

Design Principles for Health Information Infrastructures in Developing Countries

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Acronyms

II	Information Infrastructure
IS	Information System
HIS	Health Information System
HII	Health Information Infrastructure
IT	Information Technology
ICT	Information Communication Technology
ICT4D	Information Communication Technology for Development

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Abstract

This thesis explores the design and implementation, empirically and theoretically, of health information systems in Vietnam. It contributes to current debates on health information systems and information infrastructures by theorizing design problems and principles.

Designing and implementing health information systems in developing-country settings is challenging. Many health information systems do not go beyond the pilot stage, and tend to vanish when external funding is over. In other cases, multiple fragmented health information systems remain, but these are unable to talk to each other. And more often than not, data collected by health information systems are not used in decision making.

To better understand and address these problems, this thesis employs an information infrastructure perspective and views health information systems as parts of larger and complex social-technical networks. This thesis is based on action research projects exploring the dynamics and processes of designing and implementing four health information systems in Vietnam between 2012 and 2016. Based on my involvement in these projects, I identify, analyze and discuss four key design problems in this particular setting: a) the scaling and sustainability problem, b) the all-or-nothing problem, c) the competing systems problem, and d) the information use for action problem.

This thesis contributes to the current knowledge with a set of rich empirical descriptions of the design and implementation of health information systems in Vietnam. Theoretically, it contributes to information infrastructure discussions in the information systems domain by presenting four design problems and suggesting five design principles and 15 design rules to meet them.

These design principles and rules also offer practical guidance for managers and designers involved in the design and implementation of health information systems in developing countries.

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1 INTRODUCTION

This chapter sets down the purpose of this thesis and orients readers to the research problem it aims to address. It elaborates the scope of the research and identifies the problem domain and research question. At the end, an outline of the thesis is presented following the discussion on expected contributions and personal motivation.

1.1 Research problem

Increasingly huge investments are going into the development of different kinds of health information systems (HISs) in developing countries. More often than not, these systems fade away as pilot systems or end up as failures. The problems of integration and interoperability are primary and various efforts at both policy level and implementation level emphasize the need for a more holistic approach which conceptualizes these systems not as standalone ones, but interconnected and reflecting information infrastructures (II). However, the application of ideas around IIs in research and practice still remains relatively limited, especially so in the context of developing countries, which is a focus of this thesis.

More and more in developing countries, health information systems are taking on II characteristics, such as the increasing interconnectedness and heterogeneity of social-technical elements that form the health information systems. This interconnectedness and heterogeneity implies the need for integration and sharing of data, the development of systems that are at scale rather than as pilots, and the combination of different platforms and devices. Despite this rapid growth of systems with II characteristics within the health sector, research and practice have lagged behind. There are a growing number of studies that conceptualize health information system (HIS) as health information infrastructure (HII) in both developed and developing country context. For example, Hanseth and Aanestad (2003) use the II theoretical lens to examine three cases of building Information and Communication Technology (ICT) networks for healthcare in Norway. Sanner et al. (2014) describe the large-scale mobile-based health information systems in India and Malawi as HIIs, arguing for the need of “grafting” mobile-based Information Technology (IT) initiatives into social arrangements to make the IT component grow faster and in a more goal-oriented way. Braa et al. (2007) use the cases of HISs in South Africa, Ethiopia, and Thailand to discuss several strategies to develop II standards. In their work, they emphasize flexible standards and integrated independence as two important strategies to achieve scalable, sustainable, and evolutionary IIs.

However, there is not a specific body of literature which provides guidance on the design and development of health information infrastructures (HIIs) in developing countries. In the West, based on studies of systems like the Internet, there have been rapid advances in research into HII, such as design principles for II developed by Hanseth and Lyytinen (2010), which were proven useful by Aanestad and Jensen (2011) in their examination of the principles’ application to the national HII in Denmark, as well as in their application to the national HIIs in other Western countries. However, it is urgent that researchers in the domain of HIS for developing

countries within the broader framework of Information Communication Technology for Development (ICT4D) develop design principles which can work with the particularities of developing countries. Developing countries have characteristics regarding infrastructure, politics, resources, capacity, etc., which are quite different from those that exist in the West, and which have been the basis for II design principles to date. This thesis is about trying to identify design problems and propose design principles and design rules relevant to the research and practice of HIS in developing countries. To that end, it is vital to first identify and define any design problems related to HII in developing countries. Based on that, new design principles are needed to address these problems. Finally, concrete design rules are derived from design principles to better guide the design and development of HIIs in developing countries. In this way, the contribution of this thesis will be two broad areas. First, to expand the body of work relating to design theory of II. Second, to provide practical guidance to designers on the building of II for healthcare in developing nations.

The specific research question this thesis explores is:

How can we design information infrastructures for the health care sector in developing-country settings?

1.2 Research setting and method

The specific empirical cases covered in this thesis are those in the public healthcare sector of Vietnam. The action research basis for this thesis was conducted within the aegis of the Health Information System Program (HISP), a network spanning multiple countries in Africa and Asia including Vietnam. The primary goal of HISP is to strengthen HISs in developing countries through software development, implementation, and capacity building. In this action research, I have engaged in building several health information systems for Vietnam between 2012 and 2016. Throughout this period, I was deeply embedded in the daily routines of software development, implementation, and training. Through a number of action research cycles, both theoretical and practical knowledge was generated and shared with the client (Ministry of Health - MoH), which informed the revisions of subsequent actions.

1.3 Research findings

This thesis comprises a total of five papers whose summaries are provided in Chapter 5 and included in the thesis appendices. These papers are:

1. Nguyen, TN, Ha ST, and Braa J (2015), "Assembling a National Health Information Infrastructure: The Case of Vietnam", Published in *The Electronic Journal of Information Systems in Developing Countries*, 66, 7, 1-18.
2. Nguyen, TN, Braa J (2016), "Scaffolding Health Information Infrastructure's Generativity by Scaffolded Gateways – The Case of Vietnam", Published in *The Electronic Journal of Information Systems in Developing Countries*, 75, 4, 1-22

3. Nguyen, TN, Nielsen P, Braa J (2016), “The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor”, Revised and resubmitted to *Information Technology for Development*.
4. Nguyen, TN, Nielsen P, Braa J (2017), "Scaling Information Infrastructures: the Case of the Medical Licensing System in a Southeast Asian Country", Published in *Australasian Journal of Information Systems* 21, DOI: 10.3127/ajis.v21i0.1518
5. Nguyen, TN, Nielsen P (2017), “From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making Them Public”, *14th International Conference of IFIP Working Group 9.4 "ICTs for promoting social harmony: Towards a sustainable information society"*, May 22 - 24, 2017, Yogyakarta, Indonesia, *Proceedings*.

1.4 Contributions

This research makes contributions to both theory and practice. Theoretically, the key contribution is towards strengthening the II perspective in the context of developing, through the articulation of a set of design problems, design principles and design rules. The research process involved for this articulation has consisted of taking existing design rules for IIs built for Western contexts developed by Hanseth and Lytinen (2010), analyzing them conceptually and empirically with respect to the contextual conditions encountered in Vietnam, and then seeking to extend them with new design principles and design rules. This process and its results form the core of my contribution. Practically, the research contributes to the design of several HISs in Vietnam, along with supporting design guidelines which can help to address design problems related to, in particular, fragmentation, scaling, integration and interoperability, information use for action, etc.

1.5 Personal Motivation

I have worked in the domain of HIS in Vietnam for many years as a software developer. Through that longitudinal engagement, I have seen many failures where systems do not yield what they were intended to, despite huge investments. When I got the opportunity to study in Oslo, I was exposed to II theory and design principles. Inspired by that theory, I believed I could apply it to the study of HISs in Vietnam. However, I found the principles to be rather restrictive and not directly relevant to the particularities of the contextual conditions found in Vietnam and other developing countries. My main motivation at that point became trying to develop design principles and rules that would be more appropriate for and applicable to HISs in Vietnam and other developing countries.

This thesis was also motivated by my desire to contribute practically to efforts of building a health information infrastructure (HII) in Vietnam, a resource-constrained country which faces increasingly serious health issues such as rampant communicable and non-communicable diseases, hospital overloads, and poor quality of health professionals, corruption, and discrimination. Insights from this research, I believed could help strengthen the evolving HII in the country, which could contribute to improving health outcomes.

1.6 Short summary of the chapter and structure of the thesis

In this chapter, I have provided general information about the research problem, methods, findings and contribution of the thesis. The rest of the thesis is organized as follows:

Chapter 2: Related research

This chapter reviews key literature related to the topic of research. I highlight theoretical gaps and propose a theoretical framework that aids in understanding the problems related to HII design in developing countries and extends II design theory to address these problems.

Chapter 3: Research context and the cases

This chapter presents the setting and context where this research was conducted. I highlight contextual conditions in Vietnam and potential influences they have on HII design and development. This chapter also describes the empirical cases that form the basis for this thesis.

Chapter 4: Research methods

This chapter discusses research methods employed, including the different phases of action research, data collection and analysis methods, and ethical considerations.

Chapter 5: Findings

This chapter summarizes findings from individual papers and how these together contribute to answering the research question of the thesis.

Chapter 6: Discussions

This chapter discusses four design problems identified through the empirical analysis process, followed by the discussion of five design principles and 15 design rules required to tackle those four design problems situated within HISs in developing countries.

Chapter 7: Contributions

This chapter discusses theoretical and practical contributions and suggests areas of future research.

2 RELATED RESEARCH

This chapter presents an overview of theoretical perspectives that informed the data collection and analysis in this research. It starts with the discussion of II and II design principles followed by the argument for the need to extend II design theory to address specific design problems related to HISs in developing countries. Finally, a theoretical framework that guided the analytical process is presented.

2.1 From Information System (IS) to Information infrastructure (II)

IS and IS design is a well-established branch of research (see, for example, Mills et al. (1986) Walls et al. (1992) and Bally et al. (1977)), in which generic methodologies and approaches have been developed to guide the IS design and development process. Walls et al. (1992) argue: *“The benefit of an IS design theory...is to articulate the boundaries within which particular design assumptions apply. IS design theories make the design process more tractable for developers by focusing their attention and restricting their options, thereby improving development outcomes. In addition, IS design theories inform researchers by suggesting testable research hypotheses.”*

(Quoted in Markus et al. (2002), p.180)

Researchers commonly have the ambition of distilling “how-to” guidelines (design principles) that address specific design problems for particular contexts and domains. Markus et al. (2002), for example, developed a design theory for building systems to support emergent knowledge processes relating to basic research, strategic management, etc. In this study, they devised a number of design principles such as customer engagement, knowledge translation, knowledge integration, etc. Similarly, Lindgren et al. (2004)—also interested in delving deeper into design principles in order to create better guidelines by undertaking an action research which aimed to build a competence management system—developed several design principles including transparency, interest integration, and real-time capture to guide the process of building similar systems. Even in the healthcare domain, design principles were discussed early on with regard to the subject of designing systems when Michel et al. (1999) was researching how to build effective information systems for intensive care units.

When systems become increasingly connected thanks to the advancement of networking technologies such as Internet, their complexities also increase. To deal with their complexities, some researchers argue that these systems should be better conceptualized as IIs (see, for example, Ciborra (2000), and Hanseth and Braa (2000)). Markus et al. (2002), however, argue for the need of having new methods and approaches:

“[A]s IT develops and technical knowledge grows, IT is applied to new application areas that were not previously believed amenable to IT support. In the process, new kinds of systems and new development methods are also created” (p.180).

The prevalence of large-scale and complex systems of systems is gradually recognized by scholars working in the software engineering discipline. For example, Sommerville et al. (2012) argue:

“[T]here is a fundamental reason why current software engineering cannot effectively manage inherent complexity, with the consequence that our software engineering methods are unsuitable for building 21st century wicked systems. To understand this, we need to examine the essential ‘divide-and conquer’ reductionist assumption that is the basis for modern engineering” (ibid, p.4).

Such large-scale and complex systems are coined as information infrastructures (II) (Ciborra and Hanseth, 1998) involving multiple and heterogeneous stakeholders with asymmetric power relations (Sahay et al., 2009), conflicting goals, and diverse approaches for their design and evolution. This represents a new phenomenon, which differs from the traditionally existing standalone systems, and is currently attracting significant research interest (Henfridsson and Bygstad, 2013, Tilson et al., 2010, Hanseth, 2002). Traditional approaches which pervade in designing and building information systems are often incapable of tackling emerging issues related to constructing such large-scale and complex IIs that are distributed with no clear borders related to what is a part of the II and not, and with no clear start and end dates for their construction. These IIs are subject to the problem of “drift”, which refer to the circumstances when the outcome of an ICT project significantly diverges from what was anticipated or planned (Ciborra, 2000). The problem of drift thus motivates the development of deeper insights into the endogenous mechanisms (Henfridsson and Bygstad, 2013) that contingently drive the evolution and growth of IIs. There are calls for more theorizing of the dynamics around the design, development and evolution of IIs. For example, Tilson et al. (2010) argued for the need to overcome the paucity in IS research and focus on studying IIs, which are becoming as necessary as roads, electricity, water, and similarly vital infrastructure systems.

There are a number of studies dedicated to understanding the different facets and dynamics of IIs. This includes research conducted from within the domains of Science and Technology Studies (Hughes, 1987, Hughes, 1979), Complexity Theory (Lewin, 1999), and Actor Network Theory (Law and Hassard, 1999). In the Information Systems field, Hanseth and Monteiro (1998) conceptualized IIs as networks comprising sociotechnical assemblages characterized by the following six properties:

- *Shared:*

An II is shared by a larger community which is a collection of users and user groups. It loses its value if decomposed into separate components being used by different user groups autonomously.

- *Open:*

An II is open in the sense that its functional boundary is constantly expanded to cope with changes in information needs and user practices. Furthermore, in an II, there are no limits in the growing number of stakeholders, contributors, vendors, nodes, and sociotechnical components in general. One cannot delineate clear borders of an II that keeps changing.

- *Evolving:*

An II is steadily moving forward with more users and more functionality to not only adapt to changes in its environment but also deepen its influences on user practices. The evolving nature

of an II also reflects the fact that due to the frictions and inertia created by its installed base, changes rarely happen fast and radically, but rather in small-scale steps over time.

- *Heterogeneous:*

Heterogeneity is often defined as the multiplicity of components, types, and speed of changes. Heterogeneity is an innate property of an II which is formed by connected sociotechnical components with complex bonds. Diverse user groups and stakeholders with a multiplicity of backgrounds, multiple standards, flexible interpretations and adaptation of different components contribute to the ever-growing heterogeneity of an II.

- *Standards:*

Standards are important elements that facilitate compatibility and interoperability among components within an II. II standards are often built and evolved through everyday practices rather than being predefined by formal standard organizations.

- *Installed base:*

An II is not built from scratch and it typically involves a process spanning over a long period of time. What already exists forms the installed base which largely determines how new elements are built and integrated into it. During the evolution of an II, to respond to the new requirements, some constitutive elements are often replaced by new components while large parts of the II are still preserved. Because of the installed base, the II is rarely ever designed and built from scratch as are traditional and standalone ISs. To deal with the installed base, cultivating the existing, rather than designing from scratch, is the common approach.

Coming from Science and Technology Studies (STS), Star and Ruhleder (1996) proposed a slightly different perspective on IIs, emphasizing social relations as the cornerstone of an II, which is characterized by the following dimensions:

- *Embeddedness:*

Information infrastructure is “sunk” into and inside of, other structures, social arrangements and technologies;

- *Transparency:*

Infrastructure is transparent in its use, in the sense that it does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks;

- *Reach or scope:*

This may be either spatial or temporal – infrastructure has a reach beyond a single event or one-site practice;

- *Learned as part of membership:*

The taken-for-grantedness of artifacts and organizational arrangements is a sine qua non of membership in a community of practice. Strangers and outsiders encounter the infrastructure as a target object to be learned about. New participants acquire a naturalized familiarity with its objects as they become members;

- *Links with conventions of practice:*

Infrastructure both shape and are shaped by the conventions of a community of practice, e.g., the way that cycles of day-night work affect and are affected by electrical power rates and needs.

- *Embodiment of standards:*

Modified by scope and often by conflicting conventions, infrastructure takes on transparency by plugging into other infrastructures and tools in a standardized fashion.

- *Built on an installed base:*

Infrastructure does not grow de novo; it wrestles with the “inertia of the installed base” and inherits strengths and limitations from that base.

- *Becomes visible upon breakdowns:*

The normally invisible quality of a working infrastructure becomes visible when it breaks down and disrupts social life.

(ibid, p.113)

Both the perspectives by Hanseth and Monteiro (1998) and Star and Ruhleder (1996) recognize the vital role of the installed base in determining the path of development of IIs. Due to the frictions and inertia created by the installed base, designing and building an II is never as straightforward and linear a task as a traditional single-owner IS would be. From this viewpoint, changes to the II thus often undergo processes which are incremental, stepwise, and evolutionary rather than being a big leap, drastic and revolutionary. Because of the installed base, the II slowly evolves, and because of its complexities, the II is hardly designed or built quickly and in a straightforward fashion. Because an II is comprised by a network of heterogeneous actors with conflicting interests and varying levels of autonomy, absolute control of the development of the II is unattainable. Predetermined development plans of an II are seemingly non-existent as compared to a traditional IS where requirement engineering is the main driving force shaping how and when the system would be built. The trajectory of an II is thus largely provisional and contingent. This evolutionary nature of an II is completely contrary to that of ICT projects which are very goal-specific and confined within predefined timeframes and budgets.

New methods, methodologies, and approaches required to develop IIs are visible in different scholarly works which will be presented in the next section.

2.2 II design problems, design principles and design rules

Although the complexities and lack of central control are inherent in IIs, various scholars have acknowledged room for design interventions. An exemplary case which happened before the era of the Internet is the development of the electrical system in the US, which was conceptualized as a large-scale and sociotechnical system. Hughes (1979) coined the term “system builders” to denote a class of actors whose role is vital to assembling disconnected and heterogeneous worlds, including various institutions, manufacturers and investors, into a working and goal-oriented system. In order to do so, system builders must cross disciplinary and functional boundaries and “*force unity from diversity, centralization in the face of pluralisms, and coherence from chaos*” (Hughes, 1987, p.52). Therefore, although information infrastructures are hardly built from scratch, they could be cultivated incrementally based on what already exists, the installed base. Cultivation is a process through which an installed base is bootstrapped and incrementally augmented with IT capabilities to cope with emergent requirements (Hanseth and Monteiro, 1998). This meta-level approach can be conceptualized as a form of design intervention for IIs.

To tackle the challenges involved in building information infrastructures, there have been several attempts by researchers to develop a design theory for them. One prominent example is the work of Hanseth and Lyytinen (2010), which proposed and articulated a united design theory, primarily addressing two design problems: bootstrapping and adaptability.

The bootstrapping problem refers to the situation where an II cannot take a leap by itself but needs some form of kick-starting. An II has a self-reinforcing mechanism through which it can evolve by itself thanks to its evolving momentum. However, at the beginning when none or little of the installed base exists in terms of functionality, data and other users, it is hard to attract early users.

The adaptability problem refers to the situation when an II grows to a certain level with a large installed base; it is trapped by various lock-ins in terms of user base and technology, which constrain its adaptability to new situations. There are two variations of this adaptability problem. The first relates to the existence of a multiplicity of standards adopted by the user community which is hard to unify or make uniform because switching costs are too high. The second relates to the incapability of a certain technology to fit new requirements. A technology could be widely adopted by a large user community despite the fact that over time it will become obsolete and new technologies will arrive to substitute it. This replacement also incurs substantial costs.

While the origins of the two design problems of bootstrapping and adaptability are not clearly stated, there are further considerations to be accounted for. For example, the seminal work of Shapiro and Varian (2013) highlights the significance of understanding the fundamental economics of networked information technologies. That is how a network increases its value when its base of users soars. If we conceptualize an II as a network, one of the tasks its designers must address is how to attract as many users as possible. This is the theoretical construct from which the bootstrapping problem emerges. The second problem of adaptability is touched upon in the works of Zittrain (2006) or Hughes (1987), which explore the significance of adaptation of technical systems when they expand their boundaries to encompass other specificities and particularities.

The ultimate goal of any theory is to create appropriate strategies and approaches through building a deep understanding of the phenomena and its dynamics. With this perspective, Hanseth and Lyytinen (2010) proposed five design principles to tackle the two design problems of bootstrapping and adaptability. Their design theory aims to “*generate attractors to propel users to adopt the IT capability so that its growth will reach a momentum*” (ibid, p.8) and “*guarantee that the II will grow adaptively and re-organize constantly with new connections between II components*” (ibid, p.13).

According to Hanseth and Lyytinen (2010), design principles are “*broad guidelines how the design can be carried out and where the designer can focus his or her attention during function and form shaping*” (ibid, p.5).

The design principles are further divided into design rules “*that formulate in concrete terms how to generate and select desired system features as to achieve stated system goals*” (ibid, p.5).

Details of the design principles and design rules and their examples are summarized in Table 1.

Table 1: Design problems and design principles and design rules

Design principles	Design rules	Description/Examples from Internet case
1. Design initially for direct usefulness	DR1. Target IT capacity to a small group.	A small user population needs to be identified and targeted. Internet: Internet was initially built for only a small group of researchers
	DR2. Become useful even without installed base.	As initial users are incurred high cost, the proposed IT capability has to offer the group immediate and direct benefits. Internet: Login and file downloading were among the first IT capabilities offered by Internet.
	DR3. Simple to use and implement.	Because first adopters accrue high adoption costs and confront high risks, the IT capability of being adopted must be simple, cheap and easy to learn. Internet: Internet employed simple protocols.
	DR4. Prioritize one-to-many IT capabilities.	IT capabilities supporting asymmetrical interactions (one-to-many) and thus less dependent on network effects should be implemented first as the growth can be promoted locally. Internet: Remote login functionality was built first.
2. Build upon existing installed base	DR5. Build IT capabilities that do not depend on new support infrastructure.	Internet: TCP/IP can run on variety of existing infrastructure: mobile phone, LAN, etc.
	DR6. Deploy existing transport infrastructure.	Internet: all early capabilities were introduced without any new related transport infrastructure
	DR7. Build gateways to existing service and application infrastructures.	Internet: Gateways between email protocols and Common Gateway Interface (CGI) which connects databases and applications were implemented.
	DR8. Use bandwagon associated with other II.	Internet: Internet increased its acceptance with the diffusion of workstation/Unix/LAN technologies.
3. Expand installed base by persuasive tactics to gain momentum.	DR9. User before functionality	When a simple version of the IT capability is available, the II designer needs to seek as many users as possible.
	DR10. Enhance the IT capabilities within the II only when needed.	New functionality should be added only when it is truly needed.

	DR11. Build and align incentives as needed.	Development and use are intertwined to build communities.
	DR12. Develop support communities	Developers and users are both innovators for IT capabilities and have organized support communities to do so.
4. Make the IT capability as simple as possible.	DR13. Make the II, in terms of its technical and social complexity, as simple as possible.	Internet: This rule was explicitly stated and followed early on the Internet history.
	DR14. Promote partly overlapping IT capabilities instead of all-inclusive ones.	Internet: The use of many open standards allows multiple overlapping capabilities.
5. Modularize II	DR15. Divide infrastructure recursively into transportation, support, and application infrastructure.	Internet: Separate components and sub-infrastructure are established and operated by independent actors.
	DR16. Build gateways between specification versions.	Internet: The use of tunneling in the transition from version 4 to version 6 of the IP protocol is an example of gateway use.
	DR17. Build gateways between layers.	Internet: All layers of Internet are connected through open gateways.
	DR18. Build gateways between infrastructures.	Internet: Gateways are used to connect different networks (BITNET, Decnet) with Internet e-mail protocols.
	DR19. Develop transition strategies in parallel with gateways.	Internet: Transition strategies are carefully introduced into the new versions of the protocol specifications.

Although the design theory proposed by (Hanseth and Lyytinen, 2010) is very comprehensive, the socio-technical approach to ISs cautions us that their theory's design principles and design rules cannot be universal and would need to be sensitively extended to different settings and contexts. In fact, Hanseth and Lyytinen (2010) have called for future research to explore additional design problems that have not been covered in their design theory. My thesis is a step in this direction of building upon and extending these design rules of IIs, specifically to be relevant for HIIs in developing countries. This contextualization and extension will need to address the different challenges identified with HISs in developing countries, which we discuss next.

2.3 HISs in developing countries, and their challenges

Health information systems (HISs) have gained the increasing interest of practitioners, researchers, and policy makers (Zhang, 2013, Blumenthal, 2009). HISs span a broad range of health management activities from “daily provision of services” and “patient level data in hospitals” to *“specific functional areas, such as human resources, drugs and logistics, finance, and inventory management, and others relating to specific diseases such as for HIV/AIDS, Tuberculosis and Malaria”* (Braa and Sahay, 2012).

Research and practice around HISs in developing countries have grown exponentially in the last two decades or so. Without trying to elaborate on the entire landscape of this research domain, I focus on describing three key challenges which have been discussed extensively in

the literature, and addressing them becomes imperative for a proposed design theory. These three challenges identified are:

- Systems not achieving integration and interoperability,
- Systems not attaining full scale and with it becoming unsustainable,
- Systems not leading to effective use of information for supporting health action and local work practices.

Details of each of the above challenges are articulated as follows:

- Systems not achieving integration and interoperability

The challenge of integration and interoperability refers to the situation in which there exists a multiplicity of isolated and fragmented information systems introduced by various donors and governmental agencies (Heeks, 2006). There are several versions of this challenge. One of them relates to the situation where different health programs exist but do not talk to each other even they are coordinated by the same agency, i.e., the health ministry (Chilundo and Aanestad, 2005). Sometimes, it is the coexistence of systems for both vertical health programs and an integrated HMIS with overlapping datasets and data elements (Chilundo and Aanestad, 2005). In other circumstances, multiple systems serving the same functional roles attempt to encroach upon and substitute themselves for each other (Nielsen and Sæbø, 2016).

System fragmentation often results in duplication of functions and wastage of time and resources. It requires health workers to work on multiple systems at the same time, creating more workload on health workers who are already over-burdened with clinical care and other administrative tasks (Mosse and Sahay, 2003). Also, multiple governing structures must be organized to maintain and support these separate systems (Chilundo and Aanestad, 2005). Not only does fragmentation create more work, the redundancy between systems also has adverse effects on data quality, as argued by Sahay et al. (2009):

“Due to redundancy between systems, health workers may have to report the same data several times: for example, both in the routine reports (within the districts) and in program-specific reports of so-called “vertical” health programs (e.g., on malaria, tuberculosis and HIV/AIDS). Poor coordination and linkages between and across health programs adversely influence both health delivery and the quality of the reporting systems (Braa et al. 2004). For example, HIV-positive pregnant women who are enrolled under the Mother and Child program for antenatal care services may fail to show up in the Prevention of Mother-to-Child Transmission program, which comes under the umbrella of the HIV/AIDS program (Shidende, 2005)”
(*ibid*, p.401)

Researchers have identified different underlying reasons for fragmentation. Braa et al. (2007) argue that the heterogeneity of health systems with overlapping institutional bodies in terms of geographical areas (province, district, etc.), vertical programs (HIV/AIDS, Tuberculosis, etc.), and service deliveries (healthcare, lab, drug, etc.), and the absence of shared standards are the root causes of fragmentation. This challenge is further exacerbated when international donors pour resources on specific health areas and invest to build new systems without integrating with the existing ones (Braa et al., 2007). Chilundo and Aanestad (2005), however, argue that poor

coordination should not be attributed to fragmentation but rather the multiplicity of rationalities, and they explicate the need for a process of political negotiation of interests to remedy the problem. Similarly, Sahay et al. (2009) postulate that *“The fragmentation of technical systems cannot be seen in isolation from the very diverse political interests of the donors, the countries and politics they represent, the money they bring in, and the particular diseases in which they are interested”* (ibid, p.2).

- Systems not attaining full scale and with it becoming unsustainable

Very often, HISs in developing countries were funded by donors, and those programs stopped when funding was ceased (Heeks and Baark, 1999). This challenge also relates to the sustainability of HISs, regarding which Braa et al. (2004) argue for the need to align local actions within a network where technological artifacts, lessons, and experiences could be mutually shared among countries. Another facet of this was the challenge to scale a successful pilot project to a larger geographical area, i.e., to cover a full district or province. To become useful for decision making, HISs must be able to provide full data coverage. Braa et al. (2004) define this problem as “all or nothing” and argue its significance due to the need of health equity and “health for all” endorsed by top politicians. Scaling of HISs in developing countries is uneasy to attain (Sahay et al., 2013). Sahay and Walsham (2006) argue that scaling is not simply a replication or parachuting of a technology from point A to point B but often requires different strategies to deal with the escalation of technical complexities as well as human resources with adequate skills and experiences.

- Systems not leading to effective use of information for supporting health action local work practices

Having good data does not provide a guarantee for data use (Nutley and Reynolds, 2013, Rhoads and Ferrara, 2012), as data is a necessary but not sufficient condition to enable effective decision making. While the final goal of any HIS is to improve decision making through the support of data, little data use is thus a big issue threatening the sustainability of HISs (Braa et al., 2007). Unfortunately, the problem of little or no data use is widespread in the context of HISs in developing countries (Scott, 2016, Braa et al., 2012, Donaldson and Lohr, 1994).

Data use problem is part of the “vicious cycle” (Braa et al., 2012), a term referring to the factors which affect the success of HISs initiatives. Efforts have been made into improving the data use issue with a variety of techniques including the introduction of tools that could facilitate the discussion, sharing, and learning toward data use (see, for example, Manya et al. (2015), Moyo et al. (2016) and Braa et al. (2012)). Despite investments in and improvements of health information systems, data use problem remains more or less the same (Wyber et al., 2015).

To deal with these HISs challenges, there is a need to have a theoretical lens that takes both social and technical elements into consideration. For this, the II perspective is a strong candidate. In applying the II perspective, HISs must be conceptualized as HIIs. This conceptualization is possible for several reasons. First, HISs share many similar characteristics with IIs. For example, HISs are heterogeneous systems comprising many sociotechnical components and types of domain knowledge including medicine, pharmacy, public health and IT. HISs are open,

evolving and not confined within any boundary. They span a wide range of domains including electronic patient records (EMR), hospital management systems, health management information systems, lab information systems, health workforce information systems, etc. To be effective, these different systems must be capable of speaking to each other. Their data must be mutually shared between systems and with different user groups: peer health facilities, epidemiological research centers, and governmental agencies at both local and global levels, i.e., Global Health Security Initiative, and the public at large. HISs are never built from scratch but are based upon some sort of installed base such as paper-based systems, reporting templates, fragmented data spanning various formats such as Access, Excel, and Word, etc.

Further, their evolutionary trajectories are not decided by a single actor but shaped through the interplay between multiple actors such as health ministries, donors, global and regional health organizations, software providers, health facilities, practitioners, and patients. For example, most of the HIS projects in developing countries are funded by international aid agencies. They can influence the choice of technologies, reporting formats, software vendors, etc. Global players like the World Health Organization (WHO) can also influence the HISs of a country through various recommendations and standards. Health facilities and practitioners as a collective have a great impact on the adoption of the system, data production, and use. For such reasons, HISs are more appropriately conceptualized as HIIs rather than standalone information systems. In fact, there have been many studies that adopt the II perspective to examine HISs (see, for example, Sahay and Walsham (2006) and Braa et al. (2007)).

To address HISs challenges using the II perspective, Hanseth and Lyytinen (2010) II design theory is a good point of departure as the theory clearly defines design problems and suggests design principles and rules to solve the problems. Despite being promising, little work has been done with regard to applying and extending their theory with the exception of Jensen (2013), who has adapted this theory to the healthcare context in a developed nation, i.e., Denmark. However, the application to developing-country settings, which have particular political and infrastructure situations, remains limited to date. HIIs have their own idiosyncrasies that are distinct from other IIs, such as the Internet—the domain and context on which the II design theory proposal is based (for example, see Richardson (2006)). Second, the empirical basis for this study is HISs in Vietnam, a developing country with its own particularities and which shares many similarities with other developing countries in terms of culture, politics, infrastructure, governance, and capacity. The great discrepancy between this contextual background and setting of the Internet thus requires the contextualization and extension of the existing II design principles (Nhampossa, 2005, Gizaw et al., 2016, Sahay et al., 2013).

After having examined HIS challenges more closely, it is now important to review the literature on contextualizing design with a focus on developing-country setting in the next section.

2.4 Contextualizing design

Design science is an important research paradigm in the IS discipline (von Alan et al., 2004). Design is always situated and for a particular context (Simonsen et al., 2014). Contextualizing design is a branch of IS research that focuses on understanding the contextual conditions that

affect the effectiveness, cost, and outcomes of adoption, development, and use of ISs. Kling (1993) argues that in order for the focal technology to work effectively, there must be adequate and corresponding infrastructure. Take for example the theatre or movie; we only focus on visible elements such as castings, script writers, and directors, etc. while the complete production of a movie or play often involves many people with different responsibilities, such as electricians, caterers, grips, etc. Such invisible elements in fact play crucial roles in ensuring the success of the film or play. Another illustration used by Kling (1993) is the urban architecture. New York City, for example, is well-known for its skyscrapers. However, other invisible elements that contribute to the daily life of the city, such as transportation, electricity, and communication, are often largely invisible.

Based on the two illustrations, Kling (1993) contends that computerized IS also depends on computing infrastructure to work. In his definition, computing infrastructure refers to supporting resources such as physical (place, space), technological (electricity and communication lines), and social (skills, practices). He proposes the web model that defines a social context in which the ISs are developed and used. This model emphasizes:

“

The social relations between a set of participants who can influence the adoption, development, or use of the focal computing technologies;

The infrastructure available for their support;

The history of commitments made in developing and operating related computer-based technologies

”

(ibid, p.6).

This situated design argument is also made by other scholars such as Greenbaum and Kyng (1992) and Suchman (2002). Greenbaum and Kyng (1992) call for careful rethinking on the sets of processes that we call design, emphasizing the need to consider the embeddedness of social interactions in the daily work of a designer. They also argue for a number of important factors that affect the design process:

“

The need for designers to take the work practice seriously;

The fact that we are dealing with human actors, not cut-and-dried human factors;

The idea that work tasks must be seen within their context, and are therefore situated actions; and perhaps the most important of all, as it links the rest together

”

(ibid, p.5).

Similarly, Suchman (2002) discusses three perspectives on design: design from nowhere, detached intimacy, and located accountability. She argues that “*designers are effectively encouraged to be ignorant of their own positions within the social relations that comprise technical systems, to view technologies as objects and themselves as their creators*” (ibid, p.5). As knowledge is socially constructed (Haraway, 1988), the view of design from nowhere “*by losing track of the social mediations of technical production, supports the impossibility of*

specifically locating responsibility for it” (Suchman, 2002). In other words, technology design should be embedded within the context of use to ensure that it will work. Universality can only be achieved through collective knowledge of multiple locations and contexts (Haraway, 1988).

In contextualizing design, it is important to balance between local adaptation with global standards, especially in the case of IIs when they often span across a wide range of contexts with diverse and heterogeneous sociotechnical conditions. Rolland and Monteiro (2002) discuss the pragmatic balance approach which refers to the dilemma of global and local tensions. IIs have to follow some sort of standards to ensure interoperability between different components, but they also need to incorporate local requirements. To that end, there are some costs that must be paid to achieve working solutions. Costs involve improvisations and additional work for the whole II design efforts to make local solutions achieve an acceptable degree of universality.

The existing II design principles and rules being developed based on empirical experiences in Western contexts would need to be contextualized, adapted, and extended to be relevant for other contexts, such as for health in developing countries, which is the focus of this thesis.

2.5 Contextualizing design for HIIs in developing countries

2.5.1 Design in the developing-country context

Suchman (2002) argues that design is innately prone to context and its embeddedness to social relations should always be considered by designers. Systems are subject to contextualization even when they are developed and used in Western contexts where sociotechnical conditions such as infrastructure, resources, human capacity are typically less incongruent and unbalanced, compared to those in developing countries. The gap between design and reality is wider when a technology is developed in the North and transferred as-is to the South.

To improve the chance of success, there are many studies that emphasize the need to strengthen the link between design and reality. One such study is the work of Heeks (2003), in which the author argues that the gap between designers’ assumptions and actual use, in reality, is the major reason for IS failures. To understand the design-reality gap, Heeks (2003) proposes a model comprising seven dimensions: information, technology, processes, objectives and values, staffing and skills, management systems and structures, and other resources such as time and money. Heeks (2003) argues that the wider the gap in each dimension, the higher the chance of failure for an ICT project.

Likewise, Lind (2006) argues that reality is made of facts which are conveyed into words and languages and subsequently to models. However, a model will not have the same meaning when there is a lack of collective understanding to support it. Therefore, the way reality works must be reflected in the software system. Furthermore, a computerized system which is very successful in one place does not necessarily yield equal results in other places. This also applies to other areas than ICT. For example, policy related to computing which is sound and effective in one country could be unfit under the sociotechnical conditions of another country.

In her discourses on ICT and development, Avgerou (2010) focuses on two perspectives for the analysis of IS in developing countries. The first perspective relates to technology transfer and diffusion in which “*material/cognitive entities that comprise IS technologies and associated practices of organizing are adequately independent from the social circumstances that give rise to them to be transferable, more or less intact, into any other society*” (ibid, p.4). Although researchers who follow this approach challenge the feasibility of transferring a technology to developing-country contexts with the expectation of the same outcomes, they still have the same assumption on validity, effectiveness and efficiency of the technology based on rational judgment. Therefore, I argue that translation, which often involves the process of social embeddedness (rather than transfer and diffusion), is necessary when a technology is moved from one place to another. This translation process involves not only technological artifacts or software systems themselves, but also many other related things such as methods, guidelines, design principles, learning, training materials, etc. In this thesis, my point of departure is the existing II design principles which I seek to analyze and examine in the context of my empirical experiences. Because IIs are used in the West, to apply them in a different context, such as the context of developing countries, contextualization and adaptation are necessary. Since HIIs are particular instances of IIs, arguably the original design principles apply, but the design rules need to be adapted with sensitive consideration of the context.

Having covered why II design principles are relevant for designing HIIs in developing countries, as well as the need for contextualizing and extending HIIs, it is now useful to propose and present a theoretical framework.

2.5.2 Particularities of developing-country context that shapes HII design

In this section, I summarize a number of contextual factors that influence the design of HIIs, drawing also from my empirical experiences and literature review.

a) Hospital overloading and seasonal disease patterns

Developing countries including Vietnam suffer from problems of hospital overload, where two or three patients would share the same bed or be lying on the floors of the hospital corridors. The periodic and seasonal surge of communicable diseases such as dengue fever (An, 2016, Hu et al., 2013) also contributes to exacerbating the hospital overcrowding problem. Therefore, in order to be efficient, designers should also take into account such seasonal conditions and disease patterns that could influence the decision on what IT capability could generate most direct usefulness.

b) Fickle politics and system-replacement decisions without prior notice or a rational basis

The notion of “usefulness” used by Hanseth and Lyytinen (2010) typically represents efficiency considerations of saving time and money (Webster, 2017), while in Vietnam and also in many other developing countries, there are alternative rationalities at stake. For example, Walsham and Sahay (1999) have written about the use of GIS for identifying points to dig water wells to deal with problems of low water levels in India. They report that while the GIS models based on scientific parameters (of soil, slope and rainfall) would identify points on the map where a

well should be dug, the decision-making politician in charge of providing the budgets would override the GIS model recommendations and order the well to be dug in his/her political constituency. In Vietnam, decision makers necessarily must belong to the communist party and they were typically politicians who did not understand the technical merits of the proposed solutions (Security, 2017).

Second, healthcare systems in developing countries are largely dependent on external funding from international donors. To measure the efficiency of their interventions, donors often spend resources to build their own HISs. As a result, HISs in developing countries are overlapping, fragmented and isolated (Smith et al., 2007, Kimaro and Nhampossa, 2007). Sometimes, substitution and encroachment take place between systems, resulting in a significant cost burden. There have been many cases reported from developing countries such as India (Sahay et al., 2009) and a West African country (Nielsen and Sæbø, 2016), where the power of money won out when it came to building the systems, because the decisions were not based on the systematic assessments of what works best.

c) Ambiguous standards and procurement formalities

In Vietnam, procurement conditions tend to favor complex rather than simple solutions involving new and modern ICTs and there is an absence of effective regulatory environment and technical standards which constrain the establishment of a level playing field where the best technical solution can win (Law, 2017). Furthermore, project contingencies often do not allow for incremental and systematic development, but require multiple results to be demonstrated simultaneously and in unreasonably short timeframes (see for example ADB (2014)). Finally, corruption in developing countries, especially in the healthcare sector, is very serious and wastes the scarce and precious resources used for improving the health systems (Sahay and Puri, 2008, Vian et al., 2012).

These contextual conditions are very specific in the context of HIIs in developing countries. Designers of HIIs must take these contextual conditions into account so that the success of design endeavors may be increased (Simonsen et al., 2014). A theoretical framework that aims to support designers as they deal with contextual conditions inherent to HIIs in developing countries is proposed in the next section.

2.6 Existing studies on health information systems in Vietnam

The size of studies on health information systems in Vietnam is relatively similar to other developing countries. A quick search on Google Scholar, a scholar database that indexes full text and meta-data of scholarly work across publishing formats and disciplines, with keywords “health information” + Vietnam, returns 17,000 results. Substituting the keyword Vietnam with the names of other Asian countries such as Philippines, Thailand, Myanmar, and China, the results are 16,300, 25,400, 4,600, and 62,100 respectively. The results for African countries such as Tanzania, Malawi, and Nigeria are 20,400, 12,400, and 25,600 respectively.

The existing body of research on health information systems in Vietnam is focused on specific case studies of different kinds of information systems. This includes health management information systems (Population.Council, 2012), electronic medical records (Hochwarter et al., 2014), aged-care (Nguyen, 2010), maternal health (O'Neill, 2015) and child care (Cheng, 2015), dengue fever and malaria (Erhart et al., 2007), HIV/AIDS (USAID, 2016), laboratory information system (Vu and Nguyen, 2010), etc. The main theme running through these studies is how a system was built to address specific health problems. For example, O'Neill (2015) discusses how a mobile-based system called mMOM was developed to connect remote mountain wards with provincial health departments so that timely support can be provided to pregnant women of ethnic minority groups. Another example is Erhart et al. (2007), who raise the issue of inaccurate data collected by the current health information systems for malaria in Vietnam. According to their study, up to 95% of active malaria cases were missed by the HISs. In yet another example, Vu and Nguyen (2010) discuss the technical aspects of the process of building a laboratory information system, which can connect to medical laboratory equipment to retrieve data and store them in a central server. It helps doctors to access patients' test results quickly, thus shortening the diagnosis process.

In general, health information systems in Vietnam are relatively weak in terms of the number of systems in use and the level of use in comparison with other countries (Hoang and Tran, 2012). The biggest challenge for Vietnam MoH now is to integrate multiple existing fragmented systems that are mostly closed source and not following any standardized interfaces or gateways (Hochwarter et al., 2014). There are other challenges related to technology, human resource, and finance, etc., that need to be addressed as well (Cheng, 2015). However, Vietnam has a centrally controlled health system where most hospitals are state owned, making it advantageous for scaling and standardization (Cheng, 2015).

Studies of health information systems in Vietnam are not focused on how to develop and implement systems. One exception to this is a study on how to design laboratory information systems for healthcare in Vietnam (Vu and Nguyen, 2010). Still, this study focuses mainly on the technical aspect of the system-building process and ignores social components. This thesis is one step towards filling this gap by providing a study on the design and implementation of a number of information systems for the healthcare sector in Vietnam.

2.7 IS methodologies, Agile approaches and design principles

Information Systems Development (ISD) has been the center of research and practice of Information Systems (IS) (Avison and Fitzgerald, 2003). In the early days of software development history, software was built by writing code and then debugging the code (Whitgift, 1991). There was no formal design or analysis process. This approach became problematic when complex software systems were required. Lessons learned from building complex hardware systems inspired a new software development model known as waterfall (El-Seoud, 2016). Waterfall is an approach to development that emphasizes completing a phase of the development before proceeding to the next phase (El-Seoud, 2016).

The waterfall model, however, is subject to much criticism. One complaint, for example, is the argument that customers often do not know what they need before they see the working software, which leads to late changes in the software requirements, resulting in increased costs to redesign, redevelopment, and retesting of the software (Parnas and Clements, 1986). Despite criticism, there have been many attempts to improve the waterfall model (El-Seoud, 2016). One such attempt is the prototyping software approach, which is aimed at better understanding customers' requirements (Smith, 1991). Another attempted improvement is the Rational Unified Process (RUP) developed by Rational Software Corporation, an IBM division. RUP, an adaptable process framework that can be tailored to specific projects (Kruchten, 2004), acknowledges the role of milestones to ensure the project plan but encourages interaction (Jacobson, 2004).

One design approach to information system development is participatory design, which originated with Norwegian Union projects (Bødker, 1996). Known as the Collective Resource Approach, this method developed strategies that allowed workers to have their voice heard with regard to the design and use of computer applications (Bjerknes et al., 1987). This action research method was used to ensure the benefits of researchers as well as workers, allowing the workers to benefit from the project, rather than them being merely the subject of the research (Ehn and Sandberg, 1979). In fact, action research is a very appropriate method for system development (Mansell, 1991). For example, Baskerville (1999) examines an action research that aims to design a database system as well as generate theory related to system design. Other examples include cases discussed by Kock and Lau (2001), Byrne (2006), Sein et al. (2011).

In response to the criticism that conventional software development methods are often too regulated, planned, and micro-managed, a number of methodologies have been developed and evolved since 1990, including rapid application development, SCRUM, Extreme Programming, feature-driven development, and more (Hoda et al., 2013). These methodologies are often referred to as agile development methods (Van Waardenburg and Van Vliet, 2013). Agile approach in IS development advocates adaptive planning, evolutionary development, early delivery, and continuous improvement, and it encourages rapid and flexible response to change (Larman, 2004).

The Agile manifesto, a formal proclamation made by Agile advocates, encompasses 4 key contrasts from traditional software development methods:

- Individuals and Interactions Over Processes and Tools
 - Working Software over Comprehensive Documentation
 - Customer Collaboration over Contract Negotiation
 - Responding to Change over Following a Plan
- (Tessem, 2014, Hoda et al., 2013, Vrhovec, 2016)

A key characteristic of the Agile methodology is that it gives priority to having working source code through short iterations, i.e., code sprints. This will give end users opportunities to provide early feedback to development teams (Drury-Grogan, 2014). In contrast, in traditional software

development methods, users can only see the system at very end of the development cycle. It is then too late to change (Drury-Grogan, 2014, Wood et al., 2013).

Agile methodology also draws attention to informal communication. Agile advocates believe that informal communication can help reduce managerial burden (Vrhovec, 2016). Informal communication takes place outside project report structure, directly between end users and developers, and it can therefore speed up the feedback loop and in many instances, set out the priorities of functionalities to be built (Rivero et al., 2014, Herbsleb and Mockus, 2003)

Since their introduction, Agile approaches have spread rapidly and are widely accepted as a standardized software development methodology (Vrhovec, 2016). However, the use of Agile in large-scale projects, especially in the healthcare sector, is relatively understudied (Vrhovec, 2016). Based upon empirical inquiry to building large-scale and complex information systems, the information infrastructure theory is developed by Hanseth and Lyytinen (2010) to address those specific problems adherent to large-scale and complex systems. The II design theory shares some analogies and has some gaps with Agile methodology. For example, both of the approaches emphasize, foremost, a working system over anything else. They acknowledge the importance of incremental and iterative development. The key difference is that Agile does not explicitly discuss the role of installed base, which is an assemblage of contextual factors that critically influence the outcome of system building, a key focus in information infrastructure design theory.

Appreciating all the previous work on software development methodologies, I used, in this thesis, an action research approach to understand the challenges and approaches in building health information systems in Vietnam. The approach I used is similar to Agile in the sense that it focuses more on providing end users a working system rather than wasting too much time on documentation and planning. However, my approach emphasizes the necessity of early successful adoption, even on a small scale, as well as a number of situated techniques that will boost the use, such as the accumulation of political support, making health data public, and so forth.

2.8 Software platforms

Van Alstyne et al. (2016) argue that platforms existed long before the arrival of information technology. Examples include shopping malls, which connect clients and merchants, or newspapers that connect readers and advertisers. The platforms enabled by IT, however, do not depend on physical infrastructure and can scale easily and cheaply (Van Alstyne et al., 2016). The move to platform is triggered by three key shifts: from resource control to resource orchestration, from internal optimization to external interaction, and from customer value to ecosystem value (Van Alstyne et al., 2016). Uber, Alibaba, and AirBnB are examples of platform businesses that disrupt their industries (Van Alstyne et al., 2016).

Tiwana (2013) defines software platform as an extensible software-based product or service that serves as a foundation on which outside parties can build complementary products or

services. It provides core functionalities shared by apps that interoperate with it and facilitate interaction between two groups or sides, which want to interact with and need each other (ibid). A related concept of platform is ecosystem or platform's ecosystem, which is a collection of platform and apps (or add-on software or software services) with it (Tiwana, 2013). All platforms have ecosystems with basic structure: owner, producer, and consumer (Van Alstyne et al., 2016). There are many examples of platform ecosystem such as Apple's IOS, Google's Android, Google Chrome, Facebook, Ubuntu Linux. In a platform ecosystem, the role of developers is important, as argued by Parker et al. (2016):

- The number of developers at certain thresholds can invert a firm
- There are different implications between platform-platform competition and developer-developer competition
- More developers give a firm more chances to succeed.

There are criticisms of this perspective because it tends to focus more on technology and excludes end users, and sometimes views a platform as a published standard (Fishenden and Thompson, 2012), and is generally lacking when it comes to accounting for the complex relationship between people, technology, and their interests (Msiska and Nielsen, 2017).

In addition, current research on the platform does not pay much attention to the capacity building process, which is crucial to healthcare in developing countries. Furthermore, innovation on this platform is not solely in the hands of app developers, but is also influenced by laws, regulations, capacity, technological contexts, etc.

(Braa and Sahay, 2012, Msiska and Nielsen, 2017, Grisot et al., 2014, Hanseth et al., 2012).

Recently, Roland et al. (2017) have argued the need for a platform to serve as an architecture that can enable large-scale participation design. Msiska and Nielsen (2017) argue that mainstream discourse paid limited attention to innovation at peripheral levels which were disconnected from the core where the platform is developed. They propose a socio-technical perspective to understand how technical attributes of a platform interplay with human relationship in enabling innovation activities in a resource-scarce country.

This thesis furthers that discourse on software platforms by presenting a case of customization of a software platform for Vietnam's healthcare sector. The platform, named DHIS2, has been used in more than 50 countries. The thesis presents challenges and approaches to adapting the generic software platform for a specific context. Unlike previous studies, this thesis focuses more on how information infrastructure design theory can be extended to overcome challenges posed by adapting an open source software platform to a resource-scarce context. The thesis also tries to understand how technical attributes of a platform influences its success in a particular context. For example, whether web-based design is important, or how open source solutions are accepted in tender processes where proprietary software is favored.

2.9 Proposed theoretical framework

As discussed earlier, HIIs can be seen as a subset of II. The existing design principles and rules from IIs are applicable in the context of HIIs in developing countries to deal with the two problems bootstrapping and adaptability. However, as HIIs in developing countries pose situated challenges which are different from bootstrapping and adaptability, it is important to frame these challenges as emergent design problems, and work to develop and operationalize new design principles to create rules to address those problems. To guide the analysis process, the following steps were carried out:

1. Identifying HII challenges

This step was done partially through the literature review process with the focus on the challenges of building HIIs in developing countries. Identified challenges were subsequently compared and related to the empirical materials to confirm their contextual relevance.

2. Framing HII challenges as emergent II design problems

This step entailed juxtaposing each of the challenges identified in step 1 with the existing II design problems. The overall aim of this step was to understand how HII challenges are similar and different from the existing II design problems. A set of emergent design problems would be the point of departure for developing design principles and rules.

3. Building new design principles and design rules

In this step, attempts to develop new design principles and rules to cope with the design problems were made.

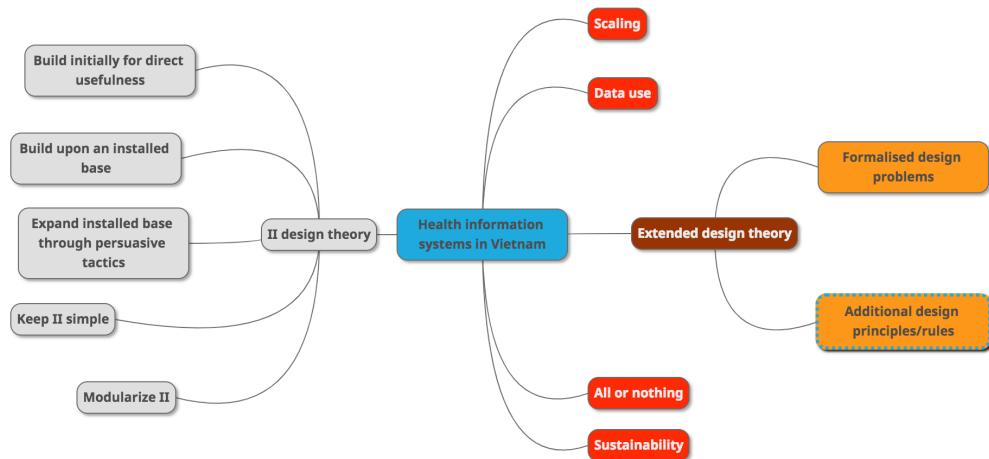
4. Evaluating the robustness of these design principles and rules to other contexts and domains

There was also the attempt to evaluate the new design principles and rules in other contextual settings. The discussion aimed to evaluate the relevance and applicability of these design principles and determine what further research is needed.

To summarize, Figure 1 illustrates my theoretical framework that guides the analytic process with the following elements:

- Design principles of the design theory are served as inputs
- The context is the healthcare sector in Vietnam with problems identified from HISs literature (data use, all or nothing, scaling and sustainability, etc.)
- The output is the extended design theory with formalized design problems and specific design principles and detailed design rules.

Figure 1: The proposed theoretical framework



This chapter has reviewed current debates on II design principles and how they could contribute to resolving the problems of creating functional HISs for developing countries. Based on the empirical work conducted in this thesis, HII emergent design problems will be identified and discussed, followed by a list of new design principles and rules needed to resolve those problems. Both emergent HII design problems and design principles and design rules represents the primary contributions of this thesis.

The next chapter discusses the research context and empirical cases that form the basis for this research.

3 RESEARCH CONTEXT AND THE CASES

Vietnam is the setting in which this research was carried out. In this chapter, I provide discussion on various social, political, and technical conditions in Vietnam which arguably had a bearing on my research. The discussion follows a vein in which social conditions of the country are described, followed by presentation of its healthcare system and the supporting HIs. Events and initiatives that had substantial impact on the situation are also discussed.

3.1 The contextual settings

3.1.1 Geography and politics

Vietnam is a country located in the Southeast Asia region. The country has historically been severely devastated by several prolonged and fierce wars: with France (1945-1954), with America (1960-1975), with the Khmer Rouge (1979-1989), as well as a brief border war with China (1979). These wars have had significant impact on the psychology of Vietnamese people and the social and economic conditions of the country.

Following the collapse of the Soviet Union and the Eastern Bloc, the communist government in Vietnam started a reform program in 1986, which reflected a partial restoration of market economic principles such as abolishing central controlled price determination and planning, permitting private businesses, dissolving co-operatives and allowing farmers to do farming by themselves.

The re-establishment of market principles has contributed to the development of the country in the last 25 years in terms of poverty reduction, increase of life expectancy, and improvement of key health indicators. The agriculture sector has dramatically changed and turned Vietnam from a starving country to one of the top exporters of rice, coffee, fish, etc.¹ In 2010, Vietnam became an average income country with a Gross Domestic Production (GDP) per capita greater than 1000 USD².

3.1.2 Centralized administration and its impact on the healthcare system

Geographically, Vietnam covers an area of 331,210 square kilometers and is embraced by the East Sea (South China Sea). The country is divided into 63 provinces. Each province is subdivided into districts which in turn are divided into wards. Each province has a number of provincial departments responsible for different sectors such as health, education, police, foreign affairs, trade, sports and culture. Districts have a number of offices corresponding to the structure in the province.

This administrative structure impacts the way the health system is organized. Overall, Vietnam has about 1200 hospitals, of which 170 are private, and about 30,000 clinics of all kinds (public,

¹A century ago, the Mekong delta region (Southern Vietnam) was in the top rice exporter.

² <https://data.worldbank.org/country/vietnam>

private, military, international, etc.). Public hospitals play a central role in the healthcare system, while the number of private hospitals in Vietnam currently only accounts for 15 percent of all hospitals in the country. This has many implications on how Information Communication Technology (ICT) applications are built, implemented and scaled. For example, the MoH and provincial health departments have strong influences over selection and adoption of a software system.

3.1.3 Education and health human resources development

The Vietnamese people have a traditional fondness for learning (Nguyen and Johanson, 2007). After the economic reform in 1986, education regained its momentum and more private schools and universities were founded, and the number of students increased per capita. Regarding medical education, Vietnam had a total of 11 public universities providing programs on medicine, dentistry, and pharmacy. Medical education used to be strictly controlled by the government. However, since 2010, the Vietnamese government loosened its control on medical training by permitting private universities to open health science-related programs. Consequently, the number of health professionals surged quickly. Medical universities in Vietnam now offer medical doctor degrees for students who complete a program of 6 years. Graduates can start working in hospitals as interns for 1.5 years in a particular specialty before they can apply for a medical license. Practitioners with 4.5 years' experience can apply for a license to practice independently, which allows them to be head of a department in a health facility or to open a private clinic, usually at home, to practice after office hours.

After graduating from medical universities, most doctors struggle to get a job in public hospitals in big cities, as it is highly competitive. Despite the huge demand for doctors in rural and remote areas, few doctors want to work there. To alleviate the doctor shortage issue, the government issued a policy under which nurses, after some years of serving in these areas, could attend a special doctoral training program (in Vietnamese: “ChuyenTu”) lasting about 4 or 5 years. They then come back to their hospitals and practice as doctors.

3.1.4 The Information Communication Technology sector

Vietnam is among the countries that have the fastest ICT growth rate. The penetration of mobile and Internet has increased dramatically. In 2016, Vietnam had about 127³ million mobile phone subscribers whereas its total population was less than 100 million. The number of Internet users was approximately 47⁴ million in 2015. ICT infrastructure in the healthcare sector is also well developed. According to a survey in 2013, all Provincial Health Departments had computers and Internet and about 40% of hospitals used electronic medical record systems.

3.1.5 The healthcare sector

Vietnam has made significant progress in modernizing and reforming its healthcare sector. Life expectancy is 72.8 years which is even higher than that of countries with equal GDP per capita (Hinh and Van Minh, 2013). The rates of infant mortality and maternal mortality have fallen

³ <http://english.vietnamnet.vn/fms/science-it/149883/vietnam-has-127-mil--mobile-phone-subscribers.html>

⁴ <http://www.internetlivestats.com/internet-users/viet-nam/>

significantly. The number of instances of children under five years old suffering from malnutrition has also dramatically dropped. Vietnam spends 7.2% of its GDP on healthcare the highest rate in the Southeast Asia region. The economic growth has increased people's awareness and demand for healthcare services, triggering the development of the private health sector (Pham, 2016). Despite these achievements, the healthcare sector still faces many difficulties and challenges.

