Journal of the Association for Information Systems

JAIS

Research Article

Exploring the Formation of a Healthcare Information Infrastructure: Hierarchy or Meshwork?

Joan Rodon
ESADE, Universitat Ramon Llull
joan.rodon@esade.edu

Leiser Silva
University of Houston
lsilva@uh.edu

Abstract

The digitalization of economic and social activity has brought information infrastructures (IIs) to the forefront of research. This paper studies II formation processes and their outcomes; namely, II architecture and distribution of control rights. We conduct an in-depth exploratory case study of an electronic prescription II and report on two formation processes: stratification and meshworking. The stratification process in our case study involved classifying the IIs' diverse socio-technical components into homogeneous groups and consolidating them into a coherent hierarchical structure that standardized the components' behavior. The outcome of this stratification was a dual and hierarchical architecture and a fairly centralized locus of control. The meshworking process, by contrast, assembled heterogeneous components without homogenizing them; the components were distributed in a way that enabled them to self-organize. The outcome of this meshworking process was a modular architecture that decoupled the central nodes from the users' installed base and a more decentralized structure. Consequently, the final II architecture was a hybrid offering both centralized control and autonomy of the parts. Our research further illustrates how this architecture then influenced the project's complexity and the actors' position in the sector. We build our contribution on extant II research.

***Keywords**: Information Infrastructure, Architecture, Formation, Meshwork, Hierarchy, Emergence, Design, Healthcare, Control.*

* Jannis Kallinikos was the accepting senior editor. This article was submitted on 31st May 2013 and went through three revisions.

Volume 16, Issue 5, pp. 394-417, May 2015

Exploring the Formation of a Healthcare Information Infrastructure: Hierarchy or Meshwork?

1. Introduction

The notion of information or digital infrastructure (II), as a perspective on and a new category of IT artifact, has gained much attention following the work of Geoffrey C. Bowker, Claudio Ciborra, Ole Hanseth, Eric Monteiro, Susan Leigh Star, and others in the 1990s. An II is a shared, evolving, open, heterogeneous large-scale socio-technical system comprising an installed base of IT capabilities and their corresponding user, operations, and design communities (Hanseth & Lyytinen, 2010; Tilson, Lyytinen, & Sorensen, 2010). According to these authors, one core trait that IIs share is that they do not grow exnovo; they wrestle with the inertia of the existing installed base of technical systems, organizational structures, practices, user preferences, and behavioral patterns; hence, IIs need to be designed for backward compatibility (Ciborra, 2000; Hanseth & Lyytinen, 2010; Star & Ruhleder, 1996).

Acknowledging this central role of the installed base, existing II literature has converged to report several strategies that have proven to be effective in resolving tensions between the design and user communities, which has ultimately led to IIs' successful implementation and evolution. These strategies address diverse challenges faced by IIs; for instance, bootstrapping (Hanseth & Aanestad, 2003; Hanseth & Lyytinen, 2010), adaptation (Hanseth & Lyytinen, 2010), mobilization (Aanestad & Jensen, 2011), generativity (Bygstad, 2010; Grisot & Vassilakopoulo, 2013), flexibility (Braa, Hanseth, Heywood, Mohammed, & Shaw, 2007; Hanseth, Monteiro, & Hatling, 1996), and interoperability (Ure et al., 2009). These strategies are abstractions that take the form of descriptive regularities (process patterns), self-reinforcing mechanisms that produce observable events, and meanings that capture the researchers' interpretations of events. Moreover, these implementation strategies are related with the II architecture resulting from the design process. For instance, Aanestad and Jensen (2011) illustrate in one case how a design based on a modular architecture minimized the challenges of stakeholder mobilization because it "did not require every potential stakeholder's participation, investment and commitment upfront" (p. 173). Braa et al. (2007) suggest a strategy to develop flexible standards that improve healthcare IIs in developing countries through vertical and horizontal modularization.

These results connect to an emergent research stream that analyzes how II architecture and the locus of control condition the evolutionary outcomes of IIs (Henfridsson & Bygstad, 2013; Tiwana et al., 2010). II architecture includes an II's technical components (e.g., computers, network devices, databases, software applications, APIs, etc.), the components' function (i.e., what they do), and how they are arranged and interact to provide the II's overall functionalities (Ulrich, 1995; van Schewick, 2010). According to this stream of research, II architecture and the distribution of control rights shape, for instance, the actors' capacity to innovate and extend the II with new services, the cost of those innovations and extensions, and who might benefit from those innovations. This research stream tends to conceive II architecture and the locus of control in terms of dichotomies: tightly versus loosely coupled architecture, and centralized versus decentralized control.

Though useful to know that specific design strategies, architectural choices, and the locus of control influence II implementation and evolution, we still do not understand how II architecture and the locus of control are formed or how an infrastructure initiative might successfully move toward a given architecture and a certain distribution of control rights. Hence, these two streams of II research fail to pay explicit attention to the II formation process; that is, the process that gives form to IIs. Research on II formation is of special significance. First, as Jackson, Edwards, Bowker, and Knobel (2007) argue, "the distribution of benefits and losses, and the general rules of the game are all being worked out simultaneously" (p.3) during II formation. Second, the architecture and locus of control are defined during II formation (i.e., the distribution of control rights over the II). Both outcomes will lay the groundwork for the future applications and create the conditions for future events (Tiwana et al., 2010). Consequently, the study of II formation processes can improve our understanding of IIs' distributional consequences and the patterns of II growth and evolution. Accordingly, this paper addresses two research questions: 1) what are the underlying processes in II formation?, and 2) what architecture and locus of control emerge from these processes?

Our research is based on an in-depth case study about the design of an electronic prescription II (EPII) in the public healthcare sector in Spain. The EPII was sponsored by a regional healthcare service administration. We use II literature to frame our case narrative. In this respect, our account decenters the agent to focus instead on the wider infrastructural dynamics that extend beyond what a single actor can observe. As such, we emphasize the role and cultivation of the socio-technical installed base and issues of backward compatibility.

Our empirical case spans three years (2004-06), the period during which the II emerged and stabilized. We analyze the case results in light of the morphogenetic processes that De Landa (2000) identifies in economic, urban, biological, and linguistic history. We consider that we can conceptualize the formation of this EPII as the combination of two abstract processes with different outcomes. The first process is stratification, leading to a dual and hierarchical architecture and a fairly centralized control structure. The second process is meshworking that produces a modular architecture that decouples the central nodes from the installed base of the user systems and creates a more decentralized control structure. Our analysis shows that both hierarchies and meshworks can co-exist and intermingle in a given II.

We structure the paper as follows. In Section 2, we present the II formation processes that constitute our theoretical framework. In Section 3, we describe our research methodology, and, in Section 4, we present our case data. In Section 5, we analyze and discuss our results. Finally, in Section 6, we conclude the paper and reflect on the contributions and relevance of our findings.

2. Information Infrastructure Morphogenesis

In order to explore the formation of IIs, we draw on Manuel De Landa's (2000) work *A Thousand Years of Nonlinear History*. De Landa (2000) develops a bottom-up approach to historiography that stems from a new understanding of material processes as defined by the theory of nonlinear dynamic systems. He offers a study of history giving priority to long-term historical structures over events. He carves out a space for the formation of geological, organic, social, and linguistic structures to narrate the different ways in which semi-stable structures that are constitutive of the natural and social world are formed. We view the use of De Landa's (2000) work to study II formation not only as novel in II literature, but also consistent with II studies that focus on infrastructural dynamics rather than on the agency of social actors.

De Landa (2000) describes the geological, biological, and linguistic histories of Western urban centers in terms of two abstract structure-generating (or morphogenetic) processes. The first process is called stratification. It produces hierarchies that have a fairly centralized structure and tend to homogenize the constituent parts. In these structures, relations among the parts are bound to central nodes that provide hierarchical coordination. For instance, these hierarchical structures are quite common in government-sponsored electronic health record infrastructures built to improve the effectiveness and efficiency of healthcare delivery (Greenhalgh et al., 2008; Maughan, 2010; Rodon & Chekanov, 2014). Most of these infrastructural initiatives follow a top-down approach and aim to standardize the practices of healthcare professionals and patients and produce centralized data repositories.

