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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

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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.*

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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) interdependicies.

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 improvization (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.

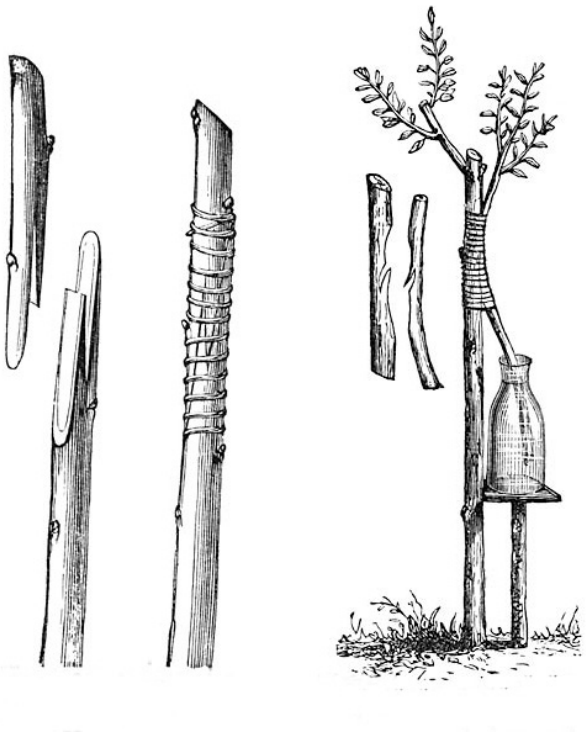

Figure 1. Example of a Grafting Technique (Left) and an Approach to Grafting (Right) (Adapted from Trousset Encyclopedia, 1886-1891)

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, Aanestad 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.

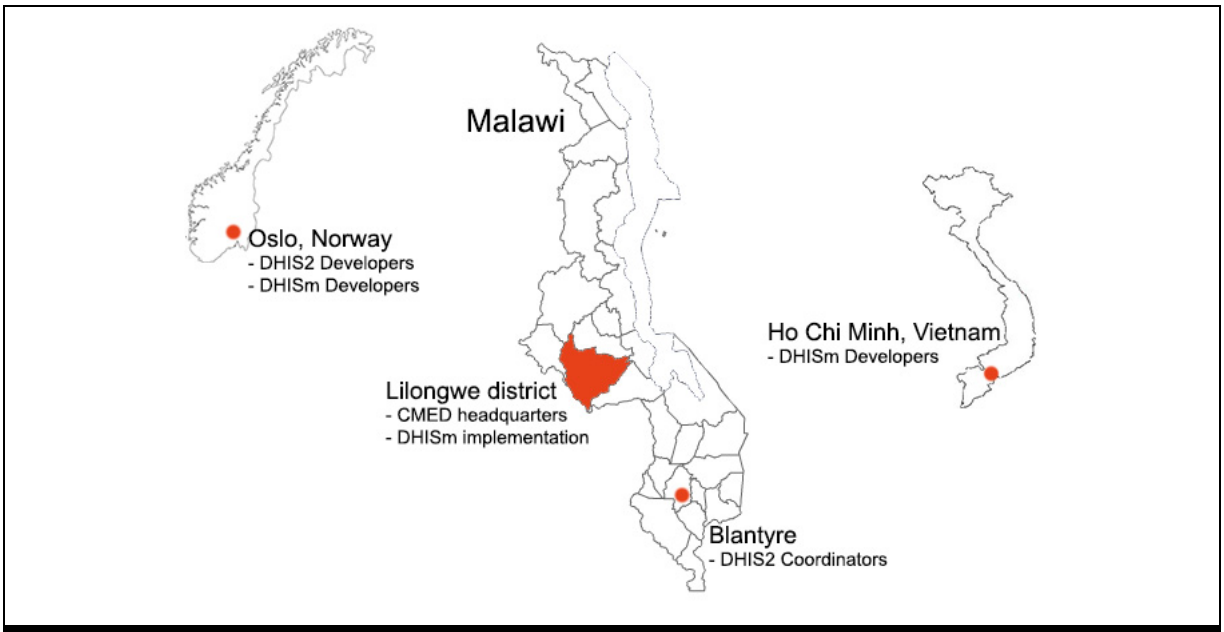

Figure 2. DHISm Implementation Coordination Across Geographical Proximities

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 discusses 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.

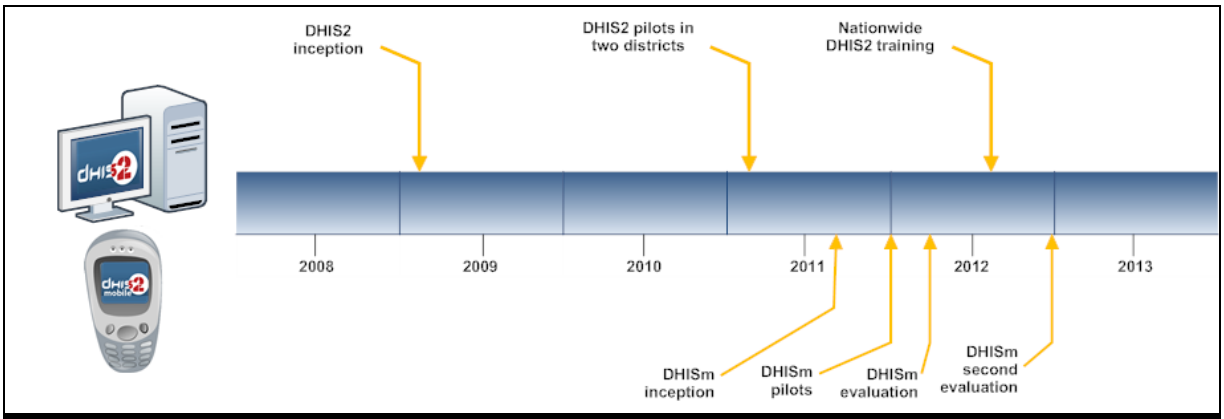

Figure 3. Implementation Timeline for DHIS2 and DHISm in Malawi

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 II 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 minstry. 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 Nuturing

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 manoeuvering 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 activites 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 cration 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 refence, 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 longnitudinal grafting processes that stretch beyond the scope of the current study.

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About the Authors

Terje A. SANNER is a PhD candidate at the University of Oslo's Department of Informatics. His research is concerned with strenghtening health information infrastructure in resourse 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 telcommunication 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.