First, the levels of health infrastructure and human resources still do not meet the growing demand. Vietnam has only 7-8 health workers and 25 hospital beds per 10,000 citizens while the global average numbers are 15 and 30 (Pham, 2016). A remarkable number of patients go to big cities to seek better treatment. As a consequence, hospitals in big cities are seriously overloaded. It is very common that two or three patients have to share a single bed during a night's stay. Even worse, sometimes patients have to lie down on the floor of the hospital. Receiving a check-up in public hospitals is extremely arduous, especially for those who use health insurance. To complete a check-up within a day, patients must arrive early in the morning around 4:00 AM and then wait until 7:00 AM to get a queue number. After that, patients wait to see doctors for several hours, and if any lab tests or radiology is needed, the patients must join another queue, which often takes an additional 2 to 3 hours, plus another wait on top of that for the results to be printed. After receiving the results, patients have to wait to see the doctor again. All in all, visiting hospitals has become a painful experience and there have been many complaints about that. Therefore, one of the promises of the new health minister when she took office was to fight against hospital overloading and to improve hospital quality⁵. This problem was one important contextual condition that enabled the emergence of many health information systems such as for Hospital Quality Evaluation.

Second, Vietnam is struggling with the double burden of non-communicable diseases (cardiovascular, cancer, diabetics, etc.)⁶ and communicable diseases (HIV/AIDS, malaria, dengue fever, etc.)⁷, and to support an aging population⁸.

Third, the problem of health equity and access across regions and socioeconomic groups is serious. Chronic diseases are highly prevalent in rural populations where health infrastructure is significantly undeveloped (Hoang and Tran, 2012).

Fourth, corruption in Vietnam is a big issue which could significantly affect the goals of equity, access, and quality (Vian et al., 2012). For example, patients pay informal fees to doctors and health workers to get priority in treatment. There is also an abuse of health insurance funds through fraudulent treatments. Corruption is also widespread in drug and health medical equipment procurement in public hospitals, having significantly weakened the health sector, making it inefficient and damaging the respectable image of health professionals. To address such problems, it is vital to have reliable and timely health data that could support the planning

⁵ <https://www.talkvietnam.org/2012/03/minister-proposes-solutions-to-hospital-overload/>

⁶ <http://sggpnews.org.vn/health/vietnam-has-burden-of-non-communicable-diseases-66784.html>

⁷ <https://vietnam.vnanet.vn/english/vietnam-challenged-by-double-disease-burden/161436.html>

⁸ <http://vietnamnews.vn/society/health/393500/viet-nam-prepares-to-support-aging-population.html>

and policy-making process to ensure the reasonable allocation of resources and other interventions (Braa et al., 2004).

This section discusses the contextual settings where this research was embedded, along with some of the real-world problems that require a solution. These problems are reflected in the cases studied in this thesis, which will now be discussed in an overview form.

3.2 The cases

This section describes the design process of four software systems that formed the basis of my empirical work.

3.2.1 The Medical Licensing System

On November 23rd, 2009, the Vietnam Assembly enacted a law of medical examination and treatment (herein after the Law). The Law which became effective on January 1st, 2011 set an important legal precedent to regulate medical practicing activities in Vietnam. The three subjects regulated by the law include medical practitioners (doctors, nurses), patients, and medical facilities. The law enforces patient privacy, legalizes the ability for medical practitioners to have a part-time job outside their work in public medical institutions, and prohibits bribery in any form. Most importantly, it officially requires medical professionals to be licensed before they can practice. Each health professional is mandated to have a license, which is granted for lifetime, although holders need to provide proof of continuous medical education. The law was expected to increase the quality of medical services delivery that was considered to be relatively low compared to other countries.

The Law was followed by the Government's issuance of the decree (87/2011/NĐ-CP dated 27/9/2011) which served as a detailed guideline on how to implement the Law. On November 14th, 2011, the Ministry of Health issued a circular (41/2011/TT - BYT) to elaborate formalities and processes to apply and obtain medical licenses for individuals as well as facilities. The enactment of the Law is part of Asia Development Bank's (ADB) support through the Health Human Resources Sector Development Program (HHRSDP) project, which consists of a number of components. One of these components is to support the development of a registration system for health professionals with aims to 1) regulate professional qualifications and skill standards, 2) monitor individual performance, 3) regulate on disciplinary action when problems arise, and 4) enforce continuous skills development (ADB, 2013). In its project proposal, ADB also emphasizes the fact that Vietnam is among the few countries in Asia which do not have a functioning system to regulate and manage the registration of the health workforce (ADB, 2013). Therefore, a plan to provide support to the Vietnam Ministry of Health to build a computerized licensing system was part of ADB's agenda.

In early 2012, a specialist from MoH (hereinafter DrS), whom I knew through a friend, contacted me and asked me if I could recommend any international firm which could provide software solutions for medical licensing. I accepted his request and tried to contact a number of HISP country nodes. However, I could not find any company because at that time HISP

activities mainly involved aggregate-based reporting systems. I suggested to him that I could try to build a prototype based on DHIS2, which is an open source software specialized for healthcare developed by the University of Oslo, in Norway, to see if it was feasible to develop that system locally instead of purchasing it from international vendors. He supported this plan and encouraged me to proceed.

To begin, I extended DHIS2 by developing a web module on top of it. The prototype was ready in a short time and I showed it to DrS. One province in the South of Vietnam (hereafter SouthProvince) was selected to pilot the prototype thanks to the relationship between me and the Head of the Licensing Office in SouthProvince (hereinafter DrP). DrP attended various health informatics courses organized between 2007 and 2008 in Ho Chi Minh City in which I was one of the instructors. DrP had an interest in software systems, so when he heard about the licensing system, he agreed to pilot it in his province. I provided him the link to the licensing system and created an account for him. Soon, he got back to me and gave me a list of suggestions to improve the system. I was working closely with him to address all the comments. When all the major problems were solved, he started to use the system to process licensing applications in his province. During the pilot phase, whenever he found some areas of improvement, DrP discussed these with me and I quickly fixed them for him.

After nearly one year piloting it in SouthProvince, the system was evaluated by the MoH and Asian Development Bank (ADB) as ADB was providing aids to strengthen the health human resources in Vietnam through a number of projects. Both of the agencies were happy with the system. They decided to support piloting it in five more provinces.

To implement that plan, ADB provided a small grant to improve and implement the system. With the ADB support, seven people were hired to form a team to work on customizing the system and provide support to end-users (hereafter the Team). The MoH sent a letter to request that the five provinces participate in the pilot. With both financial and political support, the implementation progressed well. Lots of new functionality was added to the system, making it effectively support the transformation of work practices in the pivot provinces.

Subsequently, the scope and size of the implementation of the licensing had a big leap forward. In early 2013, during two notational conferences on licensing management, the MoH allocated time for the Team to present the system to all provinces. Following the conferences, a Vice Minister signed a letter to all the provinces not currently participating in the previous pilot, requesting them to register a minimum of 150 applications into the system. Based on that arrangement, the Team worked intimately with the provinces to support them—not only with the registration of the 150 applications but also to advise them on how to align their workflows to comply with the computerized licensing system. To facilitate the implementation process, the Team built a tool to convert data from Excel files to be compatible with the system. This approach was welcomed by many provinces and not only did they register their requisite 150 applications, they started to use the system to support their work.

The national scaling of the system comprised not only consent but also challenge and protest. Some provinces said that using the system took more of their time than using Excel files and complained that they did not have enough staff to do that. However, there was one event that completely changed the scaling process. SouthProvince made a request to the Team to build functionality that allowed their hospitals to participate in the process by registering applications at hospitals prior to handing hardcopy applications in to the licensing office. SouthProvince argued that this approach might reduce the workload of licensing officers. The Team consented to the request and extended the system with that functionality. User accounts were also created and given to SouthProvince. Enlisting hospitals in the licensing process proved to be an effective approach. Many neighboring provinces expressed interest in visiting SouthProvince to observe and learn. Through efforts of the Team, the approach quickly spread to other provinces. By the end of the year, from the original plan of pilots in 5 provinces, the licensing system was expanded to all provinces in the country.

Through each milestone, the system was gradually augmented with more functionalities. When being piloted in South Province, only basic functionality to process licensing applications was developed, including:

- Applicants' bio information such as name, gender, date of birth, address
- History of practice details such as name of hospitals, positions, from when to when
- Medical certificate information such as name of medical university, year of graduation

When it was about to be deployed to 5 provinces, however, the system was extended with many advanced functionalities such as batch processing, i.e., licensing officers can work on multiple applications at the same time, and searching and filtering. The key feature that was added to the system when it was expanded to all provinces was application registration at the hospital level.

In 2014, ADB opened tendering to allow firms to bid on the chance to extend the licensing system to include other modules, such as continuous education, human resources, payroll, etc. After many rounds, a local firm (hereinafter BigFirm) was chosen and awarded a contract. As the licensing module was fully functioning, ADB provided another grant to the Team to continue supporting it and to help integrate with BigFirm's modules. According to the Terms of References defined by ADB, BigFirm had to work with the Team to integrate their newly developed modules with the licensing system. Modules that would be developed by BigFirm included facility licensing, continuous medical education, human resource management, payroll, business intelligence and reporting.

Between 2015 and 2016, there were many meetings organized by ADB to facilitate the collaboration between BigFirm and the Team to find solutions for system integration. The Team insisted that BigFirm should use DHIS2 so that integration could take place easily, while BigFirm wanted to use its own platform and technology stack.

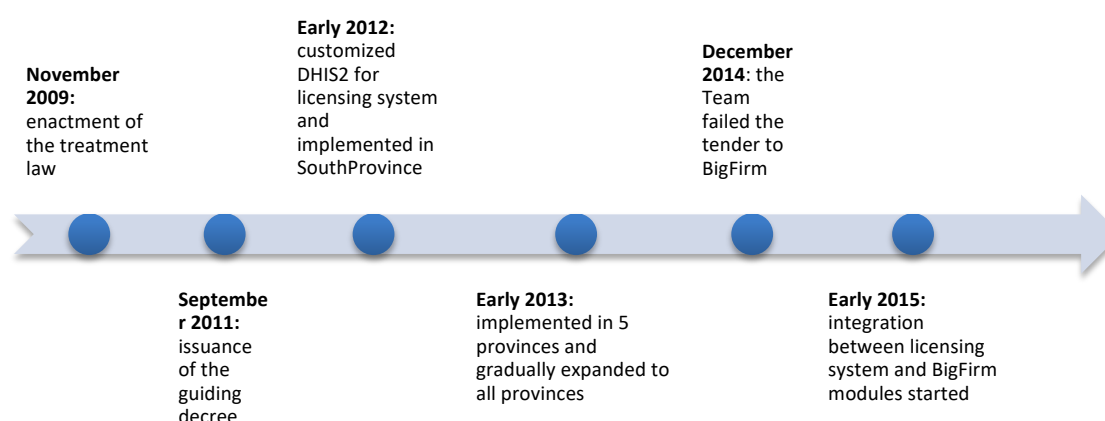
In the end, both sides reached an agreement that each team could use its own architecture and platform, independently from each other. To ensure compatibility, The Team would publish data from the licensing system to an online data warehouse. The BigFirm's modules would

connect to the data warehouse to copy data into their own database through web services. End users could use both systems with the same user account, thanks to the use of OpenID protocol.

In mid-2016, after more than one year of development, BigFirm completed seven modules. It received permission from the MoH to pilot in a couple of provinces. The process of integration between the two systems has been ongoing.

Figure 2 summarizes key events of the Medical Licensing System:

Figure 2: Key events in the Medical Licensing System



3.2.2 The Hospital Quality and Inventory Management System

After the licensing system was implemented nationwide in 2013, the Team gained trust from many MoH staff. There were a number of discussions between the MoH and the Team on how to replicate the licensing system to support other areas of health management. At the end of 2013, the MoH prepared and released Hospital Quality Evaluation Guidelines for the first time. The guideline consisted more than 3000 criteria, which were used to assess a hospital. To support that process, a computerized information system was needed.

Originally, in May of 2013, the Team had developed a separate module for health facilities licensing, which was cloned from the (professional) licensing system, but the system was not implemented for many reasons. First it conflicted with the plan of ADB to have a tender to select a firm to build all required modules. Second, the Team did not have resources to carry out the implementation without funding. The process of both of the systems is very similar except that one focuses on professionals and the other on facilities. Therefore, much of the code and design could be reused. The Team had planned to build the module so that in case they won the tender, they could have everything ready.

Understanding the emergent need to have a system to support hospital quality assessment and hospital inventory, the Team showed what had been built to the MoH and proposed that it could customize the module to meet the requirements of the Hospital Quality Evaluation and Inventory System. The MoH approved the proposal and asked the German Aid Agency

(Deutsche Gesellschaft für Internationale Zusammenarbeit – GIZ) to provide financial support for the implementation. After receiving the funding, the Team started the software customization process. To expedite the process, a number of ‘temporal gateways’ were used. For example, the Team prepared an Excel file that contained all assessment criteria, transformed and loaded them into a database, which significantly reduced the effort of inputting them manually. There were more than a thousand hospitals in Vietnam, thus creating accounts for all of them could involve a lot of manual work. The Team built a simple program using Java to automatically generate user accounts containing both username and password for all hospitals. The module was extended to become an independent system that supports the following areas:

- Hospital quality assessment, including more than 3000 criteria in 5 categories: patient service orientation, human resources development, performance, continuous hospital quality improvement
- Inventory including administrative data, staff, organization chart, drug, equipment, service scope, service delivery.

Because the time was too short, the MoH planned to roll out the system and bypass the pilot stage. Some MOH staff objected to this plan, arguing that it was too risky. The disagreement of several officials from the MoH, in fact, offered more time to the Team to improve and polish the system. After many rounds of discussion and lobbying through the relationship with a high-ranking official who supported the Team, eventually, the go-ahead plan was approved and the system was rolled out.

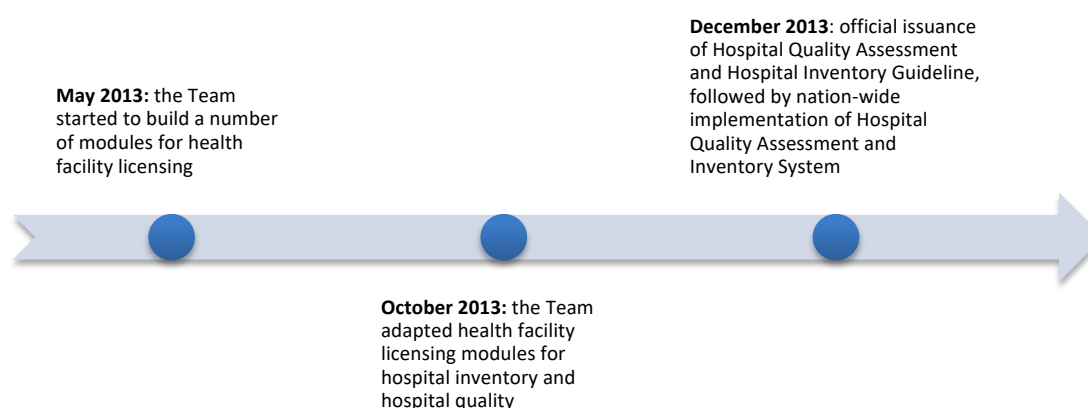
To start, a member of the Team was assigned to make separate Excel files, each containing accounts of hospitals for each province. Through contacts at health departments in provinces acquired when the Team implemented the licensing system, accounts were distributed to all hospitals. The relationship between the Team and provincial health departments and hospitals, which was strengthened after one year of implementing the Licensing System, was very useful for the Team in supporting this system.

There were many technical issues in the first week of the implementation, but they were resolved quickly. Based on user feedback, the system was gradually improved to be better and better, thus increasing users’ satisfaction. Many hospitals started to use the system to assess their quality and report inventory. The result was later independently verified by provincial health departments. In the end, a report that ranked the quality of all hospitals was generated by the system, giving the MoH necessary data for action.

The positive outcomes of the implementation of the Hospital Quality and Inventory System played an important role in convincing the MoH to use electronic systems for other routine data reporting. The Lunar New Year Reporting System presented in the next section is one such example.

Figure 3 summarizes key events of the Hospital Quality and Inventory System

Figure 3: Key events in the Hospital Quality and Inventory System



3.2.3 *The Lunar New Year Reporting System*

Following the implementation of the Hospital Quality and Inventory System, the Lunar New Year Reporting System was built and implemented in January 2014. Lunar New Year, which is called Tet in Vietnamese, is the biggest holiday festival in Vietnam, often lasting from 7 to 10 days. Extended leisure activities during Tet often increase risks of traffic accidents, food poisoning, and fireworks burns and injuries. Government agencies, especially the MoH, really need timely and accurate accident and emergency figures in order to respond effectively.

Motivated by the success of the Hospital Quality and Inventory System implemented before, the MoH asked the Team whether it could support to build and implement a Tet Reporting System. As the time was too short, some members in the Team were skeptical, but in the end, they agreed to provide support even though there was no budget for this work.

Also based on DHIS2, the Tet Reporting System was developed to provide functionality for capturing both aggregate and case-based data. Basically, the system consists of an entry form to collect the following data:

- Number of hospitalized cases
- Number of deaths and injuries by traffic accidents, by illegal use of firecrackers, by food poisoning, and by violence.

For traffic accident, firecracker, and violence, detailed patient data must be reported to avoid duplication and later inspection. There is a separate form to capture patient-level data, i.e., patient name, gender, age, address, date of admission, etc.

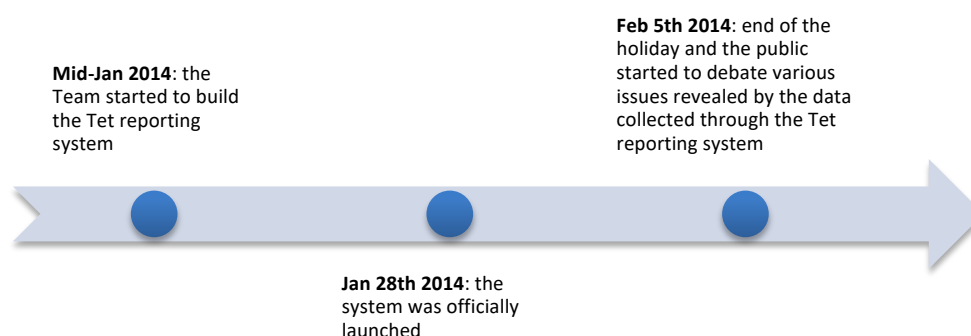
The team managed to complete the system in 2 weeks' time. The MoH sent a letter to hospitals and provincial health departments to inform about the use of the system for Tet reporting. In the letter, there were basic instructions on how to use the system, as well as some hotline telephone numbers that users could call if they needed support. Because there would be no time for formal training, the system was designed in a way that it could ensure that all hospital users could use it easily. For example, the use of a single-page entry form allowed users to input data of all reporting days on one screen, and beside that were help-line numbers. A button to print reports was also integrated into the same screen.

After the Hospital Quality and Inventory System was implemented, hospital users were quite familiar with online reporting, which is a method to report data by using a web browser such as Google Chrome or Firefox. The advantage of online reporting is that only a computer with Internet connection is required, and no software installation is necessary. The implementation of the Tet Reporting System went relatively smoothly with only a few issues related to data validation, which were quickly fixed by the Team.

In 9 days of the Tet holiday, daily data were aggregated and released to the public through mass media before noon the following day. By the end of the Tet holiday, the public realized that the figures of traffic deaths and injuries between the MoH and the Ministry of Public Security were not consistent, with much higher numbers in the MoH report. This fueled a big public debate regarding accidents and emergencies during the Tet holiday and people insisted measures be taken at various levels (policy, individual, etc.) to remedy the issue.

Figure 4 summarizes key events of the Tet reporting system

Figure 4: Key events in the Tet reporting system



3.2.4 The Epidemic Notification System

Shortly after the Lunar New Year of 2014, the North of Vietnam was struck by a severe measles epidemic. Thousands of patients, mostly children, were hospitalized, and hundreds of them died. The public was very anxious. There was even more panic when they realized that the number of deaths published by the MoH was not consistent with the number revealed by a local hospital. The anger of the public turned directly to the MoH, with several calls to strike at the MoH headquarters. The General Department of Preventive Medicine had built a system to collect epidemic data. However, at the time of the epidemic outbreak, the system was not fully scaled to all provinces, making it impossible to collect the aggregate figures of the whole country. In March 2014, an official from Vietnam Administration of Medical Services approached the Team to discuss extending the Tet Reporting System for measles surveillance. Seeing the opportunity to contribute to solving a public health issue that affected many people, the Team decided to take part in this. In just a few weeks, the Epidemic Notification System was completed and implemented in all hospitals, collecting data on measles-related cases across

the country. Summarized reports were compiled every day and sent to all relevant agencies such as the Government Office, General Department of Preventive Medicine, and public media to inform the public about the status of the epidemic. Eventually, the epidemic was pushed back and under control after some months. Later, the system was expanded to cover many other diseases such as dengue fever, foot-hand-mouth, etc.

In February 2014, Vietnam joined the Global Health Security Initiative⁹ led by the United States of America. The joint initiative of 26 countries aims to enhance mutual support between member countries to help prevent, detect, and respond to outbreaks of communicable diseases. As part of the collaboration, the US Center for Disease Control and Prevention (USCDC) would provide support to Vietnam in building an Emergency Operations Center (EOC). To proceed, USCDC staff began to contact Vietnam Administration of Medical Services and General Department of Preventive Medicine to discuss how to integrate systems run by these two entities with the data warehouse to be developed by the USCDC.

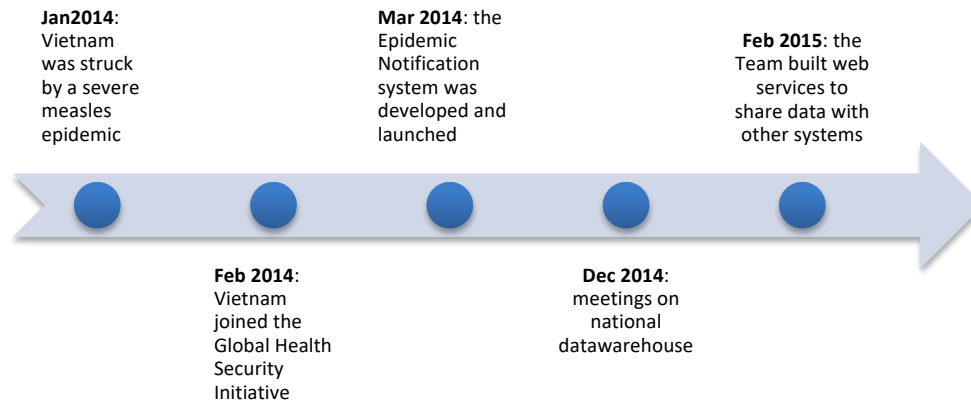
To proceed, between December 2014 and January 2015, the USCDC and its partner in Vietnam (PATH) organized a number of meetings and workshops to discuss the situation and seek the best approach to build an infectious disease data warehouse. Among available options, PATH and General Department of Preventive Medicine planned to use data collected from General Department of Preventive Medicine system to feed into the data warehouse. Seeing that bilateral collaboration as a threat, Vietnam Administration of Medical Services and the Team proposed that they could change the system to feed patient data related to infectious diseases from hospitals into the General Department of Preventive Medicine system. The idea was welcomed by other actors. Following that, the Team built a Web Application Programming Interface (API) that transferred data from the Epidemic Notification System to General Department of Preventive Medicine's system. To ensure interoperability, the Team proactively initialized discussion with the technical team behind General Department of Preventive Medicine's system and agreed on data sharing standards and exchange protocols.

As a result of this collaborative effort, a software ecosystem was built from separated systems developed by different software vendors and endorsed by different governmental agencies. One of the important criteria of these processes was that each system must find its own areas of contribution, i.e., functional roles, and reconfigure itself to fulfill such roles. It is also critical to develop an ecosystem approach which could strengthen the ecosystem as a whole rather than using only the best components and removing others. It also means that by enrolling into such a network, individual systems can have better protections from mutual exclusion and become more adaptive to other future changes.

Figure 5 summarizes key events which took place in the Epidemic Notification System:

Figure 5: Key events in the Epidemic Notification System

⁹ <http://vietnamembassy-usa.org/vi/node/5524>



This section discussed the development and implementation of four different systems that formed the basis of this thesis. In the next chapter, research method and approach will be presented.

4 RESEARCH METHODS

4.1 Research foundations

4.1.1 *Positioning my research*

Ontology is the nature of reality (Hudson and Ozanne, 1988) and the epistemology can be defined as the relationship between the researcher and the reality (Carson et al., 2001), or how this reality is captured or known. Throughout this research, I employed the interpretivist standpoint (Walsham, 1995). Ontologically, I believe that there is no direct access to the real world and there is no single external reality.

Epistemologically, I hold the view that a researcher is part of the reality and immersed within the research context. And because of that, research is context-dependent; the real world is seen through the lens of researchers. A study is always grounded in a specific and concrete context, and from there, knowledge is inferred to other contexts. I believe there is no single and universal truth that is context-free.

The chosen research position, i.e., interpretivist, has influenced my research approach in a number of ways.

First, throughout my research, I deliberately seek alternative explanations for the same phenomena to avoid any bias and systematic distortion of interpretations. For example, I actively collaborated with other researchers in writing research papers. Because of that, I had opportunities to re-examine the issues under different perspectives. I also brought my draft papers to PhD-workshops and research days, events organized by the Department of

Informatics, University of Oslo, so that other authors could comment and inspire alternative interpretations.

Second, as context is important in the interpretivist tradition, I have tried my best to foreground specificities and contextual factors of my cases at different levels. For example, when presenting my research, I explicitly discussed all relevant backgrounds of the cases such as history, culture, work practices, norms, etc. I also considered all these factors in collecting and analysing research data.

Third, the interpretivist standpoint encourages the interaction between researchers and research subjects. In this research, I constantly sought to increase the level of interaction between the research sites and me. In every phase of research cycles, I had chances to interact with stakeholders and users through a number of activities: requirement elicitation, prototyping, coding, capacity building, and supporting end users.

4.1.2 Motivation for choosing the action research approach

Among three common research methods used in qualitative research tradition—action research, case study, and ethnography—action research was chosen for this research. Because the aim of this research is to design and implement health information systems in the context of Vietnam, I found the action research approach to be a better fit than case study and ethnography. Case study is a research approach that investigates a contemporary phenomenon within its real-life context when boundaries between phenomenon and context are not clearly defined (Yin, 2008). The strength of the case study is that it allows in-depth analysis of an event, individual, or organization over a long period of time from multiple sources of evidence. A limitation with the case study is that it does not bring changes or provide solutions to real problems, and the aim of this research is about building and implementing health information systems. In doing information system research, some researchers adopted ethnography-based approaches, such as those of Star (1999) and Suchman et al. (1999). Ethnography allows researchers to develop deep understanding of work practices and subtleties, which are useful in building well-working information systems (Aanestad, 2002). The downside of ethnography is similar to that of case study. In both ethnography and case study approaches, change and testing hypothesis through change are not emphasized.

Action research helps to provide solutions to actual and specific problems that this thesis aims to solve. The choice of an action research approach was also influenced by personal motivation and opportunities. First, through a long-term personal relationship with staff from the MoH, I was privileged to take part in the development and implementation of the medical licensing system. This gave me a unique and exclusive opportunity to take part in the system-building process and to incrementally build trust through delivery of successful systems. Second, there was a demand from clients (MoH and ADB) to have a working system for licensing and other health management areas. It was consequently only possible to achieve through using an action research approach, since action research is highly clinical (Schein, 1995). Third, the nature of my research question is related to how to design information systems that is argued by Banville

and Landry (1989) as a very appropriate field for the use of action research. Fourth, it is also worth mentioning that the role I played in this study was as an active member who acted as a mediator between the Team and other stakeholders, as well as being deeply engaged in the daily project activities. I was also an active member with an agenda, dedicated to the success of the Licensing System, and in opposition to BigFirm in the beginning, but later shifting to collaboration after ADB granted them the contract.

4.2 Action research approach

Action research is a research method that aims at not only solving a real-world problem but also generating theoretical knowledge (Winter, 1989). I chose action research as my mode of inquiry, as it is effective for studying technology in human contexts (Baskerville and Wood-Harper, 2016). Action research is also distinct from other methods in its ability to develop knowledge for both practice and theory (Suchman, 2002). Furthermore, action research allows researchers to test and examine the differences between hypothesis and actual change, which serves as a motivation to understand how to improve and solve actual practical problems during the course of conducting research.

There are many types of action research; however, canonical action research (CAR) is considered to be a rigorous and prominent type. A typical canonical action research involves one or many action research cycles (Davison et al., 2004). Each cycle, in turn, includes five phases:

- **Diagnosing** refers to the process of identifying problems that need to be addressed based on mutual agreement between researchers and client,
- **Action planning** entails considering different solutions that could resolve the problems identified in the diagnosis phase,
- **Action taking** is the implementation of the plan outlined in the action planning phase,
- **Evaluating** refers to the process of examining and assessing outcomes of the interventions to see whether the actions are actually improving the problems as expected,
- **Specifying learning** relates to the process of summing up and reflecting on what has been learned through the earlier phases and how it feeds into the next cycle.

In this thesis, an action research comprising three cycles was attempted. Table 2 summarizes activities happening during each phase of the three research cycles.

Table 2: Summary of three action research cycles

#	Action Research Cycle	Phases
1	January 2012 – December 2012 Prototyped and piloted the Medical Licensing System in one province	<ul style="list-style-type: none"> - <i>Diagnosing:</i> The need for a centralized licensing system to govern the licensing process nationwide - <i>Action planning:</i> Building a prototype based on open source software to support the pilot Using II design principles to guide the design process - <i>Action taking:</i> Building a prototype and piloting in one province through participation approach - <i>Evaluating:</i>

		<p>A system was built incrementally through step-wise pilot</p> <ul style="list-style-type: none"> - <i>Specifying learning:</i> <p>The significance of bottom up and participation approach in shaping outcomes of the HII building process</p>
2	<p>January 2013 – October 2013</p> <p>Scaled out the Medical Licensing System to all provinces</p>	<ul style="list-style-type: none"> - <i>Diagnosing:</i> <p>Scaling beyond the pilot was a big problem</p> <ul style="list-style-type: none"> - <i>Action planning:</i> <p>Gradually expanding the pilot to 6 provinces Using II design principles to guide the design process</p> <ul style="list-style-type: none"> - <i>Action taking:</i> <p>Scaling the licensing system to 6 provinces and rapidly to all provinces and also to hospital level</p> <ul style="list-style-type: none"> - <i>Evaluating:</i> <p>System was planned for pilot in 6 provinces but implemented in all provinces and hospitals</p> <ul style="list-style-type: none"> - <i>Specifying learning:</i> <p>Throwaway gateway components could catalyze and facilitate the scaling process.</p>
3	<p>October 2013 – April 2014</p> <p>Built and implemented the Hospital Quality Evaluation and Inventory System, the Lunar New Year Reporting System, and the Epidemic Notification System</p>	<ul style="list-style-type: none"> - <i>Diagnosing:</i> <p>More systems to support other areas of the healthcare sector Integration and interoperability was a real challenge Little data use was identified as a big problem</p> <ul style="list-style-type: none"> - <i>Action planning:</i> <p>Building and deploying new systems based on the existing system</p> <ul style="list-style-type: none"> - <i>Action taking:</i> <p>Four systems were built and deployed on the same infrastructure Data of the Tet Reporting System were shared to the public through mass media</p> <ul style="list-style-type: none"> - <i>Evaluating:</i> <p>Additional systems were built <i>ad hoc</i> to respond to emerging needs</p> <ul style="list-style-type: none"> - <i>Specifying learning:</i> <p>Expanding functionality for the same user base as one form of scaling Data use could be leveraged through mass media and public debate, etc. Functional reconfiguring to confront substitution and exclusion</p>
4	<p>April 2014 – January 2016</p> <p>Collaborated with other software vendors to extend and integrate the Medical Licensing System and Epidemic Notification System</p>	<ul style="list-style-type: none"> - <i>Diagnosing:</i> <p>Integration and interoperability was a problem</p> <ul style="list-style-type: none"> - <i>Action planning:</i> <p>Shift from confrontation to collaboration</p> <ul style="list-style-type: none"> - <i>Action taking:</i> <p>Integrating health professional licensing system with modules built by BigFirm Integrating epidemic notification system with systems developed by competing stakeholders.</p> <ul style="list-style-type: none"> - <i>Evaluating:</i> <p>Challenges in guarding against replacement</p> <ul style="list-style-type: none"> - <i>Specifying learning:</i> <p>Collaborating in asymmetric conditions</p>

As there are many forms of action research, it is essential to have evaluation criteria to ensure that an action research project is rigorous. Avison et al. (1999) proposed a framework

containing five principles to assess an action research, which I discuss further below, and explain in Table 3 how my action research attempted to follow these principles.

Table 3: Evaluating my action research

#	Principle	Description	Relevance to my research
1	Researcher-client agreement	A mutual agreement between researcher and client on various issues such as responsibility, scope, and evaluation criteria should be established before starting the action research project.	Agreements between researcher (myself) and client (MoH) were specified in three formal contracts with clear scope, responsibility of each side, detailed activities, evaluation criteria.
2	Cyclical process model	Should progress through sequential phases to ensure its systematic rigor.	As illustrated earlier, four cycles of action research were conducted, each of the cycles followed cyclical process model: diagnosing, planning, action, evaluating, and reflection.
3	Theory	Theory plays an important role in action research. It guides researchers' action, avoids the danger of "irrelevant subjects", and prevents researchers from getting lost in sea of data.	The overarching theoretical model employed to guide the research approach was II perspective and II design theory.
4	Change through action	This principle emphasizes that change is the core and essence of any action research project. If there is no change, it suggests that there is no meaningful problem.	Actions were undertaken to improve situated problems. Changes and improvements were examined and discussed in the evaluating phase of each cycle. For example, the licensing system which was implemented nationwide has changed the way licensing officers worked. Similar changes were also observed as consequences of the implementation of other systems.
5	Learning through reflection	Both practical and theoretical knowledge generated through intervention process must be reflected, documented, and shared with both client and research community on a timely basis.	The client (MoH) was informed and could monitor the outcome of the research through various channels: emails, workshops, meetings, and conferences. Final reports were written and submitted as part of contract duties. Simultaneously, several research papers were written and published in journals to contribute to the research community. Some of them became part of this thesis.

Although this action research followed principles and guidelines of canonical action research, I was also partially influenced by the network of action approach advocated by Braa et al. (2004). This approach aims to solve the problems of unsustainability and limited scalability of action research projects of HISs in developing countries. It is argued that local action intervention should be linked with larger network efforts in other locations. Through the network, shared knowledge, learning, and support can mutually flow among nodes, contributing to sustaining local action projects. My research was inspired by the network of action approach in three ways. First, the evolution of the systems in my study was tightly coupled with milestones of DHIS2 releases. It means that functionality available in new releases of DHIS2 was quickly integrated into the system in Vietnam. Second, support from the HISP global network was sought on many

occasions to address problems that the Team could not resolve. Third, experiences from the implementation of the Medical Licensing System and Epidemic Notification System were shared with other HISP nodes such as South Africa, Nigeria, etc

4.3 Research design

4.3.1 Multiple cases and their timeframes

Spanning a period of nearly four years between 2012 and 2016, my action research involved multiple cases engaging different stakeholders from governmental agencies to non-profit originations (NGOs) and health facilities. Each case related to the design, implementation, and scaling of a particular software system for a specific health management purpose such as medical licensing, hospital quality evaluation, epidemic notification, Tet reporting, etc. Personally, I was very fortunate when I had opportunities to take part in the unfolding of many systems over a long period of time, which helped me to collect empirical material to answer my research question. Table 4 summarizes key activities of my research.

Table 4: Timeframes of different activities related to the cases

#	Periods	Activities
1	January 2012 –December 2012	Prototyped and piloted the Medical Licensing System in one province
2	January 2013 – October 2013	Expanded the Medical Licensing System to all provinces
3	November 2013 – April 2014	Built and implemented the Hospital Quality Evaluation and Hospital Inventory System, the Lunar New Year Reporting System, and the Epidemic Notification System
4	April 2014 – January 2016	Collaborated with other software vendors to extend and integrate the Medical Licensing System and Epidemic Notification System

4.3.2 Multilevel engagement

During this research, I had opportunities to work with stakeholders at various levels of the health system including health facilities, provincial health departments, and the MoH. I also had an opportunity to work with the global HISP team. This multilevel engagement gave me chances to better understand how II design means different things to different people. For example, users at the hospital level were more concerned about how to use the systems and how systems could support their work, and most importantly reduce their workload. MoH officials often had a different perspective which focused more on integration and standardization. At the global level, as the DHIS2 team had limited time to support particular countries, it only focused on providing generic solutions of global relevance. Requirements from one country might not be considered if not seen as relevant elsewhere. This multilevel engagement allowed me to analyze the differences and similarities between diverse perspectives. This understanding contributed to the shaping of new design principles and design rules.

4.3.3 Approach to studying II

For studying II, Star (1999) gives three pieces of advice. First, it is important to focus on master narratives which make other parts of the infrastructure invisible and unnamed. Second, as unnoticed and unrecognized work always exists behind the scenes, it is necessary to make them visible and take them into account when studying II. Third, it is crucial to understand the interplay between computer resources, organizational routines, and day-to-day tasks. Therefore, in order to better understand how II is built and influenced, it is necessary to drill down and identify activities of each actor involved (Nielsen, 2012).

Because the aim of this research is to understand the process of building HII in the context of developing countries, I used the action research approach, which allowed me to closely follow the HII-building activities of any “single developer” and their “pocket of control” (Nielsen, 2012). For example, by participating in the daily activities of the Team, it was possible for me to become aware of often neglected and unrecognized components, such as the tool built to move data from Excel to the Licensing System. These components played an important role in building II.

4.4 Data collection

Given my initial chosen theoretical frame, its evolution, and choices of cases, data was collected both in deliberate planning and in an *ad hoc* manner (opportunism). Methods of data acquirement were from traditional qualitative approach methods adapted to the needs of particular cases. For example, while onsite observation (field visits to hospitals, provinces, and MOH offices) was widely used in the case of the Licensing System, thanks to financial support from ADB, it was limitedly used in other cases.

4.4.1 Participatory observation

Observation techniques are widely accepted as an important method of data collection in qualitative research. They provide a number of advantages over interviews and questionnaires; for example, researchers can directly see things when they occur without relying on interview informants’ “*retrospective or anticipatory accounts*” (Sapsford and Jupp, 2006, p.59).

Being a researcher in a network of action, this participatory observation approach was a rich source of data for me. My longitudinal engagement with many projects in Vietnam gave me chances to follow each case from inception to closure. Broad involvement in the projects in various roles allowed a richness of collected data. Moreover, this approach was really helpful for me to get a deep understanding of people, organizations, and the contexts in which systems were implemented over a long period of time. Also, the approach enabled direct contact with different data sources (Myers, 1999).

My participation varied from case to case, depending on the roles I played. For example, as an implementer, I had many chances to work with health workers and users who directly used the systems for their daily work. When I played the role of a developer, I was involved in technical issues and responsible for translating requirements to technical languages, and worked with

different groups. When acting as a system designer, I participated in high-level meetings with the MOH and donors to plan for implementation.

More often than not, I could take time for reflection shortly after important events such as meetings, workshops, and training sessions. Notes taken during observations were used as materials for this reflection, and it often resulted in more complete and systematic understanding and writing. With substantial time spent in the field and being an action researcher, participation was an important mode of my data collection.

Sapsford and Jupp (2006) warn researchers on the validity of data collected by using participation and observation techniques. According to them, data produced from these sorts of activities can be valid only if the conducted observation follows several rules. One of them is that systematic and effective measures of recording of observation must be implemented. This rule was deliberately taken into account in my research approach. Being a longitudinal researcher also gave me advantages when it came to building relationships and fostering trust with hospitals, provincial health departments, the MoH, and donors. Furthermore, research diaries and reflections helped me to alleviate the problem of data distortion and increase the correctness of collected data.

4.4.2 Documents analysis

The other method of data collection employed in my research was document analysis. Documents used in my research varied in type, including a) archives of electronic communication tools such as email, mailing lists, chat logs; b) documents relating to software design, development and implementation processes such as source code, bug-tracking tools, wikis, blueprints, and user manuals; and c) legal documents such as laws, decrees, and circulars enacted by the Vietnam National Assembly and the MoH.

To manage emails, I created an archive of all emails related to the development and implementation of the systems that formed the empirical basis for this research. This archive allowed me to trace activities, discussions, and interactions with other stakeholders.

Technical documents, meeting minutes, and project reports were other important data sources. A collaborative project was created using Bitbucket¹⁰ to allow team members to discuss technical issues, report bugs, and keep track of other issues posed during the development and implementation of the systems. A bulk of the technical documents was produced to communicate with the client as well as to train new members of the Team. They also served as part of the deliverables that would be transferred to the client after the acceptance meetings.

4.4.3 Interviews

In qualitative research, the interview is a common method for data collection (Seidman (2006); Kvale (1983); DiCicco-Bloom and Crabtree (2006); Wengraf (2001)). Seidman (2006) argues

¹⁰<https://bitbucket.org/>

that the flexibility of interviews makes them attractive for data collection. Interviews can range from quantitative, structured (questionnaire) to qualitative, unstructured or semi-structured ones, depending upon choices and strategies of researchers. Interviews can be particularly useful when observations are not possible due to the restriction on access to research sites or through time limitations (Seidman, 2006). Interviews were also used in my research to complement data collected from other sources. In my research, the interview approach varied across the different action cycles and action phases. It also followed the pragmatic approach, where most of the planning was done based on the specific situation. Therefore, the details of interviews, selection of interviewees, and questions asked were different from case to case and from phase to phase (in each case).

Selection of informants

The informants to be interviewed were chosen based on the relevance and nature of their involvement in the project. In my research, informants were diverse and included users at hospitals, provincial health departments, and the MoH. First criteria for selecting interviewees were based on how much the informants were involved in the daily goings on of the projects. For example, in the case of building the licensing information systems, licensing officers at the provincial level who directly used and were affected by the system were selected. The second group of interviewees included MoH officers because, in many cases (except the licensing), the design and deployment of systems were initialized and directed by the MoH. Understanding the motivations and intentions of those who worked for the MoH was crucial to understand the broader contexts within which the systems were built. This later provided empirical evidence for theoretical construction. For example, how important political support at the end affects the scaling. There were also cases when an interviewee introduced me to his/her colleagues when an interview question went beyond his/her scope of work. The number of interviews was decided based on specific cases. For example, in the pilot phase of the licensing system, I conducted at least one interview for each provincial licensing office participating in the pilot. In Vietnam, each licensing office often has only three staff but only one of them would have direct interaction with the software. When rolling out the system to other provinces, there was a support telephone line to receive comments and feedback from users, so interviews were not used.

Length and venues of interviews

The standard length of each interview was between 45 minutes and 1 hour. Some interviews lasted longer than 1 hour when there were many issues that needed to be clarified. A very few interviews were much shorter when an informant was called for an urgent meeting. If the interviews could not be rescheduled, often, follow-up questions were communicated via email or telephone. Venues for interviews also varied. Some were conducted at the offices of informants. Other interviews were conducted via telephone and instant messaging when face-to-face meetings could not be arranged.

Types of interviews, questions, and answers

In qualitative research, unstructured and semi-structured interviews were mostly used to gather data, as they enabled informants to freely describe their perspectives, feelings, and

explanations, which can give “*insight into what the interviewee sees as relevant and important*” (Seidman, 2006, p.313).

Unstructured interview allows the conversation between interviewer and interviewee to freely flow. It does not limit the range of the topics an interviewee wants to share. Semi-structured interviews require researchers to develop an interview guide before conducting the interview. The interview guide contains a list of key questions to be asked. However, it does not prescribe exactly how an interview must be conducted, but instead leaves the interviewer room to include any other additional questions based on responses he/she receives. In my study, both unstructured and semi-structured interviews were used to collect data. For example, to understand the broader context within which the medical licensing system worked, I used unstructured interviews that contained no specific number of questions. Sample questions asked during interviews with provincial licensing officers included:

- Can you describe the overall process of licensing? Is there a standard guideline from the MoH on that?
- How is the process in your province different from the standard provided by the MoH? Why is it different?
- What are the challenges that you face when running the manual licensing process without support from an information system?

These questions conducted at the very early phase of the action research cycle helped formulate and identify the problem and provide the basis for action planning and action undertaking.

Later, after the system was deployed and went live, interviews when I visited to other provinces were semi-structured.

Apart from other questions, the following two questions were used for interviews after the system was deployed:

- What are the difficulties you face when moving to use the electronic licensing systems?
- Did you use **the application review list functionality** offered by the system? How could it be improved to help you more?

The application review list is a functionality that helps licensing officers to prepare a list for a reviewing meeting.

For these questions, answers received from licensing officers were also greatly varied. For example, in one provincial licensing office, an answer I received for the first question was as follows:

“My staff was not very good at using computers, so it took me some time to train her. Apart from that, we have only few staff but there are too many applications to process. The system could not be accessed for some time, preventing us from registering an application”

In another licensing office, the informant told me:

“There was not much problem learning to use the system. I was the only one in charge of licensing. Our province is rather small and does not have very many applications to process. So far, I haven’t encountered any serious problems.”

For the second question, the informant from the first province said:

“The application review list functionality is nice and flexible, but sometimes it doesn’t sort applications in the order I want. For example, I want the employment history of an application displayed by most recent first, but I could not get it done.”

The informant from the second province, however, complained about this functionality:

“In our province, we prepare our reviewing list in Microsoft Word and each application is one MS Word file. The current system does not support that—it only allows us to export to Excel, and so we could not use the system.”

Table 5 summarizes all interviews conducted for my research.

Table 5: Interview summary

#	Cases (Number of Interviews)	Interviewees, time and places
1	The Medical Licensing System (10)	Provincial Licensing Officers (6): - Binh Duong: two interviews on January and March 2012 at the Binh Duong Health Services Office - Ho Chi Minh City: one interview on May 2012 at Ho Chi Minh City Health Services Office - Da Nang City: one interview on December 2012 at Da Nang Health Services Office - Ha Noi: one interview on November 2012 at Ha Noi Health Services Office - Ha Giang: one interview on November 2012 at Ha Giang Health Services Office
		ADB Project Management Unit (2): - Project coordinators (2): one interview on March 2012 via phone and one on November 2012 face-to-face in Ha Noi
		Vietnam Administration of Medical Services (2): - Officer in charge of licensing (1): one on November 2012 at MoH Office in Ha Noi - IT specialist (1): one interview on January 2012 via phone
2	The Hospital Quality Evaluation and Inventory System (5)	Hospital Quality Division (1): - Head of Division: one interview on October 2013 at MoH office
		Hospital Users (2): - People 115 Hospital: one interview on October 2013 at the hospital - Columbia Binh Duong Hospital: one interview on October 2013 via telephone
		Provincial Health Department (2):

		<ul style="list-style-type: none"> - Bac Giang province: one interview on October 2013 at Bac Giang Health Services office - Kien Giang province: one interview on October 2013 via telephone
3	The Lunar New Year Reporting System (4)	Vietnam Administration of Medical Services (1): - Deputy Head: one interview on January 2014 at MoH office
		Provincial Health Department (1): - Tien Giang province: one interview on January 2014 at Tien Giang Health Services office
		Hospital Users (2): - Thu Duc hospital (Ho Chi Minh City): one interview on January 2014 via telephone - Dong Da hospital (Ha Noi): one interview on January 2014 via telephone
4	The Epidemic Notification System (6)	Centre of Disease Control (1): - Project officer (1): one interview on December 2015 in Ho Chi Minh City
		PATH (1): - Local project officer: one interview on December 2015 in Ho Chi Minh City
		General Department of Preventive Medicine (2): - IT specialist (1): one interview on January 2016 in Ha Noi - Project officer (1): one interview on January 2016 in Ha Noi
		Vietnam Administration of Medical Services (2): - Officer in charge of reporting (1): one interview on January 2016 via telephone - IT specialist (1): one interview on January 2016 via telephone

4.4.4 Software prototyping

In designing complex software systems, determining user requirements is a challenging task (Mike and Albert, 2001, Kaj, 1989). One of the solutions to this problem is to give users a nearly “working” system (Davis, 1995), i.e., a prototype. Through many feedback loops, the prototype evolves and gradually gains critical mass to become a real system. This approach was employed throughout my action research but heavily used during the first cycle relating to the licensing system. In this cycle, the prototyping period lasted nearly one year with many interactions with the pilot province before the system became mature and ready for use.

4.4.5 Capacity-building programs

In supporting the scaling of many systems, two types of capacity-building activities were organized. Formal training in classrooms was set up during the implementation and scaling of the licensing system thanks to the financial support from ADB. However, for other systems, a telephone helpline dubbed “hotline” was established to support users. Personally, I was involved in building training materials and acted as a lecturer in some training sessions. I also directly supported users via telephone or emails to better understand their problems and expectations. Table 6 summarizes all data collection methods used in different cases.

Table 6: Modes of data collection used in different cases

#	Case	Modes of Data Collection	Description
1	The Medical Licensing System	Software Prototyping	Worked closely with the first pilot province to iteratively revise the software
		Document Analysis	Law on Examination and Treatment (40/2009/QH12)

			Circular 41/2011/TT-BYT on medical licensing Other project documents
		Participation Observation	Software development, Field visits, Project meetings
		Interviews (number of interviews: 10)	Provincial Licensing Officers, ADB Project coordinator, Vietnam Administration of Medical Services IT specialists
		Capacity Building Program	Directly conducted training classes in Ho Chi Minh City and Ha Noi
2	The Hospital Quality Evaluation and Inventory System	Software Prototyping	Updating and extending facility licensing system for Hospital Quality and Inventory
		Document Analysis	Decision 4858/QĐ-BYT, Public Dispatch 1334/KCB – QLCL
		Participation Observation	Software development; two conferences in Ha Noi and Ho Chi Minh City
		Interview (number of interviews: 5)	Vietnam Administration of Medical Services IT specialists, GIZ IT coordinator
		Capacity Building Program	Support via telephone
	The Lunar New Year Reporting System	Software Prototyping	Software development in interaction with Vietnam Administration of Medical Services
		Document Analysis	Directive 01/CT-BYT, Public Dispatch 79/KCB-QLCL Online newspaper articles Other project documents
		Participation Observation	Software development
		Interview (number of interviews: 4)	Provincial health managers, Hospital users
		Capacity Building Program	Support via telephone
4	The Epidemic Notification System	Software Prototyping	Software development in interaction with Vietnam Administration of Medical Services
		Document Analysis	Circular 48 /2010/TT-BYT, 54/2015/TT-BYT on infectious disease reporting
		Participation Observation	Individual meeting and Group meeting with CDC, PATH, General Department of Preventive Medicine Software development and reconfiguration Internal project meetings
		Interview (6)	General Department of Preventive Medicine IT staff, Vietnam Administration of Medical Services IT specialists
		Capacity Building Program	Support via telephone, training

To better understand users' requirements, problems, and expectations, I made many field trips to hospitals, provinces, and the MOH office to talk face to face with the users and observe how the systems were used in reality. Table 7 summarizes my field visits.

Table 7: Summary of the timelines of my fieldwork

Time	Place: Vietnam	Activities	Data collection methods
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April 2012 – December 2012	5 field visits to Binh Duong province	Designed, developed and implemented the health professional licensing system (pilot in 1 province)	Software prototyping, Participation observations, interviews, document analysis
December 2012	Field visit to Da Nang city	Designed, developed and implemented the health professional licensing system (pilot in 6 provinces)	Software prototyping, Participation observations, interviews, document analysis
January 2013	Field visit to Ha Noi city	Designed, developed and implemented the health professional licensing system (pilot in 6 provinces)	Participation observations, interviews, document analysis
January 2013	Field visit to Ha Giang province	Designed, developed and implemented the health professional licensing system (pilot in 6 provinces)	Participation observations, interviews, document analysis
January 2013	Working with Vietnam Administration of Medical Services in Ha Noi city	Designed, developed and implemented the health professional licensing system (pilot in 6 provinces)	Participation observations, interviews, document analysis
April 2014	Field visit to Hoa Binh province	Integration between licensing system and mother modules developed by BigFirm	Participation observations, interviews, document analysis
April 2014	Field visit to Bac Giang province	Integration between licensing system and mother modules developed by BigFirm	Participation observations, interviews, document analysis
April 2014	Field visit to Tien Giang province	Integration between licensing system and mother modules developed by BigFirm	Participation observations, interviews, document analysis
October 2015	Attending conference in Can Tho city	Integration between licensing system and mother modules developed by BigFirm	Participation observations, interviews, document analysis
September 2015	Attending conference in Da Nang city	Integration between licensing system and mother modules developed by BigFirm	Participation observations, interviews, document analysis

4.5 How data was recorded

In qualitative research, handwritten notes are important as a way to capture collected data (Sutton and Austin, 2015). Most researchers use a folder of field notes, which can help them to record and comment upon impressions, environmental contexts, and behaviours, etc., they may encounter during their field trips (Sutton and Austin, 2015).

In my research, I maintained a research diary, which contained a number of notebooks that I used to take notes during my interviews, meetings, or participant observations. Anything could be written down into the research diary. It could be narratives from informants during interviews or facts or events that I found relevant to my research questions, as exemplified in the following excerpt. For example, Figure 6 shows one excerpt about a group meeting with stakeholders on data warehousing for communicable diseases that took place in January 2016.

Figure 6: Excerpt from research diary

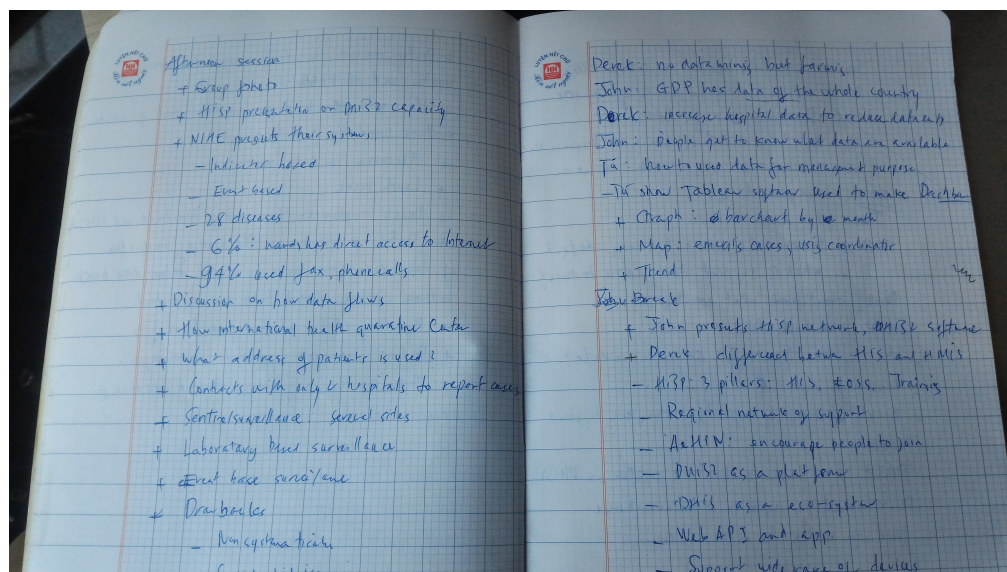
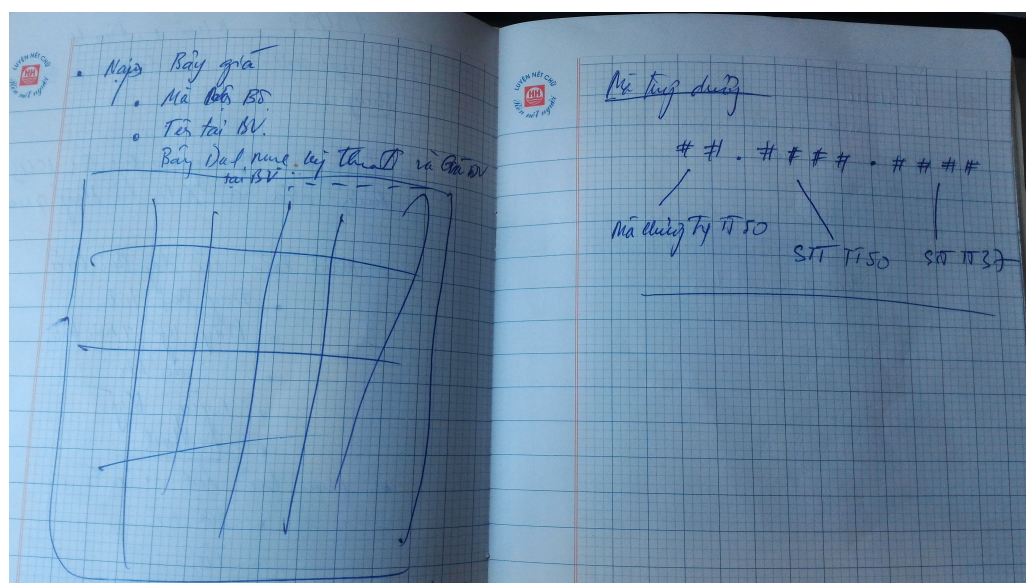


Figure 7 illustrates an excerpt from notes that were recorded in an interview with an IT specialist from Vietnam Administration of Medical Services. This note was actually filled by the IT specialist as a response to the interview question: “What do you want the data entry form to look like?”

Figure 7: Field note from research diary



To complement field notes, during my field visits, hundreds of photos were taken. Some photos document paper-based forms or reports produced and used in a licensing office. Other photos show the positions or movement of staff during the registration or printing licensing certificate processes. There are also photos taken to record the models and version of computers, printers, scanners being used in hospitals, or provincial health services that could help us to make the software system more compatible. There are some photos taken in the reception area of the licensing office which contains public notices about the medical licensing application process

(see for example Figure 8, Figure 9, and Figure 10). There are also many photos taken during capacity program sessions.

