

GRAFTING INFORMATION INFRASTRUCTURE

Mobile Phone-based Health Information System Implementations in India and
Malawi

Terje Aksel Sanner

The Department of Informatics,
Faculty of Mathematics and Natural Sciences,
University of Oslo

January 2015

© Terje Aksel Sanner, 2015

*Series of dissertations submitted to the
Faculty of Mathematics and Natural Sciences, University of Oslo
No. 1616*

ISSN 1501-7710

All rights reserved. No part of this publication may be reproduced or transmitted, in any form or by any means, without permission.

Cover: Hanne Baadsgaard Utigard.
Printed in Norway: AIT Oslo AS.

Produced in co-operation with Akademika Publishing.
The thesis is produced by Akademika Publishing merely in connection with the thesis defence. Kindly direct all inquiries regarding the thesis to the copyright holder or the unit which grants the doctorate.

To Marit

*for your patience with the man
behind the laptop computer
in the navy blue armchair
under the 'elephant foot' palm tree*

ACKNOWLEDGEMENTS

Thank you, Kristin Braa, for your initial faith in my ability to complete this journey, and for sticking with your conviction despite superior evidence to the contrary. Thank you Bendik Bygstad for your guidance at an early stage of my research and for your critical observations always delivered with an encouraging twist. Thank you Petter Nielsen for your precise and witty remarks, and thank you for saying that “*grafting* is the answer to everything”, even if we both know that it is not so.

Thanks Sundeep Sahay, Ole Hanseth and Margunn Aanestad for always lifting your gaze from your computer screens and lending an ear whenever I wandered into your offices in a state of academic bewilderment. Thanks Ola Henfridsson, Miria Grisot, Bjørn Erik Mørk and Knut Staring for your helpful comments to some of my early drafts.

Thanks Johan, Tiwonge and Lars Kristian for your close collaboration in writing. Thanks Ime, Rangarirai, Saptarshi, and Hanne Cecilie, my brothers and sister in arms, for taking time out of your busy schedules to read, comment on and discuss my manuscripts at various stages.

Last but not least, thanks to the numerous informants of this study for your collaboration, support and friendship. In particular, thanks to the health workers both in India and Malawi, whom I encountered during my field work, for lending your time and allowing me to tag along – my deepest admiration goes out to you for your extremely important and hard work!

T ABLES AND FIGURES

Figure 4-1 End user training on mobile reporting in Patiala district.....	27
Table 4-1 Major trips of fieldwork to Punjab, India, and Lilongwe, Malawi.....	29
Figure 4-2 Group interview at a sub-district health facility in Lilongwe.....	36
Figure 5-1 Family planning consultation in a Punjabi household	42
Figure 5-2 Examination of a suspected case of malaria in a village in Malawi	47
Table 6-2 Institutional logics at play in ICT4D	58
Figure 7-1 Horticultural grafting technique and an approach to grafting	63
Table 7-1 Practical recommendations	71

ABSTRACT

In the wake of ‘the mobile revolution’ there has been an immense upsurge in mobile phone-based health innovations, or *mHealth* for short. Expected efficiency gains and health benefits with such innovations, however, have been notoriously difficult to realize in the resource sparse settings of less developed economies. Scholars and industry specialists have found the implementation of a large portion of mobile phone-based innovations *unsustainable* beyond short-term pilot projects.

This dissertation is positioned within the information systems (IS) research tradition and develops a nuanced understanding of so called *mHealth sustainability* challenges through two qualitative and exploratory interpretive case studies, one in India and one in Malawi. Both mobile phone-based implementations under study were commissioned by health authorities to strengthen routine reporting of public health data. A ‘big-bang’ roll-out to 5000 community-based health workers was initiated in India while incremental ‘baby-steps’ were favored in Malawi. The two empirical cases highlight different technical, infrastructural, socio-political, and institutional hurdles. The dissertation draws theoretical inferences from both cases through the proposition of *information infrastructure grafting*, whereby complex and fragile multi-stakeholder ICT implementation processes are conceptualized analogously with horticultural grafting (read: gardening).

There is one simple maxim to plant grafting – the grafted branch or shoot has to take hold before it can grow. The merge between *congenial* plant parts can be assisted, but not asserted, by a gardener’s careful application of appropriate grafting techniques. The grafting metaphor foregrounds the need for care and tenderness in information infrastructure development, particularly in resource sparse settings. *Information infrastructure grafting*, then, is a fragile process whereby innovative ICT capabilities merge and coevolve with extant technologies, work practices, physical and digital infrastructure, and social institutions.

This dissertation explores how *congeniality* between innovative ICT capabilities and extant socio-technical arrangements, and not merely ‘technology fit’ or ‘organizational readiness’, paves the road towards more sustainable implementations. This has practical implications for health information system policy makers and strategists, international funding agencies, ICT project managers and mHealth practitioners. Based on empirical investigations and an ecological conceptualization of socio-digital change, this dissertation engages constructively with the discourse on sustainable development as it pertains to ICT-based implementations in general and mHealth research and practice in particular.

PREFACE

This dissertation is submitted in partial fulfilment of the requirements for the degree of Philosophical Doctorate (PhD) at the Faculty of Mathematics and Natural Sciences, University of Oslo, Norway. The research has been completed through my participation in the Global Infrastructures (GI) research group at the Department of Informatics.

The dissertation consists of *five* peer reviewed and published articles and an introductory segment that elaborates on and synthesizes the research contributions of the articles. The introductory segment presents the empirical and theoretical framing of the research agenda, positions the research in relation to relevant related research, reflects on strengths and limitations with the research approach and discusses practical and theoretical implications from the core contribution of my work – *a grafting perspective on information infrastructure development*. Summaries of the five articles are presented in *chapter six* entitled ‘Research Findings and Contributions’. The full length articles are included as Appendices I-V.

- I. Braa, K., & Sanner, T. A. (2011). Making mHealth Happen for Health Information Systems in Low Resource Contexts. *In Proceedings of the 11th International Conference on Social Implications of Computers in Developing Countries*, Kathmandu, Nepal, May 2011, 530-541.
- II. Sanner, T. A., Roland, L. K., & Braa, K. (2012). From pilot to scale: Towards an mHealth typology for low-resource contexts. *Health Policy and Technology*, 1(3), 155–164.
- III. Manda, T. D., & Sanner, T. A. (2012). Bootstrapping Information Technology Innovations across Organisational and Geographical Boundaries: Lessons from an mHealth Implementation in Malawi. *In Selected Papers of the Information Systems Research Seminar in Scandinavia*. Akademika, 25-39.
- IV. 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
- V. Sanner, T. A., & Sæbø, J. I. (2014). Paying per diems for ICT4D project participation: A sustainability challenge [IFIP special issue]. *Information Technologies & International Development*, 10(2), 33–47.

Contents

1	Introduction	1
1.1	The Mobile Revolution meets Health Information Systems	1
1.2	Purposes and Limitations with Routine Health Information Systems	2
1.3	‘Pilotitis’ or: Failing to sustain mHealth Implementations	4
1.3.1	Being Specific about Mobile Technologies	6
1.3.2	Mobile Technology Implementation: Becoming Part of the Ecology	8
1.4	Aim and Disposition of the Dissertation.....	9
2	Related Research	12
2.1	Sustainability of Health Information System Implementations	12
2.2	The ‘All or Nothing’ Predicament of Routine Health Information Systems	14
3	Analytical Perspective	16
3.1	Information Infrastructure as Ecology.....	17
3.2	Fostering Change: Bootstrapping, Gateways, and Installed Base Cultivation	19
3.3	From Project to Information Infrastructure	22
4	Research Approach	25
4.1	Research Context.....	25
4.1.1	Mobile Phone-based Implementations in India and Malawi.....	26
4.2	Philosophical Underpinnings: Qualitative Interpretive Case Study Research.....	30
4.2.1	Understanding Information Systems through Metaphorical Transference	32
4.3	Empirical Data Collection and Analysis.....	34
4.3.1	Observations, Field Notes and Photos	34
4.3.2	Interviews and Focus Group Discussions	35
4.3.3	Document Studies and Naturally Occurring Data	37
4.3.4	Adding Structure to Data Analysis: Use of Computer Software	37
4.4	Ethics: Do no Harm and Strive for Reciprocity	38
5	Two Stories of Mobile Phone-based Implementations	40
5.1	‘Big-bang’ Roll-out in Punjab, India	40
5.2	Incremental ‘Baby-steps’ in Lilongwe, Malawi.....	46
6	Research Findings and Contributions	52
6.1	Summaries of Research Articles	52

6.1.1	Article I: ‘Making mHealth Happen’	53
6.1.2	Article II: ‘An mHealth Typology’	54
6.1.3	Article III: ‘Bootstrapping Technology Innovations’	56
6.1.4	Article IV: ‘Grafting Information Infrastructure’	57
6.1.5	Article V: ‘Paying Per Diems for Project Participation’	58
6.2	Synthesis of Research Findings: Unpacking ‘mHealth Sustainability’	60
7	Information Infrastructure Grafting	62
7.1	Four Information Infrastructure Grafting Themes	63
7.1.1	The Point of Union has Long-term Implications	64
7.1.2	Co-evolution through Socio-technical Congeniality.....	65
7.1.3	From ICT-Project to Collaborative Nurturance	67
7.1.4	ICT Capabilities Propagate Across Domains and Regions	69
7.2	Implications for Policy and Practice	69
7.3	Concluding Remarks	72
8	References	74

Chapter One

Introduction

1.1 The Mobile Revolution meets Health Information Systems

It is an early morning in November 2011. My colleagues and I move about in a leased Toyota Hilux. Our agenda is to train sub-district health facility staff on mobile phone-based periodic reporting of routine health data¹. Our destination is a small government owned hospital called Kabudula. The hospital sometimes serves as a meeting ground for staff working at neighboring health facilities. It is located in the rural outskirts of Lilongwe district in Malawi. Rainy season is about to kick in. The rain turns dirt roads into mud. This may be our last chance to reach Kabudula without too much inconvenience.

Placed neatly along the dusty roads are tall wooden poles. They used to be utility poles, but they have been relieved of the wires that united them. They used to be telecom infrastructure. I ask my friend and colleague sitting next to me in the car about the poles. Tiwonge, a Malawian, explains that the wires have been looted and sold for their copper value. “The copper has probably found its way to foreign factories by now”, he adds. Only small stumps of wire, one and a half meters long at the most still protrude from the top of the poles. The Malawi government has given up on these poles.

The expansion of mobile phone networks and the proliferation of inexpensive mobile handsets have put digital information and communication technology capabilities in the hands of people who lack access to proper roads, clean drinking water, basic health services, electricity and major sources of publicly relevant media such as television and newspapers. By 2011 the swiftly advancing Global System for Mobile Communications (GSM) was estimated to cover more than 93 percent of the population of Malawi, while only 11 percent had access to the national hydro powered electricity grid (Foster & Shkaratan, 2011). Not only are robust low-end mobile phones to be found everywhere, so is also the competence to nurture and repair them.

We reach Kabudula hospital. Power is out. The mobile network signal is gone. During power outages mobile towers are supposed to be powered by generators, but the mobile operator has been unable to service the generators due to persistent fuel shortages. There is a fuel crisis in Malawi². Last night we bought diesel on the ‘black market’ so that we could make our field trip in the morning. We have brought a projector in order to start the training session with a live demonstration of the functionality of the mobile application. Without

¹ Aggregate routine health data or *health metrics* does not contain sensitive data about individual patients.

² Malawi had severe fuel and foreign-currency shortages after falling-out with donors in the period 2011-2012.

power we cannot do the demonstration. Next, we were going to distribute phones and do hands on training with workshop participants. Without a mobile network signal we cannot do the hands on training. We sit and chat for a while. We conduct an improvised focus group discussion about challenges with the current paper based reporting of routine health data. I learn that health workers at sub-district health facilities in Malawi are used to information and communication technologies (ICTs) such as radios and telephones not working. They also frequently do not receive help when their ICTs are not working. Power comes back on along with the mobile network signal. We proceed with the mobile training.

Power outages, fuel shortages and flooded roads are part and parcel of health workers' lived experiences in resource sparse settings. Consequently, transmission of paper-based reports from sub-district health facilities to higher organizational levels is characterized by improvisation. For instance, reports may be carried by bicycle or they can be handed over to ambulance drivers who happen to pass by (Sanner, Manda, & Nielsen, 2014). Urgent messages and alerts can be delivered via radio (if available) or through mobile phones by sending text messages (SMS) or by 'beeping'³ colleagues and supervisors. In a recent study, Asiimwe et al. (2011, p. 32) recount infrastructural challenges when implementing an SMS based tool for monitoring stock-outs of malaria medicines in Uganda accordingly, "although the use of mobile phones for data reporting via SMS overcomes many of the issues associated with data collection from health centers [...], maintaining internet access and a steady electrical supply is still challenging in remote areas, even at the district headquarters". Their experiences from Uganda are reminiscent with my own experiences from Malawi and, to a lesser extent, Punjab in India.

Low-end mobile phone-based solutions show particular promise in their ability to meet information and communication needs even at the periphery of national health systems (Black et al., 2009; Braa & Sanner, 2011; Haberer, Kiwanuka, Nansera, Wilson, & Bangsberg, 2010). However, as the next section elaborates, unless sound routines and a sober information culture is in place, mobile phone-based innovations will most likely only help an already weak and underperforming health information system to *appear* more modern and efficient.

1.2 Purposes and Limitations with Routine Health Information Systems

For the past four years I have been involved with mobile phone-based health information system implementations in India and Malawi. Both implementations have focused on routine reporting (e.g., weekly, monthly or quarterly) of numerical public health data from sub-district health facilities. Through my involvement with the two implementations I have observed how outreach health workers such as health surveillance assistants (HSAs) in

³ *Beeping* is the practice of placing a 'missed call', with the expectation that the receiver will interpret it as a request to return the call and hence cover the communication costs (Donner, 2007).

Lilongwe (Malawi) and auxiliary nurse midwives (ANMs) in Punjab (India) filtered a myriad of tacit knowledge sources and employed word of mouth to traverse rural villages, locate beneficiaries targeted for preventive or curative health care, refer sick or injured people to clinics, and meticulously record routine health data. Using pen and paper they collected and collated data about public health incidences such as number of new malaria cases, number of pregnant women consulted, number of condoms distributed, and amount of protective (malaria) bed nets provided to mothers with infants or young children.

I particularly recall accompanying an HSA one afternoon as he performed his chores in a Malawian village. Soon after our arrival in the village, the village *headman*, a traditional authority figure, came to greet me in English. He insisted that I inspect the local source of drinking water. In seconds children residing in the village had gathered around the well to demonstrate the poor quality of the presumably contaminated water. While interacting with the well the children threw grins and curious glances at me. The village headman explained that he had tried to contact local authorities to request help with a new borehole, but to no avail. He went on to request my assistance.

At the time, the routine health data being recorded by HSAs in Malawian villages included number of cases of ‘diarrhea with dehydration’ and ‘diarrhea with blood’. Diarrhea is usually caused by contaminated drinking water and is one of the main causes of infant and young child mortality. Confronted by the hopeful villagers I suddenly felt that I had to explain, both to them and to myself, that this ‘white wanderer’ (*Mzungu* in Chichewa and other Bantu languages) had only come to investigate how routine reporting on such incidences could be improved – preferably by leveraging mobile phones. I was not there to remove the actual culprit, which the village residents, in this case, had presumably identified. I would have loved to assist the villagers in their vital quest for clean drinking water, but I did not know of anyone who could influence the commissioning of boreholes in Malawi. My area of expertise was with mobile technologies and my contacts in Malawi were mainly researchers and government officials involved with routine health information systems.

In accordance with the primary health care⁴ mantra of ‘health for all’, the collection of routine health data is a key priority inasmuch as it informs “the pursuit and monitoring of the extent of *coverage* with essential health services to the entire population with emphasis on reaching the currently underserved population groups” (Health Metrics Network, 2009, p. 93, my emphasis). Timely, complete and accurate data may be used to calculate health service indicators⁵ which describe health problem trends and reveal inequalities in health

⁴ Primary health care (PHC) came on the international development agenda with the Alma Ata declaration in 1978. More recently, the PHC agenda has been revitalized through the Millennium Development Goals (MDGs) and Universal Health Coverage (UHC).

⁵ Indicators relevant to public health administration include quantitative measures of the level and trend of health problems, health service performance, or health resource availability, allocation and use. In relation to the routine health data itself, indicators can be calculated to measure similar attributes including coverage (of reporting), quality (of data), timeliness and use.

service provision. By examining indicators, public health managers at *health districts*⁶ can identify hazards such as poor drinking water, allocate resources, and take appropriate and effective actions. However, health service indicators need to be analyzed and interpreted by managers who are in fact dedicated to evidence-based public health decision making (Rodrigues, 2000; Stansfield, Walsh, Prata, & Evans, 2006).

Even when relevant information is available, decision makers may not understand it in such a way that it can inform action and policy (Walsh & Simonet, 1995). Hence, health information systems are only as effective as the health system activities they facilitate and support (Sandiford, Annett, & Cibulskis, 1992). Also, for appropriate actions to be taken, data frequently needs to be shared across fragmented and poorly coordinated ministries, departments, programs and projects. The Ministry of Health in Malawi, for instance, does not commission boreholes – the Ministry of Irrigation and Water Development does. Finally, accurate health information is of limited value if the resources necessary to act simply are not available. For a financially poor country like Malawi, the funding⁷ and technical assistance required to implement solutions often stem from powerful international donors who may or may not have village boreholes on their current list of priorities. For instance, in Malawi's neighboring countries, Mozambique and Tanzania, Kimaro & Nhampossa (2005, p. 291) found that health information system implementations are typically driven by “the donors’ perspective, while the [Ministry of Health] plays essentially a political and symbolic role”.

The past few years have seen international donors running in packs to fund so called *mHealth* projects at the periphery of public health systems in less developed economies. Many of these implementations, however, have not been able to move beyond initial pilot project stages. Consequently, researchers, consultants and development practitioners have embarked upon a search for ‘critical factors’ and ‘success criteria’ that can facilitate mHealth sustainability. The next section provides an overview of this problem and motivates my empirical study of mobile-phone based routine health information system implementations in India and Malawi.

1.3 ‘Pilotitis’ or: Failing to sustain mHealth Implementations

With a plethora of so called mHealth projects emerging to support work at the fringes of public health organizations, it is becoming increasingly difficult for governments in less developed economies to consolidate disparate efforts into overarching health information system architectures (Estrin & Sim, 2010; Norris, Stockdale, & Sharma, 2009). These

⁶ The ‘health district’ is the administrative level that balances local needs with national strategies and reforms in a decentralized public health system (Lippeveld, 2001; Lippeveld, Sauerborn, & Bodart, 2000).

⁷ According to World Bank statistics, non-domestic funding have ranged between 50 and 80 percent of yearly health expenditures for Malawi between 2003 and 2013:
<http://data.worldbank.org/indicator/SH.XPD.EXTR.ZS>

challenges are exacerbated by a lack of well-defined national health information system strategies, which in turn may be attributed to lack of coordinated funding, weak or possibly corrupt management and lack of technical expertise. Unfortunately, ministries of health in developing economies often lack skilled personnel with the competence to develop appropriate policies and routines to oversee and maintain donors' numerous ICT projects (Kimaro & Nhampossa, 2005; Lucas, 2008; Mechael et al., 2010). For instance, in 2012, the Uganda Ministry of Health, overwhelmed by the presence of uncoordinated mHealth projects, issued a stop work order to coerce collaboration between donors' uncoordinated initiatives⁸.

The current wave of fragmented mHealth initiatives in less developed economies echoes the last two decades of vertical disease-specific donor programs in public health care (Pfeiffer, 2003; Philips & Verhasselt, 1994), with each program supported by its own 'silo' information system (Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007; Chilundo & Aanestad, 2004; Estrin & Sim, 2010; Mudaly, Moodley, Pillay, & Seebregts, 2013). Stansfield et al. (2008, p. 7) point out that the uncoordinated surge in health information system funding has "created a plethora of tools, methods and practices for data collection and analysis that have placed a counterproductive and unsustainable burden on front line health workers". Consequently, overburdened health systems do not have the capacity to make long-term commitments to donors' technology innovations.

The high failure rate associated with donor funded mHealth projects has led researchers and industry specialists to diagnose the field with 'pilotitis' (Curioso & Mechael, 2010; Germann, Jabry, Njogu, & Osumba, 2011; Labrique, Vasudevan, Chang, & Mehl, 2013; Lemaire, 2011), or "the unfettered proliferation of lightweight mHealth 'solutions' which fail to translate or scale into health systems" (Labrique et al., 2013, p. 2). The failure to sustain technology innovations, although symptomatic to ICT for development (ICT4D) (Ali & Bailur, 2007; Best & Kumar, 2008; Kleine & Unwin, 2009) and health information system implementations in general (Heeks, 2006; Kimaro & Nhampossa, 2005; Kreps & Richardson, 2007; Littlejohns, Wyatt, & Garvican, 2003), has been particularly pronounced with so called mHealth projects in less developed economies (Mechael et al., 2010).

Out of a number of mHealth pilot projects that have been able to demonstrate technical feasibility and/or short-term efficiency gains (e.g., Chang et al., 2011; Cole-Lewis & Kershaw, 2010; Evans, Abrams, Poropatch, Nielsen, & Wallace, 2012; Gurman et al., 2012; Horvath, Azman, Kennedy, & Rutherford, 2012; Tamrat & Kachnowski, 2012), many solutions have not warranted widespread adoption and long-term commitment by national governments. Rather than focusing on short-term projects goals, interventionists may need to be more alert to how the long-term sustainability of ICT innovations are tightly intertwined with the

⁸ On the 17th of January 2012 Uganda Ministry of Health issued a 'stop work order' to all mHealth projects in the country (McCann, 2012).

overall functioning of health systems and health information systems. In summary, lack of collaboration across numerous initiatives with a pilot orientation, lack of alignment with extant health information systems and limited local capacity to absorb, manage and maintain technology innovations appear to be among the key challenges to the long-term sustainability of so called mHealth projects.

1.3.1 Being Specific about Mobile Technologies

Mobile health (mHealth) innovations range all the way from sophisticated wearable sensors for self-monitoring of chronic diseases by an ageing population in western countries (Dobkin & Dorsch, 2011; Istepanian, Jovanov, & Zhang, 2004; Mirza, Norris, & Stockdale, 2008) to frugal mobile phone-based tools for outreach health workers in resource sparse settings (DeRenzi et al., 2011). Beyond addressing practical challenges such as communication and information sharing, mHealth projects in less developed economies often boast technology deterministic⁹ ambitions of bringing about social and political change such as to ‘mobilize’ and ‘empower’ outreach health workers and their ‘local communities’ (Akter & Ray, 2010; DeRenzi et al., 2011; Gerber, Olazabal, Brown, & Pablos-Mendez, 2010).

In remote and developing regions of the world mobile phone-based solutions have been employed for a variety of public health related purposes including population surveillance (Rajput et al., 2012), monitoring of communicable diseases (Asiimwe et al., 2011; Kamanga, Moono, Stresman, Mharakurwa, & Shiff, 2010), supply chain management and stock-out monitoring (Barrington et al., 2010), decision support for health workers (Afridi & Farooq, 2011), health educational messages and videos (Gurman et al., 2012; Ramachandran, Canny, Das, & Cutrell, 2010; Thirumurthy & Lester, 2012), electronic health records management (Ganesan et al., 2011; Haberer et al., 2010; Meankaew et al., 2010), and routine data collection and reporting (Andreatta, Debpuur, Danquah, & Perosky, 2011; DeRenzi et al., 2011; Lemay, Sullivan, Jumbe, & Perry, 2012; Mukherjee, Purkayastha, & Sahay, 2010). In addition, health workers stationed at remote health posts can simply pick up a mobile phone to call colleagues, supervisors or patients – granted there is a mobile network signal, the phone has been charged and call credits are available (Mukherjee et al., 2010).

Given the diverse examples of mobile technologies and application domains outlined above, it should be of no great surprise that a shared and standardized definition of *mHealth* has yet to be established. Studies that have attempted to define mHealth have arrived at relatively broad definitions. Istepanian et al. (2004, p. 405) provide an early definition of mHealth as “mobile computing, medical sensor, and communications technologies for healthcare”. Similarly, in the context of a global eHealth survey, the World Health Organization, by the Global Observatory for eHealth, defined mHealth as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices” (Kay, 2011,

⁹*Technological determinism* is the belief that “technology and its corresponding institutional structures are universal, indeed planetary, in scope” (Feenberg, 1992).

p. 6). Furthermore, mHealth can be considered both an extension to and integral part of *eHealth* (Mechael, 2009) and *telemedicine* (Istepanian et al., 2004). In the context of 'north-south' development collaborations, mHealth may also be considered integral to ICT4D (Sanner & Sæbø, 2014).

Similarly to 'eHealth' and 'ICT4D', 'mHealth' is a beast of a term that conflates different mobile technologies, health related agendas and stakeholder's ideals, visions, policies and programs. 'mHealth' is predominantly an industry term that resonates well with international donors and development project managers who wish to convey that their activities are at the frontline of 'the mobile revolution'. However, *mHealth* is not a very tenable object of study for academic research. As a conglomerate of different mobile technologies, activities and agendas that change over time and vary across contexts and purposes, mHealth does not offer much in terms of characteristic traits or processes to study.

Nonetheless, studies to date have tended to treat mHealth as a meaningful category for which 'success criteria' can be identified and leveraged for cross-comparison and evaluation across initiatives. Some scholars assume replicability of findings across mobile technologies, projects and settings and call for expanding the 'mHealth evidence-base' through randomized controlled trials (Germann et al., 2011; Labrique et al., 2013; Tomlinson, Rotheram-Borus, Swartz, & Tsai, 2013). An experimental research design, I would argue, is particularly ill-suited for studying mHealth implementations typically characterized by complex, dynamic and highly politicized multi-stakeholder collaborations with ambiguous goals and time-frames (Asangansi, 2012). Efforts to differentiate between various types of mobile technology solutions and application domains may be more fruitful.

The 'mHealth cake', however, can be sliced in many ways. Norris, Stockdale, & Sharma (2009), for instance, make a clear distinction between mHealth solutions that primarily support clinical practices and non-clinical solutions such as tools for routine data collection and reporting. From a privacy and data security point of view it is important to differentiate solutions that store and transmit data about individual patients such as *electronic health records* from solutions that are used primarily to share non-sensitive de-individualized aggregate numbers and statistics (Kotz, Avancha, & Baxi, 2009; Mancini, Mughal, Gejibo, & Klungsoyr, 2011; Olla & Tan, 2008). Furthermore, in the context of government administered projects, Mechael (2009) distinguish mobile solutions that are integrated into the official administration of the health sector from more 'lightweight' mobile services that are used to engage the general public in health-related activities.

In an effort to chart the mHealth landscape, Olla & Tan (2008) arrive at five key dimensions: communication infrastructure, device type, data display, application purpose and application domain that apply to most mobile technology implementations. More specifically, Mechael et al. (2010) specify five mHealth application domains: treatment compliance, data collection and disease surveillance, point of care support, health promotion and disease prevention, and emergency medical response. Finally, heeding the call, made more than a decade ago by

information systems researchers Wanda Orlikowski & Suzanne Iacono (2001), “to take technology seriously”, Sanner et al. (2012) develop an mHealth typology and discuss strengths and weaknesses with different mobile phone-based solution types such as SMS, Java applications (J2ME), mobile web-browsers and interactive voice and response (IVR) for large-scale health information system implementations.

Challenges to the *sustainability* of so called mHealth implementations may vary across mobile devices, communication infrastructures, application purposes, application domains and socio-political contexts. In light of the stratifications outlined above, the two mobile phone-based implementations studied in this dissertation leverage *low-end mobile phones* (device type) and *GSM/GPRS networks* (communication infrastructure) for public health routine data collection and reporting (application domain). This is achieved by employing a mix of SMS, Java application and mobile web-browser features. Furthermore, the data being reported consists of non-clinical and not-so-sensitive aggregate figures collated and reported routinely from sub-district health facilities. Rather than striving for generalizations and comparison across different mobile technologies, projects and settings, this dissertation employ qualitative research to explore how two mobile phone-based implementations, one in India and one in Malawi, interplay with the technical, infrastructural, socio-political, and institutional arrangements of extant routine health information system ecologies.

1.3.2 Mobile Technology Implementation: Becoming Part of the Ecology

Previous studies of mobile technology implementations in health in less developed economies have pointed out the need for a holistic approach based on an ecological understanding. In an early, yet comprehensive, literature review, Michael et al. (2010) examined 172 academic articles, white papers and project reports concerned with mHealth in low and middle income countries. The authors found use of mobile technologies for routine data collection and information sharing to be well documented in the literature, but “implementations remain modest in size and often sit outside of the broader government-led district [health information system] deployments” (ibid, p 13). They go on to suggest that implementations need to target an agreed set of global health objectives while adhering to national policies, and they propose that “[w]e need to start by thinking of health as an overall project or ‘enterprise’ or ‘eco-system’ with many stakeholders” (ibid, p 54, my emphasis).

Similarly, considering the rapid advances of mobile technology in developing regions, Etzo and Collender (2010) and Kleine and Unwin (2009) argue that closer collaboration between diverse stakeholders such as governments, mobile companies, banks, and donors is necessary to realize current potentials. Mobile technology implementations in health grow out of novel collaborations, innovative technical configurations, communication infrastructure advances and enabling eHealth/health information system policies and strategies (Gerber et al., 2010; Lemaire, 2011; Michael et al., 2010). However, innovations

that conflate advances in both global health and mobile communication technology are particularly challenging to manage and maintain due to reliance on diverse and previously uncoordinated stakeholders with different aspirations and modes of operation (Kaplan, 2006).

To better understand how mobile phone-based implementations in public health can evolve beyond project-based technical support and funding, we need to study how inputs from various stakeholders with diverse interests such as ministries of health, NGOs, foreign consultants, international donors and available local technical human capacity may be summoned to nurture innovations into viable extensions to extant health information systems. Apart from a few studies, e.g., Asangansi and Braa (2010), Braa and Nielsen (2013), and Braa and Purkayastha (2010) little attention has been paid to how mobile technology implementations in less developed economies may extend, and coevolve with national health information systems. Implementations of mobile technology innovations need not to be studied independently; rather they need to be seen as parts of an ecology bound together through complex socio-technical and multi-stakeholder arrangements. Understanding the nuances of this understudied, yet crucial, dimension of mobile technology implementations in public health in less developed economies is at the heart of this dissertation's exploratory research agenda.

1.4 Aim and Disposition of the Dissertation

This research was initially guided by the belief that mobile phone-based solutions could and should extend and enrich health information systems in less developed economies, particularly in areas with weak or unreliable physical infrastructure. In tune with international practice-oriented mHealth discourses and much of the extant literature on mobile technology implementations in public health, I set out with an urge to understand how *sustainability* of such implementations could indeed be facilitated. However, from my empirical experience, sustainability turned out to be an elusive and slippery ambition that was difficult to operationalize. Sustainability certainly meant different things to different people in different roles; such as short-term contracted technology experts, grant funded researchers, representatives of international donors, health managers, and community-based health workers. Hence, as my study progressed and I gained insights from my involvement with the two different empirical settings, I came to see the initial framing of my research agenda as somewhat problematic.

Although my initial concerns have helped me bound and limit the scope of my research, over time, my quest for 'mHealth sustainability' in India and Malawi became only one aspect of a more exploratory endeavor. Through observation, participation and personal involvement my attention turned towards the meticulous efforts that went into mobilizing limited resources and capacities to foster health information system change with mobile phone-based solutions. This change, as I saw it, grew out of an increasing number of multi-stakeholder collaborations and interdependencies across technological, organizational and

geographical boundaries. Consequently, the focus of my research became the study of the fragile process of nurturing novel ICT capabilities into viable extensions of health information systems, which, according to Aanestad & Jensen (2011, p. 173) involves having to “deal with the challenges of organizing, mobilizing and coordinating multiple independent stakeholders”.

This work is based on my engagement with the two empirical settings and my familiarity with literature that describes and theorizes the evolutionary development of large, dynamic and interconnected information systems, called *information infrastructure*. In particular this research builds on and contributes to previous academic work that employ biological metaphors such as ‘cultivation’, ‘growth’ and ‘fostering’ (e.g., Aanestad, 2002; Edwards, Jackson, Bowker, & Knobel, 2007) to highlight that information infrastructure development is a combination of both intentional design and evolutionary emergence (Karasti, Baker, & Millerand, 2010). The conceptualization of information infrastructure innovation as *grafting*, the core contribution from this research, is presented in *chapter seven* where it is organized into four *grafting themes*, summarized accordingly:

- i) *The point of union* has long-term Implications. Early ICT project arrangements, both social and technical, are shaped by the initial framing of the problem to be addressed and the concerns of the stakeholders initially involved in defining the heuristics to solve the problem. The initial framing of an ICT innovation may have long-term and practically irreversible consequences as a range of early decisions and arrangements materialize.
- ii) *Congeniality*, a term commonly employed in plant grafting, characterizes the merge and co-evolution between situated socio-technical arrangements and innovative ICT capabilities. Congeniality is a *bi-directional* relational attribute. It differs from *unidirectional* relational notions such as ‘technology fit’ or ‘organizational readiness to change’. Congeniality highlights that both the ICT innovation and extant arrangements such as ICT portfolios, software platforms, work practices and physical infrastructure need to accommodate each other for the innovation to take hold.
- iii) Reliance on collaborations between previously uncoordinated stakeholders, who control parts of extant socio-technical arrangements, makes the implementation of novel ICT capabilities inherently *fragile* on the ‘supply side’ of information infrastructure (Jansen & Nielsen, 2005; Nielsen, 2006). As the novel ICT capability takes hold initial project-oriented *control* is distributed through situated articulation work and further innovation.
- iv) Novel ICT capabilities that leverage and extend information infrastructure in one particular context may propagate as *hybrids* across application domains and geographical locations.

Through the development of the four grafting themes this dissertation highlights previously understudied aspects and addresses identified gaps with extant theorizing of information infrastructure innovation reviewed in *chapter three*. The disposition of the remaining chapters of the dissertation is as follows:

Chapter Two reviews related research concerned with sustainability challenges endemic to health information system implementations, particularly in less developed economies. The chapter considers the lack of clarity with the term ‘sustainability’ and motivates critical reflection concerning the role of sustainability as the Holy Grail of ICT4D. More specifically, the chapter considers *how* and *why* comprehensive *scale* may sometimes be a prerequisite, but not a guarantee, for the long-term sustainability of routine health information system implementations.

Chapter Three reviews literature that develops an *ecological* understanding of information infrastructure development. This body of literature constitutes the *analytical perspective* this dissertation draws on and extends, by proposing and developing a grafting metaphor, to highlight fragility with information infrastructure innovation processes.

Chapter Four presents the interpretive philosophical underpinnings of my research, the qualitative research approach, the setting for the two case studies and my role in the mobile phone-based implementations, the data collection and data analysis techniques employed and ethical reflections concerning the conduct of my research.

Chapter Five presents two stories of mobile phone-based implementations in Punjab India and Lilongwe Malawi. The two empirical narratives highlight different technical, organizational, infrastructural and political challenges to the long-term sustainability of the implementations. The narratives provide an empirical backdrop for the synthesis of my research findings in *chapter six* and my discussion of contributions to theory and practice in *chapter seven*.

Chapter Six provides a summary of the five research articles that lay the foundation for this dissertation. Each article contributes to the development of a nuanced description of so called mHealth sustainability challenges. The further elaboration on the grafting perspective initially developed and proposed in Article IV is the key theoretical contribution of this dissertation. The five articles are included as Appendices I-V.

Chapter Seven draws on a grafting metaphor, constitutive of the four themes outlined above, to offer a new perspective on information infrastructure development and provide practical recommendations for future mHealth and ICT4D implementations in public health in less developed economies. The chapter provides some concluding remarks on limitations with the current study and suggests venues for further research.

Chapter Two

Related Research

The global discourse on ‘sustainable development’ gained momentum with the United Nations 1987 Brundtland Commission¹⁰ report. The report reconciles economic growth with an ecological rationale and defines *sustainability* in the context of international development as meeting “the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 43). Since then, sustainability has become a hallmark of success in development projects. The idea of ‘sustainability’ is influential in international development agendas, funding mechanisms and implementations strategies – sometimes with perverse and contradictory implications for development practice (e.g., Blaikie, 2006; Swidler & Watkins, 2009). Sustainability has become a central concern regarding ICT projects in less developed economies (e.g., Mansell & Wehn, 1998). Simply put, sustainability is the Holy Grail of ICT4D.

However, the ‘sustainability’ discourse and its role in framing development projects has also been criticized for being Western-centric, paternalistic, imperialistic and indifferent to context (e.g., Easterly, 2006; Escobar, 1995; Ferguson, 1990; Stiglitz, 2003). These broader critical examinations of sustainability in the context of development have in turn informed critical reflections concerning development interventions in primary health care (Pfeiffer, 2003; Pfeiffer et al., 2008; Ridde, 2008) and ICT4D (Ali & Bailur, 2007; Avgerou, 2010; Prakash & De’, 2007). Unfortunately, as discussed in section 1.3, a similar level of critical reflections concerning sustainability have been nearly absent in mHealth literature. This dissertation engages constructively with the current lack of critical reflection concerning the dominant discourse on sustainable development in mHealth research and practice. This chapter sets the stage for such an engagement by reviewing extant literature concerned with the sustainability of information system implementations in public health, a particularly complex, dynamic and highly politicized domain.

2.1 Sustainability of Health Information System Implementations

Walsham and Sahay (2006) assert that sustainability, despite its long-standing influence in development rhetoric and practice, has been an understudied and neglected topic by information system researchers. *Sustainability* may simply refer to the persistent adoption and use of a technology beyond external financial and technical support (Best & Kumar, 2008). However, sustainability is more than the ability to carry on with a set of technology-

¹⁰ The Brundtland Report, *Our Common Future*, was produced by the World Commission on Environment and Development in 1987. It is often referred to as the Brundtland report after the chairperson of the commission, then Prime Minister of Norway, Gro Harlem Brundtland.

centered activities after the end of external involvement and funding. Sustainability stretches beyond having program costs and maintenance activities incorporated into ministerial budgets, which at any rate may be heavily subsidized by international donors. Sustainability is also about *institutionalization* of routines and practices and the development of local capacity to innovate on top of acquired ICT capabilities.

Previous researchers have highlighted the importance of *institutionalization* to the sustainability of national health information system implementations (Currie & Guah, 2007; Kimaro & Nhampossa, 2007; Sahay, Sæbø, Mekonnen, & Gizaw, 2010). Institutionalization is a deep-rooted and longitudinal process of institutional change, where an institution is seen as a “socially constructed, routine-reproduced, program or rule systems” (Jepperson, 1991, p. 149). Institutions precondition actors’ sense-making choices with “regulative, normative and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life” (Scott, 2008, p. 56). Institutionalization, then, is “the process through which a social order or pattern becomes accepted as a social ‘fact’” (Avgerou, 2000, p. 236).

In the context of health information system implementations, institutionalization involves the creation of “roles, responsibilities, structures, and budgets to ensure that the [health information system] becomes part of the existing organizational routines” (Kimaro & Nhampossa, 2005, p. 278). Once ICTs become accepted as organizational and social facts, they may be maintained and catered for because of their *legitimacy* regardless of the evidence of their technical value or efficiency (Noir & Walsham, 2007; Silva & Backhouse, 1997). However, many ICT-oriented health information system implementations in resource sparse settings have been found *unsustainable* due to factors such as short-term donor funding, lack of development of local capacity, and too much focus on technological rather than social issues (Avgerou, 2008; Heeks, Mundy, & Salazar, 1999; Kimaro & Nhampossa, 2007; Lucas, 2008). Given the shortage on financial resources and technical expertise in less developed economies, implementations often succumb when project money runs out or foreign experts and contracted NGOs resign from projects (Baark & Heeks, 1999; Lewis, 2006).

To address some of the challenges outlined above, researchers have called for and proposed new modes of stakeholder collaboration (Pfeiffer, 2003), business models (Kaplan, 2006; Kleine & Unwin, 2009), project governance principles (Jensen & Winthereik, 2013) and project evaluation criteria (Greenhalgh & Russell, 2010) that can help ensure more sustainable implementations in tune with national eHealth and health information system strategies. The ongoing search for ‘critical factors’ that can facilitate the sustainability of ICT4D and mHealth can be seen as a continuation of the *information technology transfer* discourse of the 1990ies (e.g., Baark & Heeks, 1999; Braa, Monteiro, & Reinert, 1995; Büscher & Mogensen, 1997; Foltz, 1993). The progression from a focus on *technology transfer* to a preoccupation with *sustainability* may signify a growing awareness that the

same ICTs do not fit all socio-economic and political contexts and that a fair amount of sensitivity is required to identify, implement and maintain appropriate solutions. Yet, exactly what sustainability entails in the context of health information system implementations is often unclear, partly due to ambiguities with the term itself.

Ali and Bailur (2007) are critical towards unreflective use of the term 'sustainability' in ICT4D research. To them 'sustainability' is an unrealistic concept. As an alternative, they point to Ciborra's (2002; 1992) notion of *bricolage*. Ali and Bailur suggest that ICT4D needs to be more open to *local improvisation* and "accept the changing nature of the ICT artifact and the unintended consequences of technology" (Ali & Bailur, 2007, p. 1). An implementation strategy based on bricolage highlights the importance of locally apposite improvisation through the expedient combination of resources at hand. In Ciborra's own words: "[w]ith bricolage, the practices and the situations disclose new uses and applications of the technology" (Ciborra, 2002, p. 49). Furthermore, Ciborra posits that with bricolage "[n]o general scheme or model is available: only local cues from a situation are trusted and exploited in a somewhat blind and unreflective way" (ibid, p. 45).

However, as Ali and Bailur (2007, p. 1) themselves note: "since the majority of ICT for development projects still continue to be funded by donor agencies and multinationals, improvisation faces many practical challenges". Furthermore, Ali and Bailur's optimistic assessment of the unintended consequences of technology is based on empirical cases of Internet use by one higher education institution in Saudi Arabia and one telecenter in rural India. Such open ended projects may very well benefit from experimentation and heuristic problem solving. However, as the next section highlights, routine health information systems in less developed economies are required to meet certain needs that render improvisation and serendipity largely inappropriate as ICT implementation strategies.

2.2 The 'All or Nothing' Predicament of Routine Health Information Systems

ICT innovations in public health have faltered because they could not *scale* to a level where they were useful and meaningful to public health decision makers. *Scaling*, in this context, refers to how a technology "is taken from one setting and expanded in *size* and *scope* within that setting and/or also incorporated within other settings" (Sahay & Walsham, 2006, p. 185, my emphasis). With regard to ICT innovations in the context of routine health information systems, scalability across settings may be "a prerequisite – not a luxury – for sustainable local action" (Braa, Monteiro, & Sahay, 2004, p. 341). This is so, because sustainability emerges from collaborations that reproduce "learning processes alongside the spreading of artifacts, funding and people" (ibid, p. 338). Both Braa et al. (2004) and Sahay and Walsham (2006) highlight the 'all or nothing' dilemma of routine health information systems. This dilemma is rooted in the premises of primary health care itself, where access to affordable essential health services is considered an individual *right*. Hence, to avoid mismanagement of scarce health care resources and to identify underserved populations, health managers

need access to health service data such as child immunization and maternal mortality figures from *all* health facilities in a region, as opposed to a limited set of reports from a preselected pilot area (Braa et al., 2004; Stansfield et al., 2008).

Paradoxically, as donor-funded health information system interventions are typically evaluated in terms of their *impact* on a few performance indicators (read: cost-efficiency), the problems of the worst-off and hardest to reach populations, are often dealt with last (Kleine & Unwin, 2009; Lucas, 2008; Pfeiffer et al., 2008; Ridde, 2008; Walsham, 2001), if at all. With so called mHealth implementations this issue is exacerbated due to reliance on mobile communication networks. As Mechael et al. (2010, p. 58, my emphasis) point out, “the continuing lack of universal [mobile] *coverage* in some rural areas weakens the ability to implement mHealth initiatives at a *national scale*”. Informed by a revenue maximizing mode of operation, mobile operators often do not extend their coverage to the most remote and vulnerable populations, which further marginalize those population groups.

In recognition of the varying availability of reliable communication infrastructure and other essential resources across geographical regions, Shaw, Mengiste, & Braa (2007) suggest an alternative to instantaneous scaling to all regions. Based on case studies concerning the computerization of health information systems in Nigeria and Ethiopia they propose that resourceful health districts with available technology, infrastructure and human capacity should be given priority. The authors predict that successful implementations in more developed regions may spread and serve other regions over time. Similarly, Braa et al. (2007) argue that traditional paper based routines and novel computerized information systems needs to be able to interoperate smoothly, while computerized systems gradually replace paper based ones. In favor of their argument they emphasize the importance of scaling-up the availability of *health data* (content) rather than *technology* (container). Furthermore, they suggest targeting specific key priorities of the public health services *first*, in order to attract interest from both local and national stakeholders.

However, caution needs to be exercised to avoid ‘cherry picking’ of health problems, which has characterized disruptive, and fragmented health information system interventions in less developed economies (AbouZahr & Boerma, 2005). Rather than focusing activities around a particular ICT innovation or a specific health problem, implementations also need to leverage and extend health information systems holistically. Extant literature on *information infrastructure development*, reviewed in the next chapter, offers a promising route for the holistic conceptualization of health information system implementations.

Chapter Three

Analytical Perspective

This dissertation is positioned within the information systems (IS) research tradition, which has grown out of empirical studies of the interplay between information and communication technologies on the one hand and situated work practices and organizational routines on the other. As pointed out by for instance Kaplan (2004) and Walsham (1995), information system research has employed theoretical insights and approaches from various fields such as computer science, organization studies, sociology, political science, anthropology and ethnography. More recently, however, information systems researchers have become attentive to the need for new insights that can help explain what is happening in the information society – constitutive of large and interconnected digital ecologies of information systems (Monteiro, Pollock, & Williams, 2014; Yoo, Henfridsson, & Lyytinen, 2010).

Seminal knowledge contributions centered on the design, implementation and use of software and ICT capabilities within single organizations (Barley, 1986; Markus & Robey, 1988; Orlikowski & Robey, 1991; Zuboff, 1988) are insufficient to account for the dynamics of complex corporate-wide (Bygstad, 2003; Ciborra et al., 2000; Pollock & Williams, 2008; Rolland & Monteiro, 2002), inter-organizational (Karasti et al., 2010; Reimers, Johnston, & Klein, 2004; Ribes & Finholt, 2009), or even global information infrastructure such as the Internet (Hanseth & Lyytinen, 2010; Hanseth & Monteiro, 1997; Hanseth, Monteiro, & Hatling, 1996). The proliferation of distributed large-scale information systems has created challenges such as how to standardize and align relevant networks, applications, and databases with each other and with different work practices (Edwards, 2010).

Studies of mobile phone-based implementations in resource sparse settings, which form the empirical basis for this dissertation, are relevant for generating new theoretical insights that can develop this body of knowledge further. As cases of information infrastructure development, such implementations highlight how actors from different social worlds need to collaborate across organizational, cultural, socio-political, professional and geographical boundaries in order to negotiate and foster desirable change. For instance, many so called mHealth and ICT4D innovations are *conceived* of by academics at western universities, designed by contracted developers and programmers, become *implemented* in governmental organizations in less developed economies through *partnerships* with local technical assistants and NGOs, are *funded* by international donors such as the World Bank and the International Monetary Fund, and *rely* extensively on mobile network providers' physical infrastructure. The remainder of this chapter considers the relative merits of different conceptualizations of dynamics of change in the context of large interconnected socio-digital information systems, called information infrastructure.

3.1 Information Infrastructure as Ecology

Information infrastructure studies are concerned with interconnected ensembles of information systems, including both social and technical elements. As Claudio Ciborra and Ole Hanseth (2000, p 2) posit in their introduction to the book “From control to drift”:

Corporate information infrastructures are puzzles, or better collages, and so are the design, and implementation processes that lead to their construction and operation. They are embedded in larger, contextual puzzles and collages. Interdependence, intricacy, and interweaving of people, systems, and processes are the culture bed of infrastructure.

Information infrastructure constitute interconnected systems and modules that are developed, enacted, and maintained in a distributed and episodic manner by a multitude of individual and organizational stakeholders with diverse interests and aspirations (Aanestad & Jensen, 2011; Star, 1999). This characteristic distinguish information infrastructure from a more isolated intra-organizational information system.

To date, studies of information infrastructure development have employed a variety of theoretical approaches such as network economics (Hanseth, Ciborra, & Braa, 2001; Varian & Shapiro, 1999), complexity theory (Braa et al., 2007; Hanseth & Lyytinen, 2010), relations between situated work practices (Pipek & Wulf, 2009; Star & Strauss, 1999; Star & Ruhleder, 1996), socio-technical networks (Aanestad & Jensen, 2011; Hanseth & Monteiro, 1997) and political stakeholder analyses (Sahay, Monteiro, & Aanestad, 2009). Some of these theoretical lenses foreground engineering and design by highlighting the growth enabling potential of different infrastructural *configurations* (Henfridsson & Bygstad, 2013), the contested placement of *control points* within digital infrastructure (Elaluf-Calderwood, Eaton, Herzhoff, & Sørensen, 2011; Tilson, Lyytinen, & Sørensen, 2010), and interoperability between systems through intermediary *gateways* (Edwards et al., 2007; Egyedi, 2001; Hanseth, 2001). Other, ‘softer’, approaches have emphasized *co-evolution* (Jansen & Nielsen, 2005) and socio-technical *alignments* as the *modus operandi* of information system *ecologies* (Baker & Bowker, 2007; Constantinides & Barrett, 2005; Hepsø, Monteiro, & Rolland, 2009).

Most information infrastructure studies to date have employed a combination of the theoretical approaches outlined above, albeit with one perspective chosen to foreground the analysis. Hanseth and Lyytinen, for instance, define information infrastructure as “a shared, *evolving*, heterogeneous installed base of IT capabilities among a set of user communities based on open and/or standardized interfaces” (Hanseth and Lyytinen, 2010, p. 9, my emphasis). While the authors maintain a view of information infrastructure as an evolving whole, they, at the same time, postulate five ‘design principles’ and derive a total of 19 ‘design rules’ to assist information infrastructure ‘builders’.

In contrast to such prescriptive recommendations, Edwards, Bowker, Jackson, & Williams (2009, p. 369) suggest that information infrastructure change agents “rarely if ever ‘build’

infrastructure; they must nurture it and, if they are lucky, help it to grow". Similarly, Edwards, Jackson, Bowker, & Knobel (2007) argue that descriptions of efforts to 'design' and 'build' information infrastructure elevates the roles of designers or central system builders and downplays the importance of social, institutional, organizational, legal, cultural and other non-technical influences. In their view, it is more appropriate to draw on organic metaphors to characterize the unfolding change of information infrastructure. In their words; "[s]ince infrastructures are incremental and modular, they are always constructed in many places (the local), combined and recombined (the modular), and they take on new meaning in both different times and spaces (the contextual). Better, then, to deploy a vocabulary of 'growing', 'fostering', or 'encouraging' in the evolutionary sense when analyzing cyber-infrastructure" (ibid, p 7).

The application of seemingly divergent theoretical approaches and vocabularies, sometimes within the same studies, hint at the difficulties with arriving at generalizations about the nature of human preemptive action in relation to these complex socio-digital phenomena. On the one hand, scholars do not wish to take an overly bleak and technology deterministic position where the inertia of the *installed base* (Hanseth et al., 1996; Star & Ruhleder, 1996) – the historical accumulation of information systems and practices – appears to determine all future possibilities. On the other hand, scholars have warned against the illusion that information infrastructure can be designed, implemented and managed in the same controlled manner as traditional intra-organizational information systems (Ciborra et al., 2000).

Encountering Information Infrastructure

Efforts to theorize information infrastructure based on studies of the Internet (Hanseth & Lyytinen, 2010; Zittrain, 2006), an open ended information highway in the public domain, have highlighted characteristics such as generativity, complexity, lack of coordination and lack of centralized control. Such accounts differ markedly from studies that have their empirical basis in more bounded parts or compartments of information infrastructure that server specific purposes such as collaborative research networks (Karasti et al., 2010; Ribes & Finholt, 2009; Zimmerman & Finholt, 2007) or national health information systems (Aanestad & Jensen, 2011; Jensen & Winthereik, 2013; Sahay et al., 2009). In the two latter scenarios, information infrastructure is maintained somewhat collectively by distributed stakeholders who share at least a few goals and interests such as the long-term use and re-use of ecological environmental data for scientific research (Baker & Bowker, 2007; Karasti et al., 2010) or the cross-cultural and multilevel monitoring of international development aid financing (Jensen & Winthereik, 2013). The two cases of mobile phone-based routine health information system implementations, that lay the empirical foundation for this dissertation, can be considered as belonging to this latter category of efforts to extend more bounded parts of (health) information infrastructure.

Not only are different compartments of information infrastructure organized and maintained differently, information infrastructure is also experienced differently by different groups and actors (Star, 2002; Star, 1999). As Star (2002, p. 116) remarks, “[o]ne person’s infrastructure is another’s brick wall”. How individuals and organizations perceive and experience information infrastructure varies according to their roles, agendas and frames of reference, which in turn are shaped by the institutional environment in which they operate. Organizations operating within the same domains or industries tend to have similar information and communication needs, challenges, aspirations, and values. For instance, different organizations involved with international public health may have different short-term information and communication needs, while they collectively aspire to develop information infrastructure that enable the long-term monitoring of progress towards shared targets such as the *Millennium Development Goals*¹¹ and *Universal Health Coverage*¹². Consequently, these organizations may encounter, understand, and utilize the ICT capabilities afforded by a shared and evolving information infrastructure in somewhat similar ways.

As the next section highlights, the perceived potential for intentional design vis-à-vis information infrastructure varies not only across empirical objects of study, but also with the different strategies and aspirations of the heterogeneous stakeholders under study (Aanestad & Jensen, 2011; Sahay et al., 2009), the temporal orientation of their activities (Karasti et al., 2010; Ribes & Finholt, 2009) and the chosen level of analytical abstraction with the study itself (Pollock & Williams, 2010). No wonder then that some scholars talk of *building* infrastructure (Nielsen, 2006) while others envision a nearly inevitable progression towards unmanageable *drift* (Ciborra et al., 2000).

3.2 Fostering Change: Bootstrapping, Gateways, and Installed Base Cultivation

Layers and dependencies between layers play a central role in the evolution of information infrastructure. New ICT capabilities, applications and services can leverage communication and storage capabilities of lower layers (Tilson et al., 2010) while lower layers may be reconfigured to reflect emergent needs and patterns of use at higher layers. The notion of infrastructural ‘layering’ highlights these interdependencies. Actors who acquire or control ‘the bottom layers’ such as technical devices, physical infrastructure and service platforms (Elaluf-Calderwood et al., 2011) are sometimes able to exercise more control over the socio-digital ensemble than actors who innovate on top of those layers (Stefan Klein et al., 2012; Nielsen, 2006).

¹¹ The Millennium Development Goals constitute an eight-goal action-plan to improve life conditions around the globe. These goals included the reduction of extreme poverty, combating AIDS, improving mother and child health and ensuring environmental sustainability.

¹² Universal health coverage (UHC) is defined by the World Health Organization (WHO) as ensuring that all people can use the promotive, preventive, curative, rehabilitative and palliative health services they need, of sufficient quality to be effective, while also ensuring that the use of these services does not expose the user to financial hardship.

Innovative ICT capabilities build on and extend arrangements that are social (e.g., norms and work practices), technological (e.g., legacy systems, standards and technical configurations) and institutional (e.g., organizational structures and overarching architectures) in nature. The potential for developing new ICT capabilities and services on top of existing layers and modules can be restricted through regulatory arrangements such as resource reservation control mechanisms imposed by mobile telecom operators or the design of application programming interfaces (APIs) by the developers of digital platforms. In essence, “[i]nfrastructural incumbents may exploit their historically-accrued strengths to effectively hold infrastructure in place, stacking the deck against new, less organized, or less favorably placed actors, thereby limiting the scope and vision of new infrastructural possibilities” (Edwards et al., 2007, p. 26).