According to De Landa (2000), the stratification process involves two operations: 1) sorting dissimilar parts into homogeneous groups forming a relatively hierarchical structure, and 2) consolidating those parts into a coherent entity with emergent properties. De Landa (2000) illustrates this double operation with the formation of social classes. Social classes reflect the existence of differentiated roles in a society to which not everyone has equal access. These different roles are classified into a scale of prestige. This sorting process involves diverse dynamics. For instance, members of a group who have acquired preferential access to some roles begin to acquire the power to control further access to those same roles. Similarly, the criteria used by dominant groups to order the rest of society into sub-groups begin to crystallize. However, a second operation is needed for social classes to become a separate entity. The "sorting criteria need to be given a theological interpretation and a legal definition, and the elites need to become the guardians and bearers of the newly institutionalized tradition, that is, the legitimizers of change and delineators of the limits of innovation"

(p. 61-62). This theological interpretation and legal definition further consolidate and justify the stratification. This double operation of stratification is also common in electronic data exchange standardization initiatives (Markus, Steinfield, & Wigand, 2006; Rodon, Pastor, Sese, & Christiaanse, 2008). In these, committees first define an order for a set of messages, while laws and contracts among the user firms then firmly consolidate the messages and enforce their use.

On the other hand, the second morphogenetic process produces more-decentralized self-organized structures called meshworks that maintain the heterogeneity of the different parts. For instance, the Internet is a meshwork that has grown without a central plan for the most part. No one has planned either the extent or the direction of its development (De Landa, 1998; Hanseth & Lyytinen, 2010). Similarly, the literature has reported on several healthcare IIs that started as small local projects in a hospital and had no planned growth but that eventually expanded into large-scale IIs used in multiple hospitals (Grisot, Hanseth, & Thorsend, 2014; Jensen, 2013).

The meshworking process comprises three operations. First, heterogeneous elements are brought together based on their functional complementarities. According to De Landa (2000), small-town markets that “have been the traditional meeting place for people with heterogeneous needs” (p. 65) are an example of a meshwork. The second operation in the meshworking process requires the presence of a special class of operators or intercalary elements to affect those interconnections. In the case of small-town markets, the heterogeneous needs of buyers and sellers are matched and interlocked not by a central planning mechanism but by prices that “transmit information about the relative monetary value of different products and create incentives to buy and sell” (p. 65). Prices set themselves; the wholesaler in the town does not. In the absence of price manipulation, money functions as an intercalary element. The third operation in the meshworking process is the emergence of a stable, endogenously generated pattern of behavior that results from the interlocked heterogeneities. For instance, those weekly small-town markets “generate endogenous stable states, particularly when commercial towns form trading circuits” (p. 66).

To illustrate, we can identify the three meshworking process operations in the context of IIs used in self-managing heath. For example, patients with a given disease and developers of apps to deal with that disease are brought together by the role that apps play in satisfying both parties’ needs. Recognition for the app developer can function as the facilitator for the exchange between users and app developers. Another example of an intercalary element might be a gateway (Hanseth, 2010) that allows a mobile app to access patients’ health records stored in other healthcare providers’ systems. Finally, a stable pattern of behavior between patients and app developers arises because an increase in the number of apps attracts more end users (patients) who, in turn, encourage more app developers to join the II. This creates a self-reinforcing feedback loop (Hanseth & Lyytinen, 2010; Henfridsson & Bygstad, 2013).

We have to see this dichotomy between hierarchies and meshworks in purely relative terms because it is hard to find pure cases of these two structures (De Landa, 1998). IIs comprise complex mixes of both kinds of structures. For instance, while Apple’s App Store maintains centralized control over the application approval process, payment terms, and architectural rules, the structure supporting interactions between end users and app developers is more of a meshwork. Accordingly, as IIs evolve, their hierarchical components can give rise to meshworks, and these can lead, in turn, to hierarchies. Although Tilson et al. (2010) describe these dynamics (e.g., the constant jockeying to create points that centralize or decentralize control over the II), the literature has still not applied a process thinking and theorizing about II formation. In light of the foregoing insights on the morphogenetic processes described by De Landa (2000), we re-instantiate these abstractions in the II domain.

3. Research Method

We conducted an in-depth, longitudinal exploratory case study (Yin, 2009) about an electronic prescription II for the public healthcare service in the autonomous region of Catalonia in Spain. Yin recommends this type of case study when there are no theories to explain the phenomenon under research; hence our decision to adopt it to study II formation. We briefly overview the research site and unit of analysis before describing the method in the following section.

3.1. Site and Unit of Analysis

Our case study focuses on the formation of an electronic prescription II (EPII) in Catalonia. Thus, our unit of analysis is that particular EPII. We selected the EPII not only because of our interest in this subject but also because we were aware of how its architecture had evolved from its inception to its final implementation in a way that impacted the institutional arrangement. In addition, one of the authors had extensive access to information sources and could closely follow the case. The public Catalan Health Service (CHS) sponsored and managed the project to design the EPII initiated in mid-2004. The EPII entailed digitalizing the existing, mainly paper-based, prescription, dispensation, and invoicing processes (see Figure 1).

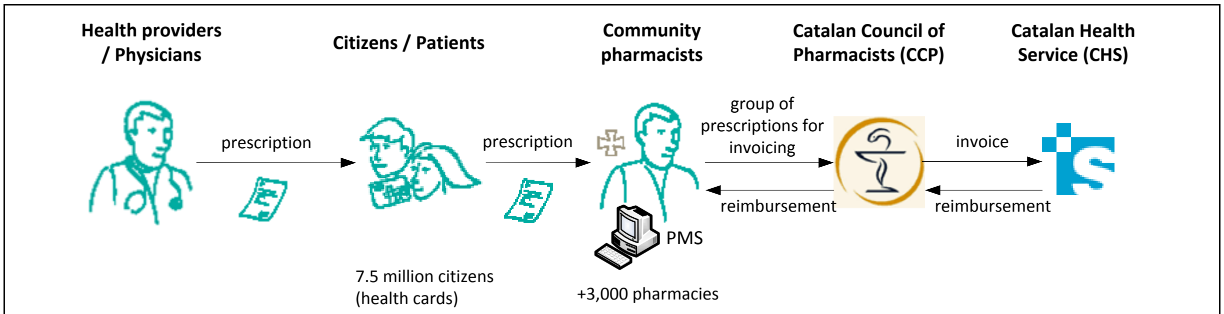

Figure 1. Data Flows for Paper-Based Prescribing, Dispensing, and Invoicing

Before the implementation of electronic prescriptions, the paper-based prescription system was as is in Figure 1. Once physicians had decided on the drug treatment for their patients, they would give them a paper prescription. Physicians used clinical workstations to write up the prescriptions and print them. The patients then took their prescriptions and individual medical cards to the community pharmacy that dispensed the prescribed drug. Pharmacists signed and saved those paper-based prescriptions and dispensed the drugs. They used a pharmacy management system (PMS) for tasks such as sales management, inventory, and purchase orders. Periodically, pharmacies gathered all the paper-based prescriptions they had dispensed over a given period of time and sent them to the Catalan Council of Pharmacists (CCP[1]). The CCP then checked all the prescriptions, scanned them, forwarded the scanned and original paper prescriptions to the CHS, and handled the invoicing for the individual pharmacies. In particular, the CCP submitted a single invoice to the CHS. Consequently, the CCP, not pharmacists, was in charge of invoicing the CHS. The CHS reimbursed the invoices to the CCP, which checked for errors and finally paid pharmacies according to the signed prescriptions they had previously dispensed and forwarded.

In this scenario, the information about patients' treatments (what a patient was prescribed and dispensed) was fragmented in the multiple healthcare providers' and pharmacies' systems, whether electronic or on paper. This meant that only the CHS had a retrospective view of pharmaceutical consumption and patients' treatments. It could find out about these only when pharmacies invoiced the CHS for the drugs prescribed and dispensed, not at the time when physicians actually prescribed treatments or pharmacists dispensed them.

3.2. Data Collection and Analysis

We collected qualitative data over a three-year period (2004-2006) during which the EPII emerged. We gathered these data from several sources (semi-structured face-to-face interviews, informal

[1] The CCP is a corporate and public legal body that represents the interests of all pharmacists in Catalonia and individual community pharmacy owners. It also ensures that the sector respects current regulations. Thus, professional, commercial and trade interests, healthcare priorities, and legal issues all fall in the CCP's ambit.

conversations, press documents and reports, on-site observations, meeting minutes, workshop attendance, and newsletters) to triangulate the data obtained (Yin, 2009). We undertook data collection in two stages (see Table 1): 1) from May to December 2008 when the EPII was being piloted, and 2) from January 2009 to September 2010 when the EPII was being rolled out.