Figure 8: Public notice on licensing procedures

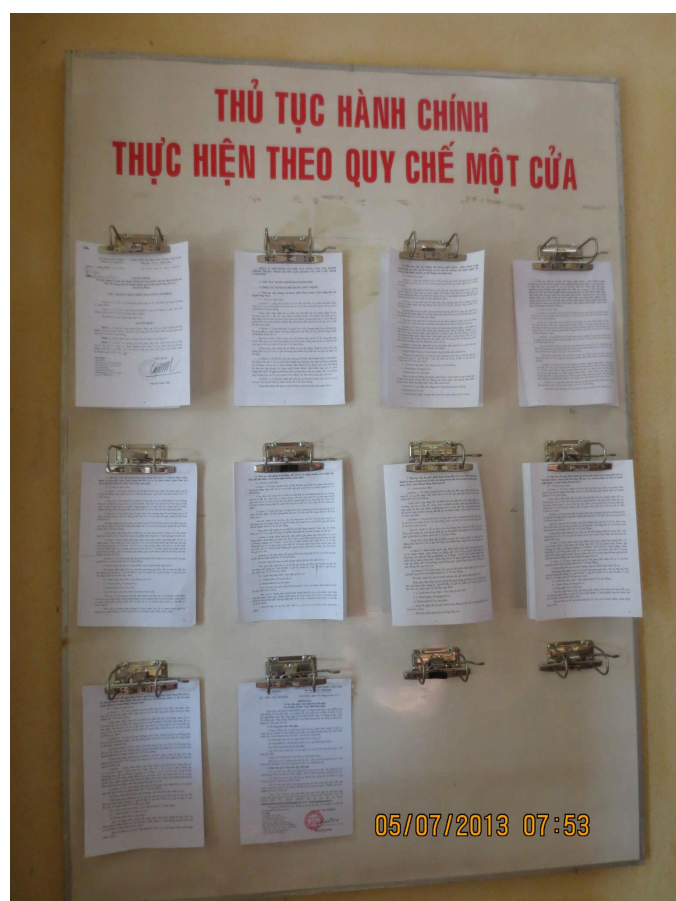


Figure 9: A provincial health services office



Figure 10: A training session



Apart from my research diary and photo taking, thousands of emails exchanged with other stakeholders and team members were maintained to serve as a complementary source of data. Email was a useful method that helped me work remotely with other team members as well as users across the country.

Figure 11 illustrates an excerpt from an email exchange about integration of the licensing system:

Figure 11: Excerpt from email exchange on integration issue

Dear all,

I will be in Hanoi and work with you during the week of 18-22 January. Deadlines for finalising the system are approaching and we need to get a full overview of the situation. Please provide an update of the situation with a focus on these three areas:

1. The interoperability features of the licensing system based on the DHIS2 platform are now fully operational: please update on:
 - a) How SAVIS modules are using the DHIS2 based license database as source for licensed health staff (getting /accessing the data) and
 - b) how the data on licenses are being updated by the SAVIS modules in the DHIS2 (putting the updated /changed data back).
2. The same interoperability for the facility licensing system; a) how the master facility list in DHIS2 is used as source and b) how it is updated by SAVIS modules.
3. Update on status and field tests of the 7 modules.

The health staff Licensing part of the system is now a system in full production and its data are in reality owned and managed by the MoH, as all data input / output is carried out and managed by MoH. What is critical for a full takeover by MoH of the system and server is to establish capacity and leadership in MoH and as well as adequate support of the MoH team.

4.6 How data were triangulated

Combining more than one method of data collection allows triangulation of data, which adds a number of benefits such as validation and verification of data, enrichment of data, and discovery of inconsistencies (Rothbauer, 2008). Data source triangulation permits researchers to use evidence from different types of sources such as interviews, archival records, and observations to increase the trustworthiness of data and research (Denzin, 2017).

In my research, the use of multiple data collection methods such as interviews, observations, document analysis, and capacity building allowed me not only to gain richer data, but also to provide more than one source in order to help cross-check that data so as to give a more detailed and balanced picture of the case (O'Donoghue and Punch, 2003, Altricher et al., 2005).

The typical scenarios in which I employ triangulation are when identifying any inconsistencies between what informants answered and what I observed when they carried out their tasks. For example, when a licensing officer was asked if they were using the online licensing system to prepare and print licensing certificates, they said yes. However, when observing the workflow in their office, I found that the printouts were prepared using Microsoft Excel. In response, the licensing staff stated that pre-printed papers issued by the MoH made it too difficult to print licensing certificates correctly. After that visit, I made a recommendation to the MoH to change the design of their pre-printed papers so that licensing offices could print licensing certificates directly from the online system. A short while after that, the MoH responded by providing a new design of their pre-printed papers. This discovery later helped build insights on how scaffolding the continuity of use is critical to sustainability.

A second example of using data triangulation in my research is related to a decision on the future of the licensing system. In a meeting with all stakeholders to evaluate the first phase of the licensing system project, everyone from the team and the sponsor seemed to understand that the MOH would issue a decree to mandate the use of the online licensing system officially.

However, later in a dispatch issued by the MoH, it was determined that they were only asking to enter 150 applications per province for trial purposes. By combining two sources of data (the group meeting and document analysis), the inconsistency was discovered and it helped us to understand the challenge of attaining political support and how crucial such support is for scaling the system.

4.7 How data was analyzed

As mentioned previously, the II design theory was employed to guide the data collection as well as the data analysis process. During the analysis process, I attempted to answer the following questions:

1. What were the emergent problems related to the design and implementation of HIIs in Vietnam?
2. How did the existing design principles for II work in resolving the emergent problems drawn from my empirical experience?
3. What new principles could be interpreted through the cycles of action research?
4. What detailed and operational design rules could be derived from the newly identified design principles that warrant the successful design and implementation of HIIs in Vietnam?

Next, I tried to look at the similarities and differences around these emerging design principles and design rules in order to make them more generic. These were then formulated into papers and comments from reviewers that helped me to sharpen and deepen the analysis.

This process was repeated for each of the cases. At the end, emergent design problems, the new design principles and their detailed design rules were put together to form a theoretical framework that helps understand the problems of HIIs in developing countries and guide the design process. The framework will be further examined in the discussion chapter, and the detailed process of data analysis will be described.

4.7.1 Three levels of data analysis

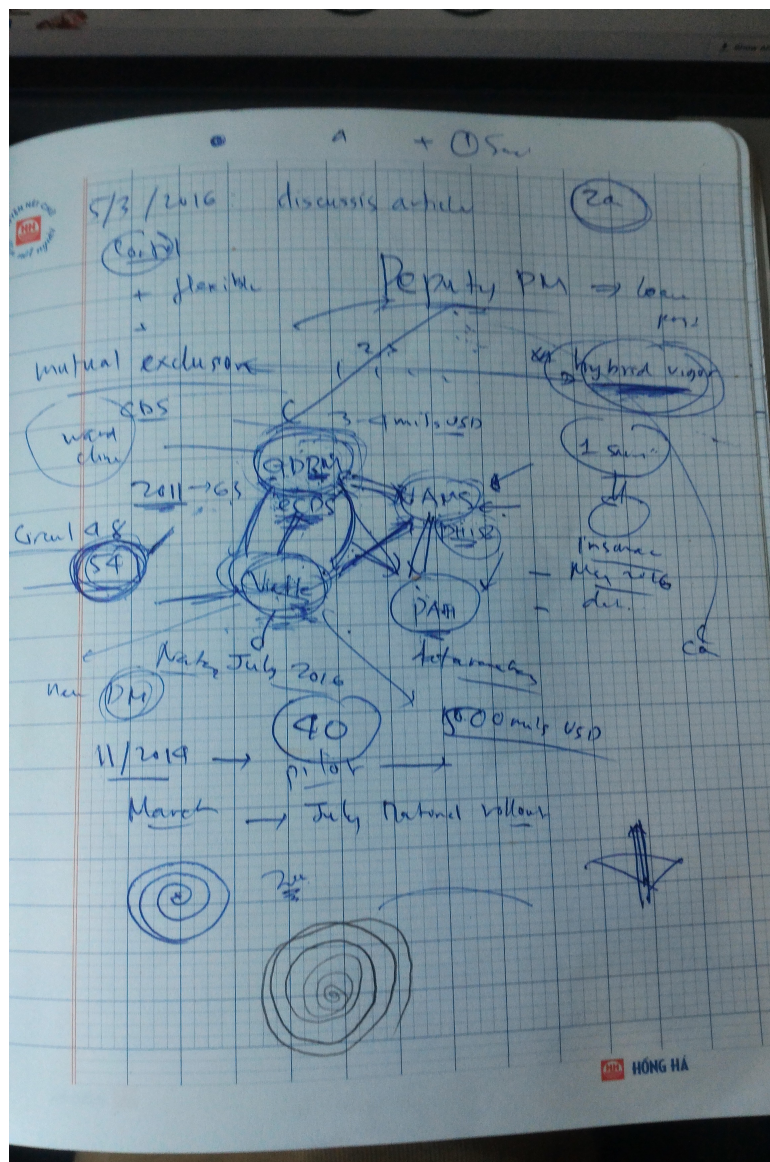
The data analysis process in my research was carried out at different levels. First, it consisted of daily analysis of data collected throughout my day-to-day interactions in the field, including meetings, discussions, interviews, system development, capacity building, and so on. The data analysis activities at this level were also varied, ranging from practical problem solving to more theoretical concept building that linked to my research questions. For example, finding a solution to a problem identified when interacting with end users entails a specific problem-solving analysis.

The next level of analysis was done after an interval, usually following an event, a milestone, or a phase of research cycle, or before starting a new action cycle. The interval of this analysis level was often anywhere between months and years. At this stage, a significant amount of data had been collected, enabling a higher level of analysis. Usually, meetings and discussion sessions were organized between me and other researchers who were doing research with me to evaluate the outcomes, specify the learning outcomes, and plan for the next actions.

Collaboration with other researchers allowed me to gain a diverse interpretation of data and search for alternative paths of analysis.

Also, at this stage the use of theory was important to guide the data analysis direction. Although sometimes the employed theory was just used for scaffolding purposes, and could be removed after the theoretical building process was completed (Walsham, 1995), it was useful for my analysis. For example, in the paper titled “From Routine to Revolt: Improving Routine Health Data Quality and Relevance by making them Public”, my co-author and I first employed the concept of scaling (Sahay and Walsham, 2006, Monteiro, 1998) to start the analysis process. We found the concept was very helpful in tracking different driving forces that enabled the scaling process. However, we later shifted our focus to the data-use problem of health information systems (Nutley and Reynolds, 2013). In this level of analysis, I also sought feedback from our Global Information Infrastructure research group at the Department of Informatics, University of Oslo to revise my theoretical concepts and constructs. For example, the above-mentioned paper was presented at Research Day, a biannual event organized by the Global Information Infrastructure research group. Feedback and comments from other researchers helped me to revise and improve the paper. Figure 12 shows an example of an “analysis session” between my co-author and me.

Figure 12: Excerpt from an analysis session



The third level of my data analysis had a longer time span. Typically, it was the time I synthesized all the constructs and concepts in individual papers for this thesis. It involved the re-analysis of empirical data, comparing and contrasting different theoretical concepts, to form a theoretical framework that responded to the research question. This process of analysis has lasted more than a year, including different phases such as writing the thesis for trial defense, incorporating feedback, and doing a major revision as required by the thesis committee. It also involved activities such as revising and resubmitting the two papers entitled “The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor” and “Designing Large Scale and Complex Information Systems: The Case of the Medical Licensing System in a Southeast Asian Country”. This process allowed me to sharpen my theoretical concepts, making them more focused, and enabling alternative interpretations and data analysis directions.

In my research, the unit of analysis included both micro and macro perspectives. At the micro level, examining the data flows and work processes in provincial health services helped improve situated problems, increase user engagement, and impacted the adoption and later scaling. At the macro level, the national and international levels analysis allowed gaining understanding

from other standpoints, i.e., what are the agendas of global health agencies in issues such as global health security or national strategy on e-government (online licensing) and e-health (data integration), etc. In identifying units of analysis, the approach recommended by Monteiro (2000) was used to flexibly adjust the size of the analytical unit to a level that was both relevant to my research question and workable in practice.

4.7.2 How data were coded

Data coding was done throughout the analytical process, and was particularly intensive when I wrote papers for journals and conferences. Based on notebooks I used during the data collection process, I used side-notes to highlight and group similar and related events, facts, and other empirical evidence into generic themes. One theme that emerged from my coding process was “implementation expansion”. All events, activities, actions, and stakeholders’ positions related to this theme were linked under the same code. This theme later emerged as a broader one: problem and strategy for scaling, the all-or-nothing problem. Another approach I used to code my empirical data was sorting events and activities by chronological order. This helped identify links between actions in a cause-effect manner. I found this approach was very useful in finding answers to my research question. For example, the support from the MoH was gradually increased proportionally with the result of system implementation and positive feedback from provinces and vice versa. Data coding was mostly done manually without support from coding software, since the focus was on depth and meaning rather than volume and breadth (John and Johnson, 2000). During the coding process, I created various kinds of memos. Sometimes, I used an additional notebook to summarize data on one theme. On other occasions, I used an Excel sheet with each tab representing a theme and containing a list of related data items. Such memos facilitated discussions with other researchers and my supervisors.

4.7.3 Theory construction process through three action research cycles

In organizational research, theory building is the central activity (Baskerville, 1999). Theory development has often been done through combining literature, common sense and experience, and is rarely linked to actual data (Baskerville, 1999). Glaser and Strauss (1967) advocate grounded theory approaches which as they argue can allow theoretical development based on the empirical reality. The process of building theory from cases is also described by Yin (2008) and Miles and Huberman (1984). Based on these studies, Eisenhardt (1989) develops a roadmap for building case study research, including a number of steps detailing how to shape hypotheses, how to search evidence to confirm hypotheses, and how to stop searching evidence when it reaches a status called theory saturation.

Theory generation from empirical data is also used in the action research project Baskerville (1999). For example, Baskerville (1999) examines the process of generating and adjusting theory from an action case study, which involves the development of a database system by a consortium of universities and governmental organizations. According to Baskerville (1999), at the initial diagnosis phase, the research team identified problems related to complexity of the system information requirement and the inability to enroll users in the design process. The

information engineering theory was considered but proved infeasible, as it required database specialists. The research team turned to the prototype theory, which would enable a successful design since it allows visible results, increased communication and shared understanding, etc. The plan was subsequently implemented following the hypothesis formed in the diagnosing phase. In the specifying learning phase of the first cycle, the prototype approach was considered a success. However, there were still some problems related to complex and changing design and programming workload that we were unable to sustain. Adjustment was made for the next cycle where semantic database design was used in which programming rules replaced functional specifications. Finally (after two action cycles), a theory emerged that contributed to the research body on information system design: use prototypes to capture semantic database design. Following the process of theory construction for action research discussed by Baskerville (1999), I now describe how the extended design theory emerged through three cycles of my action research.

The first action cycle in my study was related to the development and pilot of the licensing system in Binh Duong province. In its diagnosing phase, the Team comprising me and the MoH specialist had spent time discussing the appropriate approach to build a system for licensing management. With knowledge gained from my studies at the University of Oslo, I proposed we follow the II design theory (Hanseth and Lyytinen, 2010), which has specific principles and rules that could help to deal with the problem of bootstrapping, i.e., how to get started. The key principle guiding the design process in this cycle was designing for direct usefulness. A specific province was selected to pilot with the hope that it could offer usefulness for users in that province. Following the II design theory, the Team put all energy on functionality that could bring immediate usefulness to end-users. In the learning-specifying phase, it was experienced that the design for direct usefulness principle was not specific enough. I suggested an extension to the design theory be made which comprised specific rules, such as use of open source software and temporal gateway in order to have a working system more quickly, as well as the use of web-based for easy support. Apart from these technology-related lessons, I realized that the role of local champions who were knowledgeable and enthusiastic users was important as well. These lessons learned were carried to the next cycle.

The second cycle involved the scaling of the licensing system to 5 provinces and the whole country after ADB provided a small funding to the Team. In its diagnosing phase, the identified problems were how to scale and sustain the implementation and also how to ensure full coverage. Apart from the learning gained in the first cycle, the plan in this phase was focused on understanding the crucial role and dilemma of a full-coverage implementation, as it is needed in order to get political support. The dilemma is that political support is also needed in order to achieve a full-coverage implementation. Also, the plan was to understand the role of motivation of use and expansion of the licensing system and explore specific means to achieve that. In the action-taking phase, a dedicated support team was formed to ensure that users could receive timely support that would make them happy and likely to become 'loyal customers'.

Apart from that, lessons learned from the first cycle, such as use of temporal gateway and web-based systems, were systematically applied so as to quickly provide features that users needed.

For example, a temporal gateway to import data from Excel files was built to give users access to all licensing data of their provinces in the licensing system. For political support, a high-profile official in the MoH was approached and convinced about the potential of the system in improving quality of health service delivery. As a result, a letter to implement the licensing system in all provinces was enacted, which legalized the Team to scale the system to all provinces. In the second cycle, the problem of data use also arose. Literature on data use suggested a number of approaches: full-coverage data, data use capacity, etc. The proposed plan was thus to combine literature on data use with a new approach: making health data public. To implement this plan, data from the Tet reporting system were shared with the public through mass media and they were thus able to engage the public in the data use debate.

A concrete learning obtained through the second cycle was related to the influence of political person to full coverage implementation and the role of various means such as support team, temporal gateway, in supporting scaling and user enrollments, and finally, how making data public is important to encourage the use of data. The second phase was closed with some success, but still there were many problems with the design and implementation that required that the theory be adjusted. These lessons were added to the design theory along with what was learned from the first cycle and applied to the subsequent cycle.

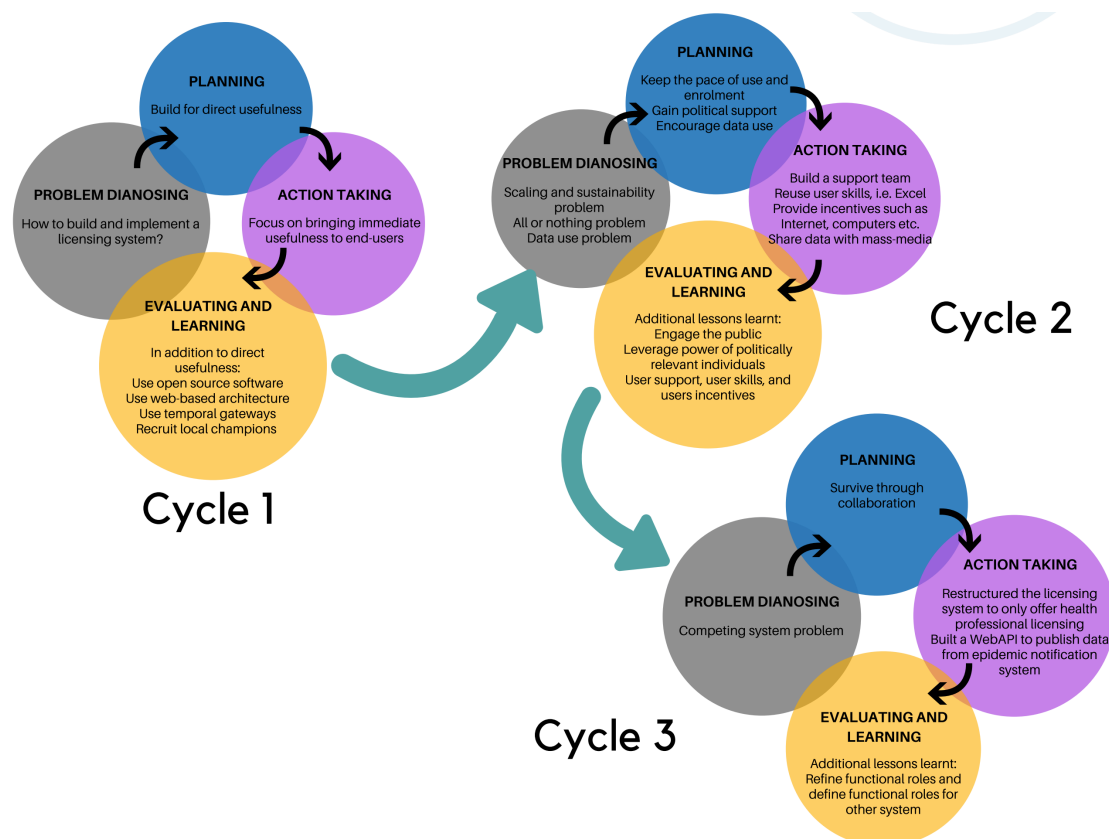
In the third action cycle, the list of design principles and rules was expanded based on the learning from the previous cycles. In the diagnosing phase of the third cycle, competing systems were identified as a problem that needed to be addressed. To cope with competing systems problems, the plan was to redefine functional roles of some systems, such as licensing, to integrate with new systems. Both the licensing system and the epidemic notification system, which were developed during this action cycle, were shrunk in terms of the features they offered. The cycle ended with a synthesis of lessons learned, which were accumulated throughout the three cycles, and specifically the lesson from this cycle that relates to the role of functional reconfiguration to avoid encroaching and substitution. Based on that, a number of scientific research papers were written and published to publication outlets to contribute to the body of knowledge of information system design.

To shape hypotheses and test them in the action-taking phase, I followed the guideline of Eisenhardt (1989), which requires identification of replication logic across cases. For example, the role of political support in scaling could be found in the case of the licensing system, the case of hospital quality and inventory, and the case of the Tet reporting system. Another example of replication logic is the reconfiguration of functional roles in the licensing system and the epidemic notification system, both helped them to survive and avoided substitution by competing systems.

To increase the validity of the theory, I also followed Eisenhardt's (1989) advice on enfolding literature. To implement that, I compared the design principles and rules that were formed during the theory construction process with the extant literature on IT design (the reference theory) to see how they are different. The process was extended to other related literature on Agile software development methods and platform ecosystems.

Figure 13 summarizes lessons learned and especially the double-loop learning from the three action research cycles:

Figure 13: Summary of action cycles



4.8 Ethical considerations

There were several ethical issues which I had to contend with given the multiplicity of roles I played during the course of my research. These roles included being a PhD student who needed to complete a focused piece of research, a software developer who was contracted by the MOH to build multiple systems—sometimes with monetary compensation and sometimes without, and finally, acting in an individual capacity as an advocate for the use of open source software in the public health sector in Vietnam. This multiplicity of roles I had to play often resulted in different kinds of dilemmas.

4.8.1 Research versus money

Being a PhD student doing research on systems I was personally involved in building was a source of a major problem I had to engage with. This dual role created ethical issues where I could necessarily be biased when evaluating a system I had developed. As the system builder, I tended to overly focus on presenting the success of the implemented system in terms of size and numbers of users, while giving reduced importance on analyzing how the system could

actually contribute to solving existing health-related problems. Sometimes, a required functionality was not developed immediately because it was outside the scope of the agreed contract. For example, many provinces asked for a facility licensing system which could be integrated with the existing licensing system to better support their work. However, it was not implemented due to the terms of the existing contract. As an action researcher, committed to improving the licensing processes, I should have implemented the system, and also reported critically on its absence. I did neither, as that would have undermined the basis for my payments. Some of my choices were also influenced by how I believed the donor would select the vendor for the second phase of the project.

4.8.2 Competition with other software vendors

Being a systems developer, I constantly faced threats to the systems I was involved in developing as they were encroached upon (Nielsen and Sæbø, 2016) by other software vendors. To respond to this, I employed rapid scaling strategies to try and expand the user base as fast as possible. In this quest for speed, a mismatch between the requirements of the end users and the managers was often created. For example, the introduction of free-text fields in the Medical Licensing System was intended to speed up data entry, which significantly contributed to the scaling process. However, as a result, many of the statistical reports could not be generated from these un-coded data, although such reports were critical for decision making. Sometimes, design decisions—especially those relating to system reconfiguration and integration—were made in order to prevent the threat of substitution rather than improving the system effectiveness.

4.8.3 Influenced by Scandinavian tradition in IS development and open source software ideology

Being strongly influenced by Scandinavian tradition in IS development (Iivari and Lyytinen, 1998, Ehn, 1993) as a result of my Master and PhD studies at the University of Oslo, I tried to show that the participation and cultivation approach was applicable to my research in the context of Vietnam. I was also highly motivated by the open source software ideology (Raymond, 1999), which strives to ensure software remains free and available to anyone, as I believed open source software would benefit developing countries in terms of freedom, development, and capacity building. These perspectives that I believed in definitely had an influence on my system design choices, and maybe at times I did not critically consider the realities of the context. I argued that non-open source software-based solutions were inappropriate without critically assessing the merits and demerits of the competing solutions.

I had no clearly defined approach to deal with these dilemmas, and neither can I say in retrospect whether I made the right or wrong choices. At this stage of writing the Kappa, I can say in my defense that I was profoundly aware of these dilemmas and thought about my actions in the light of these. I often would discuss these issues with my supervisors or colleagues, and take their advice.

In addition to this, I took the necessary precautions to ensure I followed ethical principles in my research. Prior to conducting a research interview, I would inform the respondent of my

background, and would also assure them that whatever they said would remain confidential. In my writings, I made sure I never mentioned the name of a respondent or facility, and none of these individual entities could be identified. Further, I did not deal with any patient level data, and did not use any such data in the course of my research. Most of my research notes were made in notebooks, and I did not type any transcripts with names of individuals.

This chapter has examined the research method and approach discussed in this thesis, and in the next chapter, the summary of findings is presented.

5 FINDINGS

This chapter comprises two parts. The first discusses the findings of individual papers forming this thesis. The second part presents the synthesis of the findings from all the papers and how they help to answer the thesis's research question.

5.1 List of papers and findings from individual papers

Five papers forming the thesis are listed as follows:

1. Nguyen, TN, Ha ST, and Braa J (2015), "Assembling a National Health Information Infrastructure: The Case of Vietnam", Published in *The Electronic Journal of Information Systems in Developing Countries*, 66, 7, 1-18
2. Nguyen, TN, Braa J (2016), "Scaffolding Health Information Infrastructure's Generativity by Scaffolded Gateways – The Case of Vietnam", Published in *The Electronic Journal of Information Systems in Developing Countries*, 75, 4, 1-22
3. Nguyen, TN, Nielsen P, Braa J (2016), "The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor", Revised and resubmitted to *Information Technology for Development*
4. Nguyen, TN, Nielsen P, Braa J (2016), "Designing Large Scale and Complex Information Systems: The Case of the Medical Licensing System in a Southeast Asian Country", *Australasian Journal of Information System* 21, DOI: 10.3127/ajis.v21i0.1518.
5. Nguyen, TN, Nielsen P (2017), "From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making Them Public", *14th International Conference of IFIP Working Group 9.4 "ICTs for promoting social harmony: Towards a sustainable information society"*, May 22 - 24, 2017, Yogyakarta, Indonesia, *Proceedings*.

In all the papers listed above, I collaborated with other researchers who are mainly my supervisors. In writing these papers, I played the role of lead and corresponding author, contributing to all parts and steps of the research cycle including research planning, data collection and analysis, writing, submission, and revising the papers.

My detailed involvement and roles of other co-authors in each of the papers are articulated in Table 8:

Table 8: Summary of contributions of each author to the papers

Paper	Contributions
Assembling a National Health Information Infrastructure: The Case of Vietnam	<ul style="list-style-type: none"> - My role: In this paper, I was involved in data collection and analysis, writing the paper. I also acted as the corresponding author, interacting with the journal editor. - Son Thai Ha: Involved in data collection and analysis, and writing several parts of the paper. - Jorn Braa: Involved in discussions during the analytical process, revising the paper, and refining the paper's key concepts.
Scaffolding Health Information Infrastructure's Generativity by Scaffolded Gateways – The Case of Vietnam	<ul style="list-style-type: none"> - My role: I was involved in the entire process of writing this paper, from forming the idea, collecting and analyzing the data, writing the paper, and submitting it to the journal. I was the key contact, interacting with the editor and the reviewer during the revision process. - Jorn Braa: Involved in data collection, analysis, and drafting the paper. He also contributed to the revision process.
The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor	<ul style="list-style-type: none"> - My role: I played the role of the lead author who took part in the data collection and analysis process. I was also involved in writing the draft and revising it through different stages. - Petter Nielsen: Participated primarily in the analytical phase, asking critical questions, refining the concepts, and revising the paper. - Jorn Braa: Involved partly in the data collection process, jointly defining initial concepts used in the paper.
Designing Large Scale and Complex Information Systems: The Case of the Medical Licensing System in a Southeast Asian Country	<ul style="list-style-type: none"> - My role: I was the lead author for this paper. I was with the second author collecting and analyzing data, writing early draft versions, proposing the initial versions and concepts presented in the paper such as control and trajectory. I was also active in revising the paper. - Petter Nielsen: Actively involved in the analytical part of the paper, asking various critical questions, and revising the paper. - Jorn Braa: Involved in both collecting and analyzing data, contributing to the writing of draft versions of the paper.
From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making Them Public	<ul style="list-style-type: none"> - My role: I was the lead author, contributing to all parts from collecting and analyzing data to writing and revising the paper. - Petter Nielsen: Participated primarily in the analytical phase, asking critical questions, refining the concepts, and revising the paper.

Following, findings and contributions of the individual papers are presented.

5.1.1 Paper 1: Assembling a National Health Information Infrastructure: The Case of Vietnam

This paper is situated within the discourses of II design. It employs architectural knowledge concept as a theoretical lens to unpack the process of HII development, implementation, and scaling. Architectural knowledge helps identify and improve bottleneck components. Based on discussing four dimensions of architectural knowledge, the paper suggests strategies that help catalyze, enable, and support the process of building HIIs in developing countries. The four dimensions are now discussed:

- *Technical capacity awareness:*

The implication of this dimension of architectural knowledge highlights the need to be relentless, persistent, and longitudinal in enabling technical innovation and intervention. It is also important to build a team with experienced members who have prolonged engagement in the health informatics field. Technical capacity awareness dimension emphasizes the need to be part of a larger network of action (Braa et al., 2004). By participating in a network of action, a country team can learn from the experiences of other country teams, thus increasing its awareness about technical capacity. As a result, the team will know what functionality is available and how to adapt and contextualize it. This will give designers more options and thus will significantly increase the chance of success.

- *Use-context sensitivity:*

Apart from awareness of technical capacity, sensitivity to the context of use is crucial for the success of II building. This is in line with discourses in situatedness design (Haraway, 1988), which emphasize the roles of understanding the local context in order to fruitfully introduce a technical innovation. To that end, in the context of HISs in developing countries, it is critical to set up a local team that has team members from different disciplines such as public health and informatics. The mix of expertise helps the team better understand the context of use and thus reduce the design-reality gap (Heeks, 2002).

- *Business model understanding:*

Financial resource is an important factor that contributes to the sustainability of an ICT project. In developing-country settings, funding for public ICT projects is often provided by international donors with predefined timeframes and clear deliverables. This approach, however, does not fit well with the nature of II evolution where continuous and prolonged interventions are required. Because donors are a major source of funding for HIS, it is important, when securing an HIS, to seek multiple sources of funding. Furthermore, it is necessary to follow a parsimony approach, which keeps the running cost as low as possible. At the same time, local capacity building programs and institutionalization of technical teams must be organized to reduce the cost and minimize dependence on external funding.

- *Boundary spanning competence:*

This dimension suggests that the project team should constantly seek opportunities outside the system being developed. As politics relating to HII implementation is highly charged, boundary spanning competence helps the team find ways to reconfigure its systems to deal with competition and threats from other systems and thus increase its chance of survival.

5.1.2 Paper 2: Scaffolding Health Information Infrastructure's Generativity by Scaffolded Gateways – The Case of Vietnam

This paper is situated within the debates of II standardization, flexibility, and adaptability and evolution of II. The paper proposes the concept of a *scaffolded gateway*, which is a combination between scaffolding (Orlikowski, 2006) and gateway (Hanseth, 2001) to highlight the temporality of a gateway—a property which is not a focus in prior studies of gateways. Scaffolded gateway is software component that can be built quickly, often for one-time use, and thrown away after its mission is completed. Properties that are quick to build, easy to replace, and for one-time use distinguish scaffolded gateways from other gateways.

The paper discusses a number of examples of scaffolded gateways in supporting the development and implementation of HII in Vietnam. One of them is the Converter: a software tool that migrated data from Excel files to the licensing system. The tool, which was built very quickly, played a very important role in speeding up the implementation. It was, however, short-lived. After all data from Excel were moved, it was no longer needed.

Because scaffolded gateways are quick to build and easy to replace, II designers can swiftly create a scaffolded gateway and if it does not work, there are still many chances for other trials. The loss and cost are thus minimized. Scaffolded gateways offer several advantages. First, they allow for adequate learning and experiments which have been argued as crucial for II design. Second, scaffolded gateways help speed up the HII implementation and scaling process.

5.1.3 Paper 3: The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor

This paper brings in the discussion of competition between systems that provide similar functionality. System competition represents a common problem related to HISs in developing countries (Sahay et al., 2009, Nielsen and Sæbø, 2016). The paper argues that overlap and fragmentation are not necessarily a result of poor coordination between donors and health programs, but that they imply multiple logics endorsed by different stakeholders.

The interplay between multiple software systems represents a form of software ecosystem hosted by governmental agencies who define rules of interactions between these multiple components. Central to the discussion is the issue of functional architecting in II development. The paper extends prior work by introducing the fourth strategy with regard to functional architecting. While the three strategies proposed by Nielsen and Sæbø (2016) are relevant, they do not fully capture the dynamics of functional architecting in contexts where overlap, competition, and substitution are in place. Therefore, the hybrid vigor strategy is critical in offering a tool to capture such dynamics. This strategy involves the following dimensions:

- *The politics involved in the negotiation between the functional roles of the different systems*
When a change occurs, actors must reconfigure their systems to avoid exclusion. Depending on their positions, they will focus to change their systems in a way that other actors must rely upon. This mutual dependency gives each actor the power of negotiation, forcing other actors to reconfigure accordingly.

- *The power and the central role of governmental agencies in shaping functional roles*

This paper emphasizes the powerful role of governmental agencies and their impact on defining functional roles. However, the level of impact of each agency varies depending upon the sub-domain they are in charge of. A move in the policy often triggers the reconfiguration process to which all actors must respond in order to continue their existence.

- *The configuration of the resulting ecosystem*

This paper discusses the difference between the *connecting* strategy of Nielsen and Sæbø (2016) and that of hybrid vigor, highlighting the fact that the connecting strategy focuses on data sharing and complementary functionality while hybrid vigor attempts to improve and strengthen the infrastructure (ecosystem) as a whole. As a consequence, the resulting ecosystem will be reconfigured accordingly and will inherit superior traits as compared to individual systems.

5.1.4 Paper 4: Designing Large Scale and Complex Information Systems: The Case of the Medical Licensing System in a Southeast Asian Country

This paper discusses the problem of scaling in health information systems in developing-country contexts. Moving a system from small pilot to national implementation poses a big challenge to systems designers and health managers. Many projects dissolve and die before they reach the scale where they can become useful for action. The concept of bootstrapping from the II literature has proven useful to discuss and understand how to initiate and grow large-scale, complex and networked information systems from scratch. The paper employs this concept to analyze and discuss an empirical case of building a large-scale medical licensing system in Vietnam. The paper suggests extensions to make the bootstrapping strategy more relevant in the context of HISs in developing countries. The extensions include the ideas that:

- Different parts of the system can also be relevant for different users. Therefore, users should be targeted accordingly.
- Personal relationships and networks can be leveraged to motivate use.
- While development is driven by users' needs, which were not based on justification of complexity and criticality, it is important to mindfully convince users to start with prioritized use cases.
- It is important to pursue and exploit indirect means to motivate use such as laws, decrees and official dispatch, free supply of computers, printers, and other stationaries, payment for data entry
- While a full-scale solution may be required for full value, the value for lower-level organization should be exploited initially.
- Open source software should be considered due to its flexibility and availability. Web-based solutions should be considered to reduce maintenance and support costs.
- Installed base should also refer to user experiences and skills, and not only software systems, i.e., MS Excel skills.
- It is wise to consider developing temporary gateways—which can be built quickly and thrown away easily—to allow for the maximum possible number of experiments.

5.1.5 Paper 5: From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making Them Public

This paper discusses a common problem of HISs in developing countries, which is little or no data use for action. Using an empirical case which involves the development and implementation of a reporting system for accidents and emergencies during the Vietnamese Traditional New Year (Tet), the paper identifies a list of design strategies that can be leveraged to address the problem of little or no data use. These strategies are discussed as follows:

- *Collecting data that are of high relevance to the public*

There are two things related to this strategy. First, the reporting system should focus on collecting few data elements, but ensuring that those collected are highly relevant to the public. This will give health workers adequate time to collect and report data. Second, it is important to make data understandable to the public, particularly considering that routine health data is often too complex to understand, even for health professionals (Moyo et al., 2016).

- *Engaging mass media and fueling public debates*

To attract the public's attention on critical health issues, novel channels of rapid and large-scale data propagation must be sought. One such channel is the mass media, i.e., newspapers and magazines. With large numbers of readers and hourly news postings, online newspapers can draw the attention of the public in a quick and effective way. Also, thanks to the rhetoric of journalists, titles of articles are often written in an impressive and attractive way, which no doubt make the boring and mundane data seem livelier, thus attracting the attention of the public.

- *Creating feedback and triangulating data*

While the overlap in data collection should be minimized to the best extent, on some special occasions, there is a chance for restructuring and improvement. For example, in the case of traffic accident reporting, the MPS and MoH are the two agencies that have routine data collection systems. The contradictions in data reported by the two systems make the public suspicious about the veracity of the data. The number of traffic accidents reported by the MPS system was unreasonably smaller than the number reported by the MoH system. As a result of this triangulation, the Head of National Traffic Safety Committee agreed that the data from the MoH system would be incorporated into the report the following year.

- *Getting full-coverage data ready and disseminating them*

The MoH tends to use health data for internal management only, and the ministry is not obliged to publish the data to the public. However, the decision to share the data in a timely manner with the public is an important step towards accountability and transparency. Transparency in turn leads to emphasizing the accountability of the MoH, because they must be responsible for the data published. In addition, publishing data is only attainable when full-coverage of data is ready. To do that, rapid scaling must be prioritized through leveraging the existing user base and other supporting infrastructure.

5.2 How do the individual papers contribute to my overall research aims?

This section discusses how each individual paper contributes to answering the thesis research question and the linkages between papers.

The central theme of all the papers is about design strategies for large-scale and complex information systems for healthcare in developing-country settings. Every paper presents

different II design problems and corresponding design strategies to deal with the issues. As a synthesis, they bring together aspects of II design, development, and implementation. Thus, the papers are linked through the attempt to articulate a set of design strategies which emerge from the discussion of individual cases in each of the papers.

As the primary aim of this thesis is to understand design problems of II in the context of the health sector in developing countries, and to identify design strategies to deal with them, I now describe how all the findings from the papers contribute to answer my research question before summarize them in a table.

Paper 1 (Assembling a national health information infrastructure) contributes to the research question through describing the problem of scaling and sustainability health information systems. The conclusion of this paper mainly focuses on the role of architectural knowledge in building and scaling information infrastructure. All components of architectural knowledge have a direct link to information infrastructure. For example, technical capacity awareness, business model understandings, etc., are important factors to build complex and large-scale systems. Although the findings from this paper are not used directly in any design rules and principles, they inspired the shaping of many design rules. For example, the boundary spanning competence is important to do functional reconfiguration to deal with encroaching.

Paper 2 (Scaffolding Health Information Infrastructure's Generativity by Scaffolded Gateways – The Case of Vietnam) describes the process of building a number of temporal gateways that helped expedite the scaling and expanding of the Licensing System. The implementation of the Licensing System was placed under the constant threat of substitution by another system because the tender was ongoing and a firm was soon selected. The strategy for survival was to expand the system to all provinces as quickly as possible and the use of temporal gateway could help to achieve that. For example, the use of the Excel-importing tool helped migrate all legacy data in Excel files to the online database. This allowed many provinces to switch to the Licensing System easily. When the tender that selected a firm was completed, ADB decided to integrate new modules with the Licensing System instead of replacing it. The paper thus contributes to answering the research question by describing two design problems and the benefits of using temporal gateways.

Paper 3 (The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor) highlights the problem of Competing systems through the demonstration of the collective efforts in building an integrated system for communicable diseases management. There were three systems (Epidemic Notification System, Communicable Disease Reporting System, and Data Warehouse for Communicable Diseases) backed by different governmental agencies that offer similar functionality and could replace other systems to become a sole system that plays the functional role in communicable diseases area. The paper also illustrates how collaboration was enabled through functional reconfiguration and political intervention. The paper contributes to answering the research question by identifying and discussing in detail the competing systems problem and shows how functional reconfiguration played the key role in solving the problem.

Paper 4 (Designing Large Scale and Complex Information Systems: The Case of the Medical Licensing System in a Southeast Asian Country) reiterates the common problems in HISs in developing countries: sustainability, scaling, and all or nothing. The paper also provides empirical evidence to prove how the use of open source, web-based software, prior user skills and experiences, etc., could help expedite scaling, how personal relationships could get the implementation started, and how power and influence of politically relevant individuals could help to gain full-implementation coverage. For example, full-implementation coverage was only attained when the vice minister issued a letter to trial the Licensing System in all provinces, which was a leapfrog jump compared to the original plan, (i.e., pilot in 5 provinces only). This paper contributes to answering the research question by providing design principles and rules for many problems: sustainability, scaling, and all or nothing.

Paper 5 (From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making Them Public) identifies and examines the problem of data use that is prevalent in the health information systems domain, especially in the context of developing countries. From the literature review, the paper identifies reasons that led to little or no data use, such as poor data quality, culture of using data for decisions, and capability of using data. The paper contributes to answering the research question by listing a set of design rules that aim exclusively to boost data use through engaging the public in the health data debate. To gain attention from the public, a number of measures must be implemented: focus on the data that are most relevant to them, e.g., lives and deaths, etc., and disseminate the data through the mass media. The empirical data showed that once the public was involved in the debate, it triggered the participation of experts, policy makers etc. Eventually, it contributed back to improving data quality. No hospital wants to report false or poor data, as it can be spotted easily by millions of eyeballs.

The link between findings of papers and the research question is now summarized in Table 9.

Table 9: Mapping papers' results to the research question

Paper	<i>Research question: How can we design information infrastructures for the health care sector in developing-country settings?</i>	
	Design problems	Design principles/rules
Assembling a National Health Information Infrastructure: The Case of Vietnam	<ul style="list-style-type: none"> - Scaling is not merely a replication of system from one site to another (Scaling problem) - When scaling, technical and managerial complexities increase exponentially 	
Scaffolding Health Information Infrastructure's Generativity by Scaffolded Gateways – The Case of Vietnam	<ul style="list-style-type: none"> - Data from a few pilot sites are not useful for health managers, thus making a system secure from replacement (All or nothing problem, Competing systems problem) - Implementation of systems need to be expanded quickly to avoid encroachment by other systems (Competing systems problem) 	<ul style="list-style-type: none"> - Employ gateway components that are quick to build and easy to replace
The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor	<ul style="list-style-type: none"> - Many systems offer the same or similar functionality (Competing systems) - Conflicting interests among stakeholders (Competing systems) 	<ul style="list-style-type: none"> - Identify and fill functional roles - Reconfigure systems to strengthen the software ecosystem as a whole - Seek political support for reconfiguration
Designing Large Scale and Complex Information Systems: The Case of the Medical Licensing System in a Southeast Asian Country	<ul style="list-style-type: none"> - Moving a system from small pilot to national implementation poses a big challenge to systems designers and health managers (Scaling problem). - Many projects dissolve and die before they reach the scale where they can become useful for action (Sustainability problem) - The MoH needs data from all provinces to recognize the merits of a system (All-or-nothing problem) 	<ul style="list-style-type: none"> - Use personal relationships and networks to motivate use - Pursue and exploit indirect means to motivate use - Open source software, web-based solutions, temporal gateways, prior user skills should be leveraged - Identify and recruit local champions - Target politically relevant individuals and use cases
From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making Them Public	<ul style="list-style-type: none"> - Poor data quality hampering data use (Data use problem) - No culture of using data for decision making (Data use problem) - Limited capacity in analyzing and utilizing data (Data use problem) 	<ul style="list-style-type: none"> - Collect data that are of high relevance to the public - Create feedback and triangulate data - Get full-coverage data and disseminate them through mass media - Fuel public debates through data dissemination

The following chapter takes these findings to a higher level of abstraction, and works to identify emergent HII design problems and propose II design principles to deal with them.

6 DISCUSSIONS

This chapter aims to answer the research question posed earlier by discussing the problems of designing HIIs in Vietnam and proposing design principles to address them. These problems are also prevailing in many other developing countries which share contextual conditions with Vietnam. Therefore, the design principles discussed here should also be relevant in those settings.

6.1 HII Design Problems in Vietnam

As discussed earlier, HII is a subset of II, and thus will also share the bootstrapping and adaptability design problems. While these design problems could be effectively met based on the use of the existing II design principles and design rule, my research identifies four additional design problems.

6.1.1 The scaling and sustainability design problem

This problem refers to a common phenomenon of HII in developing countries where many systems, despite huge investments, end as pilots; in other words, they could not scale. The scaling problem can be seen as the failure in transferring local successes to other settings (Braa et al., 2004). Because it is often too expensive to maintain an HII that is only implemented on a small scale, the HII faces threats of death after external funding is over. One example from my empirical work illustrating this phenomenon was about a department within the MoH, which received significant funding from external donors through several projects to build a health management information system (HMIS). Thanks to the funding, many systems were built, yet they were piloted on a very small scale, i.e., one or two districts. However, all of the systems soon became inactive and were forgotten. In 2012, I was personally contracted by a European donor to build a system to track gender equity indicators for Vietnam. After completion, this system was transferred to the MoH, but since that time, I have not heard anything about how the system was used (does not imply much). Recently, a department within the MoH had a project to build a national Electronic Medical Record (EMR) exchange framework with a budget of nearly 5 million USD. A large and complex system was built with many components to load, transform, and store patient data. It was piloted in two big hospitals, but it has been silent since.

Apart from the scaling issue, from my empirical investigation, I also found that there were many HII efforts which were stopped even after being largely scaled and providing useful

functionality for both hospitals and health managers. Medisoft was such an example. This software was developed in 2000 and quickly attained national scale thanks to great support from a Deputy Minister of the MoH. It was implemented in all hospitals throughout the country to collect basic patient admissions data, and the software was legitimized by an official Circular. However, the system soon lost its momentum when there was conflict between the company and the MoH regarding copyright of the source code. The stopping of support from the MoH soon made the system obsolete. In the cases that I was directly involved in, such as Patient Survey and Patient Complaint, the challenge of sustainability was significant. For example, the Patient Complaint System, which was built and implemented in all hospitals, had become a useful tool to improve hospital quality and patient satisfaction. However, its implementation was stopped because there was a lack of financial resources to hire data entry clerks who transferred complaints from patients to the system so that these complaints could be disseminated to respective hospitals.

6.1.2 The all-or-nothing design problem

This design problem refers to the particular requirement that HIIs are only useful when they are implemented in “*all corners of a district, to all districts in a province, and to all provinces in a country*” (Braa et al., 2004 , p.340), offering full-coverage data. This is becoming increasingly important with the efforts by governments in many countries to address the issue of health equity and insurance for all, such as in South Africa and Thailand (Braa et al., 2004), and with the current focus on universal health coverage. One example from my empirical work illustrating this need for scale is the case of the Communicable Disease Reporting. During 2010, the General Department of Preventive Medicine developed a comprehensive communicable disease reporting system with substantial support from international donors through a bottom-up and participatory approach (Ehn, 1993). The implementation of the system was steadily expanded from the first pilot province to 10 provinces and then to 23 provinces (over 63 provinces of the country). This scaling process was carried out incrementally and step by step because it depended heavily on financial support from the donors. As a result, when the measles outbreak occurred in early 2014, the system could not provide MoH leaders with sufficient data to make decisions. This, however, created opportunities for other systems with a better scaling strategy—i.e., Epidemic Notification System—to step in and fill a yet-to-be-taken functional role (Nielsen and Sæbø, 2016). Another example relates to the early approach of HISP when it first came to Vietnam in 2004 through the introduction of the Ministry of Science and Technology (MOST). After a number of meetings, HISP was assigned to work with two

provinces to pilot its DHIS software, which at that time was in version 1.3. The pilot lasted for nearly 10 years but yielded very little visible outcome and quickly fell into a vicious circle of non-use (Braa et al., 2004). Because the pilot was on a very small scale, i.e., in 2 districts in Ho Chi Minh City and 2 districts in Thua Thien Hue province, it could not give provincial health managers data that they need, resulting in the health managers not taking ownership of the system and not wanting to invest in making it fully implemented (Braa and Sahay, 2012b).

6.1.3 The competing systems design problem

The competing systems problem partially refers to the fragmentation of HII in developing countries where multiple donors invest in systems for their own reporting and management purposes and ignore the existence of other similar systems. This problem is escalated when multiple systems offering similar and overlapping functionality attempt to exclude each other, i.e., through encroachment (Nielsen and Sæbø, 2016). Actors involved in such a competition are often backed by various donors, companies, governmental agencies with competing interests.

In Vietnam, Medisoft software was under constant attack by other software vendors who blamed them for monopolizing the hospital management software market. In the case of the communicable disease reporting system, the software system owned by General Department of Preventive Medicine, and developed and implemented based on support from external donors, was replaced by a system developed by a giant state-owned telecom conglomerate to become the Communicable Disease Reporting System. The reasons for substitution, however, were often not clearly stated. In another development, through a modified circular, General Department of Preventive Medicine managed to mandate hospitals to report communicable diseases-related data in its system rather than depending on the Epidemic Notification System. The General Department of Preventive Medicine's Communicable Disease Reporting System could have served the functional role that the other systems did, including the Epidemic Notification System managed by Vietnam Administration of Medical Services, and thus excluded other competing vendors.

While it is argued that competition is healthy for innovation and evolution, the competition between software systems in public health is more acute than in other sectors due to a number of factors. First, the number of potential customers, e.g., clinics, health centers, is fixed and

hard to expand. The market for HII is thus very limited. Second, the MoH is usually the agency that chooses a particular software system for the national healthcare sector. There are rare occasions on which more than one solution is allowed to stay for the same purpose, e.g., different provinces may use different systems. Additionally, the culture of the Vietnamese people being notoriously very poor on collaboration and teamwork was influential (Nguyen and Johanson, 2007). The concept of collaboration or buying an existing software solution was almost non-existing. Rather, when a contract winner is identified, a new system is likely built from scratch.

6.1.4 The information use for action design problem

Information use for action is one of the motivations and main purposes of building HIIs (AbouZahr and Boerma, 2005). However, when the task of collecting data and generating information is addressed, developing countries continue to face the challenge of using information in decision making (Braa et al., 2012). With the Medical Licensing System in Vietnam, there was no clear plan on how to use data of health professionals for human resource development and planning. There were, however, casual inquiries by various institutions regarding several indicators such as the number of doctors in different specializations and the gender distribution of health professionals. In the case of the Hospital Quality Evaluation System, the data from more than 3,000 quality criteria, which were evaluated by all hospitals and their provincial health departments, was used modestly. Only a few basic indicators were generated, such as the ranking of hospitals based on their quality. Additionally, there were also lots of data about things like medical equipment, medical service and drug use that have not been used for action.

Table 9 summarizes the emergent design problems and empirical examples illustrating them:

Table 10: Summary of HII design problems

Design problem	Description	Empirical examples
Scaling and Sustainability Problem	Local successes of HII find it hard to be replicated to other settings and cannot continue after the external funding is over.	<ul style="list-style-type: none"> - The EMR exchange system built by the Department of IT, MoH could not go beyond two pilot hospitals. - The pilot of DHIS2 in 2 districts of 2 provinces could not be further expanded.

		- The Patient Complaint System could not continue due to lack of funding.
All-or-Nothing Problem	Often linked with the political visions of promoting equity in access to health services, HIIs are only useful to health managers if they can provide data for the entire catchment area.	<ul style="list-style-type: none"> - The communicable disease system in only 23/63 provinces could not provide useful data for MoH leaders. - The licensing system could not help to verify and remove duplicate applications before scaling to national level.
Competing Systems Problem	Multiple actors promote competing systems that offer overlapping IT functionality.	<ul style="list-style-type: none"> - The system developed by BigFirm attempted to exclude the Medical Licensing System - The Communicable Disease Reporting System funded by international donors was replaced by a new system developed by a local state-owned company
Information Use Problem	Successfully implemented II generates information that is not used in decision making.	- Data from many systems such as Hospital Inventory System, Hospital Quality Evaluation System has not been used for strategic planning.

After locating the emergent design problems, the next section discusses design principles to address those problems.

6.2 Proposed principles for designing HIIs

With the emergent design problems, there is a need to extend the existing II design principles. In this section, I will propose a number of principles identified through my empirical analysis. Following Hanseth and Lyytinen (2010) approach, I also operationalize these principles by suggesting design rules.

These principles and rules are elaborated below and summarized in Table 10.

6.2.1 Design Principle 1: Create an attractor through early successful adoption

This principle aims to address the problem of scaling and sustainability. When discussing the problem of scalability of HIIs in developing countries, Braa and Sahay (2012a) proposed the concept of attractor, which is inspired by Complex Adaptive System theory, to emphasize the role of initial success in attracting more and more users. I argue that the scaling process can be kick-started if such an attractor is created early. In the context of HIIs in developing countries, an attractor could be a successful pilot even on a very small scale. This pilot should be able to

demonstrate the alignment between the software system and situated context. Specifically, the piloted software system could offer useful functionality to support daily work routines and promise the greater network return if there are more adoptions. Through my empirical analysis, I operationalize this principle into three design rules that are elaborated as follows:

- *Design rule 1.1: Reuse and adapt open-source software components*

To quickly have an attractor, one approach is to adapt and reuse open-source software solutions that have been used by in other settings. This is a useful tactic given the rapid advancement of generic open-source software applications such as DHIS2 and OpenMRS, which are dedicated to the healthcare domain. In the early phase of the licensing system, the prototype was built based on DHIS2 rather than developed from scratch. This approach partly contributed to the evolution of the II because it helped to shorten the time required to build the system. While the international bid would take a long time to settle, the idea of having an interim system offering core functionality would be easily endorsed by important stakeholders such as the donors and the MoH.

However, to maximize the effect of reusing and adapting open source software, the approach must be very flexible. For example, in some cases we may need to connect and add, while in others, there could be the need to first remove and then add. The particularities of the tactic employed will largely depend on situated conditions like the opportunities available, the political climate and the existing infrastructure and systems. For example, although DHIS2 was adopted, it was not taken in its totality. Only its core modules and architecture were reused. The name-based module of DHIS2 at that time appeared to be unready for production. Indeed, the module subsequently underwent many major revisions. Furthermore, the 3-month release cycle of DHIS2 development did not fit with the requirements from the context where initial results must be demonstrated quickly.

- *Design rule 1.2: Use web-based solutions*

In dealing with the problem of scaling, web-based solutions should be considered, since they offer several advantages. First, it is much cheaper to scale a web-based application. When the cloud technologies become increasingly ubiquitous, the cost of hosting drops dramatically. On the client side, anyone who has a computer with an Internet connection can become a user. No expensive hardware is required to connect. The cost of maintenance is also reduced because the support can be done online. Second, web-based applications increase accessibility and availability. Users can start to use the system as soon as they receive a link and account. They

do not have to wait for support to install the software locally, which often requires some level of expertise. The benefits of using web-based solutions were easily seen from the cases. Many systems were scaled rapidly thanks to the accessibility enabled by web-based technologies. The Licensing System reached national coverage in less than 2 years. The Hospital Quality Evaluation System was roll-outed in few months. The Tet Reporting System was nationally scaled in within less than a month.

- *Design rule 1.3: Use gateways that are quick to make and easy to replace*

While agreeing upon the importance of gateways in interlinking fragmented IIs, I argue for the need of having gateways that are quick to make and easy to replace. As the attractor must come as early as possible, these gateways contribute to expediting the process. In the Hospital Inventory System, there were many hospitals with data related to drugs and commodities in local databases. Ideally, they should be connected to the MoH's Hospital Inventory System through standardized WebAPI. However, as the construction of such components could take a great deal of time and resources, a temporary gateway that allowed users to copy and paste data from their local systems to the online system was built.

By showing positive results rapidly, the II could accumulate and gain enough political support needed for its own existence. For example, in the cases of Medical Licensing and Hospital Inventory, there were several temporal gateways built to scaffold the rapid expansion of the user base. First, the gateway that migrated data from legacy systems such as MS Word, Excel, Access played an important role in convincing provincial licensing offices to start to use the II because the gateway ensured their continuity of work without interruption caused by changing systems. Second, although many provinces had started to use the licensing system, they still preferred to use Excel for printing licensing certificates. To support users, a gateway was quickly built to export data from the online system to Excel format. Gradually, when users became confident with the online system, this functionality would be abandoned. By deploying that gateway, the II can be rapidly scaled to a level that easily demonstrates usefulness and survivability.

- *Design Rule 1.4: Identify and recruit champions*

To quickly illustrate a good result that attracts more adopters, it is important to have local champions. As early versions of software are never perfect, a champion with knowledge and enthusiasm could overcome obstacles more easily and give constructive feedback to improve

it. However, identifying and recruiting those champions might be a challenge. In Vietnam, personal relationships and social networks are important factors that determine the outcome of collaboration. This was clearly illustrated in the case of the medical licensing system where the Head of the licensing office in the first pilot province was a friend of the leader of the development team. This personal relationship gave the Head confidence to experiment with a new system and to invest time and resources on it. Through the actual use, he provided feedback to improve the system. Once this feedback was addressed, he developed the feeling of ownership. In conferences or meetings, he shared his own experiences with pride. This “speaking on behalf” helped to convince other provinces. Indeed, there were many visits from peer provinces to his province to observe and learn experiences on how to do the licensing through an online system. When early users could have come from other provinces, the one identified through personal relationship and social network appeared to be easier to get started.

6.2.2 Design Principle 2: Scaffold the enrolment and continuity of use and expansion

After creating an attractor which is usually a “beautiful” showcase, it is important to maintain the rhythm of enrollment and the continuity of use. To achieve that, different user support structures must be in place. These structures are established to mitigate the difficulties that new adopters often face, as well as to motivate and encourage the continuity of use and expansion. The term scaffold is deliberately used to imply the temporary nature of these structures. It also entails that these structures must be flexible enough to support different demands during different stages of enrollment and use.

Similarly to the first design principle, this design principle also aims to address the problem of scalability and sustainability. I now discuss three design rules that are related to this design principle.

- Design Rule 2.1: Pursue and exploit indirect means to motivate use

In Vietnam, as well as other developing countries, where political legitimacy plays a central role in shaping changes, it is necessary to pursue and exploit indirect means to motivate use such as laws, decrees and official dispatches. As illustrated through the empirical cases, every IT capability introduced was triggered by a legitimate document such as law, decree, or official letter from the MoH. Other material incentives were also used in the case of the medical licensing system when every licensing office was supplied with printers, computers, and stationaries. To encourage backward data entry, payment for data entry was also implemented. This tactic appears to be helpful in enrolling reluctant users who are not very sure about the

benefits brought by the II. As a result, both groups of highly motivated and least motivated users enroll into the network and support scaling.

- *Design rule 2.2: Institutionalize a user support team*

Building an effective user support team is critical for scaling. In cases where official training cannot be organized, a support team can play the role of trainers who teach users on how to use the system. Thus, the support team must be organized in such a way that it effectively supports a wide range of activities:

- Answering questions and guiding users to use the system
- Fixing data entry errors and doing various data administration tasks
- Communicating with the technical team when a bug is found or a particular functionality is required by users.

In the case of Vietnam, the implementation of the web-based system has enabled users to work at any time and from anywhere, but it also demands the support team work outside office hours. This involves organizing shift work for weekends, holidays. In addition to this, there is a need to use software tools to improve efficiency of support. For example, it was very tough for users who mainly had medical backgrounds to explain the IT technical problems they had. In such circumstances, the use of desktop sharing software such as TeamViewer could help to facilitate the communication between users and the support team.

In summary, to facilitate scaling, dedicated and professional user support teams that can work outside of office hours must be organized and equipped with relevant software tools to support their work.