Bootstrapping and coupling Information Infrastructure

Extant literature is divided on how it approaches the limitations of control in relation to information infrastructure innovation. Depending on the empirical case and the chosen analytical perspective, scholars have proposed different strategies and tactics such as *bootstrapping* i.e., ‘jump-starting’ a user base in relation to an information infrastructure innovation (Hanseth & Aanestad, 2003; Skorve & Aanestad, 2010), or serendipitous patchwork and *bricolage* (Ciborra, 2002; Ciborra, 1992). Others have focused on the seemingly mundane, incremental and distributed day-to-day *articulation work* that is required to develop, maintain and ‘grow’ information infrastructure over time (Pipek & Wulf, 2009; Star, 1999; Suchman, 2002).

Bootstrapping, as proposed by Hanseth and Aanestad (2003), is a particularly prescriptive strategy for turning innovative ICT capabilities into viable extensions of information infrastructure. The strategy focuses on how growth in user uptake and demand may be encouraged at an early stage where self-reinforcing network effects have not yet come into play. Following the prescriptions of a bootstrapping strategy, the change agent or designer is advised to mitigate implementation risks and complexity by focusing on the provision of simple and immediately useful ICT capabilities to an initial group of probable solution adopters. As the number of users grows, more users will adopt the innovative service or ICT capability because of the value generated in the network by previous adopters.

Bootstrapping, as a strategy, assumes a certain level of autonomy and foresight, residing with the change agent, to determine which tasks and routines to support. In contrast, Information infrastructure development, according to Edwards et al. (2007, p. 39) “will depend less on the Herculean figure of the master engineer, and more on a series of pragmatic, modest, and strategically-informed interventions undertaken on the basis of imperfect knowledge and limited control”. The decision making power implicit with the bootstrapping strategy may be particularly misguided in the context of health information system implementations in less developed economies where control is volatile and tied to short-term project-based multi-stakeholder arrangements (Manda & Sanner, 2012).

Furthermore, network economic rationalization of technology appropriation may be less relevant to the adoption and use of ICT capabilities in hierarchical public health organizations – often with a highly centralized and bureaucratic administration.

Beyond the initial ‘jump-start’ of novel ICT capabilities, information infrastructure development also entails coupling different parts or compartments of infrastructure into integrated networks, or networks of networks. To highlight the flexibility and modularity of information infrastructure, some researchers have referred to these linkages as ‘gateways’. Gateways such as technical plug adapters (hardware), syntactic conversion algorithms, and document format converters (software) allow for information exchange and communication across different parts of information infrastructure (Edwards et al., 2007; Egyedi, 2001; Hanseth, 2001). According to Edwards et al. (2007, p. 16) “[g]ateways are often wrongly understood as “technologies,” i.e. hardware or software alone”. To them it is more appropriate to understand gateways as a combination of technical solutions and social choices. However, in my view the metaphorical notion of a ‘gateway’ foregrounds mechanical construction and does not bring into view the multitude of stakeholders with different ideas and aspirations about what they try to create. Even the development of inexpensive hardware and software gateways require investments of time, labor, money, and rely on mutually beneficial alliances between stakeholders who own or control different parts of information infrastructure.

Gateways are not apolitical bridges between systems. The actual design and implementation of gateways, such as *Health Level-7(HL7)*¹³, a standard for exchange of electronic health information, influences how hardware, software and people become arranged and configured into socio-technical networks. As ICT capabilities mature and take hold through adoption and use, early arrangement may constrain the options available to further improve and extend the socio-technical ensemble. Hence, early choices, including what gateways to leverage, create historical *path dependencies* that limit what innovations can be imagined and developed in the future (Klein, Schellhammer, Reimers, & Riemer, 2008). Path dependency refers to how available options at any given time are constrained by decisions made in the past, based on limited foresight and circumstances that may no longer be of relevance.

Cultivating the Installed Base

The conceptualization of information infrastructural change as the *cultivation of an installed base* of socio technical arrangements (Bergqvist & Dahlberg, 1999; Hanseth & Lyytinen, 2010; Hanseth et al., 1996) has allowed scholars to account for the development infrastructure at the verge of unmanageable complexity and drift. Cultivation recognizes human aspirations to direct and guide the development of information infrastructure, while the limitations with such efforts are acknowledged. Aanestad (2002, p. 17) posit that the cultivation metaphor

¹³ Health Level-7 or HL7 refers to a set of international standards for transfer of clinical and administrative data between healthcare provider organizations' information systems

encourages an emphasis on the ‘nurturing’, or provision of adequate support and resources, e.g. technical skills, support personnel, training. By doing so, it also emphasizes the role of the ‘gardeners’ or the ‘farmers’ that perform this work, who often go unrecognized and overlooked.

However, as pointed out by Jensen & Winthereik (2013) the term ‘cultivation’ gives a sense of orderly growth and consensual progression towards a desirable future. Hence, ‘cultivation’ does not give voice to the numerous tensions, inequalities and information infrastructure development efforts that succumb and fail. Instead of making the meticulous efforts of developing information infrastructure visible, the notion of ‘cultivation’ lends itself more to the metanarrative of *successful* information infrastructure development. Installed base cultivation is sometimes explained in more concrete and mechanical terms as “*extending and improving* the installed base” (Hanseth & Monteiro, 1998, p. 1), or “*modifying and extending* what already exists” (Monteiro, Pollock, Hanseth, & Williams, 2012, p. 24). What is missing from extant conceptualizations of information infrastructure development is a bridge between what we understand as deliberate efforts to extend information infrastructure, usually conceptualized by drawing on mechanical metaphors, and what we see as an evolving and unmanageable whole, more commonly portrayed through biological and ecological metaphors.

In this dissertation I address this conceptual gap by accounting for how ICT projects that *extend* extant socio-technical arrangements, at a particular place and point in time, if successful, inevitably transforms into distributed *nurturance* performed by a growing network of stakeholders. This process is what I refer to as *information infrastructure grafting*. The next and final section of this chapter reviews recent contributions to information infrastructure studies that are similarly concerned with how short-term funded ICT projects, such as mHealth in less developed economies, may contribute to long-term information infrastructure development and how this process may be conceptualized.

3.3 From Project to Information Infrastructure

Both Ribes and Finholt (2009) and Karasti et al. (2010) are concerned with how short-term funded ICT projects can contribute to long-term infrastructure development. Their US based studies of collaborative research networks, called *cyberinfrastructure*, highlight how sustainability challenges with innovative ICT capabilities are exacerbated by the unpredictability of project-based funding arrangements and a preoccupation with short-term project deliverables in order to secure renewed grants. The tensions they identify between short-term funding and the long-term development of information infrastructure are similarly relevant to mHealth and ICT4D in public health in less developed economies, where a pilot project orientation is the norm (Sanner et al., 2012; Sanner & Sæbø, 2014).

Apart from long-term planning and funding, Aanestad and Jensen (2011) argue that conceptualizations of information infrastructure development need to account for challenges with the mobilization and coordination of inputs from multiple independent

stakeholders. However, the social arrangements required to develop information infrastructure are often time consuming and costly to develop and maintain (Karasti et al., 2010; Suchman, 2002). Taking these challenges seriously, Aanestad and Jensen (2011) warn against coordination overhead in the initial stages of information infrastructure development efforts. As an alternative, they propose that stakeholder collaborations, similarly to technical configurations, can be managed in a *modular* fashion. Hence, if possible, stakeholders who are able to identify common interests should move forward and demonstrate how value and benefits may be generated from information infrastructure development, without reliance on input from potential partners who sit on the fence or drag their heels. Managing the involvement and interests of infrastructural stakeholder in a gradual and modular fashion, however, is a daunting task. As Edwards et al. (2007, p. 28) recognize, the “careful nurturance of infrastructural change, and attending to the tensions that emerge from it, is a managerial and political skill of the highest order”.

Based on the empirical study of innovation in the context of content service platform for mobile phones in Norway, Nielsen & Aanestad (2006, p. 186) argue that “relinquishing control can be a prerequisite, as opposed to an impediment, for successful design and operation of information infrastructures”. Their idea of relinquishing control to spur further innovation contrasts the traditional managerial urge to hold on to centralized control. However, previous studies have shown that innovation in both scientific cyberinfrastructure and national health information systems needs to be balanced against some element of central coordination to allow for the long-term pursuit of collective goals (Aanestad & Jensen, 2011; Karasti et al., 2010; Ribes & Finholt, 2009). What these studies have in common is the recognition that the development of corporate or industry-wide compartments of information infrastructure may not be completely controllable, but, unlike parts of the Internet, it can also not be allowed to drift.

In summary, development of information infrastructure is shaped *both* by the inertia of relatively stable socio-technical arrangements and the preemptive and opportunistic summoning of available resources to accommodate new patterns of use as ICT capabilities travel across domains and geographical contexts (Edwards et al., 2007; Monteiro, 1998; Rolland & Monteiro, 2002). Furthermore, ICT projects that aspire to contribute to the long-term development of information infrastructure may benefit from avoiding the involvement of too many stakeholders early on, particularly infrastructural incumbents who may leverage their positions to hijack innovations and retain control.

Notions such as ‘layers’, ‘gateways’ and ‘modules’ are useful for describing relational aspects with information infrastructure, while tactics, such as ‘bootstrapping’, are helpful for making sense of the adoption of new ICT capabilities in an emergent network. However, such notions convey a neat image of rational design that underrepresents political tensions and the continuous contestation of agendas and meanings on the ‘supply side’ of information infrastructure development (Jansen & Nielsen, 2005). Similarly, ‘cultivation’ recognizes the

limits of human preemptive actions and control pertaining to information infrastructure development, but does not give voice to the many ICT innovations that falter and fail to become part of information infrastructure. In chapter seven I address these gaps with extant conceptualizations of information infrastructure development through the proposition of a grafting perspective. Grafting highlights the fragile transition from ICT-projects to viable extensions of information infrastructure. This involves a movement from design to collaborative nurturing, whereby ownership, maintenance responsibilities and further innovation become distributed and aligned with different stakeholder's activities and interests. Such transitions require tenderness and care as "infrastructures can be a site of intense conflict, through which relevant social actors [...], the distribution of benefits and losses, and even the general "rules of the game" are worked out simultaneously" (Edwards et al., 2007, p. 24). The next chapter describes my approach to the study of information infrastructure development through the conduct of two qualitative interpretive case studies of mobile phone-based routine health information system implementations in India and Malawi.

Chapter Four

Research Approach

In this chapter I discuss practical and methodological considerations with my research. As the chapter elaborates, my research aim has been continuously revised based on empirical experiences and my exposure to relevant literature. Similarly, my data collection and my review of relevant literature have also been ‘moving targets’ throughout the study. Data collection has been guided by my emergent and increasingly reflexive research agenda and prior sensitization to literature, while the continuous process of reviewing literature has been sharpened by empirical findings.

In section 4.1, I reflect on my role in an international network of collaborative health information system implementation research and my engagement with two mobile phone-based routine health information system implementations. Section 4.2 describes the interpretive philosophical underpinnings of the research, while section 4.3 details my qualitative approach to data collection and analysis. Finally, in section 4.4 I consider ethical aspects of my work.

4.1 Research Context

This research has come about through my affiliation with the Health Information Systems Program (HISP), a loosely coupled network of multidisciplinary research and health information system strengthening activities in developing countries (see Braa et al., 2007, 2004). My engagement with HISP has brought me in contact with researchers, public health professionals, health information system managers and independent consultants who, in one way or another, have participated in the co-construction of my academic journey.

HISP activities are focused around the development and implementation of an open source health information data warehouse called the District Health Information Software (DHIS2). DHIS2 is used for reporting, analysis, and presentation of routine health data at national and district levels in countries in Africa, Latin America and Asia, including entire states in India. The widespread adoption of the platform and the growing demand for DHIS2 support and implementation capacity has led to the establishment of regional entities such as HISP South Africa, HISP India, HISP East Africa, and HISP West Africa. Since the inception of the program in 1994 (see Braa & Hedberg, 2002), HISP Oslo, located with the Global Infrastructures (GI) research group at the Department of Informatics at the University of Oslo, has played a central role in staking out the HISP action research agenda and catering for the core development of DHIS2.

With the rapid uptake of mobile technologies in less developed economies, HISP activists have embraced the opportunity to bring digital health information system capabilities to

health workers at remote sub-district health facilities where there are no computers, unstable power supply and limited accessibility by road. To this end, the MobiHealth action research project was initiated at the University of Oslo during autumn 2010. I was enrolled as a PhD student and have been affiliated with MobiHealth since its inception. MobiHealth has coordinated the international development, testing, piloting and implementation of DHISm – a suite of mobile phone-based functionalities that extend the capabilities of DHIS2.

4.1.1 Mobile Phone-based Implementations in India and Malawi

Throughout the past four years I have participated in workshops, technical roadmap discussions, and functional requirement meetings concerning the iterative development and implementation of DHISm. These activities have been concerned with the use of DHISm for different purposes in different settings such as to monitor efforts to combat malaria in Zambia, to support continuity of care in mother to child HIV transmission prevention programs in Uganda, and to strengthen surveillance of communicable diseases in Tanzania.

My main area of interest and concern, however, has been with the use of mobile phone-based solutions for reporting of routine health data from sub-district health facilities. This focus has informed my involvement with two mHealth implementations – one ‘big-bang’ roll-out orchestrated by HISP India in collaboration with the state of Punjab and one incremental ‘baby-steps’ implementation of DHISm in Lilongwe district, in Malawi. The latter implementation received direct financial and technical support from the MobiHealth project. In both contexts the ministries of health acted as the formal owners and hosts of the implementations. Both ministries envisioned that they could enhance their use of the already adopted DHIS2 data warehouses with mobile functionalities, but lacked the technical capacity to fully support the implementations.

My role with the Implementation in Punjab

Technical support for the implementation of mobile phone-based routine reporting in Punjab was provided by HISP India – a contracted NGO with ties to the international HISP network. Through my involvement with MobiHealth, I was given the opportunity to participate in the implementation in Punjab at an early stage of my PhD. I spent two months, from mid-September to mid-November 2010, following the implementation in Punjab. I predominantly played the role of an observer although I assisted short-term contracted HISP India employees in the training of Auxiliary Nurse Midwives (ANMs) in five districts in Punjab: Gurdaspur, Jalandhar, Kapurthala, Patiala and Mohali. Figure 4-1 below depicts a mobile training session in Patiala district. Throughout my involvement I provided advice and feedback to HISP India employees and monitoring and evaluation officers at the Ministry of Health state headquarters in Chandigarh.



Figure 4-1 End user training on mobile reporting in Patiala district

My participation in the mobile trainings allowed me to meet with district level data clerks, statisticians, monitoring and evaluation officers, civil surgeons, and other government employees as they attended and oversaw training sessions in their respective districts. I was able to engage in informal and impromptu conversations with district managers and their colleagues during the morning *chai*¹⁴ breaks before the commencement of the trainings. In the afternoons, I was sometimes able to follow government vehicles back to district headquarters or to have dinner with district staff. These less formal settings allowed me to develop a nuanced understanding on how people in various roles felt about the state wide roll-out of mobile phone-based reporting of routine health data.

Each mobile training session was attended by about 40 ANMs – the actual end users of the mobile reporting solution. On three different occasions I made arrangements with individual ANMs to visit their designated sub-district health facilities and the villages they served. During these full day visits I observed how ANMs employed tacit knowledge and paper based tools to collect routine health data from rural villages. Furthermore, as we spent whole days together I had the opportunity to learn more about their thoughts concerning the introduction of mobile phone-based reporting.

Although participation in mobile training sessions granted me access to informants and allowed me to boost my empirical data collection, my close affiliation with HISP India also

¹⁴ *Chai* simply means tea in various languages, including Punjabi.

proved restrictive at times. As ICT4D researchers such as Anokwa et al. (2009) and Sterling and Rangaswamy (2010) have pointed out, local NGOs often serve as key gatekeepers who both facilitate and restrict the level of access that visiting researchers have to empirical settings and informants. Ambiguities with my role as a researcher started to emerge as ANMs began to rebel against mobile phone-based reporting. Their grievances were directed towards what they perceived as a job surveillance tool built into the mobile phone-based solution in the form of a *daily* reporting requirement (see section 5.1). My association with HISP India, one of the stakeholders in the emergent conflict between the state of Punjab and more than 5000 sub-district health workers obscured my ability to develop of a nuanced understanding of unfolding events. As tensions arose, I was advised by HISP India managers to rely on accounts from HISP India employees rather than to look into matters on my own. Consequently, the political tensions with the implementation were left to linger at the back of my mind, while technical configurations and their long-term consequences became the focus of the early stages of my research.

My role with the Implementation in Malawi

The emergent tensions in Punjab and their unclear implications for my long-term access to the empirical setting led me to get involved with the start-up DHISm implementation in Malawi. Whereas my role in relation to implementation activities in Punjab had primarily been that of an observer, my involvement in Malawi was more engaged and resembled what has been characterized as an *action case* study – a small scale intervention with a deep contextual understanding (Braa & Vidgen, 1999; Vidgen & Braa, 1997). Hence, *action* and *intervention*, although present, have not been key components in my research design. I have provided guidance and engaged with practical implementation activities whenever I have had the knowledge and experience to do so. This close involvement has offered me a way – perhaps the only plausible way – to engage closely with peoples’ experiences and concerns regarding the two mobile phone-based implementations.

The DHISm implementation team in Malawi comprised of five people, including myself. Allan and Enoch were master students with the University of Malawi. Tiwonge, a Malawian, and Saptarshi, from India, were my fellow PhD students affiliated with the University of Oslo. A preliminary baseline study was conducted whereby Allan and Enoch visited 15 health facilities and collected data using a structured interview guide, which Tiwonge and I had prepared beforehand. This baseline survey, which was predominantly concerned with the paper-based routine health information system, was later supplemented by repeated observation visits made by Saptarshi, Tiwonge and myself to nine health facilities. These visits were performed during my first period of major field work in Malawi from late September to late December 2011. As part of these visits we conducted interviews and focus group discussions concerned with information and communication challenges experienced by facility staff. By the end of this baseline assessment I was confident that the envisioned mobile phone-based reporting of routine health data could help bridge the communication

gulf between remote and isolated sub-district health facilities and the district health office in Lilongwe district in Malawi, if not the whole nation.

As part of the DHISm implementation team I made decisions about what handsets to purchase and distribute to sub-district health facility staff. I took part in the installation of DHISm Java applications and configured web-browsers and menu systems on the mobile phones. I also developed end-user training manuals with instructions on how to submit mobile data reports. In addition, I participated in the training of end-users, negotiated terms with two mobile operators for mobile data bundles and call credits, and negotiated terms for the DHISm implementation with the Central Monitoring and Evaluation Division (CMED) at the Ministry of Health headquarters and the district health office in Lilongwe. As part of my second field trip to Malawi, from mid-April to mid-May 2012, I participated in DHISm pilot evaluation activities. This involved inspection of the actual data submitted through mobile phones on the DHIS2 server, focus group evaluation sessions conducted with end-users, and visits to sub-district health facilities to observe how mobile phone-based reporting blended in with health workers other tasks and routines.

The fact that I did not initially *plan* to conduct *two* case studies is an obvious limitation with my research design. When I started my fieldwork in India, I had no idea that I would eventually move on to Malawi. However, my engagement with both settings has allowed me to contrast the particularities of each case and arrive at a nuanced understanding of challenges with mobile phone-based routine health information system implementations. My early experiences from Punjab allowed me to plan and sharpen the focus of my research before I got involved with the startup implementation in Malawi, while my involvement in Malawi helped me reflect soberly on my experiences with political tensions in Punjab.

My empirical data collection has involved three major trips of field work, one to Punjab and two to Lilongwe. In both settings I have interacted with outreach health workers, medical officers, statistical assistants, monitoring and evaluation officers, local HISP representatives, fellow researchers, mobile trainers, DHIS2 and mobile application customizers, technical support staff, project coordinators, and state and district health information system managers. Table 4.1 summarizes field work activities in terms of duration, my role(s), and the data collection techniques employed.

Table 4-1 Major trips of fieldwork to Punjab, India, and Lilongwe, Malawi

Place and Time	Role(s) and Activities	Data Collection Techniques
Punjab (India) 23.09.2010 - 17.11.2010 (two months)	Visits at district and sub-district levels Mobile training of ANMs Implementation support to HISP India and state of Punjab Implementation evaluation Writing status report with HISP-team and state monitoring and evaluation officers	Observation (field notes) Document studies Interviews Shadowing outreach health workers Photographing Ad hoc conversation and discussion
Lilongwe (Malawi) 20.09.2011 - 20.12.2011	Project planning Negotiation of terms with Ministry of Health and other	Observation (field notes) Document studies

(three months)	stakeholders Development of training material and conducting training Setting up pilot implementation Customization of forms for mobile reporting Configuring handsets and mobile application Field visits to Lilongwe district health office, health area hospitals and sub-district health facilities Collaboration with DHIS2 coordinators in Blantyre	Structured interviews and surveys Focus group discussions Interviews Shadowing outreach health workers Photographing Ad hoc conversation and discussion
Lilongwe (Malawi) 18.04.2012 - 16.05.2012 (one month)	Pilot evaluation Project revisions Field visits and support to Lilongwe district health office, health area hospitals and sub-district health facilities	Observation (field notes) Document studies Focus group discussions Interviews Ad hoc conversation and discussion

4.2 Philosophical Underpinnings: Qualitative Interpretive Case Study Research

With particular reference to information system research, Orlikowski & Baroudi (1991), following Chua (1986), distinguish between *positivist*, *interpretive* and *critical* approaches. While these three epistemological positions may appear philosophically distinct as *ideal types*, in empirical (social) research the distinctions are not so clear-cut (Lee, 1989). There is considerable disagreement as to whether these research ‘paradigms’ necessarily contradict each other or if each perspective can add a meaningful layer to a single study without necessarily being contradictory (see e.g., Gable, 1994; Lee, 1991).

Whereas positivist positions have emphasized the creation of objective and predictive knowledge, others have pointed out that interests and values are intertwined with the facts and knowledge claims constructed through science (e.g., Guba & Lincoln, 1994; Kuhn, 1970), just as they are intertwined with any other human endeavor. For instance, mHealth implementations are part of a complex socio-political landscape, which pulsate in tune with the budget cycles of powerful international donors. Hence, the searches for ‘evidence’, ‘benchmarks’ and ‘success criteria’ that can demonstrate the ‘sustainability’ of mHealth initiatives are not devoid of social and political interests, no matter how value-neutral and ‘scientific’ the chosen experimental research design may appear to be. Since mHealth implementations are complex and politicized processes that are framed and understood differently by different stakeholders, the philosophical underpinnings for this research are founded in an *interpretive epistemology*, with inclinations towards *critical intent*.

Interpretive Case Studies

The key assumption with interpretive research is that the verbal world, in which we live, embraces everything in which our insight can be broadened and deepened. In his seminal work “Truth and method”, Hans-Georg Gadamer posit that “[a]ll understanding is interpretation, and all interpretation takes place in the medium of a language” (Gadamer, 2004, p. 390). From this it follows that we do not have access to knowledge of a ‘real world’ that lies beyond all language, although in any *world view* such a ‘real world’ is intended. Whatever notions, expressions and metaphors we draw on to make sense of our

experiences, we only succeed in gaining a slightly more *nuanced* view of the world. Whenever we act, we seek to influence what we perceive as *real* in accordance with our convictions. Our convictions, in turn, are rarely entirely subjective. Rather, they are shared, co-constructed and intersubjective, and constitutive of the practices, norms, institutions and cultures through which we enact and live our lives (Taylor, 1971). What is considered real to us is a product of our shared social construction of reality which shapes our understanding of experiences in our physical and cultural environment. Hence social processes and phenomena do not exist separately from social actors' ways of constructing and describing them. Our cultural values, norms and assumptions cannot be 'switched off' or filtered according to our whims. Rather, they are ever present in our experience of the 'world' so that our cultures and institutions are ingrained in the experiences themselves. When our conceptual understanding of a phenomena changes, so also changes what is real to us, how we perceive the world, and ultimately how we act in it.

With reference to qualitative interpretive case studies, (Miles & Huberman, 1994, p. 10) suggest that emphasis is placed on a "focused and bounded phenomenon embedded in its context. The influences of the local context are not stripped away, but are taken into account". Hence, the use of Interpretive methods in information systems research is "aimed at producing an understanding of the *context* of the information system, and the *process* whereby the information system influences and is influenced by its context" (Walsham, 1993, p. 5, original emphasis). Consequently, as has been the case with this study, the research aim is not set in stone from the beginning of the study but emerges as the researcher gains experience with a phenomenon through fieldwork and reflection.

Critical Intent

By critical intent, I mean *critical* in a broader sense than the application of a particular *critical social theory* to the study of information systems, such as studies inspired by the critical work of Jürgen Habermas and Michel Foucault (see e.g., Alvesson & Willmott, 1992; Forester, 1992; Klein & Huynh, 2004; Ngwenyama, 1991). Simply put, critical research is aimed at changing social reality and practices in such a way that the "perceived negative effects of the way society and organizations are run will be kept at a minimum" (Walsham, 2005). Similarly, Stahl (2008, p. 3) describe critical research as "characterized by an intention to change the status quo, overcome injustice and alienation, and promote emancipation". Whereas positivist and interpretive research can be purely descriptive, critical research is explicitly normative in its aspiration to reveal conditions of domination and change social realities, and can thus be perceived as distinct from other research traditions (Orlikowski & Baroudi, 1991). Methodologically, however, critical research does not distinguish itself clearly from other approaches (McGrath, 2005; Walsham, 2005).

Previous studies have pointed out that when information system intervention researchers report on their experiences and exploits in less developed economies they generally abstain from providing explicit references to ethical justifications for their activities (Berente, Gal, &

Hansen, 2011; Walsham, 1996) or to bring attention to the ethical implications of technical choices (Walton & DeRenzi, 2009). Being explicit about the ethical assumptions and justifications behind efforts aimed at introducing change – for instance through mobile phone-based interventions in public health – is important not just to allow for public scrutiny and criticism of those assumptions, but also as a way of guarding oneself from self-delusion in the urgency of solving practical challenges such as managing technical configurations, negotiating terms with other stakeholders and securing funding.

In the context of this particular study, *critical intent* follows from the premises of primary health care itself, where access to equitable essential health services is considered an individual *right*. Activities in public health, at least in less developed economies, have historically been guided by the primary health care ethos of ‘health for all’ staked out by the Alma Ata declaration in 1978 and later revitalize through international agendas such as the Millennium Development Goals and Universal Health Coverage. These normative aspirations with public health have implications for mobile phone-based routine health information system implementations. Mobile technologies *should* help us reach and account for the most vulnerable and least accessible population groups. Furthermore, mobile phone-based innovations have the potential to enrich the work lives of outreach health workers and empower them with relevant information. However, mobile technologies can also be configured to facilitate work force surveillance and centralized control. The two mobile phone-based implementations in India and Malawi, described in *chapter five*, are indicative of the paradoxical possibilities of empowerment and repression inherent with mobile technologies at the lower levels of health systems in less developed economies.

Given the interpretive and inherently critical nature of this research, the proposition of a grafting metaphor as the core contribution of my research calls for some reflections as to what kind of research contributions metaphors may be. The following sub-section considers how metaphors can broaden our understanding of information systems in new and creative ways. Importantly, as the following sub-section highlights, metaphors are not just matters of language or interpretation, they are also influential in shaping our social worlds, what we consider to be real, and how we act and live our lives.

4.2.1 Understanding Information Systems through Metaphorical Transference

Gadamer (2004, p. 428) posit that “to regard the metaphorical use of a word as not its real sense is the prejudice of a theory of logic that is alien to language”. George Lakoff and Mark Johnson (1980) in their seminal book “Metaphors we live by” elaborate on the central role of metaphors in human understanding, thought and action. The primary function of metaphor, they posit “is to provide a partial understanding of one kind of experience in terms of another kind of experience”(ibid, p. 154). They make a distinction between *conventional* metaphors and *new* metaphors. Conventional metaphors such as ‘the server is *down*’, ‘this Internet connection is *weak*’, or ‘this argument has a *strong foundation*’, are pervasive in

everyday language, structure the conceptual system of our cultures and institutions, and play a central role in determining what we experience as real and true.

Metaphors are not just matters of interpretation. Whose metaphors prevail and are considered legitimate shape social, cultural and political realities and has real implications for how we act and live our lives. For instance, the Indian development economist Amartya Sen (1999) asks us to understand development as *freedom*, while the anthropologist Arturo Escobar (1995) tells us that development is the export of Western ideologies through a form of cultural *imperialism*. New metaphors have the power to create new realities. This happens when we start to understand and structure our past and present experiences in terms of the metaphor and more fundamentally when we begin to draw on the metaphor to set goals, execute plans and guide future action. In relation to information systems, Dahlbom and Mathiassen (1993, p. 115) argue that metaphors:

are useful, not because they are accurate descriptions [...] but because they can open our eyes to disregarded aspects of such systems and make us think along new lines. Metaphors make us creative. They are a way of drawing on our experiences from different areas of reality, making fruitful combinations of ideas that we have a tendency otherwise to keep separate.

However, today's creative metaphors may become tomorrow's taken for granted categories. *Information infrastructure*, for instance, becomes real to us once we start to look for it in our everyday lives, and so also does strategies and tactics for dealing with user adoption, innovation and scaling of information infrastructure, such as installed base cultivation, bricolage and bootstrapping. Metaphors allow some aspects of our experiences with certain phenomena to come into view as a coherent whole, while other aspects that do not fit this coherence remain hidden. Metaphors do not simply bring our attention to similarities between ranges of experiences; they also reveal and hide certain aspects with those experiences. As Lakoff and Johnson (1980, p. 154, italics in original) highlight, "the only similarities relevant to metaphor are *similarities as experienced by people* [...] not *objective*, similarities". Hence, when new metaphors are employed to characterize information systems or information infrastructure, what matters is that they allow us to structure our experience in ways that helps us broaden our understanding of these phenomena.

My personal experience with grafting apple trees at my family farm at the west coast of Norway may very well be the reason why a metaphorical overlay of experiences with mobile phone-based routine health information system implementations was imaginable to me. However, I would probably not have considered such a structuring of my empirical experience appropriate, and certainly not the core contribution of my research, had I not been familiar with the use of biological metaphors such as 'cultivation', 'growth', 'nurturing' and 'fostering' in extant theorizing of information infrastructure. Paraphrasing Walsham (1993, p. 70), my prior sensitizing to a particular body of literature has been both a way of seeing and a way of not-seeing, since the use of particular metaphors exclude other ways of

making sense of the same events. Extant literature on information infrastructure development has guided my attention towards particular issues and influenced my decision to leave out and discard other aspects in my empirical data.

4.3 Empirical Data Collection and Analysis

Field notes based on observations and brief verbatim excerpts from naturally occurring conversations with informants have been my primary source of textual data. Observational visits at sub-district health facilities have been supplemented with ad-hoc interviews of medical officers, statistical clerks, monitoring and evaluation officers and public health managers at districts and higher levels of the two ministries of health. Fieldwork in both settings has involved extensive interaction with mobile workshop trainers, international DHIS2 and DHISm software developers and customizers, representatives of mobile network operators, technical support staff, and local NGO representatives.

To supplement these major sources of empirical data I have picked up documents and reports, both in digital and paper format, when informants have brought their existence to my attention. Consequently, this research has emerged from the continuous analysis of qualitative textual data including observation field notes, interview transcripts and documents. In this section I account for the data collection techniques employed in my research and how empirical data collection and data analysis have been intertwined throughout the study.

4.3.1 Observations, Field Notes and Photos

In addition to empirical data collection, most of my field visits were motivated by practical tasks such as the facilitation of mobile trainings, pilot evaluation, and project management activities. I also had the opportunity to tag along with outreach health workers both in Punjab and Lilongwe. These visits helped me get a sense of how health service provision and routine data collection was carried out on the ground.

Throughout the duration of the study, field notes were jotted down in a total of six field diaries (A5-pages). Taking notes on paper caused little distraction and could easily be supplemented by simple drawings, mind-maps and tables that I shared with informants and fellow researchers for immediate comments. After a full day of fieldwork, I would sometimes sift through my notes and add immediate personal reflections and impressions in the margins to elaborate on my observations and conversations with informants. At times this simple form of data analysis was supplemented with the inclusion of references to relevant literature and the labeling of passages in my notes with concepts that came to mind. I made a habit out of typing up my field notes on a laptop computer late in the evening. Sometimes I managed to do this on the same day as they had been recorded and with events and conversations still fresh in mind, but often it took me as much as a week to find time for it. When deemed useful and in agreement with my informants, I have supplemented my observational field notes with digital photos.

4.3.2 Interviews and Focus Group Discussions

For audio recording of interviews and focus group discussion I have used a digital voice recorder, whenever this was feasible and in agreement with the informants present. Some recorded sessions were transcribed in full while other sessions were only partially transcribed. Whenever informants mentioned something particularly interesting during a recorded session I noted the time displayed on the recorder in my field diary. This allowed me to find and play back the particular sequence later on. The distinction between interviews and mere conversations has been blurred throughout my interaction with DHISm developers, local software customizers in India and Malawi, mobile trainers, national health information system managers, district health managers, data analysts, statistical clerks, sub-district health facility staff and outreach health workers. The key distinction between conversations and interviews has perhaps been the presence of my recorder during what could be described as interviews. Some informants for this study have remained in correspondence over a prolonged time both during field work and subsequently via email and skype calls. At the end of this four-year journey, I consider some of the people I have met, traveled, cooked dinner, gone shopping, watched Bollywood movies, and worked with as friends, rather than mere informants.

Semi-structured Interviews with Individuals

During the initial stages of fieldwork, both in Punjab and Malawi, I conducted semi-structured interviews with informants in their own work environments or during meetings, training sessions and workshops. For instance, during the first two weeks of fieldwork in Malawi a total of 17 semi-structured interviews were conducted and recorded at nine sub-district health facilities with staff members responsible for the collation and reporting of routine health data. Interviews have helped me get a quick overview of the role of routine health information systems in the two contexts, existing communication infrastructure and information flows, and peoples' initial expectations towards mobile phone-based routine data reporting. As noted by Walsham (1995a, p. 78), even for the engaged (participant) observer, interviews are still an important source of data "since they enable researchers to step back and examine the interpretations of their fellow participants in some detail", and – I would add – the researchers own assumptions and interpretations as well. In particular, interviews were useful for getting access to the birds-eye-view held by higher level government officials, such as the deputy director of CMED in Malawi, the district health office manager in Lilongwe, and civil surgeons in charge of health information systems in districts in Punjab whom I was not able to interact with on a day-to-day basis. The tendency towards employing interviews at higher levels of the health system hierarchy can be ascribed to the fact that "participant observation is a research technique that does not travel well up the social structure" (Gusterson, 1997, p. 115).

Focus Group Discussions

Whereas interviews with individuals were conducted as part of both case studies, focus group discussions and interviews in small groups were only conducted in Malawi. Focus group discussions were employed due to the fact that several PhD candidates were conducting research in Malawi together, but on different topics. We arranged to meet with informants such as outreach health workers, sub-district facility managers, health information system focal persons, and district statistical clerks so that several PhD candidates were able to collect their empirical data. This coordination allowed us to cause as little disturbance as possible to already overburdened civil servants. Figure 4-2 below depicts the conduct of a small group interview at a sub-district health facility in Lilongwe. The session was attended by one head nurse (seated), one routine health information system focal person (standing) and one integrated disease surveillance and response (IDSR) focal person (seated, left) in addition to Marlene, a Malawian PhD candidate (standing), and myself (seated, right).



Figure 4-2 Group interview at a sub-district health facility in Lilongwe

As the implementation progressed, focus group discussions also served as venues where participants were able to raise their own concerns and voice their opinions about the mobile phone-based routine health information system implementations. For instance, some of the perverse consequences of monetary incentives associated with the conduct of training workshops were raised by participants themselves and were a key source of empirical data for Article V in this dissertation.

4.3.3 Document Studies and Naturally Occurring Data

In addition to the data collection techniques outlined above, I have also obtained a range of relevant documents. Documents have ranged from WHO and World Bank national statistics and reports, national/state eHealth policies and strategies, organograms, annual ministerial health information system reviews and situation analyses, intra-ministerial health information system feedback and performance reports, and assessments of national health information system performance by external reviewers such as the Health Metrics Network¹⁵. I have also obtained status, progress and evaluation reports concerning the two mobile phone-based implementations from mobile trainers, project coordinators, district/state/national level data analysts, and monitoring and evaluation officers.

In addition, all training sessions conducted as part of the implementations both in Punjab and Lilongwe were followed immediately by participants filling out an anonymous feedback form where respondents were asked to share their immediate reflections and concerns. With the implementation in Punjab, HISP India had designed the feedback survey form. For the trainings in Lilongwe I designed a similar one. I took photos of the filled forms from all the training sessions that I participated in both in Punjab and Lilongwe to supplement my qualitative assessment of end-users perceptions of the implementations. In Punjab I asked one of the HISP India employees to help me translate comments whereby ANMs expressed grievances with mobile phone-based reporting requirements. These grievances are discussed in more detail in section 5.1.

Through interactions with mobile operators in Malawi I obtained tariffs, coverage rates and terms of service documents. In addition, paper copies of extant routine health information system reporting formats, facility registers, activity plans, tally sheets, and other structured information products and tools were either photographed or simply examined to get a sense of the actual use of such resources at the sub-district health facilities and higher organizational levels. Among other things this led me to notice that the practice of conducting health information system review meetings at sub-district health facilities in Malawi had ceased two years prior with the termination of a World Bank funded grant – an issue that is considered in more detail in Article III, IV and V.

4.3.4 Adding Structure to Data Analysis: Use of Computer Software

No clearly defined coding scheme was adopted for data analysis in this mainly exploratory and descriptive research. Rather, based on my reading of a diversified body of information systems research literature, I maintained a dynamic list of notions which I used as *tags* in Nvivo, a qualitative data analysis software package, and Zotero, a bibliographic reference management tool. The list could be considered a list of codes (Miles and Huberman, 1999)

¹⁵ WHO's now-disbanded Health Metric Network (HMN), aimed at mobilizing development partners to strengthen health information systems in developing countries (Health Metrics Network, 2008).

based on thematic categories (Bogdan and Biklen, 1998). It consisted of concepts from literature and empirically informed notions. These notions were applied to chunks of textual data. The dynamic list of codes reflected the different aspects that I was interested in exploring in the empirical data. Only a few notions have been central throughout the study such as 'sustainability', 'scaling', 'cultivation', 'bricolage', path dependency' and 'control'.

I used Nvivo to structure and organize the empirical material associated with the two case studies. This allowed me to index and query textual data and to annotate and add tags to segment of raw data. Digital data stored in the Nvivo database included photos, typed up field notes, transcribed interviews and focus group discussions and digital copies of obtained documents. I used built-in Nvivo features for the transcription of my audio recordings. In particular, the Nvivo transcription tool allowed for notes and tags to be associated with particular sequences within audio streams for later retrieval, playback and coding. This feature was particularly useful when working with more than 32 hours of audio recorded interviews and focus group discussions from Malawi for the data analysis in Article V. Nvivo comes with a range of sophisticated features that can be leveraged in analysis of qualitative data (see Beekhuizen, von Hellens, & Nielsen, 2010; Dean, Sharp, & Genc, 2006; Leech & Onwuegbuzie, 2011; Siccama & Penna, 2008). However, beyond adding a bit of structure to my data such as categories, tags and timelines, I did not use Nvivo extensively for data analysis. More elaborate data displays have been co-created, over time, with my co-authors, by taking turns with different colored markers on whiteboards. In this way collective data analysis has involved discussions about what concepts to draw on, what rows and columns to include in tables and what dimension to include in models and drawings. Typically, at the end of numerous such sessions I have taken a picture of the whiteboard so that I could return to the data displays and arguments later on.

Similarly to how I employed Nvivo to organize my empirical data, I used Zotero, a free and open source reference management tool for managing my literature reviews. Throughout the study I have maintained a Zotero library with tagged articles using the aforementioned dynamic list of codes. Finally, I have used software like Microsoft Visio™, Microsoft Power Point™ and SmartDraw™ to create digital versions of hand drawn data displays such as figures, timelines, and information flowcharts. A few of these data displays have been included in the five articles that are part of this dissertation (see Appendix I-V).

4.4 Ethics: Do no Harm and Strive for Reciprocity

In a recent literature review, Dearden (2012, p. 1) points out that "the quantity, quality, and detail of advice that directly addresses the [ethical] issues arising in interventionist ICTD is limited". Similarly, Walsham and Sahay (2006) argue that researchers involved with information system implementations in developing countries tend to omit explicit reference to the ethical justification and grounding of their activities. In section 4.2 I elaborated on how the public health ethos of 'health for all' has informed the critical intent of this research and motivated my personal involvement in the two mobile phone-based implementations.

My close engagement with the mobile phone-based implementations has led me to juggle the roles of researcher, technical advisor, trainer, implementer, tourist, friend, and guest. Different roles have been associated with different commitments which in turn have influenced how my empirical data has been co-constructed in collaboration with my informants. In the following I reflect on one particular ethical concern that has surfaced during my fieldwork, namely the potential conflation of *informed consent* and formal *research clearance*.

The Conflation of Research Clearance and Informed Consent

In preparation for my fieldwork I was only able to find very fragmented pieces of relevant ethical guidelines from either Malawi or India that concerned social studies in public health care organizations. However, the lack of clear guidelines in countries where interventionist research is conducted does not excuse relaxed attitudes towards ethical considerations. It is rather a strong argument for the opposite, as local institutions are not in place to protect the interests of potentially vulnerable project participants and informants. This intensifies the need for intervening researchers, like me, to engage in ethical self-monitoring.

As my engagement with the two mobile phone-based health information system implementations progressed, so also did my emergent research agenda. This left me with the following dilemma: if the aim of my exploratory research was continuously revised in response to new leads and changing circumstances, then how could I maintain a relationship of 'informed consent' with my informants? Furthermore, as my research involved interaction with large hierarchical governmental organizations in less developed economies, research clearance had been formally obtained from managers at state or national levels. Clearances at higher levels were coupled with formal letters that introduced my research, in very superficial terms, to people employed at lower organizational levels. Hence, formal approval at higher levels translated into coerced co-operation and participation at lower levels.

Under such circumstances I believe it is up to the researcher to make sure that informants feel comfortable about their roles in the study. From my experience, informed consent is perhaps not the key challenge in intervention research. As Fluehr-Lobban (1994) argues, values of 'informed consent' have been nurtured in the 'developed' context of the West and are sometimes difficult to translate to the contexts in which 'informed consent' is being sought. During my fieldwork I have tried to ensure that relations in the field do not become one sided and rewarding only to me, the intervening researcher. However, not all informants are in a position to leverage potential benefits from collaborating with foreign researchers equally well. Managers in higher positions and with higher education stand a greater chance of reaping benefits from interaction with foreign experts for instance by expanding their social network and learning about education and work opportunities abroad. In the end, our best option as intervention researchers may be to treat all people we encounter with equal respect, try to do no harm, provide advice based on our expertise when we can, and strive to be fun, honest and rewarding people to work with.

Chapter Five

Two Stories of Mobile Phone-based Implementations

This chapter presents two empirical narratives. Both narratives are concerned with mobile phone-based routine health information system implementations in resource sparse settings. The mobile technologies, the application domain, and the application purpose with the two implementations are largely the same. The first narrative reports on a ‘big-bang’ implementation where a small pilot study is scaled-up to a state-wide ‘roll-out’ involving about 5000 health workers in Punjab. Punjab is a predominantly agricultural state north-west in India with more than 25 million inhabitants and the native home of the *Sikhs*. The second narrative reports on an incremental ‘baby-steps’ implementation in Lilongwe district in Malawi, initially involving 17 sub-district health facilities and later expanded to 44. Malawi, a landlocked country in sub-Saharan Africa with about 16 million inhabitants, is also an agriculture-based economy and one of the financially poorest countries in the world. Despite numerous contextual differences (e.g., geography, size, communication infrastructure, financial resources, demographics and culture), both case studies highlight aspects with the complex socio-technical and intrinsically politicized processes of mobile phone-based routine health information system implementation.

The case narrative from Punjab (section 5.1) highlights how early technical configurations may have long term socio-political consequences and vice versa. The second implementation narrative (section 5.2), from Lilongwe, is a story about health service and health information system *coverage*. The public health struggle for national health information system coverage is transferred to the mobile phone-based solution, both in functional and geographical terms. Both narratives serve as empirical backdrops for the subsequent presentation and synthesis of the five articles in *chapter six*. Furthermore, the empirical material presented in this chapter is drawn on in conjunction with findings from the five articles to substantiate the practical and theoretical contributions of the dissertation in *chapter seven*.

5.1 ‘Big-bang’ Roll-out in Punjab, India

At the time of the commencement of my fieldwork in autumn 2010, every Auxiliary Nurse Midwife (ANM) in Punjab was required to provide outreach and in-facility health services to a catchment population of about 5000 people (approximately 1000 households or up to a dozen villages). Formally, every household in a catchment area was supposed to be visited by the ANM each month. However, as noted by a senior medical officer, one of the ANMs’ direct superiors in the public health hierarchy, “this is only happening under ideal conditions, if at all”. In practice, ANMs interpreted the national requirements flexibly to suit their local

context. The need to do so was apparent with the ANMs' extensive list of duties including administering child immunization camps in villages every Wednesday and providing in-facility services at sub-district health facilities¹⁶ in the afternoons. In addition, the distances between villages within a given catchment area were sometimes more than eight kilometers. Finally, ANMs, who were primarily middle-aged married women, did not feel comfortable about providing outreach health services after sundown due to risks associated with walking alone between villages.

The fact that every household in a catchment area could not be visited every month was not a great concern to the ANMs I met and spoke with. ANMs knew well the communities they served. They knew who was chronically ill, who was pregnant¹⁷ and which households had children who had not been immunized. They knew peoples' names and faces and the inside of households in the villages. Figure 5-1 shows an ANM (right) and an Accredited Social Health Activist¹⁸ conducting a family planning consultation while sitting on the bed with the woman of the household (left). The picture conveys the close ties ANMs had to the population they served. The quality and efficiency of the ANMs' public health services depended to a large extent on knowledge that resided in the ANM's personal network, or as one ANM put it: "we just know".

I had the privilege of visiting three ANMs at their respective sub-district health facilities and follow them as they provided outreach health services. As I was following an ANM in one of the five villages in her catchment area, we stopped by the residence of an old and nearly blind lady. This lady turned out to play a central role in the ANM's tacit knowledge management system by acting as the ANM's ears in the village. The lady invited us into her home and served a yoghurt based drink called *lassi*. She then told us about a man who had fallen from a rooftop and hurt his leg. The wound was infected, she explained, and the ANM had been asked for. The old lady went on to mention that a young pregnant woman from the village had moved to the household of the mother in-law and intended to stay there until child birth. The ANM took notes on a piece of paper which she had prepared with hand-drawn columns and rows. Based on this and other pieces of information, the ANM was able to plan her route and deduce a few short-cuts through the village.

At the end of each month ANMs' partly tacit knowledge management systems were translated into the categories of a structured national routine health information system. Historically, ANMs collected and collated data throughout the month in field diaries and registry books and transferred it onto the appropriate paper-based summary forms. The forms were then carried to higher levels (block or district) where the data was entered into

¹⁶ In Punjab *health districts* are divided into 'blocks'. Hence, the *sub-district health facilities* in Punjab (also called *Sub-Centers*), could just as well have been referred to as sub-block health facilities. I have used the term sub-district health facility to maintain a consistent naming convention across the two empirical cases.

¹⁷ Out of a total population of 5000 roughly 20 women would be pregnant at any given time.

¹⁸ *Accredited Social Health Activists* (ASHAs) are community health workers instituted by India's Ministry of Health and Family Welfare as part of the National Rural Health Mission (NRHM).

computers by clerks. Computers and landline Internet connectivity was generally not available at sub-district health facilities in Punjab.



Figure 5-1 Family planning consultation in a Punjabi household

The Mobile Phone-based Implementation in Punjab

In 2008 The National Rural Health Mission (NRHM) in India initiated a pilot project to facilitate mobile phone based reporting of routine health data from peripheral sub-district health facilities. The pilot was conducted in five *blocks* (sub-district public health administrative level) in five different districts in five different states in India and involved about 200 ANMs. HISP India was contracted to develop the mobile application, which would allow for routine health data to be sent via SMSs to a DHIS2 server. After completion the pilot project received favorable assessments based on high reporting rates through mobiles. In addition, ANMs were taking advantage of the possibility to use mobile phones for making free calls within a closed user group (CUG) to doctors or colleagues and by taking photos of patient wounds and work related events (Mukherjee et al., 2010). The swift mobile reporting of data into the computerized data warehouse was welcomed by health managers, especially in areas that were experiencing transportation and communication challenges.

Based on the favorable pilot evaluations, during spring 2010, the state of Punjab, by the state Principal Secretary and the Mission Director of the NRHM, decided to strengthen the community-level routine health information system by introducing mobile phone-based sub-district health facility reporting. HISP India was contracted to advise the state, develop an

appropriate technical solution and provide end-user training and initial support. At the time, there were 2948 sub-district health facilities in Punjab staffed with about 5000 ANMs across 20 districts. The state of Punjab decided to purchase Nokia 2330 Classic mobile phones for all ANMs, as this handset met technical and budgetary prescriptions. A cost assessment led the state to decide on using SMS for data transport rather than GPRS. The mobile applications were set up to send compressed SMSs (70% compression rate) to a state server, but this was not apparent to users interacting with the Java application (J2ME) through the graphical user interface in Punjabi. The J2ME application was configured to allow for the reporting of 139 data elements – a sub-set of the national reporting requirements – related to routine health services such as antenatal care (ANC), child immunization and family planning, while also including financial data for the sub-district health facilities managed by the ANMs.

As a last minute change, the state of Punjab by the Mission Director decided to include an additional form for *daily* mobile phone-based reporting consisting of *ten* data elements. The managerial motivation for the inclusion of a daily data set for reporting has been interpreted by other researchers as a way to “strengthen control of the health workers’ activities, to know what they were doing on a daily basis” (Braa & Sahay, 2012, p. 13). Similar interpretations were offered by district and higher level managers during ad-hoc conversations. For instance, one female Monitoring and Evaluation (M&E) officer in Gurdaspur district explained that she was happy about the daily mobile reporting requirement as it would “enforce the day-to-day recording of services provided”, rather than allowing ANMs to “produce estimates at the end of each month”.

In preparation for the roll-out of mobile phone-based reporting, a team of ten HISP India employees tested and installed the J2ME applications on all 5000 Nokia handsets via Bluetooth during a period of one and a half months. One of the key features with the mobile reporting solution was integration with DHIS2, the routine data warehouse employed by the state of Punjab. However, in order to safeguard the existing information flow through the current paper and computer-based setup for reporting and entering data into DHIS2, a parallel DHIS2 server instance was set up to accommodate reporting through mobile phones. The intention was to phase out paper-based reporting once mobile reporting had proven reliable on a state-wide scale.

A challenge with the mobile reporting solution was the unanticipated frequency of accidental deletion of the J2ME application by ANMs. As Bluetooth technology and the competence to use Bluetooth for file transfer was generally not available at the sub-district level, the application had to be installed by travelling representatives of HISP India’s support staff. This challenge was exacerbated by a combination of socio-technical factors. Many ANMs were unaware that the mobile application could be deleted. In addition, the menu options on the chosen Nokia handset made the deletion of non-native application particularly easy to perform by mistake. The issue could have been mitigated if the

application had been factory installed on the phones. However, HISP India's request to have this done had been rejected by the manufacturer as the order of 5000 phones was considered too small.

Emerging Tensions Concerning Mobile Reporting

From the very onset the ANMs contested the mobile reporting of ten daily data elements. This was even made apparent on the feedback and evaluation forms filled out by ANMs directly after they had received training on mobile reporting. Translated from Punjabi to English the vast majority of ANMs handwritten remarks pointed out that "daily reporting should not be there" or "daily reporting should be weekly". In fact, the requirement for daily reporting had been advised against in dialogue with the state, by HISP India's technical and public health consultants. However, the state Mission Director at the time had not been willing to negotiate this requirement.

The ANMs' grievances with the daily reporting were multifaceted. First, they felt that the daily reports would be used as a crude mechanism to monitor their activities. Second, the majority of the ten data elements in the daily reports were related to child immunization activities which were conducted in the villages only on Wednesdays. This implied that on all other days of the week they would report zero values, which could be interpreted by detached managers as the ANMs not performing their chores. Finally, one of the ten data elements for mobile reporting concerned the number of deliveries assisted at sub-district health facilities. However, since no deliveries are supposed to be conducted at the vast majority of sub-district health facilities in Punjab, this data element would mostly be reported as zero as well. Both ANMs and senior medical officers (block level managers) expressed their concern with the limited recognition and understanding of ANMs' work that was exhibited by the request for daily mobile reports on these specific data elements.

Consequently, the ANM's labor union staged an organized protest against the mobile reporting and asked all ANMs to discontinue mobile reporting, including monthly reports, until the daily reporting requirement was removed. The labor union also circulated a letter of demands to the state, where the discontinuation of the daily reporting through mobile phones was explicitly mentioned. The state of Punjab by the Mission Director responded to the protest by distributing a directive dated 1st of February 2011 to all civil surgeons (head of health districts in Punjab) to "stop the salary of those ANMs who are not uploading the data on mobiles". Furthermore a team of clerks were put in place to make phone calls to all ANMs who were not reporting to instruct them to proceed with the daily reports or risk that their salaries would be stopped. Only a few weeks later the escalating tension between ANMs and the state came to a sudden halt when a new Mission Director was assigned in Punjab. The new Mission Director decided that daily reporting should be discontinued and that the ten data elements in the daily mobile report should be submitted on a weekly basis instead. The mobile reporting rates for monthly and weekly reports, which could be

inspected on the DHIS2 server instance, rose steadily after daily reporting requirements had been revised to weekly.

As a result of the implementation the ANMs in Punjab now had work phones and were able to make free calls and send SMSs within a closed user group (CUG). Furthermore, a central human resource database with the names and phone numbers of all ANMs in Punjab had been created as a side-effect of the implementation. This resource was considered a substantial asset by higher level health managers who envisioned that they could now call any ANM directly instead of having paper based messages and queries transmitted through the organizational hierarchy. In addition, mobile reporting was instantaneous. As soon as mobile reports were submitted they could, at least in theory, be inspected by all organizational levels with Internet access (i.e., block, district, and state). In turn, this allowed for timely data completeness checks and follows-up of health workers who had not reported on time.

In the wake of the implementation, the data elements reported through mobile phones were only a portion of the total number of routine health data still captured by ANMs on paper-based forms. However, the aforementioned decision to use only SMS for data transport hampered the inclusion of more reporting formats. Interviews with ANMs, monitoring and evaluation officers and senior medical officers in districts in Punjab suggested that the existing paper based reporting to block and district levels had been working quite well even before the mobile implementation, since Punjab had an elaborate road network and a well-functioning transportation infrastructure. One senior medical officer pointed out that other states in India with more hilly areas and more severe communication challenges such as parts of Bihar would be in greater need of mobile reporting of routine health data. Similarly, some ANMs complained that the mobile phone-based reporting solution laid claim to limited public health resources that could have been put to better use by addressing pressing concerns such as staff shortages and medicine and equipment stock-outs at sub-district health facilities or by purchasing ambulances to carry women in labor from rural villages to hospitals.

The vision of going paperless and managing all sub-district health facility reporting through the mobile phone was a key motivation with the state's initiative. However, three years after the 'roll-out', ANMs were still submitting the traditional paper-based forms in parallel to mobile reports with the same data elements. This was partly due to delays in the planned migration from a technical setup with two DHIS2 server instances running in parallel (one catering for mobile reporting and one for all other HMIS reports) to a setup with only one integrated data warehouse. The technical transition had proven difficult due to differences in configuration between the two server instances. Despite these challenges, the state requested their contractor, HISP India, to develop several new mobile features such as: more mobile phone based routine data reports, birth and death registration, tracking of pregnancies and child immunization, and mass distribution of SMS-based queries to ANMs.