Table 1. Data Collection Stages and Methods

Period	Methods
May 2008-Dec 2008	• 10 in-depth interviews (1 CHS executive, 2 external consultants, 1 CCP vice president, 1 pharmacist, 5 members of healthcare providers involved in the project) • 1-day workshop about the project during its pilot phase (informal conversations and 4 video-recorded presentations)
Jan 2009-Sep 2010	• 115 documents (CCP meeting minutes, annual reports, newsletters, editorials, published interviews with representatives of the Catalan Ministry of Health, CHS managers, and CCP's board of governors, monthly CCP publications, communiqués from the CCP to its members, and research articles from a pharmaceutical journal) • 1-day workshop about the status of the project during its roll-out phase • 5 in-depth interviews (1 CCP vice president, 1 former CCP vice president, 2 pharmacists, 1 general IT coordinator in the Ministry of Health)

During the first stage (May-December 2008), we conducted ten semi-structured interviews with people playing various roles in the system's design and subsequent development (see Table 2). We identified interviewees by applying the snowball sampling technique (Miles & Huberman, 1994); that is, identifying subjects for inclusion in our sample by referral from other subjects. We asked about their opinions concerning the project and the role they played and about the expected outcomes and the events they thought were most critical. We transcribed each interview verbatim and analyzed it immediately after it concluded. Two of the authors also attended a one-day workshop in December 2008. The two authors attended the workshop to present the results of the EPII pilot and discuss its impact on all medical and pharmaceutical professionals. We took detailed notes during the workshop and held informal conversations with the diverse agents involved in the project. Most of the presentations in the workshop were video-recorded. We transcribed verbatim the video recordings of the presentations given by the Catalan minister of health, the CHS executive in charge of the project, and the president of the CCP. We collected data and analyzed them iteratively. Our data analysis concentrated on the main components of the EPII architecture, though we paid special attention to how specific aspects of the EPII architecture prevailed over others. We constructed an initial timeline of events in the EPII's design, and we drafted a preliminary thickly descriptive narrative of the case (Langley, 1999).

Table 2. List of Interviews

Stakeholder / affiliation	Number of interviews	Interviewees' position	Interviewees' role in the project
Catalan Health Service (CHS)	1	Manager of a pharmacy	Project leader
Catalan Ministry of Health	1	General IT coordinator	Project sponsor
Consultancy supporting the CHS	1	Consultant	Consultant in charge of analyzing the system
Catalan Council of Pharmacists (CCP) Board	3	CCP Vice President	Project leader from the pharmaceutical point of view
Consultancy firm in charge of the CCP's technical office	1	Consultant	Manager of the CCP's technical office
Pharmacies	3	3 pharmacists	Users involved in the project since the early stages
Healthcare providers	5	CIO, pharmacy managers, physicians	Representatives of the respective companies involved in the project

During the second stage (January 2009-September 2010), we identified and analyzed 115 documents covering a variety of EPII issues affecting pharmacists (see Appendix A). These documents, which spanned eight years (from 2003 to June 2010), included CCP meeting minutes, annual reports, newsletters, editorials, and published interviews with the Catalan Ministry of Health, CHS managers, and the CCP board of governors. Moreover, during the first half of 2010, the first author was able to make some direct empirical observations of how pharmacists used the EPII in their daily work. We conducted five additional interviews with two CCP vice presidents, two pharmacists, and an IS manager in the Ministry of Health in which we focused again on retrospective and real-time events. The first author also attended a one-day workshop organized by the CHS in September 2009. The latter served to present the project's status (at that time, the project was in the roll-out phase). The first author held informal conversations during this workshop with members of the CHS and the CCP involved in the project. These conversations enabled us to collect more data and to check the results of our analysis.

All these data served to enrich the narratives we developed in the first stage. After analyzing the 115 documents, we organized the events related to the II's design chronologically (e.g., this included, among others, passing an act about the EPII's pilot or roll-out, an official presentation of the EPII's design, an invitation to tender bids for the development of a software module to deploy the pharmacists' virtual private network, the start of the pilot and the roll-out, the release of a new version of the APIs for pharmacy management system (PMS) vendors, and a PMS vendor receiving official recognition).

All these data enabled us to move beyond the initial descriptive narrative we had constructed to write a more detailed account of the EPII's formation. We discussed a draft of the case narrative with two of the central actors involved in the project (one from the CHS and another from the CCP). In so doing, we established the validity of our case study based on multiple data sources (e.g., interviews, presentations, internal project documents, public reports, and field observations). In Section 4, we present this narrative of our results that spans from mid-2004 to the end of 2006. We structure the narrative into two chronological phases: problematizing the EPII's initial architecture and proposing an alternative architecture for the EPII.

4. Case Narrative

4.1. Problematizing the EPII's Initial Architecture

In mid-2004, the Catalan Health Service (CHS) laid the foundations for the building of an EPII in Catalonia. With this EPII, the CHS aimed to improve the efficiency and effectiveness of the region's healthcare system by streamlining patient access, controlling drug spending, and reducing prescription and dispensation errors due to a lack of coordination between the agents involved in those processes. The CHS created an organizational structure for the project that included all healthcare agents: "We believe in the 'middle-out' approach to the governance of ICTs in the Catalan health-care system… ICT introduction and deployment can only be achieved with the participation of the entire sector" (General IT coordinator in the Catalan Ministry of Health).

From the outset, the Catalan Council of Pharmacists (CCP), the representative body of community pharmacists, accepted CHS's invitation and acknowledged that, given its position regarding the CHS (defined in the pharmaceutical agreement between the CCP and CHS) and the fact that the project would certainly be carried out, it was advisable that it cooperated with the administration. At an ordinary general meeting of the Association of Pharmacists of Barcelona, the CCP President justified their involvement in the project in the following terms:

> *Another project that the CHS would like to get started for the end of next year is the electronic prescription. Tomorrow we are attending the first joint work meeting because we believe that, if this project is going to be carried out, it is much better for us if we collaborate from the beginning than for it to be developed without our input.*

The CHS initially set two key functional requirements for the EPII. Firstly, the system had to integrate all the data (e.g., prescriptions, dispensations, invoices, patients, drugs, healthcare providers, physicians, pharmacies, and pharmacists) and make this information accessible online for the diverse stakeholders: physicians, pharmacists, and the CHS. Secondly, the prescription and dispensation processes should run in real time; that is, any community pharmacy in Catalonia could dispense a drug immediately after it was prescribed regardless of the prescribing physician's location. To fulfill these requirements, the CHS proposed an architecture consisting of a central system (called SIRE) owned and managed by CHS and containing an integrated database with all the data. Community pharmacists would have to connect directly to SIRE for the dispensing and invoicing processes (Figure 2).

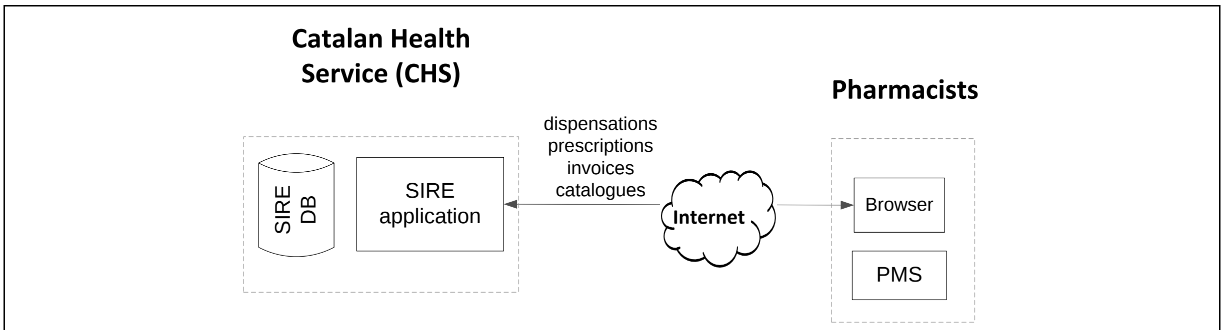

Figure 2. EPII's Initial Architecture to Dispense and Invoice

However, the proposed architecture bypassed the CCP's traditional central role in the invoicing process (see Figure 1). Although the CCP felt that losing control was inevitable, it was more concerned about the consequences this system might have for pharmacists. The latter had already had a previous bad experience with an orthopedic application that required them to connect directly to one of the CHS' central systems. Pharmacies had experienced numerous technical problems when using the system (e.g., in terms of response time from the CHS application), problems which the CHS did not resolve satisfactorily. Their poor resolution demonstrated that an architecture involving a direct relationship between CHS and pharmacies left the latter in a vulnerable position.

Secondly, the architecture (Figure 2) resembled that used in the autonomous region of Andalusia. In the latter system's design, the Andalusian Health Service centralized all the data were centralized in a single server, and pharmacists had to log in to that system to dispense drugs. This meant that pharmacies had to use two systems in practice: a system to manage sales, patients, orders, and stock (the PMS in Figure 2) and the Andalusian Health Service's electronic prescription system to dispense the drugs (a system representing a burden for them). Moreover, the Andalusian Health Service's design required that pharmacies individually organize themselves to contract connectivity services or adapt their internal IT systems as necessary. Since the pharmacies' technological readiness in terms of connectivity services and IT systems to support their practice was not homogeneous, that design could entail differences in the level and pace of the EPII's adoption. For instance, smaller pharmacies and those in rural areas would lag behind larger pharmacies, which were generally found in cities. Pharmacies that were unable to adopt the EPII would not be able to dispense drugs in the public healthcare system. In this respect, the architecture could create a gap between pharmacies in terms of their readiness to use EPII, and, in turn, in terms of the service they could provide patients. This would lead to heterogeneity regarding the type of service that pharmacists provided.