- *Design Rule 2.3: Reusing user skills and experiences*

While building upon installed bases through interconnecting existing systems is identified as a mechanism of scaling (Sahay et al., 2009), I argue that leveraging user experiences and skills is also useful to enable scaling. For example, in the case of licensing systems, licensing certificates were printed on pre-printed papers as they were controlled and distributed by the MoH. This requirement posed many difficulties for licensing offices. However, licensing officers cleverly used the mail merge functionality from Excel to solve the problem. When the web-based system was introduced, there were many configurations required to make the printing work perfectly. And it was even more problematic when users changed their printers

or web browsers, because the settings needed to be readjusted. To support them, the Team decided to leverage the existing users' skills and experiences with Excel by exporting data to Excel and letting the users continue to use mail merge to do the printing.

6.2.3 Design Principle 3: Seek political support to reach full coverage

While scaling is important to expand the user base and increase the network effect, addressing the scaling problem does not guarantee full-scale implementation because adoption of HII, in many cases, is just voluntary. To deal with that, there must be a strong political legitimation to mandate the use. Design principles dealing with the all-or-nothing problem thus must compose design rules that help accumulate enough political support to ensure a full-scale implementation. Two design rules are now identified and elaborated upon below.

- Design Rule 3.1: Target politically visible use cases

To rapidly attain full-coverage adoption, it is important to align IT capabilities with political interests. By doing so, the II can receive the proper support to evolve and expand. For example, the Licensing System was started as just an experiment while waiting for the bid to be approved by the donors and the MoH. However, once it showed potential to be a system that could demonstrate good leadership, i.e., anti-fraud and corruption in medical licensing, the system was quickly endorsed by top leaders. To actualize that vision, data from all provinces must be available. In some cases, when provinces were too reluctant to use the system, creating a gap in collected data, stronger measures from the MoH were sought. For example, one province was very reluctant to use the licensing system, arguing that they were too busy. This situation was only changed when there was a report from another province saying that data from this province were not in the system, so they could not verify whether an issued license certificate was counterfeit or not. It turned out that the license certificate was faked. This provoked Vietnam Administration of Medical Services and a strong warning was dispatched to the province, which quickly complied with using the system.

To make a use case become politically visible requires time and effort. In the case of medical licensing, the message was clearly defined and communicated repeatedly in all the meetings that had the presence of the MoH's top leaders. While a system often offers multiple useful use cases, it is important to pick up the use case that can easily attract political support. With that, full-coverage implementation becomes more attainable.

- *Design Rule 3.2: Leverage the power and position of politically relevant individuals.*

To solve the problem of all or nothing, the HII must target a full coverage (the entire catchment population). By proposing this design rule, I argue that politically relevant people need to be enrolled early, as they could determine the full coverage. Fully implementing a system requires lots of work to be done by different stakeholders, i.e., donors, hospitals, provinces, the MoH, etc. However, there are a few critical steps that need to be gotten through. These are often decided by top managers. Therefore, it is important to consider and leverage these human obligatory passing points when dealing with the all-or-nothing problem. In the case of licensing, at the beginning, the idea of building an online system for licensing registration was strongly rejected by some members of Vietnam Administration of Medical Services due to various political reasons. By chance, during a meeting, an adviser from the donor sat next to a Vice Minister and had the opportunity to explain to her in detail. The Vice Minister was convinced and she started to support the system. Not only did she give her verbal support, she also signed several letters which would enable the full-coverage scaling of the system: from one province to five provinces and from five provinces to all provinces.

6.2.4 Design Principles 4: Shift from confrontation to collaboration

Identified through my analysis, this principle addresses the problem of competing systems which involves substitution, encroachment, and replacement between direct competing software components in the context of HISs in developing countries (Nielsen and Sæbø, 2016). The healthcare systems in developing countries are largely dependent on external funding from international donors. To measure the efficiency of their interventions, donors often spent resources to build their own HISs. As a result, there are multiple highly overlapping, fragmented and isolated systems offering the same functionality (Smith et al., 2007; Kimaro and Nhampossa, 2007) and these tend to encroach upon each other (Nielsen and Sæbø, 2016).

The issues of fragmentation and overlapping ICT investments are sometimes not a result of poor coordination but a result of competition and battle between different stakeholders. The case of the communicable disease reporting system discussed in my paper “Battleground of IT4D: From mutual exclusion to hybrid vigor” illustrates this situation. This design principle highlights the importance of shifting from confrontation to collaboration, because collaboration within an ecosystem framework will strengthen the ecosystem as a whole. Through the process of refining and defining functional roles, individual systems find their best place to live and let other systems live in a win-win and mutual benefit cooperation.

The design rules for this design principle are discussed as follows:

- *Design Rule 4.1: Proactively refine functional roles*

Involved actors in the competition should always take precautions and seek opportunities to refine their functional roles to respond to threats posed by other systems. Proactively redefining functional roles helps the system to change from confrontation to collaboration. This strategic move will make the system appear less threatening to others and enable collaboration and entry rather than blocking and preventing. Two examples from my cases demonstrate this approach. The first one is how the Licensing System was reconfigured to focus only on medical professionals licensing. The module built for medical facilities licensing was completely reconfigured to function as Hospital Inventory and Hospital Quality Evaluation. This self-reconfiguration helped the Medical Licensing System survive even in case the Team failed the BigFirm tender. Indeed, when the tender was opened, another company was selected as winner. However, due to the reconfiguration done previously, the Licensing System was allowed to stay alongside the BigFirm modules.

The second example was related to the case of the communicable disease reporting system. The Team had built an additional component that could exchange hospitalized case data related to communicable diseases with the system backed by General Department of Preventive Medicine. By doing so, the Epidemic Notification System offered some advantages to its competing system, the Communicable Disease Reporting System. First, having data from hospitals saved General Department of Preventive Medicine from expensive and time-consuming implementation of its system to hospitals. Second, although hospitals are required to report communicable disease cases to health centers, they are often reluctant to do so for a variety of reasons. Letting Vietnam Administration of Medical Services work directly with hospitals is a wiser strategy which could help to reduce lots of resistance and avoid delays in reporting.

- *Design Rule 4.2: Proactively define and reserve functional roles for other systems*

This design rule suggests involved actors not only refine their own roles to adapt to change but also identify, assign, and reserve functional roles for other competitors. This reflects the fact that powerful actors, i.e., those who have the greatest influence, are not necessarily the ones who have insights and experience to propose how refining and defining functional roles should

take place or describe why this could ensure mutual benefits for all other actors. In the Medical Licensing case, the Team followed this rule by defining and reserving the facility licensing part for the BigFirm while it only concentrated on the professional licensing part. Similarly, in the case of communicable disease reporting, the Team proposed that it could export data from its system to support the expansion of the system backed by General Department of Preventive Medicine.

- *Design Rule 4.3: Seek political support for refining and defining functional roles*

One of the driving forces that triggered the reconfiguration of the Epidemic Notification System was the change in the Circular regulating communicable diseases reporting, i.e., Circular 54/2015/TT-BYT. According to the new circular, hospitals must report their data directly to the General Department of Preventive Medicine's system through electronic means rather than by papers. This change presented a threat to the Epidemic Notification System and forced it to change. To apply this design rule there must be some considerations. One of them is to recognize the significance of politics in reshaping functional roles. To better survive, it is crucial to seek political support that can trigger changes in other competing systems. In the case of communicable disease reporting, the change in the circular was deliberately proposed by General Department of Preventive Medicine. While similar chance for political maneuvering is small, it is important for stakeholders to keep an eye out for any emerging opportunities.

6.2.5 Design Principle 5: Engage the public in public health data

This is another design principle identified through my empirical data. It deals with the problem of "Information Use for Action." Many studies have discussed this problem; however, most of the proposed solutions focus on improving data quality (Braa et al., 2012) and strengthening the ability to use data (Moyo et al., 2016). I suggest a new design principle that emphasizes the importance of making health data publicly available and engaging the public into the debates of critical health issues. As the public health system is highly political and its efficiency is often used as a demonstration of good leadership and governance, the concerns of the public could attract attention of top leaders to health data and require them to take action. This design principle is further detailed in the following design rules:

- *Design Rule 5.1: Collect data relevant to the public and commodify health data*

This design rule highlights the importance of collecting data that are highly relevant to the public on matters such as life, death, etc. Moreover, the collected data must be presented in a

way that is understandable for the public, i.e., simple and succinct. For example, unlike traditional HMIS, which contain thousands of data elements to be collected, the Tet Reporting System had only a few data elements, but they were of great relevance to the public. The small number of data elements reduced the reporting burden that hospital users had to do, thus encouraging them to report accurately, fully, and in a timely manner. Furthermore, the reporting structure was also significantly simplified, i.e., the reduction of breakout of genders and age groups and the using of indicators was avoided. Because of that, the published data became easier for the public to understand, and helped to raise awareness about the seriousness of the traffic accidents and violence.

- *Design Rule 5.2: Engage mass media and fuel public debates*

Normally, data from HISs are only circulated within the health system, i.e., in hospitals, health centers, and the MoH. They are often out of the public's concern. To draw the public's attention on critical health issues, novel channels of rapid and large-scaled data propagation must be sought. One such channel is mass media, i.e., newspapers and magazines. With a huge number of readers, newspapers (both paper-based and online) can draw attention from the public in a quick and effective way. Also, thanks to the rhetoric of journalists, titles of articles are often written in an impressive and attractive way, which no doubt makes the boring and mundane data become livelier, attracting the attention of the public. In the case of the Tet Reporting System, once the public was engaged in the debate of health issues through the data propagated by mass media, they raised their voices. The public demanded corresponding governmental agencies to step in and provide firm responses. For example, after expressing concerns over the high number of people killed in traffic accidents, the Prime Minister ordered the heads of provinces and all Ministers to create some effective measures to reduce traffic accidents.

- *Design Rule 5.3: Create feedback mechanisms and triangulate data*

Another design rule to address the problem of information use for action involves the creation of multiple feedback mechanisms and the triangulation of data from different sources. Often, reporting flow in HISs is unidirectional, i.e., upward from hospitals. In the case of the Tet Reporting System, through the published data, the public got to know more about the work of hospitals during the holiday. And the way the public reacted to the published data, i.e., judgement on the reliability of the data, gave hospitals a sense of participation, making them feel the mundane process of collecting and reporting data was relevant. Also, as the organization in charge of giving data to the public, the MoH had a responsibility to ensure the quality of

published data. To do that, it had to assign its staff to watch reported data and contact hospitals if any suspicious data were spotted. All in all, it formed multiple feedback loops, from the public to hospitals and the MoH, and from the MoH to hospitals. Furthermore, the publishing of MoH data on traffic accidents challenged the exclusive role of the Ministry of Public Security (MPS). For the first time, data from two sources were juxtaposed and compared. The inconsistency between the two sources perplexed the public, who started to question the veracity of both ministries' numbers. Under that pressure, both the MoH and the MPS joined a debate about data quality. It turned out that their methods of data collection were fundamentally different, thus leading to data variances.

6.3 The novelty of thesis findings compared to the reference theory

The theoretical stance this thesis is built upon is: information infrastructure design theory, i.e. (Hanseth and Lyytinen, 2010). As a result, the design framework developed through this thesis contributes to literature in those areas. I will now try to position my findings in relation to the existing literature, how it challenges that reference theory and goes beyond it.

This thesis contributes primarily to the information infrastructure theory. Using the basis of the design rules of Hanseth and Lyytinen (2010), I have added 4 design problems accompanied by a set of 5 design principles to address them. These findings contribute to this reference theory in a number of ways.

First, the thesis extends the original design theory by making its design problems more specific and augmenting them with additional problems. For example, the problem of competing systems is a more detailed and specific version of the adaptability problem. In Hanseth and Lyytinen's work, there is no explicit discussion on the issue of systems directly encroaching each other's.

In addition, the thesis identifies and discusses the problem of all or nothing. This problem shares both similarities and differences with the adaptability problem defined by Hanseth and Lyytinen (2010). All or nothing is similar to adaptability, as both of them have to be able cope with change, especially when there is an increase in number of users. However, the all-or-nothing problem demands that all users in a particular geographical area, e.g., a district or a province, etc., must be enrolled whereas the adaptability problem focuses on how to adapt to increased number of users or increased requirements.

Second, the design principles and rules proposed in the thesis are developed to address issues inherent to health information systems in developing countries. While Hanseth and Lyytinen's work has a particular focus on a bottom-up approach where bootstrapping and self-adapting drives system evolution, this thesis emphasizes the role of politics and governmental agencies in the adoption and scaling processes.

Third, the problem of data use is not discussed in the reference theory, though it is a common issue in the health information systems domain (see, for example, Braa et al. (2012)) and probably in other domains as well. The current trend in Big Data (Wyber et al., 2015, John Walker, 2014), Data Mining (Hand, 2007), and Business Intelligence (Chen et al., 2012) are good examples showing how data use is critical in large-scale and complex information systems. This thesis suggests a number of approaches to dealing with this issue in the particular context of HISs in Vietnam. It shows that once the data use problem is resolved, it can contribute back in order to sustain and expand the system. For example, when a system shows that its data can be used for action or decision-making, it is easy to earn support and legal permission to expand so that it can enrol more users and attract more funding.

In summary, this thesis extends the reference theory by identifying additional design problems that have not been covered by the original design theory. Based on the identified design problems, the thesis suggests new and revised design principles and rules to deal with the problems.

Table 11 summarizes the design principles and design rules that address the emergent design problems related to HII, as well as the empirical evidence that formed the basis of the principles.

Table 11: Summary of the amendment to the II design theory

Design problems	Design principles	Design rules	Evidence that formed the design principles
Scaling and Sustainability	Create an attractor through early successful adoption	<ul style="list-style-type: none"> - Reuse and adapt open-source software components - Use web-based solutions - Use gateways that are quick to make and easy to replace - Identify and recruit champions 	<ul style="list-style-type: none"> - Using open-source software, DHIS2 expedited the deployment process - Because DHIS2 is a web-based software, it shortened the time required for implementation - The use of a number of temporal software programs reduced the time it took to switch from paper to the online system, e.g. the Excel importing tool. - Licensing officers at the first 5 provinces supported the systems and helped convince the MoH and donors
	Scaffold the enrolment and continuity of use and expansion	<ul style="list-style-type: none"> - Pursue and exploit indirect means to motivate use - Institutionalize user support teams - Reuse user skills and experiences 	<ul style="list-style-type: none"> - Providing computers, printers, scanners and software for free reduced resistance from provinces when it came to using the systems. - A dedicated support team helped increase the adoption coverage - Functionality to export data to Word, Excel formats increased the use of the systems
All or Nothing	Seek political support to reach full coverage	<ul style="list-style-type: none"> - Target politically visible use cases 	<ul style="list-style-type: none"> - Selecting communicable diseases and Lunar New Year reporting as a focus helped gain more support from the MoH

		<ul style="list-style-type: none"> - Leverage the power and position of politically relevant individuals 	<ul style="list-style-type: none"> - Direct lobbying through foreign consultants and IT specialist resulted in a number of official dispatches that mandated the use of the systems.
Competing Systems	Shift from confrontation to collaboration	<ul style="list-style-type: none"> - Proactively refine functional roles - Proactively define and reserve functional roles for other systems - Seek political support for refining and defining functional roles 	<ul style="list-style-type: none"> - The Team only focused on health professionals licensing management functionality and left the other areas for the BigFirm - VAMS only focused on hospital data and shared them with GDPM and other stakeholders - GDPM summoned political support to enact a decree that legitimates its authority in epidemic data.
Information Use	Engage the public in public health data	<ul style="list-style-type: none"> - Collect data relevant to the public and commodify health data - Engage mass media and fuel public debates - Create feedback mechanisms and triangulate data 	<ul style="list-style-type: none"> - The public was only concerned about few important numbers such as traffic accidents, violence, etc. - Hundreds of news articles about traffic accidents and violence attracted public interests. - The MoH was very careful in verifying data with hospitals before publishing them.

This chapter has answered the research question posed in the introduction chapter through articulating design problems related to HIIs in Vietnam and discussing design principles and design rules to address those problems. The next chapter discusses how these insights contribute to the body of knowledge relating to health information systems and information infrastructure and to the practice of developing and implementing HIIs in developing countries.

7 CONTRIBUTIONS

The primary aim of this research is to improve our ability to design and implement HISs in developing countries. To that end, II theory is employed as a theoretical lens to examine the challenges related to HISs in developing countries and to build theoretically informed interventions to deal with these challenges. Specifically, this research identifies design problems related to HISs in developing countries and suggests design principles and design rules to resolve them within a framework of II design theory. The thesis thus mainly contributes to the literature on HISs in developing countries. It also contributes to II literature by framing more design problems and defining more design principles and rules to the II design theory.

While the summary of the papers in chapter 5 focuses primarily on the findings from the individual papers, this chapter seeks to bring them together and develop broader contributions.

7.1 Generalizations of findings

The biggest challenge of a case study approach, as well as in action research and qualitative research, is the ability to generalize the findings to other settings and contexts (Malterud, 2001). As discussed previously, the extended design theory developed in this thesis is not a prescription on how to act in other cases, but researchers and practitioners in the health information systems domain could find some useful suggestions for their specific circumstances.

- For HISs in developing countries:

The contextualized design principles developed in this thesis could be useful for HISs in other developing countries for several reasons.

First, many problems discussed in this thesis for which the design principles are developed to deal with, exist also in other developing countries. For example, the problem of scalability and sustainability is discussed in many studies on HISs in developing countries. Kimaro (2006) discusses the challenge of sustainability in Tanzania. Similarly, Kimaro and Nhampossa (2007) present a comparative case study between Tanzania and Mozambique to highlight the problem of sustainability in healthcare sectors in these countries. Miscione and Sahay (2007) discuss the problem of scalability in India and propose a practice-institutionalized approach to address it. On the other hand, the problem of data use and “all or nothing” also has been examined in many studies. For example, Moyo et al. (2016) discuss the problem of data use in Malawi and how the implementation of a software system could remedy the problem. Charles and Geoff (2007) argue that the use of health data in India is merely a ceremony and not for action and change at all. Braa et al. (2004) discuss the problem of all or nothing that applies for healthcare sectors in all developing countries.

Second, the healthcare sectors in developing countries share many similarities. They include “*health-related challenges, rampant diseases, and limited resources and capability*” (Consulting, 2009, p.5). There is a need for frugal approaches that work in such conditions. The

contextualized design principles developed in this thesis follow a frugal approach (Sahay and Walsham, 2014) that should be affordable for developing countries. For example, adaptation of open source software (in principle 1) can significantly cut down the cost of software development (Camara and Fonseca, 2007). Using web-based solutions (also in principle 1) can reduce the supporting efforts and costs for implementation (Zoroja et al., 2014). Shifting from confrontation to collaboration (principle 4) can help avoid wasteful overlapping in terms of functional role. Another design rule (in principle 2), which demands a support team that is skilful in troubleshooting and providing support via phone, is also very relevant to developing countries because formal training can be costly and difficult to arrange.

At the same time, applying the two design principles (principle 3 and 5) to other contexts outside Vietnam can be a challenge because it might be difficult to identify local champions as well as politically relevant individuals. This might also be a challenge even in Vietnam in cases where a new system needs to be developed but such champions are no longer available. Also, the engagement of the public in the health data debate could be challenging since the culture and mass media systems in other countries may work differently. Furthermore, the engagement of the public through mass media (mostly online newspapers) depends very much on the number of Internet users. This number is relatively high in Vietnam compared to other Asian and African countries (Statista, 2017).

- For HISs in countries outside the developing world

The design theory developed by Hanseth and Lyytinen (2010) is for information infrastructure in general. It means that they should be applicable to all kinds of systems not limited to the healthcare sector given that such systems take characteristics of information infrastructure, e.g., shared, evolving, installed base, etc. There is also an assumption that these design principles should work across countries regardless of whether they are developed or developing.

Therefore, some design principles and rules developed in this thesis could be relevant for HISs in developed countries as well, especially those principles and rules that are related to scalability problems. Jensen (2013), when reporting her study on scaling an electronic patient records system from a small pilot project to a national scale in Denmark, suggests the need to have a flexible and modular strategy and to identify key stakeholders to provide immediate benefits. While the rule related to finding relevant stakeholders identified by Jensen is somewhat similar to the design rule developed in this thesis (Identify and recruit champions), I find that the two other rules are highly appropriate to address the problem of scalability in HISs in developed countries. The first relevant rule is that of using temporal gateways. Temporal gateways are small components that could be built and thrown away quickly to interconnect, synchronize, and migrate data of discrete components and systems in other contexts. The second relevant rule, related to organizing a supporting team, is also useful here. A central support team can improve communication between (many) users and a development team, thus helping to encourage the use of the system and increase the enrolment of new users.

Furthermore, the design principles and rules developed to deal with the problem of competing systems are also relevant to the integration problem. Integration problems present a huge

challenge for HISs in developed countries (Hartswood et al., 2008, Mäenpää et al., 2009). As Michelsen et al. (2015) point out, integration problems are not only a technical issue, such as with regard to standards, but are also related to coordination, cooperation, and governance. The design rule on functional reconfiguration, i.e., changing the functional role of a system, suggests some detailed steps to increase and open a chance for cooperation.

However, other findings from this thesis are rooted in the context of healthcare in developing countries. From that perspective, additional problems have been identified and they bring attention to the need to extend the design theory. Other design principles and rules might need to undergo field tests with rich empirical data from developed countries to see how they are relevant.

7.2 Theoretical contributions

First, this thesis contributes to II literature by extending the II design theory with design problems not previously defined and discussed. It further suggests additional design principles and rules to deal with these problems. Efforts to use the II perspective to examine HISs in developing countries have been made by a number of researchers (see for example Sahay and Walsham (2006), Sanner et al. (2014), Nielsen and Sæbø (2016)). This thesis contributes to such efforts by bringing the II perspective more strongly and practically into the analysis. To operationalize that ambition, the thesis has identified four design problems related to HIIs in developing countries and has proposed five design principles with 15 detailed design rules to address these problems. These principles and rules have been discussed together with contextual factors that have shaped their formulation. The design problems, design principles and design rules together form a theoretical framework that is useful to examine not only HISs in developing countries but also systems in other settings and domains.

Second, this thesis provides a strong perspective to analyze the challenges of designing and implementing HIIs in developing countries. So far, studies on HIIs in developing countries tend to discuss these problems separately (see, for example, Sahay and Walsham (2006) on scaling, Sahay et al. (2009) on integration, Moyo et al. (2016) on information use), although they are interrelated. In this thesis, the four key problems of HIIs are coherently investigated in order to find holistic approaches to address them. A holistic strategy is needed to avoid situations in which a problem addressed in one place causes problems in other places (Sahay et al., 2017). For example, in the case of the Medical Licensing System, there existed three problems: scaling, all or nothing, and competing systems. There was pressure to scale the system beyond the pilot province to gain the political support needed for its survival because the larger its scale, the more promising the system appeared to top health managers and donors. To support the MoH in making decisions related to health and human resource development, the system must have enrolment of all provinces so that it can provide data for the whole country. When the BigFirm won the contract, the system needed to find a way to co-exist. Therefore, without having a coherent and overarching approach to dealing with multiple problems which happened to the same system, HII designers might be lost and unable to respond to social and political changes. The theoretical framework developed in this thesis provides a tool to deal with that situation.

In summary, the theoretical contributions of this thesis are primarily to the development of a theoretical framework inspired by II design theory that helps understand and address HII design problems in developing-country settings.

7.3 Practical contribution

As part of an action research effort, this thesis contributes to practice by generating practical knowledge relevant to the research setting. The design principles and rules proposed in this thesis offer practical guidelines for HII managers and designers to effectively tackle design problems pertinent to HIIs in developing countries.

7.3.1 Focus on small but early and successful adoption

There have been a number of scholarly discourses discussing the problem of scaling of HIIs in developing countries. Braa and Sahay (2012) argue that creating an attractor is one of the mechanisms for scaling. This thesis argues that early successful adoption is a good candidate for such an attractor for a number of reasons. First, an early successful adoption can create immediate usefulness for its early users (Hanseth and Aanestad, 2003), and when they are satisfied with the system, they can speak on behalf of those who try to promote the system (Callon, 1984). Second, an early successful adoption can act as a means to seek political support needed for scaling. In the case of medical licensing, the first implemented province became a showcase attracting interest from other provinces, as well as a means for gaining political endorsement necessary for scaling, i.e., funding and official letters. Third, an early successful adoption is important due to the fact that it can help avoid the threat of competing systems. Longer times would allow big software vendors to have enough time to mobilize resources to provide alternative software systems. With their larger network of relationships and money power, these software vendors can block the scaling process of the implemented system or even descale it.

Apart from proving the importance of early successful adoption, this thesis also contributes by proposing a design principle with a total of four design rules to enable early successful adoption. These include an adaption of open source software and web-based solutions, and increased use of gateway components that are quick to build and easy to replace. These rules partially actualize the bricolage approach (Ciborra, 2000), which emphasizes the need to sum all scarce resources at hand to pragmatically improvise the II building process. The ultimate goal of these rules is to have a functioning system as quickly as possible. The early availability of such a system enables early engagement and participation, and thus allows adequate time for cultivation (Hanseth, 2002) and evolution (Hughes, 1987). And it is worth emphasizing the importance of recruiting local champions (Sahay et al., 2017) through personal relationships and social networks. In its early phase, an II can hardly offer any incentive to its users (Hanseth and Aanestad, 2003), because it might only be in the form of a prototype. Personal relationships thus play a role here.

In addition, as scaling is viewed as expanding and spreading of a technical artefact to a larger setting (Gizaw, 2014), to solve the problem of scaling, it is important to maintain the rhythm of

enrolment of users (hospitals, provinces, health facilities) and the continuity of use. To that end, this thesis contributes by proposing three design rules which involve the use of indirect means to motivate enrollment, organizing a robust support team, and taking prior users' experiences and skills into the consideration of system design.

7.3.2 *Prioritize politically visible use cases*

Another contribution of this thesis involves suggesting guidelines to solve the all-or-nothing problem (Braa et al., 2004). Strategies for scaling help increase the size of implementation. However, they might not be able to ensure a full-coverage implementation. The findings of this thesis highlight the importance of enrolling political support in attaining a full-scale HII implementation. To accumulate enough political support, the thesis proposes two design rules that involve prioritizing politically visible use cases and leveraging the power and position of a politically relevant person. The findings reveal that political support can be summoned through focusing on use cases that have the potential to demonstrate good leadership. Additionally, the findings indicate that it is necessary to constantly approach a politically relevant person who can influence the full-coverage scaling.

This approach is indeed similar to the call for a combination of top-down and bottom-up approaches recommended by researchers in the field of health informatics (see, for example, Berg (2003), Sahay et al. (2017)). This thesis contributes to that debate by proposing two design rules to implement the top-down approach to HII design process.

7.3.3 *Define and reserve functional roles for other systems*

Fragmentation and integration is a wicked problem prevailing in HIIs in developing countries (Sahay et al., 2017). Efforts to address the problem through technical solutions has yielded little success and even created more problems elsewhere (Sahay et al., 2017). Chilundo and Aanestad (2005) suggest that negotiation across multiple rationalities is a potential approach to approaching the fragmentation problem. As the existence of different systems has its own logics, it is necessary to understand these logics and negotiate them to settle the problem. However, efforts to negotiate integration are never easy since integration of HIIs involve highly charged politics. In order to survive, participant systems need to be highly configurable to adapt to changes (Sahay et al., 2009, Nielsen and Sæbø, 2016). The thesis operationalizes that strategy by arguing that configuration should be seen as the ability of a system to refine and define its functional roles. Refining functional roles entails shifting focus to areas where the system can play best. Defining functional roles relates to identifying and reserving functional roles that other systems can fill. This strategy can be seen as hybrid vigor. Hybrid vigor views the competing systems problem as an opportunity to formulate a software ecosystem. The hybrid vigor strategy thus seeks to strengthen the ecosystem as a whole and tries to shift from confrontation to cooperation. The thesis recommends that instead of fighting until the last man dies, stakeholders behind competing systems should actively participate in the refining and defining process. Following this strategy could help avoid the problem of repercussions when a system replaces other systems in turn being replaced by another system.

7.3.4 Engage the public and mass media in conversations around health data

Sahay et al. (2017) argue that the information use problem cannot be addressed by simply adding more technical solutions that improve data quality, streamline reporting flows, and build tools to visualize and analyze data. Instead, they propose three approaches to improving information use. These approaches focus on building conversations around data, a community of practice, and strengthening the link between IT solutions and work practices. This thesis contributes to implementing these approaches through engagement of the public in discussing health data. The findings reveal that the public has particular interests in data that directly concern them. Among that, data related to life and death matters such as communicable disease outbreaks, accidents, and emergencies are on their top list of priority concerns. To create conversations around data, it is important to collect data that the public wants to know. The thesis also indicates that mass media is a useful channel to facilitate such a “community of practice” (Lave and Wenger, 1991) on health information use. As a result, conversations around data help create indirect feedback from the public to data entry clerks at health facilities. There is an invisible pressure that makes them become more attentive to improving data quality in terms of timeliness and accuracy.

Finally, as part of the practical contribution, the thesis contributes to system design and system building processes. Through many action research cycles, a number of systems such as medical licensing, hospital quality evaluation, hospital inventory, epidemic notification, and Lunar New Year reporting have been built and are still in use. To some extent, these systems have contributed to transforming the healthcare sector through improving the quality of healthcare service provision, transparency, and accountability of health facilities and authorities. In particular, the licensing system has supported licensing officers nationwide in processing more than 300,000 health professional licensing applications.

7.4 Future research

One identified area for future research could be the application of these design principles and rules into other developing-countries settings. This process will give a chance for these design principles and design rules to be tested in a setting other than Vietnam. Such processes will not only challenge these design principles and rules but also empirically test and extend these principles and rules that ultimately enhance the evolution of the II design theory.

REFERENCES

- Aanestad, M. (2002). Cultivating Networks: Implementing Surgical Telemedicine. Department of Informatics. Oslo, University of Oslo. **PhD**.
- Aanestad, M. and T. B. Jensen (2011). "Building nation-wide information infrastructures in healthcare through modular implementation strategies." The Journal of Strategic Information Systems **20**(2): 161-176.
- AbouZahr, C. and T. Boerma (2005). "Health information systems: the foundations of public health." Bulletin of the World Health Organization **83**(8): 578-583.
- ADB (2013). "Viet Nam: Health Human Resources Sector Development Program (Second Tranche)." Retrieved December 1st, 2014, from <https://www.adb.org/sites/default/files/project-document/79414/40354-031-prtr.pdf>.
- ADB (2014). "GRANT-0209 VIE: Health Human Resources Sector Development Program - CS 005 Enhancement of the National Registration and Certification System for Health Professionals (40354-013)." Retrieved June 10th, 2017, from https://uxdmz06.adb.org/OA_HTML/OA.jsp?OAFunc=XXCRS_CSRN_PROFILE_PAGE&selNo=115827.
- Altricher, H., et al. (2005). Teachers investigate their work: An introduction to action research across the professions. UK, Routledge.
- An, H. (2016). "Increasing deaths by dengue fever." Retrieved February 5th, 2016, from <http://suckhoe.vnexpress.net/tin-tuc/suc-khoe/11-nguoi-tu-vong-do-sot-xuat-huyet-3418141.html>.
- Avgerou, C. (2010). "Discourses on ICT and development." Information Technologies & International Development **6**(3): pp. 1-18.
- Avison, D. and G. Fitzgerald (2003). Information systems development: methodologies, techniques and tools. USA, McGraw Hill.
- Avison, D. E., et al. (1999). "Action research." Communications of the ACM **42**(1): 94-97.
- Bally, L., et al. (1977). "A prototype approach to information system design and development." Information & Management **1**(1): 21-26.
- Banville, C. and M. Landry (1989). "Can the Field of MIS be Disciplined?" Communications of the ACM **32**(1): 48-60.
- Baskerville, R. L. (1999). "Investigating information systems with action research." Communications of the AIS **2**(3es): 4.
- Berg, M. (2003). Health information management: Integrating information and communication technology in health care work. UK, Routledge.
- Bjerknes, G., et al. (1987). Computers and democracy: A Scandinavian challenge. UK, Gower.
- Blumenthal, D. (2009). "Stimulating the adoption of health information technology." New England Journal of Medicine **360**(15): 1477-1479.
- Braa, J., et al. (2007). "Developing health information systems in developing countries: the flexible standards strategy." Management Information Systems Quarterly **31**(2): 381-402.
- Braa, J., et al. (2012). "Improving quality and use of data through data-use workshops: Zanzibar, United Republic of Tanzania." Bulletin of the World Health Organization **90**(5): 379-384.
- Braa, J., et al. (2004). "Networks of action: sustainable health information systems across developing countries." Management Information Systems Quarterly **28**(3): 337-362.

- Braa, J. and S. Sahay (2012). Participatory Design within the HISP network. Routledge International Handbook of Participatory Design. J. Simonsen, Robertson, T., UK, Routledge: 235-256.
- Braa, J. and S. Sahay (2012). Integrated Health Information Architecture: Power to the Users. Delhi, Maxwell Publishers.
- Byrne, E. (2006). "Using action research in information systems design to address change: a South African Health Information Systems case study: reviewed article." South African Computer Journal **2006**(37): 19-29.
- Bødker, S. (1996). "Creating conditions for participation: conflicts and resources in systems development." Human-computer interaction **11**(3): 215-236.
- Callon, M. (1984). "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay." The Sociological Review **32**(S1): 196-233.
- Camara, G. and F. Fonseca (2007). "Information policies and open source software in developing countries." Journal of the Association for Information Science and Technology **58**(1): 121-132.
- Carson, D., et al. (2001). Qualitative marketing research. UK, SAGE.
- Charles, N. and W. Geoff (2007). "The great legitimizer: ICT as myth and ceremony in the Indian healthcare sector." Information Technology & People **20**(4): 313-333.
- Chen, H., et al. (2012). "Business intelligence and analytics: from big data to big impact." Mis Quarterly: 1165-1188.
- Cheng, S. (2015). A Situation Analysis of the Maternal and Child Health Information System in Vietnam. Oslo, University of Oslo. **Master**.
- Chilundo, B. and M. Aanestad (2005). "Negotiating multiple rationalities in the process of integrating the information systems of disease specific health programmes." The Electronic Journal on Information Systems in Developing Countries **20**(2): 1-25.
- Ciborra, C. (2000). From control to drift: the dynamics of corporate information infrastructures. Oxford, Oxford University Press.
- Ciborra, C. U. and O. Hanseth (1998). "From tool to Gestell: Agendas for managing the information infrastructure." Information Technology & People **11**(4): 305-327.
- Davis, A. M. (1995). "Software prototyping." Advances in computers **40**: 39-63.
- Denzin, N. K. (2017). Sociological methods: A sourcebook. UK, Routledge.
- DiCicco- Bloom, B. and B. F. Crabtree (2006). "The qualitative research interview." Medical education **40**(4): 314-321.
- Donaldson, M. S. and K. N. Lohr (1994). Health Data in the Information Age: Use, Disclosure, and Privacy. Washington, DC, National Academies Press.
- Drury-Grogan, M. L. (2014). "Performance on agile teams: Relating iteration objectives and critical decisions to project management success factors." Information and Software Technology **56**(5): 506-515.
- Ehn, P. (1993). "Scandinavian design: On participation and skill." Participatory design: Principles and practices: 41-77.
- Ehn, P. and A. Sandberg (1979). Systems development: Critique of ideology and the division of labor in the computer field. Stockholm, Swedish Center for Working Life.

- Eisenhardt, K. M. (1989). "Building theories from case study research." Academy of Management review **14**(4): 532-550.
- El-Seoud, S. A. (2016). "A Comparison of Various Software Development Methodologies: Feasibility and Methods of Integration." International Journal of Recent Contributions from Engineering, Science & IT (iJES) **4**(4): 50-54.
- Erhart, A., et al. (2007). "Accuracy of the health information system on malaria surveillance in Vietnam." Transactions of the Royal Society of Tropical Medicine and Hygiene **101**(3): 216-225.
- Fishenden, J. and M. Thompson (2012). "Digital government, open architecture, and innovation: why public sector IT will never be the same again." Journal of public administration research and theory **23**(4): 977-1004.
- Gizaw, A. (2014). Open Generification: The case of District Health Information Software. Department of Informatics, University of Oslo. **PhD**.
- Gizaw, A. A., et al. (2016). "Open generification." Info Systems J. doi: 10.1111/isj.12112.
- Glaser, B. and A. Strauss (1967). "The discovery of grounded theory." London: Weidenfeld and Nicholson **24**(25): 288-304.
- Greenbaum, J. and M. Kyng (1992). Design At Work-Cooperative design of Computer Systems. Hillsdale, NJ, L. Erlbaum Associates Inc.
- Grisot, M., et al. (2014). "Innovation of, in, on infrastructures: articulating the role of architecture in information infrastructure evolution." Journal of the Association for Information Systems **15**(4): 197-219.
- Hand, D. J. (2007). "Principles of data mining." Drug safety **30**(7): 621-622.
- 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. (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 manuscript)." Retrieved 01/05/2016], from http://heim.ifi.uio.no/~oleha/Publications/ib_ISR_3rd_resubm2.html.
- Hanseth, O. and K. Braa (2000). Who's in control: Designers, managers-or technology? Infrastructures at norsk hydro. From Control To Drift: The dynamics of corporate information infrastructure. C. U. Ciborra, Braa, K., Cordella, A., Dahlbom, B., Failla, A., Hanseth, O., Hepsø, V., Ljungberg, J., Monteiro, E. and Simon, K. A. New York, Oxford University Press: 125-147.
- Hanseth, O., et al. (2012). ICT standardization strategies and service innovation in health care. International Conference on Information Systems, Orlando.
- Hanseth, O. and K. Lyytinen (2010). "Design theory for dynamic complexity in information infrastructures: the case of building internet." Journal of Information Technology **25**(1): 1-19.
- Hanseth, O. and E. Monteiro (1998). "Understanding information infrastructure (Unpublished book)." Retrieved 01/05/2016], from <http://heim.ifi.uio.no/~oleha/Publications/bok.html>.
- Hanseth, O. and M. Aanestad (2003). "Design as bootstrapping. On the evolution of ICT networks in health care." Methods of information in medicine **42**(4): 384-391.
- Haraway, D. (1988). "Situated knowledges: The science question in feminism and the privilege of partial perspective." Feminist studies **14**(3): 575-599.
- Hartwood, M., et al. (2008). Special Issue Editorial Integrated health records: practice and technology. London, UK, SAGE Publications Sage.

- Heeks, R. (2002). "Information systems and developing countries: Failure, success, and local improvisations." The information society **18**(2): 101-112.
- Heeks, R. (2003). Most e-government-for-development projects fail: how can risks be reduced?, Institute for Development Policy and Management, University of Manchester Manchester.
- Heeks, R. (2006). "Health information systems: Failure, success and improvisation." International Journal of Medical Informatics **75**(2): 125-137.
- Heeks, R. and E. Baark (1999). Evaluation of Donor Funded Technology Projects in China, Working Paper, Institute for Development Policy and Management (IDPM), University of Manchester.
- Henfridsson, O. and B. Bygstad (2013). "The generative mechanisms of digital infrastructure evolution." Mis Quarterly **37**(3): 907-931.
- Herbsleb, J. D. and A. Mockus (2003). "An empirical study of speed and communication in globally distributed software development." IEEE transactions on software engineering **29**(6): 481-494.
- Hoang, V. M. and B. X. Tran (2012). "Assessing the household financial burden associated with the chronic non-communicable diseases in a rural district of Vietnam." Global health action **5**: 1-7.
- Hochwarter, S., et al. (2014). "Towards an electronic health record system in Vietnam: a core readiness assessment." Journal of Health Informatics in Developing Countries **8**(2).
- Hoda, R., et al. (2013). "Self-organizing roles on agile software development teams." IEEE transactions on software engineering **39**(3): 422-444.
- Hu, W., et al. (2013). "Hot spot detection and spatio-temporal dispersion of dengue fever in Hanoi, Vietnam." Global health action **6**.
- Hudson, L. A. and J. L. Ozanne (1988). "Alternative ways of seeking knowledge in consumer research." Journal of consumer research **14**(4): 508-521.
- Hughes, T. P. (1979). "The electrification of America: the system builders." Technology and Culture **20**(1): 124-161.
- Hughes, T. P. (1987). "The evolution of large technological systems." In: Bijker, W.E., Hughes, T.P., Pinch, T. (Eds.), The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology. MIT Press, Cambridge, MA: 51-82.
- Iivari, J. and K. Lyytinen (1998). "Research on information systems development in Scandinavia." Scandinavian journal of information systems **10**(1-2): 135-185.
- Jacobson, I. (2004). "Use cases—Yesterday, today, and tomorrow." Software & Systems Modeling **3**(3): 210-220.
- Jensen, T. B. (2013). "Design principles for achieving integrated healthcare information systems." Health informatics journal **19**(1): 29-45.
- John Walker, S. (2014). Big data: A revolution that will transform how we live, work, and think, Taylor & Francis.
- John, W. S. and P. Johnson (2000). "The pros and cons of data analysis software for qualitative research." Journal of nursing scholarship **32**(4): 393-397.
- Kaj, G. (1989). "Rapid Prototyping With Fourth Generation Systems – An Empirical Study." Office Technology and People **5**(2): 105-125.
- Kimaro, H. and J. Nhampossa (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): 1–10.

Kimaro, H. C. (2006). "Strategies for developing human resource capacity to support sustainability of ICT based health information systems: a case study from Tanzania." The Electronic journal of information systems in developing countries **26**: 1-23.

Kling, R. (1993). Behind the terminal: The critical role of computing infrastructure in effective information systems' development and use. Challenges and Strategies for Research in Systems Development. W. C. a. J. Senn. London, John Wiley: 153–201.

Kock, N. and F. Lau (2001). "Information systems action research: serving two demanding masters." Information Technology & People **14**(1): <https://doi.org/10.1108/itp.2001.16114aaa.16001>.

Kruchten, P. (2004). The rational unified process: an introduction. USA, Addison-Wesley Professional.

Kvale, S. (1983). "The qualitative research interview: A phenomenological and a hermeneutical mode of understanding." Journal of phenomenological psychology **14**(2): 171–196.

Larman, C. (2004). Agile and iterative development: a manager's guide. USA, Addison-Wesley Professional.

Lave, J. and E. Wenger (1991). Situated learning: Legitimate peripheral participation. Cambridge, Cambridge university press.

Law, C. (2017). "Vietnam - Government Procurement Tender Decisions Will Be Subject To International Arbitration And Investments Subject To Investor State Dispute Settlement And Enforcement." Retrieved March 10th, 2017, from <http://www.conventuslaw.com/report/vietnam-first-time-in-history-government/>.

Law, J. and J. Hassard (1999). Actor network theory and after. USA, Wiley-Blackwell.

Lewin, R. (1999). Complexity: Life at the edge of chaos. Chicago, University of Chicago Press.

Lind, P. (2006). Computerization in developing countries. UK, Routledge.

Lindgren, R., et al. (2004). "Design principles for competence management systems: a synthesis of an action research study." Mis Quarterly **28**(3): 435-472.

Malterud, K. (2001). "Qualitative research: standards, challenges, and guidelines." The lancet **358**(9280): 483-488.

Mansell, G. (1991). "Action research in information systems development." Information systems journal **1**(1): 29-40.

Manya, A., et al. (2015). A socio-technical approach to understanding data quality in health information systems: Data quality intervention in Kenya. IST-Africa Conference, 2015, IEEE.

Markus, M. L., et al. (2002). "A design theory for systems that support emergent knowledge processes." Mis Quarterly **26**(3): 179-212.

Michel, A., et al. (1999). "Design principles of a clinical information system for intensive care units (ICUData)." Studies in Health Technology and Informatics **77**: 921-924.

Michelsen, K., et al. (2015). Promoting better integration of health information systems: best practices and challenges, WHO Regional Office for Europe.

Mike, C. and S. D. Albert (2001). "System development conflict during the use of an information systems prototyping method of action research: Implications for practice and research." Information Technology & People **14**(1): 91-108.

Miles, M. B. and A. M. Huberman (1984). "Drawing valid meaning from qualitative data: Toward a shared

craft." Educational researcher **13**(5): 20-30.

Mills, H. D., et al. (1986). Principles of information systems analysis and design. San Diego, Academic Press.

Miscione, G. and S. Sahay (2007). Scalability as Institutionalization-Practicing District Health Information System in an Indian State Health Organization. Taking Stock of E-Development, São Paulo, Brazil, 28-30 May, 2007.

Monteiro, E. (1998). "Scaling information infrastructure: The case of next-generation IP in the Internet." The information society **14**(3): 229-245.

Monteiro, E. (2000). Actor-network theory and information infrastructure. From control to drift. Oxford, Oxford University Press: 71-83.

Mosse, E. L. and S. Sahay (2003). Counter Networks, Communication and Health Information Systems. Organisational information systems in the context of globalization. M. Korpela, Montealegre, R. and Poulymenakou, A. Boston, Kluwer Academic: 35-52.

Moyo, C., et al. (2016). "The Information Transparency Effects of Introducing League Tables in the Health System in Malawi." The Electronic journal of information systems in developing countries **75**: 1-16.

Msiska, B. and P. Nielsen (2017). "Innovation in the fringes of software ecosystems: the role of socio-technical generativity." Information Technology for Development: 1-24.

Myers, M. (1999). "Investigating information systems with ethnographic research." Communications of the AIS **2**(4es): #1.

Mäenpää, T., et al. (2009). "The outcomes of regional healthcare information systems in health care: a review of the research literature." International Journal of Medical Informatics **78**(11): 757-771.

Nguyen, D. H. and V. M. Hoang (2013). "Public health in Vietnam: scientific evidence for policy changes and interventions." Global health action **6**: 1-6.

Nguyen, L. (2010). Introducing health information systems to aged care in Vietnam. PACIS 2010: Proceedings of the 14th Pacific Asia Conference on Information Systems, Taiwan, National Taiwan University.

Nguyen, T. T. and G. Johanson (2007). "Culture and Vietnam as a Knowledge Society." The Electronic journal of information systems in developing countries **33**(2): 1-16.

Nhampossa, J. L. (2005). Re-thinking technology transfer as technology translation: A case study of health information systems in Mozambique. Department of Informatics, University of Oslo Norway. **PhD**.

Nielsen, P. (2012). Studying information infrastructures. Phenomenology, Organizational Politics, and IT Design: The Social Study of Information Systems. Pennsylvania, IGI Global: 143-158.

Nielsen, P. and J. I. Sæbø (2016). "Three Strategies for Functional Architecting: Cases from the Health Systems of Developing Countries." Information Technology for Development **22**(1): 134-151.

Nutley, T. and H. W. Reynolds (2013). "Improving the use of health data for health system strengthening." Global health action **6**(1).

O'Donoghue, T. and K. Punch (2003). Qualitative educational research in action: Doing and reflecting. UK, Routledge.

O'Neill, M. (2015). "Building maternal e-health in Vietnam." Retrieved February 1, 2017, from <https://www.idrc.ca/en/article/building-maternal-e-health-vietnam>.

Orlikowski, W. J. (2006). "Material knowing: the scaffolding of human knowledgeability." European

Journal of Information Systems **15**(5): 460-466.

Parker, G. G., et al. (2016). Platform Revolution: How Networked Markets Are Transforming the Economy and How to Make Them Work for You, WW Norton & Company.

Parnas, D. L. and P. C. Clements (1986). "A rational design process: How and why to fake it." IEEE transactions on software engineering(2): 251-257.

Pham, P. (2016). "Vietnam's Healthcare Sector Is Poised For Decades Of Growth." Retrieved 01/12/2016, from <http://www.forbes.com/sites/peterpham/2016/05/31/vietnams-healthcare-sector-is-poised-for-decades-of-growth>.

Population Council (2012). "Strengthening the Health Management Information System (HMIS) in Thai Nguyen Province, Vietnam." Retrieved February 1, 2015, from <http://www.popcouncil.org/research/strengthening-the-health-management-information-system-in-thai-nguyen-provi>.

Raymond, E. (1999). "The cathedral and the bazaar." Knowledge, technology & policy **12**(3): 23-49.

Rhoads, J. and L. Ferrara (2012). "Transforming healthcare through better use of data." Electronic Healthcare **11**(1): 25-31.

Richardson, S. M. (2006). Healthcare information systems: design theory, principles and applications. Department of Management Information Systems. USA, University of Central Florida. **PhD**.

Rivero, J. M., et al. (2014). "Mockup-driven development: providing agile support for model-driven web engineering." Information and Software Technology **56**(6): 670-687.

Roland, L. K., et al. (2017). "P for Platform. Architectures of large-scale participatory design." Scandinavian journal of information systems **29**(2): #1.

Rolland, K. H. and E. Monteiro (2002). "Balancing the local and the global in infrastructural information systems." The information society **18**(2): 87-100.

Rothbauer, P. (2008). "Triangulation." The SAGE encyclopedia of qualitative research methods **1**: 892-894.

Sahay, S., et al. (2009). "Configurable politics and asymmetric integration: Health e-infrastructures in India." Journal of the Association for Information Systems **10**(5): 399-414.

Sahay, S. and S. Puri (2008). "The dynamics of corruption and ICT projects: Case study from the public health system in India." ICIS 2008 proceedings: 51. <http://aisel.aisnet.org/icis2008/2051>

Sahay, S., et al. (2017). Public Health Informatics: Designing for change - a developing country perspective. Oxford, Oxford University Press.

Sahay, S., et al. (2013). "Scaling of HIS in a global context: Same, same, but different." Information and Organization **23**(4): 294-323.

Sahay, S. and G. Walsham (2006). "Scaling of health information systems in India: Challenges and approaches." Information Technology for Development **12**(3): 185-200.

Sahay, S. and G. Walsham (2014). Building a better world: Frugal hospital information systems in an Indian state. Thirty Fifth International Conference on Information Systems, Auckland.

Sanner, T. A., et al. (2014). "Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation." Journal of the Association for Information Systems **15**(4): 220-243.

Sapsford, R. and V. Jupp (2006). Data collection and analysis. UK, SAGE Publications.

Schein, E. H. (1995). "Process consultation, action research and clinical inquiry: are they the same?" Journal

of Managerial Psychology **10**(6): 14-19.

Scott, V. E. (2016). A health system perspective on factors influencing the use of health information for decision-making in a district health system, School of Public Health, University of the Western Cape, South Africa. **PhD**.

Security, G. (2017). "Communist Party of Vietnam (CPV)." Retrieved February 4th, 2017, from <https://www.globalsecurity.org/military/world/vietnam/cpv.htm>.

Seidman, I. (2006). Interviewing as qualitative research: A guide for researchers in education and the social sciences. New York, Teachers College Press.

Sein, M. K., et al. (2011). "Action design research." Mis Quarterly: 37-56.

Shapiro, C. and H. R. Varian (2013). Information rules: a strategic guide to the network economy. Boston, Massachusetts, United States, Harvard Business Press.

Shidende, N. H. (2005). Challenges and approaches to the integration of HIS: Case studies from Tanzania, Department of Informatics, University of Oslo. **Master Thesis**.

Simonsen, J., et al. (2014). Situated design methods. Cambridge, Massachusetts, United States, MIT Press.

Smith, M., et al. (2007). "Integrated health information systems in Tanzania: experience and challenges." The Electronic journal of information systems in developing countries **33**(1): 1-21.

Smith, M. F. (1991). Software prototyping: adoption, practice and management. New York, NY, USA McGraw-Hill, Inc.

Sommerville, I., et al. (2012). "Large-scale complex IT systems." Communications of the ACM **55**(7): 71-77.

Star, S. L. (1999). "The ethnography of infrastructure." American behavioral scientist **43**(3): 377-391.

Star, S. L. and K. Ruhleder (1996). "Steps toward an ecology of infrastructure: Design and access for large information spaces." Information systems research **7**(1): 111-134.

Statista (2017). "Number of internet users worldwide from 2005 to 2017." Retrieved January 5, 2018, from <https://www.statista.com/>.

Suchman, L. (2002). "Located accountabilities in technology production." Scandinavian journal of information systems **14**(2): 7.

Suchman, L., et al. (1999). "Reconstructing technologies as social practice." American behavioral scientist **43**(3): 392-408.

Sutton, J. and Z. Austin (2015). "Qualitative research: data collection, analysis, and management." The Canadian journal of hospital pharmacy **68**(3): 226.

Tessem, B. (2014). "Individual empowerment of agile and non-agile software developers in small teams." Information and Software Technology **56**(8): 873-889.

Tilson, D., et al. (2010). "Research commentary-digital infrastructures: the missing IS research agenda." Information systems research **21**(4): 748-759.

Tiwana, A. (2013). Platform ecosystems: aligning architecture, governance, and strategy. Massachusetts, Morgan Kaufmann

USAID (2016). "USAID SMART TA - Sustainable Management of the HIV/AIDS Response and Transition to Technical Assistance." Retrieved February 5, 2017, from http://pdf.usaid.gov/pdf_docs/pa00mh3k.pdf.

- Van Alstyne, M. W., et al. (2016). "Pipelines, platforms, and the new rules of strategy." Harvard business review **94**(4): 54-62.
- Van Waardenburg, G. and H. Van Vliet (2013). "When agile meets the enterprise." Information and Software Technology **55**(12): 2154-2171.
- Vian, T., et al. (2012). "Confronting corruption in the health sector in Vietnam: patterns and prospects." Public Administration and Development **32**(1): 49-63.
- Vital Wave Consulting (2009). Health Information Systems in Developing Countries: A Landscape Analysis. USA, Vital Wave Consulting, Retrieved from <http://www.minsa.gob.pe/oegi/conferenciaops/recursos/43.pdf>.
- von Alan, R. H., et al. (2004). "Design science in information systems research." Mis Quarterly **28**(1): 75-105.
- Vrhovec, S. (2016). Agile development of a hospital information system. Information and Communication Technology, Electronics and Microelectronics (MIPRO), 2016 39th International Convention on, IEEE.
- Vu, D. H. and D. T. Nguyen (2010). Design of laboratory information system for healthcare in Vietnam BK-LIS. Communications and Electronics (ICCE), 2010 Third International Conference on, IEEE.
- Walls, J. G., et al. (1992). "Building an information system design theory for vigilant EIS." Information systems research **3**(1): 36-59.
- Walsham, G. (1995). "Interpretive case studies in IS research: nature and method." European Journal of Information Systems **4**(2): 74-81.
- Walsham, G. and S. Sahay (1999). "GIS for district-level administration in India: problems and opportunities." Mis Quarterly **23**(1): 39-65.
- Webster, M. (2017). "Definition of usefulness." Retrieved January 5th, 2017, from <https://www.merriam-webster.com/dictionary/usefulness>.
- Wengraf, T. (2001). Qualitative research interviewing: Biographic narrative and semi-structured methods. UK, SAGE Publications Limited.
- Whitgift, D. (1991). Methods and tools for software configuration management. New York, NY, USA, John Wiley & Sons.
- Wood, S., et al. (2013). "Successful extreme programming: Fidelity to the methodology or good teamworking?" Information and Software Technology **55**(4): 660-672.
- Wyber, R., et al. (2015). "Big data in global health: improving health in low-and middle-income countries." Bulletin of the World Health Organization **93**(3): 203-208.
- Yin, R. K. (2008). Case study research: Design and methods. USA, SAGE Publications.
- Zhang, Y. (2013). "Welcome to Health Information Science and Systems." Health Information Science and Systems **1**(1): 1-3.
- Zittrain, J. L. (2006). "The generative internet." Harvard Law Review **119**(7): 1974-2040.
- Zoroja, J., et al. (2014). "E-learning implementation in developing countries: Perspectives and obstacles." Online Tutor **2**: 97-118.

APPENDICES

1. Nguyen, TN, Ha ST, and Braa J (2015), "Assembling a National Health Information Infrastructure: The Case of Vietnam", Published in *The Electronic Journal of Information Systems in Developing Countries*, 66, 7, 1-18.
2. Nguyen, TN, Braa J (2016), "Scaffolding Health Information Infrastructure's Generativity by Scaffolded Gateways – The Case of Vietnam", Published in *The Electronic Journal of Information Systems in Developing Countries*, 75, 4, 1-22
3. Nguyen, TN, Nielsen P, Braa J (2016), "The Battleground of ICT4D: From Mutual Exclusion to Hybrid Vigor", Revised and resubmitted to *Information Technology for Development*.
4. Nguyen, TN, Nielsen P, Braa J (2017), "Scaling Information Infrastructures: the Case of the Medical Licensing System in a Southeast Asian Country", Published in *Australasian Journal of Information Systems* 21, DOI: 10.3127/ajis.v21i0.1518
5. Nguyen, TN, Nielsen P (2017), "From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making Them Public", *14th International Conference of IFIP Working Group 9.4 "ICTs for promoting social harmony: Towards a sustainable information society"*, May 22 - 24, 2017, Yogyakarta, Indonesia, *Proceedings*.

ASSEMBLING A NATIONAL HEALTH INFORMATION INFRASTRUCTURE: THE CASE OF VIETNAM

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ABSTRACT

Digital infrastructure development and evolution is a topic that has gained increasing interests from researchers, practitioners, and policy makers. Conceptualized as a large scale system transcending boundary of single organisation and involving multiple stakeholders, the evolutionary trajectory of information infrastructure is contingent, unpredictable, and in many cases end up in the so called drifting status quo. Some researchers believe such systems could not be designed but instead should be “cultivated”, a term referring to the process of incremental build and upon something rather than at once and from scratch. This paper explored the four dimensional concept of “architectural knowledge” proposed by Andersson et al. (2008) with the aim to identify additional approaches to cultivation. Using empirical data from a longitudinal and action research project that lasted three years from 2012 to 2014 in building the health information infrastructure in Vietnam, we found out that architectural knowledge could be a powerful lens in understanding generative mechanisms of information infrastructure.

1. INTRODUCTION

Literature on information systems in general and health information system in particular is replete with failures and negative outcomes (Krishna and Walsham 2005, Heeks 2006, Sahay and Walsham 2006, Kimaro and Nhampossa 2007). Reasons for failures are plentiful, scattering from a wide range of social and technical factors such as design-reality gap, complexities, shortage of competent human resources, poor supporting infrastructure, conflicting institutional logics, politics, etc. Practitioners and researchers have attempted many different approaches to remedy the situation. One of the prevailing ones is the conception of information systems as a system of systems or web of interconnected components. Researchers have coined this in the term information infrastructure (Monteiro and Hanseth 1996; Hanseth and Monteiro 1998; Hanseth 2010; Hanseth and Lyytinen 2010) (or digital infrastructure to distinguish them with other infrastructures such as railway, electricity, water pipe).

Defined as a complex social technical system, information infrastructure conveys its own characteristics (open, shared, social-technical, heterogeneous, and installed base) which differentiate it with traditional information systems. As a new kind of system, information infrastructure thus requires new methodologies in developing it. (Hanseth 2010) proposes a transition from design to the so called “cultivation”, a term that denotes the modular, gradual, and incremental build rather than all at once and builds upon something (installed base) rather than from scratch. Although this approach has shed lights on understanding how such contemporary systems are shaped, “more nuanced conceptualization” is needed to get better insight into “generative mechanisms” upon which they emerge, evolve, and scale (Aanestad and Jensen 2011; Henfridsson and Bygstad 2013).