Due to the initial choice of using only SMS transmission over GSM for data transport, any new software feature like the inclusion of more forms for mobile reporting would require another round of Bluetooth installation on all 5000 handsets. This was problematic as all the 5000 phones would either have to be collected, reconfigured and then redistributed; updated in-situ by a travelling team of implementers; or simply discarded and replaced by another handset with new software features installed. Even the daily reporting format which had been formally revised to weekly reporting still carried the label “Daily data set” on the ANMs’ mobile phones since there had been no mechanism in place to update the application. In essence, any substantial enhancements to the mobile reporting solution in Punjab would involve an upgrade of mobile subscriptions to GPRS connectivity and the deployment of a new J2ME application or a mobile web based client that could be updated using mobile data. This would allow subsequent form revisions and new features to be coordinated from a central server. However, as of late-2012, no such costly revision in terms of money, time, retraining and stakeholder coordination had been implemented.

5.2 Incremental ‘Baby-steps’ in Lilongwe, Malawi

During autumn 2011 agreements were reached between the MobiHealth project, the Ministry of Health in Malawi represented by the Central Monitoring and Evaluation Division (CMED), and the Lilongwe district health office, on the preliminary scope of a pilot project for mobile reporting of routine health data from sub-district health facilities. Lilongwe was chosen as the pilot district because it was the first district to embark on the nation-wide implementation of DHIS2, a web-based data warehouse with support for data capture through mobile phones. The mobile solution to be piloted in Malawi, called DHISm, was loosely based on the functionality of the application that had been implemented in Punjab. The source code, however, had been radically reworked based on subsequent implementations in Tanzania, Nigeria, the Gambia and Zambia. The technical solution could now support report submission using mobile data. In addition, mobile data connectivity allowed for server side updates of the J2ME client application and mobile web-forms.

Challenges with Routine Health Information Systems in Malawi

At the time, data concerning the populations’ health status such as deworming, sanitation, child immunization, antenatal care and registration of births and deaths was, at least partly, collected in village health registers by Health Surveillance Assistants (HSAs). HSAs provided essential outreach health services and recorded public health related incidences. Figure 5-2 shows how a suspected case of malaria was investigated by an HAS (to the right). In the picture the HSA compares the color of the palm of the feverish girl in a pink dress with the palm of the girl’s mother. Due to a perceived difference in palm color, the incidence was classified as a “suspected case of malaria” on the tally sheet residing on the chair in front of the HSA. In this example the HAS had to make do with an unreliable diagnostic technique that, if widely used, would cause over-reporting of suspected malaria cases in the population

and lead to unreliable health statistics. The girl was referred to the nearest health facility for further examination.



Figure 5-2 Examination of a suspected case of malaria in a village in Malawi

The activities of HSAs in Malawian villages were coordinated by senior HSAs who in turn were affiliated with sub-district health facilities. Divergent interpretations existed throughout the health services as to what should be done with the data captured by HSAs. According to a recent Ministry of Health situation analysis (Bhana, 2013), some health workers and their managers held the view that since community level data was captured within the designated catchment areas of sub-district health facilities, it should be compiled together with in-facility data to produce an integrated report. Others held the view that public health data collected through outreach services should be recorded separately and reported directly, either monthly or quarterly, to district level managers responsible for different programs such as malaria, HIV/AIDS, Tuberculosis, and mother and child health. In general, routine health data reports collated at sub-district health facilities were verified and signed by facility in charges and carried to district health offices. Computers were generally only available at districts and higher organizational levels, where the data was entered into electronic databases by statistical assistants. The divergent interpretations regarding reporting requirements from catchment areas may in part explain why a sizable portion of public health data appeared to be missing from the national health statistics database (Bhana, 2013; Kanjo, 2011).

Furthermore, some routine health data had a controversial status in Malawi. A large portion of births in Malawi had historically been assisted by Traditional Birth Attendants (TBAs). Due to the disputed role of the TBAs in the public health services and the Malawi society at large, their health service data had often not been formally collected, and if collected, not collated,

processed and acted upon by health authorities (Kanjo, 2011). This contributed to a significant information loss concerning the quality and reach of essential mother and child health services in Malawi.

At rural sub-district health facilities, a widespread lack of printed paper forms was impeding health worker from collating information altogether. The lack of proper forms at the facilities was, among other factors, caused by overshot district budgets for printing and inefficient supply chains. At some sub-district facilities staff tried to address the issue by drawing columns and rows on blank pieces of paper to produce forms. This, however, led to inconsistencies across facilities and haphazard omissions of data elements. In order to submit filled reports, sub-district health facility staff would employ a variety of improvised means such as handing the reports over to ambulance drivers or awaiting personal trips to the district center. During rainy season the physical transportation of paper forms from some sub-district health facilities was simply not feasible due to flooded roads.

Despite numerous socio-political, infrastructural and technological challenges that affected the *reliability* of routine health data, the *timeliness* of data reporting was perhaps the greatest concern to public health managers in Malawi. Reports that failed to reach decision makers on time were of no use in informing the distribution of limited resources and prioritization of health care interventions. In addition, as pointed out by the Deputy Director of CMED, “often the district statistical assistants – they wait for all the reports from the facilities to reach [the district health office] before they enter the data”. This situation was exacerbated by the relatively low rank of the statistical assistants at the district health offices (Hamre & Kaasbøll, 2008). Due to their low rank in the overall health system statistical assistants felt uncomfortable about requesting missing reports from facility in charges at sub-district health facilities, who formally outranked them. It was envisaged by CMED that the introduction of mobile phone-based reporting would circumvent some of the socio-political and technical obstacles with paper-based reporting.

The Mobile Phone-based Implementation in Lilongwe

The pilot implementation in Lilongwe utilized two different DHISm solution types for mobile reporting. One solution type allowed sub-district health facility staff to open mobile browser-based web-forms, fill in data, and submit the forms to the DHIS2 server. The other solution was a Java-based (J2ME) application installed on the mobile handsets, which allowed users to access the same forms using mobile data.

A total of 17 health facilities distributed across two health areas, called Kabudula and Area 25, in Lilongwe district were enrolled in the pilot project. They received preconfigured Nokia feature phones, and were trained on mobile reporting. The mobile reporting initially only covered two forms. One form was for weekly reporting of integrated disease surveillance and response (IDSR) and was concerned with communicable diseases. The other form was called HMIS-15 and consisted of a monthly summary of essential data elements for most

public health programs in Malawi. Before training of end-users could commence, the two forms had to be configured for mobile reporting on the national DHIS2 server. Consequently, the DHISm implementers established contact with local DHIS2 coordinators located at the Malawi College of Medicine in Blantyre, about 300 kilometres away from the Ministry of Health's headquarters in Lilongwe. However, it was problematic for the DHIS2 coordinators in Blantyre to allocate time for mobile form customization on the national server, as they were already behind schedule with rolling out DHIS2 to districts in Malawi.

As the Ministry of Health in Malawi does not have sufficient IT expertise to manage the national DHIS2 server and other mundane IT-tasks, the DHIS2 coordinators in Blantyre were responsible for all DHIS2 implementation and maintenance activities, including system customization and end-user training. It was also in the DHIS2 coordinators interest to retain their exclusive roles as DHIS2 server customizers as this was perceived as a key aspect of their routine work. In order to commence with the preparations for mobile reporting, the DHISm implementers reached a compromise with the DHIS2 coordinators involving the use of another DHIS2 server instance, which had mainly been used for live demonstrations and teaching purposes. DHISm implementers were given full administrative rights for the DHIS2 demonstration server which allowed them to configure the IDSR and the HMIS-15 forms for mobile reporting.

At the start of the pilot, the Lilongwe district health office and the health area offices at Kabudula and Area 25 did not have reliable Internet access. For this reason they were unable to access the online DHIS2 demonstration server and inspect the data being reported from the 17 sub-district health facilities through mobile phones. Mobile phone-based reporting thus bypassed the traditional custodians of routine health data. After noting this problem, the DHISm implementers provided the two district health area offices and the Lilongwe district health office with internet dongles (USB Internet modems) and orientations on how to use DHIS2 to monitor mobile phone-based reports.

Baby-steps towards Long-term and Large-scale

Focus group discussions, project review meetings, and interviews with staff at sub-district health facilities were conducted over a period of one and a half years. These interactions revealed that staff at sub-district health facilities would prefer all paper-based reports, including program-specific reports for HIV/AIDS Tuberculosis, malaria and mother and child health, to be replaced by mobile phone-based reporting. This functional scale-up of the mobile phone-based reporting solution was necessary to alleviate staff from the burden of transporting paper reports to the district health office altogether.

As the two health-area offices and the district health office in Lilongwe had noticed marked improvements in reporting rates and timely availability of data, it was decided to embrace mobile phone-based reporting as the official approach to routine reporting from all 44 government administered sub-district health facilities in Lilongwe. Four additional reporting

formats were customized for mobile phone-based reporting to cover the majority of reporting requirements for the majority of sub-district health facilities in the district. At the same time, mobile reporting of routine health data was transferred from the demonstration server to the national DHIS2 production server.

As of March 2014 CMED had expressed ambitions to scale DHISm geographically. In particular, CMED was eager to put DHISm in place at sub-district health facilities in remote areas of the country where lack of electricity, Internet connectivity, and road accessibility posed severe communication challenges. These facilities were struggling to meet the requirements of paper-based reporting on time, or at all. The scale-up was deemed plausible due to high estimated mobile network coverage rates in Malawi, although these would need to be verified in practice. Steps towards long-term technical support and further local development of DHISm in Malawi were taken through the employment of a project-funded technical assistant working out of CMED's offices. The arrangement was seen as an intermediate circumvention of the slow and bureaucratic process of creating a new IT position within CMED. The technical assistant was to work closely with the DHIS2 coordinators who were in the process of relocating from Blantyre to Lilongwe. Furthermore, terms of reference to be used by the Ministry of Health in engaging future full-time in-house IT positions had been developed in order to transfer responsibilities for the mobile phone-based reporting function onto organizational roles rather than specific individuals or projects.

Layers of Coverage

Public health managers require reliable and timely health service data to calculate indicators that convey the health status of the population and reveal how many of those that should have received certain types of health services actually received them. In Malawi, a combination of unreliable data collection techniques, the political controversy associated with some data elements, and haphazard routines for data reporting made it difficult to determine if public health data was simply erroneous, missing, or if vulnerable populations were being deprived of essential services such as assisted child birth by trained health personnel. More specifically, with unreliable communication channels from sub-district health facilities it was difficult for middle and higher level managers to determine whether whole reports were missing because of lack of stationery at sub-district health facilities, unreliable transportation channels, or simply neglect. Hence, health status and health service coverage rates calculated for districts and regions in Malawi conflated potential discrepancies introduced at multiple *layers of coverage*. These layers included the actual reach of health service provision, the coverage of data capture concerning health service provision, and the coverage of reporting for those data. Discrepancies introduced at different layers could not easily be differentiated post-hoc by public health decision makers.

Mobile phone-based routine health data reporting, although envisioned to circumvent some of the challenges with paper based communication, introduces yet another source of potential discrepancies to health status and health service coverage estimates. Not only are

mobile communication devices dependent on the reliability of mobile networks to perform different tasks, such as sending SMSs, making phone calls or mobile web-browsing, their use is also dependent on the availability of electricity for regular charging. Furthermore, different mobile network operators cover different geographical regions and employ different business models that further complicate the use of mobile phone-based solutions for routine data reporting. As mentioned in the literature review in *chapter two*, a key principle with ICT-based routine health information system implementations is to focus on the timely availability of the actual *health data* (content) rather than the *technology* (container). How mobile phone-based reporting can coexist and coevolve with extant paper based health information system routines and work practices on a national scale in Malawi remains an unanswered empirical question. The next chapter reviews and provides a synthesis of finding from the five peer-reviewed articles that lay the foundation for this dissertation and discusses 'mHealth sustainability' in the context of routine health information systems in less developed economies.

Chapter Six

Research Findings and Contributions

This dissertation synthesizes and extends the individual contributions of five peer reviewed and published articles, of which the full text versions are included as Appendices I-V. Each article makes a distinct research contribution that corresponds to a particular framing of the research agenda for a particular audience. The diversity in the chosen publication outlets i.e. health policy, information systems research and ICT4D reflects the transdisciplinarity of the research as a whole. In this chapter I present summaries of the five articles (section 6.1) and consider their individual contributions in light of the overarching aim to develop a nuanced understanding of sustainability challenges to mHealth in less developed economies (section 6.2).

6.1 Summaries of Research Articles

The five articles are presented in order of their publication dates. Each summary details the *purpose* of the article, the *research approach*, *key findings*, and implications for practice and further research.

- I. Braa, K., & Sanner, T. A. (2011). Making mHealth Happen for Health Information Systems in Low Resource Contexts. *In Proceedings of the 11th International Conference on Social Implications of Computers in Developing Countries*, Kathmandu, Nepal, May 2011, 530-541.
- II. Sanner, T. A., Roland, L. K., & Braa, K. (2012). From pilot to scale: Towards an mHealth typology for low-resource contexts. *Health Policy and Technology*, 1(3), 155–164.
- III. Manda, T. D., & Sanner, T. A. (2012). Bootstrapping Information Technology Innovations across Organisational and Geographical Boundaries: Lessons from an mHealth Implementation in Malawi. *In Selected Papers of the Information Systems Research Seminar in Scandinavia*. Akademika forlag, 25-39.
- IV. 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
- V. Sanner, T. A., & Sæbø, J. I. (2014). Paying per diems for ICT4D project participation: A sustainability challenge [IFIP special issue]. *Information Technologies & International Development*, 10(2), 33–47.

6.1.1 Article I: 'Making mHealth Happen'

Purpose – Mobile phone-based health information system implementations are often seeded as brief donor funded pilot projects. The impacts of implementations, such as timely use of relevant routine health information, often deteriorate as soon as funding is discontinued. To approach this challenge the article takes early steps towards the development of an *ecological view* on mobile phone-based routine health information system implementations in resource sparse settings.

Research approach – Interviews, observations and document studies were conducted through the two authors' engagement with mobile phone-based implementations in India and Nigeria. The targeted health facilities were not able to utilize computers and Internet connectivity due to lack of physical infrastructure such as roads and power supply, financial constraints and/or limited human resources. Analytically, the study considers ICT implementations as *installed base cultivation* and foregrounds the mutual shaping of mobile phone-based solutions and existing socio-technical arrangements.

Findings – Mobile phone-based enhancements to health information systems needs to be considered in conjunction with a broad range of existing socio-technical arrangements such as situated work practices and human competencies, local ICT resources such as health workers' own mobile phones and mobile network providers' physical infrastructure, business models and tariffs.

Research implications – The study suggests that the notion of 'installed base cultivation' (see e.g., Aanestad, 2002), although useful for making sense of the overall development of a national health information infrastructure, is too elusive to portray the nitty-gritty patchwork, quick-fixes and problem solving activities that characterize mobile phone-based health information system implementation. To complement an evolutionary view, the authors draw on the notion of *bricolage* (e.g., Ciborra, 2002) to describe the distributed and locally apposite articulation work that in sum constitute the cultivation of digital health information infrastructure.

Practical implications – The article considers the practical challenge of sustaining mobile technology innovations in low resource contexts. In particular, the article focuses on the utilization of low-end mobile phones to report routine health data and the challenges associated with different mobile technology solution types in terms of human resources for development and implementation, network connectivity, usability and financial costs.

Contribution to overarching research aim – The article highlights that socio-technical arrangements such as established work practices, and ICTs already in place shape and are shaped by mobile technology implementations and that long-term sustainability grows out of distributed local improvisations and carefully applied patchwork. Strengths and limitations with the conceptualization of health information system strengthening as a process of *installed base cultivation* through distributed patchwork and *bricolage* are considered.

6.1.2 Article II: ‘An mHealth Typology’

Purpose – The article builds further on the practice oriented contribution of Article I. Through the development of a reference typology, the article explicates tradeoffs between; (i) usability, (ii) flexibility, (iii) solution robustness and (iv) financial costs pertaining to four different types of mHealth solutions. The four solution types are interactive voice and response (IVR), plain-text SMS, locally installed mobile applications (e.g., J2ME, Android, SIM Toolkit), and mobile web browser. The resulting typology is intended as a tool and a framework for mHealth project managers and policy makers in less developed economies who struggle to realize current potentials with mobile technologies, partly due to limited awareness of the inherent tradeoffs between different solution types.

Research approach – The study is based on qualitative data gathered through the authors’ longitudinal involvement with mHealth implementations that introduce mobile phone-based routine reporting of community health service data in India, Malawi and Zambia, including the roll-out of 5000 Java enabled mobile phones to field nurses in Punjab (India).

Findings – As different types of mobile phone-based solutions scale both in number of users and functional scope they shape and limit the space of future solution enhancements in ways that are often unanticipated. However, with a clear understanding of the strengths and limitations with different types of mobile technology solutions, some pre-emptive choices can be made to consciously avoid certain pitfalls.

Research implications – The analytical focus is on the role of technical configurations in shaping the long-term viability of mobile phone-based implementations. In particular, the study highlights how technology choices made during early pilot stages may lead to *path dependencies* that limit the future space of possible solution choices when initiatives are scaled-up to cater for whole regions.

Practical implications – The paper contributes to practice by juxtaposing four types of mobile phone-based solutions as they relate to health information systems in low resource settings. The reference typology in Table 6-1 (below) is reproduced from Sanner et al. (2012, p. 160) and highlights strengths and disadvantages associated with each of the four solution types according to the four dimensions *robustness* (R), *flexibility* (F), *usability* (U), and *cost* (C). Initial socio-technical configurations that may markedly narrow down the future space of choices include the use of end-users’ own phones, support for offline data entry, and/or mobile operator specific service arrangements.

Contribution to overarching research aim – The term ‘mHealth’ conflates a variety of socio-technical choices and configurations, some of which have restrictive and detrimental long-term implications as pilot projects are scaled up. The article starts to unpack ‘mHealth sustainability’ by examining tradeoffs, strengths and limitations with different mobile phone-based solution types for health information system strengthening.

Table 6-1 mHealth reference typology for low-resource contexts

Solution type	Strength	Disadvantage
Interactive Voice Response	<p>R: Can be used from landline phones as well as mobiles</p> <p>R: Does not rely on mobile data coverage</p> <p>U: Does not require high levels of literacy</p>	<p>R: Requires mobile call coverage</p> <p>U: Complex use cases may be difficult to handle via IVR because of the lack of visual feedback</p> <p>C: Voice service infrastructure, which has higher costs than web</p>
Plain-text SMS (no application on handset)	<p>F: Can push information to users with unknown handsets</p> <p>F: All handsets support SMS</p> <p>U: High prevalence of SMS mastery in most contexts</p> <p>U: Easy to use for simple low-interactivity use cases</p>	<p>R: Requires mobile coverage</p> <p>F: Supports a limited array of simple use cases</p> <p>U: Users may need to learn short codes and keywords</p> <p>U: Requires literate users</p> <p>C: Robust SMSC connections can have a high upfront cost</p>
Mobile Applications (sub-categories below)	<p>R: Can store data locally and supports offline usage</p> <p>F: Easy to make more interactive applications for complex use cases</p> <p>U: Supports low literacy through images</p> <p>U: Can handle errors through interactive user interface</p> <p>C: Can compress data so that use is typically cheaper than plain-text SMS or browser</p>	<p>F: Compatibility issues between different handset models and platforms</p> <p>F: More complex to update than browser solution</p> <p>U: The application can be deleted by the user</p> <p>U: The application may be difficult to locate and navigate on certain phones</p>
<i>Application with SMS-based transport</i>	<p>R: SMS is more reliable than mobile data in low-coverage areas (disputed)</p>	<p>F: Installation procedure on large number of handsets can be time consuming and complex</p> <p>F: Difficult to update compared to GPRS</p>
<i>Application with GPRS-based transport</i>	<p>F: Application can be downloaded; thus easier to update and distribute</p> <p>C: Use of mobile data is generally cheap compared to SMS, depending on the local operator</p>	<p>F: Setup of mobile data on some handsets can be cumbersome</p> <p>C: May be difficult to control cost and limit mobile data usage for other services</p>
Browser-based solution (marked differences between phones)	<p>F: Easier to provide compatibility across many handsets and platforms</p> <p>F: Easier to upgrade application</p> <p>U: Supports low literacy through images</p> <p>U: Can handle errors through interactive user interface</p> <p>C: Use of mobile data is generally cheap and operator independent</p>	<p>R: Only high-end browsers have offline capability</p> <p>C: Requires more mobile data use than applications</p> <p>C: May be difficult to restrict mobile data usage for other services</p>

6.1.3 Article III: 'Bootstrapping Technology Innovations'

Purpose – The article considers information infrastructure *bootstrapping* as a strategy for mitigating risks and tensions with a mobile phone-based health information system implementation in Malawi. The implementation under study is funded by a research project at the University of Oslo and hosted by the Ministry of health in Malawi. Bootstrapping entails the initiation and management of an ICT innovation until self-reinforcing mechanisms emerge through extended adoption and use. In brief, bootstrapping, as proposed by Hanseth & Aanestad (2003), advocates focus on immediate use, initial support for less critical and less complex work tasks, and leveraging the installed base of socio-technical arrangements.

Research approach – The study is based on qualitative data gathered through observation, semi-structured interviews and focus group discussions. The first author, a Malawian national, was at the center of coordinating the mobile phone-based implementation. His approach to governance was from the very outset inspired by his understanding of previous scholarly contributions to the bootstrapping strategy (Hanseth & Aanestad, 2003; Skorge & Aanestad, 2010). Empirical data analysis was centered on sorting implementation activities as either in conformance with, or deviance from, the bootstrapping strategy.

Findings – The study contemplates implementation challenges that fall outside the prescriptions of a bootstrapping strategy. These challenges emerge, at least in part, from distributed control over available infrastructural resources and complex multi-stakeholder interdependences.

Research implications – Whereas the bootstrapping algorithm offers advice on how to manage an early user base and mitigate complexity, it lacks recommendations on how to manage stakeholder politics on the 'supply-side' of information infrastructure innovation across organizational and geographical boundaries and divergent timeframes and interests.

Practical implications – The Ministry of Health in Malawi's inability to support ICT innovations both financially and technically suggests that external dependencies and alliances with multiple implementation partners, both domestic and international, cannot be easily done away with. Comprehensive health information infrastructure development efforts in less developed economies need to take the long-term implications of complex stakeholder interdependences and irregular funding into consideration.

Contribution to overarching research aim – Limitations with bootstrapping as a strategy for information infrastructure development is discussed in light of the politicized dynamics on the 'supply side' of information infrastructure innovation. Article IV, presented next, considers grafting as an alternative conceptualization that highlights the inherent fragility with multi-stakeholder information infrastructure innovation processes.

6.1.4 Article IV: 'Grafting Information Infrastructure'

Purpose – The paper introduces the metaphorical notion of grafting to help explore information Infrastructure innovation processes in settings where control over existing socio-technical arrangements is distributed and episodic. The article is concerned with how novel ICT capabilities harness inputs and commitment from previously uncoordinated stakeholders to become viable extensions of information infrastructure such as national health information systems.

Research approach – The study follows the implementation of mobile phone-based reporting of routine data from sub-district health facilities in Malawi. The venture was embarked upon by the Ministry of Health to overcome challenges associated with paper-based reporting. Analytically, the implementation is considered an instance of information infrastructure innovation.

Findings – The article highlights how existing socio-technical arrangement including technical devices, physical infrastructure, and service platforms implicates certain actors who control parts of extant infrastructural resources in the process of innovating on top of existing 'layers'. Control on the supply-side of information infrastructure innovation gradually becomes more volatile and embedded as novel ICT capabilities merge and co-evolve with existing socio-technical arrangements.

Research implications – Existing conceptualizations of information infrastructure innovation have not focused specifically on the summoning of different actors who own and maintain different parts of infrastructure at certain points in time. The grafting perspective highlights fragility with information infrastructure innovation processes and explores how heterogeneous ICT innovations developed at different times and in different places are combined and nurtured into hybrid capabilities.

Practical implications – The grafting perspective considers the process of merging an information system innovation with differentiated local constituencies. A significant amount of domain and context-specific knowledge and much sensitive and well-targeted practical work is needed for the innovation to take hold and co-evolve with extant (health) information infrastructure.

Contribution to overarching research aim – The article develops the key theoretical contribution of this dissertation – a grafting perspective on innovation in the context of large and dynamic information infrastructure. Through this perspective the article considers the challenge of translating project-oriented quick-fixes and external dependencies into sustainable extensions of national health information infrastructure in resource sparse settings in less developed economies.

6.1.5 Article V: ‘Paying Per Diems for Project Participation’

Purpose – The article explores the contradictory role per diem payments play in swiftly attracting local participation in ICT for Development (ICT4D) projects, such as mHealth, while undermining long-term sustainability with such efforts.

Research approach – Sustainability challenges endemic to ICT4D are examined through a case study of a mobile phone-based health information system implementation in Malawi. The article explores challenges at multiple levels of analysis through the notion of ‘institutional logics’. Institutional logics relate individual agency, cognition, and behavior to socially constructed practices and structures (Friedland & Alford, 1991). The article draws on an institutional logics perspective to identify and discuss the consequences of the interplay between two institutional orders referred to as *development project impact*, characterized by the swift production of quantifiable deliverables and demonstrable project gains, and *aid entitlement* i.e., participants exploitation of development project incentives.

Findings – ICT4D projects pay inflated per diems to amass local attention and produce swift impacts, while civil servants hunt for and monopolize access to ICT4D project roles to supplement meager salaries. The involved parties’ pursuit of short-term interests through each other, within the confines of pilot project workshops and trainings, challenges the sustainability of ICT4D activities. Table 6-2 is reproduced from Sanner and Sæbø (2014, p. 42) and portrays the institutional logics of *aid entitlement* and *development project impact* along with the practices and legitimacy claims through which they are reproduced. The table also indicates the implications of these broader institutional dynamics for ICT4D as a field.

Table 6-2 Institutional logics at play in ICT4D

Institutional Logic	Practice	Legitimacy Claim	Implication for ICT4D
<i>Aid Entitlement</i>	Participate in ICT4D projects for personal financial gains Monopolise workshop participation	Access to donor’s projects boost civil servants meagre salaries Exploiting access to donor’s funding to maximise financial and social capital is condoned	Attention is sold to the highest bidder ICT4D project participants take on more roles than they can handle The “wrong” people attend workshops and trainings
<i>Development Project Impact</i>	ICT4D implementers focus on easy-to-measure objectives, such as “number of workshops held” Initiatives compete for attention	Short term and quantifiable results permeates development harmonisation Paying per diems is the surest way to attract attention	Limited coordination and sharing of technology and expertise between initiatives Uncoordinated projects pay inflated per diem rates

Research implications – The article differs from previous studies concerned with the interdependency between development project evaluation criteria, and local actors’ income and social capital maximizing behavior (e.g., Jordan Smith, 2003; Pfeiffer, 2003; Ridde, 2010;

Søreide, Tostensen, & Skage, 2012) in that it highlights how ICT4D practices, centered around per diem payments and simplistic project impact evaluations, reproduce and are reproduced by the mutually legitimizing *development project impact logic* and *aid entitlement logic*.

Practical implications – Sustainability of ICT innovations cannot be ensured by the short-term attention amassed by donor-driven projects. Rather, it needs to emanate from a strengthened capacity within government structures to absorb innovations. A strategy to alleviate endemic sustainability challenges associated with the use of per diems will have to resonate at multiple levels (i.e., projects, organizations, and international community) and needs to address both the practices and material subsistence (e.g., evaluation criteria, incentives) of both civil servants in less developed economies and their development project partners. One way to strengthen the capacity of local structures would be to establish a shared pool not only of donor funding but also technical assistance that stretches beyond the lifespan of individual projects. Such arrangements, however, would require different project evaluation criteria that emphasize harmonization over short-term quantifiable impacts.

Contribution to overarching research aim – The sustainability of a novel ICT capability may not be facilitated simply through technology configurations, the manipulation of within-project ‘variables’, or meeting certain project ‘success criteria’. The study highlights the reinforcing dynamics between ICT4D practices and the institutional orders that permeates them. The long-term sustainability of ICT innovations in government organizations in resource sparse settings are shaped by the institutional landscape in which development activities take place. The widespread use of perverse monetary incentives, dubbed *perdiemitis*, is only one, albeit important and often overlooked element, in these complex development dynamics.

6.2 Synthesis of Research Findings: Unpacking 'mHealth Sustainability'

Sustainability is often a stated ambition with ICT4D and mHealth projects. However, it is not only unclear *how* sustainability may be achieved but also *what* exactly is to be sustained and for *whom*? Is it a mobile technology, a piece of software, the activities of an implementing NGO, the NGO itself, a new work practice, or maybe aspects of a Western value system? In this dissertation sustainability is assumed to pertain primarily to an ICT capability, which cannot easily be differentiated from the hardware, software, activities and values it is infused and intertwined with. The five articles that together constitute this dissertation employ different analytical approaches to consider emergent socio-political, technological, infrastructural and institutional challenges with two mobile phone-based routine health information system implementations in India and Malawi. Article I and II focus on the dynamics between social and technological configurations and long-term implications with early technology choices. Article II pays particular attention to the role of the IT-artifact – the mobile phone – and the strengths and limitations with its different affordances for supporting routine health data reporting through different mobile communication standards.

Article III and IV highlight the fragility with information infrastructure innovation processes in settings where control over existing socio-technical arrangements is short-term and distributed across multiple previously uncoordinated stakeholders or *change agents*. Finally, Article V draws on an institutional perspective to discuss sustainability challenges that cannot be resolved from within isolated mHealth and ICT4D projects. Overall, the articles become progressively more attentive to the idea that 'mHealth sustainability' to a large extent lies beyond project control. The discouraging fact that systemic challenges such as *perdiemitis* and *pilotitis* lie beyond the manipulative reach of individual interventions and require collective action and systemic change may be one of the reasons why they are rarely considered and discussed in mHealth and ICT4D research and practice. Sustainability challenges endemic to mHealth and ICT4D are reminiscent of experiences with ICT projects involved with cyberinfrastructure development in the US (Karasti et al., 2010; Ribes & Finholt, 2009), where meeting immediate needs and the production of short-term demonstrable impacts within the timeframes of grant funding receive priority over collaboration and coordination between projects. The lack of incentive structures that reward inter-project coordination is particularly problematic in the context of health information systems in less developed economies, where ministries of health do not have the capacity to coordinate donors' numerous ICT innovations, much less to maintain them.

This research highlights the importance of being specific about what ICT capabilities are put in place on top of what type of digital communication infrastructure and for what health related purpose (Braa & Sanner, 2011; Sanner et al., 2012). Some mobile phone-based innovations in health may be viable with only a few users such as outreach health workers using mobile images to consult colleagues or a doctor with infected patient wounds. Other

solutions, such as mobile phone-based reporting of routine health data may require massive scale, continuous funding and substantial technical support before they become meaningful assets to public health decision makers (Sahay & Walsham, 2006). Both solutions may be considered examples of mHealth, but only very general project management strategies, and technical recommendations are applicable in both scenarios.

By ascribing *sustainability challenges* to broad categories of technology such as eHealth, mHealth or ICT4D, we implicitly emphasize technology-oriented considerations such as the availability of stable wireless communication infrastructure, access to battery charging facilities, usability, and technical maintenance and support. Such a focus is problematic if it draws our attention away from other important factors such as the socio-political context of implementation, the cultural and institutional environment, and the actual health related challenges the ICT innovation is supposed to engage with and address. Even in the context of primary health care, mobile ICTs can be leveraged across a range of different tasks, with different information and communication needs, such as treatment compliance, routine data collection and disease surveillance, point of care decision support, health promotion and disease prevention, and emergency medical response (Mechael et al., 2010). A mobile phone-based routine health information system implementation that puts public health concerns before technical considerations need to consider the solutions overall capacity to improve *data coverage*. Emphasis needs to be put on the availability of timely, reliable and comparable routine health data at all organizational levels so that the health status of the population and the *quality* and *coverage* of equitable essential health services can be effectively monitored.

To improve data coverage across regions with different human, technical, infrastructural and financial resources, mobile phone-based routine health data reporting will most likely need to coexist with computers and paper-based tools, while digital solutions gradually replace paper-based routines (Braa et al., 2007). Hence, the 'real' sustainability of innovative ICT capabilities lies in their ability to get along with socio-technical arrangements already in place and become part of a dynamic and evolving information infrastructure. The challenge with an incremental and evolutionary approach to the development of health information infrastructure is the ensuring coexistence of multiple reporting structures and technical configurations that require continuous patchwork and articulation work simply to keep things going (Matavire & Manda, 2014). Overall, this research highlights the need for ICT implementations to employ a combination of long-term goal-oriented directional change strategies with the opportunistic summoning of available situated resources and competencies on the 'supply side' of information infrastructure. The balance between these two aspects is considered in more detail in the next chapter where I present *grafting* as a new and alternative conceptualization of (health) information infrastructure innovation.

Chapter Seven

Information Infrastructure Grafting

In this chapter I introduce and position *information infrastructure grafting* vis-à-vis extant theorizing of information infrastructure development. Sanner et al. (2014, p. 225) define grafting as a process whereby “organizational goal-oriented information system innovations merge with and extend existing socio-technical arrangements so that the parts continue to grow”. The grafting perspective coincide with the view held by Klein et al. (2012) that inter-organizational information systems are well defined strategic and purposeful assets on the one hand and a shared and evolving information infrastructure with multiple forms of use on the other. More specifically, grafting extends previous work concerned with the temporal transition from intentional ‘design’, in the form of short-term ICT projects, to evolutionary emergence of information infrastructure (Karasti et al., 2010; Ribes & Finholt, 2009).

Information infrastructure grafting refers analogously to horticulture, or gardening, where grafting entails placing a *shoot* or *cultivar* from one plant, into or on a stem, root, or branch of another plant, called the *rootstock*, in such a way that a union forms and both parts continue to grow. Etymologically, *grafting* originates from ancient Greek ‘to write’, via Latin *graphium*, which means ‘stylus’. The use of the notion in horticulture stems from the resemblance of a shoot to a pointed pencil. Horticultural grafting allows for the swift propagation of commercially grown plants. Grafting is frequently employed to combine rootstocks that tolerate difficult environmental conditions with cultivars that would otherwise be unable to survive and yield desirable results. A crucial factor in plant grafting is the compatibility, or *congeniality*, between the cultivar and the rootstock, which allows for the merged parts to take hold. A fair amount of practical work is involved in tending to the graft such as the application of protective wax onto the graft, holding the graft in place with grafting tape or rubber budding strips, or through provisioning a provisory source of nourishment. Figure 7-1 is adapted from Trousset Encyclopedia (1886-1891) and depicts a horticultural grafting technique (left) and an approach to grafting (right).

To information infrastructure research grafting offers a different perspective on how ICT projects are transformed into nurturing activities performed by an increasing number of stakeholders with varying interests and modes of involvement. In particular, grafting captures the gradual distribution of human agency and control in evolutionary processes of information infrastructure development. If the graft holds, agency is inevitably distributed and embedded in the socio-technical fabric of ‘layered’ infrastructural dependencies such as stakeholder alliances, legal contracts, technical configurations and policy revisions. The

grafting metaphor contributes to a nuanced understanding of the role of preemptive action and temporary project-based arrangements in the politicized development of novel information infrastructure capabilities.

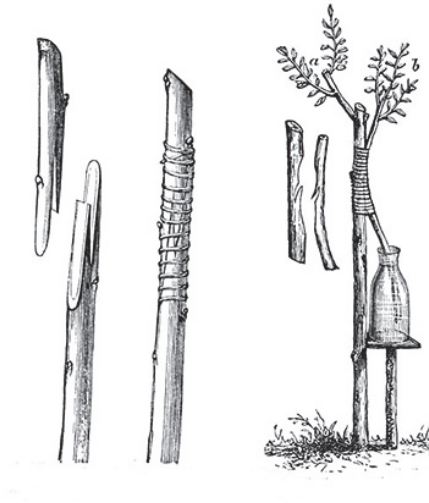


Figure 7-1 Horticultural grafting technique and an approach to grafting

Section 7.1 presents information infrastructure grafting as an alternative conceptualization of information infrastructure innovation in more detail, while section 7.2 provides practice-oriented recommendations from this research. Finally, section 7.3 offers some concluding remarks and considers venues for further research.

7.1 Four Information Infrastructure Grafting Themes

This section is structured into four sub-sections, with each section elaborating on one out of four *grafting themes*. The themes are substantiated by findings from the five articles reviewed in *chapter six* and examples from the two empirical narratives in *chapter five*. The four grafting themes are organized as follows:

- i) The initial conceptualization of an information infrastructure innovation and the *point of union* between the innovation and extant socio-technical arrangements may have long-term and practically irreversible implications.
- ii) Co-evolution through socio-technical *congeniality* rather than ‘technology fit’ or ‘organizational readiness’ characterizes the sustainability of novel ICT capabilities in the context of information infrastructure development.
- iii) Information infrastructure innovations are *fragile* and require nurturing inputs from a growing network of, often previously uncoordinated, stakeholders.
- iv) Once ICT capabilities take hold in one setting they may propagate as *hybrids* across application domains and geographical locations.

7.1.1 The Point of Union has Long-term Implications

Grafting starts with the identification of a problem with existing information infrastructure and the proposition of a novel ICT capability as a solution to the perceived problem. Hence, the initial work of the infrastructural change agent is to “create needs by pointing out the existence of a desirable innovation” (Zimmerman & Finholt, 2007, p. 246) and to convince infrastructural stakeholders of the desirability of the envisioned change (Tilson et al., 2010). In the two empirical cases from Punjab and Malawi, the initial framing of an information infrastructural problem concerned the timeliness and completeness of routine health data reporting from sub-district health facilities.

The initial proposition and framing of an innovative ICT capability has lasting implications because it identifies the *point of union* with the ‘rootstock’ i.e., parts of the *installed base* of socio-technical arrangements that are immediately relevant to the innovation process. More specifically, the *point of union* refer to *parts* and *layers* – the tissue – of extant information infrastructure such as networks, communication standards and databases that the innovative ICT capability need to leverage, interact with and extend from the very beginning. In turn, the identification of a point of union implicates the need to secure buy-in from actors in control of relevant parts such as ministries of health and mobile network operators in the two empirical cases.

In the context of so called mHealth and ICT4D projects in less developed economies, the point of union between the innovative ICT capability and extant arrangements are often negotiated through stakeholders’ involvement in *pilots*. Pilots, in turn, are often of short-term and focused on trying out *technical configurations* to address a particular ‘use case’, while long-term socio-political considerations are postponed or overlooked. In particular, within the temporal scope of a grant funded ICT project, the change agent or interventionist is not necessarily in a position to choose or dictate what functional requirements to support, what technical platforms and human competencies to elicit, and, more importantly, who to collaborate with to gain access to and leverage existing information infrastructural components. As Manda and Sanner (2012) argue, this may render the perceived level of autonomy residing with the change agent or ‘infrastructure designer’, as implicated by the prescriptive elements of a *bootstrapping* strategy (Hanseth & Aanestad, 2003; Skorve & Aanestad, 2010), somewhat unrealistic and inappropriate. An additional challenge with pilots, as a means for initiating large-scale implementations, is that involved stakeholders may be reluctant to raise their opinions and concerns early on (Sanner & Sæbø, 2014), in the hopes that potential differences may sort themselves out through subsequent revisions and elaborations. However, revisions to early socio-technical configurations are often no longer plausible once pilots have been deemed ‘successful’ and funding for their scale-up has been secured (Braa & Sanner, 2011; Sanner et al., 2012).

The choice to only utilize SMS for data reporting appeared to be the only affordable solution to achieve massive geographical scale and the enrolment of all 5000 ANMs in Punjab.

However, this choice also had restrictive long-term implications for the maintenance, and modification of the implemented solution. When a new Mission Director was appointed and gave order to have the daily mobile phone-based reports replaced by weekly ones, the restrictive implications from earlier decisions became apparent. The reporting formats could not be updated or revised remotely on the 5000 distributed handsets. Even the label “Daily data set” remained unchanged on the ANMs mobile screens as a reminder of the socially insensitive introduction of mobile phone-based routine data reporting. Another unanticipated challenge with the implementation in Punjab was the widespread unintentional deletion of the J2ME application by ANMs. Coincidentally, the menu options on the chosen Nokia handset made the deletion of non-native mobile applications particularly ‘easy’ to execute by mistake. This created unforeseen challenges as Bluetooth technology and the competence to use it was generally not available at sub-district health facilities or at the administrative level above.

These examples emphasise the importance of careful consideration of both immediate and long-term implications of early socio-technical configurations such as what type of mobile devices, mobile communication standards, databases, and mobile network operator services to leverage in the strengthening of national health information systems (Sanner et al., 2012). Early choices that configure the point of union between an innovative ICT capability and extant socio-technical arrangements may turn out to be practically irreversible once the innovation is scaled up. ‘Point of union’, as constitutive of a grafting perspective, highlights how a range of early project-oriented decision, some of which may be made unreflectively, become interdependent and intertwined right from the start. The long-term socio-political and information infrastructural implications of these interdependencies and the potential *path dependencies* they co-create can be difficult to discern, particularly during the initial technology-oriented pilot stages of grant funded ICT projects.

7.1.2 Co-evolution through Socio-technical Congeniality

How can ICT innovations leverage and extend parts of existing socio-technical arrangements such as established work practices and technologies already in use? To this end, *congeniality* between the innovative ICT capability and existing socio-technical arrangements is important. Not only does the innovative ICT capability need to address an initial infrastructural problem and accommodate immediate stakeholder needs, it also needs to co-evolve with existing arrangements and adapt to emergent requirements over time (Jansen & Nielsen, 2005). An important aspect with the notion ‘congeniality’ is that it describes a relational tie where both the innovative ICT capability and the installed base of ICT portfolios, software platforms, work practices and physical infrastructure need to accommodate each other for the innovation to take hold. ‘Congeniality’ differs from unidirectional relational terms such as ‘technology fit’, ‘organizational hostility’ or ‘hospitality’. By drawing on unidirectional relational terms we increase the risk of simplifying complex interdependencies to one-way causal influences. More specifically, in the context of information infrastructure development literature, there is a tendency to highlight the powerful unidirectional force of

the *installed base inertia* of extant socio-technical arrangements (e.g., Star & Ruhleder, 1996), which change agents can only aspire to 'foster', 'grow' and 'extend', if they are lucky (Edwards et al., 2007). 'Congeniality', as constitutive of a grafting perspective, helps us pay attention to the need for a balance between the malleability of an innovative ICT capability and the capacity with existing socio-technical arrangements, including people and their aspirations, to manage, configure and *adjust* to the innovation over time. Hence, congeniality highlights that information infrastructure innovation processes alter and change the installed base itself and not merely extend it.

By the time DHISm was to be implemented in Malawi the solution was able to facilitate submission of routine health data using mobile health data through a Java application (J2ME) or a mobile web-browser. Overall, the solution had a range of generic and configurable qualities which implicated the involvement of different solution developers and customizers to adapt it to the local setting (Sanner et al., 2014). The malleability with the technology was however balanced with a 'baby-steps' implementation strategy that limited the complexity of the overall solution at its initial stages (Manda & Sanner, 2012). This included choices to adapt only two reporting formats, called IDSR and HMIS-15, at first, and to initially implement mobile phone-based reporting at only 17 sub-district health facilities. In addition, mobile reports were initially only submitted to a DHIS2 demonstration server instance originally set up for teaching purposes. This was done to avoid the reluctant involvement of overburdened DHIS2 coordinators in the configuration of mobile reporting forms and reliance on the national production server which was already undergoing customization in response to the ongoing national DHIS2 roll-out. These decisions mitigated what Aanestad and Jensen (2011) has referred to as *coordination overhead* at the early stages of information infrastructure development. In particular these choices deliberately postponed the involvement of more powerful 'infrastructural incumbents' with specific data management interests such as Tuberculosis, HIV/AIDS and mother and child health programs in Malawi. Hence, mobile phone-based routine health data reporting was envisioned to cause minimal disruption and simply 'get along' with extant socio-technical arrangements.

As sub-district health workers and district health staff started to express interests towards replacing all other paper-based reports, the potential value of integrated mobile phone-based reporting into a shared national data warehouse was portrayed for semi-autonomous public health programs in Malawi. The improved timeliness and completeness associated with mobile phone-based reporting was further used as leverage in subsequent negotiations until agreements were reached on the inclusion of four more reports catering for program specific information needs. At the same time, the national rollout of DHIS2 was nearing completion. This allowed for the mobile phone-based reporting to be integrated with the now more reliable national DHIS2 server instance, while customization of mobile reporting forms received higher priority with the DHIS2 coordinators. Hence, intermediate arrangements that had allowed for the innovative ICT capability to co-evolve with extant socio-technical arrangements and receive temporary nourishment were gradually phased

out and replaced by adjustments to more stable parts of the installed base such as work practices, production server instance configurations and stakeholder agreements.

7.1.3 From ICT-Project to Collaborative Nurturance

As the case studies from India and Malawi highlight, information infrastructure development may involve stakeholder collaborations that span technological, organizational, cultural and geographical boundaries. Although the two empirical cases may be extreme in terms of boundary spanning – even oversea – interdependencies, they also represent a global trend where information systems that primarily serve intra-organizational purposes become entangled in an intricate web of ICT portfolios, physical networks, databases, work practices and different stakeholder agendas (Monteiro et al., 2012).

How are previously uncoordinated stakeholders who own or control parts of existing socio-technical arrangements summoned to legitimize and nurture fragile ICT capabilities into viable extensions of information infrastructure? Grafting emphasizes fragility in the process of merging an innovative ICT capability with differentiated socio-technical contingencies, especially on the ‘supply side’ of information infrastructure innovation (Jansen & Nielsen, 2005; Nielsen, 2006). By doing so it contrasts more mechanical conceptualization of the ‘design’ and ‘construction’ of information infrastructure as leveraging semi-autonomous network economic mechanisms and integration between parts of information infrastructure through gateways (Egyedi, 2001; Hanseth, 2001).

Grafting highlights the meticulous effort involved in facilitating a transition from targeted and goal-oriented intervention to collaborative nurturing. This involves the transfer of ownership and maintenance responsibilities, and the distribution of initial project-oriented control. Over time, control becomes further distributed through situated articulation work performed by different information infrastructure change agents with different agendas. Detailed attention to these often politicized dynamics on the ‘supply side’ of information infrastructure innovation, including tensions, inequalities and failures, tend to get lost in metanarratives of the steady *cultivation* of an installed base through distributed, incremental and modular changes (Aanestad, 2002; Aanestad & Jensen, 2011).

As Braa and Sanner (2011) point out, Ciborra’s notion of *bricolage* comes close to filling this conceptual gap by paying attention to the constant need for expedient manipulation of resources at hand in response to unfolding contingencies (Ciborra, 2002; Ciborra, 1992). However, ‘bricolage’ addresses the more *chaotic* aspects with infrastructure development and reduces the activities of change agents to solving immediate crises in an unreflective manner while the installed base inertia of extant socio-technical arrangements are untamable and in constant drift (Ciborra et al., 2000).

In contrast, grafting highlights the possibility of injecting an element of goal-oriented and desirable change, in the form of an innovation ICT capability, into more stable and slowly evolving parts or compartments of information infrastructure. These more stable parts such

as collaborative research networks (Karasti et al., 2010; Ribes & Finholt, 2009) or national health information systems (Aanestad & Jensen, 2011) are held in place through their shared purpose across multiple stakeholders. As a perspective on information infrastructure innovation, grafting emphasizes a focus on *how* the installed base of relatively stable socio-technical arrangements is mobilized and drawn on. This involves summoning nurturing inputs from various stakeholders with diverse interests, resources and capacities such as ministries of health, NGOs, foreign consultants, mobile operators, international donors and available local technical human capacity (Manda & Sanner, 2012; Sanner et al., 2014).

A challenge that threatened to undermine the implementation of the mobile phone-based routine data reporting solution in Malawi was the lack of relevant competence within CMED to support novel ICT acquisitions. The historical dependence on funding and technical expertise from uncoordinated donors had allowed for a plethora of competing and technically incompatible mHealth solutions to create a situation where it was difficult for the ministry to maintain long-term goals and carefully prioritize projects (Sanner & Sæbø, 2014). With the implementation of DHISm this was compensated for by the hiring of a project funded technical assistant working out of CMED's offices, while awaiting the bureaucratic process of creating a new and much needed IT-position. Similarly, terms of reference were negotiated with the Ministry of Health for use in the future employment of full-time in-house IT positions. These negotiations were considered imperative to the transition from project-oriented tasks and responsibilities to durable organizational roles and routines, which would help institutionalize mobile phone-based routine health data reporting in Malawi.

Collectively tending to the graft across multiple stakeholders involves continuous contestation, aversion and embracing of emergent socio-technical dependencies and infrastructural agendas. However, the ability for any stakeholder to choose how and when to *retain* and *relinquish control* pertaining to the innovative ICT capability is inevitably narrowed down through the historical accumulation of interdependencies such as reliance on a particular mobile communication standard or service such as a closed user group provided by a specific mobile operator (Sanner et al., 2012).

Tending to the graft also involves ensuring that potential users of the ICT innovation are able to leverage its capabilities and do not become marginalized by its implementation. With the implementation of DHISm in Malawi, care was taken to ensure that the mobile phone-based reporting did not circumvent and sideline the traditional custodians of routine health at the Lilongwe district health office and the two health areas offices. USB Internet modems were provided along with training on how to access the national DHIS2 server instance and inspect the electronic reports submitted from mobile phones. As the next sub-section highlights, distribution of control through alliance building, capacity strengthening, and knowledge generation across a growing collaborative network of stakeholders are required

not only to maintain, legitimize and institutionalize the innovative ICT capability, but also to allow for further information infrastructure innovation through new grafts.

7.1.4 ICT Capabilities Propagate Across Domains and Regions

A branch from an orange tree does not take hold on an apple tree, while branches from apples, plums, and cherries can all take hold on a rowan (mountain ash) trunk. Similarly, some ICT capabilities and software packages can be leveraged across industries and domains due to their *generic capabilities* which allow them to address relatively similar information and communication needs (Pollock, Williams, & D’Adderio, 2007). This is possible because organizations that operate within the same domains or industries such as international public health tend to have similar institutional environments, routines, and work practices. In addition, actors operating within the same domain often identify with a few shared goals or principles such as the primary health care mantra of ‘health for all’.

ICT capabilities, such as mobile phone-based routine data reporting solutions, can take on new meanings as they propagate and accommodate new patterns of use across application domains and settings. The DHISm solution implemented in Malawi was not developed specifically for that purpose. DHISm emerged from various implementation processes that could at the very least be traced back to the statewide roll out in Punjab. Before the DHISm suite of solutions reached Malawi it had gone through several iterations that involved the transference of technologies, knowledge, open-source code, and people across settings in Tanzania, Nigeria, the Gambia and Zambia. These iterations led to the development of an increasingly more generic solution and implementation strategy.

However, as the generic qualities of ICTs and software packages increase, so does the domain and context-specific knowledge and well-targeted practical work required to facilitate their appropriation to particular contexts of implementation. As Suchman (2002, p. 139) posits, in the context of spreading infrastructural ICT capabilities, “[t]he greater the distance – geographical, economic, cultural, experiential – the greater the need for reworking is likely to be”. Unfortunately, in the context of less developed economies, the need for local adaptation often puts an unrealistic burden on local (government) organizations to obtain technical capacity and know-how to customize, integrate and innovate further on top of interventionists’ many uncoordinated and constantly propagating ICT innovations. These challenges are addressed in more detail in the follow section which details implications for policy and practice from this study.

7.2 Implications for Policy and Practice

The current wave of so called mHealth innovations in less developed economies puts pressure on health information system managers and policy makers to develop sensitive eHealth strategies that emphasize coordination and harmonization over short-term quantifiable impacts. Ministries of health need to strike a balance between destructive ‘anything goes’ approaches that leads to fragmentation and health information system ‘silos’

and equally crude ‘moratorium-approaches’ exemplified by the mHealth ‘stop work order’ issued by the Ministry of Health in Uganda in 2012. The latter approach does not only alleviate coordination challenges, but puts an undesirable lid on innovation as well. In particular, sophisticated strategies need to identify ways to combine the creative use of ICT innovations at the fringes of national health information systems with centralized coordination and control over core ICT capabilities and services such as a national routine health data warehouse. This balance is necessary to facilitate the long-term and steady pursuit of collective information infrastructural goals (Aanestad & Jensen, 2011; Karasti et al., 2010; Ribes & Finholt, 2009), without causing unnecessary disruptions to existing work practices, career trajectories and information flows.

International donors and NGOs can play an important role in maintaining this balance by providing much needed long-term financial and technical assistance, rather than brief bursts of external support. Not only is there an urgent need for local ownership and capacity to maintain solutions, but also local long-term funding arrangements and local competencies to leverage ICT acquisitions and extant networks, platforms and databases for further innovation. To paraphrase the Brundtland Commission report (WCED, 1987, p. 43), sustainability emerges from local capacity to meet the needs of the present without compromising the ability of future generations, *of health information system users*, to meet their own needs.

This mainly exploratory and descriptive research does not have an elaborate prescriptive agenda. However, some concrete recommendations may be derived from my empirical experiences with the two mobile phone-based implementations. The following recommendations to policy and practice are intended for an audience of eHealth and health information system strategists in less developed economies, representatives of international funding agencies and NGOs, and mHealth and ICT4D project managers. The four grafting themes developed in the previous section are drawn on to structure the practical recommendations in Table 7-1 (below). Hence, the recommendations can be thought of as pertaining predominantly to different phases of an information infrastructure grafting process. Unfortunately, condensed lists of recommendations to ICT4D and mHealth policy and practice, of which many can be found, tend to point out *what* should be done, but not *how* to do it. How-to questions typically require much more elaborate answers and deep contextual insights. Consequently, each recommendation in Table 7-1 is followed by a bracket that points to more elaborate empirical examples and discussions either as part of *chapter five* or in the five articles included as Appendix I-V.

Table 7-1 Practical recommendations

Grafting theme	Recommendations to Practice
The point of union has long-term implications	<p>Make sure ICT projects are socially appropriate and that proposed solutions address actual end-user needs (Section 5.1 and 5.2)</p> <p>Avoid early technology configurations and stakeholder dependencies that impede geographical and functional scale beyond the immediate pilot project or ‘use case’ (Article I and Article II)</p> <p>Identify and evaluate strengths and limitations with different (mobile) technology options, for instance by employing frameworks such as the proposed ‘mHealth typology’ (Article II)</p> <p>Avoid incentivizing ICT4D project participation (Article V)</p>
Co-evolution through socio-technical congeniality	<p>Draw on an ecological perspective and extend existing ICTs, software platforms, routines and work practices (Article III and IV)</p>
From ICT project to collaborative nurturance	<p>Move forward in an incremental manner and gradually involve more stakeholders, geographical regions and functionalities (Article III and IV)</p> <p>Align with and contribute to national eHealth and health information system strategies (Article IV)</p> <p>Involve users at all organizational levels in implementation and evaluation activities to avoid marginalization of important stakeholders and contradiction with existing career trajectories (Article III and IV)</p> <p>Help describe and instill local roles that maintain and innovate ICT acquisitions further when external people resign from projects (Article IV and V)</p>
ICT capabilities propagate across domains and regions	<p>Identify similarities across domains and geographical regions and develop solutions that can cater for more than one ‘use case’ in more than one setting (Article IV)</p>

In addition to the mainly project-oriented recommendations provided in Table 7-1, this research warrants *five* more overarching recommendations to long-term national eHealth and/or health information system policy development. These recommendations do not pertain specifically to different stages or phases of information infrastructure innovation but rather the holistic stewardship of a national health information infrastructure.