In short, although the initial architecture (Figure 2) aimed to bring homogeneity to pharmacists by centralizing and standardizing the control over their practices, it could also potentially lead to heterogeneity in the service they provided because not all pharmacists had the same capacities.

Given this backdrop and precedents, the CHS and CCP discussed the proposed architecture and negotiated several of its main features. These included the dispensation and invoicing processes, the role of pharmacists' diverse profiles (e.g., owners versus assistants) in the act of dispensing, the invoicing conditions, and so forth. The CCP also argued that the EPII's design should mirror the existing Catalan model of pharmacies. The latter comprised a networked structure that was highly capillary with pharmacies spread out throughout the territory[2]. Hence, the CCP developed and disseminated the idea that, to protect and enhance this networked structure, it would need to build a virtual private network (VPN) that mirrored the structure. This VPN would not only connect the pharmacies with the CCP as its main node but would also serve as a technological resource for the CCP to strengthen its claim that it represented pharmacies. One CCP vice president described the model of pharmacies and the importance of the VPN in the following terms:

> *We are a network* [the Catalan model of pharmacies] *that needs a network* [the VPN]*… Politicians argue in favor of a capillary model of pharmacies, that is, that pharmacies have to be spread out throughout the country. We have to transfer this network of pharmacies to the electronic world. We cannot allow for what is there physically to not exist electronically.*

4.2. Proposing an Alternative Architecture for the EPII

The CCP then proposed an alternative architecture (see Figure 3) that comprised a virtual private network (VPN) that interconnected all the pharmacies plus a central server, called SIFARE, that replicated the CHS system data pharmacists needed (i.e., prescriptions, dispensations, and data catalogues). Thus, community pharmacies would have direct access to SIFARE (the CCP's server) through a VPN, while SIFARE would synchronize with SIRE (the CHS' server) in real time. With this new architecture, the CCP continued handling the invoicing process for pharmacies and extended its intermediary role to the dispensing process[3].

Moreover, the control that the CCP would have over the new architecture would enable it to adopt a new role: that of information service provider for pharmacies. In particular, the CCP depicted this new

[2] The geographic and demographic planning of community pharmacies is undertaken by each autonomous region to ensure an even distribution of pharmacies and guarantee a model with high capillarity (99% of Spaniards have a community pharmacy in their municipality).

[3] Of course, this new architecture would not solve the issue of pharmacists having to use an additional system besides the PMS to dispense drugs. We describe the resolution of this issue later in this section.

architecture as an opportunity for the development of new services in the pharmacy sector (e.g., services such as remote backups, SMS text messaging to customers, video surveillance, and distance learning). It would also serve to re-professionalize the practice of pharmacists (e.g., through new services such as pharmaceutical-therapeutic records, pharmaceutical care services, electronic prescription for private healthcare providers, electronic invoicing, dispensation guides, diffusion of health warnings, etc.). As one CCP vice president noted, “for our professional development those services are essential”.

The new architecture also mirrored the model of pharmacies’ existing structure, particularly with regards to invoicing. The project leader and CHS manager would later acknowledge this mirroring in the following terms:

> *Why do pharmacies invoice us through the CCP? Well, I think it is something that is good for both of us. Having 3,000 interlocutors compared to just one as occurs with the CCP is not the same. Of course it has its good and bad aspects for both sides. However, for the CCP, this means empowering the group and adopting a role as representative of that collective. I imagine that the members of the CCP* [pharmacists] *are interested in somebody that brings them together and defends them in the negotiations.*

The new architecture still fulfilled the two central requirements that the CHS had initially defined for the system (online data integration and real time process execution). In addition, it did not represent any additional costs for the CHS but, rather, for the CCP that would assume the costs of the SIFARE server and the VPN. It also simplified the CHS’ management of the project in the sense that, with the new design, the CHS would have to interact with only one spokesperson, the CCP, and not three thousand pharmacies. One CCP vice president involved in this project commented:

> *In my opinion, this design has several advantages for the CHS. The CHS now has a filter* [the CCP]. *They only have to worry about their server and their database. They do not have to manage usernames, digital certificates and passwords for 3,000 pharmacies or deal with incidents from pharmacists or with the diverse information system providers for pharmacies. We do that. In the current model there is one server, SIRE, that establishes a trust-based relationship with our server, SIFARE, that filters and performs all these functions.*

In mid-2005, the CHS approved the new architecture (Figure 3). The CCP then issued a call for proposals to deploy a VPN to connect all the Catalan community pharmacies. In April 2006, the CCP signed an agreement with a telecommunications provider. That agreement standardized the service conditions for all the community pharmacies, regardless of their location and size. Each pharmacy would have an asymmetric digital subscriber line (ADSL) and an integrated services digital network (ISDN) line as a backup to connect to the CCP’s central server (SIFARE). This facilitated participation by pharmacies because they perceived that the conditions and services they would receive as a group were far superior to what they would have obtained individually.

In September 2005, that architecture became more stable with the preparation and signing of an amendment to the agreement between the CHS and the CCP. This amendment established the clauses for the development of the EPII pilot and specified that the CCP would build and own its own network and a server, finally called SIFARE, through which community pharmacies could access the prescription data stored in SIRE.

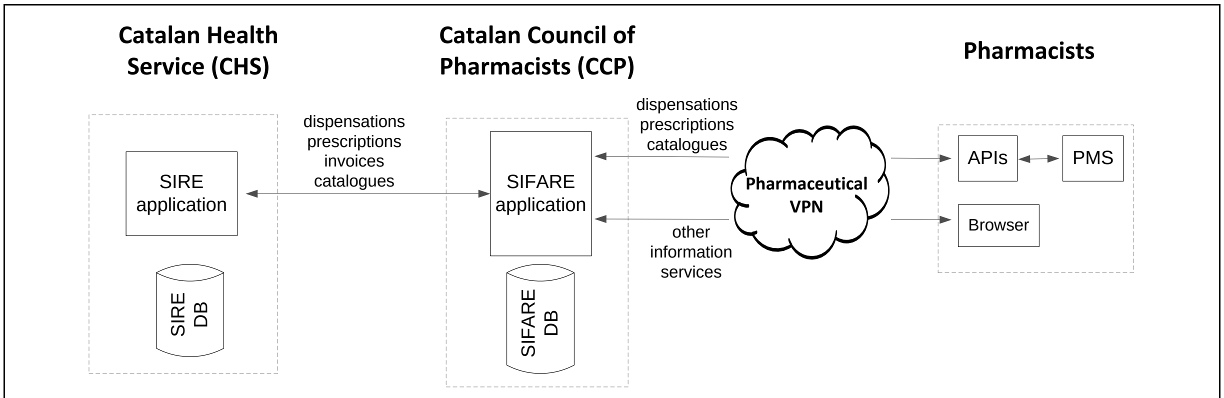

Figure 3. Final EPII Architecture Approved

Another relevant design decision was that SIFARE had to be as transparent as possible for community pharmacies, such that the EPII did not require pharmacists to use an additional information system in their daily operations. This meant that pharmacists would be able to keep their existing pharmacy management systems (PMS) and integrate them with SIFARE in a way that minimized the changes to their existing routines. To ensure this seamless integration, the CCP launched a recognition program for PMS vendors that detailed how PMSs should interact with SIFARE and how the PMS vendors would have to deliver and develop their services in the future. One CCP vice president explained:

> *At the beginning of this project we seated the PMS vendors around a table and told them that electronic prescription was coming and that all those who had passed the recognition program for the healthcare card were already a part of the club… Because it is clear that those who do not pass the recognition program will not be at this table, and those who are not at this table will not have the APIs* [application program interface], *and those who do not have the APIs will have numerous problems in updating their applications and will thereby not have access to the market. Therefore, they had no option but to come this way.*

The CCP developed a set of Web services for SIFARE and an API. Those vendors who passed the recognition program got the API from the CCP to interconnect their PMS solutions to SIFARE.

Finally, in September 2006, the CHS launched the pilot program in two healthcare areas of Catalonia. Participants included 70 physicians, 56 pharmacies, and 17,000 patients. This phase ended in May 2008, and the deployment of the EPII to the rest of Catalonia began. By the end of 2010, all the primary healthcare centers and all 3,075 community pharmacies were using the EPII.

5. Analysis

In Section 4, we empirically depict the formation of the electronic prescription information infrastructure (EPII). In this section, we analyze the EPII's formation processes and their outcomes; namely, the EPII architecture and the distribution of control rights over the EPII. Our results portray the EPII's formation as a combination of the two morphogenetic processes identified by De Landa (2000) (see Tables 3 and 4).

