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:

User motivation and knowledge 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.
Use area and situation 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.
Nature of technology Several dimensions of technology, including cost, flexibility, simplicity and availability, could have high impact on the users' attitudes.
Coordinating institutions 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.

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.

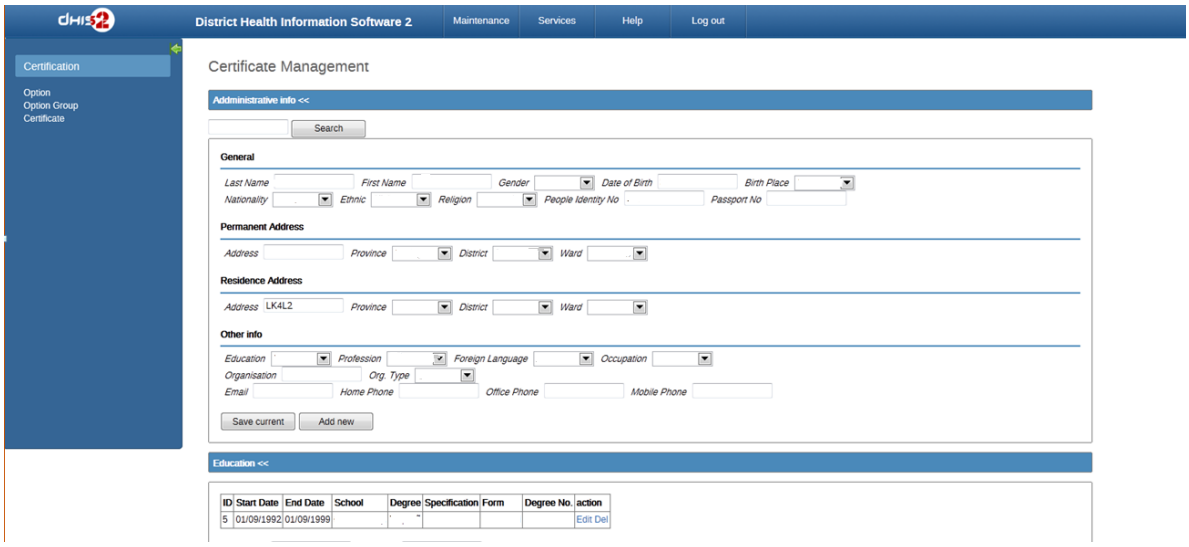

Figure 1: Screenshot of the first version of the prototype

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 conductive 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 Iacucci et al. (2002)	Tactics from our case
Use	
1. Useful even with a small number of other users.	*Addition:* 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.	*Addition:* 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.	Addition: 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.
	New: 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.	*Addition:* 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.	*Addition:* 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.	*Addition:* Installed base should also refer to user experiences and skills, not only software system; i.e., MS Excel skills
7. Use gateways.	*Addition*: 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 infastructures,* 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 Gøteborg, 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.