- ✓ Develop state and/or national level mHealth and ICT4D *minimum requirements* to ensure that multiple projects and ‘use cases’ can be supported through reuse of devices, charging facilities, physical networks and software platforms
- ✓ Create a state and/or national board and/or a stakeholder forum chaired by the ministry of health where (mobile) ICT innovations can be coordinated and harmonized over the long-term
- ✓ Establish a shared pool of donor’s financial resource and technical support dedicated to health information system strengthening that stretches beyond the scope of grant funded ICT interventions

- ✓ Establish a joint contact point and a standard term agreement with mobile operators on service provision across donor's numerous ICT projects
- ✓ Create more IT-positions within ministries of health to oversee eHealth strategies and architectures and manage ICT innovations at the fringes not national health information systems

As this dissertation has emphasized, far from all challenges to the sustainability of ICT4D and mHealth implementations can be resolved at the level of individual projects. Some challenges cannot easily be resolved through government policy revisions and national stakeholder forums either. Systemic challenges such as *pilotitis* and *perdiemitis* require significant international collaboration where both donors and governments strive to harmonize ICT-oriented development activities. This can for instance involve the development of evaluation criteria and incentives structures that emphasize collaboration between projects and long-term commitment to national and international health information infrastructure strengthening (Sanner & Sæbø, 2014).

7.3 Concluding Remarks

This dissertation has been based on empirical studies of mobile phone-based routine health information system implementations in India and Malawi between autumn 2010 and spring 2014. These implementations have been analyzed as cases of information infrastructure development. Interdependent social, political, technological and infrastructural challenges to the long-term sustainability of the implementations have been explored and synthesized through the proposition of a grafting metaphor. Grafting offers a new perspective on information infrastructure development as a fragile processes in need of nurturing inputs from multiple, and often previously uncoordinated, stakeholders.

The case studies were conducted by a researcher novice, with a computer science background, who was at the outset of this research alien to both public health and the socio-cultural contexts where the implementations took place. The research design of the study has gone through several revisions, including the major decision to conduct two case studies rather than one. The relevance of the proposed grafting perspective in the further theorizing of information infrastructure development should be explored through empirical studies in other domains and other settings. The value of the grafting metaphor rests with its ability to help other researchers and practitioners structure their experience with information infrastructure innovation in ways that broaden their understanding of the phenomena.

The understudied issue of sustainability explored in this dissertation warrants further in-depth investigations by information system researchers in other application domains and in relation to other (mobile) ICT innovations. More critical studies are also needed to consider further the dominant role of 'sustainability' in informing ICT4D rhetoric and practice in less developed economies, particularly in the highly politicized domain of international public health. More specifically, why is it that ICT projects in less developed economies are always problematized according to their sustainability, while ICT projects in the west are considered

along dimensions such as innovation, generativity, cost-efficiency, organizational learning, and, of course, blown budgets?

Globally, national health information systems are slowly transitioning towards data capture of transactional and individual patient based data, from which aggregate public health statistics can be generated. For such solutions to be comprehensive, however, they require sophisticated privacy and security measures, sound legal frameworks that protect individual citizens' rights, and well-functioning national ID and civil registration schemes. As these criteria are not met in many less developed economies, ICT innovations that can help alleviate the practical burden of collecting, collating and reporting timely and reliable routine health data will continue to play an important role in years to come. More research is needed to identify ways through which traditional routine health information systems can co-evolve, through new grafts, with the coming wave of 'lightweight' patient-oriented mobile ICT capabilities.

References

- Aanestad, M. (2002). Cultivating networks: implementing surgical telemedicine.
- Aanestad, M., & Jensen, T. B. (2011). Building nation-wide information infrastructures in healthcare through modular implementation strategies. *The Journal of Strategic Information Systems*, 20(2), 161–176.
- AbouZahr, C., & Boerma, T. (2005). Health information systems: the foundations of public health. *Bulletin of the World Health Organization*, 83, 578–583.
- Afridi, M. J., & Farooq, M. (2011). OG-Miner: An Intelligent Health Tool for Achieving Millennium Development Goals (MDGs) in m-Health Environments. In *System Sciences (HICSS), 2011 44th Hawaii International Conference on* (pp. 1–10).
- Akter, S., & Ray, P. (2010). mHealth-an ultimate platform to serve the unserved. *Faculty of Commerce-Papers*, 94–100.
- Ali, M., & Bailur, S. (2007). The Challenge of “Sustainability” in ICT4D—Is Bricolage the Answer? In *Proceedings of the 9th International Conference on Social Implications of Computers in Developing Countries, São Paulo, Brazil*.
- Alvesson, M., & Willmott, H. (1992). *Critical management studies*. Sage Publications Ltd.
- Andreatta, P., Debpuur, D., Danquah, A., & Perosky, J. (2011). Using cell phones to collect postpartum hemorrhage outcome data in rural Ghana. *International Journal of Gynecology & Obstetrics*, 113(2), 148–151.
- Anokwa, Y., Smyth, T. N., Ramachandran, D., Sherwani, J., Schwartzman, Y., Luk, R., ... DeRenzi, B. (2009). Stories from the field: Reflections on HCI4D experiences. *Information Technologies & International Development*, 5(4), pp–101.
- Asangansi, I. (2012). Understanding HMIS Implementation in a Developing Country Ministry of Health Context - an Institutional Logics Perspective. *Online Journal of Public Health Informatics*, 4(3). <http://doi.org/10.5210/ojphi.v4i3.4302>
- Asangansi, I., & Braa, K. (2010). The emergence of mobile-supported national health information systems in developing countries. *Stud Health Technol Inform*, 160(Pt 1), 540–544.
- Asiimwe, C., Gelvin, D., Lee, E., Amor, Y. B., Quinto, E., Katureebe, C., ... Berg, M. (2011). Use of an innovative, affordable, and open-source short message service–based tool to monitor malaria in remote areas of Uganda. *The American Journal of Tropical Medicine and Hygiene*, 85(1), 26.
- Avgerou, C. (2000). IT and organizational change: an institutionalist perspective. *Information Technology & People*, 13(4), 234–262.
- Avgerou, C. (2008). Information systems in developing countries: a critical research review. *Journal of Information Technology*, 23(3), 133–146. <http://doi.org/10.1057/palgrave.jit.2000136>
- Avgerou, C. (2010). Discourses on ICT and Development. *Information Technologies and International Development*, 6(3), 1–18.
- Baark, E., & Heeks, R. (1999). Donor-funded information technology transfer projects: Evaluating the life-cycle approach in four Chinese science and technology projects. *Information Technology for Development*, 8(4), 185–197. <http://doi.org/10.1080/02681102.1999.9525309>
- Baker, K. S., & Bowker, G. C. (2007). Information ecology: open system environment for data, memories, and knowing. *Journal of Intelligent Information Systems*, 29(1), 127–144.
- Barley, S. R. (1986). Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments. *Administrative Science Quarterly*, 78–108.
- Barrington, J., Wereko-Brobby, O., Ward, P., Mwafongo, W., Kungulwe, S., & others. (2010). SMS for Life: a pilot project to improve anti-malarial drug supply management in rural Tanzania using standard technology. *Malar J*, 9, 298.

- Beekhuizen, J., von Hellens, L., & Nielsen, S. (2010). The Nvivo Looking Glass: Seeing the Data Through the Analysis. In *Proceedings of QuallT2010: International Conference on Qualitative Research in IT & IT in Qualitative Research, Brisbane, Australia, Griffith University*.
- Berente, N., Gal, U., & Hansen, S. (2011). Ethical implications of social stratification in information systems research. *Information Systems Journal*, 21(4), 357–382.
- Bergqvist, J., & Dahlberg, P. (1999). Scalability through cultivation. *Scandinavian Journal of Information Systems*, 11, 137–156.
- Best, M. L., & Kumar, R. (2008). Sustainability failures of rural telecenters: Challenges from the sustainable access in rural india (sari) project. *Information Technologies & International Development*, 4(4), pp–31.
- Bhana, J. (2013). Situation analysis of the Ministry of Health's Central Monitoring and Evaluation Department in Malawi. HMST.
- Black, J., Koch, F., Sonenberg, L., Scheepers, R., Khandoker, A., Charry, E., ... Soe, N. L. (2009). Mobile solutions for front-line health workers in developing countries. In *e-Health Networking, Applications and Services, 2009. Healthcom 2009. 11th International Conference on* (pp. 89–93).
- Blaikie, P. (2006). Is small really beautiful? Community-based natural resource management in Malawi and Botswana. *World Development*, 34(11), 1942–1957.
- Braa, J., Hanseth, O., Heywood, A., Mohammed, W., & Shaw, V. (2007). Developing Health Information Systems in Developing Countries. *The Flexible Standards Strategy. [Special Issue] MIS Quarterly*, (31), 1–22.
- Braa, J., & Hedberg, C. (2002). The struggle for district-based health information systems in South Africa. *The Information Society*, 18(2), 113–127.
- Braa, J., Monteiro, E., & Reinert, E. S. (1995). Technology transfer vs. technological learning: It-infrastructure and health care in developing countries. *Information Technology for Development*, 6(1), 15–23. <http://doi.org/10.1080/02681102.1995.9525252>
- Braa, J., Monteiro, E., & Sahay, S. (2004). Networks of action: Sustainable health information systems across developing countries. *MIS Quarterly*, 28(3), 337–362.
- Braa, J., & Sahay, S. (2012). *Integrated health information architecture: power to the users : design, development and use*.
- Braa, K., & Nielsen, P. (2013). Leveraging the Potentials of Mobiles in Developing Country Health Initiatives: From ICT4D to Information Infrastructures 4D. In *Proceedings of the 12 th International Conference on Social Implications of Computers in Developing Countries* (pp. 132–143).
- Braa, K., & Purkayastha, S. (2010). Sustainable mobile information infrastructures in low resource settings. *Studies in Health Technology and Informatics*, 157, 127.
- Braa, K., & Sanner, T. (2011). Making mHealth Happen for Health Information Systems in Low Resource Contexts. In *Proceedings of the 11 th International Conference on Social Implications of Computers in Developing Countries* (pp. 530–541).
- Braa, K., & Vidgen, R. (1999). Interpretation, intervention, and reduction in the organizational laboratory: a framework for in-context information system research. *Accounting, Management and Information Technologies*, 9(1), 25–47.
- Büscher, M., & Mogensen, P. H. (1997). Mediating change: translation and mediation in the context of bricolage. In *Proceedings of the IFIP TC8 WG8. 6 international working conference on diffusion, adoption and implementation of information technology on Facilitating technology transfer through partnership: learning from practice and research* (pp. 76–91). Chapman & Hall, Ltd.
- Bygstad, B. (2003). The implementation puzzle of CRM systems in knowledge based organizations. *Information Resources Management Journal (IRMJ)*, 16(4), 33–45.
- Chang, L. W., Kagaayi, J., Arem, H., Nakigozi, G., Ssempijja, V., Serwadda, D., ... Reynolds, S. J. (2011). Impact of a mHealth intervention for peer health workers on AIDS care in rural Uganda: a

- mixed methods evaluation of a cluster-randomized trial. *AIDS and Behavior*, 15(8), 1776–1784.
- Chilundo, B., & Aanestad, M. (2004). Negotiating multiple rationalities in the process of integrating the information systems of disease-specific health programmes. *EJISDC*, 20(2), 1–28.
- Chua, W. F. (1986). Radical developments in accounting thought. *Accounting Review*, 601–632.
- Ciborra, C. (2002). *The labyrinths of information: Challenging the wisdom of systems*. Oxford University Press, USA.
- Ciborra, C. U. (1992). From thinking to tinkering: the grassroots of strategic information systems. *The Information Society*, 8(4), 297–309.
- Ciborra, C. U., Braa, K., Cordella, A., Dahlbom, B., Failla, A., Hanseth, O., ... Monteiro, E. (2000). *From control to drift: the dynamics of corporate information infrastructures*. Oxford University Press, USA.
- Cole-Lewis, H., & Kershaw, T. (2010). Text messaging as a tool for behavior change in disease prevention and management. *Epidemiologic Reviews*, 32(1), 56–69.
- Constantinides, P., & Barrett, M. (2005). Approaching information infrastructure as an ecology of ubiquitous sociotechnical relations. In *Designing Ubiquitous Information Environments: Socio-Technical Issues and Challenges* (pp. 249–260). Springer.
- Curioso, W. H., & Mechael, P. N. (2010). Enhancing “M-health” with south-to-south collaborations. *Health Affairs*, 29(2), 264.
- Currie, W. L., & Guah, M. W. (2007). Conflicting institutional logics: A national programme for IT in the organisational field of healthcare. *Journal of Information Technology*, 22(3), 235–247.
- Dahlbom, B., & Mathiassen, L. (1993). *Computers in Context: The Philosophy and Practice of Systems Design*. Blackwell Publishers.
- Dean, A., Sharp, J., & Genc, S. (2006). Getting the most from NUD* IST/NVivo.
- Dearden, A. (2012). See no evil?: ethics in an interventionist ICTD. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development* (pp. 46–55).
- DeRenzi, B., Borriello, G., Jackson, J., Kumar, V. S., Parikh, T. S., Virk, P., & Lesh, N. (2011). Mobile Phone Tools for Field-Based Health care Workers in Low-Income Countries. *Mount Sinai Journal of Medicine: A Journal of Translational and Personalized Medicine*, 78(3), 406–418.
- Dobkin, B. H., & Dorsch, A. (2011). The Promise of mHealth Daily Activity Monitoring and Outcome Assessments by Wearable Sensors. *Neurorehabilitation and Neural Repair*, 25(9), 788–798.
- Donner, J. (2007). The rules of beeping: exchanging messages via intentional “missed calls” on mobile phones. *Journal of Computer-Mediated Communication*, 13(1), 1–22.
- Easterly, W. R. (2006). *The white man’s burden: why the West’s efforts to aid the rest have done so much ill and so little good*. Penguin.
- Edwards, P., Jackson, S., Bowker, G., & Knobel, C. (2007). Understanding Infrastructure: Dynamics, Tensions, and Design.
- Edwards, P. N. (2010). *A vast machine: Computer models, climate data, and the politics of global warming*. Mit Press.
- Edwards, P. N., Bowker, G. C., Jackson, S. J., & Williams, R. (2009). Introduction: an agenda for infrastructure studies. *Journal of the Association for Information Systems*, 10(5), 364–374.
- Egyedi, T. (2001). Infrastructure flexibility created by standardized gateways: the cases of XML and the ISO container. *Knowledge, Technology & Policy*, 14(3), 41–54.
- Elaluf-Calderwood, S., Eaton, B. D., Herzhoff, J., & Sorensen, C. (2011). Mobile Platforms as Convergent Systems: Analysing Control points and Tussles with Emergent Socio-technical Discourses. *Mobile Communications (to Be Published in September)*. G. Scerbe, Intech-Open Access Publisher.
- Escobar, A. (1995). *Encountering development: The making and unmaking of the Third World*. Princeton University Press Princeton.
- Estrin, D., & Sim, I. (2010). Open mHealth architecture: an engine for health care innovation. *Science(Washington)*, 330(6005), 759–760.

- Etzo, S., & Collender, G. (2010). The mobile phone “revolution” in Africa: Rhetoric or reality? *African Affairs*, 109(437), 659–668.
- Evans, W. D., Abrams, L. C., Poropatich, R., Nielsen, P. E., & Wallace, J. L. (2012). Mobile health evaluation methods: the Text4baby case study. *Journal of Health Communication*, 17(sup1), 22–29.
- Feenberg, A. (1992). Subversive rationalization: Technology, power, and democracy 1. *Inquiry*, 35(3-4), 301–322.
- Ferguson, J. (1990). *The anti-politics machine: “development,” depoliticization, and bureaucratic power in Lesotho*. CUP Archive.
- Fluehr-Lobban, C. (1994). Informed Consent in Anthropological Research: We Are Not Exempt 1. *Human Organization*, 53(1), 1–10.
- Foltz, A.-M. (1993). Modeling technology transfer in health information systems: learning from the experience of Chad. *International Journal of Technology Assessment in Health Care*, 9(03), 346–359.
- Forester, J. (1992). Critical ethnography: on fieldwork in a Habermasian way. *Critical Management Studies*, 46–65.
- Foster, V., & Shkaratan, M. (2011). Malawi’s infrastructure: a continental perspective. *World Bank Policy Research Working Paper Series, Vol.*
- Friedland, R., & Alford, R. R. (1991). Bringing society back in: Symbols, practices and institutional contradictions. In W. W. Powell, & P. J. DiMaggio (Eds.), *The new institutionalism in organizational analysis* (pp. 232–263). Chicago, IL: University of Chicago Press.
- Gable, G. G. (1994). Integrating case study and survey research methods: an example in information systems. *European Journal of Information Systems*, 3(2), 112–126.
- Gadamer, H. G. (2004). *Truth and method*. Continuum Intl Pub Group.
- Ganesan, M., Prashant, S., Mary, V. P., Janakiraman, N., Jhunjhunwala, A., & Waidyanatha, N. (2011). The use of mobile phone as a tool for capturing patient data in Southern Rural Tamil Nadu, India. *Journal of Health Informatics in Developing Countries*, 5, 219–227.
- Gerber, T., Olazabal, V., Brown, K., & Pablos-Mendez, A. (2010). An agenda for action on global e-health. *Health Affairs*, 29(2), 233–236.
- Germann, S., Jabry, A., Njogu, J., & Osumba, R. (2011). The Illness of “Pilotitis” In mHealth – Early Lessons from the KimMNCHIP Partnerships in Kenya. Retrieved June 22, 2014, from
- Greenhalgh, T., & Russell, J. (2010). Why do evaluations of eHealth programs fail? An alternative set of guiding principles. *PLoS Medicine*, 7(11), e1000360.
- Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. *Handbook of Qualitative Research*, 2, 163–194.
- Gurman, T. A., Rubin, S. E., & Roess, A. A. (2012). Effectiveness of mHealth Behavior Change Communication Interventions in Developing Countries: A Systematic Review of the Literature. *Journal of Health Communication*, 17, 82–104.
<http://doi.org/10.1080/10810730.2011.649160>
- Gusterson, H. (1997). Studying up revisited. *PoLAR: Political and Legal Anthropology Review*, 20(1), 114–119.
- Haberer, J. E., Kiwanuka, J., Nansera, D., Wilson, I. B., & Bangsberg, D. R. (2010). Challenges in using mobile phones for collection of antiretroviral therapy adherence data in a resource-limited setting. *AIDS and Behavior*, 14(6), 1294–1301.
- Hamre, G. A., & Kaasbøll, J. (2008). Motivation and Demotivation: a Case Study of the Malawian Health Management Information System. *Electronic Journal of Health Informatics*, 3(2), e11.
- Hanseth, O. (2001). Gateways—just as important as standards: How the internet won the “religious war” over standards in Scandinavia. *Knowledge, Technology & Policy*, 14(3), 71–89.
- Hanseth, O., & Aanestad, M. (2003). Bootstrapping networks, communities and infrastructures. On the evolution of ICT solutions in health care. *Methods of Information in Medicine*, 42(4), 385–391.

- Hanseth, O., Ciborra, C. U., & Braa, K. (2001). The control devolution: ERP and the side effects of globalization. *ACM SIGMIS Database*, 32(4), 34–46.
- Hanseth, O., & Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: the case of building internet. *Journal of Information Technology*, 25(1), 1–19.
- Hanseth, O., & Monteiro, E. (1997). Inscripting behaviour in information infrastructure standards. *Accounting, Management and Information Technologies*, 7(4), 183–211.
- Hanseth, O., & Monteiro, E. (1998). Understanding information infrastructure. *Unpublished Book*, [Http://heim.lfi.uio.no/~oleha/Publications/bok.html](http://heim.lfi.uio.no/~oleha/Publications/bok.html).
- Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing Information Infrastructure: The Tension Between Standardization and Flexibility. *Science, Technology & Human Values*, 21(4), 407–426. <http://doi.org/10.1177/016224399602100402>
- Health Metrics Network. (2008). *Framework and standards for country health information systems (2nd ed.)*. Geneva, Switzerland: World Health Organization.
- Health Metrics Network. (2009). Guidance for the Health Information Systems (HIS) Strategic Planning Process: Steps, Tools and Templates for HIS Systems Design and Strategic Planning | HRH Global Resource Center. Health Metrics Network.
- Heeks, R. (2006). Health information systems: Failure, success and improvisation. *International Journal of Medical Informatics*, 75(2), 125–137.
- Heeks, R., Mundy, D., & Salazar, A. (1999). Why health care information systems succeed or fail.
- Henfridsson, O., & Bygstad, B. (2013). The generative mechanisms of digital infrastructure evolution. *MIS Quarterly*, *Forthcoming*.
- Hepso, V., Monteiro, E., & Rolland, K. H. R. (2009). Ecologies of E-Infrastructures. *Journal of the AIS*, 10(5), 430–446.
- Horvath, T., Azman, H., Kennedy, G. E., & Rutherford, G. W. (2012). Mobile phone text messaging for promoting adherence to antiretroviral therapy in patients with HIV infection. *Cochrane Database Syst Rev*, 3.
- Istepanian, R. S., Jovanov, E., & Zhang, Y. T. (2004). Guest editorial introduction to the special section on m-health: Beyond seamless mobility and global wireless health-care connectivity. *Information Technology in Biomedicine, IEEE Transactions on*, 8(4), 405–414.
- Jansen, A., & Nielsen, P. (2005). Theorizing convergence: Co-evolution of information infrastructures. *Scandinavian Journal of Information Systems*, 17(1), 67–100.
- Jensen, C. B., & Winthereik, B. R. (2013). *Monitoring movements in development aid: Recursive partnerships and infrastructures*. Cambridge, MA: MIT Press.
- Jepperson, R. L. (1991). Institutions, institutional effects, and institutionalism. *The New Institutionalism in Organizational Analysis*, 6, 143–163.
- Jordan Smith, D. (2003). Patronage, per diems and the “workshop mentality”: The practice of family planning programs in southeastern Nigeria. *World Development*, 31(4), 703–715.
- Kamanga, A., Moono, P., Stresman, G., Mharakurwa, S., & Shiff, C. (2010). Rural health centres, communities and malaria case detection in Zambia using mobile telephones: a means to detect potential reservoirs of infection in unstable transmission conditions. *Malaria Journal*, 9, 96.
- Kanjo, C. (2011). Pragmatism or policy: Implications on health information systems success. *The Electronic Journal of Information Systems in Developing Countries*, 48.
- Kaplan, B. M. (2004). *Information systems research: relevant theory and informed practice: IFIP TC8/WG8. 2 20th year retrospective: relevant theory and informed practice—looking forward from a 20-year perspective on IS research, July 15-17, 2004, Manchester, United Kingdom* (Vol. 143). Springer Netherlands.
- Kaplan, W. A. (2006). Can the ubiquitous power of mobile phones be used to improve health outcomes in developing countries? *Globalization and Health*, 2(1), 9.
- Karasti, H., Baker, K. S., & Millerand, F. (2010). Infrastructure time: long-term matters in collaborative development. *Computer Supported Cooperative Work (CSCW)*, 19(3-4), 377–415.

- Kay, M. (2011). mHealth: New horizons for health through mobile technologies. *World Health Organization*.
- Kimaro, H. C., & Nhampossa, J. L. (2005). Analyzing the problem of unsustainable health information systems in less-developed economies: Case studies From Tanzania and Mozambique. *Information Technology for Development*, 11(3), 273–298. <http://doi.org/10.1002/itdj.20016>
- Kimaro, H., & Nhampossa, J. (2007). The challenges of sustainability of health information systems in developing countries: comparative case studies of Mozambique and Tanzania. *Journal of Health Informatics in Developing Countries*, 1(1).
- Kleine, D., & Unwin, T. (2009). Technological Revolution, Evolution and New Dependencies: what's new about ict4d? *Third World Quarterly*, 30(5), 1045–1067. <http://doi.org/10.1080/01436590902959339>
- Klein, H. K., & Huynh, M. Q. (2004). The Critical Social Theory of Jürgen Habermas and its Implications for IS Research. In J. Mingers & L. P. Willcocks (Eds.), *Social Theory and Philosophy for Information Systems* (pp. 157 – 237). Chichester: Wiley.
- Klein, S., Reimers, K., Johnston, R. B., Barrett, M., Modol, J. R., Tan, Y.-H., & Henningsson, S. (2012). Inter-organizational Information Systems: From Strategic Systems to Information Infrastructures. *The 25th Bled eConference*. 2012, 302–319.
- Klein, S., Schellhammer, S., Reimers, K., & Riemer, K. (2008). Evolutionary paths of inter-organizational information systems (IOIS). In *12th Annual Conference of the International Society for New Institutional Economics* (pp. 20–21).
- Kotz, D., Avancha, S., & Baxi, A. (2009). A privacy framework for mobile health and home-care systems. In *Proceedings of the first ACM workshop on Security and privacy in medical and home-care systems* (pp. 1–12).
- Kreps, D., & Richardson, H. (2007). IS Success and Failure—The Problem of Scale. *The Political Quarterly*, 78(3), 439–446. <http://doi.org/10.1111/j.1467-923X.2007.00871.x>
- Kuhn, T. S. (1970). *The structure of scientific revolutions*. University of Chicago Press Chicago.
- Labrique, A., Vasudevan, L., Chang, L. W., & Mehl, G. (2013). H_ppe for mHealth: More “y” or “o” on the horizon? *International Journal of Medical Informatics*, 82(5), 467–469.
- Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. University of Chicago press.
- Lee, A. S. (1989). A scientific methodology for MIS case studies. *MIS Quarterly*, 13(1), 33–50.
- Lee, A. S. (1991). Integrating positivist and interpretive approaches to organizational research. *Organization Science*, 2(4), 342–365.
- Leech, N. L., & Onwuegbuzie, A. J. (2011). Beyond constant comparison qualitative data analysis: Using NVivo. *School Psychology Quarterly*, 26(1), 70.
- Lemaire, J. (2011). *Scaling Up Mobile Health: Elements Necessary for the Successful Scale Up of mHealth in Developing Countries* (White Paper). Advanced Development for Africa.
- Lemay, N. V., Sullivan, T., Jumbe, B., & Perry, C. P. (2012). Reaching remote health workers in Malawi: baseline assessment of a pilot mHealth intervention. *Journal of Health Communication*, 17(sup1), 105–117.
- Lewis, D. (2006). *The management of non-governmental development organizations*. Taylor & Francis.
- Lippeveld, T. (2001). Routine health information systems: the glue of a unified health system. In *Keynote address at the Workshop on Issues and Innovation in Routine Health Information in Developing Countries, Potomac, March* (pp. 14–16).
- Lippeveld, T., Sauerborn, R., & Bodart, C. (2000). *Design and implementation of health information systems*. World Health Organization Washington, DC.
- Littlejohns, P., Wyatt, J. C., & Garvican, L. (2003). Evaluating computerised health information systems: Hard lessons still to be learnt. *BMJ*, 326(7394), 860.
- Lucas, H. (2008). Information and communications technology for future health systems in developing countries. *Social Science & Medicine*, 66(10), 2122–2132. <http://doi.org/10.1016/j.socscimed.2008.01.033>

- Mancini, F., Mughal, K. A., Gejibo, S. H., & Klungsoyr, J. (2011). Adding security to mobile data collection. In *e-Health Networking Applications and Services (Healthcom), 2011 13th IEEE International Conference on* (pp. 86–89).
- Manda, T. D., & Sanner, T. A. (2012). Bootstrapping Information Technology Innovations Across Organisational and Geographical Boundaries: Lessons from an mHealth Implementation in Malawi. In *IRIS*. Akademika forlag.
- Mansell, R., & Wehn, U. (1998). *Knowledge societies: information technology for sustainable development*. United Nations Publications.
- Markus, M. L., & Robey, D. (1988). Information technology and organizational change: causal structure in theory and research. *Management Science*, *34*(5), 583–598.
- Matawire, R., & Manda, T. D. (2014). Intervention Breakdowns as Occasions for Articulating Mobile Health Information Infrastructures. *The Electronic Journal of Information Systems in Developing Countries*.
- McCann, D. (2012, February 22). A Ugandan mHealth moratorium is a good thing. Retrieved from <http://www.ictworks.org/2012/02/22/ugandan-mhealth-moratorium-good-thing/>
- McGrath, K. (2005). Doing critical research in information systems: a case of theory and practice not informing each other. *Information Systems Journal*, *15*(2), 85–101.
- Meankaew, P., Kaewkungwal, J., Khamsiriwatchara, A., Khunthong, P., Singhasivanon, P., & Satimai, W. (2010). Application of mobile-technology for disease and treatment monitoring of malaria in the. *Malaria Journal*, *9*(1), 237.
- Meachael, P., Batavia, H., Kaonga, N., Searle, S., Kwan, A., Goldberger, A., ... Ossman, J. (2010). *Barriers and gaps affecting mHealth in low and middle income countries: Policy white paper*. Columbia university. Earth institute. Center for global health and economic development (CGHED): with mHealth alliance.
- Meachael, P. N. (2009). The case for mHealth in developing countries. *Innovations: Technology, Governance, Globalization*, *4*(1), 103–118.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. SAGE publications, Inc.
- Mirza, F., Norris, T., & Stockdale, R. (2008). Mobile technologies and the holistic management of chronic diseases. *Health Informatics Journal*, *14*(4), 309–321.
- Monteiro, E. (1998). Scaling information infrastructure: The case of next-generation IP in the Internet. *The Information Society*, *14*(3), 229–245.
- Monteiro, E., Pollock, N., Hanseth, O., & Williams, R. (2012). From artefacts to infrastructures. *Computer Supported Cooperative Work (CSCW)*, 1–33.
- Monteiro, E., Pollock, N., & Williams, R. (2014). Innovation in Information Infrastructures: Introduction to the Special Issue. *Journal of the Association for Information Systems*, *15*(4), IX.
- Mudaly, T., Moodley, D., Pillay, A., & Seebregts, C. J. (2013). Architectural frameworks for developing national health information systems in low and middle income countries. In *Enterprise Systems Conference (ES), 2013* (pp. 1–9). IEEE.
- Mukherjee, A., Purkayastha, S., & Sahay, S. (2010). Exploring the potential and challenges of using mobile based technology in strengthening health information systems: Experiences from a pilot study.
- Ngwenyama, O. K. (1991). The Critical Social Theory Approach to Information Systems: Problems and Challenges. In H.-E. Nissen, H. K. Klein, & R. Hirschheim (Eds.), *Information Systems Research: Contemporary Approaches & Emergent Traditions* (pp. 267 – 280). Amsterdam: North Holland.
- Nielsen, P. (2006). *A conceptual framework of information infrastructure building*. Faculty of Mathematics and Natural Sciences, University of Oslo, Norway.
- Nielsen, P., & Aanestad, M. (2006). Control Devolution as Information Infrastructure Design Strategy: A case study of a content service platform for mobile phones in Norway. *Journal of Information Technology*, *21*(3), 185–194.

- Noir, C., & Walsham, G. (2007). The great legitimizer: ICT as myth and ceremony in the Indian healthcare sector. *Information Technology & People*, 20(4), 313–333.
- Norris, A. C., Stockdale, R. S., & Sharma, S. (2009). A strategic approach to m-health. *Health Informatics Journal*, 15(3), 244–253.
- Olla, P., & Tan, J. (2008). Designing a M-Health framework for conceptualizing mobile health systems. *IGI Global*.
- Orlikowski, W. J., & Baroudi, J. J. (1991). Studying Information Technology in Organizations: Research Approaches and Assumptions. *Information Systems Research*, 2(1), 1–28.
- Orlikowski, W. J., & Iacono, C. S. (2001). Research commentary: desperately seeking the “IT” in IT research—A call to theorizing the IT artifact. *Information Systems Research*, 12(2), 121–134.
- Orlikowski, W. J., & Robey, D. (1991). Information technology and the structuring of organizations. *Information Systems Research*, 2(2), 143–169.
- Pfeiffer, J. (2003). International NGOs and primary health care in Mozambique: The need for a new model of collaboration. *Social Science & Medicine*, 56(4), 725–738.
- Pfeiffer, J., Johnson, W., Fort, M., Shakow, A., Hagopian, A., Gloyd, S., & Gimbel-Sherr, K. (2008). Strengthening health systems in poor countries: a code of conduct for nongovernmental organizations. *American Journal of Public Health*, 98(12), 2134–2140.
- Philips, D., & Verhasselt, Y. (1994). *Health and development*. Routledge.
- Pipek, V., & Wulf, V. (2009). Infrastructuring: Towards an integrated perspective on the design and use of information technology. *Journal of the Association for Information Systems*, 10(5), 447–473.
- Pollock, N., & Williams, R. (2008). *Software and organisations: The biography of the enterprise-wide system or how SAP conquered the world*. Taylor & Francis US.
- Pollock, N., & Williams, R. (2010). E-infrastructures: How do we know and understand them? Strategic ethnography and the biography of artefacts. *Computer Supported Cooperative Work (CSCW)*, 19(6), 521–556.
- Pollock, N., Williams, R., & D’Adderio, L. (2007). Global Software and its Provenance Generification Work in the Production of Organizational Software Packages. *Social Studies of Science*, 37(2), 254–280.
- Prakash, A., & De’, R. (2007). Importance of development context in ICT4D projects: A study of computerization of land records in India. *Information Technology & People*, 20(3), 262–281. <http://doi.org/10.1108/09593840710822868>
- Rajput, Z. A., Mbugua, S., Amadi, D., Chepnéno, V., Saleem, J. J., Anokwa, Y., ... Ndege, S. K. (2012). Evaluation of an Android-based mHealth system for population surveillance in developing countries. *Journal of the American Medical Informatics Association*, 19(4), 655–659.
- Ramachandran, D., Canny, J., Das, P. D., & Cutrell, E. (2010). Mobile-izing health workers in rural India (pp. 1889–1898). Presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 1753610: ACM. <http://doi.org/10.1145/1753326.1753610>
- Reimers, K., Johnston, R. B., & Klein, S. (2004). The shaping of inter-organisational information systems: Main design considerations of an international comparative research project. In *17th Bled eCommerce Conference: “eGlobal”*, (Y. Tan, D. Vogel, J. Gricar & G. Lenarts.), Faculty of Organizational Science, University of Maribor, Bled, Slovenia.
- Ribes, D., & Finholt, T. A. (2009). The long now of technology infrastructure: articulating tensions in development. *Journal of the Association for Information Systems*, 10(5), 375–398.
- Ridde, V. (2008). “The problem of the worst-off is dealt with after all other issues”: The equity and health policy implementation gap in Burkina Faso. *Social Science & Medicine*, 66(6), 1368–1378.
- Ridde, V. (2010). Per diems undermine health interventions, systems and research in Africa: Burying our heads in the sand. *Tropical Medicine & International Health*. <http://doi.org/10.1111/j.1365-3156.2010.02607.x>
- Rodrigues, R. J. (2000). Information systems: the key to evidence-based health practice. *Bulletin of the World Health Organization*, 78(11), 1344–1351.

- Rolland, K. H., & Monteiro, E. (2002). Balancing the local and the global in infrastructural information systems. *The Information Society*, 18(2), 87–100.
- Sahay, S., Monteiro, E., & Aanestad, M. (2009). Configurable Politics and Asymmetric Integration: Health e-Infrastructures in India. *Journal of the Association for Information Systems*, 10(5), 399–414.
- Sahay, S., Sæbø, J. I., Mekonnen, S. M., & Gizaw, A. A. (2010). Interplay of institutional logics and implications for deinstitutionalization: Case study of HMIS implementation in Tajikistan. *Information Technologies & International Development*, 6(3), 19–32.
- Sahay, S., & Walsham, G. (2006). Scaling of health information systems in India: Challenges and approaches. *Information Technology for Development*, 12(3), 185–200.
- Sandiford, P., Annett, H., & Cibulskis, R. (1992). What can information systems do for primary health care? An international perspective. *Social Science & Medicine*, 34(10), 1077–1087.
- 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.
- Sanner, T. A., Roland, L. K., & Braa, K. (2012). From pilot to scale: Towards an mHealth typology for low-resource contexts. *Health Policy and Technology*, 1(3), 155–164.
- Sanner, T. A., & Sæbø, J. I. (2014). Paying Per Diems for ICT4D Project Participation: A Sustainability Challenge. *Information Technologies & International Development*, 10(2), pp–33.
- Scott, W. R. (2008). *Institutions and organizations: Ideas and interests* (3rd ed). Los Angeles, CA: Sage Publications.
- Sen, A. (1999). *Development as freedom*. Oxford University Press.
- Shaw, V., Mengiste, S., & Braa, J. (2007). Scaling of health information systems in Nigeria and Ethiopia—considering the options. In *Proceedings of the 9th International Conference on Social Implications of Computers in Developing Countries*.
- Siccama, C. J., & Penna, S. (2008). Enhancing validity of a qualitative dissertation research study by using NVivo. *Qualitative Research Journal*, 8(2), 91–103.
- Silva, L., & Backhouse, J. (1997). Becoming part of the furniture: the institutionalization of information systems. *Information Systems and Qualitative Research*, 389–414.
- Skorve, E., & Aanestad, M. (2010). Bootstrapping Revisited: Opening the Black Box of Organizational Implementation. *Scandinavian Information Systems Research*, 111–126.
- Sørdeide, T., Tostensen, A., & Skage, I. A. (2012). *Hunting for per diems: The uses and abuses of travel compensation in three developing countries* (No. 2/2012 Study). Oslo, Norway: Norad Evaluation Dept.
- Stahl, B. C. (2008). The ethical nature of critical research in information systems. *Information Systems Journal*, 18(2), 137.
- Stansfield, S. K., Walsh, J., Prata, N., & Evans, T. (2006). Information to improve decision making for health. *A Custom Publication of the Disease Control Priorities Project*, 157.
- Stansfield, S., Orobato, N., Lubinski, D., Uggowitz, S., & Mwanyika, H. (2008). The Case for a National Health Information System Architecture; a Missing Link to Guiding National Development and Implementation. *Making the eHealth Connection*, Bellagio.
- Star, S. L. (1999). The ethnography of infrastructure. *American Behavioral Scientist*, 43(3), 377–391.
- Star, S. L. (2002). Infrastructure and ethnographic practice: Working on the fringes. *Scandinavian Journal of Information Systems*, 14(2), 6.
- Star, S. L., & Ruhleder, K. (1996). Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information Systems Research*, 7(1), 111–134.
- Star, S. L., & Strauss, A. (1999). Layers of silence, arenas of voice: The ecology of visible and invisible work. *Computer Supported Cooperative Work (CSCW)*, 8(1), 9–30.
- Sterling, S., & Rangaswamy, N. (2010). Constructing informed consent in ICT4D research. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development* (pp. 1–9).
- Stiglitz, J. E. (2003). *Globalization and its Discontents*. WW Norton & Company.

- Suchman, L. A. (2002). Practice-based design of information systems: Notes from the hyperdeveloped world. *The Information Society*, 18(2), 139–144.
- Swidler, A., & Watkins, S. C. (2009). “Teach a man to fish”: The sustainability doctrine and its social consequences. *World Development*, 37(7), 1182–1196.
- Tamrat, T., & Kachnowski, S. (2012). Special delivery: an analysis of mHealth in maternal and newborn health programs and their outcomes around the world. *Maternal and Child Health Journal*, 1–10.
- Taylor, C. (1971). Interpretation and the sciences of man. *The Review of Metaphysics*, 25(1), 3–51.
- Thirumurthy, H., & Lester, R. T. (2012). M-health for health behaviour change in resource-limited settings: applications to HIV care and beyond. *Bulletin of the World Health Organization*, 90(5), 390–392.
- Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Research commentary-digital infrastructures: the missing IS research agenda. *Information Systems Research*, 21(4), 748–759.
- Tomlinson, M., Rotheram-Borus, M. J., Swartz, L., & Tsai, A. C. (2013). Scaling up mHealth: where is the evidence? *PLoS Medicine*, 10(2), e1001382.
- Trousset, J. (1886, 1891). Grafting Technique. In *Trousset encyclopedia*. Paris, France: Librairie illustrée.
- Varian, H. R., & Shapiro, C. (1999). Information rules: a strategic guide to the network economy. *Harvard Business School Press, Cambridge*.
- Vidgen, R., & Braa, K. (1997). Balancing interpretation and intervention in information system research: the action case approach. In *Information systems and qualitative research* (pp. 524–541). Springer.
- Walsham, G. (1993). *Interpreting information systems in organizations*. New York, NY: John Wiley & Sons.
- Walsham, G. (1995a). Interpretive case studies in IS research: Nature and method. *European Journal of Information Systems*, 4(2), 74–81.
- Walsham, G. (1995b). The emergence of interpretivism in IS research. *Information Systems Research*, 6(4), 376–394.
- Walsham, G. (1996). Ethical theory, codes of ethics and IS practice. *Information Systems Journal*, 6(1), 69–81.
- Walsham, G. (2001). *Making a world of difference: IT in a global context*. Wiley.
- Walsham, G. (2005). Learning about being critical. *Information Systems Journal*, 15(2), 111–117. <http://doi.org/10.1111/j.1365-2575.2004.00189.x>
- Walsham, G., & Sahay, S. (2006). Research on information systems in developing countries: Current landscape and future prospects. *Information Technology for Development*, 12(1), 7–24.
- Walsh, J., & Simonet, M. (1995). Data analysis needs for health sector reform. *Health Policy*, 32(1-3), 295–306.
- Walton, R., & DeRenzi, B. (2009). Value-sensitive design and health care in Africa. *Professional Communication, IEEE Transactions on*, 52(4), 346–358.
- WCED. (1987). *Our common future* (Vol. 383). Oxford University Press Oxford.
- Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research commentary-The new organizing logic of digital innovation: An agenda for information systems research. *Information Systems Research*, 21(4), 724–735.
- Zimmerman, A., & Finholt, T. A. (2007). Growing an infrastructure: The role of gateway organizations in cultivating new communities of users. In *Proceedings of the 2007 international ACM conference on Supporting group work* (pp. 239–248). ACM.
- Zittrain, J. L. (2006). The generative internet. *Harvard Law Review*, 1974–2040.
- Zuboff, S. (1988). *In the age of the smart machine: The future of work and power*. New York: Basic Books.

MAKING MHEALTH HAPPEN FOR HEALTH INFORMATION SYSTEMS IN LOW RESOURCE CONTEXTS

Kristin Braa (kbraa@ifi.uio.no)
University of Oslo

Terje Aksel Sanner (terjeasa@ifi.uio.no)
University of Oslo

Abstract: The paper offers a reference typology for large scale mHealth solutions in low-resource contexts. The proposed typology is produced through action research engagement with various mHealth initiatives within primary health care; including one fully deployed large-scale solution, medium-sized pilot studies and projects currently being implemented. Our investigations are informed by theoretical assumptions about the cultivation of health *information infrastructures*, through evolutionary strategies of *installed base cultivation* and local patchwork through *bricolage*. We view the extension of national Health Information Systems (HIS) through mobile phones to the community level as a socio-technical cultivation process shaped and determined by the availability of communication infrastructures, handset dispersion, telecom service provider schemes and tariffs, local politics & policies available skilled manpower and established work practices. Through the proposition of a reference typology for mHealth implementation strategies we aim to address the need for identification and cross-fertilization of appropriate mobile based approaches for extending digitized HISs to the community health facilities in a continuously changing development context.

Keywords: mHealth, Health Information Systems (HIS), Low-Resource Context

MAKING MHEALTH HAPPEN FOR HEALTH INFORMATION SYSTEMS IN LOW RESOURCE CONTEXTS

1. INTRODUCTION

“It is not because countries are poor that they cannot afford good health information; it is because they are poor that they cannot afford to be without it” (AbouZahr & Boerma 2005).

At present, considerable efforts are made by international aid agencies (notably the World Health Organization - WHO) and the United Nations (UN) in addressing primary health care related human deprivations such as; poor health, rampant communicable diseases (e.g. HIV/AIDS, malaria, cholera), starvation, malnutrition and high rates of maternal & young child mortality. Wilson and Smith (1991 cited Wilson 2000) suggest that, “the creative use of microcomputer technology is one of the most promising means of improving the quality, timeliness, clarity, presentation, and use of relevant information for primary health care” (Wilson, 2000, p. 199). Similarly, Stansfield *et al.* (2006, p161) details that; “timely and accurate health information is required for strategic planning and the setting of priorities; clinical diagnosis and management of illness or injury; quality assurance and quality improvement for health services; and human resource management”. Despite many current difficulties, recent research experience finds that ICTs can play an important role in strengthening national Health Information Systems (HIS) in developing countries (Braa and Hedberg 2002, Lippeveld *et al.* 2000, Wilson 2000, AbouZahr & Boerma 2005), including important monitoring of Millennium Development Goals related to mother and child health¹.

Unfortunately, the enabling infrastructures, skills and human capacity required for adopting and utilizing computers and landline Internet connectivity for routine HIS has been unavailable or unattainable to the majority of health information users in developing countries (Wilson 2000). Experiments with PDAs and low cost laptops have similarly met obstacles to realization in the public health care scenario in India (Ranjini & Sahay, 2005). In order to strengthen medical and primary health information systems at the grass-roots (i.e. local community), alternative strategies like *mHealth* are currently being explored (Mukherjee, Purkayastha & Sahay 2010, Braa, Purkayastha 2010, Braa, Purkayastha & Grisaw 2010).

In accordance with Germanakos, Mourlas, & Samaras (2005), we understand mHealth as the; “medical and public health practice supported through mobile devices for collecting community and clinical health data, delivery of healthcare information to practitioners, researchers, and beneficiaries, real-time monitoring of beneficiary vital signs, and direct provision of care”. Although mHealth encompasses all kinds of mobile devices from wireless chip-based solutions to portable computers, we advocate that *low-end* mobile phones bear some important characteristics that make them suited to large-scale deployment in low-resource primary health care scenarios; the extensive and swift rollout of mobile telecom infrastructures; widespread domestication of affordable and robust handsets; ease of mastery - leading to high levels of low-end mobile phone literacy; local competencies on servicing and repairing low-end handsets and; low consumption of scarce power.

Within the primary health care domain, mobile phones show promise in filling the digitization gap at the grass-root levels and assist in capturing routine health data even during Community Health Workers (CHWs) interaction with beneficiaries. Mobile data collection and reporting can help reduce errors associated with manual aggregation of routine health data. In addition, it promises to address issues of untimely or unreported data due to transportation of paper reports by foot, bike or

¹ The official United Nations site for the Millennium Development Goals Indicators including child and maternal mortality can be inspected at <http://unstats.un.org/unsd/mdg/Default.aspx>

vehicle over long distances on poor or climatically challenged roads. Thirdly, the on-the-spot digitalization promises to free up time currently spent on monotonous tasks of manually transferring data from paper to paper and into the digitized HIS for aggregation and analysis at higher organizational levels. Finally, the early digitalization of data allows for data sharing and integration between currently isolated HISs that do not communicate across multiple coexistent health programs (WHO 1994). In short, mobiles are believed to assist in improving data quality and affect efficiency in reporting and sharing of data.

Through the proposition of a reference typology for mHealth implementation strategies, this paper aims to address the need to identify, cross-fertilize and maneuver in the space of appropriate mobile based approaches to extending digitized HISs to the community health facilities in a dynamic development context.

In the following section we disclose our theoretical assumptions about the cultivation of health *information infrastructures*. In section three we report on our *networks of action* approach to research. Next, we present the case of a large scale mHealth implementation, involving 5000 low-end handsets, in the Indian state of Punjab. Based on the presented case and our involvement with various other mHealth implementations we propose the reference typology for mHealth implementation strategies in section five. Finally, in section six we suggest some directions for future work on the typology and elaborate on the contribution this paper offers.

2. SUSTAINABLE HEALTH INFORMATION INFRASTRUCTURES IN LOW-RESOURCE CONTEXTS

A World Bank report by McNamara, McNamara & Kerry S. (2003) suggests that many ICT development initiatives are seeded as short-term donor funded pilots without regard to scalability and sustainability, which implies that the anticipated impact and benefits of the projects deteriorate as soon as pilot funding is discontinued or key activists resign from the projects. Similarly, attempts to computerize HISs have too often produced only pilot systems or systems that fail to exist after donor-based funding has ceased (Heeks and Baark 1999). The projects that actually aim for large scale intervention may be forced to go for a single “big bang” implementation due to short donor driven time schedules and attention spans (Cain, 2001). Kimaro and Nhampossab (2005) suggests that scalability is hampered due to the inability to mobilize long term national support, the focus on top-down strategies as opposed to a focus on local needs and the lack of focus on building local competencies to maintain and integrate the HIS interventions.

The political vision of equity in access to health services further intensify the need for scalable and sustainable approaches to the utilization of mHealth for extending digitized HISs to the community health facilities in low resource contexts. This has been characterized by Braa, Monteiro, Sahay (2004) as the *all or nothing problem* of HISs intervention within primary health care. Here we refer to it as the issue of *full scalability*, implying that local success is not sufficient as the mHealth solution has to scale to whole regions and whole nations in order to be of practical value. Existing research into the topic of how sustainable mobile HISs can be effectively deployed and scaled is limited (Donner, 2008), and hence this topic lies in the frontiers of health information systems research. Similarly, Rashid & Elder (2009) review of IDRC²-supported mobile phone driven development projects conclude that there is a “dearth of research exploring mobile phone’s role in health”. To address this gap in research we explore the utilization of low-end mobile phones in HISs in *low resource contexts* through the notion of *health information infrastructures*.

With the term low-resource context we refer to the lack or instability of enabling infrastructures (e.g. roads, public transport, power-supply, and electronic communication networks), shortages in human capacity and skill (i.e. primary health and technology competence), as well as an inherent

² IDRC is a Canadian Crown corporation that works in close collaboration with researchers from the developing world in their search for the means to support growth and development.

price sensitivity in addressing these and other shortcomings. By *health information infrastructure* we refer to the complex socio-technical and socio-political ensemble of communication networks, information systems, and work practices that constitute the primary health information scenario.

Hanseth (2002) emphasize *installed base cultivation* as the most feasible ICT intervention strategy for complex socio-technical information infrastructures. Installed base refers broadly to whatever is already in place. In our case, this includes health workers and their paper registers at the community health facilities; computers and data analysts at the district levels; the servers and monitoring & evaluation officers at the state level; in addition to basic infrastructures required to support mobile phone use; charging facilities, maintenance support and network coverage. The installed base cultivation strategy acknowledges the lack of control any one stakeholder have over the full ensemble and sees the opportunities and choices of the present as shaped and determined by the materiality and institutionalization of previously stabilized alignments. Thus, addressing the shortcoming of more traditional top-down enterprise architecture strategies where work practices and infrastructures are supposed to be redesigned and implemented in one fell swoop.

Although subscribing to this evolutionary view on ICT intervention, we find that cultivation as an information infrastructure design strategy fails to guide the fine grained and nitty-gritty patchwork and problem solving happening on the ground in low-resource contexts. We therefore draw on the concept of *bricolage* to describe the constant trying out and re-ordering of people and resources. Bricolage (lat. *bricola* catapult) means “tinkering through the combination of resources at hand” as “[t]hese resources become the tools and they define *in situ* the heuristics to solve the problem” (original emphasis, Ciborra, 2002 p 49). The power of bricolage is that it is highly situated and exploits the local context and resources at hand, while often pre-planned ways of intervening appear to be less effective because they do not fit with the contingencies of the moment. Bricolage “tend to include an added element of ingenuity, experience and skill belonging to the individual and their community (of practice)” (ibid, p50).

3. RESEARCH APPROACH

The study presented in this paper is guided by a *network of action* research approach. The approach is aimed at tackling the issue of sustainability in research driven interventions by recognizing that local intervention needs to be part of a larger network in order to achieve robustness. In short, the approach sees scalability as a prerequisite – not a luxury – for sustainability of local action. The network creates opportunities for sharing of experience, knowledge, technology, and value through multiple sites of action and use (Braa, Monteiro, Sahay, 2004). Hence, the emphasis on scale through a focus on networks is *not* so much about size as facilitating the necessary learning processes for sustainability (Elden and Chisholm 1993, p. 293). The focus on full scale and sustainability challenges the tendency of designing and reporting on action research as well-defined phases. Susman and Evered’s (1978) classic model outlines five such phases: diagnosing, action planning, action taking, evaluating, and specifying learning. While these cycles are implicit and ongoing in our interventions, we cannot categorize them neatly into different phases with a clear start and end.

Both authors are involved with the Health Information System Programme (HISP); an international research network doing open source development and implementation of District Health Information Systems (DHIS2) in more than 15 countries in Africa and Asia. DHIS2 is implemented in 20 states in India for intrastate HMIS reporting. The DHIS software is developed, customized and used for reporting, analysis and presentation of aggregated health data while catering for various health programs (HIV, ANC, Malaria, EPI etc).

This study draws its empirical material from mHealth implementations aimed at seamlessly integrating and extending DHIS to the community level; where there are no computers, no Internet and often unstable power supply. The suite of applications are referred to as DHIS-Mobile and address both capturing of aggregated routine data (facility reporting), as well as tracking

beneficiaries throughout the duration of the health program they are enrolled in such as ANC, child immunization and HIV/AIDS (name-based). One of the authors manages the DHIS-Mobile project (Author 1), while the other author is a Ph.D. student (Author 2) enrolled in the project since August 2010.

3.1. mHealth implementations

The authors have been involved in the iterative development of various solutions for DHIS-Mobile (Table 1); ranging from design, implementation, training, project coordination, and evaluation activities. In the following, we describe the different projects informing this study and the roles of the authors in the various projects.

	Project Initiated	Current Stage	Application	Users Trained
Five state pilot (India)	May 2009	Pilot	Java / SMS	250
Nigeria	September 2009	Pilot	Java / SMS	60
Punjab	June 2010	Full-scale	Java / SMS	5000
Name based	In startup	Pre-pilot	SMS/GPRS	-

Table 1. DHIS-Mobile Projects

Case study of IDSP pilot in Andhra Pradesh

In order to learn from an ongoing mHealth project in India a short case study of a SMS based reporting system for Integrated Disease Surveillance Project (IDSP) was conducted in February 2009 by Author 1 together with colleagues from HISP. The pilot was initiated in August 2008 and was implemented in six out of Andhra Pradesh's 23 districts. The solution supports weekly reporting of data through plain SMS with alpha-numeric codes. Data of the prescribed IDSP formats is sent from the reporting units to a server at the state capital. To secure the confidential information being transmitted, the system identifies every reporting unit with a unique identification number and the SMSs are accepted only from pre-registered mobile numbers. The alpha-numeric codes include; facility ID, disease code, number of registered cases, deaths, etc. The system sends out automatic alerts to concerned officials whenever the frequency of particular events cross pre-set threshold levels.

The short case study served the purpose of learning about routine facility reporting, getting feedback on the facility reporting prototype for DHIS-Mobile and discussing possibilities for supporting Community Health Workers (CHWs) through mobile applications. A range of stakeholders involved in the pilot project were interviewed; including director of epidemics, district epidemic officer, district medical officer, data manager and the IDSP team. Three health facilities were visited and two monthly meetings were attended in order to discuss the experiences of 38 CHWs and 60 voluntary health workers.

Facility reporting Pilot in five Indian states

Simultaneously, facility reporting was initiated in five Indian states; Kerala, Rajasthan, Gujarat, Himachal Pradesh and Nagaland. CHWs were provided with an application on mobile phones to report routine outreach service data (e.g. ANC, immunization) to the district and state level. Over 250 people including CHWs and state/district/block-level medical officers were trained. The detailed findings of this study are reported in (Braa et al 2010, Mukherjee, Purkayastha, & Sahay 2010). The application was based on the national HIS form for CHWs coordinated by the National Rural Health Mission.

In February 2009 a pre testing of the prototype was performed among health workers in Andhra Pradesh (mentioned above) and Kerala. In Kerala Author 1 visited three health facilities and interviewed CHWs, block health administrative people and the village head. In July 2009 and April 2010 Author 1 was involved in the evaluation of the pilot in the two states Kerala and

Rajasthan. Six community health facilities were visited and two focus groups were organized; with 15 facilities represented in each. A total of 30 CHWs were interviewed.

Pilot in Nigeria

Based on experience from of the IDSP pilot and the facility reporting solution, a pilot was initiated in the two Nigerian states Yobe and Katsina in September 2009. Health workers from 26 health facilities and 34 local government area Monitoring & Evaluation officers were involved, thus, covering the whole state of the Katsina and parts of Yobe. The Nigerian solution is very similar to the Indian pilots, although in Nigeria, the mobile application was developed based on the existing national HIS facility forms and implemented at the facility and district levels (Asangansi & Braa, 2010). Due to unstable power supply the pilot faced difficulties in maintaining server uptime and a power backup system was put into place. In order to receive all SMS's, the modem had to be switched on at least daily as the mobile operator in Nigeria only store SMS for 24 hours. Author 1 was involved in the whole process from negotiating the pilot, designing the application, installing the application on handsets, training users and later evaluating the experience. Interviews were conducted with stakeholders from both states - including health and government administration.