The first process involves stratification in which the diverse sociotechnical components of the EPII were sorted out into homogeneous groups and assembled them together. In our case, the Catalan Health Service (CHS) and the Catalan Council of Pharmacists (CCP) leveraged the preferential rights and access they had over specific resources (e.g., the CHS was the EPII's sponsor and the agency responsible for healthcare services in Catalonia; the CCP is a corporate and public legal body that represents the interests of all pharmacists in Catalonia) to sort the rest of the components. The CHS and the CCP defined the division of roles, rights, and obligations that some of the actors (e.g., pharmacists and patients) should play in the EPII. For instance, patients would be able to fill their prescriptions at any pharmacy in a specific timeframe, which prevented patients from accumulating more drugs than necessary. Dispensing would also require face-to-face interactions between patients and pharmacists and would only take place physically in pharmacies. Similarly, pharmacists could access prescription content remotely, which avoided possible misinterpretation of prescriptions. In addition, only the pharmacies' owners could sign dispensations electronically. Lastly, the CHS would receive data on prescriptions and their dispensations in real time. This top-down process also involved technical components distributed into more or less uniform layers performing similar functions each. For instance, at lower layers, we find the hardware for SIRE, SIFARE, and VPN; right above, there are the SIRE and SIFARE Web services, the SIFARE APIs, and the ADSL lines. Then we have the PMS applications, the Web apps, and the digital signature applications for pharmacists. Finally, an agreement between the CCP and CHS reified and consolidated the technical layers and actors' roles, rights, and obligations. This new agreement comprised an amendment to the original pharmaceutical agreement.

Table 3. Stratification Process

Operations (from De Landa (2000))	Case analysis
Sorting dissimilar parts into homogeneous groups and creating a relatively hierarchical structure.	Negotiation and definition of the roles, rights, and obligations of the actors (e.g., pharmacists and patients). Pharmacists are initially treated as homogeneous entities by the CHS. Ordering and distributing technical parts into more or less uniform layers performing similar functions each.
Consolidating those parts into a coherent entity with emergent properties.	Reification and consolidation of roles, rights and obligations of the actors and technical components involved through processes such as the approval of the amendment to the pharmaceutical agreement.

The outcome of this stratification process was a tightly coupled and centralized architecture (Figure 2), though it later evolved into a dual and hierarchical architecture (Figure 3). The initial architecture detailed in Figure 2 was tightly coupled. All the data and process logic of the dispensing and invoicing practices resided and ran through the CHS' central node called SIRE. Moreover, the relationship between the central node and the pharmacists was hierarchical. With this architecture, decisions about the evolution of pharmacists' practices were centralized in the CHS. In short, the initial, tightly coupled architecture aimed to bring homogeneity to pharmacists' routines and concentrated the decisions about the pharmacists' services and practices in a central node (the CHS). However, as illustrated in the case narrative and given the preexisting diversity of pharmacists' capacities and readiness, a possible side effect of this tightly coupled architecture was that it could end up creating more heterogeneity in terms of pharmacists' degree of adoption and use of the EPII and, ultimately, in terms of the service they provided patients.

In order to avoid this and keep the CHS' central node from determining the pharmacists' behavior, the project leaders made the architecture dual (Figure 3). It now featured two central nodes (SIRE owned by the CHS, and SIFARE owned by the CCP). In terms of the relationship between these two nodes, SIRE played the lead role in the dispensing process, while SIFARE played a secondary role (i.e., SIFARE requested information from SIRE). For the invoicing process, the relationship between both was the opposite (i.e., SIFARE sent the information about pharmacists' invoices to SIRE). Thus, this dual architecture distributed the control rights between the CHS and the CCP in the dispensing and invoicing processes. Moreover, the relationship between the two central nodes was loosely coupled because the inner workings of both were hidden to each other by means of Web services. In this dual architecture, the relationship between the two central nodes and the pharmacists remained hierarchical. It conferred control to the CHS (and CCP) over pharmacists' practices by creating a homogeneous set of applications and taking data from pharmacies in a central node. However, in case any of the two central nodes crashed or service was interrupted, pharmacists could not dispense or invoice electronically[4], but, unlike with the initial tightly coupled and centralized architecture, this dual architecture gave pharmacists more control over the evolution of their working practices.

In this respect, the architecture's dual nature became a catalyst to initiate the meshworking process that assembled heterogeneous components without homogenizing them (see Table 4). This meshworking process started because the CCP took into account the pharmacists' heterogeneous local systems (the PMS) when designing and implementing the EPII; that is, the CCP cultivated the installed base of pharmacists (Hanseth, 2010). This cultivation strategy took place when PMS vendors and pharmacists were brought together by means of the recognition program and the API for PMS vendors. Similarly, telecom providers and pharmacists were brought together by means of a call for tenders for the virtual private network. These interconnection devices (e.g., recognition program, APIs, and VPN proposals) acted as gateways (Hanseth, 2010) that linked the installed base of pharmacists (e.g., their practices and the PMS) with the CCP's central node (SIFARE). These interconnections generated stable patterns of interaction between heterogeneous actors: pharmacists with PMS vendors, telecom providers, patients, and the same CHS. For instance, the recognition program for PMS vendors functioned as a facilitator for the PMS vendor-pharmacy interaction, allowing PMS vendors to retain their customers and approach new ones, while permitting pharmacists to easily identify the PMS that best fulfilled their needs.

Table 4. Meshworking Process

Operations (from De Landa (2000))	Case analysis
Heterogeneous elements are grouped in terms of their functional complementarities.	Recognition of the installed base of pharmacists. This was done by creating couplings: PMS vendors-pharmacists and telecom-pharmacies to fulfill pharmacists' needs.
A special type of operators or intercalary elements to affect those interconnections	Creation of gateways (e.g., recognition program, APIs, tender for VPN) linking the installed base of pharmacists with the central node. Those gateways articulated the heterogeneous needs of pharmacists, PMS vendors, telecom providers, and so on without reducing all the diversity.
A stable pattern of endogenously generated behavior that results from the interlocked heterogeneities.	The interconnections generated stable patterns of interaction between pharmacists and patients, pharmacists and PMS vendors, pharmacists and the CHS, and pharmacists and the telecom provider.

The outcome of this meshworking process was a modular architecture that decoupled the SIFARE central node from pharmacists' PMS systems. In particular, all of SIFARE's functionalities were decomposed into loosely coupled components, while the interface specifications for how the PMS should interact with SIFARE were coded through Web services and APIs. In so doing, the EPII architecture respected and maintained the pharmacists' heterogeneous local systems (the PMSs). Such a loose coupling between the central node (SIFARE) and pharmacists (PMS) also encouraged PMS vendors to continue innovating on the solutions they provided pharmacists without interfering with the central node (SIFARE). Hence, this architecture complemented the dual one emerging from the stratification process by allowing some decisions to be made in a more decentralized manner (e.g., a PMS vendor could upgrade its solution for its customers (pharmacists)). Likewise, the data and process logic for the dispensing and invoicing processes resided not only in the central nodes but also in pharmacists' PMS. Consequently, control expanded its reach because it did not reside only in the central nodes but was also distributed across the diverse components (e.g., the central node and the pharmacists' PMS). Albeit some degree of redundancy with this architecture, this same redundancy made the EPII more resilient because it

[4] This partially changed afterwards as the CHS and the CCP defined contingency mechanisms that enabled pharmacists to dispense drugs while being off-line (if their connection with the central nodes went down). Once the connection was restored, any offline dispensing that had occurred needed to be synchronized.

could recover more easily from any malfunctions or disruptions in the central node. For example, if SIRE crashed, pharmacists could still dispense drugs locally.

Overall, the EPII architecture (Figure 3) ensured data and process standardization and the centralization of some decisions aiming to improve the efficiency, quality, and safety of the healthcare provided. It also brought homogeneity to pharmacists' practices because they would all be able to access and use the EPII in the same conditions. At the same time, the EPII architecture conferred the CCP, pharmacists, and PMS vendors certain autonomy and the capacity to innovate and make their own decisions because the control and decision making were distributed among the central nodes, PMS vendors, and the pharmacists themselves.

Finally, the dual architecture also influenced the project's organization, distributing responsibilities among several actors. For instance, it gave the CPP rights and responsibilities over the EPII's design, implementation, and operation. In particular, the CCP was in charge of building the private network for pharmacies, building the SIFARE system and APIs, coordinating PMS vendors, and promoting the EPII's use among pharmacists. This dual architecture also forced the CCP to mobilize resources for pharmacists, and this minimized the complexity of the project for the CHS.