In this paper, we deal with an essential research question “what are appropriate strategies to cultivate digital health infrastructure in the context of Vietnam?” We applied the concept of architectural knowledge and innovation (Henderson and Clark 1990; Andersson et

al. 2008) to understand the role of this kind of knowledge in mindfully cultivating the digital health infrastructure in a modular and incremental basis.

To answer that question, we used empirical data from a longitudinal and participatory action-led research conducted in Vietnam between 2010 and 2014 (Whyte 1991; Menard 2002). This node of action was part of the bigger network of action called Health Information System Program, an alliance of various types of institutions working in health information systems across continents (Braa and Hedberg 2002; Braa et al. 2004). In this action research, we started by building a system for licensing health professionals in Vietnam. The success of a bottom-up and user participant approach (Puri et al. 2004, Dearden and Rizvi 2008) in the first five provinces had convinced Ministry of Health to approve the country-wide implementation with a total of 63 provinces. This national scale in turn catalysed the assembling of other systems into the same infrastructure, making it bigger and more sophisticated.

The rest of paper is organized as follows. Theoretical consideration is performed in section 2, followed by presentation of the empirical case and research method (section 3 and 4). Section 5 provides analysis and findings whereas the discussion and conclusion are provided in section 6.

2. THEORETICAL PERSPECTIVES

2.1 Information Infrastructure

Information infrastructure (II) is one of research streams which deal with the evolution of large-scale and complex social technical systems (Aanestad and Jensen 2011). Hanseth and Monteiro (1998) define an II as a system having the following characteristics:

- Open in the sense that it allows unrestricted integration with other systems
- Shared in the sense that "infrastructures are shared implies that their parts are linked and they are defined as shared standards" (p.10, *ibid*)
- Heterogeneous means it is comprised by social and technical elements and the interplay between them
- Installed base in the sense that it must be built upon on something rather than from scratch.
- Standardized in the sense that it must embrace standards to establish gateways for data exchange.

Researchers have gone further on theorizing II with an ambition to produce a design theory for it. Hanseth and Lyytinen (2008) propose a design guideline for cultivating an II. They argue that II should be built in a stepwise and gradual manner rather than be designed and developed all at once because "*traditional models of rational, managerial decision-making are of limited practical relevance in the context of II management*" (p.163, (Aanestad and Jensen 2011)). By being cultivated upon something, II circumvents the inertia of installed base which often strongly resists any radical changes as in the case of planning based construction approach (p.163, (Aanestad and Jensen 2011)). The cultivation approach takes the middle ground in which it treats the significance of social and technical actors equally (Hanseth and Monteiro 1998). This is to avoid falling into neither extremes of technological determinism nor social determinism. Hanseth and Monteiro (1998) argue:

"Acknowledging the importance of the installed base implies that traditional notions of design have to be rejected. However, denying humans any role at all is equally, at least, wrong"
(p.160, *ibid*)

They admit that human actor, in this case “designer”, in fact “*does have influence - they might cultivate it*” (p.160, *ibid*).

To theorize II design, Hanseth and Lyytinen (2008) propose solutions to deal with two common design challenges: bootstrap problem and adaptability problem. Details of these solutions are summarized as follows:

Design problem	Explanation	
Bootstrap problem	Design initially for direct usefulness	The solution must persuade the initial users through targeting their needs and solving their problems; easy to use and implement; useful without a larger user base Exploit existing infrastructures, platforms or communication formats already in use; no need for new support infrastructures Generate positive network effects from extending the user base; before adding new technology, ensure that the user base has grown to sustain the added cost of development and learning
	Build upon existing installed base	
	Expand installed base by persuasive tactics to gain momentum	
Adaptability problem	Make the IT capability as simple as possible Modularize the information infrastructure	Make the information infrastructure as simple as possible (both technically and socially); promote overlapping IT capabilities Separate the layers of infrastructures from each other and exploit gateways to connect different layers

Figure 1: Solutions for Common II Design Problems (adapted from Aanestad and Jensen (2011) p. 163)

2.2 Architectural Knowledge

The concept of architectural knowledge implicitly proposed by Henderson and Clark (1990), however, becomes extremely controversial when moved to the context of IT. Software architecture is a widely accepted term to describe a specialization of software engineering which deals with overall design of software system at various levels. Literature on architectural knowledge in software domain is no doubt technological dominance. Indeed, in recent work by (Amazon et al. 2012), The Software Architecture of Open Source Software, the architectural design of around 50 influential OSS projects are narrated and focus on describing architectural issues such as frameworks, layers, scaling etc. In this research stream, there is an emphasis on the need of strategically managing architectural knowledge because of its vital role in success of product design and evolution. One of examples is the work of (Jansen and Bosch 2005). Jansen and Bosch (2005) claim that software architecture should be perceived as a set of technological decisions made along the evolution of a system. Technical decisions are important for system development as they explain the rational on technical choices given a wide range of inputs and help to avoid flaws in future decision. Unfortunately, documentation of architectural knowledge (or set of decisions) is often skipped in software development process because of various reasons. To remedy this problem, Jansen and Bosch (2005) propose to use a formal language which they call Archium to capture this type of knowledge.

Although this approach is too technologically deterministic, it helps to aware of the existence of a type of knowledge discussed in Henderson and Clark (1990): architectural knowledge, a type of knowledge with definitive characteristics. It is transient, emerging during system evolution, and vanishing when a sound architecture becomes stable.

So far, there is little discussion on architectural knowledge concept in IT literature. A recent work by Andersson et al. (2008) is a substantial contribution on expanding the concept. They use an action research approach within in the Swedish transport industry to cultivate a platform for inter-organisational collaboration aiming to facilitate inter-firm IT related innovation by harnessing the formation, circulation, and application of architectural knowledge. As a theoretical outcome, a model of architectural knowledge with four dimensions is identified including technical capacity awareness, business domain understanding, context-use sensitivity, and boundary-spanning competence. This model has its root from the transportation industry of Sweden. Given the situatedness and embeddedness of

knowledge in local context, using this theoretical model as a point of departure into our study (health care sector in a less developed nation) potentially generates more insights and new findings that could contribute to the theory of innovation and knowledge.

2.3 Architectural Knowledge for Modular Innovation

Also dealing with the concept of architectural knowledge, Baldwin (2010) uses a case study of Sun Microsystems and Dell Computer to identify types of architectural knowledge utilized by innovative firms in competing to other ones. According to her, knowledge of bottlenecks in the system and knowledge of potential remodularization are among two important kinds. First, finding a bottleneck in a system involves identifying either components (or modules) that have lowest performance or ones that have higher performance compared to their peers. After figuring out bottlenecks, firms can concentrate their resources on improving them while leaving other modules (non-bottleneck) to competitors. Second, seeking for parts of the system that cause performance issue and isolating them is another important facet of architectural knowledge. Splitting a troublesome modular into smaller components can help to reduce its complexity and allow more intensive resources poured into solving the problems.

We found the modular strategy proposed by Baldwin (2010) highly relevant to the cultivation of II because the strategy also attempts to solve the problem of installed base which characterizes an II. In entrepreneur, innovation can be considered as a process of challenging the incumbents by introducing new and better (whole or partial) solutions (Chesbrough 2003, Mario 2006; Tidd 2006). This process, however, will be intensely resisted by established networks with many advantages and plethora of resources. Therefore, this modular innovation concept proves to be very powerful in getting more insight on how II is “designed” or cultivated.

2.4 Modularization for Bootstrap Problem

Innovation literature unveils that by properly applying architectural knowledge, the one focuses on how modules work and interlay, small actors can disrupt the status quo and beat the dominance of well-established players. On the other hand, the bootstrap problem is perceived as the problem of how to establishing an II while “*initially the user community is non-existent or small precludes the fact that the infrastructure can offer these benefits.*” (Aanestad and Jensen, 2011, p.163). Therefore, we believe that appropriate modular strategies especially through architectural knowledge can help to address not only the adaptability problem but also bootstrap problem.

Furthermore, the modularization strategy described by Hanseth and Lyytinen (2008) is still very generic. We are certain that by applying four dimensions of architectural knowledge identified by Andersson et al. (2008), more tuned and nuanced guidelines on this particular strategy can be derived.

Therefore, in this paper, we tried to examine a case of cultivating health II in Vietnam via lens of architectural knowledge and II design theory. The overarching goals are to get insights to the role in which architectural knowledge play in shaping the II.

This theoretical conceptualization of architectural knowledge seems highly relevant to our study because of several reasons. First, the uniqueness in design of DHIS2 software, the core artefact that is playing central role in my action research, allows the flexibility of reconfiguration of its components at various levels. Second, the idea of using existing and available components and their linkages is similar to the bottom up, incremental and build upon an installed approach that is employed by HISP, the umbrella embracing this research.

From all described above, we come up with a conceptual framework used to analyse empirical data in this research. We term this approach as architectural cultivation which refers to a marriage between architectural innovation and II cultivation. We argue that by

deliberately (or mindfully) applying architectural knowledge, disruption of installed base can take place and II can start to grow even in an incremental pace. This architectural cultivation concept, we believe, can have an explanatory power in comprehending the evolutionary and generative process of II and on the other hand can contribute to design guidelines initiated by Hanseth and Lyytinen (2008).

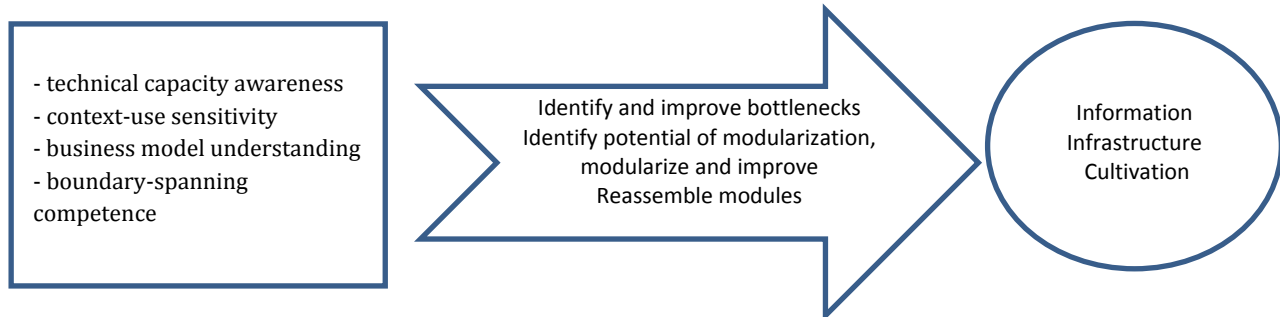


Figure 2: Theoretical Framework for Architectural Cultivation

3. RESEARCH METHODS

This research was informed by an interpretive scheme (Walsham 2006) and inspired by ethnographical approach. It was an action-based research and was part of a so called Network of Action (Braa et al. 2004). The network under which the was carried out is a Health Information System Program, a loose assembly of institutions from various types such as university, company, NGO etc. distributed across continents sharing the same interests in strengthening health information systems in resourced constrained settings. The first author of this article joined this network in 2004 the year when HISP initialized the transition from Access-based version of its flagship product District Health Information System to web-based and open source based. The second author joined HISP 10 years earlier (in 1993) and one of the founding members of this network. The third author got to know about HISP in 2009 and since then actively catalysed collaboration between HISP and Ministry of Health (Vietnam) in which he played the role of a specialist in charge of Information Technology.

Spanning for more than three years, this research can be considered as longitudinal one. This was consistent with most of other infrastructure action research which often lasted in a considerable number of years. Such length of time is needed for the infrastructures to get shaped and stabilized.

Data collection was done through daily engagement between the authors and the ongoing activities of the projects (Sahay et al. 2009) in more than three years. Set of activities is described in the following:

No	Type of activities	Means
1	Discussions, chats	Face to face, phone, SMS, emails
2	Internal and external meetings	Face to face, phone, SMS, emails
3	Building and deploying the system	On the system
4	Working with end-users	Face to face, phone, SMS, emails
5	Fixing bugs	On the system
6	Maintaining system	On the system
7	Writing reports	On the system
8	Supporting users	Face to face, phone, SMS,

	emails
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Table 1: Types of Activities which the Authors Engaged In

The main sources of data include participant observations, informal interviews, and document analysis. The following table describes details of these sources

No	Type of sources	Example
1	Participant observations	Observations performed in day to day team work, field visits to hospitals and provinces, or in meetings with other project stakeholders such as ADB PMU, Ministry of Health (MoH), provincial health departments, hospitals
2	Informal interviews	Informal interviews were conducted with interviewees from different institutions at different levels: hospitals, provincial, and national. Topics of interviews focus on requirement collection, comments and feedbacks to continuously improve the system.
3	Document analysis	Wide range of documents were used data for the research <ul style="list-style-type: none"> - Project reports issued by ADB PMU - Legal documents issued by National Assembly, Government, and Ministry of Health - System documentations include requirement, analysis, design, source code - User manuals and various training documents at different levels. - Bug tracking tools - Source code version control reports - Thousands of emails generated over three years - Data collected via the system and processed data in various forms: database, excel sheets, web pages

Table 2: Sources of Empirical Data

Data analysis was performed in an iterative process comprising many cycles. Raw data collection was processed by a number of techniques such as sorting, grouping, comparing to identify important patterns and themes. Outputs from these steps were then examined using theoretical frames. These initial findings were in turn used for guiding subsequent data collection and analysis. Therefore, data analysis took places in many stages of the research in various levels of thoroughness. For example, reflection writing which we often performed could be considered as a step of analysis process. Discussing and taking action on a particular issue were probably another form of data analysis. We deliberately use the dimensions of architectural knowledge to inform our data collection efforts by focusing on acquiring data that were relevant to matters such as business context sensitivity, technical capacity awareness, and boundary spanning competence. In order to make sense of the data, we constructed a table with cases as rows and architectural knowledge's dimensions as columns to fill with relevant facts and events which were coded in the previous phase of data analysis. This presentation of data allowed us to understand the interplay between different dimensions in separate cases.

4. THE CASE

4.1 Cultivating the Health Professional Licensing Module

On November 23rd 2009, Vietnam Assembly enacted a law of medical examination and treatment which was effective in January 1st 2011. The issuance of the law made was an important milestone in institutionalizing medical practicing activities in Vietnam. Three

subjects regulated by the law include medical practitioners (doctors, nurses), patients, and medical facilities (clinics, hospitals). The law enforces patient's privacy and prohibit bribes at any forms. Most importantly, medical physicians must be licensed before they can independently provide check-up and treatment services. To mitigate bureaucratic formalities, a license is granted for life time however holders need to provide proof of medical knowledge update (consecutive study). The law is expected to increase the quality of medical services as it legally frames medical practitioners with a set of dos and don'ts, and sanctions if they infringe them.

The law was followed by an issuance (by the government) of the decree (87/2011/NĐ-CP dated 27/9/2011) which was served as a detailed guideline on how to implement it. On November 14th 2011, Ministry of Health issued a circular (41/2011/TT - BYT) to detail formalities and processes of issuance of licenses for both health professionals and hospitals. The enactment of these legal documents happened just as the launch of the Health Human Resources Sector Development Program (HHRSDP) which was supported by Asia Development Bank (ADB) and Australian Aids Agency. The program spanned between 2012 and 2020, consisting of a number of subprojects among which one was to develop a system for processing licenses of health professionals and hospitals. The overall aims of HHRSDP were to "1) regulate professional qualifications and skill standards 2) monitor individual performance 3) take disciplinary action when problems arise 4) enforces continuous skills development". In the project proposal, ADB also emphasized that Vietnam among few countries in Asia did not have a functioning system to regulate and manage the registration of health workforce (ibid p2).

January 1st 2011 was the effective date of the Law of Examination and Treatment, however, there was yet a system to support provincial health departments in the licensing process. At that time, the second author was a medical doctor in charge of Information Technology (IT) and health statistics in Department of Medical Services Administration (DMSA) whereas the first and third authors were researchers doing action research under the umbrella of HISP network. The second author initially contacted the first author and asked for references to any international companies or institutions that had experiences in building national medical licensing systems. However, the discussion was detoured to an idea of building that system locally by extending open source software. Obviously, DHIS2 was selected as the second and third authors had been working on it for long time.

At first, we used a module called Tracker in DHIS2 to build a prototype. However, at that time (2011) the Tracker module was designed mainly for managing patients. The prototype based on Tracker was soon dropped as this approach demanded lots of major changes in the DHIS2 data model. Instead, we decided to build an independent module and plug it into the overall DHIS2 architecture. The module inherited all of DHIS2's infrastructural modules such as user management, authentication and authorization, organization unit maintenance.

After having first version of the system, we showed it to people in HHRSDP project. The chief consultant was convinced and he agreed to ask ADB for granting a start-up fund to build an interim system until the big firm was selected.

Thanks to this support, we had more resources to improve the system and develop more functionality. The second author sent the link of the system and account to his friends in some provincial health departments to request them for comments and persuade them to pilot the system in their provinces. There was one province responded enthusiastically to this request. This is a mountainous province located in the north and has border with China. With a small number of health professionals to be licensed, the doctor in charge of licensing work was able to enter all licensing applications to the system and process them electronically.

In a workshop organized by DMSA in the Ho Chi Minh City in March 2012, we met again a doctor (from now anonymously referred to as Dr Head) who used to attend a training conducted by HISP Vietnam in 2008. At the time we met again, Dr Head had become the head of the Medical Licensing Office of a next-door province of Ho Chi Minh City. He was willing to pilot this system on his province.

After returning to his office, Dr Head examined the system and made a list of comments to us. These comments were responded quickly. With his legacy data on Excel, we helped him to do the migration work so that he could work completely on the new system. Since then, he abandoned Excel and fully used the system for processing licensing applications. The first author was directly in charge of supporting the implementation in Dr Head's province. Lots of functionality developed for this province were later standardized and used in a national scale.

The success of the system in the two provinces helped to get buy-ins from MoH. In February 2013, the Director of DMSA issued an official dispatch to six selected provinces (including the two provinces which had implemented the system before), three in the north, two in the south, and one in the middle of the country, to pilot the system. This geographical scaling demanded more supports to be provided and more features to be developed. To cope with this growth, we recruited three developers and four facilitators. To effectively support the implementation distributed across the country, new members were assigned to two teams: one in Hanoi and one in Ho Chi Minh City. In the four new provinces, we received a number of comments and we quickly solved them in order to make the system satisfy local requirements.

Experiences in the first two provinces significantly contributed into success of the pilots in six provinces. Functionalities that were rigorously tested in the two provinces helped to build trust in the new provinces. Although there were certain special requirements in every province, they could be handled easily in an incremental basic. The result of the pilot was impressive. Out of the six provinces, five provinces fully processed license applications on the system. This outcome played an important role in persuading MoH to issue an official letter to request all other provinces to use this system.

To reduce workload for provincial health departments, hospitals were asked to register their staffs' licensing applications into the system. In order to meet this requirement, the system was expanded so that hospitals and provincial health departments could work together in the same applications. This feature significantly increased the number of users using the system, thus entailing more training and support. Fortunately, HHRSDP stepped in by organising many Training of Trainer (TOT) classes. Students of these TOT classes were licensing officers coming from provincial health departments. After completing the training, they went back to their provinces and could be able to use the system immediately. In the addition, they became trainers in training users from hospitals located in their provinces.

At the time of writing this article, the system had processed more than 230 thousands applications of health professionals comprising approximately 90% of total number of applications expected in Vietnam.

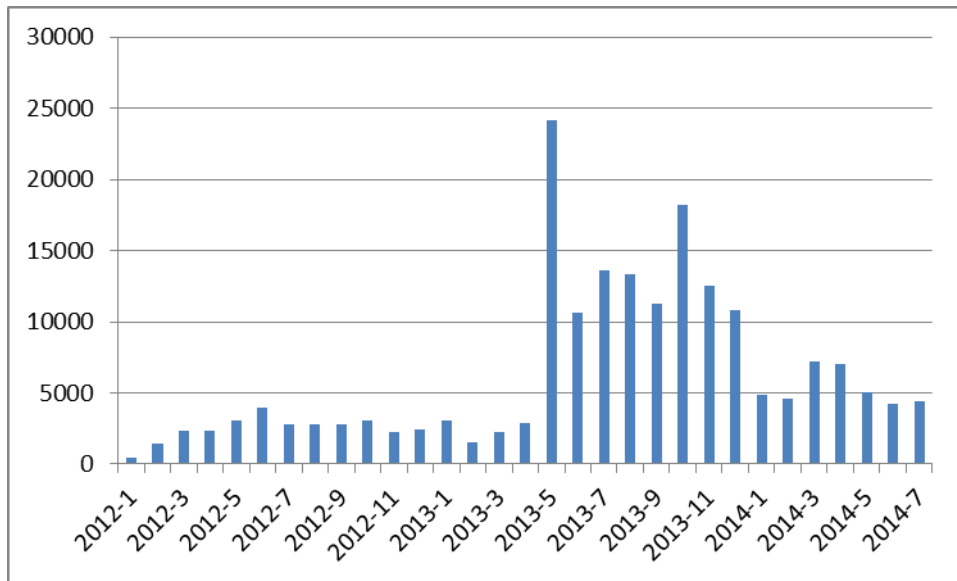


Figure 3: Number of Applications Processed by Month

4.2 Morphing the Health Facility Licensing Module to the Yearly Hospital Checking Module

During the implementation of the health professional licensing module, we received many requests from provincial health departments to have a module for licensing health facilities. As licensing offices in every province also have to grant health facility licenses, the integration of both the modules would make their work easier. In response to these requests, we have built this module and introduced it to some provinces. However, the licensing division at DMSA was not happy to see that move. They made a complaint to us and imposed us on ceasing the implementation of this module.

The destiny of this module diverged to a new direction when the head of the new founded office directly under DMSA (namely Quality Management) saw our module and realized that its functionalities fit well to their need of management of all health facilities in the country. Prior 2013, they used Excel to collect data from all health facilities. Every hospital submitted an Excel file to MoH. These Excel files were then merged into a big sheet using a macro. Nevertheless, this method was very prone to error and demanded lots of manual processing. There were lots of contentious ideas on whether to switch this Excel approach to the web-based module. Someone said it was too hasty to implement this module in a short of time and without adequate preparation. Others suspected the feasibility of the project when its scope was too broad while resources were too scant. The decision was only finalized when the Excel file was reported unable to handle the hospital ranking which required giving marks for more than 1500 criteria of each hospital.

With the approval of the Quality Management division, all political obstacles were removed. We concentrated on finding a solution to implement this module to all hospital as quick as possible. Unfortunately, the user base which we implemented for health professional licensing module could not be reused as reporting hospital operational data was responsibilities of Planning and Synthesis offices in hospitals. Another challenge was that DHIS2 did not have functionalities to create accounts in batch mode but one at a time. After consulting DHIS2 communities via mailing list, we decided to write small application to generate one account for each hospital. Each account had initial password which includes 4 digits (similar to a PIN code in ATM). The list of accounts was placed in an Excel file in which accounts of hospitals in each province was put in a distinct sheet. One team member

was assigned to send the sheet to corresponding provincial health department using email addresses that we collected during the implementation of health professional license module. From province, the accounts were dispatched to hospitals by variety of means: emails, phone calls, SMS.

After the system was launched, we set up a special team to handle inquiries and support all hospitals in Vietnam using the system. Most of the supports were done via phone calls; some special and difficult cases were processed via TeamViewer, an application that allows help desk team seeing the screens of the users to verify exact problems occurred. To encourage the hospitals using the system, we setup a special page crediting all the comments and bug reports of hospitals.

The deployment of this module was considered a success when more than 95% hospitals reporting their data. The following table summarized functionalities existing in this module

#	Feature	Type	Description
1	Hospital administrative data	Detail	Hospital name, address, contact information etc.
2	Operational data	Aggregation	185 data elements
3	Financial data	Aggregation	75 data elements
4	Human resource	Detail and aggregation	Detailed information of all staffs working a hospital
5	Hospital ranking	Aggregation	1500 criteria which were then grouped in 83 parent criteria.
6	Medical equipment	Detail	
7	List of allowed medical services	Detail	A sub-list of a master list of more than 15 thousands services

Furthermore, this module attracted buy-in from provincial health departments when many of them asked for using this module to report data of the first 6 months from hospitals within their provinces.

4.3 Plugging the Module for Vietnamese New Year Reporting

Following the success of the hospital checking module, the DMSA requested us to integrate the New Year reporting to the system so that hospitals could report their activities during the Vietnamese New Year. Three areas required reporting include traffic accident, food poisoning, and firework burning. This was a mixed module which collected both aggregate and detailed data.

By reusing the infrastructure created during the implementation of the hospital checking module such as user accounts, the deployment of this module went smoothly. The only technical challenge was that the standard DHIS2 data entry module displayed entry form by period (i.e. days) whereas in this New Year reporting module, everybody expected to see multiple periods (i.e. days) in the same form. However, this gap was bridged by the provision of a customized data entry module which allowed displaying many periods on a single data entry form.

No	Figures healthcare	Total	29 Year	30 Year	1st	2nd	3rd	4th	5th	6th	7th
			7:00 am 28/01 - 6:59 am 29/01	7:00 am 29/01 - 6:59 am 30/01	7:00 am 30/01 - 6:59 am 31/01	7:00 am 31/01 - 6:59 am 01/02					
Data elements as rows			Period as columns								
1	1. President of patients remaining in the day BEFORE ...										
2	* 2. Total number of emergency room visits, accidents	462	32	67	41	90	64	55	57	8	48
3	2.1. Total number of emergency room visits in Traffic Accidents:	63	5	16	13	11	6	4		6	02
4	2.2. Accidents due to firecrackers (BN list entry requirements in Section 6)	0									
5	2.3. Accidents caused by other explosive (BN list entry requirements in Section 6)	0									
6	2.4. TS causes other emergency	339	27	51	41		64	51	57	2	46
7	* 3. Total number of patients admitted to inpatient	48	8	8	3	3	1	5	5	9	6
8	3.1. Total surgery	45	7	8	3	4	1	5	4	8	5
9	Where: Brain Surgery Trauma caused by traffic accidents	0									
10	3.2. The total number of deliveries, including caesarean section at hospital	14	5	3	1	2			1	1	1
11	* 4. Dr. DEATH IN BV (INCLUDING PRE-HOSPITAL TV and salaries PLEASE ON TV)	0									
12	4.1. TV by traffic accidents (BN list entry requirements in Section 6.)	0									
13	4.2. TV by firecrackers (BN list entry requirements in Section 6.)	0									
14	4.3. TV by other explosives	0									
15	4.4. TV due to other causes	0									
5. Particular situation (if any):											
16	Record forms like structure Diaries Day ... / 01/2014 Evolution Processing Results ...										
17	6. Emergency patients List / deaths from firecrackers, explosives; deaths due to traffic accidents	Had function entry details. Please click on the link next to it to enter details of the case should be reported Enter details To view a detailed list please click View detailed listing here									
18	Full name of person in charge of BC Festival by date										
19	E-mail address										
20	Contact phone number										

Figure 5: Screenshots of the New Year Reporting Module

In 9 days of the Vietnamese New Year 2014, data from this module was officially used to announce to public and report to the Prime Minister. Data on patients hospitalized by firework accident were transferred to Ministry of Public Securities for further investigation.

4.4 Integrating the Patient Complaint Module

The year 2013 observed several unfortunate events to health care sector in Vietnam. In July 2013, three new born children died immediately after having Hepatitis B vaccine in a hospital. The cause was later identified as the nurse had used a poisonous drug contained in a tube which looked similar to the vaccine's one and injected this toxic for the three infants. In October, a cosmetic surgeon dumped customer's body to a river after this woman died in his surgery. So far, the body had not been found. Public was shocked and became very angry with these news. They blamed the MoH to be responsible for these scandals. To placate the public, the Minister launched a program called "hotline" in which every hospital, provincial health department, and Ministry published a mobile phone number and allocated staffs so that patients could make complaint at any time.

At the national level a local telecom company (now anonymously referred as TelecomA) voluntarily contributed their staffs to receive complaints that patients wanted to make directly to MoH via telephone.

To respond to this move, DMSA worked with us on developing a module to capture all the complaints and forward them to relevant organisations for further processing depending the scope and severity of the complaints. This module had feature to send notification by email to a hospital if it was a subject of a complaint. Email of each hospital had been collected during the implementation the hospital checking module thus gave us advantage on spreading complaints to hospitals.

At the time of writing this article, there was up to 1800 complaints received and processed in the system. Most of complaints sent to hospitals were investigated carefully and reports on the cases were replied to MoH.

4.5 Assembling the Epidemic Control Module

Early 2014 the north of Vietnam received a severe winter with extremely cold weather. In many provinces the number of patients especially children admitted and diagnosed with measles was significant compared to previous years. The situation became catastrophic when patients were voluntarily transferred to few national level hospitals in Hanoi. In here, many patients died because of nosocomial infection and other complications caused by the disease. However, Ministry of Health publicly reported only few dead cases relating to measles. The truth was only unveiled when a doctor working a hospital complained on Facebook that he felt depressed to see many patients died. One Deputy Prime Minister who was his friend saw this status and decided to visit the hospital. At the hospital he was told that more than 100 children had died. This news swiftly spread through media and angered the public.

There were many calls on social network for the Minister to resign and even calls for strike at the MoH's headquarter. Dispute was burst among government, health authorities, and public on the number of death caused by measles. Public blamed the MoH for disguising the severity of the epidemic to avoid responsibility. MoH argued that the actual number of patients who died because of measles was just a few. No one could provide out an exact number. The Department of Preventive Health (MoH) had implemented a commutable disease reporting system two years before. However, it only existed in 10 provinces over 63 provinces in Vietnam. Therefore, the idea to build an independent epidemic reporting system to collect data from all hospitals in Vietnam was discussed. It was highly supported by decision makers within MoH. An urgent dispatch signed by a Vice Minister was sent to all hospitals on May 13th 2014 requesting the hospitals to do daily reporting on measles (four more diseases were later added) starting from May 15th 2014.

Our team was asked to give support for this system because MoH realized that we had successfully deployed the New Year reporting system which was in principle very similar to this system. After customizing the entry forms (both detailed cases and aggregate data) to capture data related to the measles epidemic, we sent notification emails to all the hospitals. A copy of the dispatch was attached in every email. The system was welcomed by the hospitals. There were more than 300 hospitals reported data on the system. Data aggregated from this system were used officially for monitoring the epidemic on daily basis. As well as the decrease of the disease when weather in the north became warmer, the consistent and reliable data published every day helped to placate the public.

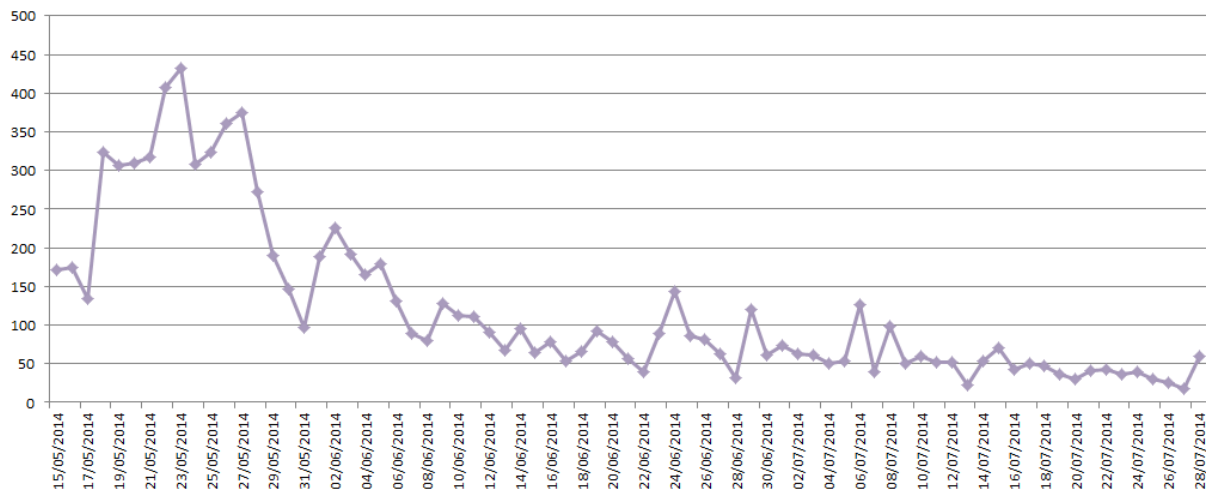


Figure 6: Number of Measles Patients Admitted between 15/5/2014 and 29/7/2014.

5. FINDINGS AND ANALYSIS

In this section, we try to analyse the case by the four dimensions defined by Andersson et al. (2008).

5.1 Technical Capacity Awareness

Andersson et al. (2008) define technical capacity awareness as “actors’ perception of the base service capability of a specific component IT base. The awareness of technological capability is governed by prior experiences pertaining to core technologies of the IT base” (p.35, *ibid*). In reality, the first and third author of this article had been engaged in the development of DHIS2 software since 2004. Because of this longitudinal involvement, every strengths and weakness of DHIS2 were highly aware by our team. For example, DHIS2 was renowned for its abilities of flexible collection of data, calculation of indicators, and various means of data analysis such as graphs and maps. In the addition, DHIS2 was experienced a broad market test in powering large scale national health information systems in a number of countries. The maturity of the software in dealing with high workload, great number of concurrent users, and constant resistance to malicious attacks was significantly improved along with its expansion of implementation.

More importantly, human resources which were cultivated and trained in a vast network of practice dealing with day to day DHIS2’s activities across the globe provide a reliable source of consultancy and backup in any negative scenarios. In particular, network of experts of HISP had saved the implementation of the licensing system in many critical circumstances. The first time happened when we initiated the transition from five pilot provinces to national wide. In the kick start training organized in the south with the participation of about 30 provincial health departments, the system was in trouble when its average response time surged. The training became very tense as no demonstration could be shown properly. When we accessed the server to figure out what was happening we found that the server memory was severely insufficient. This problem was strange to most of us as we did not have enough experience dealing with a web server. We asked for helps from a friend working for HISP who was expert in server. After some hours of working, he notified that the server was configured to use only 8 Gigabytes memory while it was physically equipped with 16 Gigabytes. He then helped us to activate another 8 Gigabytes memory. This timely support mitigated the impact of the server problem to the training, making it run smoothly in the following day.

5.2 Use Context Sensitivity

The sensitive understanding of local context came from the fact that the first and second authors are Vietnamese who had a long term of working in the Vietnam health care sector. This long exposure to day to day health activities at various levels helped the team to have sympathy with health workers, creating impulse on the team to do something to make the job of health personnel become easier. Furthermore, the second author was in charge of health statistics in MoH for more than 10 years. Being frequently asked by health managers and politicians for data, he understood thoroughly and exactly what were relentlessly needed by decision makers.

In the case of the licensing system, the ADB team in Vietnam was surprised when the second author told him about the idea of building a central database system that kept data of all health professionals who were awarded licenses. One consultant of ADB team admitted that he rarely heard such a visionary proposal from Vietnamese state workers. The idea came just as the Law of Examination and Treatment became effective, making it easily get accepted by ADB team because of the urgency of having such a system in the country. As insiders, we could convince ADB that benefits of having a centrally controlled system were enormous including reduction of costs when 63 provinces did not have to build their own systems and more importantly consistence and full coverage of data which would truly support decision making processes.

The assembling of other modules was also rooted in the sensitivity of context of use. For example, the patient complaint module was deployed when problems of the Vietnam health care system were largely visible and it became a target of increasingly criticised by public. The escalation of negative public reactions brought health managers to a highly political sensitivity and perplexed situation. Every mean and proposal to placate the public was considered, including the launch of the patient complaint system. The implementation of the hospital checking module was another example demonstrating the use context sensitivity. After some years of being used, the spreadsheet solution appeared to be incapable to deal with growing data and complex requirements. In 2014, no correct indicators were calculated due to a bug in Excel template sent to hospitals. The bug was discovered after all hospitals submitted their files, becoming too late to substitute the other template. The development and deployment of the hospital checking module was possible by a good understanding of the problems of the health care sector which were very situated and embedded in the Vietnam context.

The knowledge of the use context was proven crucial for infrastructure growth as in the case of communicable disease control module. This module was also developed and assembled to the core health II in Vietnam in a very critical moment. When the measles epidemic broke outs, MoH and its subordinate departments were troubled in getting timely, exact, and detailed data of patients contracted with the disease. There was a system being assumed to provide such data, however, it had been placed in few provinces. The second shortcoming of the system was that it relied on preventive health centres to collect data whereas hospitals were primary source of data. Understanding this gap was essential for our team to plug in the communicable disease control module which effectively helped fighting the disease.

5.3 Business Model Understanding

Regarding this dimension, to support this longitudinal cultivation of the health II we had relied on various donors. The start-up component, the licensing module, was funded by ADB. Apart from software development, this sponsorship included other activities such as training, data entry, and workshops which were covered by other actors. This collective endeavour was important to allow each actor to focus on areas that they had most experiences and

competence, thus increasing possibility of success. The subsequent expansion of the health II which involved assembling other modules was separately funded by World Health Organisation (WHO), German Agency for International Cooperation (GIZ), and European Union (EU) in Vietnam. The communicable disease control module, however, was sponsored from the state budget. This reality was not congruent to what was reported by Andersson et al. (2008) in which they portray business model understanding as the “*appreciation of business opportunities*” that are brought by the IT component (p.35, *ibid*). In our case, business model understanding should be perceived as the mobilization of actors in provision of various resources to sustain the whole infrastructure. This incongruence could be explained by the difference in nature between the sector examined in the case of Andersson et al. (2008) (transportation) and that in our case (health care in Vietnam) which traditionally follows a not-for-profit agenda.

5.4 Boundary-Spanning Competence

Andersson et al. (2008) describe boundary-spanning competence as thing that “*enables actors to redefine component knowledge in view of knowledge associated with other components of the architecture. Thus, it refers to practical skills and resources for engaging in collective efforts to develop architectural knowledge in an industry*” (p.35, *ibid*). We found this dimension interrelated to the strategies proposed by Baldwin and Von Hippel (2011). The concept of redefining component in association with other components could be specified as either identifying bottleneck and improving it or identifying potential of modularization or reassembling components.

In the addition, empirical data from our case study showed a slight variation in this dimension. In order to assemble different modules into the infrastructure, we had worked with multiple stakeholders who were in charge of such modules. For instance, the licensing module was managed by the Licensing Office within MoH and 63 provincial health departments. However, the patient complaint module was a joint effort between DMSA and Office of Ministry of Health (OMoH). The following table summarized this boundary spanning cooperation in aligning multiple stakeholders into the same infrastructure.

#	Modules	Key stakeholders	Sponsors
1	Licensing	Licensing Office	ADB
2	Hospital checking	Hospital Statistic Group	WHO, GIZ
3	Hospital quality	Hospital Quality Group	EU
4	Lunar new year report	Hospital Statistic Group	WHO
5	Patient complaint	DMSA, Office of MoH, and TelecomA	ADB
6	Communicable disease control	DMSA, Department of Preventive Medicine.	State budget

Table 3: Aligning Multiple Stakeholders into the Infrastructure

As diversity is a source of innovation (Eliasson, 1991; Almeida and Kogut, 1997; Bassett-Jones, 2005), this diversified web of actors and IT components facilitated the smooth assembling of many modules into the infrastructure. In other word, the cultivation process was catalysed by multilevel of boundary spanning which involved the configuration of both social and technical components to make the infrastructure effectively adapt to the rapid development of the local and situated health care sector in Vietnam.

6. CONCLUSION

Building an information infrastructure is often seen as contingent process due to the fact that its destiny is not decided by a single player or organisation but by a collective of stakeholders with conflicting and competing interests (Orlikowski 2010). For that reason, in many cases the outcomes of such attempts are contrasting to what was originally planned and sometime perceived as drift instead of control (Ciborra 2000). The most applicable approaches to design of such systems are ones proposed by Hanseth (2010): bootstrapping and adaptability. By allowing “*picking low hanging fruits*” (Braa and Sahay, 2012), these tactics help in quickly showing some results to attract more buy-ins and enrol more actors which ultimately will survive and sustain the network. This research contributes to further understand the bootstrapping and adaptability design areas by proposing a more nuanced approach to the problem. By applying four dimensions of architectural knowledge into reconfiguring of existing modules and introduce them in new use context, we try to show that cultivation can be done in various ways depending upon specificity of the circumstances. The research also brings more insights to the role of the little unexplored concept “architectural knowledge” in infrastructure generativity (Andersson et al. 2008; Henfridsson and Bygstad 2013). Practically, this research presented a case study on how a resource scant and centrally controlled country like Vietnam, that is often absent and voided in information system literatures, deals with the emerge and evolution of digital infrastructure (Walsham and Sahay 2006).

As an action research, this work also contributes to realization of health information infrastructure in Vietnam which is so far the unique system that reaches 100% coverage¹ (Braa et al. 2004). Findings of this research can inspire similar efforts in other settings that have analogous social technical conditions. As time and resources do not permit, we could not manage to dive into the detail of organisational change that took place in places the system was introduced. With a substantial number of hospitals (>1200), it promises a fruitful quantity analysis. Other areas for future research include in-depth case studies of separate systems involved in this research such as medical licensing system, hospital quality system, patient complaint system, and epidemic control system. Each of these systems could provide empirical materials for understanding the role of cultivation in incubating digital infrastructure and the driving force behind infrastructure’s growth and generativity.

BIBLIOGRAPHY

- Aanestad, M. and 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.
- Almeida, P. and Kogut, B. (1997). The Exploration of Technological Diversity and Geographic Localization in Innovation: Start-up Firms in the Semiconductor Industry. *Small Business Economics* 9, 1, 21-31.
- Amazon, L., Guo, X. and Xia, Z. (2012). The Architecture of Open Source Applications, *University of California Berkeley*.
- Andersson, M., Lindgren, R. and Henfridsson, O. (2008). Architectural Knowledge in Inter-organizational IT Innovation. *The Journal of Strategic Information Systems*, 17, 1, 19-38.
- Baldwin, C. and Von Hippel, E. (2011). Modeling a Paradigm Shift: From Producer Innovation to User and Open Collaborative Innovation. *Organization Science* 22, 6, 1399-1417.

¹ As of early 2014, all hospitals and health departments within the country use the system

- Baldwin, C.Y. (2010). When Open Architecture Beats Closed: The Entrepreneurial Use of Architectural Knowledge, Harvard Business School Working Paper: No. 10-063. Massachusetts: Harvard Business School.
- Bassett-Jones, N. (2005). The Paradox of Diversity Management, Creativity and Innovation. *Creativity and Innovation Management* 14, 2, 169-175.
- Braa, J. & Sahay, S. (2012) Integrated Health Information Architecture – Power to the Users. New Delhi: Matrix publishers.
- Braa, J. and 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. and Sahay, S. (2004). Networks of Action: Sustainable Health Information Systems across Developing Countries. *MIS Quarterly*, 28, 3, 337-362.
- Chesbrough, H.W. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business Press.
- Ciborra, C. (2000). From Control to Drift: The Dynamics of Corporate Information Infrastructures, Oxford University Press on Demand.
- Dearden, A. and Rizvi, H. (2008). *Participatory IT Design and Participatory Development: A Comparative Review*. Proceedings of the Tenth Anniversary Conference on Participatory Design, Indiana University.
- Eliasson, G. (1991). Deregulation, Innovative Entry and Structural Diversity as a Source of Stable and Rapid Economic Growth. *Journal of Evolutionary Economics* 1, 1, 49-63.
- 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. http://heim.ifi.uio.no/~oleha/Publications/ib_ISR_3rd_resubm2.html
- Hanseth, O. and 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. and Lyytinen, K. (2004) Theorizing about the Design of Information Infrastructure: Design Kernel Theories and Principles, Sprouts: *Working Papers on Information Environments, Systems and Organizations*, 4, 12, 208-241.
- Hanseth, O. and Monteiro, E. (1998). Understanding Information Infrastructure. <http://heim.ifi.uio.no/~oleha/Publications/bok.html>.
- Heeks, R. (2006). Health Information Systems: Failure, Success and Improvisation. *International Journal of Medical Informatics* 75, 2, 125-137.
- Henderson, R.M. and Clark, K.B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms, *Administrative Science Quarterly*, 35, 1, 9-30.
- Henfridsson, O. and Bygstad, B. (2013). The Generative Mechanisms of Digital Infrastructure Evolution. *MIS Quarterly* 37, 3, 907-931.
- Kimaro, H. and 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: <http://www.jhdc.org/index.php/jhdc/article/view/6>.
- Krishna, S. and Walsham, G. (2005). Implementing Public Information Systems in Developing Countries: Learning from a Success Story. *Information Technology for Development* 11, 2, 123-140.
- Mario, C. (2006). Classifications of Innovations: Survey and Future Directions, Institute for Economic Research on Firms and Growth-Moncalieri.
- Menard, S. (2002). *Longitudinal Research*, Sage.
- Monteiro, E. and Hanseth, O. (1996). Social Shaping of Information Infrastructure: On Being Specific about the Technology. In: Orlikowski, W., Walsham, G., Jones, M.R. and

- DeGross, J.I. (Eds) *Information Technology and Changes in Organizational Work*: Chapman and Hall: 325-343.
- Orlikowski, W.J. (2010) The Sociomateriality of Organisational Life: Considering Technology in Management Research. *Cambridge Journal of Economics* 34, 1 125-141.
- Puri, S.K., Byrne, E., Nhampossa, J.L. and Quraishi, Z.B. (2004). Contextuality of Participation in IS Design: A Developing Country Perspective. In *Proceedings of the Eighth Conference on Participatory Design: Artful Integration: Interweaving Media, Materials and Practices - Volume 1* (42-52). ACM.
- Sahay, S. and Walsham, G. (2006). Scaling of Health Information Systems in India: Challenges and Approaches. *Information Technology for Development* 12, 3, 185-200.
- Sahay, S., Monteiro, E. and Aanestad, M. (2009) Configurable Politics and Asymmetric Integration: Health e-Infrastructures in India. *Journal of the Association for Information Systems*, 10, 5, 4.
- Tidd, J. (2006). A Review of Innovation Models. Imperial College London.
- Walsham, G. (2006). Doing Interpretive Research, *European Journal of Information Systems* 15, 3, 320-330.
- Walsham, G. and Sahay, S. (2006). Research on Information Systems in Developing Countries: Current Landscape and Future Prospects. *Information Technology for Development* 12, 1, 7-24.
- Whyte, W.F.E. (1991). *Participatory Action Research*. Sage Publications, Inc.

SCAFFOLDING HEALTH INFORMATION INFRASTRUCTURE'S GENERATIVITY BY SCAFFOLDED GATEWAYS: THE CASE OF VIETNAM

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ABSTRACT

Standards and gateways are important components that play critical roles in information infrastructure (e-infrastructure) evolution. Surprisingly, little research has been conducted into this area. To fill that gap, we undertook a longitudinal action research study in the health care sector in Vietnam in the period between 2012 and 2015. The empirical work involved designing or cultivating, reconfiguring, (re)assembling multiple socio-technical components and transforming them into a larger health information infrastructure. To understand how gateways performed in our cases, we employed a concept namely “scaffolded gateways”, which was basically a hybrid between scaffoldings and gateways. We defined it as having three properties: interconnecting, supportive, and evanescent.

Keywords: health information infrastructure, scaffoldings, scaffolded gateways

1. INTRODUCTION

Information infrastructure (II) or digital infrastructure (DI) is increasingly playing important roles in our social, technological, and organizational life. In early discussions by Hughes (1987), infrastructure is a term that refers to “large technological systems” having their own patterns of evolution, being both socially constructed and social constructing. When turning to the information arena, various researchers perceive infrastructure differently. For example, inspired by Actor Network Theory (ANT) (Callon, 1999; Latour, 1996, 2005), Hanseth describes information infrastructure as a network of technical and non-technical components which is characterized by properties such as a shared, evolving, open, standardized, heterogeneous, and installed base (Hanseth, 2010; Hanseth and Braa, 2000; Hanseth et al., 2006; Hanseth and Lyytinen, 2008, 2010; Hanseth and Monteiro, 1997, 1998; Hanseth et al., 1996). On the other hand, Star and Ruhleder (1996) argue that the definition of infrastructure is a “fundamentally relational concept” (p.113), thus it is better to discuss when a thing becomes infrastructure rather than what an infrastructure is. They identify a number of parameters (dimensions) which could be configurable to “form an infrastructure” (p.113). Edwards et al. (2007) simply see DI as a “*set of organizational practices, technical infrastructure and social norms that collectively provide for the smooth operation of scientific work at a distance. All three are objects of design and engineering; a cyber infrastructure will fail if anyone is ignored.*” (p.8). Despite definitions of DI being relatively diffuse, they are analogous in various properties such as complexity, networked networks, heterogeneity of social-technical elements.

Although attracting growing interest from industry and researchers, DI has not been a main stream of information system (IS) research. For example, research performed by Tilson et al. (2010) identifies only 2% of papers published on Information System Research (ISR) which discuss infrastructure and only 5 papers that have infrastructure as a primary topic. Thus, there is a call to treat DI as a new species of Information Technology artifacts and put DI research into the center of the IS field (ibid).

In this paper, we attempt to enrich the body of knowledge of DI by examining a relatively un-explored concept used in the DI cultivation (aka design) approach, namely “gateway”. As a complement for “standard”, gateway is leveraged for the purpose of bridging unconnected networks (or different protocols, standards) to form a larger infrastructure as it is always cheaper and more feasible to link existing systems than rebuilding all of them using the same standards (Edwards et al., 2007; Egyedi, 2001). In addition, gateways play a critical role in mobilizing related parties and harmonizing their interests, making them accept the compromise, at the end it offers a final solution which will settle a closure for any “reverse salients” (Dedehayir and Mäkinen, 2011; Hanseth, 2001; Kaghan and Bowker, 2001). So far, most of the research on DI, which involves discussions of gateway only, seems to steer the analysis on the hardware or network level. The application layer (software, users etc.) of a DI which could potentially contribute many research findings and theoretical implications is rarely present in the II literature. For that reason, we are motivated on our quest to find answers for the following research question: *“How is a gateway characterized in the process of cultivating a digital health infrastructure in Vietnam?”*

To research this problem, we undertook a longitudinal (Menard, 2002; Ruspini, 2002), and action-led research project (Avison et al., 1999) in Vietnam between 2012 and 2015. The action part of this research involved building a number of (sub) systems for immediate requirements and thereafter bridging them up to assemble a larger health information infrastructure. Most of the modules of this infrastructure were built by extending, customizing, or adapting a free and open source software (FOSS), namely District Health Information System version 2 (DHIS2), which is governed and serviced by the Health Information System Program, a globally collaborative North South South network aiming to strengthen health management information systems (HMIS) in resources-constrained countries (Braa et al., 2007; Braa and Hedberg, 2002; Braa et al., 2004).

The remainder of the paper is organized as follows. We present our theoretical base in section 2. The research approach and case description are described in section 3 and section 4 respectively. Section 5 provides our analysis of empirical data and our findings before we conclude the paper in section 6.

2. THEORETICAL PERSPECTIVES

2.1 Information Infrastructure and Gateway

Information infrastructure (or cyber infrastructure, e-infrastructure) is a concept that has partly borrowed from large technical systems such as the railway, electric grid, and water pipe system etc. It was used to describe a novel phenomenon in which systems were interconnected into networks and then later webs of networks. Hanseth and Monteiro (1998) postulate that it is hard to give a clear definition of the notion of information infrastructure and suggest characterizing it by the following six attributes that differentiate an II from a traditional information system (IS):

- Enabling: an II often supports a broader use case than a strictly confined and specific application.
- Shared: an II is used by a larger community or user group as an irreducible unit or shared standard.
- Sociotechnical: an II comprises not only technical but also social components such as people, organization, rules, norms, and culture.
- Open: an II limit neither number of users or group of users nor nodes that could be plugged into it.

- Heterogeneous: an II has the ability to compromise variations of technologies, methods, approaches, and implementations to form a unity.
- Installed base: an II does not take a leap from scratch, it is incrementally built in the way that the new is added to the old and the old influences the new.

Being innate with these characteristics, an II is hardly ever designed and built in the traditional way as an IS. In addition, it is not feasible to construct II from scratch but rather cultivate “*a shared, open, socio-technical, heterogeneous installed base*” (Hanseth and Lyytinen, 2008, 2010). II is conceptualized as a big network comprising of multiple sub-systems, thus it needs different standards to interconnect these components. For that reason, standards certainly play an important role in the evolutionary process of II (Hanseth and Monteiro, 1997). However, the “open” attribute of an II drives it to a state of constant change in which it has to accept new connections or adapt itself to the new environment. This raises tension on existing standards, forcing them to change (Hanseth et al., 2006; Hanseth and Monteiro, 1997; Hanseth et al., 1996). In many situations, a “gateway” becomes a saviour for the infrastructure. Hanseth (2001) argues that gateways are very important elements in II although they are often ignored.

In its most general meaning, gateway often refers to a link or a connector between objects, elements, places, or networks. Applying it to information infrastructure, a gateway becomes an essential element for II growth because of the need of interconnecting existing sub-systems and components. As a consequence, a gateway is not the result of a failed design effort but rather a product of a deliberate and mindful cultivation process (Hanseth, 2001). Using the case of the Nordunet project in Scandinavia, in which a plug was used to enable interoperability among different network standards and protocols, Hanseth (2001) explained why a gateway is critical for II growth:

- A gateway allows learning and experience: II is such a large system that no person or organization could have time and resources to design and build different alternatives and test them out to pick up the best solution. Multiple small systems could have their own growing trajectory and the gateway helps to link them all into a big infrastructure.
- A gateway facilitates adaptation to changing environment. II must change frequently to meet new requirements. A gateway helps old and new components live together: the new provides new functionalities and the old is maintained without having to be entirely replaced.
- A gateway helps to deal with heterogeneity. An II always comprises of heterogeneous components thus a gateway is the right tool to deal with that as “*linking them through gateways may be easier and cheaper than moving to one shared protocol*” (ibid, p.15).

Since then, a gateway has been acknowledged as an important tool for II and has been attracting interest from II researchers. However, conceptualizations of the gateway still vary among researchers. For example, Egyedi (2001) examines the case of containerization in the cargo industry and eXtensible Markup Language (XML) in software industry and introduces the so-called “standardized gateway” or “gateway standard” referring to ones that act as standardized means linking up different social and technical worlds. While Egyedi (2001) views standard and gateway as one type, Hanseth (2001) contends that standards and gateways are two distinct types and have equally important roles in shaping the II’s growth and evolution. We prefer the latter as it offers a more nuanced approach in understanding the role of various components in the II development. Although the perception of gateways is varied, most of researchers agree that a gateway (or standard) is not merely a technology but a combination of a technical solution with a social choice (Edwards, Jackson et al. 2007).

To date, although there are increasing interests on gateways, the existing literature in information infrastructures often perceives gateways as sophisticated components which consume lots of time to build and are too rigid to be quickly changed and replaced. The extant literature also pictures gateways as long or ever-lasting components. See for instance, the Nordunet Plug (Hanseth 2001), the rotary converter ((David and Bunn 1988), the container and XML (Egyedi 2000, Egyedi 2001). Through our engagement in the development and implementation of the health information infrastructures in Vietnam, we realized the existence of various smaller components acting like gateways and playing a crucial role in bridging and connecting separate and diverse social-technical worlds.

Unlike most of the gateways discussed in the literature, these gateways lived shorter lives, usually disappeared without traces after accomplishing their interconnecting missions. Because of their disappearances, they have been often overlooked in the overall efforts toward building an information infrastructure. We argue this neglect could cause losses to the information infrastructure growth due to the significance of gateways.

2.2 Scaffolds, Scaffolding and Gateway

In explaining how knowledge is produced in practice, Orlikowski (2009) uses the metaphors of a scaffold, a structure used in the construction industry, to denote the process in which the learning process is materially supported and augmented. A set of features characterize a scaffold including temporal, flexible, portable, diverse, heterogeneous, emergent, dangerous, generative, and constitutive.

- Temporal: a scaffold does not last long, it exists for the duration of the project and disappears once the project is complete
- Flexible: a scaffold is robust so that it can easily fit in different conditions
- Portable: a scaffold is easy to be assembled/disassembled or moved to new locations
- Diverse: a scaffold is diverse in terms of types and purpose of use
- Heterogeneous: a scaffold is comprised of different elements in different types
- Emergent: a scaffold is “*erected over time, changing in form and function*” (ibid, p.5)
- Temporary stability: a scaffold “*affords a certain temporary stability to the disparate assembly of people, materials, and space bound together*” (ibid, p.5)
- Dangerous: a scaffold is can easily break down and fall (ibid, p.5)
- Generative: a scaffold facilitates “*the performance of activities that would have been impractical without material augmentation*” (ibid, p.5)
- Constitutive: a scaffold is “*constitutive of both human activity and outcomes*” (ibid, p.5)

Earlier, the term “scaffold” was dominantly used in education and language research where “scaffolding” referred to a teaching technique that leverages “*temporary support or assistance, provided by a teacher, peer, parent, or computer, that permits a learner to perform a complex task or process that he or she would be unable to do alone -- the technique builds knowledge/skills until learners can stand on their own, similar to scaffolding on a building*”¹. The work of Berk and Winsler (1995); Gibbons (2002); Reiser (2004) is in this genre.

In general, despite being used by different research communities in diversified nuances, the term scaffolding converges in two salient features: temporary and support. As discussed earlier, from our empirical data, we noticed that there was a special type of element that performs similar functionalities (bridging, linking, interconnecting elements such as

¹ [http://eric.ed.gov/?ti=Scaffolding+\(Teaching+Technique\)](http://eric.ed.gov/?ti=Scaffolding+(Teaching+Technique)).

subsystems, systems, worlds etc.) that a gateway usually does in addition to embracing the “evanescent” and “supportive” property which is commonly used in scaffolding context. Therefore, we propose a new concept, which is a hybrid between a gateway and scaffolding, namely “*scaffolded gateway*”. This concept refers to such elements in larger information infrastructures that convey characteristics of “*temporary, supportive, and interconnecting*”:

- **Interconnecting:** in the sense that its major role centers on bridging and linking up different technical (or social) worlds.
- **Supportive:** in the sense that it supports, bears, scaffolds, enhances, and articulates the generativity and evolution of electronic infrastructures. Supportive is also in the sense that it does not play any roles in the foreground but is underlying, invisible, and behind the scene.
- **Evanescent:** in the sense that scaffolded gateways come for a specific purpose and might later become less important or even extinct.

We believe that by rigorously examining these characteristics and the dynamics which scaffolded gateways perform in information infrastructures, insights would be drawn to help leaders, managers, and designers efficiently drive and cultivate the growth of infrastructures.

3. RESEARCH APPROACH

The first author of this article had a longitudinal engagement in Health Information System Program (HISP) which began with his Master study (in 2005) at the University of Oslo where HISP was originally initiated and coordinated. The second author was one of the founding members of the HISP network, involved in various efforts in bringing District Health Information System (DHIS) to Vietnam and cultivating a network to strengthen health information systems in the country. The first author was affiliated with a local company (now anonymously referred to as mCom) to work on the licensing system in the pilot and extension phase while the second author was an international consultant for the Component 1B, being responsible for overall architectural design and technical leadership of a larger system comprising totally 8 modules (including the licensing module). During the time between the pilot phase and the extension phase of the licensing system (2014-2015), the first author supported the Ministry of Health in building a hospital performance and quality management system as well as various other systems including a pilot electronic medical records exchange platform in 10 hospitals.