Full scale roll out in Punjab

Based on the experience from the pilots a full scale mobile facility reporting implementation was rolled out in the state of Punjab. From late September 2010, Author 2 spent a total of six weeks following the implementation stages; visiting three health facilities to observe local work practice, attending one regular monthly meeting with about 40 CHWs, and participating in five mobile training sessions, also involving about 40 CHWs each. The field work involved extensive interaction with representatives from the health organization; voluntary health workers, CHWs, medical officers, statistical assistants, and data analysts; the project HISP team; mobile trainers, application developers, technical support staff, project coordinators; and state officials/mangers. Secondary sources of data from studying the Punjab roll out include training manuals and official reports from mobile trainers, project coordinators, state level data analysts and state officials.

Global Developers Workshop

In November 2010 both authors participated in a two week global workshop for DHIS-Mobile developers in Kerala with 12 participants from India, Vietnam, Tanzania and Norway. The aim of the workshop was to design prototypes for DHIS-Mobile based on previous experiences and new requirements. In addition to improving the existing solutions, a prototype for the mobile name-based module of DHIS was developed. Three CHWs from different facilities tested the prototype and gave valuable feedback to the developers and implementers.

In order to structure the key experience and learning from engagement with previous implementations and navigate in the space of possible design solutions, different version of the reference typology for mHealth implementation strategies was presented by Author 1 and negotiated between the researchers and developers throughout the last week of the workshop. The negotiation during the workshop is just one example of how data collection and analysis has been highly interlinked in our study. The typology has been continuously re-negotiated as it has been presented by the authors to fellow researchers, students, and practitioners involved with HISP-Mobile. The typology has thus emerged, not from a well defined process of analysis, but from both authors' engagement and interaction with the HISP-Mobile project. Both our own and others shared experiences have been conceptualized and synthesized through our theoretical assumptions about installed base cultivation of health information infrastructures while allowing room for improvisation and local patchwork through bricolage.

Although our proposed typology draws insights from engagement with all the mentioned implementations, we will, in the following data chapter describe in further detail the full scale mHealth implementation in the Indian state Punjab.

4. MOBILE REPORTING OF DAILY AND MONTHLY ROUTINE DATA IN PUNJAB

The bricks and mortar of the Punjabi public health system are the CHWs stationed at the community health facilities. There are 2948 such facilities in Punjab employing about 5000 CHWs, of which a large portion is middle aged women. The primary health organization of Punjab is divided into districts, blocks, primary health centers (PHCs), and community health facilities. *Table 2* illustrates the availability of computers and Internet connectivity at the different hierarchical levels of the primary health organization.

	Reporting Units	Computers	Internet
State	-	Yes	Yes
District	20	Yes	Yes
Block	118	Yes	Yes
Primary Health Centers	396	Rare	Rare
Community Health Facility	2948	No	No

Table 2. Punjab Health Organization Units

During spring 2010, the state of Punjab decided to implement mobile phone based facility reporting from all community health facilities. An evaluation of the network signal strength in districts of Punjab led to the choice of basing the mobile data reporting on SMS rather than GPRS. All of the CHWs were provided with a SIM card and a Nokia 2330 Classic with a Java application for routine data reporting installed. The application allows CHWs to fill forms and send one daily (10 data elements) and two monthly (53 & 86 data elements) reports of routine health data (see Figure 1). A team of ten people manually installed the native Java mobile applications (*.jar files) to all 5000 handsets over a period of one month. The application utilizes only basic J2ME functionality which allows it to be installed and run on most Java enabled low-end handsets.

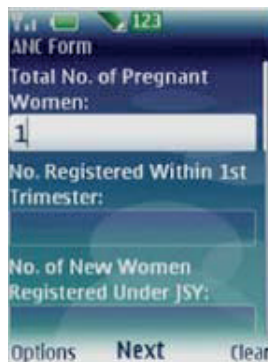


Figure 1 Screen Shot of Mobile Application Form

Training on mobile reporting and the data elements in the forms was given to all CHWs. Completed reports can be stored and retrieved locally on the mobile phone and forwarded when reception of the mobile network is sufficient. The report is sent as a compressed (70% compression rate) SMS to two GSM Modems integrated with the DHIS2 data warehouse. Block and higher facility personnel can access the reported data through the online DHIS2 software on computers (*Figure 2*).

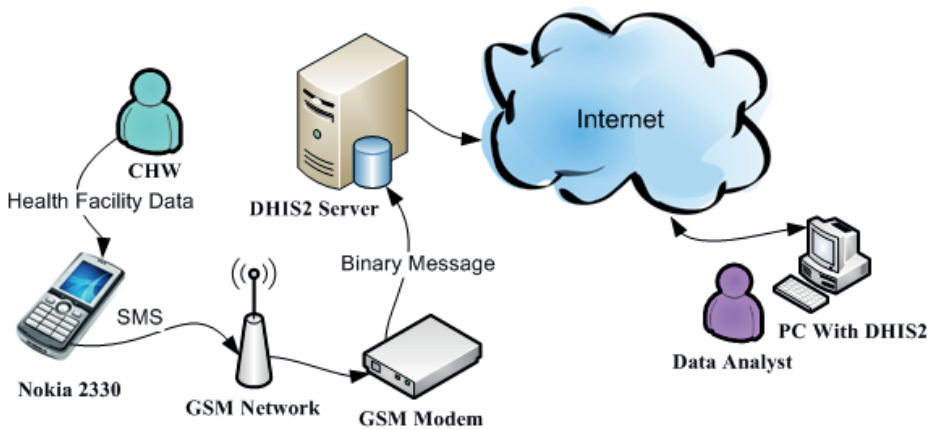


Figure 2 Mobile supported Health Information System in Punjab

Although Internet connections and computers are available at block level, Bluetooth is generally not. This has forced support staff to travel long distances in order to reinstall the Java applications to handsets in cases where CHWs have accidentally deleted them. CHWs will continue paper reporting until the mobile based reporting stabilizes and consistency with paper reports can be confirmed.

4.1. Mobile Networks, handset and service provider schemes

The state of Punjab decided to purchase the 5000 handsets in one go, in order to get the best possible discount price of 1900Rs (\$40), as opposed to the retail price of about 2700Rs (\$60). A tender document was published in national newspapers and included the required cost and technical phone specifications for mobile phone companies and lowest rental plan with Closed User Group (CUG) for service providers. The Nokia 2330 Classic was chosen for the project implementation as it supported all the technical specifications within budgetary limitations. According to the requirements of a tariff plan, customer service and network coverage in rural areas of Punjab, a service provider was chosen, however a few CHWs have complained that the service provider does not have sufficient network coverage in their catchment area. The Indian pilot studies show that having unconstrained access to managers, medical officers and colleagues through the CUG are some of the most cherished and obvious benefits recognized by CHWs (Braa et al. 2010). Thus, the CUG was part of the implementation concept in the Punjab roll out and was negotiated to include free calls within the network for health workers and 100 free SMS every month.

5. MHEALTH IMPLEMENTATION STRATEGIES FOR LOW RESOURCE CONTEXTS

In this section we will present the reference typology for mHealth implementation strategies, with the aim of identification, cross-fertilization and maneuvering in the space of appropriate mobile based approaches to extending digitized HISs to the grass-root levels (Table 3). The typology address the need to cultivate the existing resources available (the installed base) as well as creating room for improvisation and bricolage in a dynamic development context. Our intention is to

unravel a solution space that can also cater for changes in implementation strategies according to infrastructure resources.

Although mobile network coverage can be found in low resource contexts where there is not even stable power supply and roads are underdeveloped, these networks are oftentimes unstable or have weak signal strength. Within primary health care, mHealth solutions need the robustness to cope with situations where no wireless communication is available (e.g. by storing data on the handset until connectivity is available). Thus, the mobile application was designed so that the facility reports can be saved on the phone until a place with better reception is reached. SMS data can be sent even where network coverage is marginal, as illustrated by a Nigerian health worker climbing a three in order to send the SMS report. Cost of data transfer can also be a factor influencing the mHealth solution and where sending SMS is costly; GPRS can be utilized for report sending whenever the network signal is strong enough.

In Punjab the applications on 5000 phones were installed manually and took a team of ten people almost a month. With a hybrid solution where the application can be downloaded via GPRS (i.e. during user training) while reports are still sent as compressed SMSs would reduce the manual workload. Similarly, a hybrid solution would allow for a link to be sent as an SMS while GPRS would be utilized to download a new version or reinstall a deleted application. Reinstallation or updating could then be performed during monthly CHWs meetings at block or PHC if GPRS is available there.

In contexts where GPRS network is good and cover the whole area a full GPRS solution where both downloading the application and sending the data through the GPRS network may be preferable. A new implementation to be tried out in Himachal Pradesh will most likely be a mix between GPRS hybrid and full GPRS solution due to fluctuating network quality.

However, more skill and experience is required in order to design and develop a hybrid solution. Thus, we see a trade-off between human resources for application development and solution deployment. The SMS based client solution with the Java manually installed on the phone was relatively easy and fast to develop but have required more human resources to maintain. To some extent, the lack of a robust application design can be compensated for by use of manual deployment labor.

In situations where handsets cannot run Java clients, have no browsers and GPRS network is unavailable, plain SMS based solutions like the IDSP pilot may be an option - although usability is a challenge. In the pilot, CHWs found it hard and cumbersome to enter all the required digits without making errors. Thus, they relied on super users to enter the data whenever coming to a meeting. Failures in data capturing were still reported as a problem.

All the DHIS-Mobile solutions reported in this paper are based on initial purchase, application installation and subsequent distribution of phones to the health workers. This strategy was chosen because the phones people already had were frequently not Java enabled. To provide phones will not always be possible due to lack of finances and different solutions need to be explored. We have seen that pure SMS based solutions may be chosen on the expense of usability, but if the handset has a browser web based solutions can be a viable option.

In our reference typology (*Table 3*) the various mHealth implementation strategies are mapped according to the contextual parameters including network signal strength, handset availability and existing tariff plans, human capacity and user experience on low-end handsets. The reference

typology aims to support the navigation in the space of possible design solutions in low resource contexts and facilitate the cross-fertilization of synthesized experiences between different full scale and sustainable mHealth projects. The contextual parameters of the installed base are not stable, but will be subject to changes in resources availability such as network upgrades, better handsets and service provider competition.

Technical Solution	Contextual Resources			Human Capacity		Application Use
	Network	Handset	Tariff	Development	Deployment	Ease of Mastery
SMS only	Plain SMS	Works on all handsets	Cheap SMS	Simple	Easy to deploy	Error prone, complex
SMS based client	Sending compressed SMS	Java enabled phones	Cheap SMS, CUG	Simple	Demanding to install / update (manual labor)	Small learning curve
SMS based client hybrid	SMS client with GPRS sending	Java enabled phones	Cheap GPRS, CUG	Complex, time consuming	Easy to install & update	Small learning curve
GPRS hybrid	GPRS for downloading application and SMS data reporting	Java enabled phones	Cheap SMS, CUG	Complex, time consuming	Unknown	Unknown
GPRS	GPRS for downloading application and data reporting	Java enabled phones	Low data tariff, CUG	Unknown	Unknown	Unknown

Table 3 Reference typology for mHealth implementation strategies in low resource contexts

Cultivating Health Information Infrastructure

We find that the strengthening of existing HIS through mHealth solution is made feasibly by leveraging on the backbone system (i.e. the DHIS2) that is already shared in the current HIS setup and work practices. In order to extend the reach of digitized HIS we see that we need to cultivate the installed base of recourses as technologies mature and contexts change. Cultivation occurs through the constant inclusion of local innovation based on currently available resources, while bricolage is the maneuvering on the ground in this landscape of making mHealth happen.

We see bricolage as a strategy for navigating within the typology as it addresses the fine-grained situated local problem solving of “gluing” the bricks together. From the trying out in different local contexts the network of action accumulates knowledge within the community and learns to avoid the pitfalls. Learning is produced through the sharing of experience from resource trade-offs, breakdowns and successful patchwork in the network. This needs to be an ongoing process due to continuous changes in infrastructures such as network and handset availability and resource availability, thus the experience and skill required to do bricolage is accumulated in the network.

6. CONCLUSION

In this paper we have presented a reference typology for mHealth implementation strategies for matching mobile solutions to low resource contexts. We find that the theoretical lens of installed base cultivation through bricolage is useful in understanding, describing and synthesizing the learning that emerges from our networks of action oriented involvement with various mHealth implementations.

The proposed reference typology is based on a limited set of implementations conducted within the same network of action over a three year period. Our findings suggest that extending national HIS with mHealth solutions, need to match with existing work practices, local contextual resources, service provider tariffs, existing communication infrastructures and integration with the backbone HIS. Thus, solutions need to be continuously cultivated with respect to the context they are embedded in. The typology is not cut in stone and will need to be expanded and improved in the future e.g. web-based solutions will be a viable option in some low resource contexts. In this study the main focus has been on utilizing the mobile phone in the primary health scenario for scalable and sustainable data reporting, with improved data quality and timeliness as key motives, yet the pilots revealed the use of the handsets for coordination tasks and social networking within a Closed User Group (CUG) was a much appreciated benefit to health workers. Further utilization of this effect as an engine for sustainable intervention needs to be explored. Finally, we suggest that low-end mobile phones offer opportunities for giving contextualized and localized feedback to CHWs directly on the handsets, the solution space offered from the typology needs to be explored further with feedback in mind.

7. REFERENCES AND CITATIONS

- AbouZahr, C., & Boerma, T. (2005). Health information systems: the foundations of public health. *Bulletin of the World Health Organization*, 83, 578–583.
- Asangansi, I., & Braa, K. (2010). The Emergence of Mobile-Supported National Health Information Systems in Developing Countries in *Proceedings from The 13th World Congress on Medical and Health Informatics Medinfo 2010* Cape Town, South Africa.
- Braa, J., Monteiro, E. & Sahay S. (2004). Networks of action: sustainable health information systems across developing countries, *Management Information Systems Quarterly* 28(3).
- Braa, J., Hedberg, C., (2002) The struggle for district-based health information systems in South Africa, *The information society* 18(2): 113–127.
- Braa, K., Purkayastha, S., (2010) Sustainable Mobile Information Infrastructures in Low Resource Settings in *Proceedings from IT in Health Care: Socio-technical Approaches, Fourth International Conference*.
- Braa, K, Purkayastha, S., Grisaw, A., (2010) Matching mHealth Solutions with Low Resource Settings in *Proceedings from 7th International Conference on E-Governance*.
- Cain, P., (2001). Automating personnel records for improved management of human resources. In *Reinventing government in the information age*, ed. R. Heeks, pp. 135–155. London: Routledge.
- Ciborra, C., (2002). *The labyrinths of information: Challenging the wisdom of systems* New York: Oxford University Press Inc.
- Donner, J., (2008). Research Approaches to Mobile Use in the Developing World: A Review of the Literature. *The Information Society*, 24(3), 140-159.
- Elden, M., and Chisholm, R. F. (1993) Emerging Varieties of Action Research: Introduction to the Special Issue, *Human Relations* 45(2), , pp. 121-142.
- Germanakos P., Mourlas C., & Samaras G. (2005). A Mobile Agent Approach for Ubiquitous and Personalized eHealth Information Systems. *Proceedings of the Workshop on 'Personalization for e-Health' of the 10th*

International Conference on User Modeling (UM'05), 67-70.

- Hanseth, O. (2002) "From systems and tools to networks and infrastructures – from design to cultivation. Towards a theory of ICT solutions and its design methodology implications". Unpublished article available at http://www.ifi.uio.no/~oleha/Publications/ib_ISR_3rd_resubm2.html accessed 22 November 2010
- Heeks, R., Baark, E., (1999) Evaluation of Donor Funded Technology Projects in China. *Working Paper*, Institute for Development Policy and Management (IDPM), University of Manchester.
- Lippeveld, T., Sauerborn, R. & Bodart, C., (2000). Design and implementation of health information systems, World Health Organization Washington, DC.
- Kimaroa, H.C. & Nhampossab, J.L., (2005). Analyzing the Problem of Unsustainable Health Information Systems in Less-Developed Economies: Case Studies From Tanzania and Mozambique.
- McNamara, K.S. & McNamara, Kerry S., (2003). Information and Communication Technologies, Poverty and Development: Learning from Experience, World Bank, Washington D.C., USA. Available at: <http://www.infodev.org/en/Document.19.aspx> Accessed December 14, 2009.
- Ranjini, C.R., Sahay, S. (2005) , Computer-based Health Information Systems – Projects for computerization or Health Management?: Empirical experiences from India. Chapter CV - Medical Informatics: Concepts, Methodologies, Tools, and Applications, IGI Global Publications
- Rashid, A.T. & Elder, L., (2009). Mobile Phones and Development: An Analysis of IDRC-Supported Projects. *EJISDC*, 36(2), 1–16.
- Stansfield S. K et al.. (2006) Information to improve decision making for health, *A custom publication of the Disease Control Priorities Project*: 157
- Susman, G., and Evered, R. (1978) An Assessment of the Scientific Merits of Action Research, *Administrative Science Quarterly*, 23 (4), pp. 582-603.
- Mukherjee, A., Sahay,S., Purkayastha, S., (2010). Exploring the potential and challenges of using mobile based technology in strengthening health information systems: Experiences from a pilot study. Proceedings of the Sixteenth Americas Conference on Information Systems
- WHO. (1994) Information Support for New Public Health Action at the District Level: Report of a WHO Expert Committee, World Health Organization. Technical Report Series, No. 845, Geneva, pp. 1-31
- Wilson, R. G., Smith D. L., (1991) Microcomputer applications for primary health care in developing countries., *Infectious disease clinics of North America* 5(2): 247.
- Wilson, R., (2000). Using computers in health information systems. In: T. Lippeveld, R. Sauerborn, and C. Bodart, eds. Design and implementation of health information system, Geneva: WHO, 198-212.



Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/hlpt



From pilot to scale: Towards an mHealth typology for low-resource contexts ☆, ☆ ☆

Terje Aksel Sanner*, Lars Kristian Roland, Kristin Braa

Department of Informatics, University of Oslo, Post-box 1080 Blindern, 0316 Oslo, Norway
Available online 9 August 2012

Abstract

The paper classifies mobile phone based solutions for Health Information System (HIS) in low-resource contexts into four types: interactive voice response (IVR); plain-text SMS; locally installed handset and SIM-applications; and browser-based solutions. The resulting reference typology details the strengths and disadvantages associated with each solution type along four dimensions: robustness to low-resource contexts; flexibility for organisational and functional change; usability; and financial cost. The paper demonstrates how the strengths and disadvantages associated with each solution type become more evident when implementations are intended to scale in low-resource settings. Early decisions about whether or not to leverage health workers own handsets, initial arrangements with mobile operators and requirements regarding the solution's capability to support offline work may shape the choice of solution type and have long lasting implications. The typology is produced through involvement with longitudinal action research projects, including the statewide implementation of an application-based solution in one Indian state.

© 2012 Fellowship of Postgraduate Medicine. Published by Elsevier Ltd. All rights reserved.

Introduction

Considerable efforts are made by national governments and international aid agencies in order to alleviate human deprivations such as rampant communicable diseases, starvation and malnutrition, and high rates of maternal and young child mortality.¹ The availability of timely and accurate health information is, as noted in [24], required

for the “strategic planning and setting of priorities; clinical diagnosis and management of illness or injury; quality assurance and quality improvement for health services; and human resource management” ([24], p. 161). The appropriate use of information and communication technologies (ICTs) can improve timeliness, strengthen data quality, and facilitate evidence-based decision making for health [4,13,21]. However, as is pointed out in [26], the majority of health information users in less developed economies have not had access to the infrastructures required for adopting and utilising computers and landline Internet connectivity.

The extensive and swift rollout of mobile telecom infrastructures has triggered an avalanche of health related digital innovations, commonly referred to as mHealth, encompassing all kinds of mobile devices from wireless chip-based solutions to portable computers. In particular, low-end mobile phones bear some important characteristics that make them suited for mHealth initiatives in low-resource

*A shorter version of the paper was published in proceedings from European Conference on Information Systems 2012.

☆☆Research funded by the Norwegian research council (Forskningsrådet).

*Corresponding author.

E-mail address: terjeasa@ifi.uio.no (T.A. Sanner).

¹The official United Nations site for the Millennium Development Goals Indicators including child and maternal mortality can be inspected at <http://unstats.un.org/unsd/mdg/Default.aspx>.

contexts. These characteristics include widespread domestication of affordable and robust handsets, high levels of low-end mobile phone literacy, local competencies on servicing and repairing handsets, low proneness to theft, and low consumption of battery power.

Unlike laptop computers and PDAs, mobile phones feature effortless sociability as its core functionality, which may make them less likely to be left broken or abandoned in dusty corners or desktop drawers [19]. Within health care, mobile phones show promise in facilitating efficient capture and transmission of data for routine health decision making, disease surveillance, and beneficiary tracking throughout health programmes. A growing number of digitised health information systems (HIS) are now being extended to the communities through free and open source frameworks like Rapid SMS, FrontlineSMS, and DHIS-Mobile (reported on in this paper). The on-the-spot digitisation of health data also promises to free up overburdened health workers' time and limited resources spent on data transfer, from paper registers to paper forms, and from paper forms into national computerised HISs for aggregation and analysis.

Despite the promising potential of mHealth and other ICT innovations, a World Bank report [14] suggests that many ICT-for-development initiatives are seeded as short-term donor-funded pilots without regard to scalability and sustainability. The anticipated impact and benefits deteriorate as soon as pilot funding is discontinued or key activists resign from the projects. In particular, the benefits of interventions in public health can be limited unless they scale to inform evidence-based decision making and resource allocation for whole administrative regions [22].

Existing research into the topic of how sustainable mobile phone based interventions in health can be effectively deployed and scaled in developing countries is limited [6,11,15,20]. Despite the breadth of current mHealth projects, recent reviews suggest that most of the innovations have so far failed to scale or sustain beyond the pilot stage [5]. Consequently, there is an urgent need for the identification of elements that can promote the successful scaling-up of mHealth initiatives [12].

The contribution of this paper is a classification of mobile phone based solutions for HIS interventions in low-resource contexts into four empirically derived types: interactive voice response (IVR); plain-text SMS; locally installed handset and SIM-applications (e.g., J2ME, Android, SIM Toolkit); and browser-based solutions (e.g., WAP, HTML). IVR services let the user call a number and type digits or use voice recognition in response to voice prompts. Plain-text SMS solutions allow users to send SMS messages to a service number, and receive responses back via SMS. Locally installed applications support graphics and an interactive user interface, while allowing offline data entry in areas without mobile coverage. Browser-based services are generally maintained and updated on online servers, but are accessible through mobile phones using mobile browsers.

In section 'An mHealth typology for low-resource contexts', the four solution types are presented in a reference typology that details the strengths and disadvantages associated with each type along four dimensions: *robustness* to low-resource contexts; *flexibility* for organisational and functional change; *usability*; and financial *cost*. This paper shows how the strengths and disadvantages associated with

each solution type become more evident when implementations are intended to scale in low-resource settings. In particular, early decisions about whether or not to leverage health workers' own handsets, initial arrangements with mobile operators and requirements regarding the solutions capability to support offline work may shape the choice of solution type and have long lasting implications. The paper aims to identify a vocabulary that allows aspiring mHealth initiatives to synthesise and share experiences and manoeuvre in the mHealth solution space in a dynamic development context.

Conceptual framework

The concept of *installed base cultivation* [10] captures the idea that very large and complex information systems, also referred to as information infrastructures, are never designed or built from scratch, but always evolve through the extensions and improvement (cultivation) of what is already in place (the installed base) [8,9]. When we consider the extension of digitised HISs to the community level through mobile phone based interventions, the installed base refers broadly to the whole socio-technical ensemble of work practices and registers at the community level; computers, legacy systems, data entry and data analysis at the district levels; and data warehouses, servers, monitoring, evaluation and decision making at the state or national level. Furthermore, the installed base also comprises of the current diffusion of mobile phones among potential mHealth solution users, availability of charging facilities, mobile network coverage, mobile operators' tariffs and schemes.

The recognition that information infrastructures evolve, rather than being designed and controlled by any one stakeholder, also illuminates how early phases of successful mHealth interventions (e.g., pilots) can carry with it a *path dependency* that shape and limit the future space of possible solutions. Path dependency is a self-reinforcing mechanism where past events impact future development and seemingly irrelevant occurrences may turn out to have tremendous consequences. Path dependency is also referred to as a *lock in* by historical events [1]. A lock-in effect is evident in that an early technology adoption—due to its cumulative adoption and attractiveness or sheer distribution of decision-making power—makes it difficult or unfeasible to develop or coordinate a move to any alternative solutions at a later point in time.

Through the iterative analysis of our empirical data (next section) we have identified *robustness*, *flexibility*, *usability*, and financial *cost* as fruitful dimensions for characterising mHealth solution types. An mHealth solution type's robustness to low resource captures its ability to reliably scale up despite variability in quality and coverage of wireless communication networks and limited access to stable power supply.

Flexibility captures the solution type's ability to cater for improvements and innovation as organisational challenges and needs emerge, in part due to the mHealth intervention itself [2]. Similarly to [7], we conceptualise flexibility (of a solution type) as a composite of both flexibility to accommodate future change and flexibility for use across a range of tasks.

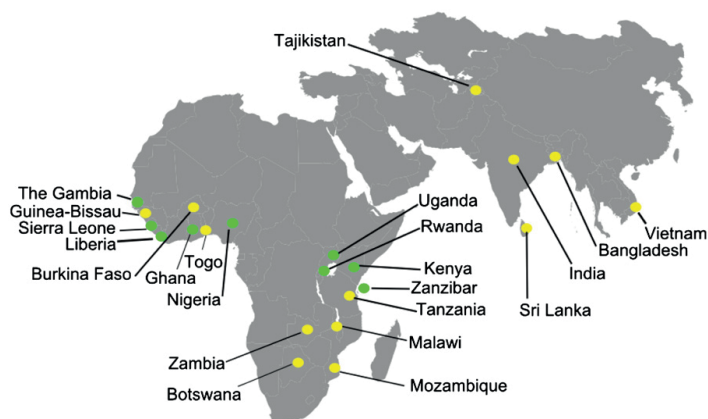


Figure 1 Map showing DHIS2 global footprint.

ISO² defines usability as “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use”. We employ the concepts in a similarly straightforward way and consider usability to be composed of, as [17] argues: the ease with which the solution is initially mastered and later re-mastered after a period of non-use; efficiency in task performance; the frequency and severity of errors; and finally how pleased the user is with the solution design. The applicability of the solution type to a breadth of end-user tasks is covered in our concept of flexibility for use mentioned above and is not part of usability. Financial *cost* is perhaps the most obvious limitation to mHealth in low-resource contexts and includes up-front investments in technology, infrastructure, development, and deployment, as well as the running costs associated with sustaining and scaling a solution type, including training and follow up of users.

Research approach

The three authors are involved with the Health Information System Programme (HISP), an international research network doing open source development and implementation of the District Health Information Software (DHIS2) in a range of countries in Africa and Asia, including whole states in India. The dots on the map in Figure 1 indicate where DHIS2 is used as the national HIS data warehouse, or is in the process of becoming the national standard. The DHIS2 software is used for reporting, analysis, and presentation of routine health data while integrating and catering for data needs of various health programmes (HIV/AIDS, tuberculosis, antenatal care, malaria, child immunisation, etc.). This study draws its empirical material from interventions aimed at seamlessly integrating and extending digitised data capturing and reporting from the community level into the DHIS2 backbone. The mobile project, referred to as DHIS-Mobile, utilises mobile phones in contexts where there are often no computers, no telephony landlines and unstable or non-existent power supply.

DHIS-Mobile thus leverage and extends DHIS2 both technically and institutionally, drawing on and elaborating established collaboration networks, human capacities and information infrastructures. In particular, much effort is invested in facilitating early buy in and ownership within health ministries.

The study is guided by a *network of action* approach to research [3]. The approach is aimed at strengthening research-driven HIS interventions by recognising that local implementations need to be part of a larger network in order to achieve sustainability. The network creates opportunities for sharing of experience, knowledge, technology, and values through multiple sites of action and use. The open-ended emphasis on scale and sustainability challenges [25] classic model of action research, which laid out five more or less well-defined phases: diagnosing, action planning, action-taking, evaluating, and specifying learning. While these elements are implicit in the presented work, we cannot categorise our research neatly into different phases with a clear start and end point.

The authors have taken part in the iterative development of various mHealth solutions for DHIS-Mobile, with activities ranging from application design and installation on handsets, field visits to health facilities, user training, stakeholder meetings, project coordination, and evaluation activities. The field work has resulted in field notes and minutes from unstructured interviews with voluntary health workers, field nurses, medical officers, statistical assistants, data analysts, mobile trainers, application developers, technical support staff, local project coordinators, and state officials. Secondary sources of data informing our study include official project reports and documents from trainers, project coordinators, state-level data analysts, state officials, and mobile operators. The authors have taken part in meetings with major mobile operators in India and Malawi, including the operator chosen for a statewide implementation in Punjab (India).

Data analysis

The distinction between the four mHealth solution types emerged early in the data analysis, as strengths and disadvantages with each type became readily apparent. However, exactly how experiences with tradeoffs between

²The International Organization for Standardization: <http://www.iso.org/iso/home.html>.

solution types were to be synthesised was not straightforward. The empirical data was initially sorted according to each solution type's sensitivity to concrete factors like handset availability among the potential users, wireless network coverage, local mobile operator tariffs, and ease of mastery. *Data displays*, as described in [16], played a central role in the reduction, grouping, and presentation of our rich empirical material. Displays in the form of tables and graphical solution mappings along conceptual dimensions allowed us to explore tensions and trade-offs between emerging concepts (i.e., usability, robustness, flexibility, and cost).

A key ambition of DHIS-Mobile is to harness a global development and implementation team—with participants currently from Zimbabwe, India, Vietnam, Tanzania, Malawi, Uganda, Kenya, Zambia, Nigeria, and Norway. Earlier versions of the typology have been shared with fellow researchers, mHealth practitioners, and government officials involved with DHIS-Mobile, in order to facilitate project coordination and discussions about the mHealth solution space in different contexts. As the contribution of our research grew clearer, we assessed our findings through unstructured reviews of other mHealth projects' official web pages, project descriptions registered with emerging online mHealth forums (e.g., mHealth Alliance), and mailing lists (e.g., ICT4CHW).

From pilot to full-scale facility reporting

Pre-study of plain-text SMS solution in Andhra Pradesh

In order for the start-up DHIS-Mobile project to gain initial insights from an ongoing mHealth initiative, a short study of a plain-text SMS-based reporting system for Integrated Disease Surveillance & Response (IDSR) was conducted in February 2009. The solution was implemented in six districts in Andhra Pradesh (India). The solution supported weekly reporting of data through SMS with alpha-numeric codes. Data of the prescribed IDSR formats were sent from the reporting health workers to a server in the state capital. The codes included: facility ID; disease code; number of new cases; deaths; etc. The system sent automatic alerts to concerned officials whenever the frequency of particular events crossed pre-set threshold levels. From the study, the DHIS-Mobile team learned that the SMS codes were difficult to adhere to and created errors. Moreover, errors could not easily be identified before submission, nor could the health workers revise their data after submissions. Some of the users developed the practice of having colleagues help them out with the data entry during monthly health worker meetings, thus undermining the potential for timely mobile phone based disease surveillance.

Handset application for facility reporting in five Indian sub-districts

In May 2009, the Indian government initiated a pilot study wherein field nurses used mobile phone-based reporting of routine data from outreach services (e.g., antenatal care and child immunisation). The pilot was implemented in five sub-districts in five different states. The field nurses, also

called Auxiliary Nurse Midwives (ANMs), were given mobile phones with the DHIS-Mobile Java application installed. The application used SMS for data transport, but this was not apparent from user interaction with the application. GSM modems for receiving SMS were connected to offline servers at sub-district, district, and state level.

The user interface of the application was envisaged to simulate the paper formats in order to maintain the health workers' familiarity with the reporting function. More than 250 people were trained, including ANMs, medical officers, and state administrators. An evaluation of the pilot found that access to managers, medical officers, and colleagues through free calls within a Closed User Group (CUG), negotiated with the mobile operator, was one of the most cherished benefits reported by the field nurses.

Full-scale mobile reporting of routine data in Punjab

In the spring of 2010, based on a favourable assessment of the solution for the Indian pilot studies, the state of Punjab decided to strengthen their community-level HIS by introducing mobile phone based facility reporting. There are 2948 community health facilities in Punjab employing around 5000 ANMs, of which a large portion is middle-aged women. The health system in Punjab, servicing a population of 27 million, is distributed into districts, sub-districts, primary health centres (PHCs), and community health facilities (CHC). Computers and Internet connectivity are generally not available at PHC and CHC levels.

The state of Punjab decided to purchase and distribute Nokia 2330 Classic mobile phones for all the 5000 ANMs, as this handset supported the technical specifications and was within budgetary limits. An evaluation of the network signal strength in districts within Punjab led to the decision to use SMS as a transport rather than GPRS. A mobile operator was chosen based on requirements of a tariff plan, customer service, and network coverage in rural areas of Punjab. However, some ANMs have complained that the chosen mobile operator does not have sufficient network coverage in their catchment area. The Closed User Group (CUG) was a key part of the implementation concept in the Punjab roll out and was negotiated with the mobile operator to include free calls within the network and 200 free SMSes every month.

A team of ten HISP India employees installed the DHIS-Mobile Java applications with a user interface in the local language (Punjabi) on all 5000 handsets via Bluetooth over a period of one and a half months. The installation was done manually as the handset provider did not agree to factory install the application on the handsets, arguing that the order was too small. The application utilises only basic J2ME functionality, which allows it to be installed and run on most Java-enabled low-end handsets.

Filled reports can be stored and retrieved locally on the mobile phone and forwarded when reception of the mobile network is sufficient. The report is sent as a compressed (70% compression rate) SMS to two GSM modems located within the state capital of Punjab. In order to safeguard the functioning of the established paper-based routines for collecting, reporting and entering data into DHIS2, a parallel DHIS2 server instance was set up to handle reporting through mobiles. Health

information users can retrieve the mobile-reported data through a web interface with the DHIS2 server (Figure 2).

Encountered challenges of scaling

During the initial training period, the implementation suffered from technical issues due to SMS-overload. Many SMSes were lost as the GSM modems could not buffer enough of the SMSes and export them to the server fast enough. Furthermore, there were technical problems related to the sending of auto-confirmation messages back to the ANMs. For that reason, the ANMs would not know whether their reported data had been stored on the server or not.

There were also some initial complaints from ANMs that their prepaid balance was decreasing without them using the phones. The cause turned out to be that the ANMs had been purchasing ringtones, background images, jokes, etc., that was advertised by the mobile operator through mass SMSes. When ANMs overshot the balance, they were barred from using the SMS and calling functions of the phones, and hence could not report their data. ANMs with little or no prior experience with mobile phones found the application difficult to learn and use, while some older ANMs found it difficult to read and navigate the application on the small screens.

A substantial challenge to the smooth functioning of the solution was the unanticipated frequency of accidental deletion of the unprotected Java application. Despite HISP India's emphasis on local capacity building through trainings at state, district, and sub-district level on application use and functionality, the problem of handling application deletion was not part of the initial capacity-building strategy. Internet connections and computers are available at the sub-district level, but Bluetooth and the competence to install applications using Bluetooth are generally not. Thus, HISP India's support staff had to travel long distances in order to reinstall the DHIS-Mobile Java application on ANMs' mobile phones.

Most of the initial hiccups mentioned above have been resolved, apart from accidental application deletion, which is a recurrent problem partly due to the factory design of the options menu for non-native applications on the chosen handset. The state of Punjab has now requested the inclusion of more mobile phone based reports and additional features (e.g., birth and death registration, tracking of pregnancies and child immunisation, IDSR, and mass distribution of SMSes) to

use the full potential of the mobile phone as a two-way communication device between the state and the field nurses.

The vision of going paperless and facilitating all health facility reporting through the mobile phone has been a key driving force behind the state's initiative. However, ANMs will continue the parallel paper-based reporting until the reliability of the mobile reporting solution has been verified. Besides, the mitigation from two parallel servers to only one server is now challenged by differences in the two server installations. For the planned migration, several other features that will increase the flexibility of the solution will be considered, including upgrading the mobile subscriptions to GPRS and deploying a new client that can be updated more easily. Due to the initial choice of using only SMS as a transport, the new application may need to once again be installed manually on all 5000 handsets. To increase the flexibility of the solution further, the server could be hosted in the "cloud", but the non-domestic hosting of national health data remains a highly contested political issue.

GPRS-based Java application and mobile browser solutions

A malaria-tracking programme in Zambia uses DHIS-Mobile's offline capable Java client, with project-funded handsets and GPRS as the data transport. The project has rolled out the service to 450 health workers and is scaling with more health workers, and additional functionality. The use of GPRS has been efficient, although the project has requested fallback support to SMS for areas where GPRS coverage is low, despite operators' insistence that coverage is there. The project is also implementing automated reimbursement by topping up the credits of the health workers' mobile numbers when reports are received. This model also allows for reimbursing prepaid and private mobile subscriptions. The project is organised by the Malaria Control and Evaluation Partnership in Africa (MACEPA) at PATH, and contributes valuable input for future enhancements within the DHIS-Mobile action research network.

DHIS-Mobile has ongoing pilots using browser-based clients with GPRS in both Malawi and Himachal Pradesh, India. Due to cost constraints, the project in India is leveraging health workers privately owned mobile phones. Preliminary findings

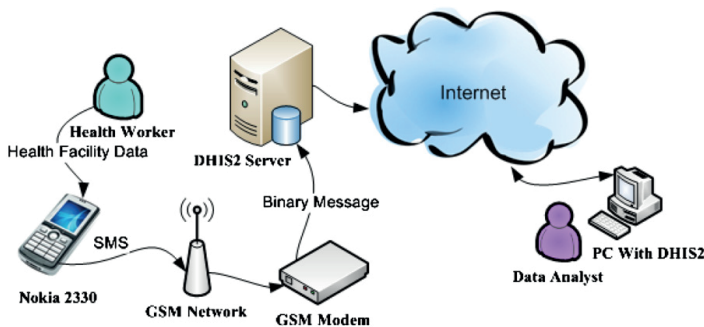


Figure 2 Mobile-supported Health Information System in Punjab.

suggest that the web browser solution does not support enough low-end handsets for a scale-up. Unstable GPRS coverage has also been a challenge with browsers lacking offline support.

An mHealth typology for low-resource contexts

This section presents the reference typology as a tool for manoeuvring in the space of possible mobile phone based solutions (Table 1). The reference typology consists of four distinct types of solutions, each suitable for different deployment situations. These are: interactive voice response (IVR); plain-text SMS; locally installed handset

applications (e.g., Java J2ME, Android, and SIM Toolkit); and browser-based solutions. In the typology, the locally installed applications are again divided into two sub-types based on the distinction between SMS and GPRS for data transport. The typology highlights strengths and disadvantages of each type along the four dimensions: robustness; flexibility; usability; and cost.

Working offline with robust solutions

During the Indian pilot studies, the servers were not connected to the Internet. GSM modems and SMS were used

Table 1 mHealth reference typology for low-resource contexts.

Solution type	Strength	Disadvantage
Interactive Voice Response	<p>R: Can be used from landline phones as well as mobiles</p> <p>R: Does not rely on mobile data coverage</p> <p>U: Does not require high levels of literacy</p>	<p>R: Requires mobile call coverage</p> <p>U: Complex use cases may be difficult to handle via IVR because of the lack of visual feedback</p> <p>C: Voice service infrastructure, which has higher costs than web</p>
Plain-text SMS (no application on handset)	<p>F: Can push information to users with unknown handsets</p> <p>F: All handsets support SMS</p> <p>U: High prevalence of SMS mastery in most contexts</p> <p>U: Easy to use for simple low-interactivity use cases</p>	<p>R: Requires mobile coverage</p> <p>F: Supports a limited array of simple use cases</p> <p>U: Users may need to learn short codes and keywords</p> <p>U: Requires literate users</p> <p>C: Robust SMSC connections can have a high upfront cost</p>
Mobile Applications (sub-categories below)	<p>R: Can store data locally and supports offline usage</p> <p>F: Easy to make more interactive applications for complex use cases</p> <p>U: Supports low literacy through images</p> <p>U: Can handle errors through interactive user interface</p> <p>C: Can compress data so that use is typically cheaper than plain-text SMS or browser</p>	<p>F: Compatibility issues between different handset models and platforms</p> <p>F: More complex to update than browser solution</p> <p>U: The application can be deleted by the user</p> <p>U: The application may be difficult to locate and navigate on certain phones</p>
<i>Application with SMS-based transport</i>	<p>R: SMS is more reliable than mobile data in low-coverage areas (disputed)</p>	<p>F: Installation procedure on large number of handsets can be time consuming and complex</p> <p>F: Difficult to update compared to GPRS</p>
<i>Application with GPRS-based transport</i>	<p>F: Application can be downloaded; thus easier to update and distribute</p> <p>C: Use of mobile data is generally cheap compared to SMS, depending on the local operator</p>	<p>F: Setup of mobile data on some handsets can be cumbersome</p> <p>C: May be difficult to control cost and limit mobile data usage for other services</p>
Browser-based solution (marked differences between phones)	<p>F: Easier to provide compatibility across many handsets and platforms</p> <p>F: Easier to upgrade application</p> <p>U: Supports low literacy through images</p> <p>U: Can handle errors through interactive user interface</p> <p>C: Use of mobile data is generally cheap and operator independent</p>	<p>R: Only high-end browsers have offline capability</p> <p>C: Requires more mobile data use than applications</p> <p>C: May be difficult to restrict mobile data usage for other services</p>

for data transports and server connectivity, thus taking advantage of the fact that mobile operators store undelivered SMSes in the network for later delivery. In contrast, GPRS solutions do not support data storage in the mobile network. Some areas in Punjab had poor mobile coverage, thus requiring a locally installed application with offline support for data entry and use. When leveraging handset applications, locally stored data can be effortlessly synchronised with the server as soon as the user reaches an area with network access. Solutions based on IVR or plain-text SMS require network coverage during use, with the exception that users can store SMSes on the handset as drafts for later submission.

In terms of usability, the ability to work offline with locally stored data is a necessity for more information-intensive work processes that require continuous data-capturing and data-revision over time. The usability of plain-text SMS solutions deteriorates dramatically with increasing amount of data capture and exchange. From the IDSR pilot in Andhra Pradesh we found that errors were frequent and could not be easily identified before report submission.

In general, a marked improvement in mobile data coverage would strengthen the argument for using GPRS rather than SMS as the data transport for application-based solutions, but we still hold that SMS may be more robust in areas with very weak signal strength. DHIS-Mobile and other mHealth projects like Pesinet in Mali are in the process of developing more robust application-based hybrid solutions capable of switching between SMS and GPRS for data transfers depending on the availability of wireless signals. Browser-based solutions on low-end mobile phones still have major drawbacks in terms of latency and lack support for offline work. As offline support is introduced on low-end mobile browsers, these solutions become more robust alternatives.

Solution flexibility in a dynamic development context

The complexity of a mobile phone based initiative increases with the number of handset brands and models the solution is required to support along with the speed with which these requirements change. When utilising locally installed applications on a variety of different handsets, a nearly unmanageable range of handset specific training material and manuals may need to be developed and frequently revised to accommodate new models. Thus, if the installed base of users' own handsets and mobile subscriptions need to be supported (e.g. due to financial constraints on handset procurement), cross-platform technologies such as browsers, plain-text SMS or IVR are favourable. In Punjab, a coordinated rollout of handsets was necessary in deploying the offline-capable Java application successfully across a large user base. The obvious drawbacks of handset procurement and distribution are costly up-front investments and potential loss of flexibility due to lock-in to the chosen handset brand or model.

The use of SMS as a data transport also tied the Punjab solution to specific service numbers. Coordinating the move from such numbers can be complex once they are widely in use. If for instance, the utilisation of GSM modems were to

be replaced by a direct link to the operator's SMSC,³ the service number would have to be reconfigured. Since the service numbers were configured on the phones, all applications would have to be reconfigured. Getting locked into service numbers reduce the flexibility of SMS as a data transport and hampers scaling across multiple mobile operators as well as the inclusion of more users. Both IVR and plain-text SMS solutions are generally characterised by lack of flexibility for the same reason.

The use of GPRS for installing applications, where this is a viable option, simplifies the application update process and increases the solution's flexibility for change. It also tackles the usability challenges caused by accidental application deletions. Using a browser eliminates the need to install and manage an application on the phone altogether, which in the Punjab case turned out to be work-intensive.

The double-edged sword of mobile operator agreements

Based on the smooth operation of the GSM modems in the Indian pilots, an evaluation of the network signal in Punjab, and financial considerations, it was decided that the full-scale implementation would utilise SMS with GSM modems for data transport and connectivity to the servers. However, SMS as a data transport caused instability and technical problems of data handling as the solution scaled. Using SMS for data transport also present additional costs and integration issues when scaling the solution across several operators. Arrangements with multiple operators may be necessary if the installed base of privately owned health worker handsets and mobile subscriptions are to be supported, or if the network coverage within the target area varies from operator to operator.

Cost control was a key argument against using GPRS as a data transport in Punjab, since it was difficult to restrict mobile data usage for post-paid subscriptions to only include communication with the project server. Most mobile operators can provide cost control for both voice calls and SMS. When the data volume is high, GPRS and mobile Internet can often be cheaper than SMS as a data transport, but only if misuse can be controlled and cost can be capped with the mobile operator. Including GPRS support for the Punjab solution will require a new round of application installations, increase the overall cost, and require a renegotiation of the agreement with the mobile operator.

The initial agreement with the operator included a CUG arrangement with free calls within the user group and cost free SMSes when using GSM modems. This prevented the project from considering a more costly and arguably more flexible SMSC-based infrastructure. Furthermore, reimbursement of mobile credits to users is generally simpler when working with only one mobile operator. Thus, the advantages of both CUG and reimbursement arrangements have contributed to creating a lock-in to the initially chosen mobile operator.

³The SMSC is the system in the operator network that handles SMS messaging. SMS can be sent and received through a mobile phone or by connecting directly to the operator SMSC.

An mHealth reference typology

Locally installed applications and browser-based solutions offer more use flexibility and better usability than IVR and plain-text SMS-based solutions, increasingly so with more complicated use tasks. However, the utilisation of a heterogeneous installed base of low-end handsets, which we currently see as unavoidable with fully scalable solutions in many low resource contexts, limits the usability even for browser- and application-based solutions. For low literate users, IVR may be the only viable mHealth solution type that works on a wide array of handsets in resource constrained contexts [23]. The reference typology (Table 1) classifies the strengths and disadvantages of each of the four solution types according to the four dimensions of the mHealth solution space: robustness (R); flexibility (F); usability (U); and cost (C).

In order to highlight some of the trade-offs between the solution types captured in the proposed typology (Table 1), Figure 3 positions the four solution types in a two dimensional solution space made up by the dimensions flexibility and robustness. Furthermore, the size of the ellipses represents each solution type's overall usability. A larger circle suggests a comparatively higher level of usability. Cost considerations are not captured directly in Figure 3.

Locally installed applications are positioned in the lower right quadrant to illustrate the solution type's lack of change flexibility, due to the challenges with updating this type of solutions. If GPRS is available and set up on the mobile phone, this can be used to download an application to the phone, perhaps by following a link sent by SMS from the solution server. However, the application update procedure is still more cumbersome and error prone than simply updating a server application and the new functionality being instantly available to all users through a web based

solution type. The application based solution type has been illustrated as a large ellipse in the diagram indicating that it is generally easier to cater for usability, due to application responsiveness and potential freedom for developers to create appropriate user interfaces. For a locally installed Java application, the main usability issues may be the difficulty in locating the application within the phone menu, the time it takes to start up the application and the possibility of accidentally deleting it.

The browser based solution type is represented in the upper left quadrant as its solution type robustness is hampered due to the lack of offline support. The arrow indicates how offline support, which is available on some smart phones, will draw this solution type towards the more desirable top right quadrant. Browser solutions may have some usability drawbacks, such as a potential latency to load each page and the user interface constraints given by a mobile browser.

The IVR solution is placed in the lower left quadrant. To some extent, IVR technology is flexible because menus can be changed on the server without requiring adaptations on the users' phones. The IVR infrastructure is however costly (not indicated in Figure 3) and also places certain limitations on use flexibility as it cannot guide users through complex tasks using graphics or other forms of visual feedback. IVR has one marked benefit in usability because it does not require literacy and may therefore be a good alternative in contexts where literacy rates are low.

The plain text SMS solution type is also placed in the lower left quadrant, but we consider it more robust than IVR because an SMS could be typed, stored and submitted later. SMS based solutions are relatively flexible for change; as it is possible to technically update the solution entirely from the server, but one could argue that the lack of interactivity limits the use flexibility. The necessity of training users whenever

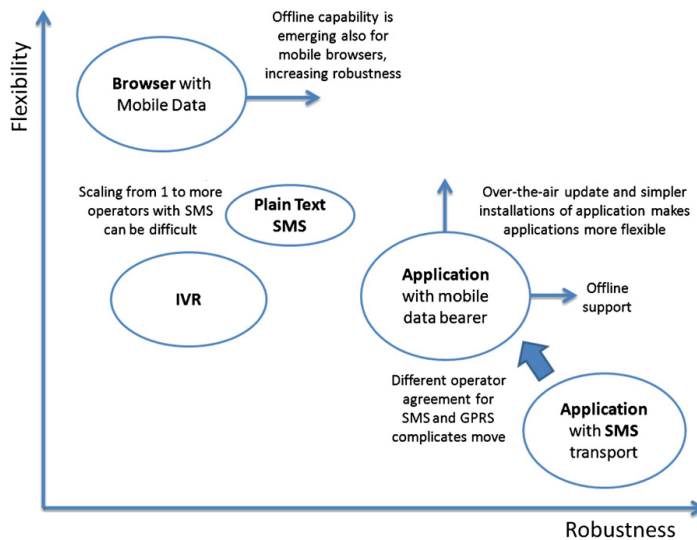


Figure 3 Trade-offs between solution type flexibility, robustness and usability.

there are changes introduced to the non-intuitive SMS commands should perhaps move plain text SMS solutions even lower, as shown in Figure 3, as it dramatically hampers the change flexibility. Plain text SMS solutions are typically not very user friendly, both because users must make sense of and remember structured commands, but also due to the lack of feedback mechanisms when entering the wrong data.

If cost was not an issue, the ideal solution would always be a bloated ellipse positioned in the top right corner—utilising maximum robustness and flexibility. The available infrastructure, human capacity and resources exercise limitation on the mHealth solution space and enforce trade-offs and tensions between the four dimensions robustness, flexibility, usability and cost. As low-resource contexts are continuously changing, mobile networks are improving, and handsets are gaining capabilities, the tradeoffs between the four dimensions for new implementations may diminish.

Conclusion

The lack of sustainability and scalability has been a serious problem with mHealth pilots in low-resource contexts [5,12]. We have proposed a reference typology, with the aim of identifying a set of dimensions and a vocabulary for the sharing of experiences in between ongoing projects, and assist initiatives in manoeuvring in the vast mHealth solution space in a dynamic development context. The typology identifies the strengths and disadvantages of each solution type along the four dimensions; robustness, flexibility, usability and financial cost. Furthermore, the paper demonstrates, through the concepts of path dependency and lock-in, how tensions between these four dimensions become more apparent, when pilot implementations are scaled up. As interventions are adopted, harnessed and become institutionalized they will be submerged into the existing information infrastructure, thus adding to the installed base inertia and possibly constraining future mHealth innovations and scale. Scaling is more than the mere replication of pilots across geographical areas or an increasing user base. Scaling may introduce growing complexity both technically and organisationally, which cannot easily be foreseen during pilots. As of now, the heterogeneity of privately owned handsets and the variability in network coverage and signal strength suggest that hybrid solutions, combining multiple solution types, may be required in order to scale in many low-resource contexts (e.g., locally installed applications that use both SMS and GPRS for data transport).

Early arrangement with mobile operators, choices about whether or not to support the installed base of health workers' own handsets, and whether or not to support offline work with data should be weighted carefully, due to potential long lasting implications of early solution type choices. We suggest that these issues should be explored through further research with particular focus on the possibility of lock-ins when going from pilot to scale. For instance, a key challenge is to facilitate a smooth transition from a donor driven pilot oriented relationship with mobile operators into a sustainable operation and a business model where the health ministry obtains capacity to assume ownership.

Ideally, mHealth interventions should extend and strengthen the national mainstream digitised HIS. For the

DHIS-Mobile project, the vision is to extend the backbone DHIS2 to the communities. Although the typology has proven useful for sharing knowledge and informing practice within one large action research network, we believe that the typology can be strengthened through systematic reviews of more mHealth projects. For more information sensitive applications, such as wireless transmission and electronic storage of individuals' health data, the typology needs to be extended with a fifth dimension, namely security. Ref. [18] offers a framework that explores security issues associated with different mHealth solutions.

Finally, it is important to recognise the inherent diversity of mHealth initiatives, even in between initiatives that utilise mobile phones in low resource contexts. Not all mHealth initiatives need massive scale in order to be useful and sustainable, although local capacity needs to be built to a level where it can regenerate itself, facilitate local innovation and share experiences within a larger network of action. The proposed typology is one way of unpacking and exploring the mHealth diversity. However, the mHealth solution space may also be differentiated and explored according to application domains (e.g. monitoring, evaluation and patient tracking, electronic health records, public health awareness, clinical decision support, patient reminders, stock monitoring). Further research is needed in order to understand the challenges and needs for sustainability and scalability within these different mHealth domains. In order to strengthen the management and evaluation of mHealth initiatives, so that scarce health care resources are not wasted, the proposed typology or other ways of unpacking mHealth may be of assistance in illuminating in what ways different initiatives are comparable.

References

- [1] Arthur WB. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal* 1989;99(394): 116-31.
- [2] Berg M. Implementing information systems in health care organizations: myths and challenges. *International Journal of Medical Informatics* 2001;64(2-3):143-56.
- [3] Braa J, Monteiro E, Sahay S. Networks of action: sustainable health information systems across developing countries. *Management Information Systems Quarterly* 2004;28(3):337-62.
- [4] Chetley, A, editor. Improving health, connecting people: the role of ICTs in the health sector of developing countries. A Framework Paper. Infodev; 2006.
- [5] Curioso WH, Mechael PN. Enhancing 'm-health' with south-to-south collaborations. *Health Affairs* 2010;29(2):264.
- [6] Donner J. Research approaches to mobile use in the developing world: a review of the literature. *The Information Society* 2008;24(3):140-59.
- [7] Hanseth O, Monteiro E, Hatling M. Developing information infrastructure: the tension between standardization and flexibility. *Science, Technology & Human Values* 1996;21(4):407-26.
- [8] Hanseth O, Aanestad M. Bootstrapping networks, communities and infrastructures: on the evolution of ICT solutions in health-care. *Methods of Information in Medicine* 2003;42:385-91.
- [9] Hanseth, O, Monteiro, E. Understanding Information Infrastructure; 2004. Retrieved from <<http://www.ifi.uio.no/oleha/Publications/bok.html>>.
- [10] Hanseth, O. From systems and tools to networks and infrastructures—From design to cultivation. *Towards a Theory of ICT Solutions and its Design Methodology Implications*; 2002.