6. Discussion

In this research, we empirically explore the formation of a healthcare II. Relying on the work of De Landa (2000), our case analysis depicts II formation as involving two types of socio-technical processes: stratification and meshworking. The stratification process involves organizing the II's diverse components into homogeneous groups and consolidating them into a coherent hierarchical structure that standardizes component behavior and centralizes control over the II. The meshworking process, by contrast, assembles heterogeneous components without standardizing them; the components are distributed in a way that endows them with the capacity to self-organize. The identification of stratification and meshworking processes in the II context is a novel contribution to the literature. Even though the literature has provided empirical evidence about the formation of IIs (see, e.g., Reimers, Li, Xie, and Guo (2014b) and Aanestad and Jensen (2011)), it has not theorized about those formation processes.

II literature has mainly reported on design strategies for successfully implementing and evolving IIs (Aanestad & Jensen, 2011; Braa et al., 2007; Hanseth & Aanestad, 2003; Hanseth & Lyytinen, 2010; Ure et al., 2009). For instance, Aanestad and Jensen (2011) show how the modularization of one II helped mobilize stakeholders in the context of electronic health record infrastructures. Braa et al. (2007) suggest flexible standardization as a strategy that enables adapting IIs to the frequent changes experienced in healthcare. Ure et al. (2009) identify governance models for using data infrastructure. These range from generic models based on top-down, scalable classification to local models that are not scalable but accommodate the preferences of user groups and the speed of change. These design strategies take diverse forms that reflect different technological installed bases, social structures in the field, and so forth. However, they can all be seen as part of the two morphogenetic processes and structures identified in this paper. Consequently, a focus on stratification and meshworking might help reveal similarities and differences between these strategies. For instance, Aanestad and Jensen (2011) report on the building of two electronic health record infrastructures in Denmark. With the first II (called B-EPR), the stratification processes were dominant as the project's sponsors aimed to build a radically new II that would replace existing systems to be used by all the actors in the Danish healthcare sector. On the other hand, with the second II (called SEP), the meshworking processes prevailed because the sponsors took into account the heterogeneous installed base of health record systems and interconnected them through layering and gateways.

Second, the literature has thus far characterized the outcome of II design in terms of the degree of coupling between the components that constitute the architecture and the degree of centralization of control (Hanseth & Lyytinen, 2010; Henfridsson & Bygstad, 2013; Tiwana et al., 2010). Our results extend this conceptualization by incorporating a new dimension: the degree of homogeneity or heterogeneity of the constituent and interconnected elements. We can characterize hierarchies by the homogeneity of components, whereas meshworks are collections of heterogeneous components forming semi-stable structures. For instance, on the one hand, the Catalan Health Service (CHS) sorted pharmacists into different homogeneous groups based on what their role in the dispensing and invoicing processes should be. On the other hand, the EPII then linked all the pharmacists and vendors of pharmacy management systems (PMS) together, which maintained their heterogeneity and endowed them with the capacity to self-organize. We analyze how the II architecture organized the homogeneity of composing elements and the locus of control and decision making. Some parts of the II architecture were homogeneous, hierarchical, and included centralized decision making (i.e., the components adapted to the central nodes above). At the same time, other parts of the architecture assembled heterogeneous components that: 1) were less subject to centralized control, 2) adapted to each other, and 3) interacted and behaved as a self-consistent aggregate. Therefore, in line with De Landa's (2000) observations, our results show that hierarchy and meshwork can co-exist and intermingle in a given II. In other words, hierarchical components are dominant in some parts of the II, and meshwork components prevail in others.

Third, by depicting the healthcare II as a combination of hierarchical (characterized by centralized control) and meshwork structures (characterized by decentralized control conferring autonomy to the components and that grow by drift), our empirical results show that both control and drift can co-exist in IIs. This concurs with extant literature (Ciborra, 2000; Tilson et al., 2010) that views IIs as being in constant tension between control and drift. Ciborra (2000) suggests that the top-down planning and centralized control approach to IIs is not reflected in practice. Rather, Ciborra (2000) shows that IIs tend to drift and deviate from their planned purposes. This is the case with the Internet, for example, which, with its decentralized locus of control, has evolved mostly by drift; no one has centrally planned either the extent or direction of its growth (Hanseth & Lyytinen, 2010). Moreover, our results show that the hierarchical and meshwork aspects of IIs not only co-exist but also constantly transform into one another (De Landa, 1998). For instance, a given II sponsor might release an API in order to boost innovation among third-party developers by increasing the diversity of developers and kinds of apps available, ultimately to attract new users. Once that II has grown to encompass a significant number of apps and users, the sponsor might start organizing that diversity, giving rise to a hierarchy of meshworks. That is, IIs can expand and grow by articulating homogeneous elements that centralize control or interlocking heterogeneous elements in varying ways without losing differences. Consequently, an interesting topic for further research would be to explore the extent to which the two processes identified in this paper can help conceptualize the evolution and growth of IIs (Henfridsson & Bygstad, 2013; Reimers, Johnston, & Klein, 2014a; Tilson et al., 2010).

II literature has argued that traditional top-down approaches combined with command-control structures (i.e., stratification process and hierarchy) lead to ineffective designs and evolution (Ciborra, 2000; Hanseth & Ciborra, 2007; Hanseth & Lyytinen, 2010). More recently, in a review of 41 cases, Henfridsson & Bygstad (2013) found three cases characterized by centralized control and tightly coupled architectures (i.e., hierarchy) in which the II evolved successfully. Based on this paper's empirical results, we consider that simply replacing hierarchies with meshworks will not necessarily lead to better evolutionary outcomes. As De Landa (1998) suggests, "demonizing centralization and glorifying decentralization as the solution to all our problems would be wrong. An open and experimental attitude towards the question of different hybrids and mixtures is what the complexity itself seems to call for" (p. 285). We believe that where the balance between hierarchy and meshwork is varies with the setting (e.g., the social structure, the technological installed base, etc.). For instance, we conjecture that, had the EPII's initial mainly hierarchical architecture (see Figure 2) prevailed, the control over the EPII would have been completely centralized on the CHS. Some of our informants noted that the concentration of power on the CHS would have favored the deregulation of the pharmacy sector and its opening to new entrants (e.g., pharmacy chains). The entry of pharmacy chains was perceived as a threat to the existing capillary model of pharmacies characterized by their even geographical distribution across the region, and, in turn, to the public health system since citizens would not receive the same kind of service regardless of their location. On the other hand, from the pharmacists' perspective, the final dual and modular architecture (a combination of hierarchy and meshwork) can be seen as a preemptive response to the potential disturbance of the existing model of pharmacies that would have possibly resulted from deregulation. In fact, the dual and modular architecture allowed pharmacists to share resources and create a basic infrastructure that served as an entry barrier for new actors; hence, it protected the existing networked structure of pharmacies in Catalonia. So, an area for future research would be to explore in different settings how diverse combinations of hierarchies and meshworks influence the evolutionary dynamics and distributional consequences of IIs.

Fourth, our results also concur with those in the II literature that show how II architecture shapes the organization and complexity of infrastructural projects (Aanestad & Jensen, 2011; Grisot et al., 2014; Hanseth & Bygstad, 2014; Rodon & Chekanov, 2014). In our case, had the final II architecture been tightly coupled and centralized as was initially proposed (see Figure 2) rather than the final dual and modular, the resulting project would have become much more complex to manage because the pharmacists' detachment from their installed base of systems and practices was problematic with the initial version of the architecture. The tightly coupled and hierarchical architecture locked pharmacists in because the decisions about the evolution of their practices (in terms of the types of services) were completely centralized. However, the final dual architecture reduced the complexity by distributing responsibilities for the project among other actors, which helped accommodate the EPII's development to the needs and capacities of pharmacists and PMS vendors. In other words, the dual architecture helped contain the ripple effects that changes on any of the sides (CHS, PMS vendors, pharmacists) might trigger. Moreover, the dual architecture served as a catalyst to initiate a meshworking process that produced a modular architecture; the latter, in turn, provided the means for pharmacists to self-organize. In this sense, the EPII's dual and modular architecture can be seen as generative; that is, the EPII architecture was bootstrapable, adoptable, adaptable, and extensible (Hanseth & Bygstad, 2014). On the one hand, the dual architecture supported bootstrapping the EPII because it was strongly aligned with the sector's existing networked structure. On the other, the decentralized nature of the modular architecture supported the EPII's scaling and extension because the new services offered by pharmacists were developed in a decentralized way. Consequently, our paper contributes to extant literature by providing empirical insights that relate the outcome of II formation (comprising architecture and distribution of control) with the generativity of IIs (Grisot & Vassilakopoulo, 2013; Hanseth & Bygstad, 2014; Yoo, 2013).