To answer the research question, we conducted a longitudinal and qualitative action research approach (Braa et al., 2004), which lasted between 2013 and 2015. To gather data for this research, various data collection methods of qualitative research tradition including participant observation, focus groups discussion, informal interview, and document analysis were used. The employment of multiple data collection methods helped gain better understanding of the studied phenomena and assured the validity of the research. Participant observations were applied to our daily interactions with the ongoing projects in activities such as discussions, meetings, and collaboration. However, as the authors were also busy with the development and implementation of the software systems, field notes of such observations were often written for important events such as weekly and ad-hoc meetings, field trips etc. Participant observations helped us understand better the work processes, practices, challenges, and expectations of key stakeholders as well as the development and implementation team,

In addition to participant observation, we extensively used document analysis to collect data for our study. As the software development team was based in Ho Chi Minh City while the most important end user, Ministry of Health, was based in Ha Noi, emails, chats and Short Message Service (SMS) were used to facilitate the communication and collaboration.

In just one year, i.e. 2014, the number of emails exchanged between the first author and an official from MoH exceeded 1000 emails. This number gave a sense of the volume of data that we had, particularly in electronic format. As we conducted a research that entailed development and implementation of software systems, source codes, blueprints, and other related documents became an important data source for study. We also consulted other legal documents that regulates healthcare service delivery, medical licensing, and medical insurance in Vietnam such as Law 40/2009/QH12, Circular 41/2011/TT-BYT, Circular 37/2014/TT-BYT, 03/2006/TTLT-BYT-BTC-BLĐTBXH, Circular 04/2012/TTLT-BYT-BTC etc. The document analysis method allowed us understand the political climates around the systems being built (legal documents), the practical problems and challenges that the development team and users faced, solutions provided to mitigate the problems, and the overall progress of projects, and reasons behind important technical and organizational decisions.

We also employed informal interviews and focus groups discussion to further understand interpretations of key participants on various facets of the systems. Informal interviews and focus group discussion were conducted during field trips, during or over tea breaks of meetings, workshops, and conferences organized to seek mechanisms of collaboration and solutions for many problems pertaining to the development and implementation of the medical licensing system as well as the electronic medical records exchange system.

The analysis process began with the iterative examination of the collected data, followed by ordering of key events in chronological order and defining codes that were associated with research objectives and theories. Larger themes identified after a number of reflections and re-reading the data were subsequently conceptualized to form the basis for theoretical constructs and propositions.

4. CASE DESCRIPTION

There are a number of cases involved in this study. As building or cultivating a large health information infrastructure is often a process of assembling (Nguyen et al., 2015) or grafting (Sanner et al., 2014) or reconfiguring (Sahay et al., 2009) one or many sub-systems (components) around an installed base, the presentation of multiple cases will help sketch an overarching picture of the infrastructure's evolution and growth. These cases are now presented.

4.1 Moving Data in Excel/Access to Cloud and Vice Versa (The Converter in the Medical Licensing System)

In 2013, the Ministry of Health of Vietnam launched a pilot study researching the health professional registration and licensing system in 6 provinces. The pilot generated positive outcomes and thus motivated leaders at the Project Management Unit of the Health Human Resource Development Program (HHRDP) and the Department of Medical Services Administration (DMSA) to roll out the system nationally. However, Vietnam has 63 medical licensing offices located in 63 provinces plus two central offices at the Ministry of Health which would pose a really big challenge for any full-scale efforts. Before piloting the medical licensing system, most of the provinces had granted medical licenses for health professionals without using software. In these provinces, the manual process of granting medical licenses was supported by various office utilities such as Word, Excel, or Access. Therefore, introducing a computer system to automate this process required moving these existing data into the system. This step was crucial in convincing provincial health departments to accept the system.

In the pilot phase, we helped Binh Duong province and Ho Chi Minh City to move their legacy data to the online licensing system by using a semi-automated approach in which we imported data from Excel or Access to a MySQL database. After that, we used several Structure Query Language (SQL) statements to alter data, making them align with the database structure of the licensing system. However, this approach appeared to be too complicated and difficult to scale out as every province had its data in different structures and formats. Therefore, we attempted a more generic approach which we hoped could work for many provinces without the need for modification. A PHP-based tool was developed to solve the problem. To save our scarce resources, the tool was built with only core functionalities and its graphical user interface was minimal. It had only one screen which allowed the uploading of Excel files and gave information about how many records were processed and imported. The user guide was also very simple containing just a few lines (in one internal email) describing how to run the tool. The underlying algorithm that drove the importing process built in the tool was relatively simple and straightforward. First, it opened the Excel file row by row, and then it parsed each row by cell. The order of a column indicated the meaning of value that it contains. For example, first column was the full name, the second column was used for gender, and the third column was the birth date etc. There were a total of 16 columns which could be categorized in four sections corresponding to several tabs on the registration form of the online licensing system, namely demographic section, educational background, internship and practicing experience, and result of the licensing application. The tab that was excluded in the importing structure was the list of accompanying documents which applicants submitted to the licensing office. The reason for removing these data was that we believed that they were only needed for processing applications but not for searching and analytical purposes. A sample of standardized Excel legacy data is depicted in Figure 1.

	A	B	C	D	E	F	G	H	I	J
1	Hoten	Gioitinh	Ngaysinh	SoCMND	NgaycapCMND	NoicapCMND	Diachi	Ngaynop	SoHS	VanbangCM
2	TRẦN VĂN TUẤN	Nam	04/12/1985	343454334	12/12/2000	Bình Thuận	13 Hùng Vương, Quận 5	08/01/2012	1093	Bác sĩ
3	PHẠM THỊ LAN	Nữ	30/08/1955	232345342	05/01/2001	Tp. Hồ Chí Minh	3 KP4, TX Thủ Dầu Một	08/02/2012	3920	Điều dưỡng viên
4										

	K	L	M	N	O	P	Q	R	S	T
	Daotao	Hanhnghe	Ketqua	Lydo	Yeucau	MaCC	Ngaycap	Noicap	Phamvi	
	01/05/2000:Trường ĐH y	1/2012-10/2012: Bệnh viện	Cấp phép			C23423	22/11/2012	Đà Nẵng	Khám chữa bệnh chuyên khoa Nội	
	05/06/2004:Trường ĐH y	1/2012-: Bệnh viện Chợ R	Chưa cấp	Thiếu tạm t	Bỏ sung xá	B234232	22/11/2012	Đà Nẵng	Thực hiện các kỹ thuật theo qui định	

Figure 1: Structure of the Excel spreadsheet used for importing data to the licensing system

Columns used in the Excel file and their meaning are described in Table 1

#	Column	Meaning
1	A	Full name
2	B	Gender
3	C	Birth date
4	D	Identity number
5	E	Identity issue date
6	F	Identity place of issue
7	G	Address
9	H	Application date
10	I	Application reference number
11	J	Types of health professionals
12	K	Educational history: combinatory field separated by semi colon (;) for every row. Each row was in turn separated by colon (:) to distinguish various values such as start date, end date, and place of study etc.
13	L	Internship and practicing history: combinatory field separated by semi colon (;) for every row. Each row was in turn separated by colon (:) to distinguish various values such as start date, end date, and place of practice etc.
14	M	Application result
15	N	Reason for rejection
16	O	Documents need to be complemented
17	P	Licensure number
18	Q	Licensure issued date
19	R	Licensure issued place
20	S	Scope of practice

Table 1: List of columns used in the Excel file and their meaning

One feature that distinguished this tool from other counterparts was that it allowed the conversion of multiple records of educations and experiences in one Excel row (which was equivalent to one application or one health professional record). Separated by a semi colon (;), each education (or experience) contained various sub-sections for other data values such as start date, end date, name of medical university (or hospital), title of degree (or position). This design helped keep the intermediate format simple and readable to humans while permitting complex data exchange which was only available in standard forms such as eXtensible Markup Language (XML) or JavaScript Object Notation (JSON).

After several testing cycles, the tool was ready, shortly before the national roll out of the licensing system. The tool was designed to work with Excel only; however, many provinces had their data in Microsoft Word format which was very arbitrary in terms of data presentation. Compared to Word, Excel is closer to database structures and easier to convert to a database. Therefore, our technical team had to spend lots of time cleaning data in Word files, copying them to a new Excel file, and placing various formulas in Excel to make the Excel file compatible with the tool. As there was no standard on data, every province had its own way to store data. This presented a big challenge for the integration of data from all provinces into a unified database.

It was not easy to get files from all provinces. Many of them were reluctant to send their files to the technical team because of many reasons. Some were too busy to make a compilation of dispersed files before sending. Others might think sending their data for

importing into the central database was not very important as the licensing system was still in the pilot phase. There were several provinces which the team had to contact several times via phone calls and email and even asked MoH for help in order to get the data files. Fortunately, at the end, the team could have files from all the provinces.

With the support from the tool, some 30,000 records of health professionals were imported to the system. This number was several times bigger than the total number of records manually entered by 6 pilot provinces in 4 months. This event created a great momentum which attracted and encouraged other provinces to adopt the system.

2013	1	3546
2013	2	1774
2013	3	2498
2013	4	3162
2013	5	23972

Figure 2: Surge in the Number of Records in the Licensing System when Using the Import Tool

Nevertheless, substituting Access/Excel/Word system by the online licensing system prevented users from using several powerful features which were only available in Access/Excel/Word. One of the important features was the merging of data from Excel to Word in order to support printing on pre-printed forms. A health professional license was a piece of paper containing demographic information of a health professional, scope of license, and issued date which was printed on pre-printed forms. These forms were exclusively issued by the Ministry of Health.

In fact, the online licensing system had functionality to deal with license printing, however configuring a template in Word and uploading to the system appeared to be unintuitive and hardly ever done by end users. In addition, every batch of pre-printed license papers was varying in size of margins and even paper size, making it a real challenge for support. Therefore, we decided to build a reverse system that dumped data from the online system to Excel. In order to ensure compatibility between the importing and exporting processes, we made the output Excel file look exactly the same as the input Excel file.

This approach received positive feedback from users, however, it brought a negative outcome for the printing functionality of the online system when licensing offices gradually skipped using the online system for printing, and instead they exported data to Excel and used merging to take care of printouts.

4.2 Lowering Barriers, Dealing with Uncertainty, and Standardizing Look Up Lists in the Licensing System (The Standardizer)

As the licensing system was developed in an evolutionary process, its features were incrementally built in close interaction and corresponding to feedback from end users. As a result, a proposed design of a feature could be easily substituted by another design which better satisfied end users. One salient example was that we had switched from using traditional select box to autocomplete box in order to increase friendliness of the system. The autocomplete approach allowed users to easily find and select an option by simply typing a few characters that are substrings of a value. For a list containing many options, i.e. more than 20 options, using the normal select box was time consuming for users because they have to scroll down through a long list. However, when substituting a select box with an

autocomplete box we faced another challenge in feeding the options for the autocomplete. For education history for example, each row would require one medical university/college to indicate where the applicant had obtained his/her degree. We had asked Ministry of Health (MoH) to provide us with such that list, however, they could not provide it because many medical universities and colleges in Vietnam are not directly managed by MoH but by Ministry of Education or provincial health departments. In addition, many health professionals had their education abroad thus creating a standard look up list which contained all pre-defined values such as medical institutions was a very challenging task. A common way to address this issue was to add an “Other – please specify” option which if selected would prompt a free text field for users to add a value that was not defined in the list. However, we decided to make a difference by introducing a feature that allowed users to pick a value from the suggestion list or enter an entirely new value to the box. This new value was then inserted into the look up list in a background process. Therefore, a value added by a user could be visible and pick-able by other users. This approach is very popular in global infrastructures such as Facebook or Google. We decided to use this design to help users to accelerate the input process with the hope that after some time, the look-up list would become full to accommodate the requirements of all users. Figure 2 depicts the analogy in the approach between the licensing system and Facebook.

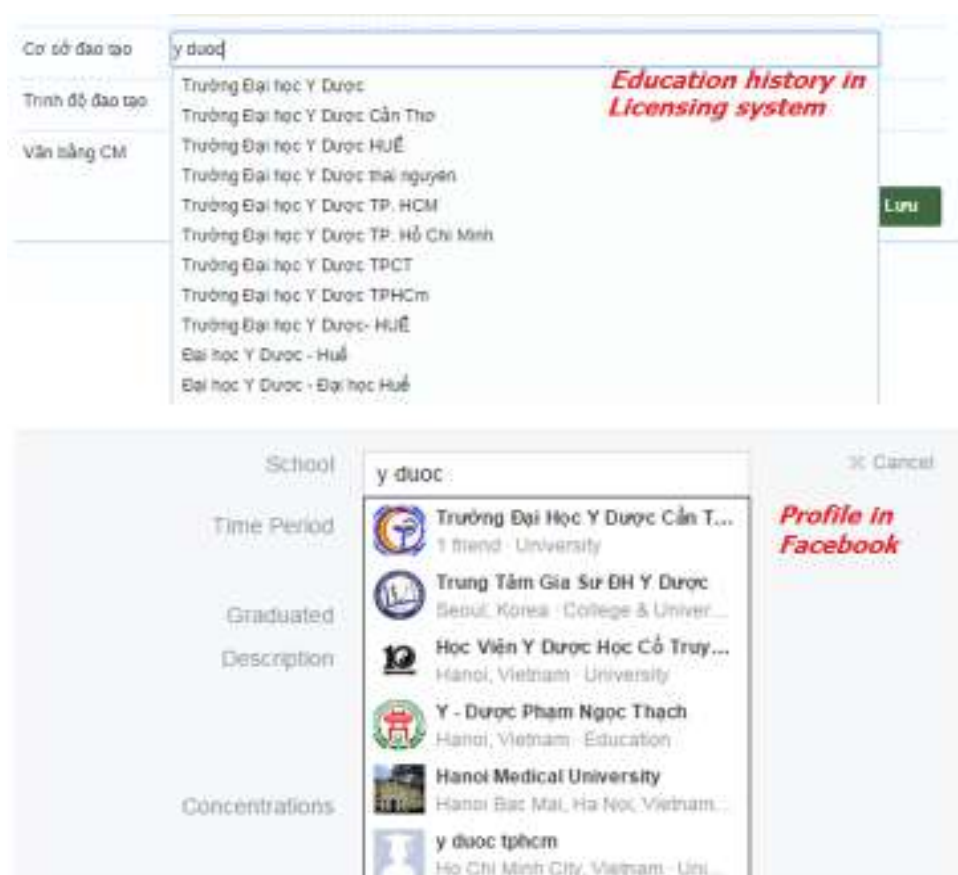


Figure 3: Screenshots of Education Section in the Licensing System and Facebook

However, the convergence was not as good as what we had expected. There were up to 10 thousands values of educational institutions added to the look up list with many duplicate values while there are some 240 thousand education history rows, meaning that on average every medical university/college trained only 24 health professionals which sounded very irrational. Therefore, we were under pressure to find a way to standardize this list. Only by standardizing this list, reports on who was trained and from what institutions could be

produced for decision making purposes. After several attempts, we accomplished a tool which we named “school pruner”, aiming to map all user-generated values to a standard list of medical universities/college in Vietnam. This tool comprised only one form with three juxtaposing list boxes. The first box listed all educational institutions working as a complete reference list to give users an idea on how the names of medical universities/colleges were entered by users. The second box displayed search results for a particular name. The third box showed a list of standardized medical universities/colleges. This list was created and refined by inputs from users. The mapping process was done by selecting multiple items in box 2 and one item in box 3 and committing the action by clicking the Clean button.

Find values, separate by comma (,)
by contain tên giang and not contain Search
Find values by sql Search

Clean

Box 1: All values

Box 2: Search results

Box 3: Standardized list

Figure 4: The “School Pruner” Used to Standardize the List of Educational Institutions

A member of the implementation team was assigned to work primarily on this task. However, other members could also take part in this process in their free time as the tool was a web-based tool. With the support of this tool, the licensing system could produce two important reports for management purposes: reports on the total numbers of health professionals who graduated from different universities/colleges and reports on the list of health professionals on a particular university/college. Although mining data from these reports was in its early phase, this kind of data facilitated evaluating the effectiveness of the medical training system in Vietnam and contributed a potent weapon in fighting fake diploma and degree which were a big problem in Vietnam². For example, in January 2015, the Department of Health in a northern province discovered 20 health professionals using fake diploma to practice³. This issue was not only notorious within Vietnam but also attracted international academic interest (Tse, 2015).

² <http://tuoitrenews.vn/society/18021/pundits-slam-use-of-fake-diplomas-at-state-agencies>.

³ <http://english.vietnamnet.vn/fms/society/121519/20-health-workers-in-thanh-hoa-use-fake-certificates.html>

4.3 Mapping Different Medical Service Standards for Electronic Patient Records (EPR) Exchange (The Mapper)

In EPR domain, having a standardized list of medical services among other standards is necessary in order to ensure interoperability and exchange of patient data. However, such a standard did not exist in Vietnam, thus challenging any efforts of implementing electronic patient record sharing and exchange. In early 2015, a Deputy Prime Minister of Vietnam made a resolution that Vietnam must leverage Information Communication Technology (ICT) in medical insurance claim and payment. Vietnam Social Security (VSS) and Ministry of Health (MoH) were assigned to jointly run this project with technical support from a state-owned Telecom corporation (now anonymously referred to as VCorp); later another company was also allowed to join. After many technical meetings among relevant agencies within VSS and MoH, everybody agreed that there must be a standardized medical services list (and other lists such as drug list etc.) to enable data sharing and exchange between medical facilities and VSS and MoH. However, none of these standardized lists were available. Vietnam had not adopted international standards for medical services such as ICD9-CM (The International Classification of Diseases, Ninth Revision, and Clinical Modification) or ICD10-PSC (The ICD-10 Procedure Coding System) on hospital management.

The earliest standardized medical service list was issued by a joint circular (Circular 03/2006/TTLT-BYT-BTC-BLDTBXH) among MoH and Ministry of Labour - Invalids and social affairs (MOLISA) and Ministry of Finance (MoF) in 2006 containing 1536 medical services categorized in several groups: checkup, bed cost, surgery, minor surgery, lab test etc. This list was released based on the calculation of input expenses such as labour cost, depreciation, material cost etc. for each service. The primary purpose of this circular was to set a ceiling price for each medical service provided in Vietnam avoiding overcharges and determining the rate of reimbursement of VSS to medical facilities. Six years later in 2012, the list was amended by another circular (Circular 04/2012 TTLT-BYT-BTC), expanding the list by 306 services and marking few outdated services which were no longer available. This list was adopted by medical facilities across the country. However, hospitals could set their own prices provided that the price was lower than the standard price. This led to a situation where the price of the same service was different between hospitals even if they were in the same grade, meaning that social insurance departments had to reimburse them differently.

In 2013, to fight against hospital overload issue in the country which two or three inpatients sharing the same bed was common⁴, MoH issued a circular (43/2013/TT-BYT) which aimed to classify medical services by hospital level. This circular was accompanied by a comprehensive list of medical services with more than 17,000 items grouped in 28 chapters. The circular divided hospitals into 4 levels: central, provincial, district, and ward. Hospitals at higher levels could provide more services than hospitals at lower levels. However, hospitals, depending on their technical capabilities, were encouraged to provide services of higher levels and decrease services that could be provided at lower levels. Based on such division of services, in theory, a health insurance agency could reject claims that included services which might be provided by a health facility at a lower level. MoH believed that this approach could effectively solve the issue of hospital overload when patients from provinces often bypassed local hospitals to seek treatment in big cities such as Ho Chi Minh City and Ha Noi.

In a separate development, the law on health insurance enacted by the Vietnam National Assembly effective from January 1st 2015 regulated that every medical service must

⁴ <http://www.thanhniennews.com/society/overloading-continues-to-plague-vietnams-major-hospitals-28206.html>.

have the same prices if provided by facilities at the same grade. According to this law, health facilities were categorized into 5 grades: special grade, grade 1, grade 2, grade 3, and ungraded. Implementing this law also required a standard list of medical services.

Because the list of medical services provided by the circular 43 was relatively ample, many hospitals proposed to use this list as the master list. However, the MoH explained that it was impossible to build prices for such a huge list of services in a short time. Instead, the MoH proposed to use the existing price list regulated by circular 03 and circular 04 amended with newly added services. Therefore, there were two lists of medical services co-existing separately. The Department of Planning and Finance (DoPF) made several attempts to link them up using a spreadsheet but they did not succeed. In early 2015, building on our long term relationship, after many projects in the MoH, we were asked to provide a tool to ease this mapping process.

A PHP-based tool was developed with an account management feature so that 28 specialist committees could work independently to perform the mapping of 28 chapters of circular 43 to nearly 2000 services included in circular 03/04. However, before this step, two important tasks had been done. First, was assigning each service in all circulars a unique code. This was easy in circular 43 because each service in each chapter was marked with a unique serial number thus code of service could be formed by formula: chapter number (.dot) sequence number. Nevertheless, it was more challenging in circular 03, 04 where sequence numbers of services were arbitrarily assigned and some service groups had no code or number. The second stage of transferring data from Excel to database was relatively simple. The main graphical user interface (GUI) of the tool is included in Figure 5, containing 3 boxes: services by circular 43, services by circular 03 and 04, and the result of mapping. There was also a history of mapping to keep track of changes related to a particular service (who changed it and when changes took place).

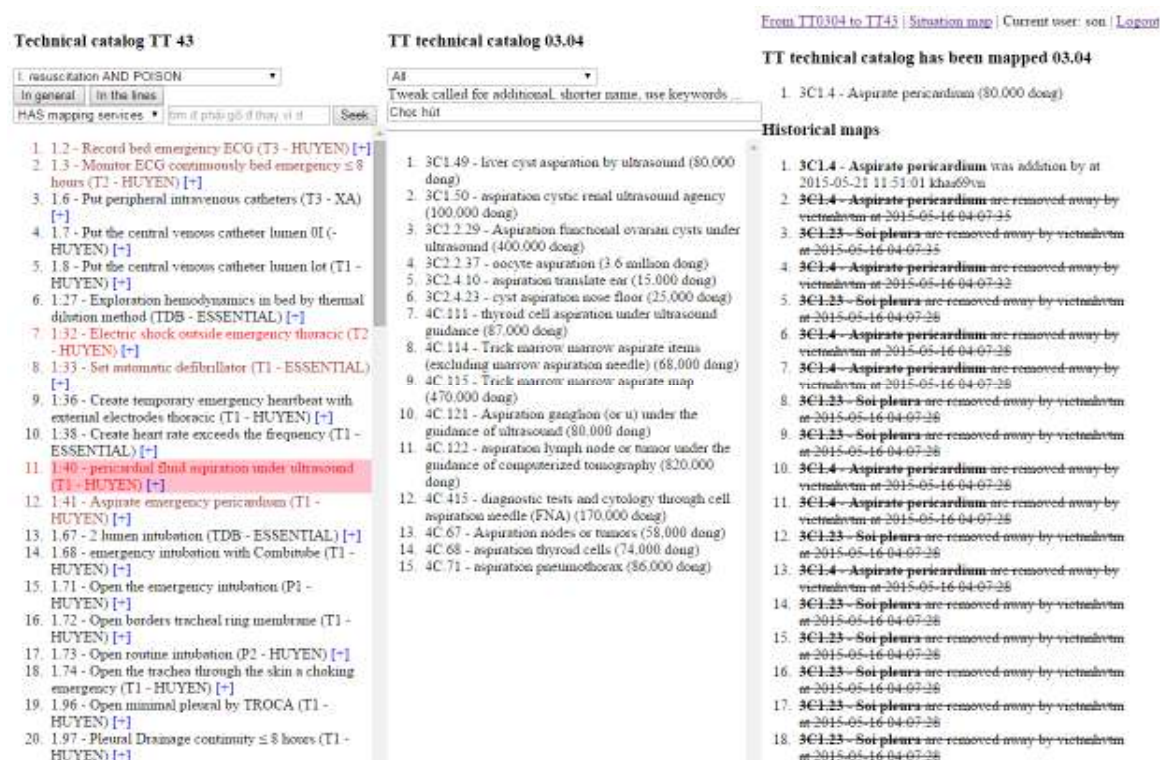


Figure 5: Screenshot of Main GUI of the Service Mapping Tool

Most of services in circular 43 could be easily mapped to a service in circular 03/04. However, there were a few services that required an expansion of the circular 03/04. Therefore, we built additional features to allow adding remarks for a mapping or classifying a service as unable to map or price update needed etc. Figure 6 shows the updated mapping status from different committees.

UPDATE mapped (HORIZONTAL VERSION)

Chapter	Total (including additional follow TT50)	Some have horizontal version	Percent%
I. resuscitation AND POISON	402	67	16.67
III. PEDIATRIC	4412	1774	40.21
II. INTERIOR DEPARTMENT	665	216	32.48
VIII. TRADITIONAL MEDICINE	497	396	79.68
VI. MENTAL	95	48	50.53
XVII. REHABILITATION	266	35	13.16
V. Dermatology	129	31	24.03
Surgical X.	1182	347	29.36
XXVII. Laparoscopic surgery	569	282	49.56
XXVI. VI SURGERY	65	44	67.69
XII. Tumor	459	335	72.98
XIII. WOMEN	247	70	28.34
XV. ENT	399	110	27.57
XVI. Dentomaxillofacial	350	51	14.57
XIV. EYES	306	172	56.21
XI. BURNS	190	23	13.16
IV. LAO	58	58	100
IX. Anesthetics	4783	29	0.61
XX. Diagnostic endoscopy INTERVENTION	117	44	VND37.61
VII. Endocrinology	256	5	1.95
XXI. PROBING FUNCTION	135	51	37.78
XXIII. Biochemistry	229	147	64.19
XXIV. Microbiology	358	54	15.08
XXII. The blood transfusion	707	290	41.02
XVIII. ELECTRO OPTICAL	753	666	88.45
XIV. NUCLEAR MEDICINE	422	221	52.37
XXV. Pathologist	115	64	55.65
XXVIII. COSMETIC PLASTIC SURGERY	516	10	1.94
Total	18 682	5642	30.2

Figure 6: The status of mapping aggregated from 28 committees.

5. ANALYSIS AND DISCUSSION

These three cases belonged to a larger health information infrastructure cultivation effort, and they all foregrounded critical roles of invisible components which we call “scaffolded gateways”. We now analyse and discuss their characteristics and implications in detail.

5.1 Interconnecting:

Interconnecting is an innate capacity of a gateway which is used to link “*two different networks or different communication protocols or standards*” (Hanseth 2001, p.1). In our case study, the first gateway which was the tool converting existing data in Excel/Access/Word to web/cloud data structure played the role of linking the two very separate worlds. Prior to the arrival of the cloud-based licensing system, most licensing offices used either Excel or Access (sometime even Word) to computerize their “systems”. These were more or less paper-based systems with little assistance from computers; however they worked quite well in their own settings with specific social cultural conditions. With an initially small number of licensing applications (which would absolutely increase in a short time), these approaches seemed to be robust, flexible, and attractive to adopt.

However, under the pressure of fighting against cheats such as fake educational degrees and counterfeit licensing, which prevail in Vietnam, moving from isolated systems to

a centralized system was critical and strongly pushed by MoH and sponsors such as the Asian Development Bank (ADB). The licensing system had good pilots in five provinces; however, scaling its implementation nationally was a challenge. To deal with that, the Excel converter played the significant role of bridging and interconnecting existing systems, assembling new components to ensure they function well in the large infrastructure.

The second gateway (the standardizer) was slightly different from the first one. It did not link two existing systems but created a bridge between an existing system and forthcoming systems. The introduction of this tool was essential for the support of the decision making process and strategy of health human resource development and planning because it provided sound data, demonstrating the effectiveness or ineffectiveness of an educational institution. Furthermore, this standardizer opened a way for new systems to evolve. For example, based on the standardized list of medical educational institutions, a system for managing long-term or short-term courses and their students could be easily grafted in because despite being small, it could offer immediately useful functionalities which could attract adoption and participation (Aanestad and Jensen, 2011; Hanseth and Aanestad, 2003). Therefore, the gateway in this case also played the role of an enabler or generator of infrastructure's growth. We could argue that scaffolded gateways did not only link existing systems (Hanseth, 2001) but also bridged an existing system with incoming systems, linking and assembling present and future.

The third gateway (the mapper) was also contrary to the other two when it did not link up any "electronic" systems. However, if we agree that e-infrastructure was heterogeneous, comprising social and technical components, this tool did not violate any criteria and truly qualified to be a gateway. The two social worlds which were circular 43 and circular 03/04 were developed in different times and for different management purposes: the first was for hospital overload reduction and the second was for entrenching the prices of medical services to avoid overcharge. They were two interrelated lists and supposed to be one or at least interchangeable but they did not. The existence of the two separate lists was a real impediment for shaping an electronic patient records (EPR) information infrastructure in Vietnam. Therefore, the mapper gateway did not only interconnect the two systems but also removed the obstacle that hampered the II's growth.

The empirical data challenges the current view on the role of gateway in the II evolution, which conceptualizes gateways as merely interconnecting components (David and Bunn 1988, Egyedi 2000, Egyedi 2001, Hanseth 2001). In our view, this standpoint has become obsolete in understanding the infrastructure growth. We believe that the notion of gateways should be viewed in broader contexts to cover places where they not only connect exiting components but also future systems.

In addition, recent literature emphasizes the role of architectures in shaping the II evolution, arguing that architectures that *"allow gradual scaling and growth tend to more flexible in seizing opportunities and facing uncertainties"* (Grisot et al. 2014, p.213). We believe scaffolded gateways are particularly suitable for such kinds of architectures. Scaffolded gateways work well in settings where the evolutionary and piecemeal approaches are preferred because they complement rather than replace the infrastructure. They gradually become part of the network and introduce changes in an incremental manner and in diverse ways (interconnector, enabler, impediment remover).

5.2 Supportive

We have conceptualized "supportive" as a property of scaffolded gateways because a scaffolded gateway often works backstage and enables the performance of other components.

In the three cases in this research, an end user could hardly see or feel the existence of any scaffolded gateways. For example, the standardizer was run by the technical team, not by end users thus the only thing they could see was the standardized education institution list shown next to the free text they had entered. The same is true in the case of the mapper, with its support, the two lists were later used (after being fully mapped) as if they were one. For example, a doctor would order a service which existed in circular 43 then in the payment system of the hospital this service was translated to a service in circular 03/04 or vice versus. Either way, no one could experience the presence of the gateway.

The supportive aspect of a scaffolded gateway can be summarized as follows:

- + A scaffolded gateway is invisible to actual users (end users)
- + A scaffolded gateway catalyzes the growth and scaling of II, creating a greater momentum for II's evolution.
- + A scaffolded gateway is not the core but the peripherals of the entire infrastructure.
- + A scaffolded gateway is often not on the original plan of infrastructure's decision makers but is a provisional and short-term solution for immediate problems.

So far, we have seen how scaffolded gateways performed in the three case studies. However, the level of support each gateway contributed to the overall infrastructure was relatively different:

5.2.1 *Enabling*

In the first case (the converter), the gateway was important but not critical in the sense that the infrastructure could still grow without its existence. Instead of using the tool to import legacy data in various formats to the online licensing system, project leaders might have hired some (or many) data entry clerks who would manually enter data to the online system. Lack of the converter might slow down the growth of the II but would have not stopped the II's evolution.

5.2.2 *Extending*

We would like to describe the extending ability of scaffolded gateways in the sense that it can establish connections between existing systems and forthcoming systems. The second case (the standardizer) clearly demonstrated this capacity of scaffolded gateways. Having a standardized list of medical educational institutions makes it easy to build and plug new systems such as medical educational institutions management system, health professionals' continuous training management system etc. into the infrastructure. These systems if constructed independently would demand substantial effort for implementation. Being plugged into the existing installed base (Hanseth, 2010), these systems would immediately generate values for users which would in turn attract more adoption and thus reinforce the infrastructure (Hanseth, 1998). For example, a licensing officer will be very happy if he could instantly verify if a diploma submitted by a health professional is fake or not.

5.2.3 *Critical*

Unlike the two above-analyzed cases, the third case (the mapper) was critical for the successful cultivation of the infrastructure. A standardized medical service list was essential for EPR systems and their interoperability. Without this, neither the EPR systems nor the medical insurance claim system could work. One can contend that every hospital's EPR can have its own service list governed locally. However, in order for them to be linked into an infrastructure in which patient and medical data could be shared and exchanged, the standard list is compulsory. Or one might argue that the two existing lists (circular 43 and circular

03/04) should be made obsolete and substituted by a completely new list which is probably a local version of international standards such as ICD9-CM or ICD10-PCS. That scenario would impose enormous rework and change in the overarching health systems in the country which nobody would welcome. In that case, there would be three lists must be maintained and require a mapping not only between circular 43 and 03/04 but also a mapping between the new list and the two existing circulars.

5.2.4 A Spectrum of Support Level that a Scaffolded Gateway Brings to II

Overall, scaffolded gateways offer a wide spectrum of effects on infrastructure which they are plugged into. This spectrum is summarized in Table 2:


Level of support	Enabling	Extending	Critical
Example	The converter	The standardizer	The mapper
Explanation	On this end of the spectrum, scaffolded gateway acts as a catalyst that accelerates the process of II's growth	In the middle of the spectrum, scaffolded gateway plays a more significant role in the II's evolution. It does not only speed up the II's scaling out (and up) process but also facilitates the generativity of II	On this end of the spectrum, scaffolded gateway is a critical component of the II. Without its presence, the II might not be actualized.
			

Table 2: Spectrum of Level of Support Which Scaffolded Gateway Give to e-Infrastructure's Growth

Orlikowski (2009) contends that scaffolding often becomes so familiar to our life that we hardly realize their existence. The same thing happens to scaffolded gateways. The supportive character makes scaffolded gateways almost invisible to their users. The visibility of scaffolded gateways has several implications. On the one hand, it downplays the significance of gateways in the II growth and draw attentions of stakeholders away from such important elements. On the other hand, it reduces the complexity of II as in the case of modularization and black-boxing. For instance, when two components are linked by a scaffolded gateway, they are merged into one component and function as one single module. The invisibility character, despite being important, is often bypassed by the II literature.

5.3 Evanescent

The last characteristic was a distinct nuance of scaffolded gateway which we would like to emphasize. Different from normal gateways but similar to scaffolds, scaffolded gateways are extinct once they have completed their missions. This is contrary to the extant literature. For example, in the cases of the AC-DC rotary converter or the Plug in the Nordunet, both of the gateways are retained to facilitate the on-going activities of infrastructure. In other words, they exist along with the infrastructure. The combination of supportive and evanescent characteristics makes scaffolded gateway become similar to a "scaffold". Scaffolded gateways

exist to facilitate, support, extend, and/or enable e-infrastructure's generativity. Scaffolded gateways are transitory, temporal, vaporous, and volatile when compared to the longitudinal evolution of II. The evanescent property was probably the reason why scaffold gateways have been overlooked and forgotten when cultivating an II despite their crucial roles in II's growth.

The evanescent property holds true for all the three cases we used in this research. First, the converter which transformed data from Excel/Access formats to the online licensing system was only actively used in the transition period between the pilot phase and the national rollout. After all data of health professionals were moved to the online system, the converter was no longer useful and abandoned shortly. Second, the standardizer which helped in building the standard list of medical educational institutions also ceased its services once the standard list was ready. Lastly, the mapper only worked for a short time, i.e. several months before it retired. There was functionality in the mapper to lock a certain chapter after its committee completed the mapping process. This was to prevent other committees to infringe services that were completely mapped. Overall, all the scaffolded gateways in our study were very short-lived and "*consequently dismantled*" (Orlikowski, 2006, p.5) after their missions have been accomplished.

Scaffolded gateways are plural in types and quantity, thus over the history of II's evolution, there would be multiple scaffolded gateways to come and go. The transitory property of scaffolded gateways brings more good than bad as it helps to some extent to keep the infrastructure slim and wiry.

Up to now, we have provided analysis on the three properties of a scaffolded gateway as summarized in Table 3:

Properties/The cases	The converter	The standardizer	The mapper
Interconnecting	Link legacy systems on Access/Excel/Word to online web-based system	Link an existing system with forthcoming systems	Link two social worlds, two medical service lists
Supportive	+Invisible to end users +Accelerate the growth of II	+Invisible to end users +Enlarge the scope of the current II and enable scaling	+Invisible to end users +Critical for medical data exchange
Evanescent	Ceased after several months of functioning, i.e. when all legacy data were migrated to the online system	Disconnected after the standard list of medical educational institutions was built	Retired when all the committees approved the mapping of services in their committees.

Table 3: Summary of Scaffolded Gateways' Properties and their Links to the Cases

The discussion of scaffolded gateways has implications for the debate over the role of standards, standardization, and flexibility in the information infrastructure growth. Some scholars argue that standard and standardization create path dependency and network lock-ins due to the increasing number of mobilized actors, artefacts, and users on the one hand and various social-technical decisions that have been made on the other hand. As a result, the networks become too big and rigid to be changed Hanseth (2001). Therefore, there have been calls for a relatively degree of flexibility to make infrastructures become extendable, evolutionary, and responsive to the ever-changing environment (Hanseth et al. 1996). This flexibility of infrastructure is similar to the flexible standard concept proposed by Braa et al. (2007), emphasizing the need to have flexibility in both use and change of standards over the course of the infrastructure growth. One might ask: how to achieve such flexibility? The answer comes from scaffolded gateways. First, the interconnecting property of a scaffolded gateway denotes its ability of bridging and linking heterogeneous social-technical components including the existing standard with large user base and a new and superior standard with no user (Hanseth et al. 1996). In this case, scaffolded gateways help remove network lock-ins and path dependency and thus enable flexibility.

Second, the supportive nature of a gateway makes it almost invisible to end users. We argue this character is inseparably associated with black boxing and modularization which are critical for gaining flexibility as stated by Hanseth et al. (1996): *“the only feasible way to cope with such a network [which is highly complex and of interconnected modules] is by modularization-that is, by decomposition or black-boxing”* (p.416).

Third, as discussed earlier, most of the conceptualizations of gateways so far overlook the transitory character that exists in some types of gateways. We argue this character offer a useful and powerful theoretical lens into understanding the underlying processes which scaffolded gateways are formed and faded away and how they increase flexibility in infrastructures comprising standardized components, technologies, and artefacts. The evanescent character of scaffolded gateways highlights the need of having temporal, situated, and provisional social-technical solutions that can quickly response to a change in the environment. Because they are easy to build, they can be ready in a short time. Because they are cheap to construct, they allow iterative experimentation and learning, meaning that a scaffolded gateway can be built and rebuilt many times until it can perfectly function. Because they are dismantled after their situated engagement with the infrastructure, they keep the infrastructure “lean” by removing all the unnecessary coupling and overlap between the constituted components of the infrastructure. As a result, the infrastructure becomes more flexible in adapting to changes.

6. CONCLUSION

All in all, the manifestation of scaffolded gateways in e-infrastructure was very much diversified and to some extent amorphous. It is quite a challenge to clearly consent that a component/element/object/actor in infrastructure should be classified or named as a scaffolded gateway. However, together with the emergence of more and more e-infrastructures, more evidence will be accumulated to give better judgments of this kind of components and their role in e-infrastructures’ evolution and growth.

We conclude this paper by reasserting the three properties that characterize a scaffolded gateway, namely interconnecting, supportive, and evanescent. Theoretically, the paper emphasizes the need of giving special treatment for silent and invisible components/elements that could substantially catalyze or even critically drive the outcomes and generativity of an e-infrastructure. Our contribution to II theory includes the introduction of scaffolded gateway concept, its characteristics, and different levels of effect they bring to

II's evolution. Furthermore, our work renews, connects, and extends the two unrelated concepts: scaffolding and gateway, highlighting their roles in II's development. In the extant literature, a gateway is often perceived as a long-lived and rigid component which is hard to build and change (see examples in Hanseth and Lyytinen, 2010). This view seems to be problematic and limits our understanding on the actual roles of gateways in II's growth and expansion. We call for a more flexible, provisional, and responsive view on gateways. This perspective is consistent with the approach proposed by Braa et al. (2007) which accentuates the roles of flexible standards that are "*well defined and simple [...] sensitive to the local context, allows change to occur through small steps*" (ibid, p.2).

On the practical side, the research contributes practical guidelines to efforts of cultivation and building e-infrastructures in settings that have similar socio-technical conditions to Vietnam. For example, by understanding the roles and characteristics of scaffolded gateways in II growth, project leaders must consider scaffolded gateways as key components rather than auxiliary ones, thus adequate resources should be invested in order to actualize them.

We believe there are many un-explored aspects of scaffolded gateways which in the scope of this research we were able to scrutinize. We hope that future research will be conducted into this area to deepen understanding on scaffolded gateways, their roles, properties, behaviors, and interplay with different socio-technical assemblages.

7. REFERENCES

- Aanestad, M. and 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.
- Andersson, M., Lindgren, R. and Henfridsson, O. (2008) Architectural Knowledge in Inter-organizational IT Innovation. *The Journal of Strategic Information Systems*, 17, 1, 19-38.
- Avison, D.E., Lau, F., Myers, M.D. and Nielsen, P.A. (1999) Action Research. *Communications of the ACM*, 42, 1, 94-97.
- Berk, L.E. and Winsler, A. (1995) Scaffolding Children's Learning: Vygotsky and Early Childhood Education. NAEYC Research into Practice Series. Volume 7 National Association for the Education of Young Children, 1509 16th Street, N.W., Washington, DC 20036-1426 (NAEYC catalog #146)
- Braa, J., Hanseth, O., Heywood, A., Mohammed, W. and Shaw, V. (2007) Developing Health Information Systems in Developing Countries: The Flexible Standards. *MIS Quarterly*, Special Issue on IT and Development, 31, 381-402.
- Braa, J., and Hedberg, C. (2002) The Struggle for District Based Health Information Systems in South Africa, *The Information Society* 18, 113-127.
- Braa, J., Monteiro, E. and Sahay, S. (2004) Networks of Action: Sustainable Health Information Systems across Developing Countries. *MIS Quarterly*, 28, 3, 337-362.
- Dedehayir, O. and Mäkinen, S.J. (2011) Determining Reverse Salient Types and Evolutionary Dynamics of Technology Systems with Performance Disparities. *Technology Analysis and Strategic Management*, 23, 10, 1095-1114.
- Edwards, P., Jackson, S., Bowker, G. and Knobel, C. (2007) Understanding Infrastructure: Dynamics, Tensions and Design, NSF Report of a Workshop: History and Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures. http://www.researchgate.net/profile/Paul_Edwards10/publication/30850107_Understanding_Infrastructure_Dynamics_Tensions_and_Design/links/0c9605239b029a3836000000.pdf.

- Egyedi, T. (2001) Infrastructure Flexibility Created by Standardized Gateways: The Cases of XML and the ISO Container. *Knowledge, Technology and Policy*, 14, 3, 41-54.
- Callon, M. (1999) Actor-Network Theory: The Market Test. *The Sociological Review*, 47, S1, 181-195.
- Gibbons, P. (2002) Scaffolding Language, Scaffolding Learning: Teaching Second Language Learners in the Mainstream Classroom: Portsmouth, NH: Heinemann.
- Hanseth, O. (2001) Gateways: Just as Important as Standards: How the Internet Won the “Religious War” over Standards in Scandinavia. *Knowledge, Technology and Policy*, 14, 3, 71-89.
- Hanseth, O. (2000) The Economics of Standards, in Ciborra, C.U., Braa, K., Cordella, A., Dahlbom, B., Failla, A., Hanseth, O., Hepsø, V., Ljungberg, J., Monteiro, E. and Simon, K.A. (Eds), *From Control to Drift. The Dynamics of Corporate Information Infrastructures*, Oxford: Oxford University Press, 56–70.
- Hanseth, O. (2010) From Systems and Tools to Networks and Infrastructures: From Design to Cultivation: Towards a Design Theory of Information Infrastructures. *Industrial Informatics Design, Use and Innovation*. IGI Global, Hershey, PA, 122-156.
- Hanseth, O. and Aanestad, M. (2003) Design as Bootstrapping. On the Evolution of ICT Networks in Health Care. *Methods of Information in Medicine*, 42, 4, 384-391.
- Hanseth, O., and Braa, K. 2000. Who’s in Control: Designers, Managers or Technology? Infrastructures at Norsk Hydro, in: Ciborra, C.U., Braa, K., Cordella, A., Dahlbom, B., Failla, A., Hanseth, O., Hepsø, V., Ljungberg, J., Monteiro, E. and Simon, K.A. (Eds) *From Control to Drift: The Dynamics of Corporate Information Infrastructures*, Oxford: Oxford University Press, 125-147.
- Hanseth, O., Jacucci, E., Grisot, M. and Aanestad, M. (2006) Reflexive Standardization: Side Effects and Complexity in Standard Making. *MIS Quarterly*, 30, 1, 563-581.
- Hanseth, O. and Lyytinen, K. (2008) Theorizing about the Design of Information Infrastructures: Design Kernel Theories and Principles. <http://heim.ifi.uio.no/~oleha/Publications/ISRinfrastructurefinal05-12-05.pdf>.
- Hanseth, O. and 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. and Monteiro, E. (1997) Inscribing Behaviour in Information Infrastructure Standards. *Accounting, Management and Information Technologies*, 7, 4, 183-211.
- Hanseth, O. and Monteiro, E. (1998) Understanding Information Infrastructure. <http://heim.ifi.uio.no/~oleha/Publications/bok.html>.
- Hanseth, O., Monteiro, E. and Hatling, M. (1996) Developing Information Infrastructure: The Tension between Standardization and Flexibility. *Science, Technology and Human Values*, 21, 4, 407-426.
- Henfridsson, O. and Bygstad, B. (2013) The Generative Mechanisms of Digital Infrastructure Evolution. *MIS Quarterly*, 37, 3, 907-931.
- Hughes, T.P. (1987) The Evolution of Large Technological Systems, *The Social Construction of Technological Systems*, in: Bijker, W.E., Hughes, T.P. and Pinch, T.P. (Eds) The MIT Press, 51-82.
- Kaghan, W.N. and Bowker, G.C. (2001) Out of Machine Age?: Complexity, Sociotechnical Systems and Actor Network Theory. *Journal of Engineering and Technology Management*, 18, 3, 253-269.
- Latour, B. (1996) On Actor-Network Theory: A Few Clarifications. *Soziale Welt*, 47, 369-381.
- Latour, B. (2005) Reassembling the Social: An Introduction to Actor-Network-Theory. New York: Oxford University Press.

- Myers, M. (1999) Investigating Information Systems with Ethnographic Research. *Communications of the AIS*, 2, 4, 1-20.
- Menard, S. (2002) Longitudinal Research (2nd Edition): (Vol. 76) Quantitative Applications in the Social Sciences. Thousand Oaks: Sage Publications
- Nguyen, T.N., Ha, S.T. and Braa, J. (2015) Assembling a National Health Information Infrastructure: The Case of Vietnam. *Electronic Journal of Information Systems in Developing Countries*, 66, 7, 1-18.
- Nilsson, A., Grisot, M. and Aanestad, M. (2002) *Electronic Patient Records: An Information Infrastructure for Healthcare*. 25th Conference on Information System Research in Scandinavia, Bautahøj, Denmark.
- Orlikowski, W.J. (2009) The Sociomateriality of Organisational Life: Considering Technology in Management Research, *Cambridge Journal of Economics*, 34, 125-141.
- Orlikowski, W.J. (2006) Material Knowing: The Scaffolding of Human Knowledgeability. *European Journal of Information Systems*, 15, 5, 460-466.
- Reiser, B.J. (2004) Scaffolding Complex Learning: The Mechanisms of Structuring and Problematising Student Work. *The Journal of the Learning Sciences*, 13, 3, 273-304.
- Ruspini, E. (2002) Introduction to Longitudinal Research, Routledge, London.
- Sahay, S., Monteiro, E. and 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., Manda, T.D. and Nielsen, P. (2014) Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation. *Journal of the Association for Information Systems*, 15, 4, 220-243.
- Star, S.L. and Ruhleder, K. (1996) Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research*, 7, 1, 111-134.
- Tilson, D., Lyytinen, K. and Sørensen, C. (2010) Research Commentary: Digital Infrastructures: The Missing IS Research Agenda. *Information Systems Research*, 21, 4, 748-759.
- Tse, E. (2015) Identifying Fraudulent Credentials From Internationally Educated Nurses. *Journal of Nursing Regulation*, 6, 1, 57-61.

Scaling Information Infrastructures: The Case of the Medical Licensing System in a Southeast Asian Country

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Abstract

Scaling health information systems from small-scale pilots to national systems in developing countries poses a key challenge to systems designers and health managers. Consequently, many projects dissolve and die before they reach the scale where they are useful for information management. The concept of bootstrapping, from the information infrastructure literature, has proven useful for discussing and understanding how to initiate and grow large-scale, complex and networked information systems from scratch. We use the concept of bootstrapping to analyze and discuss an empirical case of building a large-scale medical licensing system in a Southeast Asian country. Beyond describing the process leading up to the success of the licensing system, we contribute to the literature by identifying a range of factors influencing the bootstrapping process, and we suggest methods of making the bootstrapping strategy relevant in this context.

Keywords: information infrastructure, medical licensing, Southeast Asia, bootstrapping, scaling

1 Introduction

Health information systems (HIS) are a key component of national public health infrastructure (AbouZahr and Boerma, 2005). Timely and accurate data effectively support decision makers in making sound decisions relating to disease intervention, resource allocation, etc. (Hinh and Van Minh, 2013). The role of HIS is even more critical in contexts of developing countries where resources are scarce and fatal diseases are rampant (Braa et al., 2004). Despite substantial investment, many HIS implementation initiatives have not delivered outcomes as expected, and many projects end before they become fully functioning. Other initiatives are not able to achieve the necessary coverage to provide useful information for health managers. These challenges are related to processes of scaling (Sahay and Walsham, 2006), which means that a system must be expanded both technically and geographically to become sustainable (Braa et al., 2004). The existing literature discussing the scaling of information systems focuses on what is scaled and how it is scaled (see for example: Sahay and Walsham 2006). There are few studies that attempt to address the issue of scaling strategically, i.e., how to scale an information system.

To deal with large-scale and complex information systems, which also include HIS in developing countries, there is a stream of research which conceptualizes such systems as information infrastructures (Hanseth, 2002). Through this perspective, an information infrastructure (II) is characterized as a shared, evolving, open, standardized, and heterogeneous network (Hanseth and Monteiro, 1998). The role and the significance of information infrastructures (IIs) is getting attention from governments, academics, and the industry (Aanestad and Jensen, 2011; Ciborra, 2000; Cordella, 2006). Unlike the isolated,

disconnected, and single-owner information system prevailing two and three decades ago, IIs are complex networks comprising multiple information systems and actors with parallel and often conflicting interests (Nielsen and Sæbø, 2015; Sahay et al., 2009). IIs are described as assemblages of heterogeneous socio-technical components (Rodon and Hanseth, 2015) which relentlessly undergo stabilizing/destabilizing processes around innovation and what already exists—their installed base (Hanseth and Lyytinen, 2010).

Traditional approaches used in software engineering and information systems development are not sufficient for building IIs due to the ambiguity, multiplicity and ever-changing nature of user requirements to be met, and the complex and inter-organizational relationships between multiple and different systems, developers and users (Sommerville et al., 2012; Star, 1999; Star and Ruhleder, 1996). These complexities challenge existing knowledge, organizational structures, and IT governance, and are described as reasons for either total or partial failures of IIs (Ciborra, 2000). To tackle this situation, a growing body of research is trying to identify and understand the favourable conditions that enable successful II growth (Grisot et al., 2014; Sanner et al., 2014) and the mechanisms that contingently drive the evolutionary trajectories of IIs (Henfridsson and Bygstad, 2013). Unlike that of a traditional information system, the trajectory of an II cannot be fully controlled by one or a few actors based on planned and structured requirement engineering, implementation and governance. This is because an II does not have a single owner and its boundaries are constantly redefined (Hanseth and Lyytinen, 2010). For example, Jensen (2013), in her discussion of the case of building integrated healthcare information systems in Denmark, highlights system flexibility, strategic modularity, and the role of actors as key mechanisms to consider in understanding and dealing with the evolution of IIs.

As an II is highly complex and not in central control of a single actor (Nielsen and Aanestad, 2006), fully managing and controlling its trajectory of development is not possible. At early phases of II development, convincing initial users to adopt an II is a particularly challenging task since use typically cannot be mandated and the use value of an II is directly related to the number of other users (Hanseth and Lyytinen, 2010). Following this, another problem that II designers have to deal with is how to grow the initial small user base to a critical mass where the network attracts enough users and starts to grow on its own (Hanseth and Aanestad, 2003). The process of continuously growing the user base of an II with little or no external assistance is described by Hanseth and Aanestad (2003) as “bootstrapping”. With network technologies, the value attributed to the network by the user will depend on the number of other users. For example, the first user of a mobile phone network will see no value in the network until there are other users she would like to call or receive calls from. In settings where use is optional, but also where it is mandated, bootstrapping is about how to make such a network without value grow. It is about identifying the most adequate user for enrolment, and then building on and drawing upon the installed base of users and technology to grow an II further. With bootstrapping, user preference is not treated as static but changing, and depends upon the preferences and actions of others. According to Hanseth and Aanestad (2003), users' knowledge and motivation, use situation, nature of the technology, and coordinating institutions are four factors that affect users' preferences and thus will shape their adoption decision.

To understand how different factors influence the bootstrapping of IIs in the context of HISS in developing countries and to tease out strategies and tactics for system developers, we conducted a longitudinal case study that involved the initiation, development, implementation and evolution of an II used for managing medical licensing processes in a country in South East Asia between 2012 and 2015. Through a bottom-up and iterative process, a prototype was developed based on an open source software system specifically designed for the healthcare sector. This prototype was gradually and incrementally scaled to be fully functional in the whole country as the *de facto* medical licensing system (hereinafter the Licensing System). By December 2015, the Licensing System was adopted by all public hospitals (more than 1500) and all provincial health departments (63) and had processed nearly 300,000 health professionals' licensing applications.

The rest of this paper is organized as follows. A review of extant literature on IIs, bootstrapping and related concepts is provided in section 2. Section 3 and section 4 present research methods and the case respectively. Our analysis of the case is offered in section 5 followed by conclusions in section 6.

2 Related Literature

The problem involved in building and scaling IIs has received substantial focus in the extant II literature (Hanseth et al., 1996). Recently, the problem has attracted the interest of researchers from the software engineering field (Sommerville et al., 2012). This issue of building and scaling also exists in discussions related to information system architectures and platforms (Woodard, 2008; Herzhoff et al., 2010). Due to the complexities and distributed control of IIs, the building and scaling of IIs are often described as a process which always unfolds in small-scale and evolutionary steps. IIs develop because they have a life on their own without being controlled by human agencies, as described by Dahlbom and Janlert (1996): “*the tomatoes themselves must grow just as the wound itself must heal*” (p.6). Due to the limited control of human agencies, the trajectories of II growth are thus subject of unintended and unanticipated consequences and drift (Ciborra, 2000). It becomes problematic in domains such as health information system (HIS) when an HIS can only become useful when it is expanded to reach a certain geographical coverage, i.e., a district or a province (Sahay and Walsham, 2006; Sæbø, 2013). Indeed, many pilot HISs have died because they could not provide data useful for health managers (Braa et al., 2004). Strategies to influence II evolutionary growth in the situation of lack or limited control are thus crucial for II building efforts. To address the problem of building up the user base from scratch, II literature offers the concept of bootstrapping, which refers to the process of building a large network through initially using minimal resources, i.e., making an II grow by itself (Hanseth and Aanestad, 2003).

Hanseth and Aanestad (2003) use the logics of network to develop the concept of bootstrapping. Network logics or network economics (Shapiro and Varian, 2013) is a concept from the field which focuses on studying large-scale and complex technical networks such as telecommunication, infrastructure, and standards. Network economics refer to cases where the value of a network is increased according to the number of users who are using it. Take, for example, the telephone network: it is useful only when its user can make a phone call to many other users—similar to email systems in the early days of the Internet. The problem when building such a network is that it is difficult to convince users to start using it at the beginning when the number of users is very small.

With a relatively high number of users, a network can start to grow by itself. To resolve this challenge, it seems to be fairly easy to identify the first group of users and incentivize and subsidize their use. When the network gains its critical mass, reaching the number of users necessary to make the next user adopt without particular incentives, the network can continue to expand without further support.

Hanseth and Aanestad (2003) discuss the bootstrapping strategy as based on identifying those users who are willing to adopt technology and, in parallel, shape user preference through the design process. Hanseth and Aanestad (2003) apply this strategy in analyzing three empirical cases relating to building IIs for telemedicine in Norway. Drawing on the three cases, Hanseth and Aanestad (2003) illustrate how cases that follow the bootstrapping strategy have a greater chance of succeeding. Further, they discuss how the degree of success of the bootstrapping strategy is largely dependent on several contextual factors: user motivation and knowledge, use area and situation, nature of the technology, and coordinating institutions:

<p>User motivation and knowledge</p> <p>The bootstrapping strategy should focus on users who are most positively inclined toward IIs and who feel that IIs could help them do their work better. User knowledge of IIs is also an important factor to be considered in attracting the first users, as it could reduce the cost of adoption, e.g., by reducing training and support. However, user knowledge increases proportionally to the level of use and the exposure to IIs.</p>
<p>Use area and situation</p> <p>The use area and situation are other important factors affecting the bootstrapping strategy. For example, telemedicine may be more effective in the case of radiology than in surgery, because the practice of advice in surgery tends to require co-presence in the operation room while advice from radiologists can easily be obtained and used remotely.</p>
<p>Nature of technology</p> <p>Several dimensions of technology, including cost, flexibility, simplicity and availability, could have high impact on the users' attitudes.</p>
<p>Coordinating institutions</p> <p>When IIs grow, the need for coordinating structures is increased, which is not the case when only a few users exist. However, the introduction of governance structure at the beginning could impede the growth of IIs, which brings more harm than good.</p>

Table 1: Contextual factors influencing bootstrapping

These factors are developed based on telemedicine initiatives in a Western country context where contextual conditions are significantly different from those of developing countries. For example, most HIS projects in developing countries are funded by international donors with their own agendas. Furthermore, the centralized control of governmental agencies on selecting a technology or software provider also influences the users' preferences. And in many cases, the use of a technical solution is mandated from the top. When it comes to HISs in the context of developing countries, therefore, political climate is one of the major contextual factors that shapes users' adoption of an II, as described in the work of Sahay et al. (2009). Further, the enactment of a law which regulates and enforces certain activities could spawn the need for an II, creating favourable conditions for technology adoption.