- Retrieved from http://www.ifi.uio.no/~oleha/Publications/ib_JSIR_3rd_resubm2.html).
- [11] Kaplan WA. Can the ubiquitous power of mobile phones be used to improve health outcomes in developing countries? *Globalization and Health* 2006;2(1):9.
- [12] Lemaire, J. Scaling up mobile health: elements necessary for the successful scale up of mHealth in developing countries (White paper). *Advanced Development for Africa*; 2011.
- [13] Lippeveld T, Sauerborn R, Bodart C, editors. *Design and implementation of health information systems*. Geneva: World Health Organization; 2000.
- [14] McNamara KS, McNamara Kerry S. *Information and communication technologies, poverty and development: learning from experience*. Washington D.C., USA: World Bank; 2003. Retrieved from.
- [15] Mechael PN. The case for mHealth in developing countries. *Innovations: Technology, Governance, Globalization* 2009;4(1): 103-18.
- [16] Miles MB, Huberman AM. *Qualitative data analysis: an expanded sourcebook*. SAGE Publications, Inc; 1994.
- [17] Nielsen J. *Usability engineering*. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc; 1994.
- [18] Olla P, Tan J. Designing a m-health framework for conceptualizing mobile health systems. *International Journal of Healthcare Information Systems and Informatics (IJHISI)* 2008;1(2):1-19.
- [19] Ranjini CR, Sahay S. Computer-based health information systems—projects for computerization or health management? *Empirical experiences from India Medical Informatics: Concepts, Methodologies, Tools, and Applications*. IGI Global Publications; 2005. [chapter CV].
- [20] Rashid AT, Elder L. Mobile phones and development: an analysis of IDRC-supported projects. *Electronic Journal of Information Systems in Developing Countries* 2009;36(2):1-16.
- [21] Rodrigues RJ. Information systems: the key to evidence-based health practice. *Bulletin of the World Health Organization* 2000;78(11):1344-51.
- [22] Sahay S, Walsham G. Scaling of health information systems in India: challenges and approaches. *Information Technology for Development* 2006;12(3):185-200.
- [23] Sherwani J, Palijo S, Mirza S, Ahmed T, Ali N, Rosenfeld R. Speech vs. touch-tone: telephony interfaces for information access by low literate users. In: *Proceedings of the IEEE/ACM international conference on information and communication technologies and development*; April 2009. p. 447-57.
- [24] Stansfield, SK, Walsh, J, Prata, N, Evans, T. Information to improve decision making for health. A Custom Publication of the Disease Control Priorities Project; 2006. p. 157.
- [25] Susman G, Evered R. An assessment of the scientific merits of action research. *Administrative Science Quarterly* 1978;23(4): 582-603.
- [26] Wilson R. Using computers in health information systems. In: Lippeveld T, Sauerborn R, Bodart C, editors. *Design and implementation of health information systems*. Geneva: World Health Organization; 2000. p. 198-212.

Bootstrapping Information Technology Innovations Across Organisational and Geographical Boundaries: Lessons from an mHealth Implementation in Malawi

Tiwonge Davis Manda

University of Oslo and University of Malawi
tiomanda@gmail.com

Terje Aksel Sanner

University of Oslo
tasanner@gmail.com

Abstract. This paper informs the theoretical concept of bootstrapping, by highlighting intra and cross-organisational socio-technical factors that interplay with the implementation of information technology innovations. We draw on bootstrapping as an analytical tool to highlight risks inherent in multi-stakeholder relations and how they hamper or facilitate innovation. Thus far, scholarly contributions shaping the bootstrapping concept, as well as empirical investigations employing it as an analytical lens have focused on efficient utilization of resources to maximise growth in user adoption of novel solutions; the significance of mutual learning, throughout the evolution of novel solutions; and complexity mitigation in contexts where heterogeneous user groups, work practices and information technology solutions need to be supported.

Keywords: Bootstrapping, socio-technical, tensions, cross-organisational.

1 Introduction

In relation to the implementation of information systems, organisations need to negotiate a multiplicity of socio-technical factors that are both within and outside their immediate control. This is particularly evident within the context of health information systems implementation in less developed economies, which involves multiple stakeholders, across organisational and even national boundaries. Some risk factors common to information technology implementations include: diverging logics and interest between a multiplicity of stakeholders and user communities; management and alignment of stakeholder relationships; speed of change in information technology infrastructure evolution; lack of locally trained skilled personnel, who could act as boundary spanners, which results in over reliance on external consultants; and failures in external dependencies (Schmidt et al., 2001). Organisational culture has also been suggested as a significant factor affecting the implementation of information systems and organisational change (Scott and Vessey, 2002). Mitigation of these challenges to successful implementation of novel solutions requires effective management of technology, human arrangements, and institutional resources (Ribes and Finholt, 2009). It is also important, among other things, to understand how risk factors relate and the trade-offs or contingencies among risk factors (Scott and Vessey, 2002).

Various studies have proposed systems implementation strategies to try and manage risks related to information systems implementations (Schmidt et al., 2001; Scott and Vessey, 2002; Hanseth and Aanestad, 2003; Ribes and Finholt, 2009). Ribes and Finholt (2009) argue that development of information technology solutions must focus on both immediate and long-term goals, align stakeholder interests, and stimulate continued user contribution. Hanseth and Aanestad (2001; 2003) propose *bootstrapping* as an implementation strategy and analytical lens to guide negotiation of take-off challenges in the development of large-scale information systems or information infrastructures. The strategy addresses challenges of reaching a momentum of user adoptions of novel information technology solutions. Momentum is considered a stage of implementation where the initiative is self sustaining, with little or no assistance (i.e. technical expertise, funding) from external stakeholders. Identification of the right point of entry to maximize resource utilization, promote innovation through mutual learning, and initially mitigate complexity is essential to the bootstrapping process. This is so because solution implementations involve a multiplicity of stakeholders, work processes, and technological solutions that interplay with solutions being implemented. It is critical that novel solutions should minimize contradictions with the existing socio-technical setup (Hanseth and Aanestad, 2001; Hanseth and Aanestad, 2003; Skorve and Aanestad, 2010). Use and application of bootstrapping as an analytical lens has evolved over the last decade. Hanseth and Aanestad (2001) use bootstrapping with a focus on resource maximisation to raise the growth momentum of novel solutions. Hanseth and Lyytinen (2004) emphasise learning, from an ongoing implementation, to evolve and build up the solution under implementation. Skorve and Aanestad (2010) use the concept to analyse the need for complexity mitigation in the introduction of a technological solution aimed at supporting multiple groups of medical personnel, as well as medical practices with varying levels of complexity and criticality.

This paper contributes to the concept of bootstrapping, by highlighting risks inherent to implementations characterised by cross-organisational reliance between stakeholders, and other factors that interplay with the implementation of technology innovations in the public health domain in a developing economy. Empirical evidence for this paper has been obtained through ongoing mobile information technology for health (mHealth) pilot implementations, for monthly routine data reporting (i.e. health management information systems) in Lilongwe, Malawi. The pilot is funded by the MobiHealth project at the University of Oslo, has the Ministry of Health in Malawi, as its host organisation. Ongoing implementation efforts have also been shaped and affected by characteristics of mobile services delivered by major telecom operators in Malawi. Furthermore, lack of relevant technical competence within the Ministry of Health's and reliance on players external to the ministry, for information technology related support is another factor that stresses the relevance of cross-organisational relations. The majority of studies applying bootstrapping as an analytical lens have studied implementations in developed economies and in organizations where the uptake of information technology innovations has not perceived as mandatory or centrally legislated (Skorve and Aanestad, 2010).

2 Literature Review

mHealth, as a field, grows out of the convergence of mobile and desktop health information systems, as well as people and healthcare processes, facilitated by both wired and wireless

connectivity (Yu et al., 2006). As such, multiple system development and implementation issues need to be understood and continuously investigated to enhance the continued adoption and use of mHealth solutions. Among others, such issues include healthcare workers' information needs, workflow and usability requirements, available technology options, and how best technology can be adapted to suit these needs and requirements (ibid). This multiplicity of interacting factors is not unique to mHealth, but affects various technological innovation implementations. There have been a number of studies outlining and attempting to rank risk factors affecting information system implementations (Schmidt et al., 2001; Heeks, 2002; Scott and Vessey, 2002). Despite sharing risks considered generic to all technological innovations, mobile technology-related innovations, such as mHealth, require additional attention due to their current novelty and rapidity of change.

There are many examples of failures in implementing ICTs in developing economies, and challenges remain on how to address such difficulties (Walsham and Sahay, 2006). Many of the barriers to and gaps in mHealth scale and sustainability result from limited knowledge of what works, how it works, and how much it will cost (Mechael et al., 2010). Although it is hard to confidently claim that implementation of technological innovations in developing countries results in more success or failure rates, some studies point out factors that might result in more failure rates in developing countries. Heeks (2002) points at lack of technical and human infrastructure as key contributing factors. There is also evidence on technological innovations in developing economies being overly reliant on external financial and technical support (Lucas, 2008), and thus prone to collapse as soon as external interests are withdrawn.

2.1 Bootstrapping Technological Innovations

Bootstrapping (Hanseth and Aanestad, 2001; Hanseth and Aanestad, 2003) has been proposed as a strategy to address the problem of initiating and institutionalising technological innovations. Here institutionalisation refers to having a particular information technology solution achieve stability, becoming transparent and embedded in users' work routines, within an organisation (Silva and Backhouse, 1997). Building stable information technology solutions that ably support productivity of user communities involves continuous practical work, as solutions evolve. Dimensions of practical work at play during inception and evolution of large-scale information systems or information infrastructures include organisation of development and implementation work, solution institutionalisation, and technology enactment (Ribes and Finholt, 2009). Though critical to uptake and institutionalisation of new solutions, these dimensions of practical work are not all there is to the development of sustainable information technology solutions. There are concerns that must be pursued to enhance chances of sustainability. Ribes and Finholt (2009) argue that information technology solution developers must provide solutions that are of immediate relevance to the user population, align divergent and competing goals between stakeholder, and motivate continued user contribution. The intersection of practical dimensions of information technology solution development work and concerns for long-term sustainability give rise to a multiplicity of tensions that must be mitigated to have in place stable solutions (ibid). This involves experimentation to enable learning. Multiple competing path-ways to resolving emerging tensions also need to be employed. Navigation of such can benefit from the bootstrapping strategy.

Bootstrapping is about initiating and managing technological innovations until self-reinforcing mechanisms have emerged through extended adoption and use. It is a strategy for identifying and managing trade-offs between competing options for managing implementation challenges. The strategy advocates an incremental approach to implementing technological innovations. Hanseth and Aanestad (2001) argue that implementation of novel solutions should aim for immediate usefulness to an initial small base of early adopters, promote learning from ongoing implementation efforts, start with supporting less critical and less complex routines, and then actively expand the user base and the scope of the solution to handle more complex and critical tasks (Hanseth and Aanestad, 2001). This is bound to lessen contradictions with existing organisational socio-technical arrangements, which can adversely affect ongoing solution implementation efforts (Hanseth and Aanestad, 2003; Aanestad and Jensen, 2011). Furthermore, adoption must initially be promoted amongst what can be identified as the most motivated of potential users. The strategy advocates designing for immediate use, promoting usage through persuasive tactics, and building new innovations on a growing installed base, rather than contradicting it, as key to manage challenges related to initiation and institutionalisation of information technology innovations in organizations. Below is a presentation of the strategy, as an algorithm, by Hanseth and Aanestad (2001):

- “ 1. Start by designing the first, simplest, cheapest solution we can “imagine and which satisfy the needs of the most motivated users in their least critical and simplest practices and which may be beneficial by supporting communication and collaboration between just a few users.
2. use the technology and repeat as long as possible: enrol more users
3. if possible: explore, identify and adopt more innovative (and beneficial) ways of using the solution, go to 2
4. use the solution in more critical tasks, go to 2
5. use the solution in more complex tasks, go to 2
6. improve the solution so new tasks can be supported, go to 2”

It is important to note, as a limitation to the current theoretical development of the bootstrapping concept, that it has been drawn on to theorise user adoption in organizational contexts where adoption and use of new information technologies are at least partly optional or resistible by the end users. Furthermore, scholarly analysis of bootstrapping technological innovations in health care have mostly emphasised the influence of internal organisational arrangements on implementation efforts. Where interplay between cross-organisational entities has been reflected upon (Hanseth and Aanestad, 2003; Aanestad and Jensen, 2011), it has been in a context where stakeholders have more or less similar goals, albeit with different tactics for managing implementation complexities (Skorve and Aanestad, 2010). This leaves a gap in existing literature when it comes to exploring the potential of applying bootstrapping as an analytical lens to study information and communication technology implementations that rely on commitment from multiple stakeholders, across economic sectors (e.g. public, private, non-governmental organizations), geographical boundaries, and with different financial capacities, outlooks and interests.

3 Methodology

Data for this paper has been drawn from an ongoing action research (Avison et al., 2001) study in Malawi, aimed at implementing mobile phone-based solutions for monthly routine health data reporting, from health facilities to a district health office in Lilongwe. The action research approach is aimed at pairing interventions to solve existing organisational problems with careful reflections on the interventions to contribute to knowledge (Davison et al., 2004). Such an involved and inherently critical approach to research also allows in-depth access to people, issues, and data (Walsham, 2006).

Principal data collection methods include semi-structured interviews, focus group discussions, and three training sessions on the mobile phone solutions being piloted. Key informants for the study include medical officers, health surveillance assistants (salaried community health workers), and statistical clerks, from health facilities taking part in our pilots. Statisticians, for the national health management information system, at district health office and ministry of health levels, have also provided valuable information through participation in our pilots. In particular, the researchers have conducted meetings with ministry of health representatives at the national and district organizational level, in order to facilitate ministerial ownership and involvement of the implementation. Interactions with the MobiHealth research team in Oslo, as well as software developers in Norway and Vietnam have also provided valuable insights. These interactions have been facilitated by face-to-face meeting, exchange of emails, and conference calls. The mobile service operator providing the telecom services required for the two pilot implementations we are running, have also played a central role in the implementation and several meetings between both the researcher and various representatives of the operator have taken place on an ad-hoc basis. Naturally occurring data like national health management information system (HMIS) policy documents, status reports, yearly HMIS feedback reports from districts to facilities, registers and hand drawn graphs and tables of analyzed data at the facilities, and photographs of existing technologies physically present at the health facilities (e.g. radio communication equipment, solar panels, personal mobile phones, ground phones etc.) have served as a secondary source of information to the study. Finally, personal reflections on the role of the researchers, one being a Malawian national and the other a Norwegian, in the ongoing pilots and empirical data generation inform this paper. The Malawian researcher is the lead investigator in the ongoing pilots and finds himself very much at the center of coordinating the pilots and interacting with key stakeholders.

Interviews were mostly conducted during visits our team made to several health facilities, under Kabudula and Area 25 health areas in Lilongwe district. There are a total of nine health facilities in Kabudula health area and eight health facilities in Area 25, of which all are enrolled in the pilot studies. The main purpose of the initial visits at health facilities were to gather baseline data on existing paper-centric data gathering and reporting practices, existing feedback mechanisms, and data utilization to guide decision making at health facility level. This was mainly done between September 2011 and December 2011.

Training sessions for would-be users on the solutions under pilot were mainly conducted in December 2011, February 2012, and March 2012. The trainings had three stages. Firstly, we conducted focus group discussions, with participants, covering topics such as existing paper-centric routine health data collection and reporting practices, data use at health facility level. We also discussed what sort of feedback health facilities get from the district health

office, if any, on monthly reports they submit. Secondly, we had hand-on training on the DHIS Mobile solutions under pilot. The third part of the training was a feedback session on all matters covered during the training. This was done through another round of discussions and completion of pre-designed feedback forms. The feedback form asked the respondents to evaluate the training, reflect on the strengths and weaknesses of mobile reporting vis-a-vis paper based reporting, and to suggest possible functional enhancements to the mobile based solution. All interviews and focus group sessions were audio recorded. Selected parts of the extensive audio material was transcribed and coded by each of the researchers separately to allow for subsequent negotiation of shared interpretations. For the most part, our analysis of empirical material has been guided by the concept of bootstrapping. We have analysed case material to highlight conformance to, and deviance from, the bootstrapping strategy, as presented by Hanseth and Aanestad (2001).

4 Empirical Case

As mentioned earlier, this paper draws on experiences from pilot implementations of District Health Management Information System 2 (DHIS2) Mobile solutions for routine health data reporting, in Lilongwe, Malawi. DHIS2 is a generic server-based solution for collection, validation, analysis, and presentation of aggregate statistical data, tailored (but not limited) to integrated health information management activities. The software is developed by the Health Information Systems Programme (HISP), a global South-South-North network active in various countries in Africa and Asia. Core developers for the software are globally distributed and come from India, Ireland, Norway, Vietnam, and Tanzania. DHIS Mobile is an extension to the DHIS server solution, permitting data reporting and access from mobile devices.

In Malawi we are piloting two DHIS Mobile reporting solutions for monthly aggregate data reporting, across 17 health facilities. One solution is web browser-based and the other is a Java DHIS2 reporting client, installed on mobile devices. For the pilots we have chosen two monthly reports, the Health Management Information System-15 (HMIS-15) and Integrated Disease Surveillance and response (IDSR) summary reports. The HMIS-15 is a summary report for all health programmes in Malawi. The goal of the project is to investigate issues surrounding the use of mobile phone-based data reporting in a low resource context, and the feasibility of replacing paper-based reporting by health facilities. The existing paper based reporting flow is compromised by seasonal challenges of transportation on muddy roads, shortages of fuel, and occasional inadequate supplies of data forms at the health facilities. The district where we are doing our pilots is subdivided into five health areas. Our pilots are currently running in two.

The HMIS setup in Malawi is paper-dominated. Computer-based tools like DHIS are predominantly implemented at District Health Office and Ministry of Health levels, and not health facilities. Health facilities, therefore submit paper-based forms to a district health office, where the data is entered into computer systems. Health facilities report on in-facility and community outreach service data, to the Ministry of Health, through district health offices. In-facility service data is collected and compiled by medical practitioners. Health facilities also have salaried community health workers (Health Surveillance Assistants) responsible for primary health outreach activities, within designated communities. In some cases the Health Surveillance Assistants (HSAs) are responsible for community based health programmes, such as community-based maternal and child health. At the end of each month, HSAs are supposed to compile reports on services they have provided within that month.

These reports are then submitted to an HSA supervisor at the health facility. At health facility level, different medical officers are generally responsible for aggregating data for particular health programmes. This is mostly done at the end of each month or quarterly, depending on set requirements for data reporting.

This setup has existed and matured with the health information system setup in Malawi. As such, current practices and roles of various practitioners, with regard to data collection, storage, reporting, analysing and sharing, of various officers at each level of the health sector are centred on paper-based tools and paper based work flows (e.g. paper register, paper forms, hand written signatures on verified reports). Some of the concerned practitioners with direct roles in the paper based workflow include HSAs, medical practitioners, health facility officers in charge as well as statistical officers and programme managers, at district health offices. In relation to HMIS data the established practice has been for health facilities to designate their own focal person, preferably an individual with qualifications and interests towards collecting, tallying and to some extent analysing data. Recently some facilities have been assigned with statistical clerks with the responsibility of filling registers and doing monthly tallying. However, since their employment, more than a year ago, they have not received any formal training – due to challenges for the ministry to secure funding for conducting training.

4.1 Multi-stakeholder Involvement

The pilots involve multiple stakeholders with varying interests and priorities. Key players include health personnel at health facility level, officials and managers at district health office level, the ministry of health headquarters, the University of Oslo's MobiHealth project, mobile service providers in Malawi, the DHIS implementation team based at the Malawi College of Medicine, and a team of postgraduate students who are leading the implementation. The DHIS implementation team is responsible for all DHIS2 implementation and maintenance related tasks, which among others include system customisation, management of the national DHIS2 server, and end-user training. The team is also responsible for managing data importation from DHIS 1.3 into DHIS2, to aid migration from DHIS 1.3 to DHIS2. The Ministry of Health does not have sufficient IT expertise to manage the national DHIS server and other mundane IT tasks. In fact, the ministry of health, like health ministries in many other countries, relies on a different government agency for IT support. The ministry of health headquarters, the epitome of health data management in Malawi only has one resident IT officer, in the professional grade. The team of postgraduate researchers is responsible for managing the DHIS Mobile pilot project in Malawi. Among other things, the team is responsible for end-user training, providing technical advice on ongoing DHIS2 rollout activities in Malawi, and research.

4.2 Pilot Setup, Solution Heterogeneity and Associated Complications

At the moment the majority of district health offices in Malawi use DHIS 1.3, a legacy desktop software solution. The ministry of health headquarters, though, is pushing for a country-wide rollout of DHIS2. However, despite such efforts, the Ministry of Health headquarters is yet to start using DHIS2 for data management and analysis. This is despite the setup of a national DHIS2 online server, the commissioning of DHIS2 pilots in two districts, and active efforts to roll-out DHIS2 in all of Malawi's 28 districts. It is therefore imperative that all district health offices submit reports, to the ministry, in a DHIS 1.3 compliant format.

This has resulted in a situation where our pilot district has a challenge on how to move forward. For example, the Assistant statistician at district health office level gets data on paper-based reports from three health areas and data through DHIS2 (submitted through mobile phone reporting), from two health areas. As if this is not enough, the pilot district has been trying to migrate to DHIS 2, but the assistant statistician is required to send data to her superiors at the Ministry of Health headquarters, in a DHIS 1.3 compliant format.

An interview with the Deputy Director under the Central Monitoring and Evaluation Division and an assistant statistician at the Ministry of Health headquarters revealed multiple reasons for the failure, thus far to completely shift to DHIS2. Firstly, the statistician indicated that only data up to June 2011 had been imported to the online DHIS2 server. Importing data from DHIS 1.3 is not a straight forward task and members of the DHIS team, who are able to perform the data importing, are located in Blantyre, about 300 kilometres away from the Ministry headquarters. In as much as data can be sent over the Internet, geographical distance negatively impacts effective communication and prioritisation of issues. Secondly, the two officers indicated that the facility at the ministry of health headquarters has regular problems with Internet connectivity, which would make it hard for officers and statisticians to access the online DHIS2 server. The assistant statistician indicated that in the recent past their office had no Internet connectivity for about six months. On the other hand, when working with DHIS 1.3, a desktop-based system, the statisticians only require occasional Internet access, to retrieve data export files sent in by district health offices. These Internet based data transactions are usually done while visiting other people's offices in the ministry.

4.3 Pilot Timelines

Efforts related to the mobile pilot projects started during the second half of 2011, with consultations between a team of researchers from the University of Oslo, the Ministry of Health and Lilongwe District Health Office. The discussions were meant to establish goals and scope of the DHIS2 Mobile pilots. Through the discussions, it was agreed that we run a pilot of the mobile phone-based reporting solutions in all health facilities in Lilongwe district. This was then followed by visits to some health facilities earmarked for the pilot to document existing data collection and reporting practices, as well as data utilisation practices.

At the beginning of November, our plans for the pilot were revised from a somewhat big bang approach (rolling out to all health facilities in Lilongwe at once) to a phased approach (rolling out the solution to one health area, at a time). Trainings and solution roll-out for the two health areas taking part in the pilot were initially scheduled for the first week of December 2011. However, set dates for the training had to be revised several times, before being postponed for a couple of months. We were unable to get Internet packet data services to work on the first batch of Nokia C2-00 mobile phones we had bought for the pilots. The phones could not receive packet data configurations that are automatically sent by local mobile service providers. The configuration problem was also compounded as Nokia C2-00 mobile phones do not support manual Internet data service configurations, something most earlier models of low-end Nokia phones had supported. We therefore tried to create Internet configuration provisioning files, using various online services, and push them to the phones using Bluetooth. This also did not work. The phones were not purchased locally, and they are not widely available in the Malawian handset market. We had to send them back to India, from where they were brought. We then bought nine Nokia C1-01 phones locally, to allow

implementation in one health area to proceed. After this, an additional 16 Nokia C1-01 phones were purchased from Norway, for piloting DHIS Mobile in the second Health area. Decisions to purchase phones outside Malawi were project cost related. Management of the MobiHealth project, in Oslo, supported the idea of purchasing phones in India, because the phones cost \$50 there, as compared to \$80 in Malawi, which makes a difference when the project is intended to potentially scale to encompass 500 health facilities in Malawi. Although there was initial saving in the purchase of phones, the piloting was delayed by a couple of months due to the use of phones whose compatibility with the local context, specifically the support for configuration of the C2-00 by the leading mobile operator in Malawi, had not been verified.

4.4 Implementation-related decisions and associated implications

As has been already indicated, health facilities submit reports to the ministry through district health offices. In our pilot district, the assistant statistician dealing with HMIS-15 reporting and the district IDSR officer had no dedicated Internet connection, in their office, prior to the commencement of our DHIS mobile pilots. With DHIS 1.3 and another desktop IDSR system, the two officers could do without having a dedicated Internet connection. They were the sole gateways between paper-based monthly reports and the mentioned computer systems. After entering data into their systems, the officers would carry USB-sticks and use a different office, about 50 meters away, to email export data files from their desktop systems to the ministry of health headquarters. With the implementation of the pilots, 17 health facilities now mostly send HMIs-15 reports directly into the national DHIS 2 online server. Data reporting into DHIS 2 therefore leapfrogs the two officers, as a different path for data digitisation has opened. It has therefore become imperative that these officers get Internet connectivity so that they are not kept out of the data reporting flow. They are the formal institutional gateways for data reporting, from health facilities to the district health office.

4.5 Issues with mobile service delivery

To enable health facilities to use packet data for submission of reports, as well as enhance voice-based communication, we acquired post-paid mobile phone subscriptions for all health facilities taking part in our pilots. It was also our intention to maintain the possibility of reviewing statistics of Internet data usage volumes throughout and after the pilot phase. The mobile operator will only maintain logs of Internet use if for phone numbers registered with a post paid subscription. The agreement with the mobile service provider, as early as November 2011, was to have voice-based calls capped at MWK 1500 (~\$9 at the time of implementation) per month per phone number. However, the mobile service provider only got to cap the voice calls midway through March 2012, five months down the line, even though we had made a number of visits to their offices to have this resolved. The failure to cap the numbers resulted in some phones registering high phone bills. We had informed users that they would not be able to make any more outgoing voice call within a month, if they had reached the MWK 1500 mark. Interruptions in Internet service coverage, in some areas, have at times negatively impacted data reporting and its timeliness. At some point, we even advised personnel from one health facility to use a different mobile service provider.

4.6 Other Key External dependencies

Key software development personnel for DHIS Mobile are in Norway and Vietnam, and their attention is directed towards a broader range of DHIS Mobile implementations in various countries, with a main focus on providing generalised solutions to emerging problems. This means that certain challenges that need prioritisation for the Malawi pilots are not treated with the urgency implementers on the ground, in Malawi, would like. Sometimes, the global development team might not have solutions immediately available, even when they have prioritised certain issues. For example, between the first health area rollout and the training for the second health area we had upgraded the server in Malawi from DHIS 2.6 to 2.7. It was however discovered that a bug in DHIS 2.7 prevented the DHIS2 java client from working. Our plan was to use the java client under area 25 health area. We were therefore forced to roll-back to DHIS 2.6, because by the time of the training the bug had not yet been fixed. DHIS2 Mobile is fast evolving to accommodate various contexts of implementation, which include India, Malawi, and Tanzania, among others. This contradicts the proposition by the bootstrapping strategy to not rely on emerging technologies. Rapid development work also stretches available human resource between development of new functionality and maintaining existing functionality, as well as responding to needs from various implementation contexts.

4.7 Utilisation at Feedback Mechanisms

Meetings with medical personnel at health facilities and focus group discussions conducted during training sessions on mobile phone-based solutions being piloted, reveal the lack of extensive utilisation of data at health facility level. Informants indicated that they hardly have monthly data meetings to discuss collected data. We were informed that these meetings used to take place sometime back, under a World Bank funded project, but died out after the project and external funding had folded. According to informants, reasons for lack of data review meetings include: lack of adequate data analysis skills; lack of motivation by some officers in charge and the discontinuation of allowances associated with health facility meetings through the World Bank funded initiative. Beyond data utilisation, our interactions with the health information system setup in Malawi have shown that health facilities hardly get feedback on data they submit to district health offices. These shortcomings are a threat to the sustainability of any efforts to strengthen the national health information system, as very little can be achieved if the existing organisational culture does not appreciate the analysis of collected data to inform decision making.

5 Analysis and Discussion

The empirical case in this paper demonstrates that bootstrapping technological innovations requires coordination of efforts across organisational and geographical boundaries. The case, presents various organisational factors under the Ministry of Health, the Lilongwe district health office, and health facilities that need to be negotiated to enhance uptake of the mHealth solutions being piloted. Also highlighted are actions of other key stakeholders such as the MobiHealth project and the DHIS implementation team in Malawi, among others. Knowing this, we decided early on in our implementation efforts to use bootstrapping as a sensitising

lens to minimise implementation related risks. Although this is so, our case demonstrates aspects that both comply with, and deviate from, the bootstrapping concept.

5.1 Following the Bootstrapping Path

Our DHIS Mobile pilots were preceded by efforts to understand existing data collection and communication work practices, as well as gain buy-in from key stakeholders, such as the Ministry of Health, Lilongwe District Health Office, and personnel from health facilities. We also sought to understand existing communications infrastructure and its influence on paper-based data reporting, and potential influence on our pilots. This helped us better place our solutions for increased relevance and reduced contradiction with the installed base. For example, our solutions address important user needs such as the need to circumvent transportation challenges and lack of stationery at the facilities, by enabling remote data reporting. Our understanding of the implementation context also made it possible for us to provide participants in our pilots with mobile phones capable of supporting Internet data. We were also able to provide Internet dongles at health area office and district health office levels. In doing this we have kept key traditional gatekeepers in the paper-based setup within the loop, despite health facilities submitting reports directly to an online server.

These steps correspond to the bootstrapping strategy's recommendation to as much as possible build on the installed base, rather than contradict it (Hanseth and Aanestad, 2001; Hanseth and Aanestad, 2003; Skorge and Aanestad, 2010). Furthermore, the logic followed here corresponds with observations from related research that mHealth involves the convergence of heterogeneous components such as desktop health information systems, people and healthcare processes, healthcare workers' information needs, available technology options, and how best technology can be adapted to suit these needs and requirements (Yu et al., 2006).

Our pilot strategy also aligns with the bootstrapping strategy in that we have started by supporting a critical, but less complex task of monthly routine health data reporting. Monthly reporting of routine health data is vital to health service delivery, which makes our solutions immediately relevant to stakeholders at various levels of administration. Introducing the use of mobile phones mainly as a data transportation mechanism means does not require radical changes in the way people work, to accommodate the solutions under pilot. The current use of mobile phones for data reporting mostly compliments, rather than contradict existing socio-technical arrangements for data communication.

The decision not to go ahead with a big bang approach, where we would have rolled out to all health facilities in Lilongwe has also proved beneficial. We have faced multiple significant challenges, discussed in the next sub-section, which we had not envisaged at the beginning of the pilots, and could have been disastrous if not critically reflected upon as part of the action research approach to information systems interventions. Resolving these challenges could have been more challenging had we followed our initial planning to cover the whole of Lilongwe district at once. Starting small has better facilitated our learning process from implementation decisions taken thus far, and challenges we have faced. Learning from ongoing experiences is vital towards the improvement of information technology innovations (Hanseth and Lyytinen, 2004). Other studies on mHealth suggest that barriers to and gaps in mHealth scale and sustainability result from limited knowledge of what works, how it works, and how much it will cost (Mechael et al., 2010).

5.2 Challenges to Walking the Bootstrapping Path

Not all implementation factors at play can be reconciled nor can all competing stakeholder interests be aligned. Hanseth and Aanestad (2001) acknowledge that it is not always possible to follow the bootstrapping strategy.

5.2.1 *Cost cutting vs. time*

Management decisions like the one to initially purchase phones from India and not Malawi, the context of implementation, have had a significant impact on take-off of the pilots. Bringing in an untested technology that failed to work inflicted a two month delay to the project in Malawi. This decision deviated from recommendations of the bootstrapping strategy, to build on an existing installed base, rather than contradict it (Hanseth and Aanestad, 2003; Skorve and Aanestad, 2010). Purchasing phones from a local supplier would also have given project team members access to additional technical support. It would also have been easier to return the phones and get new ones. This is, however, not an easy matter to resolve considering that the MobiHealth project does not have limitless resources and has to balance needs local to Malawi, with other contexts where the project has a presence. A possible way to resolve this is for the Ministry of Health in Malawi, the Lilongwe district health office and health facilities taking part in the pilots to find supplementary long-term financial and technical arrangements that can also last beyond the lifespan of the current funding. This, however, is a tall order to negotiate, in particular due to the historical construction of distinct roles in the piloting game (e.g. host organization, funder, implementer, researcher, etc). When confronted with questions of long term funding and ownership of the solution, the immediate response from the national HMIS office has been to point out that “this is currently a pilot, let’s see how it works first and consider the long term implications and funding later”. This is problematic in the sense that the socio-political learning potential from pilot implementations is undermined and hidden behind a short term focus around technical feasibility.

5.2.2 *Lack of adequate technical expertise*

The case demonstrates lack of sufficient technical expertise for the Ministry of Health in Malawi to fully support its existing technological solutions. For example, the Ministry is reliant on the DHIS team, based at the Malawi College of Medicine, which is external to the ministry, to lead DHIS2 rollout in the country. The ministry also relies on a different government agency for in-house information technology-related support. This, coupled with dependence on external sources of funding to drive information technology initiatives, requires extensive coordination between stakeholders. Such a setup also introduces multiple points of possible failure, making it harder to bootstrap novel solutions. This situation supports arguments by Lucas (2008) that information technology implementations in developing countries are heavily dependent on external support (Lucas, 2008). Failure in such external dependencies can be costly for implementations (Schmidt et al., 2001).

Furthermore, our drawing upon software development support from the University of Oslo, for our pilots, and the ever-evolving nature of DHIS2 Mobile software does have significant implications on the pilots in Malawi. This is demonstrated by the case where the team in Malawi had to roll-back software versions, from DHIS 2.7 back to version 2.6, when a software bug in DHIS 2.7 prevented a Java-based client solution, which was earmarked for

piloting, from working. The ever evolving nature of DHIS2 Mobile software development to respond to needs from a range of countries does highlight the tension between meeting needs of wider user communities, whilst also trying to address need of specific user constituencies.

5.2.3 Information culture

In addition to the lack of internal information technology-related expertise, our findings suggest the lack of an evidence based information culture as a significant hurdle to our efforts. An information technological innovation to enhance data reporting and utilisation can hardly succeed if the target user group does not highly value data they collect, in decision making. Culture is a very important factor in the implementation of technological innovations (Scott and Vessey, 2002). The collapse of monthly data review meetings after the withdrawal of external support, through a World Bank funded initiative, demonstrates how difficult it is to build momentum required to sustain information technology initiatives. In as much as development of an information culture is critical to the success of solutions we are piloting, we can hardly correct the prevailing situation without support from other implementation partners. It is obvious that such a step would not be unproblematic, as an increased number of core stakeholders would necessitate an increased need for coordination between stakeholder operations and interest. Furthermore, the DHIS Mobile solution is not implemented in a static health information setup. The intervention needs to be aligned with recent systemic reforms of the HMIS function and the health system as a whole. In Malawi the HMIS function has been dramatically revised by formally creating an additional post with a statistical clerk at every community health facility. This signals systemic ambitions to emphasise the role and importance of HMIS data in the health system as a whole. Unfortunately, the lack of immediate training of the newly employed statistical clerks sends mixed signals down the health system about the appreciation of local analysis and use of HMIS data; it also illustrates a systemic failure to realize opportunities to create a potentially disruptive change to an existing information culture that is now only being reinforced or possibly even weakened.

5.2.4 Mobile Service Delivery

The relevance of cross-organisational arrangements in the bootstrapping of technological innovations is also highlighted by the quality of mobile service delivery and failure by the mobiles service operator to cap voice calls. Failure to cap voice calls for participants in the pilots places a strain on already limited financial resources. This is a factor over which the research team managing the pilots in Malawi has little control. There are only two major mobile service providers in Malawi, which greatly reduces choices available to our team. Interactions with the service provider we are using for the pilots have demonstrated that our end-goals, guiding decisions and actions, are not easy to reconcile. This in turn stems from fundamental differences in logic between profit making mobile operators, public health responsibilities, and action research bent on leveraging mobile technologies to empower peripheral health workers and strengthen decentralised evidence based decision making. Challenges we have encountered with regard to mobile service delivery place the mobile service operator more in the foreground of our routine operations, than is necessary. At the same time our limited choice of access to mobile service delivery makes it harder for us to correct present inefficiencies.

6 Conclusion

In this paper we have applied the bootstrapping concept to highlight organisation-centric and cross-organisational risk factors that need to be negotiated in the implementation of novel information technology solutions. Bootstrapping of innovations not only interplays with internal organisational arrangements, or external stakeholders with more or less common goals. Socio-technical arrangements between stakeholders working across economic sectors, organisational and geographical boundaries are just as relevant. Funding and technical arrangements that cut across organisations, as well as reliance on service delivery by commercial service providers, are good examples. For example, the pilots in Malawi are funded by the MobiHealth project at the University of Oslo, have the Ministry of health in Malawi as a host organisation, and rely on mobile service delivery by a commercial provider. The Ministry of Health in Malawi also relies on external consultants for technical support.

Weaknesses of the Ministry of Health to adequately support new information technology solutions, both financially and technically, means that significant alliances with multiple implementation partners cannot be done away with easily. It has been demonstrated in this paper that such alliances function in ways that enable or constrain bootstrapping of novel solutions. For example, stakeholders often have divergent interests. In addition, there is an increased need for coordination when there are multiple stakeholders involved. All this increases the potential for failure in the event that stakeholder relationships and dependences fail. Successful bootstrapping of novel information technology solutions therefore requires effective management of stakeholder linkages.

At organisational level, bootstrapping of novel solutions can be strengthened through building the solutions for immediate relevance, supporting vital, but less complex tasks first, and taking small incremental steps to allow experimental learning. It is also important to find solutions to weak organisational practices that are critical to the relevance of implemented solutions. An example from our case is the need to build an information culture.

Acknowledgment

We are very grateful to all members of MobiHealth, the Ministry of Health in Malawi, all pilot study participants, Kristin Braa, Margunn Aanestad, and our working group at the 35th IRIS seminar, for their valuable contributions.

References

- Aanestad, M. & Jensen, T. B. (2011). Building nation-wide information infrastructures in healthcare through modular implementation strategies. *The Journal of Strategic Information Systems*, 20, 161-176.
- Avison, D., Baskerville, R. & Myers, M. (2001). Controlling Action Research Projects. *Information Technology & People*, 14, 28-45.
- Davison, R. M., Martinsons, M. G. & Kock, N. (2004). Principals of Canonical Action Research. *Information Systems Journal*, 14, 65-86.
- Hanseth, O. & Aanestad, M. (2001). Bootstrapping networks, communities and infrastructures. On the evolution of ICT solutions in health care. *ITHC*. Erasmus University, Rotterdam, The Netherlands.

- Hanseth, O. & Aanestad, M. (2003). Design as Bootstrapping: On the Evolution of ICT Networks in Health Care. *Methods Inf Med*, 42, 385-391.
- Hanseth, O. & Lyytinen, K. (2004). Theorizing about the design of Information Infrastructures: design kernel theories and principles *Sprouts: Working Papers on Information Systems* [Online], 4. Available: <http://sprouts.aisnet.org/4-12>.
- Heeks, R. (2002). Information Systems and Developing Countries: Failure, Success, and Local Improvisations. *The Information Society*, 18, 101-112.
- Lucas, H. (2008). Information and communications technology for future health systems in developing countries. *Social Science & Medicine*, 66, 2122-2132.
- Mechael, P., Batavia, H., Kaonga, N., Searle, S., Kwan, A., Goldberger, A., Fu, L. & Ossman, J. (2010). Barriers and Gaps Affecting mHealth in Low and Middle Income Countries: Policy White Paper. Center for Global Health and Economic Development Earth Institute, Columbia University.
- Ribes, D. & Finholt, T. A. (2009). The Long Now of Technology Infrastructure: Articulating Tensions in Development. *Journal of the Association for Information Systems*, 10, 375-398.
- Schmidt, R., Lyytinen, K., Keil, M. & Cule, P. (2001). Identifying Software Project Risks: An International Delphi Study. *J. Manage. Inf. Syst.*, 17, 5-36.
- Scott, J. E. & Vessey, I. (2002). Managing risks in enterprise systems implementations. *Commun. ACM*, 45, 74-81.
- Silva, L. & Backhouse, J. (1997). Becoming part of the furniture: the institutionalization of information systems. *Proceedings of the IFIP TC8 WG 8.2 international conference on Information systems and qualitative research*. Philadelphia, Pennsylvania, United States: Chapman & Hall, Ltd.
- Skorve, E. & Aanestad, M. (2010). Bootstrapping Revisited: Opening the Black Box of Organisational Implementation. In: Kautz, K. & Nielsen, P. A., eds. SCIS 2010, 2010. Springer-Verlag Berlin Heidelberg, 111-126.
- Walsham, G. (2006). Doing Interpretive Research. *European Journal of Information Systems*, 15, 320-330.
- Walsham, G. & Sahay, S. (2006). Research on information systems in developing countries: current landscape and future prospects. *Inf. Technol. Dev.*, 12, 7-24.
- Yu, P., Wu, M. X., Yu, H. & Xiao, G. Q. (2006). The Challenges for the Adoption of M-Health. In: Service Operations and Logistics, and Informatics, 2006. SOLI '06. IEEE International Conference on, 21-23 June 2006. 181-186.

Journal of the Association for Information Systems

JAIS 

Special Issue

Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation

Terje Aksel Sanner

University of Oslo
terjeasa@ifi.uio.no

Tiwonge Davis Manda

University of Oslo
University of Malawi
tiwongem@ifi.uio.no

Petter Nielsen

University of Oslo
pnielsen@ifi.uio.no

Abstract

This paper proposes grafting as a new perspective on information infrastructure (II) innovation. We introduce the organic notion of grafting to help explore innovation processes in settings where control is distributed and episodic. Our case study follows the implementation of mobile phone-based reporting of routine data from sub-district health facilities in Malawi. Initial grafting work entails the careful alignment of available resources, capacities, and interests through the proposition of an information system (IS) innovation (e.g., mobile phone-based reporting). The nurturing of the implementation involves collaborative efforts spanning technological, professional, geographical, and organizational boundaries. This work is taken forward by the identification of opportunities for merging an innovation with existing socio-technical arrangements (e.g., health management information systems in Malawi) in such a way that the parts continue to grow.

Keywords: *Grafting, Information Infrastructure, Innovation, Health Information System, Mobile Phones.*

* Robin Williams was the accepting senior editor. This article was submitted on January 9, 2014 and went through two revisions.

Volume 15, Special Issue, pp. 220-243, April 2014

Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation

1. Introduction

People and organizations are involved in an ever-growing array of information and communication interdependencies outside their immediate sphere of influence and control (Benkler, 2006; Borgman, 2003; Castells, 2011). While information system innovations often originate in response to local needs, some innovations are nurtured into extensions of large inter-organizational and industry-wide information infrastructure such as national health information systems (Aanestad & Jensen, 2011) and collaborative scientific networks (Karasti, Baker, & Millerand, 2010; Ribes & Finholt, 2009). Such efforts, which often unfold over long periods of time, may involve collaboration across organizational, cultural, and geographical boundaries between stakeholders with varying interests, resources and expectations. In the process, existing socio-technical arrangements are mobilized and they can both enable and constrain innovation adoption. Recognizing this, a stream of information systems (IS) research has focused on how lack of centralized control and decision-making power can be ascribed to the distributed and evolutionary nature of heterogeneous networks of information systems—or information infrastructure (II) (Bowker & Star, 2000; Ciborra et al., 2000; Hanseth & Lyytinen, 2010).

By treating information infrastructure as an object of study, scholars have been able to account for both the success and frequent failures of organization-wide initiatives concerned with developing and appropriating comprehensive software packages, intranets, and novel information and communication technologies (Bygstad, 2003; Ciborra & Failla, 2000; Hanseth, Monteiro, & Hatling, 1996; Monteiro & Hepsø, 2000). As an exemplary case for theory building, scholars have drawn on the Internet's evolution to demonstrate unprecedented distributed information infrastructural innovation and growth (Hanseth & Lyytinen, 2010; Zittrain, 2006). In recognition of seemingly unmanageable complexity, scholars have conceptualized II change as the cultivation of an evolving installed base (i.e., the historical accumulation of socio-technical arrangements) (Bergqvist & Dahlberg, 1999; Dahlbom & Mathiassen, 1993). This implies that II innovations build on and extend an installed base riddled with social (e.g., legal rights and ownership) and technical (e.g., legacy systems and technical standards) interdependencies.

Proposed II cultivation strategies range from “the active *creation* of an attractor” (italics in original) (Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007, p. 4) (i.e., possible state(s) on which a complex system stabilizes and holds together) to careful adherence to growth-enabling design principles (Hanseth & Lyytinen, 2010). Although control in relation to II development is distributed and episodic, recent contributions provide guidance on “how to ‘cultivate’ an installed base and promote its dynamic growth” (Hanseth & Lyytinen, 2010, p. 15). We contend that design-centered perspectives focused on actively managing complexity tend to conceal asymmetric power relations and struggles for control between different actors shaping II development. There is a need to extend our limited knowledge and understanding of the II development processes (Lyytinen & Yoo, 2002) by exploring how certain actors are in control, even if such control is related only to parts of information infrastructure (i.e., technical devices and appliances, service platforms, and physical infrastructure) at certain points in time (Nielsen, 2006). Hence, our research is concerned with how diverse actors with different levels of ownership and involvement nurture II innovations.

This paper's key contribution is grafting: a new and different perspective on how local organizational goal-oriented information system innovations become viable extensions of shared and evolving information infrastructure. Grafting entails working with available resources and interested parties in order to merge an information system innovation with existing information infrastructure. This involves identifying opportune moments and parts of the installed base to leverage. Grafting is also about managing relationships with key stakeholders who retain some control over those parts. The grafting perspective highlights fragility in the process of merging an information system innovation with differentiated local contingencies (e.g., situated work practices).

The rest of the paper is organized as follows: in Section 2 we review literature on II innovation and motivate the argument for a grafting perspective. In Section 3, we discuss our interpretative and engaged approach to fieldwork and data analysis. In Section 4, we present a case narrative about the implementation of mobile phone-based reporting of routine health data from sub-district health

facilities in Malawi. We describe different actors' involvement with the innovative mobile phone-based solution across organizational, technological, and geographical boundaries. In Section 5, we explore the metaphorical notion of grafting as a vehicle for generating new insights about II innovation.

2. Between Control and Cultivation of Information Infrastructure

We understand information infrastructure as networks of distributed yet more-or-less interlinked and interoperable information systems. As a consequence of dispersed and distributed ownership, lack of centralized control is a fundamental attribute of information infrastructure (Ciborra & Hanseth, 1998; Hanseth & Lyytinen, 2010). Different actors shape, maintain, and extend information infrastructure "in modular increments, not all at once or globally" (Star, 1999). Managerial urges to curb complexity, mitigate risks, and facilitate interoperability across II parts are in constant tension with the need for local flexibility to accommodate situated practices (Ciborra et al., 2000; Hanseth, Monteiro, & Hatling, 1996; Ives & Jarvenpaa, 1991; Rolland & Monteiro, 2002). This tension is strengthened by the diffusion of II capabilities (Hanseth et al., 1996) because situated practices and technology appropriations diverge rather than converge over time (Forster & King, 1995).

Previous studies have conceptualized the evolution of information infrastructure as driven by the economic mechanisms of networks (Hanseth, Ciborra, & Braa, 2001; Varian & Shapiro, 1999). Network economists argue that user adoption and demand-driven mechanisms transform infrastructure development into self-reinforced growth (Hughes, 1987). As the information infrastructure grows, the power to exercise control becomes distributed and embedded in emerging socio-technical arrangements—the installed base (Star & Ruhleder, 1996). Based on this perspective, Hanseth and Aanestad (2003) have proposed a particularly prescriptive strategy for II innovation; namely, "bootstrapping".

Bootstrapping entails how early adopters are attracted and enrolled into an envisioned information infrastructure that has not yet achieved strong network effects. The initial lack of network effects could be due to the II's limited information and communication technology (ICT) capabilities and the absence of a significant number of users. Essential aspects with a bootstrapping strategy include: provision of simple and immediately useful ICT capabilities, innovation through mutual learning, and mitigation of complexity (Hanseth & Aanestad, 2003; Skorve & Aanestad, 2010). Further user adoption in the growing network is explained through the notion of self-reinforcing mechanisms that contribute to the cumulative attractiveness of adoption (Arthur, 1994). Early proponents of the bootstrapping strategy were concerned with how an initial user demand could be nurtured, and assumed that II developers are able to configure the II to attract users. Aanestad and Jensen (2011) enhance the bootstrapping strategy by addressing challenges associated with the mobilization and coordination of inputs from multiple independent stakeholders. We concur with their claim that an II innovation strategy also needs to mitigate complexity by ensuring incremental stakeholder mobilization.

Despite scholarly propositions of prescriptive design principles and strategies, II is not considered to be "built" or "deliberately designed" in accordance to a master plan (Jackson, Edwards, Bowker, & Knobel, 2007). Edwards, Bowker, Jackson, and Williams (2009, p. 369) argue that particular stakeholder groups "rarely if ever 'build' infrastructure; they must nurture it and, if they are lucky, help it to grow". In particular, the authors point to a critical stage in infrastructural innovation by what they term the "gateway phase", during which innovations are inevitably tied into networks of existing infrastructures. Gateways (e.g., technical plug adapters and software document format converters) allow heterogeneous and isolated information systems, or "modules", to facilitate information sharing and communication, while retaining the flexibility to rapidly co-evolve with a changing environment (Egyedi, 2001; Hanseth, 2001; Jackson et al., 2007). Gateways permit multiple systems to be adopted and used as if they were a single integrated system. However, even the development of loosely coupled and inexpensive software gateways may require coordination and alignment of interests and rights between actors in control of different parts of II. Design-centered perspectives such as the aforementioned tend to downplay the struggles for influence and control on the *supply side* of information infrastructure exemplified by alliances, politics, and institutionalization of dependencies (e.g., standards) through regulatory bodies.

2.1. Unpacking the Supply Side of Information Infrastructure Innovation

There are no clear-cut demarcations between the supply side and the demand side of information infrastructure. As Star (2002, p. 116) remarks: “[o]ne person’s infrastructure is another’s brick wall”. Additionally, Pipek and Wulf’s (2009) study on how organizational work practices essentially integrate and innovate parts of information infrastructure further blurs the distinction between designers and users. However, we hold that the demand and supply sides of information infrastructure can be fruitfully discerned for analytical purposes. Similar to Jansen and Nielsen (2005), we consider the II demand side to include distributed user preferences, situated practices, and local investments in information and communication technologies. Actors on the supply side are oriented towards forming alliances and competing in building physical infrastructure, developing generic ICT capabilities, and informing regulations that shape II innovation to their positional advantage. II innovation thus involves balancing demand-side utility with supply-side control and economies of scale.

Previous conceptualizations of information system innovation have emphasized mindful improvisation (Ciborra, 1999; Suchman, 2002). Ciborra’s (2002) notion of an expedient “bricoleur” (i.e., someone tinkering through the combination of resources at hand) has been further developed to study the resolution of emergent obstacles to the adoption and appropriation of information system innovations in situated contexts (Ali & Bailur, 2007; Garud & Karnøe, 2003). Similarly, Corea (2007, p. 53) emphasizes the social shaping of technology through the concept of “IT artfulness” which refer to the “creative, intelligent, or ingenious behaviour in the creation or enhancement of socioeconomic practices through the contextually adapted, socially apposite use of the capabilities of IT systems”.

However, there is a conceptual gap between the various notions of locally apposite, heroic, expedient, and artful entrepreneurs, engineers, and bricoleurs facilitating innovation in complex socio-technical environments, and the recognition of holistic and evolutionary cultivation of an installed base. In between, we find rarely accounted for contestations pertaining to long-term ownership and accountability that transform local information system innovations into viable extensions of information infrastructure. Nielsen and Aanestad (2006, p. 186) show how some actors’ intentional “relinquishing [of] control can be a prerequisite, as opposed to an impediment, for successful design and operation of information infrastructures”. Their study explores the balance between exercising and turning over partial control to drive further II innovation. Existing literature has only to a limited extent examined how II innovations harness input and commitment from a multiplicity of previously uncoordinated actors with different capacities and levels of involvement, and how these interdependencies balance short-term interests with long-term sustainability (Ribes & Finholt, 2009).

Complete control over the development of II is by definition unattainable. However, certain actors are able to exercise some control over certain parts of II at varying points in time. The abstract recognition of a supply side allows us to highlight the under-theorised role of multiple agendas interacting to shape II innovations. The rights and the opportunity to control technical devices, physical infrastructure, or service platforms, which other components extend, afford certain actors more control over II architecture than others. Thus, certain actors’ ability to identify and leverage architectural control points (Elaluf-Calderwood, Eaton, Herzhoff, & Sorensen, 2011) and windows of opportunity (Sun, Aanestad, Skorve, & Miscione, 2009) allows them to plan and implement II change. For example, de Reuver, Bouwman, Prieto, and Visser (2011) point out that mobile service platforms with secure authentication, convenient billing, and customer data for advanced mobile Internet services can be offered by mobile operators, but can also be embedded in mobile phones or at the systems of content and service providers. The evolution of the mobile Internet can thus be seen as a battle for control in a socio-technical ecosystem with unclear boundaries. Similarly, looking at health information infrastructure innovation in India, Sahay, Monteiro, and Aanestad (2009) explore how initial information system implementation choices not only resulted in technical configurations, but also had implications for the long-term arrangement of social and political stakeholders.

In summary, development of II is shaped both by the historically embedded and distributed agency of existing socio-technical arrangements (i.e., the installed base) and by the opportunistic summoning of resources, capacities, and interests around information systems innovations at particular times in

specific social contexts (Karasti et al., 2010; Sahay, 1997). Subsequently involved actors may influence or coerce local appropriations of an innovation in new and unintended ways. However, the initial summoning of resources and capacities configures the II parts to be extended and leveraged, and implicate the possible early involvement of actors who own or control those influential parts (e.g., mobile phone network operators). In Section 2.2, we propose grafting as a new perspective for understanding distributed and incremental information infrastructure development, whereby information system innovations are merged with and extend existing socio-technical arrangements.

2.2. Information Infrastructure Innovation as Grafting

Grafting, as we employ it here, owes its meaning to horticulture, where it entails the placement of a portion of one plant (called a scion) into or on a stem, root, or branch of another (called the rootstock) in such a way that a union forms and the partners continue to grow (see Figure 1). The purpose of grafting is twofold: to create hybrids by combining certain desirable varietal characteristics, and to speed the propagation of such desirable traits. For instance, it may be deemed worthwhile to graft the scion (a shoot of a plant selected for its fruits, flowers, leaves, etc) from one type of plant onto another rootstock selected perhaps for its disease resistance or tolerance to specific environmental conditions.

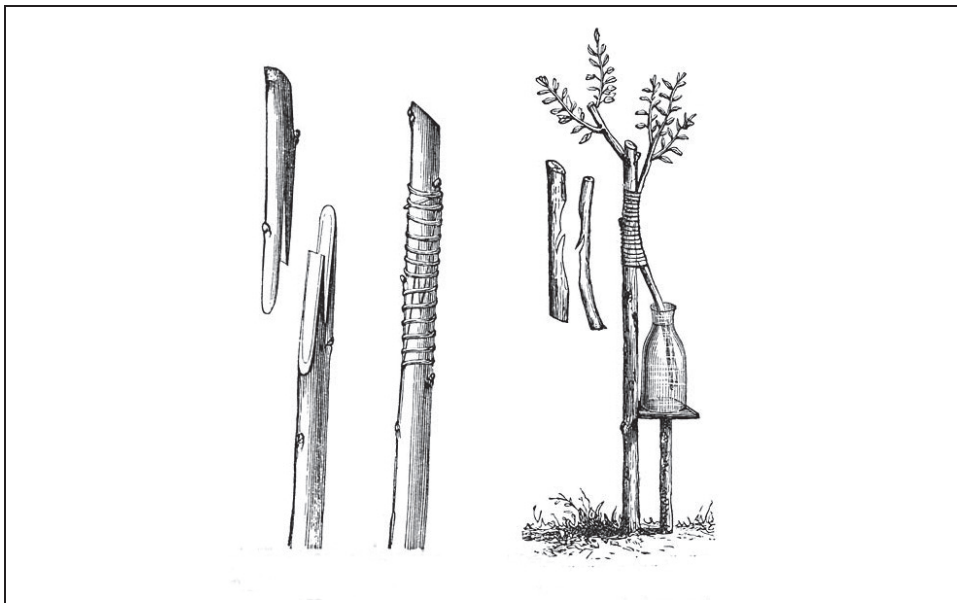


Figure 1. Example of a Grafting Technique (Left) and an Approach to Grafting (Right)
(Adapted from Troussset Encyclopedia, 1886-1891)

A critical factor in any grafting process is the compatibility of the scion and rootstock, or, in information infrastructure terms, between an information system innovation and the installed base. Compatibility or congeniality can be of various degrees, with some grafts almost always failing, others flourishing for a while but eventually failing, and others still yielding desirable results. Horticultural grafting may fail due to poor formation of the graft union, poor grafting technique, or adverse environmental conditions. A fair amount of practical work is involved in tending to the graft. This, for example, includes applying protective wax onto the graft, holding the graft in place with grafting tape or rubber budding strips applied over the point of union, or through provisioning a provisory source of nourishment (as in Figure 1). Similarly, tenderness is essential when “universal” ICTs or generic software packages are adapted and configured to

local contingencies, or when practitioners are encouraged to embrace organization-wide information system acquisitions that potentially transform their work.