Finally, our empirical account also contributes to the recent debate on materiality found in IS literature (Leonardi, Nardi, & Kallinikos, 2012). In particular, Kallinikos (2012) suggests that IS research should focus on how technological evolution dissociates function, form, and matter from each other and recombines them again. Our narrative illustrates how an II architecture (constituting the form of the EPII) became involved in defining new functions and roles and produced changes in the institutional arrangement. For instance, as a result of the EPII's dual and modular architecture, the CCP started playing the role of information service provider for pharmacists by developing new functionalities and embedding them in software applications running in the central node. Likewise, the pharmacists' role became conditioned, constrained, and enabled by the EPII architecture like never before. In particular, software applications distributed across the diverse layers of the EPII architecture partially replaced some of the tasks that pharmacists had performed until then based on their own professional and business criteria (e.g., drug substitution in the dispensing process or the decision regarding when to invoice the CHS). In line with work by Kallinikos, Hasselbladh, and Marton (2013), an interesting direction for future research would be to study how the tasks that are embodied into the diverse layers of II architecture obtain operational independence from social actors (in our case pharmacists) over time and constitute a new institutional order in the pharmacy sector.

7. Conclusion

This paper describes and analyzes a case study on the socio-technical dynamics that influence the formation of a healthcare II and builds its contribution on extant II research. First, our study extends II literature by identifying two morphogenetic processes that are defined by the locus of control and the degree of homogeneity or heterogeneity of the II's components. Our analysis also depicts the II architecture as forming a hybrid that simultaneously offers control and autonomy. Moreover, the paper contributes to II literature by showing how the II architecture in our study shaped the organization and complexity of the infrastructural initiative and became involved in the constitution of actors, roles, and the institutional arrangement. Our empirical account also contributes to the recent debate in IS literature on materiality by illustrating how existing ties between form and function were loosened, producing and combining new forms and functions. Finally, the process thinking and theorizing presented in this paper is also useful for practice. We suggest that, to the extent that designers and policy makers understand the two formation processes (stratification and meshworking) and their outcomes, they can be more effective when launching any new infrastructural initiatives.

Acknowledgements

We thank the senior editor, Jannis Kallinikos, and the reviewers at *JAIS* for their useful criticism and suggestions during the process. We are also grateful to Ole Hanseth for his insightful and helpful comments on previous draft versions of this manuscript.

References

Aanestad, M., & Jensen, T. B. (2011). Building nation-wide information infrastructures in healthcare through modular implementation strategies. *Journal of Strategic Information Systems*, *20*(2), 161-176.

Braa, J., Hanseth, O., Heywood, A., Mohammed, W., & Shaw, V. (2007). Developing health information systems in developing countries: The flexible standards strategy. *MIS Quarterly*, *31*(2), 381-402.

Bygstad, B. (2010). Generative mechanisms for innovation in information infrastructures. *Information and Organization*, *20*(3-4), 156-168.

De Landa, M. (1998). Meshworks, Hierarchies and Interfaces. In John Beckman (Ed.), *The virtual dimension: Architecture, representation, and crash culture*, New York: Princeton Architectural Press.

De Landa, M. (2000). *A thousand years of nonlinear history*. New York: Swerve Editions.

Ciborra, C. (2000). *From control to drift: The dynamics of corporate information infrastructures*. Oxford: Oxford University Press.

Greenhalgh, T., Stramer, K., Bratan, T., Byrne, E., Mohammad, Y., & Russell, J. (2008). Introduction of shared electronic records: Multi-site case study using diffusion of innovation theory. *British Medical Journal*, *337*, a1786.

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*(4), 197-219.

Grisot, M., & Vassilakopouloub, P. (2013). Infrastructures in healthcare: The interplay between generativity and standardization. *International Journal of Medical Informatics*, *82*(5), 170-179.

Hanseth, O. (2010). From systems and tools to networks and infrastructures—from design to cultivation: Towards a design theory of information infrastructures. In Jonny Holmstrøm (Ed.), Industrial informatics design, use and innovation: Perspectives and services (pp. 122-156). Hershey: IGI Global.

Hanseth, O., & Aanestad, M. (2003). Bootstrapping networks, communities and infrastructures. On the evolution of ICT solutions in healthcare. *Methods of Information in Medicine*, *42*(4), 385-391.

Hanseth, O., & Ciborra, C. (2007). *Risk, complexity and ICT*. Cheltenham: Edward Elgar Publishing.

Hanseth, O., & Lyytinen, K. (2010). Design theory for dynamic complexity in information infrastructures: The case of building internet. *Journal of Information Technology*, *25*(1), 1-19.

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing information infrastructure standards: The tension between standardization and flexibility. *Science, Technology and Human Values*, *21*(4), 407-426.

Hanseth, O., & Bygstad, B. (2014). *Generative information infrastructure architectures. A longitudinal study of ehealth infrastructures in Norway* (Unpublished manuscript).

Henfridsson, O., & Bygstad, B. (2013). The generative mechanisms of digital infrastructure evolution. *MIS Quarterly*, *37*(3), 907-931.

Jackson, S. J., Edwards, P. N., Bowker, G., & Knobel, C. P. (2007). Understanding infrastructure: History, heuristics, and cyberinfrastructure policy. *First Monday*, *12*(6).

Jensen, T. B. (2013). Design principles for achieving integrated healthcare information systems. *Health Informatics Journal*, *19*(1), 29-45.

Kallinikos, J. (2012). Form, function, and matter: Crossing the border of materiality. In P. Leonardi, B. A. Nardi, & J. Kallinikos (Ed.), *Materiality and organizing: Social interaction in a technological world* (pp. 67-87). UK: Oxford University Press.

Kallinikos, J., Hasselbladh, H., & Marton, A. (2013). Governing social practice: Technology and institutional change. *Theory and Society*, *42*(4), 395-421.

Langley, A. (1999). Strategies for theorizing from process data. *Academy of Management Review*, *24*(4), 691-710.

Leonardi, P., Nardi, B. A., & Kallinikos, J. (2012). *Materiality and organizing: Social interaction in a technological world*. UK: Oxford University Press.

Markus, M. L., Steinfield, C., & Wigand, R. (2006). Industry-wide information systems standardization as collective action: The case of the US residential mortgage industry. *MIS Quarterly*, *30*(5), 439-465.

Maughan, A. (2010). Six reasons why the NHS national program for IT failed. *ComputerWeekly.com*. Retrieved from http://www.computerweekly.com/opinion/Six-reasons-why-the-NHS-National-Programme-for-IT-failed

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis. An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Reimers, K., Johnston, R. B., & Klein, S. (2014a). An empirical evaluation of existing IS change theories for the case of IOIS evolution. *European Journal of Information Systems*, *23*(4), 373-399.

Reimers, K., Li, M., Xie, B., & Guo, X. (2014b). How do industry-wide information infrastructures emerge? A life cycle approach. *Information Systems Journal*, *24*(5), 375-424.

Rodon, J., Pastor, J. A., Sese, F., & Christiaanse, E. (2008). Unravelling the dynamics of IOIS implementation: An actor-network study of an IOIS in the seaport of Barcelona. *Journal of Information Technology*, *23*(3), 97-108.

Rodon, J., & Chekanov, A. (2014). Architectural constraints on the bootstrapping of a personal health record. *Scandinavian Journal of Information Systems*, *26*(2), 53-78.

Star, S. L., & Ruhlender, 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., & Sorensen, C. (2010). Research commentary -- digital infrastructures: The missing IS research agenda. *Information Systems Research*, *21*(4), 748-759.

Tiwana, A., Konsynski, B., & Bush, A. A. (2010). Platform evolution: Coevolution of platform architecture, governance, and environmental dynamics. *Information Systems Research*, *21*(4), 675-687.

Ulrich, K. (1995). The role of product architecture in manufacturing firm. *Research Policy*, *24*(3), 419-40.

Ure, J., Procter, R., Lin, Y-W., Hartswood, M., Anderson, S., Lloyd, S., Wardlaw, J., Gonzalez-Velez, H., & Ho, K. (2009). The development of data infrastructures for eHealth: A socio-technical perspective. *Journal of the Association for Information Systems*, *10*(5), 415-429.

van Schewick, B. (2010). *Internet architecture and innovation*. Cambridge: MIT Press.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage.

Yoo, Y. (2013). The tables have turned: How can the information systems field contribute to technology and innovation management research? *Journal of the Association for Information Systems*, *14*(5), 227-236.