Hanseth and Aanestad (2003) also discuss the step-by-step approach to bootstrapping an II and emphasize the need for "continued bootstrapping". They argue for the following approach based on the example of scaling an Electronic Data Interchange (EDI) infrastructure:

- Improve and extend the existing infrastructure
- Generalize the local message formats to support more standards
- Make similar infrastructures for other areas (other kinds of lab reports, then other kinds of forms)
- Improve the solutions to support better and more efficient service delivery
- Go for national standards and use gateway to link standards of other countries

Tactics to enable bootstrapping are also discussed by, among others, Hanseth and Lyytinen (2010). Examining the case of the evolution of the Internet, Hanseth and Lyytinen (2010) generalize three design principles to address the problem of bootstrapping:

- Build functionality that offers direct usefulness
- Reuse what already exists rather than building from scratch
- Focus on expanding the user base rather than functionality

Iacucci et al. (2002) summarizes and generalizes a list of bootstrapping tactics, taking into account both the use and design side of the building of an electronic patient record system in a large and complex Norwegian hospital:

Use
1. Target the users for which an II is useful even with a small number (i.e., installed base) of other users.
2. Start with motivated and knowledgeable users.
3. Start from a use area which is low in complexity and criticality, and which does not require radical organizational change.
Design
4. Design: Design the solution so that it is useful for some users without an existing installed base.
5. Design: An II should be as simple, as cheap, and as flexible as possible. Subsequently, move to more complex solutions.
6. Design: Build on an installed base, as much as possible.
7. Design: Increase usefulness of an II by establishing gateways to already existing IIs.

Table 2: Bootstrapping tactics

We will, in this paper, use the bootstrapping concept and the tactics to discuss our case. We will identify and discuss a range of factors influencing the bootstrapping process and we suggest extensions to make the bootstrapping strategy relevant in the context of our case.

3 Research Method and Approaches

This research was carried out under the aegis of the global Health Information System Program (HISP), a network of North-South-South collaboration where the University of Oslo, Norway (HISP UiO) has a key role. This project comprises people working in the health informatics domain with the ambition to strengthen health information systems in developing countries (Braa et al., 2004). The first author of this paper is a citizen of a country in South East Asia where the case unfolded. He joined the HISP network in 2004 and subsequently engaged in a variety of HISP activities including research, software development, customization, and implementation in various countries in Africa and Asia (including the country of the case). The second author, also a member of HISP UiO, was involved in the analysis of the case and the discussion related to bootstrapping. The third author has worked in the case country on several projects including his most recent post as a consultant for the second phase of the medical licensing project.

Through his relationship with an IT specialist from the Ministry of Health in the case country, the first author was encouraged to build a prototype assisting medical licensing processes based on the open source software platform, namely District Health Information Software version 2 (DHIS2). The prototype was subsequently endorsed by the MoH, donors, and provincial health departments, and continued to grow to eventually become a national health II. Parts of the empirical data used in this research come from the daily interactions between the authors and their ongoing participation in the activities in this project.

Data were collected from formal and informal interviews with staff from the MoH, provincial health departments, hospitals, and a donor. Observations were made during project activities such as discussions, meetings, workshops, conferences, field visits to provinces/hospitals, user support, software coding, documents writing, and system deployment. Consent to participate in these research activities from participants during meetings and workshops was explicitly sought. When meeting new participants, the first author clearly introduced himself as a researcher who was doing research for his PhD as well as a participant in the software development process. Emails were also used to inform about this participatory approach to research. Sixsmith and Murray (2001) have discussed how the ethical considerations on obtaining consent before using emails, forum postings, and other electronic Internet archives

are still contentious in the research community. Some argue that forums and other Internet posts are in the public domain, and thus can be used for research purposes without consent. Others believe that consent is also needed in such cases. However, seeking permission for using Internet data can create other ethical issues, as participants might prefer not to discuss aspects of the previous data collected on them (Sixsmith and Murray, 2001). In our case study, emails and other electronic data used were mainly private communications among team members and external stakeholders. All of them were aware that the first author had a research agenda. Such data, however, were also used with caution, and privacy and confidentiality of the participants were strictly protected. Quotations from interviews or other sources such as email, SMS, or opinions stated during workshops or meetings were anonymized to protect participants' privacy and confidentiality. Table 3 below summarizes data sources used in this research.

Sources of data	Collection tools	Quantity
Conferences and workshops	Notes	5
Field trips	Notes	10
Emails exchanged between the authors and other team members	Electronic	1000+
Formal and informal interviews conducted during field trips to provinces. Key informants included Medical Licensing Officers at province (10) and central level (2) and the donor's staff (3). Each interview lasted between 30 minutes and 1 hour.	Notes	15
Archived documents such as instant messages, bug tracking, system documents, user manuals, Short Message Service (SMS), phone logs, photos, server logs, software source code, code version control logs, and other project-related documents such as circulars, decisions, laws, technical reports, and evaluation reports.	Electronic	N/A

Table 3: Summary of data sources

It was relatively challenging to manage the data coming from multiple sources, and the collection process spanned a long period of time (between 2012 and 2016). To get a sufficient overview of what we had, key events were arranged in chronological order and subsequently grouped by themes. The concept of bootstrapping described earlier was used to guide the analytical process. Initially, critical factors causing substantial impact to II trajectory were identified. Key conditions and important factors leading up to the bootstrapping activities were sought to serve as a basis for further analysis. Finally, strategies were derived to be reused in other contexts.

4 How the Medical Licensing System Was Scaled

In this section, we chronologically describe our case and analyse the process of scaling the licensing system. We identify events that contributed to these changes in the user base and discuss contextual factors that triggered such changes.

4.1 Building a prototype for the Licensing System

In January 2012, the first author of this paper was approached by a doctor (hereinafter DoctorS) working for the Country's Administration of Medical Services (CAMS) at the Ministry of Health (MoH). Considering the author an expert in DHIS2, a web-based and open source software platform designed for the collection, aggregation, and visualization of routine health indicators, DoctorS wanted to discuss the possibility of reconfiguring the software to build a centralized system to support medical licensing activities at the national level in the Country. Based on this discussion, the author spent about one week rapidly building a prototype based on the DHIS2 platform. This licensing prototype was a very simple system with basic forms

and functionality to register the minimum of information needed from a health professional, her qualifications and work experience. DoctorS was impressed by the prototype (a screenshot is shown in Figure 1 below) and immediately shared it with his friends working in various licensing offices in the country to get their feedback. A couple of licensing officers responded and started to look at the prototype. Although no licensing office began to use the prototype in daily work, this initial feedback from the licensing officers was very useful for improving various aspects of the prototype.

Figure 1: Screenshot of the first version of the prototype

4.2 Piloting the prototype in the first province

In a national workshop organized by CAMS in April 2012, the first author had the chance to again meet a doctor (hereinafter DoctorP) who, four years prior, had attended several training classes on DHIS2 in the country. In these classes, the first author had been one of the instructors. DoctorP was at this time the head of the medical licensing office in one southern province (hereinafter SouthProvince). During a break in the workshop, there was a tripartite conversation between DoctorS, DoctorP, and the first author about the licensing prototype. Based on this, DoctorP became eager to pilot the prototype in his province in parallel with a paper-based system. Based on the prototype, he began to do some data entry with real licensing applications submitted to his province. Through that process, he sent back a list of comments regarding the prototype. These comments were in a wide range of categories from polishing the Licensing System with proper formats related to fonts, color, and text, to adding more reports such as the list of health professionals under review, other minor bug fixing, and missing functionality. Based on the comments, the prototype was revised and improved. This comment-revision cycle was repeated several times. Finally, DoctorP was able to convince the Director of the SouthProvince Health Services to approve the prototype and allow the use of for processing licensing applications in the province. Since that time, the prototype has been an official system used in SouthProvince. DoctorP played the role of a super user who was in charge of training his colleagues to use the Licensing System for their work.

4.3 Expanding the pilot to five more provinces

The pilot in SouthProvince produced very good outcomes. Based on this, DoctorS successfully persuaded the Director of CAMS (MoH) to write an official letter to six provinces (SouthProvince and 5 new provinces), encouraging them to pilot the Licensing System. These provinces were selected based on two criteria: staff at the licensing offices had a good relationship with DoctorS, and the selected provinces represented the country geographically.

In a parallel process, a program supported by the AsiaBank was planning a comprehensive information system for the licensing of health providers and health facilities, as well as additional features such as a system for patient complaints. Given the ongoing pilot activities of the Licensing System now being extended to 6 provinces, integrating the two initiatives (one by the Team and one by a firm which would be selected through a tender) was suggested. It was further suggested that the pilot should be exactly that: the Licensing System built by the Team would be only an interim system for testing out functionalities and gathering requirements and nothing more than that. Consequently, in January 2013 AsiaBank agreed to offer a small grant to support the development and implementation of the Licensing System and pilots in the selected provinces were initiated. The provision of the grant came after a consultant from AsiaBank evaluated the Licensing System and gave a positive comment: "... [the licensing pilot] *has made a lot of progress and I think your system is a good starting point for registration and licensing of health professionals*" (Email archives).

From the start, there were conflicting views on the role of the prototype system within the more comprehensive system which was planned. But an agreement was reached to allocate some limited funds for a pilot under the condition that the piloted system should be a temporary solution and only run until the winner of the planned bid for a new system would take over and incorporate the Licensing System into their software platform. The strategy the Team adopted to counter the prospect of only being a temporary solution was to work hard to scale up and become as relevant and as useful as possible. Furthermore, the more time that elapsed before the planned bid was to be awarded, the better their chances for making their own project indispensable. To support the rapid expansion of the implementation of the pilots, six people with diverse backgrounds (IT, public health, and accounting) were recruited. Together with the first author and DoctorS, the new members formed a project team (from now referred to as the Team) to support the customization and implementation of the Licensing System in the selected provinces.

4.4 Limited national implementation

A few months after the pilot system had been functioning in six provinces, AsiaBank sent a group of consultants to the pilot provinces to conduct an evaluation of the implementations. The reports by the consultants were positive about the Licensing System; the consultants also recommended that the MoH officially implement the Licensing System nationwide. However, CAMS employed a more conservative strategy by sending a letter to request 63 licensing offices in the country to enter the data of about 150 applications into the Licensing System for testing purposes. In two national conferences about medical licensing organized by CAMS in March 2013, the Team was allocated about two hours per conference to introduce the licensing system to delegates coming from all provincial licensing offices. There were many complaints about the design. For example, one delegate commented: "The complicated design of the system meant that it took nearly 2 hours to enter a single application into the system. Is it really feasible to use this in an official capacity?" To address this design issue, the Team converted the existing combo boxes into a hybrid between free-text boxes and autocomplete boxes. Users then had two options: select an item based on a previous entry or type a new value.

Following the two conferences, the Team worked to make the Licensing System more generic, so the provinces would be able to import their legacy from Excel files, and they sent a letter to convince all provinces to adopt it. Even though the letter was only about a pilot, the Team cleverly managed to continuously improve the Licensing System so that it could fully support licensing officers' daily work processes and mitigate some of their work burden. Eventually, the pilot system was widely accepted by provinces because it was useful for their work.

4.5 Licensing System expanded to support hospital users

In the implementation expansion process, the Team was very keen to contact all provincial health departments to remind them to enter the 150 applications as requested by the MoH. Some provinces consented, but some refused due to various reasons. Some provinces used Excel to process applications and they did not see the need to migrate to the new system. The

Excel-based approach was easy to learn and flexible to use for a variety of tasks, such as keeping track of applications and printing licensing certificates, thus making it the top choice of licensing officers. Others were really busy with their routine work and did not have time to learn to use the new system. Apart from convincing the provinces of the benefits of having a shared database, the Team proactively built a conversion tool based on PHP to read data from Excel and construct SQL statements to transfer data to the database. This helped to automatically import legacy data from Microsoft Excel or Word formats into the Licensing System. Before being fed into the conversion tool, Excel (or Word) files needed to be standardized in terms of number and order of columns, formats of values, etc. In this way, the provinces could seamlessly switch to the new system without any loss or re-entry of data.

In May 2013, there was an event that triggered the adoption of the Licensing System in all provinces. A feature that allowed hospitals to submit applications to provincial licensing offices by entering them directly into the Licensing System was introduced. This feature was initially developed to meet a request from SouthProvince. After successfully being introduced in SouthProvince, it was incrementally improved and later adopted by other provinces. This was beneficial to both hospitals and licensing offices. On the one hand, licensing offices could focus on processing applications rather than entering data. On the other hand, hospitals could have their staff's applications processed faster. When introduced, more and more provinces began to use the Licensing System to process applications, and within four months it became a de facto national system (see figure 3 below).



Figure 2: The number of licensing applications processed by time (year-month)

In the country, hospitals were previously not involved in the licensing processes. After the national implementation was attained, the growth in the user base stopped. When the Team enabled hospitals to register applications for their staff into the Licensing System, adoption picked up again rapidly. This growth was primarily due to the fact that hospitals were highly motivated to use the Licensing System because their staff could get licenses more quickly when they registered the applications themselves.

In August 2014, AsiaBank approved Terms of Reference (ToR) for a bid to procure a new and comprehensive system (hereinafter BigSystem) comprising many modules such as self-registration for health professionals, health facility licensing, continuing medical education (CME), patient complaints, and business intelligence. The bidding process for the BigSystem lasted many months and was restarted several times due to various procedural problems. These delays benefited the Team significantly. Eventually, in June 2015, a local company (hereinafter BigFirm) won the bid and subsequently got a contract to build the BigSystem. After the bid, the Team continued to support the Licensing System and work with the BigFirm on issues related to integration between the Licensing System and the new modules. The integration process is still going on.

5 Analysis and Discussion

5.1 Contextual factors that shaped the bootstrapping of the Licensing System

5.1.1 User motivation and knowledge

The first user of the Licensing System prototype was the head of the licensing office in a Southern province in the country (DoctorP). When considering the evolution of the Licensing System, the trajectory would have been different if he hadn't decided to pilot the system in his province. Prior to the birth of the Licensing System, DoctorP built an access-based system to support the licensing work in the province. There were some limitations in this system which did not make him completely satisfied. Therefore, when he heard about the pilot Licensing System, he was eager to be the first user. The licensing office that DoctorP worked for is located in a newly established province which has many industrial parks and stands out with its economic growth rate. The open governance of this province encouraged change, proficiency, and innovation, forming a conducive environment for DoctorP's personal decision on using a new system.

The further expansion of the pilot was supported by the donor and the MoH, and the list of pilot provinces was based on recommendations from the Team. The main criterion for selection was the relationship between DoctorS and the heads of licensing offices in pilot provinces. This is very different from the original bootstrapping model which emphasizes the need to enrol users based on their motivations and knowledge. In our case at this stage, personal trust and relationships was much more important.

5.1.2 Use area and situation

The bootstrapping strategy is largely influenced by the use area and use situation. Initiatives that support and improve current practices will more easily enroll new users. In our case, the nature of the licensing practices could be improved significantly with a computerized information system. A centralized database for health professionals was critical for human resource planning and prohibiting fraud in medical practice. That vision was powerful when it came to convincing top leaders and provinces to follow and adopt a cloud-based system, which partially contributed to the success of the bootstrapping process.

5.1.3 The nature of technology

Availability refers to the readiness and accessibility of the II designers and the supporting team. In our case, the use of cloud-based technology has significantly reduced the burden of support when the implementation took place across the country. With a centralized database, it was very easy for the supporting team to access data and, for example, verify and investigate if there was a problem with a user account. The users felt that the distance between them and the supporting team was just a matter of a phone call.

The work practices described in our case vary from province to province. Some provinces follow a full-stack approach which relies on the software system for data processing in every step of the licensing process. Some provinces export data entered by hospitals to Excel files and process licensing applications from there, and a few provinces strictly follow ISO standards and track the status of applications through each step of processing. At the national level, the focus is mainly on data aggregation and reporting, which only becomes useful when full coverage of data is attained. Thus, the Licensing System appeared to be flexible and configurable and easily adaptable to different situations.

Information systems for professionals are often complicated and require extensive training. The challenge for designers who follow the bootstrapping approach is how to make the system easy and simple to use, while simultaneously maintaining its ability to support complex work practices. The simplified design of the Licensing System enabled rapid scaling based on large-scale adoption over a short time. However, it came with a cost. The use of the hybrid text field which allowed both selecting values from a combo list and entering free text ended up causing significant problems in later phases when summary and aggregation of data was needed. Thus

there should be a balance between standards and flexibility which can both support data analysis over time and enable the bootstrapping process.

The monetary cost for adoption was almost zero. This relates to training and flexibility as mentioned above, but also the fact that no fee was incurred to buy the software or pay the support team. All costs were covered by the donor. Even the computers, Internet lines, scanners, and printers were bought and supplied to provinces by the project.

5.1.4 Coordinating institutions

Coordinating institutions are only needed when the network grows to a certain scale. Initially, the Licensing System was piloted informally and on a small scale. The coordinating institutions (i.e., the MoH) played a bigger role when it was necessary to legitimize the full-scale implementation, which was the only way to collect the data of the entire country. This legitimacy was essential to resolve the problem of “all or nothing” in HISs in developing countries (Braa et al., 2007). This was critical when a very big and important province refused to use the system. However, following the pressure from the MoH’s letter, that province finally agreed to share their database in order to integrate with the national system.

In Table 4 below, we summarize how different factors affected our case’s bootstrapping strategy:

Original factors (Hanseth and Aanestad, 2003)	How these factors operationalized in our case
User motivation and knowledge	First users were recruited primarily based on their established personal relationships with members of the Team. User motivation was also dependent on the surrounding environment in which they were located, i.e., fast-growth economics and open governance in pilot provinces.
Use area and situation	There was a need to meet requirements of users at different levels even at an early phase. Some functionality provided direct usefulness for licensing officers. But there were other factors such as reporting and data analysis which were powerful in convincing top health managers of the increase in quality, transparency and accountability in the health system.
Nature of the technology	Some technologies, such as web- and cloud-based ones, are easier to support than others because a supporting team does not have to go to the customers’ site to provide support. There was a need to find a balance between simplicity and complex business processes. Cost was not an issue to most users. Provincial health departments and hospitals did not have to pay for software; rather they received the system and many other things for free.
Coordinating institutions	Coordination from governmental agencies such as the MoH was minimal at the outset and during the entire process of scaling. However, it was crucial when it came to assuring national scaling, in that it was the governmental agencies that requested provinces use the system, even at a limited scale.

Table 4: Contextual factors influencing the bootstrapping in our case

5.2 The success of scaling the Licensing System through Bootstrapping

Based on the analysis of contextual factors that shape the bootstrapping, we identify three interrelated strategies that helped the Team successfully employ the bootstrapping strategy: technical- and boundary-spanning competence, political manoeuvring, and the building of a

large user base. While the technical competence is vital for building a good system, the political manoeuvring is important to scale and create a strong user base. This in turn becomes a powerful means for an actor to establish its system and retain its role.

5.2.1 Building technical- and boundary-spanning competence

The Team's technical- and boundary-spanning competence was harnessed to quickly produce something small yet immediately useful. Instead of building the system from scratch, the Team decided to build on top of DHIS2, a platform proven successful in healthcare settings. With this starting point, various components of the system were configured and reconfigured in a way that offered a good experience from the start and for the first user. The reconfiguration and assembling of existing components were based on architectural knowledge in combination with other competences including use context sensitivity and business models (Andersson et al., 2008; Baldwin, 2010; Henderson and Clark, 1990). The expertise of the individuals in the Team and the success of the DHIS2 platform were also well known to key people in the provinces, triggering them to approach the Team and actively join the pilot.

The technical- and boundary-spanning competences that the Team was able to leverage to construct appropriate means beneficial to its plan were not taken for granted. One member of the Team has worked with DHIS2 for a long time as a developer and implementer. Another member was a core developer of DHIS2 between 2007 and 2010 before he left to work for a private company. The team was also joined by a member who had 2 years of experience working with DHIS2 in another Asian country. Apart from that, one member of the Team responsible for implementation had more than one year working on customizing DHIS2 for a hospital reporting for the MoH. Also, the Team was mixed with members with both IT and medical backgrounds and competences. Apart from the participation of DoctorS, there was also another member with public health background working in the Team. The formation of the Team with experienced and diverse members was important to combine, retain, and circulate the technical- and boundary-spanning competence that was vital for developing a good software system and understanding the potential in its future use.

5.2.2 Manoeuvring and leveraging political support

The Team's collective competence in itself would not be enough to create a useful system without the assistance of other means over and above that. The initialization of the pilot through personal contacts of a MoH specialist was critical for this endeavour. Additionally, although the letters from CAMS and the MoH were limited in scope and effectiveness—i.e., they requested the registration of only 150 doctors—the Team managed to leverage these political linkages to increase their control over the system. Instead of supporting provinces only in their registration of 150 applications, the Team worked to allow for conversion of legacy data from Excel and developed functionality for hospital users. These extra steps were done to make the Licensing System more supportive for daily routines of licensing offices, and to eventually win the users' support.

5.2.3 Building a large user base

We can clearly see that technical- and boundary-spanning competences are important in the effort to bootstrap a system. However, such competences are not necessarily enough to succeed in the political game, which is common in the public sector, particularly in developing countries. For example, Sahay et al. discuss a case when an innovation in the healthcare sector in India was easily overthrown when a new health secretary was elected in a state of India and this new secretary favoured another system (Sahay et al., 2009). Although technical competence helps, it is not a guaranty for success if there are no other supporting structures which can act as a counterforce to political reconfiguration. In our case, the Team was successful in cultivating a large, sophisticated and nationwide user base, and covering all levels of the health system. The Team used this strong means (user base and level of use) to protect the Licensing System from substitution, especially when new software vendors (BigFirm) were selected to build additional modules for the Licensing System.

5.3 Bootstrapping tactics

Based on the analysis and discussion above, we now summarize in Table 5 the step-by-step tactics of bootstrapping used in our case, in relation with seven tactics outlined earlier. The aim is to highlight how these tactics are similar and different from the tactics suggested by Iaccuci et al. (2002) presented earlier in this paper.

Tactics suggested by Iaccuci et al. (2002)	Tactics from our case
Use	
1. Useful even with a small number of other users.	<i>Addition:</i> Different parts of a system can also be relevant for different users. Therefore, users should be targeted accordingly.
2. Start with motivated and knowledgeable users.	<i>Addition:</i> Personal relationships and networks can be used to motivate use. Also, consider users not only as individuals but also the institutions, organisations and provinces to which they belong.
3. Use area that does not require organizational change.	<i>Addition:</i> While the development is driven by users' needs, which was not based on justification of complexity and criticality, it is important to mindfully convince users to start with prioritized use cases.
	<i>New:</i> Pursue and exploit indirect means to motivate use, such as laws, decrees and official dispatches; free supply of computers, printers, and other stationaries; payment for data entry.
Design	
4. Useful even without an existing installed base.	<i>Addition:</i> While a full-scale solution may be required for full value, the value for lower-level organizational should be exploited initially.
5. Start with simple solutions.	<i>Addition:</i> Open source software should be considered due to its flexibility and availability. Web-based solutions should be considered to reduce maintenance and support costs.
6. Reuse installed base.	<i>Addition:</i> Installed base should also refer to user experiences and skills, not only software system; i.e., MS Excel skills
7. Use gateways.	<i>Addition:</i> Consider developing temporary gateways which could be thrown away easily to allow maximum experimentation.

Table 5: Amendment to bootstrapping tactics

6 Conclusion

Although bootstrapping is a powerful means of scaling an II, many contextual factors related to technology, use situation, and other institutions may affect the outcome. In this paper, we have discussed various factors and their influence on the bootstrapping process of the Licensing System in the Southeast Asian country. We have extended the original model by adding various nuances to the four aspects of bootstrapping, which involve political support, cost of technology, and personal relationships, arguing that they are important aspects to be considered when using a bootstrapping strategy. We also enhanced the bootstrapping tactics based on the empirical data of our case. We believe these extensions could be useful in analysing and pursuing the process of scaling HISs in other countries. Practically, II designers who are involved in HIS projects in developing countries should follow a contextualized bootstrapping strategy to guide design and implementation.

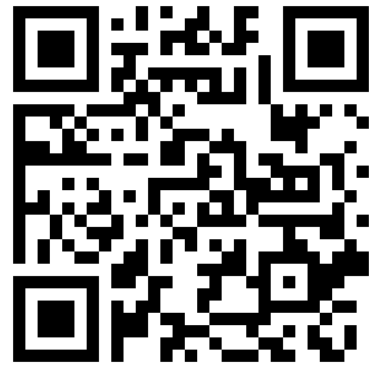
References

- 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.

- Abouzahr, C. & Boerma, T. 2005. Health information systems: the foundations of public health. *Bulletin of the World Health Organization*, 83, 578-583.
- Andersson, M., Lindgren, R. & Henfridsson, O. 2008. Architectural knowledge in inter-organizational IT innovation. *The Journal of Strategic Information Systems*, 17, 19-38.
- Baldwin, C. Y. 2010. *When open architecture beats closed: The entrepreneurial use of architectural knowledge* [Online]. Available: <http://hbswk.hbs.edu/item/when-open-architecture-beats-closed-the-entrepreneurial-use-of-architectural-knowledge> [Accessed 01/05/2016].
- Braa, J., Hanseth, O., Heywood, A., Mohammed, W. & Shaw, V. 2007. Developing health information systems in developing countries: the flexible standards strategy. *Management Information Systems Quarterly*, 31, 381-402.
- Braa, J., Monteiro, E. & Sahay, S. 2004. Networks of action: sustainable health information systems across developing countries. *Management Information Systems Quarterly*, 28, 337-362.
- Ciborra, C. 2000. *From control to drift: the dynamics of corporate information infrastructures*, Oxford, Oxford University Press.
- Cordella, A. 2006. *Information infrastructure in action*, London School of Economics and Political Science.
- Dahlbom, B. & Janlert, L.-E. 1996. Computer future. *Department of Informatics, University of Göteborg, Unpublished manuscript*.
- Grisot, M., Hanseth, O. & Thorseng, A. A. 2014. Innovation of, in, on infrastructures: articulating the role of architecture in information infrastructure evolution. *Journal of the Association for Information Systems*, 15, 197-219.
- 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 manuscript)* [Online]. Available: http://heim.ifi.uio.no/~oleha/Publications/ib_ISR_3rd_resubm2.html [Accessed 01/05/2016].
- Hanseth, O. & Aanestad, M. 2003. Design as bootstrapping. On the evolution of ICT networks in health care. *Methods of information in medicine*, 42, 384-391.
- Hanseth, O. & Lyytinen, K. 2010. Design theory for dynamic complexity in information infrastructures: the case of building internet. *Journal of Information Technology*, 25, 1-19.
- Hanseth, O. & Monteiro, E. 1998. *Understanding information infrastructure (Unpublished book)* [Online]. Available: <http://heim.ifi.uio.no/~oleha/Publications/bok.html> [Accessed 01/05/2016].
- Hanseth, O., Monteiro, E. & Hatling, M. 1996. Developing information infrastructure: The tension between standardization and flexibility. *Science, technology & human values*, 21, 407-426.
- Henderson, R. M. & Clark, K. B. 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. *Administrative science quarterly*, 9-30.
- Henfridsson, O. & Bygstad, B. 2013. The generative mechanisms of digital infrastructure evolution. *MIS Quarterly*, 37, 907-931.
- Herzhoff, J. D., Elaluf-Calderwood, S. M. & Sørensen, C. Convergence, conflicts, and control points: A systems-theoretical analysis of mobile VoIP in the UK. Mobile Business and 2010 Ninth Global Mobility Roundtable (ICMB-GMR), 2010 Ninth International Conference on, 2010. IEEE, 416-424.

- Hinh, N. D. & Van Minh, H. 2013. Public health in Vietnam: scientific evidence for policy changes and interventions. *Global health action*, 6.
- Iacucci, E., Nilsen, P. & Berge, I. 2002. Bootstrapping the electronic patient record infrastructure. *Proceedings of the IRIS 25th Edition of IRIS, Denmark*.
- Jensen, T. B. 2013. Design principles for achieving integrated healthcare information systems. *Health informatics journal*, 19, 29-45.
- 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, 185-194.
- Nielsen, P. & Sæbø, J. I. 2015. Three Strategies for Functional Architecting: Cases from the Health Systems of Developing Countries. *Information Technology for Development*, 1-18.
- Rodon, J. & Hanseth, O. 2015. Stabilization and Destabilization Processes at Work in Digital Infrastructures: The Co-Functioning of Architecture and Governance. *Working paper, University of Oslo*.
- 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, 399-414.
- Sahay, S. & Walsham, G. 2006. Scaling of health information systems in India: Challenges and approaches. *Information Technology for Development*, 12, 185-200.
- 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, 220-243.
- Shapiro, C. & Varian, H. R. 2013. *Information rules: a strategic guide to the network economy*, Harvard Business Press.
- Sixsmith, J. & Murray, C. D. 2001. Ethical issues in the documentary data analysis of Internet posts and archives. *Qualitative Health Research*, 11, 423-432.
- Sommerville, I., Cliff, D., Calinescu, R., Keen, J., Kelly, T., Kwiatkowska, M., Mcdermid, J. & Paige, R. 2012. Large-scale complex IT systems. *Communications of the ACM*, 55, 71-77.
- Star, S. L. 1999. The ethnography of infrastructure. *American behavioral scientist*, 43, 377-391.
- Star, S. L. & Ruhleder, K. 1996. Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information systems research*, 7, 111-134.
- Sæbø, J. I. 2013. *Global scaling of health information infrastructures: Circulating translations*. PhD Thesis, Faculty of Mathematics and Natural Sciences, University of Oslo.
- Woodard, C. J. 2008. Architectural Control Points. *Third International Conference on Design Science Research in Information Systems and Technology (DESRIST 2008)*. Atlanta GA, May 2008.

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The Battle Ground Of ICT4D: From Mutual Exclusion To Hybrid Vigor

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Abstract:

The integration of software components into large-scale and complex information systems is a topic attracting interests from many information systems practitioners and researchers. Less attention is given to the intricate processes in which these infrastructures are built based on multiple independent software components. Introduced by different actors, these components are pushed onto a battleground of functional roles where components are replacing and blocking each other. Based on a case study of the development of an information infrastructure for communicable diseases detection, prevention, and control in Vietnam, we discuss ICT4D as one such battleground. This paper contributes by unpacking this case and conceptualizing its success as an example of the outcome of a strategy of hybrid vigor.

1 INTRODUCTION

Information Systems are no longer designed and implemented in isolation, but are integrated with and extending already existing large-scale and complex information systems. How this situation influences the process of building successful information systems as parts of a larger whole has been a topic attracting interests from many information systems practitioners and researchers. Key aspects that make this context and the nature of the technology different from stand-alone information systems has been theorized as Information Infrastructure and their dynamics described by concepts of openness, shared, evolving, standardized, heterogeneous, and building on an installed base (Hanseth and Monteiro 1998, Hanseth 2010). Because this context is substantially different, it also requires novel approaches to design and implementation (Henningsson and Hanseth 2011). A key challenge working with a component of a larger whole is that control is distributed among different actors. Cultivation by using different means to influence other actors and changes in small steps towards a certain goal is an important technique espoused by both industry and academia (Hanseth 2010). The tenet of this approach advocates designing and building a system from what already exists rather than from scratch. In other cases where there is no (or little) installed base to utilize, one can incrementally build systems through the strategy of bootstrapping, referring to a process of producing and providing incentives to mobilize the first users of a technology and using this set of users as an installed for further development (Hanseth and Aanestad 2003).

Recently, approaches to the II design have been augmented by several researchers in a variety of ways. Sanner et al. (2014) propose grafting as a strategy to embed a component in the network of components by making sure this component can adapt well to the existing installed base through various social-technical adjustments. To that end, the choices of the right place and the right time are crucial for the success of the grafting. Other researchers have recognized the role of architecture in shaping II development trajectories, arguing that a resilient and open architecture is critical for II successful evolution (Grisot, Hanseth et al. 2014). Others have called for partial or complete devolution of control over IIs to maximize the innovation and creativity to enable success and sustainability of IIs (Ciborra 2000, Hanseth and Braa 2000, West and Dedrick 2000, Hanseth, Ciborra et al. 2001, Nielsen and Aanestad 2006, Tilson, Sørensen et al. 2012, Gregory, Beck et al. 2013, Sanner, Manda et al. 2014).

Until now, most research on II focuses on finding innovative approaches that help cultivate IIs through various strategies such as bootstrapping and recently grafting. In such studies, constitutive elements or components are introduced to either extend, complement or be integrated with the existing network. Little research has been done on contexts where multiple components are deliberately brought in to replace existing ones and potentially block other alternatives and future attempts of replacements. One exception here is the work by Nielsen and Sæbø (2016), conceptualizing the interplay between and the strategy behind different and potentially competing software components as functional architecting. They distinguish three different strategies used by proponents of different software components and discuss them as *charting*, *encroaching*, and *connecting*. Extending the work of Nielsen and Sæbø, the focus in this paper is on situations where different software components meet and the established functional architecture is challenged and changed. What we will illustrate is that the consequence of these strategies can be severe clashes of old and new components. Conflicting strategies may lead to the replacement of existing components and potentially the whole network by a single new component.

We have a particular focus on the situation when multiple actors directly compete to serve the same functional needs and thus for their own existence. To explore this area, we undertook a multiple-case study consisting of 4 individual cases, all of which involved negotiation, development, and implementation of information systems for communicable disease monitoring in Vietnam between 2010 and 2015. We were directly involved in one of these initiatives and participated in general discussions and collaboration with stakeholders in the other three. Through the analysis of these cases, we discovered *hybrid vigor* as a different strategy for functional architecting, apart from the three strategies described by (Nielsen and Sæbø 2015) which are *charting*, *encroaching*, and *connecting*. We define *hybrid vigor* as a strategy that aims towards improving the totality of the functional attributes of an infrastructure. Our definition also includes three dimensions of hybrid vigor which we identify as follows: the politics of functional negotiation, the power of governmental agencies, and reconfiguration of the resulting infrastructure.

The remainder of the paper is organized as follows. The review of related research is provided in section 2 followed by the presentation of methods and approaches we used in this study. In section 4, we introduce the case of the epidemic reporting systems in Vietnam. . Analysis and discussion are provided in section 5. We conclude the paper in section 6.

2 RELATED RESEARCH

Conceptualizations of large and complex information systems focus on complex networks or networks of systems that is comprised of heterogeneous components. Hanseth et al. characterizes them as a "shared, open, evolving, heterogeneous and evolving socio-technical systems" (Hanseth and Monteiro 1998). Appearing as a different genre of information systems, Information Infrastructures (II) cannot be built or constructed by conventional software engineering methods, methods developed for standalone and homogeneous systems (Somerville et al 2013).

A common argument in the II literature is that the complexity, uncontrollability, and the unintended consequences associated with IIs are the root causes for the failure of many large IT projects (Aanestad and Jensen 2011). Development and implementation of large scale and complex information systems demand new approaches which requires the perception of technology as more than individual tools (Tilson, Lyytinen et al. 2010). There have been many efforts to response to this demand. One of them is the design theory developed by Hanseth and Lyytinen (2010), tackling dynamic complexity in the design for IIs by addressing two key challenges: bootstrap and adaptability. The theory delineates a list of design principles which guide designers on how to "*generate attractors to propel users to adopt the IT capability so that its growth will reach a momentum*" (ibid, p.8) and "*guarantee that the II will grow adaptively and re-organize constantly with new connections between II components*" (ibid, p.13).

Another important aspect of large scale and complex information systems is the lack of centralized control and as a consequence the nature of how they change. Cultivation is used to describe the process of actualization of an II in a piecemeal and incremental manner and based on what already exists, the installedbase. II slowly evolves, emphasizing that due to its complexities, an II is hardly built or designed quickly, as it is not practically possible to ignore the legacy of: "*historical accumulation of socio-technical arrangements around it*" (Sanner, Manda et al. 2014, p.221).

Accepting the complex nature of IIs has lead researchers to study the different strategies pursued by different actors within these large scale and complex networks. For example, Sanner, Manda et al. (2014) recently introduced the concept of grafting¹ to describe a strategy where "*local organizational goal-oriented information system innovations become viable extensions of shared and evolving information infrastructure*" (ibid, p.221). Identifying the right moment and position to graft the *scion* which, in this case, is a novel software component to the rootstock (the installed base of software systems) is critical for success. The

¹ A technique popularly used in horticulture and agriculture

grafting strategy also entails effectively managing the relationships with stakeholders who are in control of parts of the existing installed base and the deliberate choice of rootstock to ensure congeniality. Another example is the concept of co-evolution, bringing the focus to how different technologies developed by different actors may intersect from time to time. Jansen and Nielsen (2005) introduced and applied the concept of co-evolution to analyze the parallel evolution of IIs using the case of two wireless communication platforms Universal Mobile Telephone System (UMTS) and Wireless Local Area Network (WLAN) in Norway. They concluded that the intra- and interlinkages of technologies, politics, interests, and user preferences within each II strongly influence the trajectory of the co-evolution. In a similar vein, based on the work of Benbya and McKelvey (2006), Shaw (2009) develops the co-evolutionary framework for managing the complexity of hospital management information systems development in resource-constrained settings. Yet another example is the literature on platforms, discussing the distribution and redistribution of control and innovative capacity between different actors and the technologies they control. For example, Tiwana, Konsynski et al. (2010) argue that the evolutionary dynamics of IIs is significantly influenced by the “*coevolution of endogenous choices by platform owners and the dynamics of an ecosystem’s exogenous environment*” (ibid, p.687). Further, several scholars including Nielsen and Aanestad (2006) and Hanseth, Ciborra et al. (2001) cleverly use the concept of devolution to describe a situation in which IIs might better evolve if centralized control is balanced with autonomy. The reduction of strict control on the II growth would permit “*the distribution of resources, risks and abilities and willingness to innovate*” (Nielsen and Aanestad 2006, p.185).

The extant II literature mainly discusses the introduction and the (re-)combination of innovative systems, subsystem, and components into existing social-technical arrangements and how these constituents shape and being shaped by the social, technical, and institutional contexts. There is a dearth of research that clearly discusses the overlap and duplication of the new and the incumbent software components, their competition and potential substitution. An important exception to this is the work of Nielsen and Sæbø conceptualizing the interplay between and the strategy behind different and potentially competing software components as functional architecting. They distinguish three different strategies when software components made for one domain is moving into another, such as for example when a corporate accounting system is also offering functionality for human resources management. *Charting* is one strategy where a software component is moving into a new domain by meeting an unmet functional need. *Connecting* is another strategy where software components from different domains are connected to leverage on the benefits of complementary functionality. Finally, *encroaching* is described as a strategy where a software component is moving into a new domain by offering functionality in direct competition with functionality already provided by other components.

Health information systems in developing countries, as in our case study, are notoriously incomplete, unreliable, obsolete and of poor quality (Heeks, Mundy et al. 1999, Braa and Hedberg 2002, Braa, Monteiro et al. 2004, Haux 2006, Heeks 2006, Braa, Hanseth et al. 2007, Garde, Hullin et al. 2007). Although there has been substantial investment from local

governments and international donors, the situation does not seem to be improved but sometime get worse due to the lack of effective coordination and technical competency as well as poor and perhaps corrupt governance. In many cases, poor coordination results in wasteful overlap and duplication of investment in software systems because donors and government agencies support the development of disparate systems that provide exactly the same functionalities for the same setting. In practice, they make these systems as direct competitors.

Braa, Monteiro et al. (2004) raise another common problem in public health systems which they call the “*all or nothing dilemma*”. There is a common need to scale an ICT innovation to full coverage, i.e. all districts in a province or all provinces in a country, to make it useful to health managers. But typically, different systems are implemented in an uncoordinated and fragmented fashion and there is no single system that meets the full coverage criterion. These systems are at risk of being substituted by new systems that will cover a larger area. At the same time, developing countries are commonly too poor to afford the substitution of all directly competing systems.

While the II literature pictures the development and evolution of infrastructure as emergent and out of limited central control, there is still room for intervention. Based on his work on the history of the electrical system in the US, conceptualised as a large scale and socio-technical system, Hughes coined the term “system builder” (Hughes 1979, Hughes 1987) . Hughes showed how this electrical system was not only technical, but also was related to and based on various institutions, manufacturers and investors. Such systems cannot satisfactorily be treated in isolation from organisational, political and economic matters, but must be integrated with their context to work and to grow. To facilitate this is the key role of the “system builders” – the creators of large-scale and socio-technical systems. “System builders” preside over technological projects from the concept and preliminary design stages through research, development and deployment. In order to do so, they need to cross disciplinary and functional boundaries and become involved in funding and political stage-setting. The core competency of the “system builders” thus lies in their ability to integrate heterogeneous physical, human and organisational components into a working and goal-oriented system: “... to force unity from diversity, centralization in the face of pluralism, and coherence from chaos.” (Hughes 1987). According to Hughes, “system builders” should have a holistic focus and see the entire system, rather than only its components. Through control and management, and with attention to the interconnection between the system’s different components, “system builders” believe that the system will not evolve and grow without someone viewing it as a coherent system. Inspired by the concept of “system builders”, we conceptualize the *hybrid vigor* strategy to capture and understand situations in which new systems are introduced and live side-by-side by the existing and what is needed to make them do so. We borrow the term *hybrid vigor* from biology where it is used to describe the improved or increased function of any biological quality in a hybrid offspring (Shull 1948). Hybrid vigor occurs through cross-breeding of plants or animals from the same species (although in different breeds) or from the same genus.

The concept of cultivation has been criticized for its lack of precision in capturing specific goal-oriented organizational interventions (Sanner, Manda et al. 2014). *Hybrid vigor* is a strategy used under circumstances in which direct competition between software components exists, and where certain actors enable the combination of components that offer almost identical functionalities. Hybrid vigor is the strategy of actors understanding the potential of and pursuing the opportunities which the cross-breed of rival software components can yield the overall information infrastructure.

In situations of direct competition, existing components and actors are in risk of being sidelined and replaced. In some instances, there will be only one “winning” component, which is best adapted to the environment, while all other fade away. The hybrid vigor strategy is based on the assumption that such a situation will be suboptimal. In particular, IIs will evolve more dynamically and support innovation and flexibility to a much larger extent if competing components can find a way to co-exist and collaborate instead of mutually excluding each other. In such a case, the strengths and weaknesses of each component will be combined and complemented which in turn foster the flexibility and the potential for expansion. In regard to functional architecting, the three strategies developed by Nielsen and Sæbø (2015) do not sufficiently capture the dynamics in which key system builders, both governmental and non-governmental agencies, regulations and politics are shaping this context. Our contribution is the conceptualization of hybrid vigor as the fourth strategy to deal with functional architecting in such contexts. Based on our case study of the building of several communicable diseases reporting system in Vietnam, we further unpack the hybrid vigor strategy by identifying and articulating its various dimensions.

3 RESEARCH METHOD AND APPROACH

This research is based on multiple-case studies (Stake 2013). First, we followed the design and deployment of the Vietnamese epidemic notification system (ENS) by the Administration of Medical Services (VAMS) in response to a fatal measles outbreak in Vietnam at early 2014. It killed hundreds of children². Two of the authors of this paper were active participants in this effort on both managerial and technical levels. Second, we examined three other initiatives pursued in parallel with VAMS by three other actors and with more or less the same goal: to support data collection, reporting, and monitoring of communicable diseases in Vietnam. These three cases include the electronic communicable disease system (eCDS) backed by the General Department of Preventive Medicine (GDPM), the new version of eCDS developed by a state-owned telecom company (VCom), and the communicable disease dashboard system supported by an international NGOs (referred to as iNGOs). Apart from separately studying these four cases, we have also focused on their intersections and the collaboration between the different actors coordinated by the iNGOs in leveraging opportunities that a joint effort could generate.

Collecting data of the first case was done in parallel with the process of development and implementation of ENS in which the two first authors directly participated. The other three

² http://www.wpro.who.int/vietnam/mediacentre/features/measles_control_vietnam_2014/en/

cases were conducted between late 2015 and early 2016 initiated by the two first authors being invited to take part in the joint effort led by iNGOs in integrating the existing communicable diseases reporting systems.

Using the case study approach, case selection is significant (Merriam 1998). While partially being opportunistic and based on our access to the field, our selection of cases to include in this paper was primarily based on our aim of understanding the battleground unfolding related to disease surveillance systems in Vietnam. The strengths of these cases combined is partly access and partly richness. On the one hand, our long-term involvement and access in the health care sector in Vietnam in general and the domain of communicable disease monitoring in particular, was crucial for a rich and longitudinal study which is useful to observe the evolutionary trajectory of IIs. Second, extreme case selection method which “*selects a case because of its extreme value on the independent (X) or dependent (Y) variable of interest*” (Seawright and Gerring 2008, p.301) was also the case, supporting our aim of theorizing hybrid vigor: “*extremes or ideal types typically define theoretical concepts*” (Henfridsson and Bygstad 2013, p.914). We do believe that cases which simultaneously involved four separate attempts to build systems with similar functionality are rare.

In gathering data for the study, we followed Benbasat, Goldstein et al. (1987) who emphasize the need for using multiple sources of data to increase the reliability of the research. In addition, careful planning before collection and meticulous record keeping during and after collection were actively applied to utilize time spent on sites and avoid loss of precious data. Our methods of data collection included participative observation, interviews, focus groups, and archival records. First, participative observation was applied when we were engaged in collaborative efforts coordinated by the iNGOs. Our exposure to events such as meetings gave us chances of “*absorbing and noting details, actions, or subtleties of the field environment*” (Benbasat, Goldstein et al. 1987, p.374). In total, we attended four different meetings organized by the iNGOs out of which one lasted for a whole day. In these meetings, demonstrations of different systems were done, giving us insights into the architectural and functional design of them. This was critical for us to understand the issue of direct functional. Also, the participative observation method was used extensively in the case in which the first and second authors of this paper were involved to develop and implement. This involvement lent us a great chance to clearly observe the political and technical negotiating processes. Being involved too closely with the case we study can cause threat of biases which we are fully aware and deliberately try to avoid. We adopted data triangulation techniques and purposely sought neutral and alternative explanations for the same phenomena. The third author had a particular role in asking the critical questions needed.

Second, interviews and focus groups were used for data collection. Interviews were conducted to get broader information relating to the systems that we were not directly involved and to enrich and discuss the data that we had collected from other sources. This also helped ruling out contradictions and inconsistencies. Formally, we conducted eight interviews. Each interview lasted about half an hour to an hour. The first group of informants included the staffs in charge of operating the eCDS at General Department of Preventive Medicine (GDPM)

(4 interviews). The second group consisted of managers and developers working for VCom in the project that entailed the redevelopment of the eCDS system being used at GDPM (4 interviews). All the interviews were recorded and transcribed for analysis purpose. Apart from that, numerous informal interviews were conducted by authors interacting with iNGOs, GDPM, and VCom. These informal interviews provided details that complemented the data we gathered from other sources. To collect collective views and experiences and beliefs of the participants from GDPM, iNGOs, and VAMS, we also used focus groups discussions during the four meetings organized by iNGOs. The purpose of each meeting, happened between October 2015 and January 2016, was varied depending on time and participants. However, it pivoted on making sure that all stakeholders understand the status quo of each system and creating opportunities for interest expression and plan discussion.

Third, the archival records method was also used to collect data that provided general information about legal issues around communicable diseases administration in Vietnam. Email exchanges, project reports, and proposals were other types of archival records used. The list of key archival records is described in table 1.

#	Names of documents	Authors, issuers
1	Circular 48/2010/TT-BYT, guiding communicable disease reporting processes and procedures.	MoH
2	Circular 54/2015/TT-BYT, modifying Circular 48/2010/TT-BYT	MoH
3	The implementation plan of the electronic Communicable Diseases Systems in 63 provinces.	GDPM
4	Official dispatch 2615/BYT-KCB dated May 13th, 2014, requesting daily reporting of measles on the online system.	MoH
	The ADB Report on the Preventive Health System Support Project http://www.adb.org/projects/3so4348-013/main#tabs-0-1	ADB
5	Presentations at the meetings	iNGOs, GDPM, VAMS
6	Emails exchanges (~ 200 threads)	Authors and stakeholders

Table 1: Data sources used in the research

The data collection process highly influenced by our prior hypotheses, assumptions, and knowledge about the research topic was conducted in an iterative manner. That means that data analysis was performed simultaneously with the data collection process. In general, our coding procedures started with predefined codes and was gradually augmented by codes emerged from the collected data. Through a number of reflections and rereading the materials, larger themes were identified, which was an important step in finding answers to the research questions. Initially, we traced the competition amongst software systems and early conceptualized hybrid vigor as a strategy that helps reconcile and neutralize conflicts between

systems' proponents. Examining the strategy we gradually discovered multiple layers of its dynamics and delineate several aspects to which we referred as dimensions of hybrid vigor.

As part of the analysis process, the cases description is presented in the following session.

4 FOUR INITIATIVES ADDRESSING THE COMMUNICABLE DISEASES REPORTING

In this section, we present the four initiatives and systems implemented to address the need of data collection, reporting, and monitoring of communicable diseases in Vietnam. The cases are described in a chronological order.

4.1 The Electronic Communicable Disease Reporting System (eCDS)

The preventive medicine system of Vietnam can be described as "a passive system" which was mainly responsible for data collection and reporting rather than epidemic control and prevention. A dearth of skilled staff and adequate infrastructure and the lack of standards and protocols in epidemic reporting and monitoring were identified to be the root causes for such weaknesses. In 2008, the Vietnam Nation Assembly enacted the Law on Communicable Diseases Prevention (03/2007/QH12). This was followed by the Circular 48/2010/TT-BYT (shortly called Circular 48) issued by MoH on December 31st 2010. Both of the documents provided a legal frame to legitimize the reporting of communicable diseases, making it a routinized and compulsory protocol.

In 2012, the Asian Development Bank (ADB) and the World Health Organization (WHO) sponsored the Vietnamese General Department of Preventive Medicine (GDPM) to build an information system to support data collection, reporting, and monitoring of communicable diseases through two projects: the Preventive Health System Support Project (PHSS) and the Vietnam Avian and Human Influenza Control and Preparedness Project (VAHIP). The information system was based on a web-based software, developed on Microsoft .NET Web Form platform, and used Microsoft SQL Server as the database management system. A local company was awarded the contract to build the software. After some months, the software was completed and ready for a pilot. Seven provinces³ representative for the different regions of the country were selected as pilot sites. The goals of the pilot were to evaluate the software and identify necessary infrastructural conditions required for successful national implementation. The implementation team was comprised of staff from GDPM, PHSS, VAHIP, WHO, as well as regional epidemic control institutes. Training sessions on using the software were organized for doctors and health workers who were in charge of preventive medicine at provincial and district levels. Continuous support to users was given by GDPM and the implementation team. The pilot phase ended with positive outcomes and most of the goals were achieved. All districts in the pilot provinces had used the system for reporting the communicable disease data on weekly and monthly basis. The software provided most of the required functionalities needed for communicable disease reporting as mandated by Circular 48. Users from various levels (ward clinics, district health center, provincial preventive

³ Hà Nội, Yên Bái, Thái Bình, Bình Định, Đồng Tháp, Bình Dương and Đắk Lắk

medicine centers, regional epidemic control institutes, and GDPM) could access the same system for data entry, validation, processing and analysis. This design facilitated the collaboration across levels and ensured interoperability of data coming from various sources.

The success of the pilot further attracted the interest of donors in scaling up the implementation across the country. ADB continued their support by sponsoring the implementation of the system (training, support, evaluation) in 45 provinces in total. WHO provided support for servers, hosting, and other hardware services. They also sponsored the implementation, monitoring and evaluation of the system in 3 provinces. The nationwide scaling up process also received support from Centers for Disease Control and Prevention (CDC, the United States) to implement the system in seven provinces. GDPM covered the implementation in the last eight provinces of Vietnam by their budget.

As of June 2014, all provinces had implemented the system at district and provincial levels. Out of them, 11 provinces had the system down to the ward level. For provinces that did not implement the system at ward level, district PMCs had to enter data from paper-based reports sent by ward clinics. This nationwide implementation thus had the potential to provide full coverage of timely and sufficient data about communicable diseases on the country level. However, this was not the case. The appendices of Circular 48 regulated reporting templates that health facilities (HF) and preventive medicine centers (PMC) must use to report communicable diseases data. These templates could be divided into three categories: aggregate data, case-based data, and outbreak. Routinely, data were reported in weekly, monthly, and yearly basis. For fatal and severe communicable diseases classified in Group A by Circular 48, reports must be sent immediately for timely intervention. Apart from upward reporting flow i.e. district health centers report to provincial health centers and peer reporting flow i.e. district hospital report to district health center, there was a feedback flow in which upper-level PMCs send lists of confirmed cases to lower-level PMCs for verification and intervention purposes. However, due to the dearth of adequate skills and equipment in PMCs at both district and provincial levels, most of the communicable diseases confirmed cases were diagnosed and discovered by hospitals only⁴. This design was the Achilles heel of the preventive medicine system in Vietnam, making the collected data relentlessly insufficient, inaccurate, and delayed. It means that PMCs are in need of infectious disease data for their intervention however they could not actively and directly collect such data. Instead, they have to rely on hospitals. Delay in reporting data from hospitals is such a serious issue that PMCs often have to send their staff to some big hospitals and stay permanently just for data collection purpose. As a result, data from other hospitals were sometimes missing or lately reported.

4.2 The Epidemic Notification System (ENS)

During new Lunar New Year of 2014, the accidents and injuries reporting system of the Vietnam Administration of Medical Services (VAMS), an electronic reporting system

⁴ <http://dost.hanoi.gov.vn/tin-hoat-dong-cua-so/-/news/0a1dDnsUqQBB/1/413986.html;jsessionid=016mt7EvyGFsd8ExlwWWg-sY.app2#>. Accessed on February 2nd 2016

tracking daily admission and emergency of all hospitals in the country, noted several cases of measles from a mountainous province in Northern Vietnam. The length and joy of the festival caused everybody overlook the significance of the harbinger of a severe epidemic. Two months later, the epidemic became very serious with hundreds of deaths and thousands of infection cases. However, public and media were not aware of the severeness of the situation. The director of a Hanoi-based pediatrics hospital had to invite journalists to visit his hospital to directly observe the seriousness of the epidemic, hoping that media could help to change the public attitudes toward the disease. Witnessing many fatalities of measles in child patients, one pediatrics doctor posted an emotional status on Facebook expressing his helplessness on fighting against the disease. Coincidentally, this post was seen by his friend who was the Deputy Prime Minister in charge of the health care sector. The Deputy Prime Minister decided to visit the hospital in person to get a closer look at the situation. The increasing number of measles patients admitted to hospitals made overcrowding a serious issue. Two or three patients had to share a sickbed. The workspace of staff was also allocated for inpatients. Respirators were mobilized from other wards in the same hospital for measles treatment. After the visit of the Deputy Prime Minister, the media were full of alarming reports about the measles epidemic, causing panic across the country.

A key challenge in this situation was that no agencies or authorities could provide the exact number of fatalities, infected and admitted cases. The official source of MoH reported only 25 deaths while data from a single hospital indicated nearly 3 times this number. It became obvious that Vietnam did not have appropriate and effective information systems to support the monitoring of communicable diseases. At that time, the eCDS backed by GDPM was still in its pilot phase. By its original design, eCDS was primarily designed to provide detailed data required for controlling a measles outbreak. For example, it supported the collection of the total number of infection cases and fatalities but did not support the tracking of data such as the number of inpatients with serious complications. This number, however, was critical for efficient allocation of scarce resources such as highly skilled doctors and respirators.

In an effort to mitigate the harshness of the situation, an official at VAMS discussed with the first author about the feasibility of reusing the annual accidents and injuries reporting system (AIRS) to build a daily reporting system to monitor the measles epidemic that was ravaging across the country. Prior to the implementation of AIRS, two of the authors had supported MoH in a number of systems such as health professionals licensing system, hospital inventory, and patient complaint system. All these systems belonged to a bigger infrastructure that covered most of examination and treatment related activities within MoH. A team was immediately formed to work on the extension. To speed up the development process, the team decided to reuse most of functionalities such as data entry forms and data dictionary management from an open source platform for health care already implemented in Vietnam, namely DHIS2⁵. After about two weeks of intensive work, the team completed the system with basic functionalities for data entry and analysis.

⁵ See e.g. www.dhis2.org

The success of previously implemented systems easily convinced leaders of MoH to approve the rollout plan. An official dispatch was sent to all provincial health departments and hospitals, requesting them to use the system for reporting measles and other infectious diseases on a daily basis. Being aware of the urgency of the epidemic, most of the health facilities consented to the request and started to report the data immediately. Just a few days later, data related to measles diseases of the whole country were collected and synthesized through the system, playing an vital role in further controlling the outbreak. Compared to the eCDS, the system developed by VAMS provided data in greater detail. With regard to the case-based data, the VAMS system did not only collect basic information about infectious and fatal cases but also monitor the treatment progress of measles inpatients. The dataset included additional data elements such as the number of discharged or transferred patients, the number of lab tests, the number of patients in critical conditions etc. In total, there were more than 20 additional data elements ENS compared to eCDS. This gap legitimated having an additional system which focused on collecting clinical data of communicable diseases. Figure 1 shows an example of a number of cases admitted daily for measles collected by the VAMS system in five months between May and October 2014 from all hospitals in the county

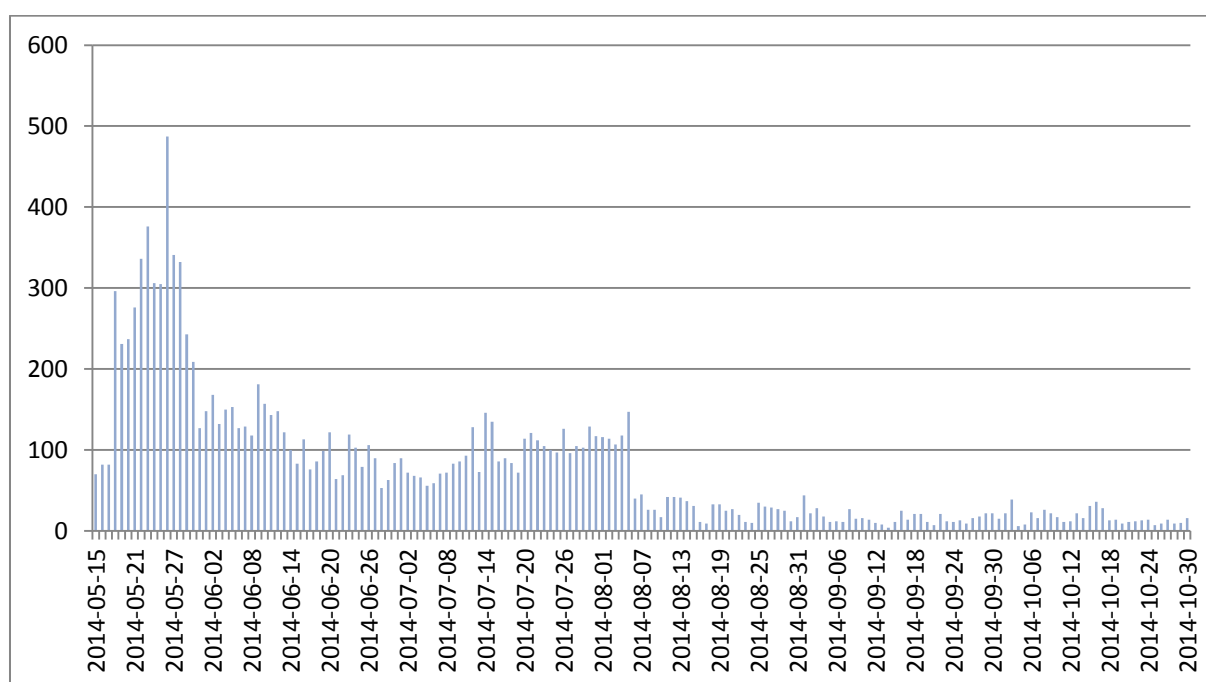


Figure 1: The total number of daily admitted cases for measles from all hospitals in Vietnam

4.3 The new Electronic Communicable Disease System (the new eCDS)

VCom is a state-owned giant corporation originally operating only in the telecom sector. VCom has ventured into foreign markets and gained considerable success. Its international presence includes countries in Asia, Africa, and Central America. Recently, VCom has gradually expanded its business scope into other areas like software and services as the growth in the telecom market has slowed down. In the software sector, VCom has ambitious plans to develop enterprise resource planning (ERP) solutions, e-Commerce, and e-Government-related products. In 2015, after many rounds of discussion, VCom and MoH

signed an agreement to collaborate in development and implementation of ICT solutions for healthcare in the period between 2015 and 2020. Following the agreement, VCom has worked with various departments within MoH to conduct situation analysis and propose plans to either improve or redevelop the systems being used in these departments. Apart from a few systems, most of the existing systems have therefore been substituted, developed or redeveloped using VCom' architecture and platform. The systems under the VCom's plans include the Official Dispatch Managements System, Electronic Communicable Disease Reporting System, Patient Complaint System, Electronic Insurance Claims and Payment System, Vaccine and Immunization Tracking System, and Online Health Professionals Licensing System.