Pollock, Williams, and D'adderio (2007) develop the term "generification work" to explore how software packages (e.g., CRM and ERP) are built to travel and work across different contexts (Rolland & Monteiro, 2002). Central to "generification work" are strategies for handling large amounts of functional requirements, of varying importance, from dispersed solution adopters (Pollock et al., 2007). The speedy propagation of generic software packages across organizational contexts resembles the product consistency obtained in the commercial farming industry (e.g., apples associated with a specific brand have the same features) by grafting scions with desired traits onto different environmentally adept rootstocks. With regard to generification work, grafting focuses on garnering support from the various local socio-technical arrangements that generic ICT capabilities and software packages are intended to merge with and become a part of.

Information system implementers often have to contend with dilemmas regarding how best to reconcile conflicting, but similarly persuasive, socio-technical factors that interplay with grafting efforts. Factors of influence include trade-offs between short and long-term performance (Ribes & Finholt, 2009), changes in intended context of use, changes in available technological options, diverging interests between involved actors, and institutional constraints. A growing body of literature has generated insights on how and why information system implementations succeed or fail by drawing on the similarities between biological ecosystems and complex networks of interconnected information systems (Baker & Bowker, 2007; Constantinides & Barrett, 2005; Hepso, Monteiro, & Rolland, 2009; Star & Ruhleder, 1996). Consequently, the application of organic terms such as evolution, cultivation, growth, and nurturing has gained prominence to describe information infrastructure development and change. Yet, the related horticultural notion of grafting has not been employed to explore incremental and distributed II development. As a noteworthy exception, Egyedi and Loeffen (2002) draw on grafting as a metaphor for technology standard development, where the intent is to improve a standard's functionality while preserving compatibility with previous contexts of use. However, the authors are more concerned with possible grafting outcomes as opposed to generating insights on the grafting process.

In this paper, we develop the notion of grafting further as a tool for exploring II innovation. We define it as a process through which organizational goal-oriented information system innovations merge with and extend existing socio-technical arrangements so that the parts continue to grow. If the graft holds, control and agency inevitably become distributed and embedded across the growing socio-technical fabric (e.g., stakeholder alliances and technical gateways) that ties the information system innovation to the installed base. While the notion of cultivation captures the evolutionary transformation of a whole information infrastructure (i.e., the sum of distributed, incremental, and modular changes), it lacks the precision to describe evolutionary change from the perspective of specific organizational goal-oriented initiatives. We need to ask: who cultivates and how? Realizing this, Aaenstad and Jensen (2011, p. 173) argue that installed base cultivation is vital, but theoretical models of II innovation also "need to deal with the challenges of organising, mobilising and coordinating multiple independent stakeholders". In this paper, we introduce grafting to highlight the role of human agency in moulding evolutionary processes. Grafting specifically addresses **how** the installed base is drawn on and extended to support II innovations.

The initial framing of an information system innovation has lasting implications because it identifies the II parts to be extended (i.e., the point of union between scion and rootstock). It also implicates whose buy-in is required to propose, legitimize, and institutionalize changes to existing socio-technical arrangements. Similar to how information infrastructure innovations become invisible through adoption and use, the line of union between grafted plant parts is frequently impossible to determine, even microscopically.

3. Methods

This research has grown out of the authors' involvement with a longitudinal international action research initiative called the Health Information Systems Programme (HISP); see Braa et al. (2007)

and Braa, Monteiro, and Sahay (2004) for more detailed descriptions of the program. Despite strong ties with the program's interventionist agenda, this research is best described as an interpretative case study (Klein & Myers, 1999; Walsham, 1993) that explores processes through which information system implementations influence and are influenced by their socio-technical contexts of use (e.g., Orlikowski, 1993; Walsham, 1993, pp. 4–5).

A unifying component across the distributed HISP action research network is the development and implementation of an open source software package called the District Health Information Software (DHIS). In its second and current generation, DHIS2 is a web-based server-client tool for collecting, validating, analyzing, and presenting data. The tool is used in more than 40 countries in Africa, Asia, and Latin America for Health Management Information System (HMIS) purposes. Since 2009, a subdivision of the HISP project has focused on developing and implementing DHISm, the mobile extension of DHIS2. DHISm permits data reporting and information retrieval through mobile phones, and thus functionally and institutionally extends DHIS2 implementations (Sanner, Roland, & Braa, 2012). Key DHISm software developers are located in Norway and Vietnam, and their activities are focused on the provision of generalized solutions to requirements from various countries (e.g., India, Malawi, Uganda, Tanzania, the Gambia, and Zambia).

The first and the second authors have participated in an ongoing DHISm implementation in Malawi since its initiation mid-2011, along with four other implementers. The second author, a Malawian national, has played a leading role in the coordination of DHISm implementation activities. Overarching implementation goals include strengthening the existing HMIS in Malawi and contributing to the refinement and further development of the DHISm suite of solutions. The researchers' engaged approach to fieldwork has allowed for access to people's verbatim responses and naturally occurring reactions to unfolding events. The third author did not take part in implementation and data collection activities in Malawi, but has been engaged in data analysis and theorizing.

Our case study follows the implementation of mobile phone-based reporting from sub-district health facilities in Malawi and examines the emergence of complex socio-technical arrangements between previously uncoordinated actors. We consider the study an extreme case of the phenomena of interest (Gerring, 2007, p. 101), which makes it well suited for generating new conceptual insights. Management of health information system interventions is particularly challenging in less-developed economies (Heeks, 2002, 2006; Littlejohns, Wyatt, & Garvican, 2003) due to cross-national public-private arrangements with divergent agendas, asymmetric power relations, and conflicting time frames. The use of novel information and communication technologies, as in the case of DHISm, further aggravates implementation challenges.

3.1. Data Collection

We collected our empirical data between September 2011 and June 2013 through our engagement with various stakeholders in Malawi and with DHISm software developers in Norway and Vietnam. Data collection in Malawi was based on interviews, focus group discussions, and observations that involved HMIS personnel at all organizational levels in the Ministry of Health (MoH). Table 1 presents a summary of key individuals and stakeholder groups with whom we interacted. Presented alongside the informants are details of the organizational level at which they operated and their key responsibilities.

Table 1. Key informants in Malawi

Informant(s)	Organization (level)	Key responsibilities
Deputy director	MoH headquarters (CMED)	Oversees the HMIS function
Assistant statistician	MoH headquarters (CMED)	HMIS at national level
HMIS officers	MoH district health office	HMIS at district level
Twenty-five HMIS focal persons (i.e., clinical officers, nurses, and statistical clerks)	MoH sub-district health facilities	Health service delivery, HMIS at sub-district level
Team of three DHIS2 coordinators	University of Malawi's College of Medicine	Coordinate DHIS2 implementation

We interviewed staff members at sub-district health facilities in situ. Additionally, we examined HMIS artefacts such as paper forms, registry books, and hand-drawn graphs put up on facility walls. Interviews with other informants were mainly conducted in the respondents' offices. Some key respondents were interviewed up to three times as they were made progressively more familiar with the DHISm initiative and our research. The deputy director at the Central Monitoring and Evaluation Division (CMED) who is in charge of the national HMIS operations was extensively involved in dialogue with the authors about the DHISm implementation and related research activities. Additionally, seven focus group discussions were conducted with representatives from sub-district health facilities and a district health office. Focus group discussions were conducted as part of three training sessions on DHISm solutions and four subsequent review and evaluation meetings. Topics discussed included priorities and challenges related to the existing HMIS and experiences from participation in DHISm pilots. In addition to the interviews and focus group discussions mentioned above, we maintained contact with informants in Table 1 throughout the period of the study. Thus, we were able to engage in additional impromptu and ad hoc discussions.

We collected other data that informs the study as part of consultative meetings with mobile service operators, DHIS2 coordinators in Malawi, and non-governmental organizations (NGOs) involved in mobile phone-based healthcare interventions in Malawi. Meetings with mobile service operators took place on an ad hoc basis. Key discussion points during meetings were issues with Internet data subscriptions and queries for assistance from sub-district health facilities. Interactions with the DHIS2 Coordinators, who were responsible for all DHIS2 implementation and maintenance activities in Malawi, were equally ad hoc and mainly centered on the synchronization of DHISm implementation with ongoing DHIS2 roll-out activities. The implementation of DHISm in Malawi and related empirical data collection relied on coordination between geographically dispersed stakeholders as Figure 2 illustrates.

Additional materials that inform our analysis include various documents related to Malawi's HMIS: policy documents, official HMIS status reports, HMIS feedback reports from the national level to districts and sub-district health facilities, paper-based facility registers, and photographs of HMIS-related tools and information products such as registry books, graphs, and paper forms. The researchers' interactions with DHISm software developers in Norway and Vietnam were facilitated through face-to-face meetings, email exchanges, and Skype conference calls.

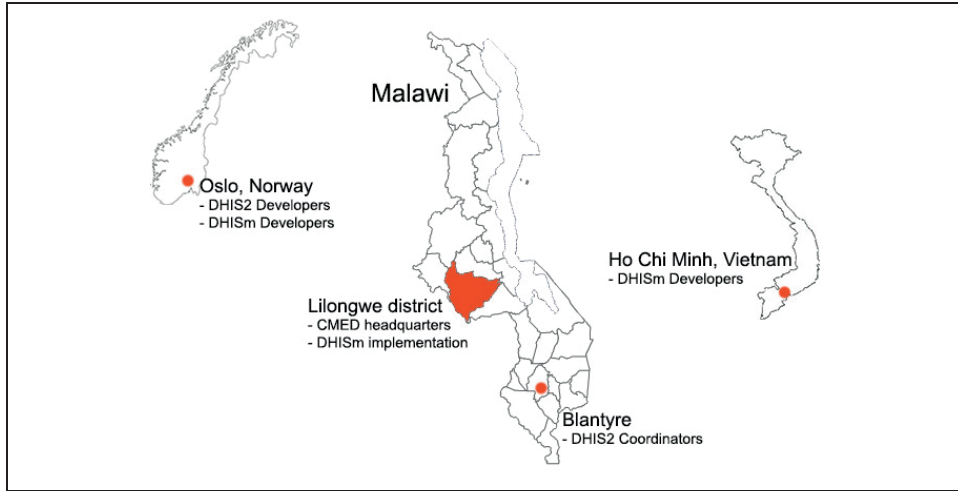


Figure 2. DHISm Implementation Coordination Across Geographical Proximities

3.2. Data Analysis

We recorded interviews and focus group discussions with participants' permissions. Parts of the extensive audio material were transcribed and selectively coded along with obtained documents to highlight important events, decision points, and tensions related to the implementation process. During this process, we also produced a timeline of key events (see Figure 3 in Section 4.6). The first author and the second author independently performed the initial coding of raw data. Subsequently, both authors wrote up case narratives about experiences and challenges with implementing DHISm in Malawi. The narratives served as starting points for engaged discussions concerning the analytical focus of the study. In light of recurring themes in the data, we explored theoretical lenses (reviewed in the theory section) affording a process view on information systems innovation in settings characterized by distributed and episodic control.

There were two principal concerns for analysis. First, there was the challenge of conceptualizing the mobilization of loosely coordinated stakeholders who did not necessarily have to adopt or subscribe to the information system innovation at hand, but nonetheless controlled important parts of existing socio-technical arrangements. Second, we were concerned with the practical challenge of facilitating and sustaining ongoing national HMIS restructuring activities in Malawi. We struggled to find concepts that would adequately capture the delicate transition from local organizational goal-oriented information system strengthening activities to the distributed nurturing of an information system innovation across a growing network of influential actors.

Addressing this conceptual gap, the proposed grafting perspective emerged from our analysis of the empirical case. Conceptual development of the grafting perspective was also informed by an earlier analysis of the DHISm implementation in Malawi (Manda & Sanner, 2012). In that analysis, we applied the notion of bootstrapping (Hanseth & Aanestad, 2003; Skorve & Aanestad, 2010) to highlight risks inherent in loosely coordinated multi-stakeholder II innovation processes. However, we hold that the nuanced negotiations for control and alliance building on the supply side of II innovation could not be sufficiently addressed from a design-centered conceptualization such as bootstrapping. Given our interest in the fragility of II innovation efforts, beyond initial take-off challenges, we contemplated the value of a more organic perspective. We presented and discuss early notions of information infrastructure innovation as grafting at a workshop with fellow researchers in Oslo (Norway) in November 2012, which resulted in valuable reflections on the core contribution of the

study. Finally, we considered the metaphorical pitfalls and revisited the empirical material to refine our understanding of the strengths and limitations of employing a grafting metaphor to make sense of information infrastructure innovation.

4. Mobile Reporting from Sub-District Health Facilities in Malawi

In this section, we follow the implementation of the mobile phone-based District Health Information Software (DHISm) for routine health data reporting from sub-district health facilities in Malawi. The case description details the collaborative efforts of previously uncoordinated stakeholders with different interests and levels of involvement (e.g., the Ministry of Health and mobile operators) pertaining to the implementation of DHISm.

Malawi, a small landlocked country in Sub-Saharan Africa, has an estimated population of 16 million. About 85 percent of the population live in rural areas, where roads, the electricity grid, and telecom landlines are underdeveloped. In stark contrast, a Malawi infrastructure assessment performed by Foster and Shkaratan (2011) points out that the global system for mobile communications (GSM) has been brought to almost the entire national territory. By reaching about 93 percent of the population, mobile phone networks serve as a particularly fertile ground for ICT innovations in Malawi. Despite gaining independence from British colonialism in 1964, Malawi currently relies on financial and technical support from multiple, often uncoordinated, international development partners and non-domestically funded non-governmental organizations (NGOs), many of which are deeply involved in the health sector.

4.1. Health Management Information Systems in Malawi

In the public health sector in Malawi, computers and software tools have predominantly been available at District Health Offices (DHOs) and higher organizational levels. Regular health facilities, maternity units, dispensaries, and district hospitals (henceforth referred to only as sub-district health facilities) have routinely submitted paper forms to DHOs, where the data has been entered into health management information system (HMIS) databases. For HMIS purposes, DHOs in Malawi were using DHIS 1.3, which was installed locally on desktop computers in all districts in Malawi during 2002. DHIS 1.3 had been developed on top of proprietary software (i.e., Microsoft Access databases) and was the predecessor to the open source and web server-client-based DHIS2. District reports generated using DHIS 1.3 were sent electronically to higher organizational levels including the Central Monitoring and Evaluation Division (CMED). At the time of writing, CMED, a division under the Ministry of Health Department of Planning and Policy Development, was responsible for national HMIS operations in Malawi.

At sub-district facilities, many health professionals have been performing HMIS related activities such as data collection and reporting in addition to provision of health services. Typically, HMIS responsibilities include aggregating data for all health programs such as malaria, tuberculosis, HIV/AIDS, mother and child health, and related drug supplies. This has mostly been done at the end of each month or quarter of the year, depending on set reporting requirements. Data collection, reporting, and analysis have been facilitated through paper-based tools and work practices (e.g., registry books, tally sheets, hand written signatures on verified reports, etc). The de facto practice in Malawi has been for sub-district health facilities to designate their own HMIS and program-specific focal persons to fill registers, and to tally and consolidate data onto reporting forms.

Since 2009, the MoH has attempted to migrate from the local DHIS1.3 installations in all of Malawi's 28 districts. The migration was motivated by the fact that distributed installations were difficult and costly to maintain compared with having one central database on a national DHIS2 server, accessible from any client device with a web browser. Additionally, further development of the DHIS 1.3 software had been discontinued. A national DHIS2 server was set up, but the migration from DHIS 1.3 to DHIS2 proved time consuming and ineffective, partly due to limited funding, database incompatibility, Internet connectivity issues, and having the DHIS2 coordinators located at the University of Malawi's College of Medicine in Blantyre, about 300 kilometres away from CMED in Lilongwe. The DHIS2 Coordinators were responsible for all country-specific DHIS2 customization, implementation, and

maintenance tasks, including exporting existing data from DHIS1.3 to DHIS2, managing the national DHIS2 server, and training users. CMED did not have sufficient in-house IT expertise to manage mundane IT tasks and the national DHIS2 server, which was also physically located at the University of Malawi's College of Medicine.

4.2. Strengthening the National Health Management Information System

Based on CMED's intention to move from DHIS 1.3 to DHIS2 and the well-developed mobile phone network in Malawi, the international DHISm initiative engaged in dialogue with CMED to explore the potential for trying out newly developed DHISm features. Initial discussions between a team of DHISm implementers, CMED's deputy director, and the Lilongwe DHO took place during the second half of 2011. In particular, issues concerning the untimely and incomplete reporting of routine data from sub-district health facilities to DHOs were raised. During the discussions, it was made clear that only two DHOs had implemented DHIS2, one being Lilongwe. The DHIS2 implementation was still considered as a pilot by CMED. DHISm implementation, which relies on the backend features of DHIS2, would therefore be initially confined to these two districts. After reaching an agreement to pilot DHISm-supported reporting, the DHISm implementers repeatedly visited nine health facilities in the Lilongwe district. The visits allowed the implementers to get an understanding of existing work practices related to routine data collection and reporting, identify ICTs in place (e.g., mobile phones), and observe existing infrastructures (e.g., GSM coverage, road accessibility, and electricity).

The paper-based communication between sub-district health facilities and DHOs was compromised by seasonal challenges such as poor and inaccessible roads, severe recurring fuel shortages all over Malawi, and inadequate supplies of printed paper forms. Staff members explained that their travel costs were neither refunded nor subsidized when they had travelled to deliver reports at the DHO. Consequently, workarounds for report submissions were commonplace. For instance, health workers would postpone report submissions until they had personal errands in town, such as collecting their salaries. Alternatively, they would send delayed reports with ambulance drivers whenever there was an emergency pick-up at the health facility. An HMIS officer based at Lilongwe DHO recalled the following incident, which illustrates the unreliability of report submission through ambulance drivers:

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, not being delivered to the district health office for months.

Reporting through mobile phone networks with features of the DHISm suite of solutions was envisaged to circumvent the above mentioned HMIS-related communication challenges. CMED and the Lilongwe DHO agreed to formally endorse the implementation of mobile reporting across all sub-district health facilities in Lilongwe district. In order to mitigate complexity, only two forms, the HMIS-15 and the Integrated Disease Surveillance and Response (IDSR) form, were targeted for mobile reporting. The HMIS-15 is a summary report containing essential data elements that cut across multiple public health programs in Malawi. The IDSR form is primarily used for tracking communicable diseases and incidences of epidemic prone diseases (e.g., cholera). The two forms were selected due to their perceived importance. During interviews HMIS focal persons, statisticians and managers expressed a desire to have the HMIS-15 form's reporting frequency revised from quarterly to monthly to encourage more timely decision making. This important transition could potentially be facilitated through a shift to mobile phone-based reporting.

Discussions with staff at sub-district levels also revealed other HMIS-related challenges such as lack of coordination and data sharing across health programs, which have also been reported on previously (Chaulagai et al., 2005). Furthermore, informants at sub-district health facilities indicated that they hardly ever conducted meetings to discuss and analyze routine data locally. In contrast, informants consistently explained that HMIS review meetings were commonplace about

two years prior, under a World Bank-supported initiative. One district level HMIS officer reflected on the matter accordingly:

I think in that period we had the subsidising donor who was funding the meetings in all facilities. So they were supposed to meet each and every month, and they were given something [allowances] to convene and some soft drinks—so it worked. But since those people left, the meetings stopped immediately.

This example illustrates deep-rooted challenges regarding the introduction of viable long-term changes in the Malawi HMIS, even if they are of critical organizational importance. Staff from sub-district health facilities also revealed that the poor local use of data was caused by a lack of adequate data analysis skills, a lack of motivation by some officers in charge, and, more importantly, a lack of funds to cover expenses and allowances, as was the case with the World Bank-funded initiative. HMIS focal persons also complained that sub-district health facilities hardly received any feedback on data submitted to DHOs, which has also been reported on earlier (Chaulagai et al., 2005; Hamre & Kaasbøll, 2008).

4.3. Setting up DHISm in Malawi

In order to commence the DHISm implementation, the selected HMIS-15 and IDSR forms needed to be customized for mobile reporting on the national DHIS2 server. Consequently, the DHISm implementers established contact with the DHIS2 coordinators in Blantyre. However, it proved difficult to get mobile form customization activities to receive priority. In particular, the team in Blantyre was preoccupied with the already delayed national DHIS2 rollout to districts in Malawi. Additionally, their funding had recently been rearranged between donor organizations, which obscured the chain of command between CMED, the DHIS2 coordinators, and other implementing partners. Nonetheless, it was in the DHIS2 coordinators' interests to retain their role of performing customization tasks on the national DHIS2 server because this was a key aspect of their regular work. In order to commence with the preparations for mobile reporting, the DHISm implementers reached a compromise with the DHIS2 coordinators involving the use of another DHIS2 server instance (hereafter referred to as the DHIS2 demonstration server), which had mainly been used for live demonstrations and teaching purposes. DHISm implementers were given full administrative rights for the DHIS2 demonstration server. This was seen as a short-term fix while negotiations went on between the two parties.

The DHISm suite of solutions allowed for monthly data reporting to the DHIS2 demonstration server through two different mobile phone-based clients. One client was a mobile phone browser (i.e., Opera Mini or a native handset browser), while the other client was a Java ME-based application for installation on Java-enabled mobile phones. Some end users were trained to use the web browser, while other users would report through the Java ME application. Trying out both client types was not only based on an interest in understanding what would be more suitable for the Malawi HMIS context, but also an interest in the international DHISm initiative to compare the two newly developed clients in a real life setting. The Java ME client was expected to be more robust in use because it supported offline data entry when there was no GPRS connectivity. This was achieved by allowing end users to save data on their mobile phones, which could then be uploaded to a DHIS2 server once GPRS connectivity was available. On the other hand, the browser-based client required consistent GPRS connectivity during use. An obvious benefit with the browser-based client was the ability to have bug fixes and form revisions instantly reflected for all users simultaneously through server side customization.

When DHISm implementation plans were being finalized, two important adjustments were made. First, there was a revision from a big bang-type approach (including all 55 sub-district health facilities in Lilongwe at once) to a phased approach starting with only 17 sub-district health facilities, which covered two out of Lilongwe's five health areas (i.e., sub-district administrative health regions). It was argued that a phased approach would mitigate risks associated with a larger implementation using novel technologies and DHISm clients that had not yet been implemented in any real life setting. Second, the DHIS2 demonstration server was upgraded from version 2.6 to what at the time was a more recent version, version 2.7. However, it was discovered that a bug in the 2.7 release prevented

the DHISm clients from interacting properly with DHIS2. With the breakdown in compatibility between the latest release of DHIS2 and the DHISm suite of solutions, both the respective international software development teams situated in Norway and Vietnam were summoned to contemplate compatibility routines between future releases, while trying to assist DHISm implementers in Malawi in reflecting the necessary changes on the DHIS2 demonstration server. The bug was not resolved in time for scheduled implementation and the DHIS2 demonstration server in Malawi was rolled-back to version 2.6 in order to commence with end user training.

4.4. Tensons and Reconciliations in Leveraging Mobile Phones

In order to mitigate complexity, the DHISm initiative provided health workers with phones instead of trying to leverage the many models and brands of phones that health workers owned. The investment was also justified by the fact that many sub-district health workers did not own mobile phones despite being able to use one. Out of those health workers who did own mobile phones, only a small proportion had handsets with general packet radio services (GPRS) (i.e., higher-level mobile services associated with Internet access), web browsers, and/or Java support, which the DHISm clients relied on.

A decision was made to purchase Nokia C2-00 phones from India. The initial decision to purchase phones from outside Malawi was cost related because each phone cost about US\$50 in India compared to about US\$80 in Malawi. For a small-scale implementation across 17 health facilities, the cost savings were marginal, but the intent of scaling to more than 500 sub-district health facilities and possibly more than 1000 end users nationwide made the price difference noteworthy. Although there were some initial cost savings from the acquisition of phones from India, the decision had some adverse consequences. The acquired mobile phones did not support manual Internet data configuration and were also, at the time, not supported for automatically pushed data configuration through the mobile service providers' networks. Because the Nokia C2-00 handsets were not yet commonly available on the local market, the mobile service providers were not compelled to address the configuration issues on their end. The implementation team then tried to create Internet configuration files with the help of various online services and push them to the phones via Bluetooth. This workaround was also unsuccessful. In the end, the phones were sent back to India. As a result of these challenges, end user training for the two health areas in Lilongwe was re-scheduled several times, and was eventually postponed for a couple of months.

Later on, in January 2012, a batch of Nokia C1-01 phones were tested and purchased locally to allow for the implementation to proceed. The phones were formally distributed to sub-district health facilities by HMIS officers and presented to end users as property of the Ministry of Health. This arrangement helped clarify issues of ownership and responsibilities and legitimized the mobile reporting function. By using simple Nokia feature phones, the implementation could draw on existing mobile phone literacy among health workers, while allowing for some freedom of choice in reporting functionality (e.g., through a web browser or Java ME application). The sturdy Nokia phones feature long standby time on one battery charge, which is essential in a context with limited access to electricity. Finally, in case of breakage, carriers of low-end Nokia phones may easily get in touch with a competent representative of the popular brand's well-established service infrastructure in Malawi.

4.5. Bringing Mobile Service Providers Aboard

Mobile phone networks, which form the basis for any mobile phone-related innovation, were distributed between two mobile operators in Malawi, of which one had substantially more geographical coverage. At any rate, the DHISm implementers perceived the mobile operators as passive infrastructure providers, and their potential involvement with the implementation was considered marginal. The ambition was to effortlessly leverage the operators' infrastructure at the lowest possible cost.

The project acquired post-paid mobile phone subscriptions for all mobile reporters. Post-paid arrangements were seen as a means to centralize the management of distributed SIM cards and phone numbers. It was also in the researchers' initial interest to retain the possibility to review end users' aggregated Internet data consumption trends. The mobile operator could only maintain logs of mobile data consumption for phone numbers registered with post-paid subscriptions. The

arrangement with the mobile service provider, as of November 2011, was to have voice call costs capped at Malawian Kwacha 1500 (~US\$9 at the time of implementation) per month per phone number. However, the mobile service provider only technically got to cap the voice calls midway through March 2012, five months down the line. This was despite the DHISm implementers' numerous inquiries to have this issue resolved. The failure to cap the subscription costs resulted in high bills for some of the registered mobile numbers. In addition, some of the staff members participating in the implementation were at times unable to submit their summary data or make outgoing calls because the chosen mobile service provider failed to refresh their call credit at the start of some months.

Due to persistent challenges with the management of post-paid subscriptions, especially on the mobile service provider's side, the DHISm implementation shifted all subscriptions to a pre-paid arrangement, effective February 2013. The post-paid subscriptions had required DHISm implementers' constant mediation between end users and the mobile service provider. With the pre-paid arrangement, end users could top-up their phone credit at any time without assistance.

4.6. Involving all Levels of the Health Management Information System

At the time of initial DHISm implementation (early 2012), the majority of DHOs in Malawi were using DHIS 1.3. The Ministry of Health headquarters, through CMED, was, however, actively pushing for a country-wide rollout of DHIS2. Paradoxically, CMED itself was yet to shift to DHIS2 for data management and analysis. This was despite the setup of a national DHIS2 online server, the commissioning of DHIS2 implementation in two districts, and ongoing efforts to implement DHIS2 in all of Malawi's 28 districts. It was therefore still imperative that all DHOs submitted reports to the headquarters in a DHIS 1.3-compliant format. An interview with the deputy director at CMED and an assistant statistician at national headquarters indicated that CMED offices had regular problems with Internet connectivity, which made it hard for statisticians to access the online DHIS2 server. The assistant statistician explained that at some point their office had no Internet connectivity for about six months. With DHIS 1.3, installed on a local computer, the assistant statistician and his colleagues only required occasional Internet access to retrieve data files sent by DHOs. These Internet-based file transfers were usually done from other peoples' offices.

Similar challenges with Internet connectivity were encountered at the Lilongwe DHO. The HMIS officer responsible for HMIS-15 reports and the district IDSR officer had no dedicated Internet connection in their office prior to the commencement of DHISm implementation. With DHIS 1.3 and another desktop IDSR system, the two officers managed without dedicated Internet connectivity. After data entry on their computers, the officers would carry USB-drives and use a different office about 50 meters away to email exported data files to CMED. The mobile pilot introduced a blend of paper-based reporting via the DHO and digital reports from 17 health facilities going directly to the DHIS2 demonstration server. Data reported through mobiles would then technically "leapfrog" the two officers. In addition, the district HMIS officer was still required to send data to her superiors in a DHIS 1.3-compliant format. It became imperative that the above-mentioned officers be provided with reliable Internet connectivity and comprehensive training on DHIS2 so that their roles in the HMIS did not become marginalized. The DHISm implementers provided Internet dongles (USB Internet modems), with pre-paid data bundles and basic DHIS2 training to get the two district health area offices and the Lilongwe DHO immediately on board the DHISm implementation.

Implementation of the DHISm suite of solutions was subsequently targeted to slowly follow in the footsteps of the nation-wide DHIS2 roll-out to all 28 districts. The timeline in Figure 3 summarizes important events for both the national DHIS2 roll-out and the DHISm implementation in Malawi. Nationwide DHIS2 training for all HMIS officers and various program coordinators at DHOs was accomplished by February 2013, but further follow-up training sessions were deemed necessary to enhance uptake. As part of the national DHIS2 implementation, HMIS officers and program coordinators at the district level were provided with Internet dongles with subscriptions financed by CMED and various partner organizations to enhance Internet connectivity.

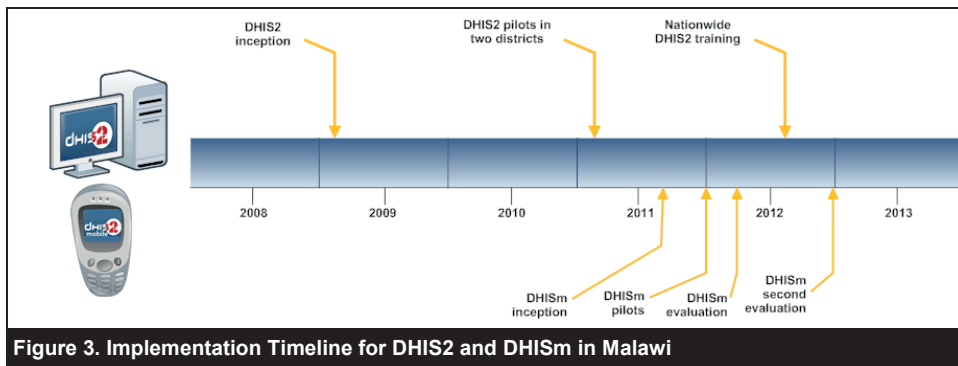


Figure 3. Implementation Timeline for DHIS2 and DHISm in Malawi

4.7. Evaluation and Evolution of the DHISm Implementation

In order to learn about users' experiences, DHISm implementers conducted focus group discussions and interviews three months after the initiation of mobile reporting. Over a period of one-and-a-half years the DHISm implementers organized five more evaluation and review meetings. From these activities, the DHISm implementers learned that mobile reporting was essentially welcomed by end users, even when users were informed that they would have to cover the charges for sending data through mobile phones. This transfer of immediate running costs was considered imperative for mobile reporting to have a life expectancy beyond the DHISm implementers' involvement. End users' self-management of call credit for data reporting had become plausible with the shift from post-paid to pre-paid arrangements. However, it was argued by end users that mobile reporting would be more useful if all other paper-based reports, including program-specific reports (e.g., HIV/AIDS, Tuberculosis, and Malaria), could be sent through the mobile phone as well. Otherwise, health workers would, at least in theory, still need to travel to the DHO to submit these other reports.

Four additional monthly reports were configured for mobile reporting midway through June 2013. Together with efforts to increase the number of supported reports, the migration of all mobile users' accounts from the DHIS2 demonstration server instance onto the main national DHIS2 server was embarked on. This shift was imperative because the DHIS2 Coordinators, who were responsible for server maintenance, largely paid attention to the national DHIS2 server instance. Downtime was much more frequent on the demonstration server instance. While the transfer between servers could be performed at this stage, the increase in number of reports to be customized for mobile reporting offered new challenges. In Malawi, some monthly reports were tied to donors' program-specific software systems at district and higher levels. Significant negotiations and alignments were required at the national level for different health programs to adopt an integrated approach where data could be reported and shared through DHIS2.

As a step toward phasing out the DHISm implementers' direct involvement, a full-time technical assistant was hired to work under the guidance of CMED and in collaboration with the DHIS2 coordinators. The technical assistant was financed by the DHISm initiative to compensate for the lack of in-house IT expertise at CMED. The arrangement was seen as an intermediate circumvention of the slow bureaucratic process of creating a new IT position in CMED. Besides hiring a full-time technical assistant, DHISm implementers have also successfully negotiated with CMED to include support for DHISm as part of the terms of reference (TOR) (i.e., contractual agreement) with the DHIS2 coordinators. At the time of writing, the DHIS2 Coordinators had relocated to Lilongwe to work more closely with CMED and the technical assistant.

4.8. Alignments for Future Expansion and Innovation

The Ministry of Health's inability to adequately support new information technology both financially and technically suggests that reliance on multiple implementation partners and donors cannot be

avoided for the time being. Malawi has witnessed a proliferation of mobile phone-centered health interventions, not unlike DHISm, over the past few years. Non-governmental organizations (NGOs) working in the health sector have initiated pilot studies at community and sub-district health facility levels. Most of the initiatives have been in the areas of patient monitoring and management, and related data collection and reporting. The Ministry of Health, represented by CMED, faces the challenges of coordinating and facilitating collaboration between these efforts because it lacks comprehensive knowledge on which stakeholders are implementing solutions for what purpose and where. Some districts appeal to many collaboration partners, while other districts are without support. Development partners working in similar areas often intervene and compete through the use of different tools and approaches.

In order to address harmonization-related challenges, a mobile health task force (mHealth-Malawi Forum) was established in June 2011. Meetings were conducted quarterly and were co-chaired by CMED's deputy director. The task force comprised stakeholders from different government departments, NGOs, development partners, and the University of Malawi. Through the task force, efforts have been made to establish a control point for the mobile technology-oriented parts of the health information infrastructure in Malawi. Some of the operational goals included: the establishment of a joint contact point and a standard term agreement with mobile operators on pricing, billing, and openness about mobile service coverage; agreement on priority areas for mobile intervention research; promotion of collaboration and sharing of information, resources, and technology maintenance tasks between various stakeholders; and, finally, integration of emerging mobile phone-centered innovations with DHIS2, the national HMIS backbone. The DHISm implementers have participated in the task force to align their own implementation efforts with other mobile phone-centered projects, so that resources, technologies, training efforts, and knowledge can be shared and new innovations extending existing initiatives can be encouraged and supported. The task force has agreed on some technical requirements for mobile phones to ensure that multiple projects can implement their solutions on the same devices.

5. Analysis and Discussion

In this section we demonstrate how the notion of grafting supports the analysis of information infrastructure innovation by discussing the empirical case. In Section 2.2, we define grafting 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. By drawing on the notion of grafting, we address the how-to question in information infrastructure innovation: how are some actors able to leverage parts of the installed base and summon stakeholders to legitimize and support an initially fragile information system innovation? Furthermore, we are concerned with how initial control on the supply side of IT innovation gradually becomes distributed and embedded as the graft takes hold through alliance building and the institutionalization of emerging work practices and technical solutions. To this end, **congeniality** between the information system innovation and existing socio-technical arrangements is a critical factor.

Congeniality focuses on the merged parts' ability and willingness to mutually adjust and co-evolve, and thus avoids ascribing causality of implementation outcomes to either an information system innovation (i.e., how well it fits a particular setting) or the social context the innovation is employed in (e.g., organizational resistance and hostility towards change). The DHISm implementation in Malawi involved revisions and adjustments as to what phones to leverage for mobile reporting, what DHIS2 server instance to utilize, and what arrangements to put in place for Internet data consumption. These adjustments were not only technical because they also implicated stakeholders in various more-or-less conflicting arrangements. The initial decision to only support two forms for mobile reporting (HMIS-15 and IDSR) mitigated complexity and avoided escalating early tensions pertaining to utilization of the national DHIS2 server between DHISm implementers and the DHIS2 coordinators in Blantyre. Later, when the need to customize more forms for mobile reporting grew stronger, this tension had already been resolved. Still, new tensions arose through the involvement of more program-specific data management interests because many donor-funded health programs had their

own dedicated software tools. Different inputs influencing the unfolding of the DHISm implementation were thus contested, avoided, and embraced as arrangements between actors evolved over time.

In Sections 5.1 and 5.2, we show how a grafting perspective allows us to generate new insights about important themes pertaining to information infrastructure innovation: how the installed base is drawn on and extended to support and shape new hybrid capabilities, how control pertaining to an II innovation becomes distributed and embedded across space and time, and how desirable innovative ICT capabilities may propagate through distributed and loosely coordinated grafting activities. Finally, we reflect on some limitations with this different organic perspective on information infrastructure innovation.

5.1. Grafting Information System Innovations Onto Existing Socio-technical Arrangements

Grafting work entails identifying a problem with existing socio-technical arrangements and proposing an information system innovation to address the perceived problem. The proposition to use mobile phones for routine data reporting from sub-district health facilities in Malawi was a response to challenges associated with the delivery of paper-based forms. Mobile phone networks in the country were well developed, and DHISm could be aligned with ongoing efforts towards a national DHIS2 rollout. These conditions appealed to the international DHISm initiative's broader agenda of improving, by trial and learning, a suite of data collection and reporting tools extending DHIS2 functionality.

Beyond responding to the opportunity presented, integrating DHISm into the existing HMIS required practical work to negotiate trade-offs between conflicting socio-technical factors over time, which has been noted previously with II innovation processes (Egyedi & Loeffen, 2002; Ribes & Finholt, 2009). Activities that enabled grafting mobile reporting capabilities onto the Malawi HMIS included negotiating service delivery arrangements with mobile service providers, experimenting with different mobile reporting clients in combination with different mobile Internet data payment schemes; identifying and acquiring appropriate handsets to leverage, ensuring interoperability between DHIS2 server instances, addressing breakdowns, balancing local and international interests pertaining to the functionality of the DHISm suite of solutions, training and supporting end users; and gradually transferring ownership and nurturing responsibilities for DHISm to CMED and its collaborating partners.

Some of the practical work involved, such as resolving emerging breakdowns and experimenting with different socio-technical configurations, remind us of Ciborra's (2002) bricoleur who manipulates resources at hand in response to unfolding contingencies. However, beyond expediency, grafting entails anticipation and pre-emptive action in trying to facilitate the long-term co-evolution between an innovation and the installed base. This is in part pursued by summoning nurturing inputs from actors who own or control influential parts of existing socio-technical arrangements. Key actors (e.g., mobile operators, district health offices, CMED, DHIS2 coordinators, and DHIS2 developers) became gradually involved in tending to the graft, albeit with different levels of engagement. There would have been no DHISm implementation in Malawi without the favourable conditions offered by the existing mobile phone networks. However, mobile operators in control of these networks remained influential yet elusive stakeholders. DHIS2 developers situated in Oslo and Vietnam were also called into action, such as when the 2.7 release of DHIS2 created compatibility issues with DHISm. The empirical case demonstrates that control over technical devices, physical infrastructure, or services platforms (i.e., the supply side of information infrastructure) positions certain actors in closer proximity to central control than actors who graft new innovations on top of existing arrangements. However, their power and influence may be invisible, even ignored, unless there is a breakdown of interdependencies.

CMED's intention to rollout DHIS2 nationally had already summoned relevant actors into a collaborative effort, which the DHISm implementation could leverage. Initially, the DHISm implementation accommodated the organizational coexistence of DHIS 1.3 and DHIS2 in the health ministry. Despite accommodating this coexistence, DHISm implementers actively supported the national DHIS2 rollout. For instance, DHISm implementers advised CMED in negotiations with international DHIS2 developers and other development partners for technical and financial support. This was done to facilitate an upsurge in ongoing DHIS2 implementation work, which the DHISm

implementation could then extend and leverage. The DHISm implementers' participation in DHIS2 implementation efforts also served to familiarize important stakeholders in Malawi with DHISm at an opportune moment and tied DHISm to broader HMIS restructuring plans. Deliberate efforts were also made by DHISm implementers not to disrupt established organizational routines and existing power structures pertaining to the HMIS in place. Health area offices and HMIS and IDSR officers at district health offices and national headquarters were kept up to speed with the DHISm implementation in terms of Internet access and DHIS2 training. The authority previously associated with hand-written signatures on verified paper reports and the hierarchical flow of information was re-articulated and aligned with the DHISm implementation's need for legitimacy and support. This was achieved, for example, by using hierarchical government structures for mobile phone and SIM card distribution to end users. The support of high-ranking HMIS officials was also solicited in following up on missing or late mobile phone-based report submissions.

As the examples above illustrate, much practical work and sensitivity is involved in tending to socio-technical grafts. The collapse of monthly data review meetings at the sub-district health facilities in Malawi after the withdrawal of financial and expert support previously provided under a World Bank-funded initiative testifies to the difficulties with sustaining HMIS innovations in the particular context, even if they are of critical organizational importance. An information culture that values assessment and use of data for local action at sub-district health facilities is arguably essential to strengthen the HMIS in Malawi further. Processed data available on the national DHIS2 server could, for instance, be made accessible through mobile phones (e.g., graphs and tables showing health metrics) and remedy the noted lack of feedback from DHOs to sub-district health facilities. New information system innovations to further extend the HMIS, such as the suggested feedback function, will again need to identify opportune moments and points of union with the installed base.

5.2. Grafting: From Implementation to Collaborative Nurturing

Grafting offers a new perspective on how local goal-oriented information system implementations are translated into nurturing activities performed by an increasing number of actors with varying interests and degrees of involvement. If the graft holds, control and agency inevitably become distributed and embedded through the growth of emerging interdependencies. This can be illustrated by the DHISm implementers' switch from post-paid mobile phone subscription arrangement to a pre-paid one. This shift was triggered by the realization that control over SIM cards and phone numbers and access to Internet data usage summaries through the post-paid arrangement was being offset by the arrangement's unreliability on the mobile operator's side. By switching to a pre-paid arrangement, the DHISm implementers relinquished some control and allowed end users to top up mobile phone call credit and resolve queries with the service provider. This switch was deemed appropriate with regard to a gradual takeover of subscription costs by end users and the envisioned scaling of mobile phone-based reporting to more than 500 sub-district health facilities.

In order to avoid tensions at an early stage of implementation, the DHISm implementers agreed to leverage a demonstration server for mobile reporting. The demonstration server instance acted as a temporary source of nourishment for the pilot while politics around the DHIS2 server were being sorted out. However, it was considered critical not to scale up the pilot while being tied to the demonstration server because this could bring about technical path dependencies and have adverse consequences later on. Evident in the examples above is an ongoing manoeuvring between pursuing and relinquishing control (Nielsen & Aanestad, 2006) in order to balance short-term needs with long-term sustainability (Ribes & Finholt, 2009) and accommodate emerging interests and practices.

Through participation in the mobile health task force, DHISm implementers aligned themselves with other mobile phone centered-innovations in Malawi to mitigate dependencies on external sources for technical assistance, user training, and financial support. In addition, participation in the task force allowed DHISm implementers to participate in formulating long-term guidelines for mobile phone-centered innovations in Malawi. The DHISm implementers' intention was to minimize their own involvement in the continued management of DHISm in Malawi, while leaving behind some structure that could support ongoing efforts. However, realizing these goals demands more than participation in

forums such as the mobile health task force. There is need for knowledge exchange and collaborative efforts to build necessary technical capacity in CMED to enhance system ownership, facilitate end user support, and ensure the sustainability of innovations.

DHISm's hiring a technical assistant to work out of CMED's offices exemplifies attempts to gradually hand over the nurturing activities tied to the implementation while still leaving room for influence. Over time, this arrangement may also help demonstrate the need to allocate additional ministerial resources for the creation of new IT-positions within CMED. A technical sub-division under CMED would help create a space where national policies could intersect with technical expertise in order to harmonize, among other things, uncoordinated mobile phone-centered activities in Malawi. CMED's expressed interest towards ensuring interoperability between DHIS2 and future mobile phone-centered innovations necessitates the availability of technical expertise to configure designated points of union (i.e., architectural control points) (Elaluf-Calderwood et al., 2011) to manage future HMIS extensions. In addition, collaboration with CMED in drawing up terms of reference for the aforementioned technical assistant and DHIS2 coordinators have provided a structure for future support for DHISm related activities. Steps taken to inform technical roadmaps, terms of reference, job descriptions, and regulations have allowed DHISm implementers to influence long-term agendas and shape arrangements on the supply side of II innovation in the public health sector in Malawi.

5.3. Concluding Remarks

Organizations, especially those operating in the same domains and sectors, often have similar information and communication needs and challenges. Information technology consultants and developers of generic software packages are concerned with tapping into economies of scale by identifying such commonalities across settings (Pollock et al., 2007). Consequently, organizational information system challenges, such as the one experienced by the Ministry of Health in Malawi, can be approached by drawing on already existing off-the-shelf solutions. Implementation efforts to address local contingencies are then embarked on based on a positive assessment of the innovations' perceived relevance to the specific organization. One may ask: why then do so many attempts at implementing relevant, even strategically crucial, information systems fail to take hold? We contend that such is the case because a tremendous amount of domain and context-specific knowledge and much sensitive and well-targeted practical work is needed to facilitate the mutual adaptation of the generic qualities of an innovative solution and local constituencies.

Efforts to strengthen local technical capacity and ongoing collaboration with developers of DHIS2 and DHISm in Norway and Vietnam were central to the implementation of DHISm in Malawi. Going forward, the availability of local capacity to add local enhancements to implemented solutions will be paramount to enable further II innovations. Implementations and appropriations of new information and communication capabilities that do take hold across distributed contexts may gradually evolve into information infrastructure. Existing capabilities may be recombined and merged through new grafting processes to create hybrid capabilities that take on new meanings as they propagate throughout time and across space. The grafting perspective extends previous theoretical work, which argues that infrastructure development is a combination of both intentional design and the emergent nature of infrastructure (Karasti et al., 2010). Grafting highlights the fragility pertaining to information infrastructure innovation and contrasts the mechanistic understanding of II innovation and growth informed by network economics (Hanseth & Aanestad, 2003; Hanseth et al., 2001; Varian & Shapiro, 1999).

In our discussion, we emphasize the meticulous efforts involved in summoning resources and capacities that allow for a progression from external dependencies to local nurturing on the supply side of II innovation. In comparison with a network economics perspective, prescriptively formulated into the bootstrapping strategy, grafting is more sensitive to the fragility and risk of failure associated with the transfer of nurturing dependencies. Grafting extends the organic notion of II cultivation to organizational goal-oriented information system innovations by paying attention to how parts of the installed base is mobilized and drawn on. Grafting entails a transfer of ownership and responsibility in order to secure the long-term viability of an innovation. Practical work, alliance building, capacity strengthening, and knowledge generation are required not only to support the innovation that has

been put in place, but also to support further II innovation. Grafting is not about fostering frivolous growth. It is about injecting envisioned desirable change into the evolutionary II development process.

Grafting is likely to unfold differently across different empirical settings. Some aspects with our presentation of the grafting perspective have been influenced by the uniqueness of the case explored here—an open source II innovation in a developing country supported by an overseas grant in a context in which public administration is weak and non-governmental organizations and donors play an important role. Such a setup results in a marked fragility in the innovation process that requires constant attention to possibilities of breakdown of socio-technical arrangements. Consequently, it is rather difficult to deeply root the II innovations described in the local context. Challenges such as those arising from interdependencies due to inadequate technical support and institutional structures might not be as prevalent in a context where technical capacities and institutions are stronger. However, the grafting perspective remains relevant to II innovation studies elsewhere. Previous studies on II innovations in both developing and developed countries have demonstrated that II innovations are significantly reliant on loosely coordinated stakeholders and project-based arrangements (Aanestad & Jensen, 2011; Jackson et al., 2007; Ribes & Finholt, 2009) and possess qualities of openness (Hanseth & Lyytinen, 2010), all of which contributes to the fragility of the innovation process.

Finally, metaphors are foundational to human thought. They make us aware of some aspects while concealing others. We note some limitations with drawing on the biological metaphor of grafting to study a socio-technical phenomenon. First, the point of union is the only point of influence between scion and rootstock in horticultural grafts, while certain capabilities from an information systems innovation and the installed base may be continuously recombined to inform new socio-technical hybrids. Second, horticultural grafting is a once-off process. There are no continued dependencies between the grafted scion and the plant it originated from. Information system innovations, on the other hand, may require some ongoing support from external developers and experts in order to obtain new capabilities and adjust to an ever-changing environment. Third, socio-technical grafts may involve feedback from local instantiations to their source of development and inform continuous refinement of ICT and software capabilities.

All in all, the passage of time is essential in telling how well grafting efforts play out because some grafts are bound to flourish for a while and then fail, while others may grow into desirable socio-technical hybrid configurations informing a steady accumulation and propagation of knowledge, technology, values, and competencies between social contexts. Further research is needed to explore longitudinal grafting processes that stretch beyond the scope of the current study.

References

- Aanestad, M., & Jensen, T. B. (2011). Building nation-wide information infrastructures in healthcare through modular implementation strategies. *The Journal of Strategic Information Systems*, 20(2), 161–176.
- Ali, M., & Bailur, S. (2007). *The challenge of "Sustainability" in ICT4D—is bricolage the answer?* Proceedings of the 9th International Conference on Social Implications of Computers in Developing Countries, São Paulo, Brazil.
- Arthur, W. B. (1994). *Increasing returns and path dependence in the economy*. University of Michigan Press.
- Baker, K. S., & Bowker, G. C. (2007). Information ecology: Open system environment for data, memories, and knowing. *Journal of Intelligent Information Systems*, 29(1), 127–144.
- Benkler, Y. (2006). *The wealth of networks: How social production transforms markets and freedom*. Yale University Press.
- Bergqvist, J., & Dahlberg, P. (1999). Scalability through cultivation. *Scandinavian Journal of Information Systems*, 11, 137–156.
- Borgman, C. L. (2003). *From Gutenberg to the global information infrastructure: Access to information in the networked world*. MIT Press.
- Bowker, G. C., & Star, S. L. (2000). *Sorting things out: Classification and its consequences*. The MIT Press.
- Braa, J., Hanseth, O., Heywood, A., Mohammed, W., & Shaw, V. (2007). Developing health information systems in developing countries. The flexible standards strategy. *MIS Quarterly, Special Issue on IT and Development*, 31, 1-22.
- Braa, J., Monteiro, E., & Sahay, S. (2004). Networks of action: Sustainable health information systems across developing countries. *MIS Quarterly*, 28(3), 337–362.
- Bygstad, B. (2003). The implementation puzzle of CRM systems in knowledge based organizations. *Information Resources Management Journal (IRMJ)*, 16(4), 33–45.
- Castells, M. (2011). *The rise of the network society: The information age: Economy, society, and culture* (Vol. 1). Wiley-Blackwell.
- Chaulagai, C. N., Moyo, C. M., Koot, J., Moyo, H. B. M., Sambakunsi, T. C., Khunga, F. M., & Naphini, P. D. (2005). Design and implementation of a health management information system in Malawi: Issues, innovations and results. *Health Policy and Planning*, 20(6), 375–384.
- Ciborra, C. (1999). *A theory of information systems based on improvisation*. Oxford University Press.
- Ciborra, C. (2002). *The labyrinths of information: Challenging the wisdom of systems*. Oxford University Press.
- Ciborra, C., & Failla, A. (2000). Infrastructure as a process: The case of CRM in IBM. In C. U. Ciborra (Ed.), *From control to drift—The dynamics of corporate information infrastructures* (pp. 105–124). Oxford University Press.
- Ciborra, C. U., Braa, K., Cordella, A., Dahlbom, B., Failla, A., Hanseth, O., & Monteiro, E. (2000). *From control to drift: The dynamics of corporate information infrastructures*. Oxford University Press.
- Ciborra, C. U., & Hanseth, O. (1998). From tool to Gestell. *Information Technology and People*, 11(4), 305–327.
- Constantinides, P., & Barrett, M. (2005). Approaching information infrastructure as an ecology of ubiquitous sociotechnical relations. *Designing ubiquitous information environments: Socio-technical issues and challenges*. IFIP TC8 WG 8.2 International Working Conference (pp. 249–260). New York: Springer Science and Business Media.
- Corea, S. (2007). Promoting development through information technology innovation: The IT artifact, artfulness, and articulation. *Information Technology for Development*, 13(1), 49–69.
- Dahlbom, B., & Mathiassen, L. (1993). *Computers in context: The philosophy and practice of systems design*. Blackwell Publishers.
- De Reuver, M., Bouwman, H., Prieto, G., & Visser, A. (2011). Governance of flexible mobile service platforms. *Futures*, 43(9), 979–985.
- Edwards, P. N., Bowker, G. C., Jackson, S. J., & Williams, R. (2009). Introduction: An agenda for infrastructure studies. *Journal of the Association for Information Systems*, 10(5), 364–374.
- Egyedi, T. (2001). Infrastructure flexibility created by standardized gateways: The cases of XML and the ISO container. *Knowledge, Technology & Policy*, 14(3), 41–54.

