which is guided by specific practical outcomes, remains contentious. Despite this, it still remains that the field would benefit from research that aims to develop theory that is faithful to the context. Studies that illuminate the difficulties and approaches used in practice will be informative to the discourse.

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Appendix 3: Paper 3

MANDA, T. D. & SANNER, T. A. (2014). The Mobile Is Part of a Whole: Implementing and Evaluating mHealth from an Information Infrastructure Perspective. *International Journal of User-Driven Healthcare (IJUDH)*. 4(1). 1-16.

Appendix 4: Paper 4

SANNER, T. A., MANDA, T. D. & NIELSEN, P. (2014). Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation. *Journal of the Association for Information Systems*, 15(4). 220- 243.

Appendix 5: Paper 5

MANDA, T. D. (2015). Leveraging Project Arrangements in Developing Health Information Systems Infrastructure. **Under review in an international journal**

Appendix 6: Research Permit

Telephone: + 265 789 400
Facsimile: + 265 789 431
e-mail doccentre@malawi.net
**All Communications should be addressed to:
The Secretary for Health**



In reply please quote No. MED/4/36c

MINISTRY OF HEALTH
P.O. BOX 30377
LILONGWE 3
MALAWI

7th November 2011

Tiwonge Manda
Chancellor College

Dear Sir/Madam,

RE: Protocol # 958: Nurturing health solution implementations for health data collection, reporting and management in low - resource contexts

Thank you for the above titled proposal that you submitted to the National Health Sciences Research Committee (NHSRC) for review. Please be advised that the NHSRC has **reviewed** and **approved** your application to conduct the above titled study.

- **APPROVAL NUMBER** : NHSRC # 958
The above details should be used on all correspondence, consent forms and documents as appropriate.
- **APPROVAL DATE** : 07/11/2011
- **EXPIRATION DATE** : This approval expires on 08/11/2012
After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the NHSRC secretariat should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING** : All serious problems having to do with subject safety must be reported to the National Health Sciences Research Committee within 10 working days using standard forms obtainable from the NHSRC Secretariat.
- **MODIFICATIONS**: Prior NHSRC approval using standard forms obtainable from the NHSRC Secretariat is required before implementing any changes in the Protocol (including changes in the consent documents). You may not use any other consent documents besides those approved by the NHSRC.
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the NHSRC using standard forms obtainable from the NHSRC Secretariat.
- **QUESTIONS**: Please contact the NHSRC on Telephone No. (01) 724418, 0999218630 or by e-mail on moh@gmail.com
- **Other**:
Please be reminded to send in copies of your final research results for our records as well as for the Health Research Database.

Kind regards from the NHSRC Secretariat.


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FOR CHAIRMAN, NATIONAL HEALTH SCIENCES RESEARCH COMMITTEE

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