The *new eCDS* is part of the holistic collaboration framework between VCom and MoH in applying ICTs to strengthen the health care sector. Prior to the agreement between VCom and MoH, two communicable disease systems had been built and put to use separately by VAMS and GDPM. After carefully examining the status quo, the VCom technical team decided to develop a completely new system to substitute the system used by GDPM (eCDS). To motivate this decision, the technical team made the following arguments. First, by virtue of the modification of Circular 48, the eCDS must be changed accordingly in order to continue functioning. Second, according to a team member, the eCDS used archaic .NET technologies (WebForm) which should be upgraded to more modern frameworks like Model-View-Controller (MVC). Furthermore, several design flaws in the eCDS could pose security risks and affect performance of the system. The redevelopment of the system also received support from the leaders of GDPM. At first, the team estimated to complete the work in only three months. However, due to many technical and communication challenges, the team spent significantly longer time than what they had planned. Ultimately, after one year, the team completed the first release with basic functionalities and sought approval to pilot the new system.

Apart from replicating all functions offered in the eCDS, the team also built additional features such as the one that automates the case-based entry task. The technical team was highly aware that most of the communicable disease cases were discovered and diagnosed by hospitals so that this feature could by reducing manual data entry increase the timeliness and coverage of reported data. According to the design, this automatic process would pull data from the epidemic notification system run by VAMS through either web services or files. In the latter case, a spreadsheet-based template file is used to make case-based data interchangeable. To implement the data exchange plan, several technical meetings were organized with representatives from GDPM and VAMS. However, the actual progress of the collaboration was slow due to the lack of adequate resources from VAMS to support for the required upgrade of their system.

4.4 The communicable disease data warehouse (CDDW)for Emergency Operations Center (EOC)

In 2014, Vietnam joined the Global Health Security Initiative (GHSI), a US-led program aiming at boosting global cooperation to detect, prevent, and rapidly response to infectious disease threats. The initiative was also joined by other 25 countries and key international agencies like such as the World Health Organization (WHO), the Food and Agriculture Organization (FAO), and the World Organization for Animal Health (OIE). With the support of the U.S. Centers for Disease Control and Prevention (U.S. CDC), Vietnam has implemented a demonstration project to improve the laboratory systems and develop an emergency operations center (EOC). However, in order to run EOC successfully, it is critical to have an operational data warehouse for infectious diseases. To that end, experts from CDC and the implementing partner PATH has actively worked with local stakeholders including GDPM, VAMS, and regional public health institutions to seek necessary resources and define processes, tools, and technologies required for the actualization of a data warehouse. The significance of this was emphasized by a CDC team member as follows:

“The Data Warehouse and visualization platform will provide opportunities for historical intelligence (analysis of data in different time periods and trends) and springboard rapid disease outbreak detection and prediction. This will further aid public health resource allocation, program planning and increased communication and collaboration at all levels nationally and internationally” (Pre-meeting materials)

In a meeting between CDC and VAMS to discuss the development of the infectious disease data warehouse, VAMS welcomed the support from GHSI and asked CDC and its partners for help in upgrading the current epidemic notification system used at VAMS. A Vice Head of VAMS also recommended the CDC team to contact the first author of this paper for further discussion about the collaboration. Following that, a short meeting was arranged. During the meeting, a technical expert from CDC asked the first author detailed questions about the existing electronic patient records system in Vietnam and suggested to reuse existing systems to avoid duplication of case-based data entry.

A few months later, the first author was invited to the PATH office in Hanoi to attend a series of technical meetings of the health information system (HIS) leads from a number of MoH agencies, implementing partners, and donors to foster data sharing and communication between the systems and plan for the development and implementation of the data warehouse. Three important processes were identified during the meeting: identifying a data source for the data warehouse, defining a list of essential data elements, and consenting to health information exchange mechanisms needed for the data warehouse operations. The meetings resulted in a number of decisions that stimulated the collaboration among stakeholders. First, to quickly produce some useful results, the focus was given to building tools to analyze and visualize the collected data on graphs and maps, supporting the usage of data for decision making. Second, training and other capacity building activities would be organized to prepare adequately skilled personnel for operating EOC.

4.5 The current relationships among the different infectious diseases systems

In this section, we move beyond the different systems and describe their relationships. The issuance of the Circular 54 and the emergence of new systems such as the eCDS backed by VCom and infectious diseases data warehouse advocated by iNGOs, have challenged the status of the two existing software systems: eCDS and ENS. In response, both eCDS and ENS have been proactively reconfigured to avoid being encroached and potentially excluded from the ecosystem.

Depending on its roles, resources, and control, the different systems have changed according to the strategic actions of its proponents:

1. VCom leveraged its role as a strategic partner of MoH to problematize the qualities of the existing eCDS and at the same time proposed to offer a new and better replacement in terms of functionality, performance, and security.
2. GDPM realized that they did not have resources and competence to upgrade its eCDS to comply with the Circular 54. Therefore, their decision was made to abandon their existing eCDS system and instead impose control over the functional design of the new eCDS delivered by VCom. The specification was simply that the new eCDS must offer the same functionality as the existing eCDS.
3. VAMS has its major influence on hospitals and not on health centers like GDPM has. Infectious diseases data mainly come from hospitals which are better equipped and have competent human resources for case confirmation and diagnosis. However, Circular 54 mandates hospitals to report with eCDS. To sustain its role in the ecosystem, VAMS decided to extend its ENS by adding functionality that allows exporting infectious disease cases to Excel files in a format compatible with the importing functionality in the new eCDS. VCom has in its long-term plan the ambition to enable data interchange between these systems via standardized means such as web services.
4. iNGOs comes as part of an international treaty between Vietnam and GHSI. This partnership allows iNGO to flexibly select the point of intervention and phase out the system development. In the first phase, they decided to reuse data collected by the existing eCDS and the infectious diseases data warehouse. At the same time, there is a plan for collaboration between iNGOs and VAMS in upgrading the ENS to be able to directly acquire data from existing electronic medical records systems in hospitals to automate data collection process and improve data quality.

The following table summarizes the relationships among the different software systems before and after the configuration:

System	System proponent (owner)	Functionality	Changes after the configuration
Existing eCDS	GDPM	- Capture aggregate infectious data from ward levels on weekly, monthly, and yearly basic.	+Temporarily feed data to infectious diseases data warehouse

		<ul style="list-style-type: none"> - Capture case-based data of critical infectious diseases. - Capture detailed data of outbreaks - Basic data visualization on graphs and maps. 	+A functional reference for the new eCDS
New eCDS	VCom	<ul style="list-style-type: none"> - Capture aggregate infectious data from ward levels on weekly, monthly, and yearly basic. - Capture case-based data of critical infectious diseases. - Capture detailed data of outbreaks - Basic data visualization on graphs and maps - Extended data set to cover reporting requirements of the Circular 54 - Allow importing case-based data in Excel files exported from hospitals 	+Import case-based data from ENS and other Electronic Medical Records System (EMRs) +Will feed data to CDDW after fully replacing the existing eCDS
ENS	VAMS	<ul style="list-style-type: none"> - Daily capture of aggregate infectious data. - Capture case-based data of all infectious diseases. - Basic reporting 	+Feed data to CDDW +Export case-based data to the new eCDS.
CDDW	iNGOs	<ul style="list-style-type: none"> - Historical intelligence (analysis of data indifferent time periods and trends) - Springboard rapid disease outbreak detection and prediction. 	+Retrieve case-based and aggregate data from eCDS and ENS for dashboard and business intelligence

5 ANALYSIS AND DISCUSSION

In this section, we first use and develop the concept of hybrid vigor to understand the competition between software systems. We unpack and analyze dimensions of hybrid vigor to find out how hybrid vigor as a strategy has been cleverly leveraged by various actors to completely change the course of the battle.

5.1 The battle amongst systems that offer identical functionality

5.1.1 *Overlap and duplication*

The overlap and duplication of investment in health information systems in developing countries is widespread and commonly attributed to the poor coordination of international donors and local governments (Sahay, Monteiro et al. 2009). The data from our cases are contesting this widespread perception. The motivation and interplay of stakeholders' interests have shaped the birth and development trajectories of four seemingly overlapping efforts in building separate systems for infectious disease reporting. Together they make up an ecosystem delivering what is needed for disease surveillance in Vietnam.

The development and implementation of the eCDS by GDPM was the first attempt aiming at providing a holistic solution for infectious disease reporting and monitoring. It was based on significant investment and support from donors and the authorities. However, during the measles outbreak in early 2014 when it was supposed to provide timely and accurate data for epidemic control, the system was not ready due to its delay in implementation. Furthermore, the rigid design of eCDS did not allow switching the data collection frequency from weekly to other period types such as daily. It also lacked important data elements such as number of inpatients who need respirators and the functionality needed to keep track of the progress of inpatients with complications. This created a need for a system supporting the collection of measles related data from inpatients at hospitals. The epidemic notification system (ENS) by VAMS managed to rapidly fill the missing piece of functionalities that eCDS could not provide. This is what Nielsen and Sæbø (2016) describe as charting. The ENS was not built from scratch. It was an extension of a larger holistic infrastructure used at VAMS to manage various activities such as medical licensing, hospital quality, patient complaints etc. The two systems (eCDS and ENS) had some overlap in functionalities and collected data but they also provided distinct features and data that could complement each other.

The introduction of the new eCDS developed by VCom with the aim to replace the eCDS is another example demonstrating that overlap and duplication are not a result of poor coordination. It was a well-planned intervention through which interested stakeholders exercise their influence and power to challenge the established network of communicable diseases reporting. The intervention was initiated by a holistic and strategic agreement between MoH and VCom, followed by a series of situation analyses and recommendations related to the existing information infrastructure at MoH. The new eCDS was a fully replacement of the old eCDS and offered identical functionality. In fact, GDPM had requested VCom to build a new system which was as similar to the old system as possible to avoid confusing the users. However, to convince all involved stakeholders to consent to their plan, VCom cleverly inscribed innovative features on the upgrade version such as automatic importing data from hospital electronic medical records systems. This liberated users from daunting manual data entry, thus attracting them.

The data warehouse for communicable diseases coordinated by the iNGOs is yet another example that reflects the vigilance of international donors when approaching the health

information systems in a developing country like Vietnam. The long-term intervention of 5 years was broken down into piecemeal phases with specific goals. The iNGOs also did a holistic situation analysis through which they were fully aware of the existence of overlapping systems used for communicable diseases reporting and monitoring. Based on their longitudinal and rich experiences with fragmented and uncoordinated efforts in many developing countries, they were very cautious to avoid any action that could lead to further fragmentation. Based on this, iNGOs selected to intervene related to the weakest part of the information infrastructure which was identified to be the data visualization and dashboard.

5.1.2 Direct Competition and Mutual Encroaching

The four systems were introduced at different points in time and reflected the interests and intentions of multiple different stakeholders. The different systems offered overlapping functionality and they were all appearing as being able to be scaled to substitute each other. Unlike in a common marketplace where multiple identical products or services can freely compete and be used by a variety of customers, the preventive health sector in Vietnam at the ministry level plays a role of being the sole client. Thus, there is hardly a chance for two overlapping systems to coexist in such a setting and direct competition will result in the exclusion of one of the systems.

The mutual exclusion demonstrated between the new and old eCDS was inevitable when it was favored broadly by social, political, and technical conditions. Politically, the substitution of the old eCDS by the new version had received consent from the top management of GDPM and MoH. And technically, the VCom team had cleverly pointed out the need for the full-blown development of the new version. A more intricate process unfolded when the eCDS by GDPM and the ENS by VAMS were built to solve different issues but at the same time offering similar functionality. They also served two different sets of users: hospitals and preventive health centers. At the same time, they could both be extended to be used by both sets of users. Initially iNGO only focused on building a central data warehouse and a dashboard module that allowed visualizing communicable diseases data via charts and maps. The data warehouse and dashboard system consumed data collected through existing systems such as eCDS or ENS. However, once the data warehouse and dashboard became fully functional, it would not be too difficult for them to evolve to cover the data collection as well.

5.2 Unpacking the dynamics of hybrid vigor

The analysis of the case so far reveals that it is not only about competition and substitution. That is more a story of different stakeholders playing the game of negotiation and strategic reconfiguration in response to the changes ignited by others.

5.2.1 The politics of negotiation of functional roles between the different systems

While competing to play functional roles, our empirical data revealed that all the different stakeholders pursued strategies of collaboration, negotiation and the establishment of mutual dependencies. Each stakeholder in our case was clearly dependent on at least one other stakeholder whose interests in turn relied upon another. For instance, GDPM needed supports

from VCom to make their system comply with Circular 54. VCom in turn depended on VAMS for their needs of timely and complete data, while VAMS needed expertise and supports in improving the ENS. In addition, iNGOs relied on GDPM for data to operate the EOC's data warehouse. The circular interdependencies among stakeholders are illustrated in Figure 5.

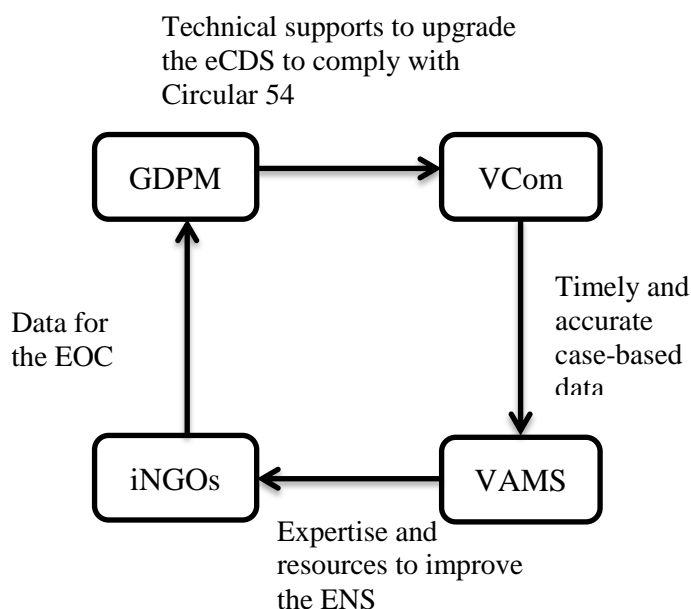


Figure 2: Circular interdependency among stakeholders

In the complex network of socially and technically heterogeneous actors with diverse interests as seen in this case, the interdependency among stakeholders plays an important role in stabilizing and sustaining the whole network. If one system could not provide any useful functionality to the network, it would probably be excluded quickly by other software components taking their functional role.

This functional interdependency is crucial for negotiations between stakeholders to take place. A change in strategy of one actor thus will affect other actors, and thus their strategies need to be adjusted accordingly. For example, when the VCom introduced functionality to import case-based data from Excel files in its new eCDS, VAMS provided corresponding functionality to export data to Excel files that can be used in the new eCDS. Second, when iNGOs came to know that eCDS and ENS are in place and function well as communicable disease data collection tools, it has changed the approach to focus on data visualization. The two examples clearly demonstrated that the reconfiguration strategy of an actor heavily depended on the dynamics of others' strategies and vice versa. For example, if VAMS rejected to participate in the functional boundary delineated by other actors, the eCDS might encroach upon the ENS and the ENS would be gradually replaced.

Certainly, the balance of mutual interests as analyzed in our case would not last forever. It is a result of a complex and ongoing process involving a myriad of negotiations and interestment and among stakeholders (Callon 1984). Thus, what is presented in Figure 5 is merely a snapshot of an ever-evolving network. Future actions and new actors will trigger changes that lead to the formation of newer version of the same network or completely new networks.

5.2.2 The power of governmental agencies in shaping functional roles

In our cases, both GDPM and VAMS are governmental actors. They have the power to define and influence policies which favor certain systems. However, the level and scope of influence greatly depend on the functional domains that they are in charge of. For example, GDPM has the greatest control over issuance of policies, development and implementation of information infrastructure related to infectious diseases in Vietnam while according to the division of departments within MoH, VAMS is responsible for all activities related to administration of medical services at all hospitals and clinics in the country. This authority allowed VAMS to deploy ENS to respond to the measles outbreak without having to wait for GDPM to intervene. As most of the diagnoses of infectious diseases are conducted in hospitals and clinics, VAMS is the only agency that has access to the nationwide and near-real-time infectious diseases data.

Despite being unable to control the functional architecting, the two non-governmental stakeholders VCom and iNGOs had their own strategy to actively respond to the functional plan that had been sketched by VAMS and GDPM. iNGOs gained their legitimacy through the Global Health Security Initiative. iNGOs was assigned to work with local stakeholders to actualize an infectious data visualization and dashboard system as part of the US aid package in strengthening Vietnam's ability to early detect, prevent, and control infectious diseases. As the data entry part has been covered by other systems, iNGOs shifted their focus to the data analysis part. This choice thus was significantly shaped by the powerful governmental actors. VCom maneuvered necessary political support and grasped the opportunity brought by the issuance of Circular 54 to redefine its functional role. The circular introduced various changes into the templates, structure, and flows of reports used in communicable diseases, thus requiring an update on the eCDS. This gave legitimacy to the VCom's plan on the replacement of the eCDS by a newly developed system.

In summary, governmental agencies are important actors playing key roles in shaping functional boundaries between systems via their legal means such as decrees, circulars, decisions etc. In our case, we observed three different instances where Circular 54 played an important role:

- 1) It trigger a functional reconfiguration process by putting pressure on all the involved actors, forcing them to change strategy to maintain their role. Prior to that, both the ENS and eCDS existed as separated systems without any interaction.
- 2) It redefined functional boundaries between systems
by requiring hospitals to use eCDS to report data to health centers. This requirement posed a threat of exclusion to ENS. Before this circular was issued, there was a clear functional

division between eCDS and ENS: eCDS being used in health centers and ENS in hospitals. However, Circular 54 redrew this boundary when eCDS was supposed to encroach upon ENS. 3) It promoted one system over the others by favoring the eCDS backed by GDPM and by doing so undermining the role other systems. This triggered the takeholders to cleverly act within the predefined functional boundaries to protect and ensure their interests.

5.2.3 *The co-configuration of individual systems and the re-configuration of the resulting ecosystem*

As argued early, direct competition poses the threat of exclusion. However, threat and opportunity often go hand in hand (Hillson 2011) and higher risk usually entails higher potential gains. We could see the density of direct competitors in the sphere of communicable diseases in Vietnam as an opportunity to not only combine strengths of each individual system but also leverage the power of collaboration to engender a better II. There are a number of possible trajectories of the II evolution in directly competitive environments.

For example, in our case study, the mutual exclusion scenario would occur when one of the four systems encroach the functional roles and replace all others. In the case of hybrid vigor, however, by inheriting some or all the strengths from each individual system, the resulting system offered much better functionality compared to any individual one alone. The superior quality of the resulting system further triggered more adoption and in turn helped attract more and more support.

The functional co-configuration which was an indirectly result of the negotiation processing between systems' proponents helped individual systems neutralize the tensions and decrease the risk of exclusion. As a result, the whole ecosystem has been transformed in an evolutionary trajectory, i.e. becoming better in the sense of providing more useful and diverse functionality.

5.3 Returning to the Hybrid Vigor strategy. Who are the followers?

The interplay between different software components is also in the topic of the software ecosystem literature. Missing a shared definition (Manikas and Hansen 2013) the common approach is to view software ecosystems as a complex environment in which multiple software components exist and interact with a software platform (the host). Both the platform and the components on top of it are interwoven in a web of symbiotic relationships. The components depend on the platform to function and become useful while the platform needs components to offer value to the users and grow. The platform plays a critical role to the existence of its components while other components easily can be replaced and substituted. In a systematic literature review, Manikas and Hansen (2013) have identified three innate attributes of a software ecosystem, one of which is pointing to the existence of a central and *common software*, referring to the software platform that all other modules or components are based upon to function. From our long-term engagement with Health Information Systems in developing countries, we have observed many cases in which the interplay of multiple software systems takes place in a considerably different way. In our case, there is not one central or common software element.

In this paper, we deal with software ecosystems in which similar or peer systems compete to meet functional needs. These systems offer to a large extent identical and overlapping functionality. As in any ecosystem, to survive, each system must align and constantly realign to coexist with others. In this process, each system reconfigures itself either by reducing or expanding its functionality. A central driving force behind the evolution of the software ecosystem is in our case the legal control of governmental agencies. These agencies have in many ways the same central role as platforms in other ecosystems. We have seen that changes can be triggered by different factors such as a change in the existing environment (new policy or new requirements) or by new actors joining the ecosystem. Such changes in policy, requirement and composition of actors trigger intricate negotiating processes, and will typically change the ecosystem in the favor of some actors and at the cost of others. Nielsen and Sæbø (2015) have identified three general strategies which actors can employ to (re-)configure their functional roles in such a game, namely connecting, charting, and encroaching. Connecting refers to a situation in which different systems offering different functionality are integrated in a complementary fashion. Charting refers to a strategy where a system extends to serve unmet functional needs and freely operates with no competition. This is different from an encroaching strategy where a system is challenging other systems by introducing competing functionality with the aim to overtake their functional roles.

The three strategies discussed by Nielsen and Sæbø (2015) are relevant to understand the strategic moves of different actors and the evolutionary trajectory of the ecosystem. But they are not sufficient to capture the dynamics of our case in terms of; 1) the politics involved in the negotiation between the functional roles of the different systems; 2) the power and the central role of governmental agencies in shaping functional roles; and 3) the configuration of the resulting ecosystem.

Borrowing from biology and genetics, we deliberate on what we see as a fourth strategy for the reconfiguration of software in a wider ecosystem, namely *hybrid vigor*. Hybrid vigor is in biology the superior qualities emerging from the crossbreed of different plants or animals. As an analogy, hybrid vigor is in case of software ecosystems the emerging superior functional attributes of an ecosystem over single systems. Where the *connecting* strategy discussed by Nielsen and Sæbø (2015) reflects an approach towards data sharing and complementary functionality, our concept of hybrid vigor focuses on a strategy towards strengthening the functional attributes of the ecosystem as a whole. We base this concept on an underlying assumption that the existence of multiple software components is a strength and a source for innovation. The current status of the infectious disease reporting system in Vietnam can be seen as the outcome of a hybrid vigor strategy with components successfully reconfigured to collectively offer superior functionality:

- The old eCDS has, despite being replaced, still acted as a functional reference for the new eCDS.
- The ENS continues to play its role in the ecosystem by providing clinical data of infectious cases to the new eCDS electronically
- The CDDW relies on data from eCDS and ENS to provide functionality for data visualizing and analysis. As the process of (re-)configuring is contingent, the evolution

of software ecosystems may take many different trajectories. What we have seen is that software components which gains strong political favor may get the required backing to expand to encroach upon other components and the functionality they offer. Other components are thus marginalized and potentially excluded. While this new configuration can offer the needed functionality, it will at the same time undermine further innovation and new cycles of reconfiguration based on the hybrid vigor strategy. Actors pursuing an encroaching strategy with the result of excluding other systems may also experience political repercussion as there are vested interests in any software component. Depending on the political climate, the power of the involved actors and endogenous configurability of components, hybrid vigor can be based on different configurations.

- As in any other strategy, hybrid vigor must be consciously followed by certain stakeholders in order to make it work. From our discussion, we could easily point out that VAMS and iNGOs are the two actors that have deliberately followed the strategy. We could argue that as they have been in a minor legitimate role in comparison with GDPM and VCom regarding the arena of infectious diseases data, hybrid vigor is vital to the existence of their systems. In whatever explanation, there is a need of having such “system builders” and VAMS and iNGOs have been playing that heroic role. This argument also contributes to the debate on the role of centralized and legitimate control of governmental agencies in II development. While their role is very important, it does not mean that roles of other actors should be ignored. It means that the course of a battle could be easily changed even its epilogue seemed to be early determined. Future research can further explore the scenarios that did not happen in our case, thus were not discussed: What is the likelihood of the resulting infrastructure in cases of a) governmental agencies pursuing the hybrid vigor strategy b) None of the actors following it.

6 CONCLUSION

The findings and the discussions this paper challenges the pervasive yet simplistic view on information infrastructure that largely ignores the intricacy of the development of its software components and their overlaps, duplication, and potential substitution. Our study has offered a closer look at the information infrastructures as software eco-systems and their how they evolve. We have in particular unpacked the interplay and dynamics of directly competing components struggling to survive throughout the course of evolution. Theoretically, by introducing the concept of hybrid vigor as a strategy for functional architecting, the study provides new insights into the evolutionary trajectories of information infrastructures as competing environment – as battlegrounds. Three dimensions of hybrid vigor (political negotiation, power of governmental agencies, and functional reconfiguration) have been identified to characterize the strategy and offer a better tool to analyze threats and opportunities imposed by crossbreeding directly competing components.

Our findings have several implications for both theory and practice. The tension of direct competition is in many cases inevitable, and it is in these situations important to adopt elastic

and flexible strategies that can leverage and combine strengths of separate yet competing components, rather than encouraging a fight until only the last man is standing. As a consequence of the hybrid vigor strategy, the resulting ecosystem will support innovation and become more responsive to any contingency and change in the environment.

REFERENCES

- Aanestad, M. and T. B. Jensen (2011). "Building nation-wide information infrastructures in healthcare through modular implementation strategies." The Journal of Strategic Information Systems **20**(2): 161-176.
- Benbasat, I., et al. (1987). "The case research strategy in studies of information systems." Mis Quarterly: 369-386.
- Benbya, H. and B. McKelvey (2006). "Using coevolutionary and complexity theories to improve IS alignment: a multi-level approach." Journal of Information Technology **21**(4): 284-298.
- Braa, J., et al. (2007). "Developing health information systems in developing countries: the flexible standards strategy." Management Information Systems Quarterly **31**(2): 381-402.
- Braa, J. and C. Hedberg (2002). "The struggle for district-based health information systems in South Africa." The information society **18**(2): 113-127.
- Braa, J., et al. (2004). "Networks of action: sustainable health information systems across developing countries." Mis Quarterly **28**(3): 337-362.
- Callon, M. (1984). "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay." The Sociological Review **32**(S1): 196-233.
- Ciborra, C. (2000). From control to drift: the dynamics of corporate information infrastructures, Oxford University Press on Demand.
- Garde, S., et al. (2007). "Towards sustainability of health information systems: how can we define, measure and achieve it?" Studies in Health Technology and Informatics **129**(2): 1179.
- Gregory, R. W., et al. (2013). "Control balancing in information systems development offshoring projects." Mis Quarterly **37**(4): 1211-1232.
- Grisot, M., et al. (2014). "Innovation of, in, on infrastructures: articulating the role of architecture in information infrastructure evolution." Journal of the Association for Information Systems **15**(4): 197-219.
- Hanseth, O. (2010). "From Systems and Tools to Networks and Infrastructures—from Design to Cultivation: Towards a design Theory of Information Infrastructures." Industrial Informatics design, Use and Innovation. IGI Global, Hershey, PA: 122-156.
- Hanseth, O. and M. Aanestad (2003). "Design as bootstrapping. On the evolution of ICT networks in health care." Methods of information in medicine **42**(4): 384-391.
- Hanseth, O. and K. Braa (2000). "Who's in control: Designers, managers-or technology? Infrastructures at norsk hydro." From Control To Drift: The dynamics of corporate information infrastructure: 125-147.

- Hanseth, O., et al. (2001). "The control devolution: ERP and the side effects of globalization." ACM Sigmis Database **32**(4): 34-46.
- Hanseth, O. and K. Lyytinen (2010). "Design theory for dynamic complexity in information infrastructures: the case of building internet." Journal of Information Technology **25**(1): 1-19.
- Hanseth, O. and E. Monteiro (1998). "Understanding information infrastructure." Unpublished book, <http://heim.ifi.uio.no/~oleha/Publications/bok.html>.
- Haux, R. (2006). "Health information systems? past, present, future." International Journal of Medical Informatics **75**(3-4): 268-281.
- Heeks, R. (2006). "Health information systems: Failure, success and improvisation." International Journal of Medical Informatics **75**(2): 125-137.
- Heeks, R., et al. (1999). "Understanding success and failure of healthcare information systems." Healthcare Information Systems: Challenges of the New Millennium: Challenges of the New Millennium: 96.
- Henfridsson, O. and B. Bygstad (2013). "The generative mechanisms of digital infrastructure evolution." Mis Quarterly **37**(3): 907-931.
- Henningsson, S. and O. Hanseth (2011). "The essential dynamics of information infrastructures."
- Hughes, T. P. (1979). "The electrification of America: the system builders." Technology and Culture **20**(1): 124-161.
- Hughes, T. P. (1987). "The evolution of large technological systems." The social construction of technological systems: New directions in the sociology and history of technology: 51-82.
- Jansen, A. and P. Nielsen (2005). "Theorizing convergence: Co-evolution of information infrastructures." Scandinavian journal of information systems **17**(1): 4.
- Manikas, K. and K. M. Hansen (2013). "Software ecosystems—a systematic literature review." Journal of Systems and Software **86**(5): 1294-1306.
- Merriam, S. B. (1998). Qualitative Research and Case Study Applications in Education. Revised and Expanded from, ERIC.
- Nielsen, P. and M. Aanestad (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.
- Nielsen, P. and J. I. Sæbø (2015). "Three Strategies for Functional Architecting: Cases from the Health Systems of Developing Countries." Information Technology for Development: 1-18.
- Sahay, S., et al. (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., et al. (2014). "Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation." Journal of the Association for Information Systems **15**(4): 220-243.

Seawright, J. and J. Gerring (2008). "Case selection techniques in case study research a menu of qualitative and quantitative options." Political Research Quarterly **61**(2): 294-308.

Shaw, V. (2009). AComplexity INSPIRED APPROACH TO CO-EVOLUTIONARY HOSPITAL MANAGEMENT INFORMATION SYSTEMS DEVELOPMENT, University of Oslo Norway 21.

Shull, G. H. (1948). "What is" heterosis"?" Genetics **33**(5): 439.

Stake, R. E. (2013). Multiple case study analysis, Guilford Press.

Tilson, D., et al. (2010). "Research commentary-digital infrastructures: the missing IS research agenda." Information systems research **21**(4): 748-759.

Tilson, D., et al. (2012). Change and control paradoxes in mobile infrastructure innovation: the Android and iOS mobile operating systems cases. System Science (HICSS), 2012 45th Hawaii International Conference on, IEEE.

Tiwana, A., et al. (2010). "Research commentary-Platform evolution: Coevolution of platform architecture, governance, and environmental dynamics." Information systems research **21**(4): 675-687.

West, J. and J. Dedrick (2000). "Innovation and control in standards architectures: the rise and fall of Japan's PC-98." Information systems research **11**(2): 197-216.

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From Routine to Revolt: Improving Routine Health Data Quality and Relevance by Making them Public

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Abstract. Health Information Systems in developing countries struggle with vicious cycles of lack of information use. Substantial investment has been spent to improve the situation but results are still very limited. Adding to the body of research on strategies and solutions to break out of such cycles, this paper focuses on the effects of making routine data public through mass media and using data to fuel debates on critical health issues. Based on an action research project building a reporting system for accidents and emergencies during the Tet holiday in Vietnam, this paper discuss how making data public can have direct impact on the use and quality of health data in the health system. We discuss and draw implications related to tactics to improve the demand and use of routine health data.

Keywords: Information use, data quality, rapid scaling

1 Introduction

Health Information Systems (HISs) have long been recognized as an important component of public health systems because they provide vital data for effective planning and sound decision making [1]. Although HISs play an important role in improving healthcare service delivery, they often fail, especially in developing countries [2]. Many HISs end their lifecycle in the pilot stage because they do not scale and provide useful data for managers [3]. Together with the scaling challenge, developing countries are also challenged by health managers' limited use of data in decision making. Nutley, Gnassou [4] argue that turning data into action is critical for improving the health services delivery and outcomes. There are many reasons attributed to limited data use, including culture and capacity [5] as well as the information needs of decision makers [6]. Another complication is the poor quality of data. Braa, Hanseth [3] use the notion of a vicious cycle to refer to situations in which "national health data are used little because they are of poor quality, and their relative lack of use, in turn, makes their quality remain poor" (p. 379). This is a hard to break cycle. Several attempts have been made to break out of the vicious data use cycle (see

for example Nutley and Reynolds [1], Braa, Heywood [2], Rhoads and Ferrara [3]). These attempts can broadly be classified into two streams. The first deals with problems related to the data supply side such as data quality, availability, and access. The second stream focuses on the demand side by encouraging data use based on changing social institutions such as information culture and human capacity.

With a focus on understanding data use and approaches to generate data demand from decision makers, we conducted an action research which involved the design, customization, and implementation of an information system that supports the collection and analysis of various health indicators during the Lunar New Year in Vietnam between 2014 and 2016. Data reported from more than one thousand hospitals and health facilities (accounting for 95% hospitals in Vietnam) revealed a harsh reality of violence and traffic accidents during Lunar New Year holidays. And the general public was perplexed when figures of traffic accidents announced by MoH and Ministry of Public Security (MPS) contradicted each other significantly. It also sparked a big public debate on data quality, data collection and related processes.

In developing countries, routine health data and indicators are not usually high in demand. Those collecting it commonly collect it only for the purpose of upward reporting and receive little if any feedback. And those receiving it commonly do not trust the data nor use it for decision making. This paper presents a contrasting case to this where the mundane and neglected routine health data suddenly was in the spotlight.

The rest of this paper is organized as follows. In the next section, we review related research and debates on the problem of data use and offer our perspective. Research method and the case description are provided in section 3 and 4 respectively. We discuss the findings and implications for theory and practice in section 5 before conclude the paper in section 6.

2 Related Research

The ultimate goal of any HISs intervention is to ensure quality data that informs decision making. Informed decisions will lead to better use of limited and often scarce resources where they are needed. If data are not used, HISs and efforts to collect, aggregate and distribute health data are meaningless. Unfortunately, despite investments in and improvements of HISs, lack of data use is common (Braa et al., 2012, Wyber et al., 2015). This section presents recent studies that discuss efforts to tackle the problem of little data use.

Lomas [7] in a study from the healthcare sector in Canada emphasizes the role of intermediaries in disseminating research results, thus facilitating the use of health data. He argues that there is a poor understanding of context where the research result is generated and realities facing policy makers. A solution to this problem is to im-

prove the communication between the two sides. He discusses the approach that has been applied in Canada for many years, which involves the institutionalization of the knowledge brokering roles in disseminating the data. In particular, research results should be communicated effectively and succinctly through Mythbusters and Evidence Boost, which are a form of research summary, to other groups of users such as legislative, administrative, and industrial decision-makers.

Bowen, Erickson [8] identify 8 different barriers that constrain the use of data for decision making in a study that involves health staff from 11 Regional Health Authorities in Manitoba province of Canada in three years. They argue that efforts to improve data accessibility and data use competency are important but might not increase the level of data use if the key barriers to the issue are not properly lifted. Their findings include an interesting discovery of “politics trumps evidence” which refers to a phenomenon where data are sought to back a political decision rather than inform decision making process. Sometimes, decision makers could not make an evidence-informed decision because they lack of means and supporting structure to implement a decision. Nutley and Reynolds [9] synthesize previous works related to the issue of health data use including the World Health Organization’s Health Metric Network tool [10], the Performance of Routine Information System Management (PRISM) framework [11, 12], Lomas [7], and Patton [13] to propose a comprehensively logical model that encompasses a set of eight processes and activities to strengthen data use.

In a developing country context, Braa, Heywood [14] conduct an action research with the aim to break the “vicious cycle” of data quality and data use. The underlying assumption of their intervention is that piecemeal increased data use can gradually improve the data quality and build up data use capacity. Quarterly workshops on data use are organized at both national and district levels. During the workshops, district staff will show data from their districts and present their own interpretation while other district staff will discuss and criticize. In three years between 2005 and 2008, there are noticeable changes in data use as a result of the intervention. Similarly, based on action research in Kenya with the aim to establish mutually agreed activities among key stakeholders to improve data use for action, Manya et al. (2015) argue that data quality audits must be organized at the same time with monthly data review meetings and training in data management in order to address the problem of little use of data. Moyo, Kaasbøll [15] also discusses the process of development and introduction of a League Table to compare the performance of different health districts in Malawi. They argue that the module is a useful tool to remedy the problem of information transparency. Also according to them, transparency of information should be treated as a totality of all aspects including disclosure, clarity, and accuracy rather than separately.

In the extant literature on the use of health data, the attention is central on how to provide health managers high quality data to support the decision making process. There is little discussion on how health data mean to the public and how the public can participate in the routine health system design and use. Presumably, most data

from the routine health management information systems (HMIS) are supposed to serve managerial purposes. The public who is subject of all health policies is often ignored from such systems and they do not have access to their data. They neither know about how such systems operate, what data are collected nor raise their voice on how such systems should be designed to benefit them. The primary aim of this research is to contribute to that discussion and more specifically focus on finding appropriate approaches that could make boring routine health data become attractive to the public.

3 Method

This research follows an action research approach [16]. Action research is a method that aims to solve practical problems and at the same time generate theoretical knowledge [17]. Action researchers have dual responsibilities: to improve the situation and to report findings of their study. Action research is different from other methods in its ability to develop knowledge for both theory and practice. In studying technology in social context, action research is a strong candidate [18]. While there are many forms of action research, canonical action research is commonly used as it ensures the rigor of the research [19].

Data for this study mainly come from the daily interactions, participation and observations of the first author in the daily activities of the project. A research diary was used to capture important events, incidents, or other important discussions related to the system development and implementation. To improve the reliability, data from this source were regularly shared with the second author to independently verify. Other modes of data collection include interviews. A total of 15 interviews with different kinds of informants: MoH officials (2), the technical and support teams (6), provincial health administrators (2), and data clerks from hospitals (5) was conducted in early 2014 through face to face and phone. Each interview lasted between 30 and 45 minutes. Notes were taken during the interviews for subsequent use in the analysis step. Informants who were hospital users were selected from those who called the supporting team to get support. The purpose of these interviews was thus to understand better users' difficulties in using the system. Examples of interview questions for this type of informants were "*How do you find the design of that functionality? How should it be improved?*". Archival records were another means utilized for collecting data. To understand the view of the public on various social issues such as traffic accidents and violence during Tet, mass media articles were also considered, mostly in the electronic form (e-newspapers) including statements of officials from the Government and Assembly.

After being collected, data was grouped into broad themes such as technical infrastructure and social infrastructure, the rapid process of development and implementation of the system, the inconsistency of reported data in comparison with other available sources, and the public's attitudes and the perspectives of different governmental

agencies. Several concepts from the literature information transparency, development, and data use were used to guide the analytical process. Part of the analysis process is the narrative of the case, which is now presented.

4 The Case

In early 2014, the Department of Medical Services Administration (VAMS) of the Ministry of Health decided to build an online system to support collecting data related to accident and emergency during the Lunar New Year (Tet) in Vietnam. A medical doctor from VAMS, who is responsible for Information Technology (IT) and health data, consulted a technical team (here after called the DHIS2 Team) that had worked in previous health information systems projects at MoH. His aim was to explore the possibilities of using an open source platform especially developed for the health sector called DHIS2 (dhis2.org) to build an online system for Tet reporting. As the decision by VAMS was made very late, they only had one week to complete the system. After some considerations, the DHIS2 Team confirmed that they were able to build the system and immediately embarked on the mission. DHIS2 is a software platform developed by University of Oslo, Norway. It provides a flexible mechanism in handling data elements and forms, making it easy to define new datasets. However, the default data entry form in DHIS2 only allowed data entry for one period at a time. This was considered to be confusing for the users. The team thus decided to design a custom data-entry form that shows multiple periods in a single screen.

After building the data entry forms, the DHIS2 Team deployed the system on one of MoH servers. A few months before Tet, MoH had implemented a hospital quality and inventory system which was also based on the same DHIS2 software. User accounts for this system were generated using a script and forwarded in Excel files to each health province which subsequently forwarded to their subordinate hospitals. The DHIS2 Team decided to leverage this existing user base. Since they already had access and knew the system, this would shorten the implementation process and eliminate the need of training. An official letter requesting hospitals to use the Tet reporting system was distributed by the MoH.

As it was the first year using the Tet reporting system, many hospitals still viewed the system as a “pilot”. As a consequence, lack of rigor in data entry was observed. Some users entered garbage numbers into important fields like injured cases by firecrackers, as if such figures would not be subsequently aggregated and reported to the government and visible to the public via mass media. It should be also noted that according to the law in Vietnam, the head of province will receive disciplinary action if there is illegal use of firecrackers in his/her province. To avoid such data entry incidents, the IT specialist from MoH who was assigned to work on this system had to frequently verify if there were any suspicious numbers entered. He also called the person who was responsible for reporting on that day in the hospital to confirm the reported numbers.

During the Tet 2014, data from more than one thousand hospitals were daily aggregated by MoH and subsequently reported to the Government Office. Many journalists approached MoH to acquire data to write articles because they believe accident and emergency during the Tet are matters of public concern. After articles were published, the public was shocked to know that nearly 7,000 people were hospitalized, out of which 15 people died, due to violence during the 9 days of the Tet holiday. The Deputy Chair of Social Committee, Vietnam Assembly said: “This figure was an alarm of the increasing violence in our society. It was very unusual because the Tet holidays were the time dedicated for joy and relax. The Committee welcomes MoH for its first time publication of the data which we did not have previously.” [20]. The Prime Minister insisted that such figures were very serious and directed all concerned agencies to propose and implement effective measures to mitigate violence [21].

In addition, many scholars, educators, and psychologists proactively joined the debate, trying to locate the root causes of the issue. An economist from the Center of Economic Research in the South stated: “People solve their conflicts by using violence because they have lost their trust on justice and government” [22]. And a researcher from Research Center of Sino-Nom said: “It is a really crisis of the crowd, once its psychology is compressed throughout the year and it bursts on the Tet. It accumulates all conflicts with the root cause of unstable and insecure society. Culture, morality, and education in Vietnam have never been degraded like they are now” [20, 22]. There was a broad agreement that in combination with stricter punishment for violent crimes, schools should focus more on ethical and behavioral education for youngsters.

Regarding the reported figures of traffic accidents, the public was at the same time very puzzled by the gap [23] between the figures announced by Ministry of Public Security (MPS) and Ministry of Health (MoH). While the figures published by MPS showed a significant decrease in the number of injuries (-25%) and death (-5%), MoH announced an increase of traffic accidents during the Tet holiday. Quantitatively, MPS reported only 408 traffic accidents whereas MoH reported more than 40,000 hospitalized cases related traffic accidents. This triggered debates related to the trustworthiness of these two different information sources. For instance, the Head of Road Transportation Department (MPS) argued that the police could only collect data from traffic accidents that were reported to them while, in reality, most victims were transferred directly to hospitals. This argument was supported by a statement made by a representative of National Committee of Transportation Safety (NCTS): “NCTS will make a proposal to the Prime Minister to get permission to use data from MoH as an official source for traffic accident reporting, instead of exclusively using data from the police” [24].

5 Analysis and Discussion

The design and implementation of the Tet reporting system can be considered as a successful story because it rapidly achieved national coverage and generated data that triggered public debates on several social issues. We now provide analysis on how the system attracted the public's attention to what is commonly treated as boring and mundane routine data.

5.1 Collecting data that highly concern the public and commodifying health data

Hospital users often see reporting duty as a burden rather than something useful for them or the healthcare sector (Krickeberg, 2007, Kuhn and Giuse, 2001, Littlejohns et al., 2003). In the case of the Tet reporting system, the number of data elements was minimal and only important data elements were included. The small dataset approach also helped reduce complexities of the system both at technical and social levels. The flat structure of dataset made the design and use of the system become easy and helped shrink "the time to market" (Smith, 2004). This small dataset approach has another implication. Data entry forms of HISs in developing countries tend to be overly complex (Sahay et al., 2010) and merely serve the need of health managers. The public, however, should have the right to know about data that directly concern their life. In other words, HISs should also be designed in a way that it collects kinds of data that are highly related to the lives of majority of citizens. This is not the case in Vietnam where figures on traffic accidents and violence are completely absent on the routine report.

Routine health data are often too complex to understand and use even for health professionals [15]. In order to attract attention of the public, the data need to be simplified and commodified. For example, the number of deaths related to traffic accidents and number of injuries related to violence are simple and easy enough for anyone to understand. The use of raw numbers to some extent gives better impression about the situation compared to the use of indicators. Regardless the size of the population, thousands of people injured by violence is something hard to believe and unacceptable.

Commodifying data also relates to the two aspects of information transparency which are disclosure and clarity [15, 25]. While disclosure only focuses on the availability and accessibility of data to interested parties which are very often governmental agencies and not-for-profits organizations, commodifying also involves making sense of data to the public. In the attempt to engage the public in the debate of critical health issues, clarity must be more focused to the level that it is understandable for the public who do not know anything about the healthcare domain.

5.2 Engaging mass media and fueling public debates

Routine health data are often moved upward, i.e. from health facilities to higher level. Little if any feedback from higher level health managers are provided to health facilities after data are reported [26]. To attract the public's attention on critical health issues, novel channels of rapid and large-scaled data propagation must be sought. One such channel is mass media, i.e. newspapers and magazines. With large numbers of readers and hourly news posting, newspapers (both paper-based and online) can draw attentions from the public in a quick and effective way. Also, thanks to the rhetoric of journalists, titles of articles are often written in an impressive and attractive way which no doubt makes the boring and mundane data become lively and attract the attention of the public.

As a general practice, mass media often engage important and renowned figures to comment on emergent social issues. They can be professors from universities, experts in various domains, and incumbent officials or politicians. This approach is to bring the readers multiple perspectives on a particular issue. In the case of violence, the debate of data accuracy was sparked by MPS officials who expressed suspicion on the big number of hospitalized cases because of violence. There was a firm response from the Head of Medical Service Administration (VAMS, MoH) about that. The response included the unpacking of procedures and systems through which the number was aggregated. This was an important step to keep the dialog continue and remain constructive. Later, the IT specialist who was the key contact point of the project agreed to give an exclusive interview to an online newspaper on the history and backstage story of how the system was built and implemented.

5.3 Creating feedbacks and triangulating data

Also through newspapers the public knew more about the work of hospitals during the holiday. This gave users the feeling of participation. Through the circulation process, data are extensively validated and flexibly interpreted by a large collection of human actors. We argue that data circulation processes are crucial for sustainable HISs as it blurs the boundaries between data collection and data use, creating the congeniality [27] between the ICT initiative and the environment. The findings of our case are slightly distinct from literature discussing the role of new social media such as Facebook, Twitter etc. on changing awareness of the public and creating new channel of two-way communication between public health experts and the public. Recent works on social media emphasize the significance and effectiveness of using social media to engage the public in public health issues [28-31]. However, we argue that depending on the situation, traditional media are still very powerful means in amplifying and visualizing health issues to the public which in turn would help to increase accountability and transparency.

We believe one factor that played an important role in the success of the Tet system was the feedback mechanism. The extant literature often reports cases of HISs in

which data reported by data entry clerks do not receive adequate feedbacks to improve the quality of data [32]. In our case, there exist two types of feedback mechanisms: feedback from MoH to hospitals and from the public to hospitals. As the reporting process took place on a daily basis, hospitals received feedback from MoH within almost the same day. This instant feedback played a crucial role in not only improving data quality but also increasing the completeness of data. In order to have timely data to report to government and share with the public, the technical team had to play the role of designer and user at the same time. For example, they had to check data on an hourly basis to early discover any mistake in reported data. They had to call hospitals to verify the figures and sometimes directly modified them. In another flow of feedback, when a data entry clerk reported a figure through the system, the figure was aggregated at the national and subsequently shared with the public. As a member of the public, the clerk also received that aggregated figure and had her own interpretation thus she became a user of the system.

Many studies report the problem of fragmentation in HISs in developing countries (see for example Chilundo and Aanestad [33]). Fragmentation refers to the situation where multiple, duplicate and overlapping systems coexist but cannot provide data necessary for decision making. While we agree that overlap in data collection should be minimized to the best extent, in some special occasions, it is a chance for restructuring and improvement. For example, in the case of traffic accident reporting, MPS and MoH are the two agencies that have routine data collection systems. The contradiction in data reported by the two systems made the public suspicious about the veracity of the data. The number of traffic accidents reported by MPS system was unreasonably too small compared to what reported by MoH system. As a result of this triangulation, the Head of National Traffic Safety Committee agreed that data from MoH system would be incorporated into the report next year.

5.4 Getting full-coverage data ready and publishing data

One of the issue that face HISs practitioners and researchers is the dilemma of “all or nothing” (see Braa, Hanseth [3]). Incomplete data for a geographical area have little value in use. Complete and Full-coverage data is only attainable when a full scale implementation of HISs is achieved. Scaling, however, is a big challenge as it is not about mechanically replicating the same technical artefact to other contexts but also multiple sociotechnical rearrangements [34].

Research emphasizes the role of installed base in terms of existing technology and established use practices in shaping (and being shaped) the outcome of ICT interventions [35]. Taking advantage of what already exists to kick-start, or bootstrap [36], is an advisable strategy. The Tet reporting system was built on the existing DHIS2 software system already implemented in the hospitals. By leveraging the existing software, the team cut down the expensive and lengthy processes of full life cycle of software development. Since users at the hospital were knowledgeable of the DHIS2 system, expensive and time consuming training was not necessary. DHIS2 has a data

entry module that is highly configurable to adapt to a wide range of requirements. However, this module is sometimes too complicated for beginners. The technical team was inspired by the design of social media tools such as Facebook where anyone can create an account and start to use Facebook without attending any training classes. Therefore, they designed the system in a way that minimal or no training was needed. For instance, the data entry form was customized to enable data entry for multiple days in a single screen. Also, a report printing button was integrated into the data entry form, making it easier for users to view and export data to other formats such as Microsoft Excel for further processing. This approach was also more responsive to changing requirements. For instance, the Tet reporting system required an additional dataset. This could be easily be made through the dataset management module of DHIS2. No line of code was required. As a result, the system became ready in a short time.

Many researchers emphasize the role of good data in improving the quality of health service delivery [37, 38]. Substantial efforts have been made in building reliable and sustainable HISs. However, having data does not automatically lead to data use. Noir and Walsham [39] discuss the ceremonial and mythical use of HISs in the public health sector in India where health centers entered data into local computers, exported them to flash drives and carried the flash drives to higher level to submit data. The authors challenge the simplistic view that ICTs adoption will directly generate efficiency and gains. In our case study, the collected data were processed by the MoH team and subsequently shared with other stakeholders and news agencies to trigger data use process. The decision of MoH to publish the data to mass media created a feedback loop that reinforced the data reporting activities at hospitals, motivating hospitals to collect and report accurate data.

Publishing data goes in hand with accountability and transparency because MoH must be responsible for data it published. Prior to the implementation of this system, MoH only used the data for internal management. It was not obliged to make the data public. This decision was thus an important step toward public transparency. And public transparency led to public accountability.

6 Conclusion

Making life better is a goal of any ICTs project. This research presents an empirical case where data collected by a software system were used to trigger public debates that could contribute to shape policy and the public's attitudes. The approach discussed in the paper emphasizes the significance of selecting matters of public concern (few critical data elements) and rapidly scaling the implementation to get full data coverage. Collected data are disseminated and amplified by mass media to attract public's attention and trigger debates. Through the mass media, public express their concerns on critical health issues. As a collective effect, voices of people are better heard by the government. Lessons learnt from this research are hoped to provide pub-

lic health administrators and IT practitioners design ideas and principles that help design sustainable HISs that empower people especially those who are marginalized. Time constraint did not allow us to venture deeply into the interpretations of collected data, i.e. geographical analysis of violent cases or traffic accidents. We believe the quantitative analysis in this area will be useful for the public and policy makers in preventing and reducing the cases related to traffic and violence. Our findings also contribute to the debates of how to improve the efficiency of HISs through the use of data for decision making.

References

1. AbouZahr, C. and T. Boerma, Health information systems: the foundations of public health. *Bulletin of the World Health Organization*, 2005. 83(8): p. 578-583.
2. Heeks, R., Information systems and developing countries: Failure, success, and local improvisations. *The information society*, 2002. 18(2): p. 101-112.
3. Braa, J., et al., Developing health information systems in developing countries: the flexible standards strategy. *Management Information Systems Quarterly*, 2007. 31(2): p. 381-402.
4. Nutley, T., et al., Moving data off the shelf and into action: an intervention to improve data-informed decision making in Cote d'Ivoire. *Global health action*, 2014. 7.
5. Braa, J. and S. Sahay, *Integrated Health Information Architecture: Power to the Users: Design, Development and Use*. 2012.
6. Davies, P., et al., Conceptualising the information needs of senior decision makers in health. *Health Inform Syst Knowl Hub*, 2011. 18: p. 1-20.
7. Lomas, J., The in-between world of knowledge brokering. *Bmj*, 2007. 334(7585): p. 129-132.
8. Bowen, S., et al., More than "using research": the real challenges in promoting evidence-informed decision-making. *Healthcare Policy*, 2009. 4(3): p. 87.
9. Nutley, T. and H.W. Reynolds, Improving the use of health data for health system strengthening. *Global health action*, 2013. 6.
10. Network, H.M. and W.H. Organization, *Assessing the national health information system: an assessment tool*. 2008: World Health Organization.
11. Aqil, A., *PRISM case studies: strengthening and evaluating RHIS*. MEASURE Evaluation, USAID, 2008.
12. Aqil, A., T. Lippeveld, and D. Hozumi, PRISM framework: a paradigm shift for designing, strengthening and evaluating routine health information systems. *Health Policy and Planning*, 2009. 24(3): p. 217-228.
13. Patton, M.Q., *Utilization-focused evaluation*. 2008: Sage publications.
14. Braa, J., A. Heywood, and S. Sahay, Improving quality and use of data through data-use workshops: Zanzibar, United Republic of Tanzania. *Bulletin of the World Health Organization*, 2012. 90(5): p. 379-384.
15. Moyo, C., et al., The Information Transparency Effects of Introducing League Tables in the Health System in Malawi. *The Electronic Journal of Information Systems in Developing Countries*, 2016. 75.
16. Avison, D.E., et al., Action research. *Communications of the ACM*, 1999. 42(1): p. 94-97.
17. Winter, R., *Learning from experience: Principles and practice in action-research*. 1989: Falmer Pr.
18. Baskerville, R.L. and A.T. Wood-Harper, A critical perspective on action research as a method for information systems research, in *Enacting Research Methods in Information Systems: Volume 2*. 2016, Springer. p. 169-190.

19. Davison, R., M.G. Martinsons, and N. Kock, Principles of canonical action research. *Information systems journal*, 2004. 14(1): p. 65-86.
20. MoH_Portal. 6.200 cases hospitalized due to violence: usual or unusual? 2015; Available from: <http://moh.gov.vn:8086/news/Pages/TinKhacV2.aspx?ItemID=569>.
21. Life&Law. Prime Minister: Violence during Tet is not minor. Life and Law 2015; Available from: <http://www.doisongphapluat.com/xa-hoi/thu-tuong-khong-the-xem-thuong-chuyen-danh-nhau-dip-tet-a84907.html>.
22. Vu, A., Why aggressive behavior is on the throne. RFA, 2015.
23. Tuong, T., Every insitution reports a different number: the public can not trust. 2016.
24. Ha, M. Death by traffic accident: contradictory figures. 2016; Available from: <http://thanhnien.vn/thoi-su/chet-vi-tai-nan-giao-thong-moi-co-quan-bao-cau-mot-kieu-667572.html>.
25. Schnackenberg, A.K. and E.C. Tomlinson, Organizational transparency a new perspective on managing trust in organization-stakeholder relationships. *Journal of Management*, 2014: p. 0149206314525202.
26. Charles, N. and W. Geoff, The great legitimizer: ICT as myth and ceremony in the Indian healthcare sector. *Information Technology & People*, 2007. 20(4): p. 313-333.
27. Sanner, T.A., T.D. Manda, and P. Nielsen, Grafting: Balancing Control and Cultivation in Information Infrastructure Innovation. *Journal of the Association for Information Systems*, 2014. 15(4): p. 220-243.
28. Abrams, L.C., R. Schiavo, and C. Lefebvre, New media cases in Cases in Public Health Communication & Marketing: the promise and potential. *Cases in Public Health Communication & Marketing*, 2008. 2: p. 3-9.
29. Heldman, A.B., J. Schindelar, and J.B. Weaver Iii, Social media engagement and public health communication: implications for public health organizations being truly" social". *Public Health Reviews*, 2013. 35(1): p. 1.
30. Newbold, K.B. and S. Campos, Media and social media in public health messages: a systematic review. Hamilton, ON: McMaster Institue of Environment and Health, 2011.
31. Willoughby, J.F. and H. Smith, Communication Strategies and New Media Platforms Exploring the Synergistic Potential of Health and Environmental Communication. *Science Communication*, 2016: p. 1075547016648151.
32. Braa, J. and C. Hedberg, The struggle for district-based health information systems in South Africa. *The information society*, 2002. 18(2): p. 113-127.
33. Chilundo, B. and M. Aanestad, Negotiating multiple rationalities in the process of integrating the information systems of disease specific health programmes. *EJISDC: The Electronic Journal on Information Systems in Developing Countries*, 2005(20): p. 2.
34. Sahay, S. and G. Walsham, Scaling of health information systems in India: Challenges and approaches. *Information Technology for Development*, 2006. 12(3): p. 185-200.
35. Grisot, M., O. Hanseth, and A.A. Thorseng, Innovation of, in, on infrastructures: articulating the role of architecture in information infrastructure evolution. *Journal of the Association for Information Systems*, 2014. 15(4): p. 197-219.
36. Hanseth, O. and M. Aanestad, Design as bootstrapping. On the evolution of ICT networks in health care. *Methods of information in medicine*, 2003. 42(4): p. 384-391.
37. Donaldson, M.S. and K.N. Lohr, Health Data in the Information Age:: Use, Disclosure, and Privacy. 1994: National Academies Press.
38. Rhoads, J. and L. Ferrara, Transforming healthcare through better use of data. *Electron Healthc*, 2012. 11(1): p. 25-31.
39. Noir, C. and G. Walsham, The great legitimizer: ICT as myth and ceremony in the Indian healthcare sector. *Information Technology & People*, 2007. 20(4): p. 313-333.