- Egyedi, T. M., & Loeffen, A. (2002). Succession in standardization: Grafting XML onto SGML. *Computer Standards & Interfaces*, 24(4), 279–290.
- Elaluf-Calderwood, S., Eaton, B. D., Herzhoff, J., & Sorensen, C. (2011). Mobile platforms as convergent systems: Analysing control points and tussles with emergent socio-technical discourses. In J. P. Maicas (Ed.), *Recent developments in mobile communications - A multidisciplinary approach* (pp 97-112). Intech-Open Access Publisher.
- Forster, P. W., & King, J. L. (1995). *Information infrastructure standards in heterogeneous sectors: Lessons from the worldwide air cargo community*. Cambridge, MA: MIT Press.
- Foster, V., & Shkaratan, M. (2011). Malawi's infrastructure: A continental perspective. *World Bank Policy Research Working Paper Series*. Retrieved from <https://openknowledge.worldbank.org/handle/10986/3363>
- Garud, R., & Karnøe, P. (2003). Bricolage versus breakthrough: Distributed and embedded agency in technology entrepreneurship. *Research Policy*, 32(2), 277–300.
- Gerring, J. (2007). *Case study research: Principles and practices*. Cambridge: Cambridge University Press.
- Hamre, G. A., & Kaasbøll, J. (2008). Motivation and demotivation: A case study of the Malawian health management information system. *Electronic Journal of Health Informatics*, 3(2), e11.
- Hanseth, O. (2001). Gateways—just as important as standards: How the Internet won the “religious war” over standards in Scandinavia. *Knowledge, Technology & Policy*, 14(3), 71–89.
- Hanseth, O., & Aanestad, M. (2003). Bootstrapping networks, communities and infrastructures. On the evolution of ICT solutions in health care. *Methods of Information in Medicine*, 42(4), 385–391.
- Hanseth, O., Ciborra, C. U., & Braa, K. (2001). The control devolution: ERP and the side effects of globalization. *ACM SIGMIS Database*, 32(4), 34–46.
- Hanseth, O., & Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: The case of building internet. *Journal of Information Technology*, 25(1), 1–19.
- Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing information infrastructure: The tension between standardization and flexibility. *Science, Technology & Human Values*, 21(4), 407–426.
- Heeks, R. (2002). Information systems and developing countries: Failure, success, and local improvisations. *The Information Society*, 18(2), 101–112.
- Heeks, R. (2006). Health information systems: Failure, success and improvisation. *International Journal of Medical Informatics*, 75(2), 125–137.
- Hepso, V., Monteiro, E., & Rolland, K. H. R. (2009). Ecologies of e-infrastructure. *Journal of the Association for Information Systems*, 10(5), 430–446.
- Hughes, T. P. (1987). The evolution of large technological systems. In W. E. Bijker, T. P. Hughes, & T. J. Pinch (Eds.), *The social construction of technological systems: New directions in the sociology and history of technology* (pp. 51–82). Cambridge, MA: MIT Press.
- Ives, B., & Jarvenpaa, S. L. (1991). Applications of global information technology: Key issues for management. *MIS Quarterly*, 15(1), 32–49.
- Jackson, S. J., Edwards, P. N., Bowker, G. C., & Knobel, C. P. (2007). Understanding infrastructure: History, heuristics, and cyberinfrastructure policy. *First Monday*, 12(6).
- Jansen, A., & Nielsen, P. (2005). Theorizing convergence: Co-evolution of information infrastructures. *Scandinavian Journal of Information Systems*, 17(1), 67–100.
- Karasti, H., Baker, K. S., & Millerand, F. (2010). Infrastructure time: Long-term matters in collaborative development. *Computer Supported Cooperative Work (CSCW)*, 19(3-4), 377–415.
- Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, 23(1), 67–94.
- Littlejohns, P., Wyatt, J. C., & Garvican, L. (2003). Evaluating computerised health information systems: Hard lessons still to be learnt. *British Medical Journal*, 326(7394), 860–863.
- Lyytinen, K., & Yoo, Y. (2002). Research commentary: The next wave of nomadic computing. *Information Systems Research*, 13(4), 377–388.
- Manda, T. D., & Sanner, T. A. (2012). *Bootstrapping information technology innovations cross organisational and geographical boundaries: Lessons from an mHealth implementation in Malawi*. Proceedings of the 35th Information Systems Research Seminar in Scandinavia, Sigtunahöjden, Sweden.
- Monteiro, E., & Hepsø, V. (2000). Infrastructure strategy formation: Seize the day at Statoil. In C. U. Ciborra (Ed.), *From control to drift: The dynamics of corporate information infrastructures* (pp. 148-171). Oxford: Oxford University Press.

- Nielsen, P. (2006). *A conceptual framework of information infrastructure building*. Unpublished doctoral thesis. Faculty of Mathematics and Natural Sciences, University of Oslo, Norway.
- Nielsen, P., & Aanestad, M. (2006). Control devolution as information infrastructure design strategy: A case study of a content service platform for mobile phones in Norway. *Journal of Information Technology*, 21(3), 185–194.
- Orlikowski, W. J. (1993). CASE tools as organizational change: Investigating incremental and radical changes in systems development. *MIS Quarterly*, 17(3), 309–340.
- Pipek, V., & Wulf, V. (2009). Infrastructuring: Towards an integrated perspective on the design and use of information technology. *Journal of the Association for Information Systems*, 10(5), 447–473.
- Pollock, N., Williams, R., & D'Adderio, L. (2007). Global software and its provenance generification work in the production of organizational software packages. *Social Studies of Science*, 37(2), 254–280.
- Ribes, D., & Finholt, T. A. (2009). The long now of technology infrastructure: Articulating tensions in development. *Journal of the Association for Information Systems*, 10(5), 375–398.
- Rolland, K. H., & Monteiro, E. (2002). Balancing the local and the global in infrastructural information systems. *The Information Society*, 18(2), 87–100.
- Sahay, S. (1997). Implementation of information technology: A time-space perspective. *Organization Studies*, 18(2), 229–260.
- Sahay, S., Monteiro, E., & Aanestad, M. (2009). Configurable politics and asymmetric integration: Health e-Infrastructures in India. *Journal of the Association for Information Systems*, 10(5), 399–414.
- Sanner, T. A., Roland, L. K., & Braa, K. (2012). From pilot to scale: Towards an mHealth typology for low-resource contexts. *Health Policy and Technology*, 1(3), pp.155–164.
- Skorve, E., & Aanestad, M. (2010). Bootstrapping revisited: Opening the black box of organizational implementation. In K. Kautz & P. A. Nielsen (Eds.), *Scandinavian Information Systems Research* (pp. 111–126). Springer.
- Star, S. L. (1999). The ethnography of infrastructure. *American Behavioral Scientist*, 43(3), 377–391.
- Star, S. L. (2002). Infrastructure and ethnographic practice: Working on the fringes. *Scandinavian Journal of Information Systems*, 14(2), 107–122.
- Star, S. L., & Ruhleder, K. (1996). Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information Systems Research*, 7(1), 111–134.
- Suchman, L. A. (2002). Practice-based design of information systems: Notes from the hyperdeveloped world. *The Information Society*, 18(2), 139–144.
- Sun, V., Aanestad, M., Skorve, E., & Miscione, G. (2009). *Information infrastructure governance and windows of opportunity*. Paper presented at the 17th European Conference on Information Systems, Verona, Italy.
- Trousset, J. (1886-1891). Grafting Technique. In *Trousset encyclopedia*. Paris, France: Librairie illustrée.
- Varian, H. R., & Shapiro, C. (1999). *Information rules: A strategic guide to the network economy*. Cambridge, MA: Harvard Business School Press.
- Walsham, G. (1993). *Interpreting information systems in organizations*. New York, NY: John Wiley & Sons.
- Zittrain, J. L. (2006). The generative internet. *Harvard Law Review*, 119(7), 1974–2040.

About the Authors

Terje A. SANNER is a PhD candidate at the University of Oslo's Department of Informatics. His research is concerned with strengthening health information infrastructure in resource sparse environments by leveraging free and open source software and mobile information and communication technologies.

Tiwonge Davis MANDA is a PhD candidate at the University of Oslo's Department of Informatics. He has 10 years working experience in academia and works as a Lecturer in Computer Science at Chancellor College, a constituent college of the University of Malawi. His research interests are mainly in large scale information systems/infrastructure development, health information systems, and mobile communication systems.

Petter NIELSEN holds a PhD in informatics from the University of Oslo. Working for 10 years as a researcher and business developer in the international telecommunication industry, he is currently Associate Professor at the University of Oslo. His research interests relate to the design and implementation of large scale and complex information infrastructures, with a particular focus on architecture, control and innovation. His empirical research ranges from mobile content services and the mobile Internet in Northern Europe and Asia to the emerging field of mHealth in developing countries.

Research Article

Paying Per Diems for ICT4D Project Participation: A Sustainability Challenge

Terje Aksel Sanner

Johan Ivar Sæbø

University of Oslo, Norway

Abstract

The article highlights the contradictory role per diem payments play in swiftly attracting local participation in ICT for Development (ICT4D) projects, while undermining long-term capacity building and sustainability with such efforts. We discuss sustainability challenges endemic to ICT4D projects in light of our case study findings from a mobile phone-based intervention in a public health management information system (HMIS) in Malawi. We explore these challenges at multiple levels of analysis by drawing on the neo-institutional notion of “institutional logics.” For practitioners and policy makers, the article offers suggestions on how to counter some of the pitfalls associated with the use of per diems to incentivize ICT4D project participants. The study contributes to the institutional logics perspective by exploring empirically the intricate interdependence between two mutually reinforcing, yet seemingly incongruent institutional logics of development project impact and aid entitlement.

1. Introduction

Long-term sustainability is a challenge with ICT for Development (ICT4D) across focus areas such as telecenters, education, agriculture, and health care. Simply put, *sustainability* refers to an ICT4D intervention's ability to work in practice, over time, in a given setting. Many ICT4D interventions in health information systems have been deemed unsustainable (Braa, Monteiro & Sahay, 2004; Heeks, 2006; Littlejohns, Wyatt & Garvican, 2003) due to underdeveloped infrastructure (Gordon & Hinson, 2007), limited duration of donors' financial support, technical bias of projects (Ali & Bailur, 2007), lack of alignment of interests and responsibilities among stakeholders (Kimaro & Nhampossa, 2005) and a “pilot project” orientation (Lucas, 2008, Sanner, Roland & Braa, 2012).

The term “capacity building” has long been used to describe efforts to enhance local governments' uptake of ICT4D innovations and address the tendency for interventions to generate external dependency and their inability to sustain the project. But if we hold that capacity building is the crux of sustainability, then why are sustainability challenges still so prevalent in the ICT4D field? We contend that capacity building and sustainability challenges are not easily resolved within the scope of a single ICT4D project. To understand these challenges we need to lift our gaze and pay attention to the dynamics of the broader ICT4D institutional landscape and development interventions.

For more than half a century, interorganizational arrangements have been cultivated to guide development collaborations among donors, implementation partners, nongovernmental organizations (NGOs), and developing world (public sector) recipients. Often such efforts have persisted despite asymmetric power relations, cultural differences, resource inequalities, political tensions, and underlying conflicts of interests. Although the experiences and strands of reasoning that various stakeholders draw on to inform and legitimize

To cite this article: Sanner, T. A., & Sæbø, J. I. (2014). Paying per diems for ICT4D project participation: A sustainability challenge [IFIP special issue]. *Information Technologies & International Development*, 10(2), 33–47.

PAYING PER DIEMS FOR ICT4D PROJECT PARTICIPATION

participation in development projects differ (Jensen & Winthereik, 2013), the players have been able to arrive at organizational forms (e.g., collaborative networks and partnerships) and practices (e.g., workshops) that mutually satisfy short-term expectations (Jordan Smith, 2003).

Inasmuch as the transfer of skills to master and maintain ICTs locally is essential, capacity-building efforts on the ground are too often equated with “training seminars” and “workshops” (Jordan Smith, 2003; Pfeiffer, 2003; Swidler & Watkins, 2009). In practice, ICT4D entails measurable interventions often centered on the conduct of capacity-building workshops with associated monetary incentives such as per diems, payment for performance, subsidized travels, and access to project equipment and resources. *Per diem* is Latin and translates to “for each day.” It is a fixed daily allowance paid by organizations (historically Western) to cover the living expenses incurred by employees’ work-related travels. Per diems are traditionally used to mitigate transaction costs involved with the creation of expense reports for reimbursement. The use of per diems in development projects became more commonplace during the 1970s to compensate for incurred travel costs and expenses associated with local participation.

Pfeiffer (2003) reports on the competitive use of per diems to garner project participation and support in Mozambique’s health care sector. He notes that per diem rates paid by donors skyrocketed during the 1990s. This resulted in a situation where one week of per diems yielded higher pay than a month’s salary in the public health services. At present, the use of inflated per diems has evolved into *perdiemitis*: where “[t]he players plan their actions around the primary goal of acquiring per diems, rather than of effecting changes among the publics targeted by their intervention” (Ridde, 2010, p. 2). As a result, the wrong people participate in project workshops and too many workshops are held at the wrong locations for too high a cost (Pfeiffer, 2003). Although a few studies pointed at these challenges with development projects more than a decade ago (e.g., Jordan Smith, 2003; Pfeiffer, 2003), inflated per diem payments remain prevalent (Søreide, Tostensen & Skage, 2012).

Malawi, a small landlocked country in sub-Saharan Africa and the empirical setting of our case study, has seen a vast upsurge in mobile phone–based ICT4D interventions in health (or mHealth) over the last few years. In particular, many mHealth pilot studies take place at the fringes of the health system to mobilize communities. Consequently, understaffed and sparsely resourced local authorities struggle to harmonize and monitor project activities. Worse yet, a plethora of ICT4D projects with associated monetary incentives threaten to undermine long-term reforms to strengthen national health management information systems (HMIS). The challenges briefly outlined here are interconnected and in part institutional and they span multiple levels of analysis.

We consider institutions as structures of social order that inform the behavior of individuals. At the same time, institutions are socially constructed and constituted by the actions of individuals and organizations (Berger & Luckmann, 1991). The neo-institutional notion of “institutional logics” offers a fruitful venue to understand the unfolding of complex social phenomena across multiple levels of analysis as it links individual agency, cognition, and behavior to socially constructed institutional practices and rule structures (i.e., the rules of the game). We draw on this perspective to identify and discuss the short-term (positive) and long-term (negative) consequences of the interplay between two institutional logics that we refer to as *development project impact* (i.e., the swift production of quantifiable intervention results) and *aid entitlement* (i.e., exploitation of development project incentives to top up meager civil servant salaries). In particular, we examine the central role per diems and simplistic short-term ICT4D impact evaluation practices play in the continuous reproduction of these two institutional logics. Theoretically, our investigation contributes to the understanding of institutional stability within an organizational field (e.g., ICT4D) by highlighting the mutually reinforcing interplay between a pair of seemingly incongruent institutional logics.

The next section presents our theoretical framework. Our case study approach to data collection and interpretive data analysis is accounted for in section 3. Section 4 presents the empirical case of a mobile phone–based ICT4D intervention at subdistrict health facilities in Malawi. Finally, section 5 discusses our findings and offers some concluding remarks and implications for further research.

2. Theoretical Framework: Institutional Logics at Play in Organizational Fields

Our study of ICT4D capacity building and sustainability challenges is informed by neo-institutional theory in general and by institutional logics specifically. Seminal works on neo-institutional theory (e.g., Meyer & Rowan, 1977; Zucker, 1977) highlight the role of culture and cognition to explain institutional stability through organizational conformity to societal requirements for *legitimacy*. Rather than being the mere reflections of individual and organizational actors' rational choices, institutions precondition actors' sense-making choices with "regulative, normative and cultural-cognitive elements that, together with associated activities and resources, provide stability and meaning to social life" (Scott, 2008, p. 56).

Organizational Fields

DiMaggio & Powell (1983) extrapolate Meyer and Rowan's (1977) focus on organizations' mimetic and habitual behavior from the societal level to the level of organizational fields that include "those organizations that, in aggregate, constitute a recognized area of institutional life: key suppliers, resources, product consumers, regulatory agencies and other organizations that produce similar services or products" (DiMaggio & Powell, 1983, p. 148). An organizational field may be considered a set of contextual factors or influences that affect organizational structures and processes. A key characteristic of organizations operating within the same organizational field is that they tend to develop similar structural and cultural environments.

We can think of *development interventions* as an organizational field that consists of subfields such as ICT4D. In turn, ICT4D has an identifiable set of influential key funders (e.g., World Bank, PEPFAR, International Monetary Fund, and national agencies such as Norad), technologies (e.g., ICT innovations and software packages), implementers (e.g., technical assistants and NGOs), consumers (e.g., governmental organizations in developing countries), and regulatory agencies (e.g., the World Health Organization and the United Nations). Through complex dialectics these players have established a set of norms (e.g., local ownership, participation, harmonization, and sustainability), quantifiable evaluation criteria, and shared practices. Some of the field-level organizing principles have even been formalized in development guidelines such as the Paris Declaration and Accra Agenda for Action.¹

Institutional Logics in Contestation and Interdependence

DiMaggio and Powell (1983) mainly focused on explaining prescribed and mimetic organizational behavior in response to cultural rationalization. In contrast, the concept of "institutional logics" grew out of studies trying to explain contradictory social practices in organizations (Alford & Friedland, 1985; Friedland & Alford, 1991). Central to institutional logics is the idea that actors' decisions result from both individual agency and the influence of institutions from which they draw legitimacy and identity (Friedland & Alford, 1991; Jackall, 1988). The institutional logics approach shares with DiMaggio and Powell (1983), Meyer and Rowan (1977), and Zucker (1977) a concern with how cultural rules and cognition shape and legitimize organizational structures. However, institutional logics address the critique of earlier neo-institutional works' narrow focus on organizations' mimetic behavior (Hasselbladh & Kallinikos, 2000). The institutional logics perspective is sensitive to the interplay of *differentiated* institutional logics and the effects this interplay has on individuals and organizations in wider institutional environments (e.g., industries or organizational fields).

Building on the ideas of both Jackall (1988) and Friedland and Alford (1991), Thornton and Ocasio define institutional logics as "the socially constructed, historical patterns of material practices, assumptions, values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality" (1999, p. 804). According to this definition, institutional logics provide a link between individual agency and cognition and socially constructed institutional practices and rule structures. Institutional actors carry "cognitive maps" for producing and reproducing the logic within a specific institutional environment and provide "meaning to their activities" (Scott, Ruef, Mendel & Caronna,

1. *The Organisation for Economic Co-operation and Development (OECD) provides a description of the Paris Declaration and Accra Agenda for Action. See <http://www.oecd.org/dac/effectiveness/parisdeclarationandaccraagendaforaction.htm>*

PAYING PER DIEMS FOR ICT4D PROJECT PARTICIPATION

2000, p. 20). In addition, institutional actors invoke, juxtapose, and combine the symbols and practices of multiple institutional logics to produce new interpretations and meanings which may effectuate institutional change (Friedland & Alford, 1991, pp. 232, 248, 251–252; Holm, 1995; Zilber, 2002).

Institutional logics also highlight the interplay between interdependent societal levels that involve “individuals competing and negotiating, organizations in conflict and coordination, and institutions in contradiction and interdependency” (Friedland & Alford, 1991, pp. 240–241). Actors’ sources of rationality change as they draw on different institutional logics residing at the level of organizational fields, domains, or industries, which, in turn, can be traced to sets of expectations of human and organizational behavior associated with institutional orders at the level of society: the state, the professions, the corporations, the family, the communities, and the market.

Practices are the key conceptual linkages between institutional logics and intra-organizational processes (Thornton, Ocasio & Lounsbury, 2012). Multiple practices may coexist within an organization or an organizational field and be interdependent (Pache & Santos, 2010). Consequently, adoption or enactment of a new practice or modification of an existing practice often has ramifications for other practices in an organization (Thornton et al., 2012; Zilber, 2002). These interdependencies are generated from social interactions that involve both communication and resource flows, thus shaping both the vocabularies and material subsistence of involved actors. At the organizational level, institutional logics provide the formal and informal rules of action, interaction, and interpretation that guide and constrain decision makers in accomplishing the organization’s tasks and in obtaining social status, credits, penalties, and rewards in the process (Ocasio, 1997).

Despite early recognition in the seminal article by Friedland and Alford (1991), the explicit exploration of *interdependencies* among institutional logics has been overshadowed by an emphasis on *competing* logics and the continuous *contestation* of meaning in studies that take an organizational field-level perspective (e.g., Currie & Guah, 2007; Lounsbury, 2007; Marquis & Lounsbury, 2007; Reay & Hinings, 2009). Currie and Guah (2007) explore how competing institutional logics within the organizational field of health care jeopardize the smooth implementation of a national program for IT in the UK. Their study reveals that the implementation of an information system infused with the logic of “patient choice” is consistently challenged by unresolved tensions with the professional logic of self-regulation and the managerial logic of efficiency. Similarly, Sahay, Sæbø, Mekonnen, and Gizaw (2010) explore the tensions that arise between a highly centralized paper-based health management information system in Tajikistan and the introduction of a computerized software with values of decentralization and local empowerment inscribed into the implementation strategy. At the health districts the institutional logic guiding the implementation found support in the informal practices that circumvent the rigidity of the Soviet-legacy information system. However, the contestation between institutional logics caused a stalemate when the software was implemented at higher levels of the health ministry.

Although interdependence between logics is an inherent assumption with the institutional logic perspective, few empirical studies have highlighted these reinforcing dialectics between logics. A recent study by Hayes & Rajão (2011) is sensitive to both synergies and contestations among sovereignty, sustainability, and economic institutional logics as they are upheld in different ways through the historical monitoring of activities in the Amazon rainforest with the use of geographical information systems (GIS). Their analysis highlights that institutional logics are always provisional and relational. In this article, we draw on the notions of organizational fields and institutional logics to discuss how short-term project impact assessments and the prevalent use of ICT4D project incentives such as per diems preserve and are preserved by the interdependence between two seemingly incongruent institutional logics.

3. Methods

This article draws upon an interpretive case study approach informed by guidelines put forth by Klein and Myers (1999) and Walsham (1993, 1995). We draw on an interpretive tradition to make sense of peoples’ behaviors and their justifications in relation to participation in a mobile phone–based ICT4D intervention in Malawi.

Context of the Study and Researcher Roles

The study grew out of the authors' close involvement with an international intervention research project called the Health Information Systems Programme (HISP). HISP activities primarily centered around the design and deployment of the District Health Information Software (DHIS2) in more than 40 countries in Africa, Asia, and Latin America (Braa et al., 2004; Braa, Hanseth, Heywood, Mohammed & Shaw, 2007). DHIS2 is a generic web server-based solution for collection, validation, analysis, and presentation of aggregate statistical data, tailored to integrated health management activities.

The empirical material was collected through the first author's involvement with the implementation of a suite of mobile phone-based functionalities, called DHISm, for routine health data reporting at health facilities in Malawi. DHISm permits data reporting through mobile phones and extends computer-based DHIS2 implementations. The second author has also held various roles in the ICT4D landscape over the last decade, including WHO's now-disbanded Health Metric Network (HMN), aimed at mobilizing development partners to strengthen health information systems in developing countries (HMN, 2008). While this article builds upon research that was carried out in Malawi, both authors have also been involved with similar ICT4D projects in other developing countries. Most relevant here is the conduct of workshops and formal training sessions carried out on behalf of either HISP or HMN/WHO.

Data Collection and Data Analysis

In between September 2011 and mid-2013, the primary author visited Malawi three times for research and DHISm implementation purposes. Each visit lasted for about one month. Initially the study focused on HMIS-related practices and information flows among health facilities, district health offices, development partners, and NGOs in Malawi. This baseline investigation was deemed crucial to the successful implementation of DHISm. Full-day observational visits were made to nine subdistrict health facilities and repeated visits were made to the district health office involved with the DHISm implementation. This baseline study resulted in ad hoc field notes, photos, and face-to-face interviews with 20 informants in their work environments. Part of this data was later interpreted in light of the subsequent refocus of the study (discussed below).

In addition to DHISm project management activities, the first author participated (as a trainer) in three end-user training sessions and in five focus group evaluation meetings, where users' experiences with the DHISm intervention and motives for project participation were discussed. A recurring theme in the training sessions and focus group discussions was the importance of per diem payments to motivate project participation. As the implementation progressed, potential challenges to the uptake of DHISm mobile reporting and to other nondomestically funded HMIS strengthening activities in Malawi were perceived to stem from disparities between stakeholders' expectations for which the payment of per diems served as a mediator. This led to a shift in the study's focus and the reinterpretation of some of the first author's own activities such as the facilitation of DHISm pilot buy-in within the Ministry of Health. The new and more explorative focus of the study informed the scrutiny of a decade's worth of policy documents and HMIS status reports that revealed sustainability challenges with ICT4D initiatives in the public health sector. Supplementary data that informs the study include face-to-face discussions, email exchanges, and Skype conference calls with fellow DHISm implementers in Malawi, DHIS2 and DHISm developers in Norway and Vietnam, and HISP global project coordinators.

Data analysis was based on transcripts from audio-recorded interviews and focus group discussions, field notes that document the primary author's interpretation of behaviors and events pertaining to DHISm project participation, and studies of the above-mentioned official documents. The analysis was carried out first by the primary author alone and later by both authors, as follows. First, the empirical material was sifted for quotes signifying preferred courses of action (i.e., practices) in relation to engagement with ICT4D projects. If discernible, these behaviors were then codified into legitimacy claims, i.e., the underlying assumptions that justify certain behaviors. The theoretical framework presented in section 2 helped us shape the analysis at an early stage, particularly through the notion of "legitimacy claims," which is a central notion to the institutional logic perspective. Legitimacy claims were paired with empirically identified practices and broader strands of reasoning

PAYING PER DIEMS FOR ICT4D PROJECT PARTICIPATION

(i.e., institutional logics). As the analysis progressed we focused on tracing interdependencies between two discernible institutional logics of development project impact and aid entitlement at the level of projects, organizations, and the ICT4D field.

Qualitative research that touches upon personal and sensitive issues, like peoples' attitudes toward the use of ICT4D per diems, may have inherent limitations. Furthermore, the study this article reports on was not initially concerned with per diems or the way ICT4D projects are conducted. This article is, rather, the product of the primary author's deep involvement with the DHISm implementation in Malawi and reflection on emerging trends in the empirical data. As a limitation, the data pertain only to one implementation in one public sector in one developing country. In favor of our findings, the study's ad hoc research design may have helped reduce potential study barriers as the topics discussed in this article were initially brought up voluntarily by informants.

4. Paying Per Diems for ICT4D Project Participation

This empirical section starts with a brief overview of HMIS restructuring activities in Malawi. These activities serve as the backdrop for the mobile phone-based DHISm intervention from which we draw our findings. Next, we reflect on the *development project logic* (subsection 4.2) that informs the funding arrangements and management of ICT4D projects such as DHISm. We then look at how local project participants rationalize their roles in such interventions by drawing on the *aid entitlement logic* (subsection 4.3). We do this by providing rich accounts of how these two logics interplay during the implementation of DHISm at subdistrict health facilities in Malawi (subsection 4.4). We focus the empirical discussion around perceptions concerning the use of per diems to attract project participation. We conclude this section with a summary of the empirical findings (subsection 4.5).

4.1. Empirical Setting: HMIS Strengthening in Malawi

A well-functioning HMIS is crucial to effectively administer scarce health care resources, address epidemics, inform policy making, and measure the impact of donors' targeted health interventions. In 1999 the Malawi Ministry of Health conducted an assessment that revealed the national HMIS' inability to provide timely and reliable information to concerned parties, including district health management teams (Chaulagai et al., 2005; Ministry of Health, 2003). In an effort to strengthen collaboration between donors' vertical programs and facilitate decentralized decision making, the Ministry endorsed the establishment of an integrated and comprehensive HMIS. The computerized District Health Information System (the first generation of DHIS) was identified and implemented at the district level and higher organizational levels from January 2002.

One decade later an HMIS assessment revealed that fragmentation had crept back into the system. This had happened despite donors' explicitly stated harmonization strategies. For example, the World Health Organization's Country Cooperation Strategy for Malawi 2008–2013 stated that the WHO will guide "planning and resource allocation through alignment with national health priorities and harmonization with other development partners" (WHO, 2009, p. vii). As a continuation of the harmonization strategy, the Ministry decided to upgrade the DHIS from stand-alone installations running independently in every district to a centralized approach with a national Web-based DHIS2 server.

Overall, migration to the Web-based DHIS2 client server setup has been ineffective, partly because the Ministry lacks sufficient in-house IT expertise to take on the management of the national DHIS2 server, system customization, end-user training, and other mundane IT tasks. At the time of writing, DHIS2 training has been conducted for all district health management teams in Malawi, but HISP and other implementation partners have been presented with the Ministry's need for assistance in the provision of refresher training to DHIS2 end users including donors' various health program coordinators.

4.2. Development Project Impact Logic: Producing Swift and Measurable Results

Implementation of DHIS2 and DHISm involves both international implementation agencies and funding donors who operate within the development intervention landscape. We first look at the overarching logics informing the behaviors of these global development actors when it comes to project realization.

The sustainability of ICT4D interventions in public health has been undermined by, among other factors, the

lack of coordination among interventions. Few technical innovations are extended and maintained across projects, and coordination and cooperation efforts are not assessed and rewarded. Anecdotally, the primary author visited a subdistrict health facility in Malawi that had four solar panels installed on its rooftop—one for each ICT4D innovation put in place by different donors' initiatives over the last few years. Only one of these innovations was still in use, a touch screen–based system for registering outpatient data for pregnant women. For the rest of the ICT innovations, facility staff did not know whom to contact for technical assistance and maintenance.

ICT4D projects must make themselves attractive to a few powerful international donors by demonstrating clearly delineated objectives, with quantifiable costs and impact projections to be realized within a fixed (typically short) time. Consequently, showcase projects often focus on isolated targets and report on simple input and output variables such as dollars spent and number of people trained, rather than project (learning) outcomes and interproject collaborations, which are harder to quantify and compare. A preoccupation with the production of measurable and quantifiable project results within a limited time frame is what we refer to as the *development project impact logic*. It is no surprise that the development project impact logic inherits values and metaphors (e.g., growth, impact, and scaling up) from the higher-level institutional logic of the market, since the historical discourse on development has been dominated by economists. The development project impact logic conflates corporate-patriarchal elements of centralized international development planning (e.g., development declarations) with the logic of the market. This centralized monitoring and evaluation (market micromanagement) performed by a few influential and uncoordinated development donors translates into fragmented ICT4D interventions put in place by development implementers and NGOs on the ground.

In response to these well-known harmonization challenges, the international community endorsed the Paris Declaration on Aid Effectiveness in 2005, with more than 100 signatory countries committing to harmonize development intervention work and assist developing country governments to formulate and implement their own development plans. However, this recognition has had limited influence on donors' funding modalities, and ICT4D efforts remain uncoordinated and fragmented nearly a decade later. Organizations involved with ICT4D implementation (e.g., HISP) are concerned with their own expansion and growth as well as the local realization of ICT4D projects. Implementing DHIS2 or DHISm in yet another country is a step toward sustaining HISP as a collaborative intervention network and generating funding for more projects (Braa et al., 2004).

4.3. Development Project Impact Logic Meets Aid Entitlement Logic: Attention Sold to the Highest Bidder

The development project impact logic has adverse consequences in developing countries. In this subsection we look at how this manifests itself in relation to health management information systems in Malawi. In particular we focus the empirical discussion on perceptions of per diem payments to ICT4D project participants.

Initially the DHISm implementation focused on two important data collection forms for mobile phone–based reporting from 17 health facilities in one district. The aim was to assist subdistrict health staff to collect and report health information. In a critically resource-constrained environment, the health workers have adopted pragmatic approaches to a range of health system and health information system limitations and challenges. Historically, the completeness and timeliness associated with paper-based reporting of routine data collection forms to district health offices have been compromised by seasonal challenges associated with muddy roads, fuel shortages, occasional inadequate supplies of stationery, or simple neglect. Staff at health facilities explained that when they travelled to the district office to deliver reports, their travel costs were neither refunded nor subsidized, thus workarounds and improvisations were commonplace. For instance, facility health workers would send reports with passing ambulances or submit their reports when going to town to collect salaries.

Government-paid salaries² in some debt-burdened developing countries have been capped and consequently diminished in relation to civil servants' income from access to "dollar projects" (Pfeiffer, 2003). This has, in turn, strengthened the need for civil servants to secure opportunities for participation in donor-funded

2. Under the Bingu wa Mutharika administration, Malawi introduced the Zero Deficit Budget, with the aim of financing all recurrent expenditures using domestic resources.

PAYING PER DIEMS FOR ICT4D PROJECT PARTICIPATION

workshops and gain access to project resources. Leveraging one's positions in hierarchical power structures to obtain a share of the monetary incentives associated with development projects is condoned. Søreide et al. report on the pervasive use of per diems in Malawi, Tanzania, and Ethiopia and argue that it could even be seen as foolish or immoral not to exploit such arrangements to cater for "one's own," as per diems "form an entrenched, informal component of the system" (2012, p. 52). We refer to this institutional logic as *aid entitlement logic*. Aid entitlement logic allows government employees to make sense of their conflated roles as underpaid, overburdened civil servants, kinsmen, and development project participants. In essence, meagrely paid civil servants legitimize opportunistic behaviors in relation to dollar projects by drawing on the aid entitlement logic, which incorporates a sense of kinship and community that transcends bureaucratic government structures.

One implication of the two logics presented is that participation at workshops depends on the payment of a per diem—it has become an expectation. During the initial stages of the DHISm project, we consulted with the officers in charge at a district health office and two district hospitals. Although these people would not be directly involved with the DHISm implementation, they advised us on the conduct of our intervention. The topic of per diems came up and one senior district hospital clinician explained: "If you want them [workshop participants] to take you seriously, you should pay about \$25 like the UN guys. They are the most serious. You also need to provide some snacks and soft drinks" (Malawi, 2011).³

The quotation illustrates two points. First, per diems are an entrenched component of ICT4D, to the extent that well-meaning bystanders feel compelled to guide new projects on how to be taken seriously. Second, attention can be bought, and the perception is that serious initiatives pay higher rates. We followed the advice of providing chips and soft drinks, but we could not afford, nor did we wish to provide, an inflated allowance for our workshop attendees. Instead we employed per diem rates of MWK 1500 (US\$8 at the time), used internally by the Ministry of Health for lower-level civil servant reimbursements. However, the per diem rates employed by the DHISm team were not announced prior to conducting the training.

In retrospect, we have had discussions about per diem rates and payments internally in the project and with other members of the HISP intervention network. HISP central coordinators are full-time university professors and proponents of a pragmatic stance to ICT4D implementation. One of the HISP global coordinators reflected on the arrangement of training and per diem payments: "All the big players [i.e., WHO, UN, PEPFAR] pay per diems, so we must also do it. We can only hope that they will collaborate with us and cover per diem costs for participants in our projects" (Oslo, September 14, 2013).

This statement signals an appreciation within HISP as being confined to mimicking other interventionist organizations within the broader development landscape.

4.4. Eroding the Sustainability of Interventions

Civil servants' expectation of per diems has a malign effect on ICT4D project sustainability. What such projects seek to implement becomes associated with the accompanying monetary incentives and may erode quickly when funding runs out. For example, after years of ministerial efforts to integrate and harmonize the national HMIS, district stakeholders (district health management teams and donor program coordinators) are now supposed to meet regularly to discuss public health trends and strategize based on summary reports generated by the DHIS software. However, a district health officer reflected on the irregular conduct of district review meetings:

We are supposed to have the analysis monthly, but due to some problems sometimes we fail, because sometimes we also need some people to join the analysis and probably they require something [per diems] at the end of the review. So if the district [management] does not [financially] support the program for the activity [monthly meeting], it fails, naturally like that. (Malawi, 2012)

Such examples could also be found at health facilities. Interestingly, informants consistently explained that health facility review meetings were commonplace about two years prior, with a World Bank-supported initiative:

3. Details about the name of the district in Malawi and the exact dates of correspondence have been omitted to preserve the anonymity of study informants.

I think in that period we had the subsidizing donor who was funding the meetings in all facilities. So they were supposed to meet each and every month, and they were given something [per diems] to convene and some soft drinks—so it worked. But since those people left the meetings stopped immediately. (assistant statistician, district health office, Malawi, 2012)

The discontinuation of monthly data review meetings at the subdistrict health facilities in Malawi after the withdrawal of financial and expert support from the World Bank initiative points to the deep-rooted sustainability challenges of HMIS strengthening initiatives in Malawi. Initially, per diem payments facilitate a win-win situation; the participants get some allowances, and the funders quickly get to demonstrate impact back home. However, the routines instilled by donors are not necessarily institutionalized and require continued external funding. Data review meetings differ from ICT4D training and the dynamics of these meetings are not directly comparable. However, there was a clear capacity-building agenda built into the supported review meetings, which had resulted in meticulously hand-drawn graphs on subdistrict health facility walls. These graphs all had in common that they were dated two years prior.

Monopolizing Access to Per Diems

Through focus group discussions during DHISm training sessions, we learned that facility staff is presented with multiple uncoordinated initiatives by organizations that conduct training and request program-specific health summary data reports. Sometimes several initiatives target the same health facilities simultaneously.

There are focal persons who have different programs; one person being focal person for maybe various programs. Now, when it comes to reporting, it means at the end of the month he has to compile reports of different programs. Is it that he gets invested and he ignores some other reports? Sometimes we try to advise them that this is a government job and we need to share. (program officer, district health office, Malawi, 2012)

We note the use of the word “share” at the end of this excerpt, as if access to donor programs’ monetary incentives is perceived by the program officer as a communal good that should be fairly distributed among colleagues. A facility health worker’s elaboration further clarifies and builds on this statement.

We have come here [DHISm training] and normally, whenever there is something like this, we have got an explanation: “If I go there, I’m going to get money. If I send this one—he gets the money. No! Let me go myself!” That may be one of the issues. Maybe because of money, they say, “No, let me of course, be involved in many things because of what I’m going to get.” I think that’s just why he was saying we should share. (HMIS focal person, subdistrict health facility, Malawi, 2012)

The excerpts above substantiate that both the responsibility for donor programs’ data reporting and the corresponding opportunities for workshop participation are treated opportunistically as a way to add to civil servants’ meager salaries. Premium payments for specific reports, new ICTs put in place to handle specific program data, and the conduct of training signal the importance of a given set of health indicators. The monopolizing behavior among civil servants around ICT4D project participation, legitimized by the aid entitlement logic, challenges the sustainability of ICT4D projects. ICT4D implementers wish to train the right people, dedicated to the project’s long-term goals, but people holding roles senior to those invited frequently show up at workshops. Despite the DHISm implementers’ awareness of this inclination and their efforts to specify that only the subdistrict facility focal persons for the two forms identified for mobile reporting should attend training sessions, their seniors either came along with them or in the place of one of them. Other important chores (e.g., patient consultation and health facility management) may be put aside, at least for the time being, by a few well-positioned individuals who take on more donors’ chores than they can realistically handle.

Currently DHISm is being scaled up to the whole district (from 17 to 44 subdistrict health facilities) and four more data collection forms have been customized for mobile reporting. Mobile reports are being submitted to the DHIS2 server and some end users have even started to report on the four new mobile Web-based forms without additional training. There are no direct monetary incentives associated with mobile reporting of the health summary data. However, subdistrict facility staff no longer need to spend a full day traveling to the district health office at their own expense or find unreliable workarounds for report submission. This convenience, we believe, is the key driver behind the current uptake of DHISm for mobile reporting.

PAYING PER DIEMS FOR ICT4D PROJECT PARTICIPATION

Table 1. Institutional Logics at Play in the Organizational Field of ICT4D.

Institutional Logic	Practice	Legitimacy Claim	Implication for ICT4D
Aid Entitlement	Participate in ICT4D projects for personal financial gain	Access to donors' projects boost civil servants' meager salaries	Attention is sold to the highest bidder
	Monopolize workshop participation	Exploiting access to donor funding to maximize financial and social capital is condoned	ICT4D project participants take on more roles than they can handle The wrong people attend workshops and training sessions
Development Project Impact	ICT4D implementers focus on easy-to-measure objectives, such as number of workshops held	Short-term and quantifiable results permeate development harmonization	Limited coordination and sharing of technology and expertise among initiatives
	Initiatives compete for attention	Paying per diems is the surest way to attract attention	Uncoordinated projects pay inflated per diem rates

4.5. Summary of Case Study Findings

The case study findings are summarized in Table 1. The table identifies the institutional logics of *aid entitlement* and *development project impact* as they play out in the ICT4D organizational field. We have distilled these *institutional logics* from individual- and project-level *practices* (i.e., behaviors and actions) and *legitimacy claims* (i.e., justifications and rationalizations). The table also indicates the broader implications of the mutually reinforcing interplay between these two logics and the ICT4D field as a whole. Specifically, these implications translate into sustainability and capacity-building challenges that face ICT4D projects, which we discuss in the concluding section of this article.

Our primary concern is with how these two logics interact through ICT4D practices. At the project level, the two identified institutional logics are maintained by two discernable strands of actors: local ICT4D participants and external development intervention practitioners.

5. Discussion and Conclusion

This section draws on the institutional logic perspective to explore challenges both to the long-term sustainability of ICT4D interventions and to ministerial efforts aimed at strengthening weak management structures in the public services. Our analysis differs from the few existing studies concerned with the interdependency between development project evaluation criteria, and local actors' income and social capital maximizing behavior (Jordan Smith, 2003; Pfeiffer, 2003; Ridde, 2010; Sørdeide et al., 2012) in that it highlights how unsustainable ICT4D practices reproduce and are reproduced by the interaction between the *development project impact logic* and the *aid entitlement logic*.

We have shown empirically that by paying for attention, ICT4D projects obtain immediate responses from an understaffed health system which sooner or later will have to retract its attention to cater for other equally important tasks. For ICT4D practitioners, the number of workshops and participants are measurable indicators by which projects are evaluated. Such indicators are crucial to the funding mechanisms of international donors. In short, a few influential donors (the service buyers) face the challenge of comparing apples to oranges to calculate the return on investment across projects implemented by local NGOs and partners (the service sellers). This leads to a preoccupation with simple performance indicators comparable across projects coupled with rapid evaluation cycles to discard bad apples. In turn, this preoccupation can be tied to economic rationalizations, budgetary periods, and political election cycles in donors' home countries.

To civil servants in developing countries, workshops' entails monetary incentives such as per diems that are

perceived as part of their legitimate income (Søreide et al., 2012). Jobs in the public health services are accepted on a low salary partly because the position gives promise of access to dollar projects. The irregularity of monetary incentives and the high probability that payments will end abruptly when project funding runs out (Bhattacharyya, Winch, LeBan & Tien, 2001) stimulate short-sighted and opportunistic behavior among ICT4D project participants. The payment of per diems induces civil servants to expect something extra simply for doing their regular job (Søreide et al., 2012, p. xvi) and to encourage officials in higher positions to monopolize project participation at the expense of lower-level colleagues in greater need of training (Søreide et al., 2012). Existing ICT4D practitioners' preoccupation with conducting capacity-building workshops satisfy "equally the competing priorities of international donor institutions and local actors" (Jordan Smith, 2003, p. 712), at least in the short term.

Development Project Impact and Aid Entitlement: A "Marriage of Convenience"

Over time the development project impact logic has entered into interdependence with the aid entitlement logic it has helped to foster and legitimize. We use the term "interdependency" (Friedland & Alford, 1991), as the behaviors and strategies informed by either institutional logic are justified and reinforced by the observable practices of *the others*. Civil servants expect money to perform the tasks of ICT4D initiatives, so it is necessary to pay them to produce a swift impact. Since short-sighted and competing initiatives pay inflated per diems for attention, it is condoned to hunt for roles in their projects to supplement meager civil servant salaries. Development interventionists *know* that the incentive structures they uphold through the conduct of their projects lead to unintended consequences (and the authors have played their part in this), the local participants in the ICT4D projects *know* that donors' incentive structures will prevail for future exploits, and everybody *knows* that everyone else knows, too. Yet—and this is at the heart of our contribution—the respective institutional logics of development project impact and aid entitlement are drawn on to legitimize activities and strategies (by both sides) to maintain the status quo. This situation is upheld despite international agreements and harmonization declarations to the contrary. Currently, ICT4D practitioners and project participants are able to coexist by infusing shared practices with different meanings (Zilber, 2002), while each camp continues to serve as a gateway to the attainment of the short-term goals of *the others*.

The institutional logics perspective sheds some light on the persistence of this situation as it points to the reinforcing dynamics between ICT4D practices and the institutional logics that permeates them. A strategy to alleviate these endemic challenges with ICT4D, we contend, will have to resonate at multiple levels (i.e., project, organization, and organizational field) and across camps. High-level international declarations of harmonization, albeit with positive intentions, are not directly helpful as long as ICT4D projects are evaluated on short-sighted, easy-to-manipulate (by paying for attention), project-centric targets. Institutional change is brought about not only by changing the rhetoric, but also the material subsistence that informs practices. The ICT4D field is in need of a shift toward long-term cooperation among initiatives. New project evaluation tools and reward structures need to be put in place to emphasize harmonization over short-sighted impact.

Theoretically, this study contributes to the exploration of the interplay between institutional logics at the level of an organizational field. We contend that dynamics between institutional logics are not necessarily captured as periods of institutional stability where one institutional logic dominates until it is eroded and replaced by another dominant logic, nor by the unresolved historical contestation of meaning between multiple competing institutional logics (Currie & Guah, 2007; Lounsbury, 2007; Marquis & Lounsbury, 2007; Sahay et al., 2010). Rather, we have identified an intricate interdependence between a pair of mutually legitimizing institutional logics. For lack of a better term, we refer to this dialectic relationship as a *marriage of convenience*. The result is not friction, but an accommodation of both logics in shared practices (e.g., workshops) through ICT4D projects. However, this interdependency produces detrimental and contradictory consequences for projects and the ICT4D organizational field over the long term. Similarly, comprehensive and longitudinal ministerial harmonization efforts are offset by haphazard adaptations to donors' "agenda of the day."

Implications for Capacity Building and Long-Term ICT4D Sustainability

Previous studies have pointed out that too many capacity-building workshops and training sessions are conducted to communicate commonsense messages about HIV/AIDS, family planning, and other subjects that attendants are already well aware of (Swidler & Watkins, 2009). ICT4D projects, we argue, differ from this

PAYING PER DIEMS FOR ICT4D PROJECT PARTICIPATION

broader class of capacity-building efforts in that end-user training is necessary to effectively leverage novel ICTs and software packages in the workplace. However, training does not always have to involve large groups of people traveling to receive inflated per diems. To avoid such a scenario, we argue that on-the-job training is a viable option, especially for refresher training. On-the-job training also allows ICT4D practitioners to perform a reality check, identify the right people for training (if they can be found), become sensitive to participants' actual work practices, and learn how technology innovations may coexist with equipment and routines already in place.

On-site training can be more costly and it takes a great deal of effort. Sometimes it is unrealistic due to the sheer number of potential end users. In addition, on-the-job training can be perceived as unfair by trainees, who may feel they are being cheated out of legitimate allowances. This makes it particularly difficult for any ICT4D initiative that wishes to break out of the per diem race to be taken seriously. However, paying per diems for attention and being unable to discern whether participants' positive responses are rooted in a genuine interest in the ICT capabilities the project has to offer or if participants are cheering the project on only in the hopes of attending follow-up workshops are both a potential waste of resources and detrimental to ICT4D sustainability. Use of per diems to attract project participation is certainly not the only obstacle to ICT4D sustainability. Other obstacles include underdeveloped infrastructure (Gordon & Hinson, 2007), technical bias of projects (Ali & Bailur, 2007), lack of alignment of interests (Kimaro & Nhamposha, 2005), and pilot project orientation (Lucas, 2008). However, we contend that per diem is a contributing factor that has not received its fair share of attention in the literature. In addition, per diem is a complicating factor that may induce recipients to abstain from critiquing unsustainable interventions.

Finally, the Malawi Ministry of Health's HMIS strengthening is challenged by the disruptive prioritization of short-term project goals over long-term restructuring, the plethora of uncoordinated interventions, and the complicated dependencies for technical assistance. One way to strengthen the capacity of local institutions, rather than undermine them, is for donors, in close collaboration with ministerial functionaries, to establish a shared pool of not only financial resources but also technical assistance that stretches beyond the lifespan of individual projects. Close collaboration among ICT4D projects, through a shared pool of technical assistance and resources, could help cultivate public sector structures that can implement policies and harmonize ICT4D projects over time. In return, expatriate interventionists may find comfort in knowing that skilled people will be around to maintain and extend their efforts when their project time has run out.

More studies are needed on how ICT4D efforts can be evaluated in the long term, with an emphasis on interproject collaboration. We believe the institutional logics perspective, with its sensitivity to the interdependence between local practice and field-level structures, can inform further studies that take the agenda for sustainable development forward. Much of what has been discussed in this article applies to the wider organizational field of development interventions. However, we contend that ICT4D is a subfield with a particularly high prevalence of technology-centered pilot projects, feasibility studies, and proofs of concept that demand too much attention from overburdened government organizations in developing countries. ■

Acknowledgments

Our gratitude goes to HMIS managers and health workers in Malawi, who spent some of their valuable time in interviews and participating in the implementation and evaluation of DHISm. The suggestions and comments from anonymous reviewers and the respective editors of this special issue are gratefully acknowledged.

Terje Aksel Sanner, PhD candidate, Department of Informatics, University of Oslo. terjeasa@ifi.uio.no

Johan Ivar Sæbø, Postdoctoral Researcher, Department of Informatics, University of Oslo. johansa@ifi.uio.no

References

- Alford, R. R., & Friedland, R. (1985). *Powers of theory: Capitalism, the state, and democracy*. Cambridge, UK: Cambridge University Press.
- Ali, M., & Bailur, S. (2007, May 28–30). The challenge of “sustainability” in ICT4D—Is bricolage the answer? In *Proceedings of the 9th International Conference on Social Implications of Computers in Developing Countries*, São Paulo, Brazil.
- Berger, P. L., & Luckmann, T. (1991). *The social construction of reality: A treatise in the sociology of knowledge*. London, UK: Penguin Books.
- Bhattacharyya, K., Winch, P., LeBan, K., & Tien, M. (2001, October). *Community health worker incentives and disincentives: How they affect motivation, retention, and sustainability*. Arlington, VA: Basic Support for Institutionalizing Child Survival Project.
- Braa, J., Hanseth, O., Heywood, A., Mohammed, W., & Shaw, V. (2007). Developing health information systems in developing countries: The flexible standards strategy [Special issue]. *MIS Quarterly*, *31*, 1–22.
- Braa, J., Monteiro, E., & Sahay, S. (2004). Networks of action: Sustainable health information systems across developing countries. *MIS Quarterly*, *28*(3), 337–362.
- Chaulagai, C. N., Moyo, C. M., Koot, J., Moyo, H. B. M., Sambakunsi, T. C., Khunga, F. M., & Naphini, P. D. (2005). Design and implementation of a health management information system in Malawi: Issues, innovations and results. *Health Policy and Planning*, *20*(6), 375–384.
- Currie, W. L., & Guah, M. W. (2007). Conflicting institutional logics: A national programme for IT in the organisational field of healthcare. *Journal of Information Technology*, *22*(3), 235–247.
- DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, *48*(2), 147–160.
- Friedland, R., & Alford, R. R. (1991). Bringing society back in: Symbols, practices and institutional contradictions. In W. W. Powell & P. J. DiMaggio (Eds.), *The new institutionalism in organizational analysis* (pp. 232–263). Chicago, IL: University of Chicago Press.
- Gordon, A. N., & Hinson, R. E. (2007). Towards a sustainable framework for computer based health information systems (CHIS) for least developed countries (LDCs). *International Journal of Health Care Quality Assurance*, *20*(6), 532–544.
- Hasselbladh, H., & Kallinikos, J. (2000). The project of rationalization: A critique and reappraisal of neo-institutionalism in organization studies. *Organization Studies*, *21*(4), 697–720.
- Hayes, N., & Rajão, R. (2011). Competing institutional logics and sustainable development: The case of geographic information systems in Brazil's Amazon region. *Information Technology for Development*, *17*(1), 4–23.
- Health Metrics Network (HMN). (2008). *Framework and standards for country health information systems* (2nd ed.). Geneva, Switzerland: World Health Organization. Retrieved from http://www.who.int/healthmetrics/documents/hmn_framework200802.pdf
- Heeks, R. (2006). Health information systems: Failure, success and improvisation. *International Journal of Medical Informatics*, *75*(2), 125–137.
- Holm, P. (1995, September). The dynamics of institutionalization: Transformation processes in Norwegian fisheries. *Administrative Science Quarterly*, *40*(3), 398–422.

PAYING PER DIEMS FOR ICT4D PROJECT PARTICIPATION

- Jackall, R. (1988). Moral mazes: The world of corporate managers. *International Journal of Politics, Culture, and Society*, 1(4), 598–614.
- Jensen, C. B., & Winthereik, B. R. (2013). *Monitoring movements in development aid: Recursive partnerships and infrastructures*. Cambridge, MA: MIT Press.
- Jordan Smith, D. (2003). Patronage, per diems and the “workshop mentality”: The practice of family planning programs in southeastern Nigeria. *World Development*, 31(4), 703–715.
- Kimaro, H. C., & Nhamposha, J. L. (2005). Analyzing the problem of unsustainable health information systems in less-developed economies: Case studies from Tanzania and Mozambique. *Information Technology for Development*, 11(3), 273–298. doi:10.1002/itdj.20016
- Klein, H. K., & Myers, M. D. (1999, March). A set of principles for conducting and evaluating interpretive field studies in information systems [Special issue]. *MIS Quarterly*, 23(1), 67–94.
- Littlejohns, P., Wyatt, J. C., & Garvican, L. (2003). Evaluating computerised health information systems: Hard lessons still to be learnt. *BMJ*, 326(7394), 860. Retrieved from <http://www.bmj.com/content/326/7394/860>
- Lounsbury, M. (2007). A tale of two cities: Competing logics and practice variation in the professionalizing of mutual funds. *Academy of Management Journal*, 50(2), 289–307.
- Lucas, H. (2008). Information and communications technology for future health systems in developing countries. *Social Science & Medicine*, 66(10), 2122–2132. doi:10.1016/j.socscimed.2008.01.033
- Marquis, C., & Lounsbury, M. (2007). Vive la resistance: Competing logics and the consolidation of U.S. community banking. *Academy of Management Journal*, 50(4), 799–820.
- Meyer, J. W., & Rowan, B. (1977, September). Institutionalized organizations: Formal structure as myth and ceremony. *American Journal of Sociology*, 83(2), 340–363.
- Ministry of Health and Population. (2003, August). *Health information system: National policy and strategy*. Lilongwe, Malawi: Republic of Malawi Ministry of Health and Population.
- Ocasio, W. (1997). Towards an attention-based view of the firm. *Strategic Management Journal*, 18(S1), 187–206.
- Pache, A.-C., & Santos, F. (2010, August). Inside the hybrid organization: An organizational level view of responses to conflicting institutional demands. *Academy of Management Review*, 35(3), 455–476.
- Pfeiffer, J. (2003). International NGOs and primary health care in Mozambique: The need for a new model of collaboration. *Social Science & Medicine*, 56(4), 725–738.
- Reay, T., & Hinings, C. R. (2009). Managing the rivalry of competing institutional logics. *Organization Studies*, 30(6), 629–652.
- Ridde, V. (2010). Per diems undermine health interventions, systems and research in Africa: Burying our heads in the sand. *Tropical Medicine & International Health*. doi:10.1111/j.1365-3156.2010.02607.x
- Sahay, S., Sæbø, J. I., Mekonnen, S. M., & Gizaw, A. A. (2010). Interplay of institutional logics and implications for deinstitutionalization: Case study of HMIS implementation in Tajikistan. *Information Technologies & International Development*, 6(3), 19–32.
- Sanner, T. A., Roland, L. K., & Braa, K. (2012, September). From pilot to scale: Towards an mHealth typology for low-resource contexts. *Health Policy and Technology*, 1(3), 155–164.
- Scott, W. R. (2008). *Institutions and organizations: Ideas and interests* (3rd ed.). Los Angeles, CA: SAGE Publications.

- Scott, W. R., Ruef, M., Mendel, P. J., & Caronna, C. A. (2000). *Institutional change and healthcare organizations: From professional dominance to managed care*. Chicago, IL: University of Chicago Press.
- Sørdeide, T., Tostensen, A., & Skage, I. A. (2012, March). *Hunting for per diems: The uses and abuses of travel compensation in three developing countries* (Report 2/2012 Study). Oslo, Norway: Norad Evaluation Dept.
- Swidler, A., & Watkins, S. C. (2009). "Teach a man to fish": The sustainability doctrine and its social consequences. *World Development*, 37(7), 1182–1196.
- Thornton, P. H., & Ocasio, W. (1999). Institutional logics and the historical contingency of power in organizations: Executive succession in the higher education publishing industry, 1958–1990. *American Journal of Sociology*, 105(3), 801–843.
- Thornton, P. H., Ocasio, W., & Lounsbury, M. (2012). *The institutional logics perspective: A new approach to culture, structure, and process*. Oxford, UK: Oxford University Press.
- Walsham, G. (1993). *Interpreting information systems in organizations*. New York, NY: John Wiley & Sons.
- Walsham, G. (1995). Interpretive case studies in IS research: Nature and method. *European Journal of Information Systems*, 4(2), 74–81.
- World Health Organization (WHO). (2009). WHO Country Cooperation Strategy 2008–2013: Malawi. Retrieved from http://www.who.int/countryfocus/cooperation_strategy/ccs_mwi_en.pdf
- Zilber, T. B. (2002). Institutionalization as an interplay between actions, meanings, and actors: The case of a rape crisis center in Israel. *Academy of Management Journal*, 45(1), 234–254.
- Zucker, L. G. (1977). The role of institutionalization in cultural persistence. *American Sociological Review*, 42(5), 726–743.