Appendix: List of Documents Analyzed

Table A1. List of Documents Analyzed

Date	Publication	Title
11/01/2003	68 - Informatiu	"Entrevista a Xavier Pomés, Conseller de Sanitat en funcions"
03/01/2004	71 - Informatiu	"ENTREVISTA A LA DRA. MARINA GELI, CONSELLERA DE SANITAT"
04/01/2004	72 - Informatiu	"ENTREVISTA A JOAN DURAN, PRESIDENT DEL COL•LEGI"
06/21/2004	Junta General Ordinaria COFB	JUNTA GENERAL ORDINÀRIA DEL DIA 21 DE JUNY DEL 2004
07/01/2004	Farmaceuticos (nº289)	"Toma de posesión del nuevo Consejo catalán de farmacéuticos"
10/01/2004	77 - Informatiu	"El Consell català homologa els programes de gestió informàtica de les farmàcies"
12/15/2004	Junta General Ordinaria COFB	JUNTA GENERAL ORDINÀRIA DEL DIA 15 DE desembre DEL 2004
02/28/2005	Correo Farmacéutico	"Receta electrónica: destacan el desarrollo profesional que supone para el boticario"
02/28/2005	El Global	"La receta electrónica: estandarte de la nueva oficina de farmacia"
04/01/2005	Offarm (24:4)	"La farmacia se abre a las nuevas necesidades sociales"
04/01/2005	Circular Farmacèutica - CCFC	"L'ADSL2 EN TEMPS DE RECEPTA ELECTRÒNICA"
04/01/2005	83 - Informatiu	"Tema del mes: Engega la recepta electrònica"
04/01/2005	83 - Informatiu	"Editorial: Mirar endavant"
06/21/2005	Junta General Ordinaria COFB	JUNTA GENERAL ORDINÀRIA DEL DIA 21 DE JUNY DEL 2005
07/01/2005	86 - Informatiu	"Editorial. Amb la xarxa, més cohesió"
07/01/2005	86 - Informatiu	"Creació de la xarxa farmacéutica de comunicacions de Catalunya"
08/01/2005	87- Informatiu	Protagonisme de la recepta electrònica
10/01/2005	Offarm (24:9)	"Quién es quién: Marina Geli"
10/01/2005	88 - Informatiu	EDS i Telefònica, partners tecnològics per a la recepta electrònica
10/01/2005	88 - Informatiu	"Editorial. Recepta mèdica i responsabilitat sanitària"
10/10/2005	Correo Farmacéutico	"Receta electrónica e interconectividad en 2007: entre la realidad y la utopía", Correo Farmacéutico
11/01/2005	89 – Informatiu	"RECEPTA ELECTRÒNICA, novetats tecnològiques i de calendari"
11/25/2005	Consumer.es	"Qué es la receta electrónica?"
11/30/2005	Diari de Girona	"Salt i la Bisbal d'Empordà inicien la implantació de la recepta electrònica"
12/15/2005	Junta General Ordinaria COFB	JUNTA GENERAL ORDINÀRIA DEL DIA 15 DE desembre DEL 2005
12/26/2005	El Global	"Las farmacias catalanas inician las pruebas del piloto de receta electrónica"
12/31/2005	Memòria CCFC	
02/10/2006	Diario Salud	"La receta electrónica es un problema político, no técnico"
04/01/2006	93 - Informatiu	"Editorial - El futur a la ma"
04/01/2006	93 - Informatiu	"Tema del mes: A punt, la xarxa de comunicacions que connectarà totes les farmàcies"
09/01/2006	97 - Informatiu	"Editorial: Arriba la recepta electrònica"
10/01/2006	98 - Informatiu	"El Consell informa"

Table A1. List of Documents Analyzed (cont.)		
Date	**Publication**	**Title**
10/09/2006	El Periodico	“Salud presenta la receta electrónica, un sistema que facilitará el control de las prescripciones”
10/10/2006	La Vanguardia	“El uso de la receta electrónica se extenderá en toda Catalunya a finales de 2007”
10/10/2006	El Periodico	"Las farmácias catalanas usarán recetas electrónicas en el 2007".
10/16/2006	Correo Farmacéutico	“Marina Geli: La receta electrónica reforzará el papel clínico del farmáceutico”
11/01/2006	99 - Informatiu	"El Consell informa"
11/02/2006	La Vanguardia	"Las farmacias catalanas se preparan para despachar mediante receta electrónica"
12/01/2006	100 - Informatiu	"Tema del mes: Hem d'estar disposatsa a apostar pels canvis per apuntar cap al futur"
12/01/2006	100 - Informatiu	"El Consell informa"
01/01/2007	101 - Informatiu	"Editorial: Indignació per la política de preu"
01/01/2007	101 - Informatiu	"El Consell informa"
03/05/2007	El Global	"La farmacia catalana apuesta por la diversificación, las redes de comunicación y la receta electrónica"
03/19/2007	Correo Farmacéutico	"CCAA adaptarán juntas el modelo andaluz de receta"
03/19/2007	Correo Farmacéutico	"Todavía falta mucho para la compatibilidad de sistemas"
03/20/2007	103 - Informatiu	"El Consell informa"
04/01/2007	104 - Informatiu	"El Consell informa"
04/16/2007	Correo Farmacéutico	"CCAA piden que el decreto de receta les deje decidir sobre el acceso al historial"
05/01/2007	105 - Informatiu	"Editorial: Pèrdua d'oportunitats per normes poc realistes"
05/01/2007	105 - Informatiu	"El Consell informa"
05/28/2007	Correo Farmacéutico	""La receta electrónica se extenderá tras el verano""
06/01/2007	106 - Informatiu	"Editorial: Molt pendents de les últimes novetats
06/01/2007	106 - Informatiu	"El Consell informa"
06/05/2007	El Periodico	"La receta electrónica pone coto al "macrobotiquín""
06/05/2007	El Periodico	"La receta electrónica pone coto al 'macrobotiquín'"
07/01/2007	107- Informatiu	"El Consell informa"
07/09/2007	El Global	"Entrevista Joan Duran"
09/01/2007	108 - Informatiu	"Editorial: Demandes justes"
09/01/2007	108 - Informatiu	"El Consell informa"
10/01/2007	109 - Informatiu	"Editorial : Imatge, reflex de la realitat?"
10/08/2007	El Global	“La e-receta catalana retrasa la inclusión de pacientes”
11/01/2007	110 - Informatiu	"La recepta electrònica continua avançant"
11/01/2007	110 - Informatiu	"El Consell informa"
11/26/2007	El Global	"La inversión que requiere la receta electrónica aún genera preocupación"
11/26/2007	El Periodico	"Andalucía hace el 80% de recetas electrónicas y Catalunya, el 0,1%"
12/01/2007	111 - Informatiu	"Editorial: Molt per endavant"
12/01/2007	111 - Informatiu	"Entrevista Joan Duran"
12/01/2007	111 - Informatiu	"El Consell informa"
12/03/2007	Correo Farmacéutico	•"En 2008 podrían verse los primeros casos de interoperabilidad en receta electrónica"

Table A1. List of Documents Analyzed (cont.)

Date	Publication	Title
12/17/2007	Junta General Ordinaria COFB	JUNTA GENERAL ORDINÀRIA DEL DIA 17 DE desembre DEL 2007
01/01/2008	112 - Informatiu	"Editorial: Pressupost, desbaratament i model de farmàcia"
01/01/2008	112 - Informatiu	"Pressupost de Salut 2008. Increment Insuficient"
01/01/2008	112 - Informatiu	"El Consell informa"
02/01/2008	113 - Informatiu	"Editorial: Model i professió"
02/01/2008	113 - Informatiu	"La signatura electrònica dels metges en prova pilot"
02/01/2008	113 - Informatiu	"El Consell informa"
03/01/2008	114 - Informatiu	"Comença el desplegament de l'e-recepta a Catalunya"
03/01/2008	114 - Informatiu	"El Consell informa"
03/25/2008	El Global	"La farmacia dse descapitaliza mientras la Administración nos pide más calidad de servicio"
04/14/2008	Correo Farmacéutico	"La receta electrónica supone más costes para la botica rural"
05/01/2008	115 - Informatiu	"Els programes informàtics de gestió homologats apliquen els processos de l’e-recepta"
05/01/2008	115 - Informatiu	"El Consell informa"
05/27/2008	Diari de Girona	"El Col•legi de metges avança el repartiment de les firmes electróniques a primària"
06/24/2008	Diari de Girona	"La recepta en paper comença a dir adéu"
06/26/2008	La Vanguardia	"Los médicos extranjeros pasarán antes de ejercer en Catalunya un curso previo de conocimiento del sistema sanitario"
06/30/2008	Correo Farmacéutico	"Andreu Suriol: "La industria ha impuesto ciertas medidas que debe replantearse""
07/14/2008	Correo Farmacéutico	"Jordi De Dalmases: "Iniciamos una nueva etapa innovadora y no continuista""
08/01/2008	117 - Informatiu	"Editorial: Cal continuar avançant"
08/01/2008	117 - Informatiu	"Nova etapa al COFB"
09/01/2008	118 - Informatiu	"Editorial: Tots els motors en marxa"
09/01/2008	Correo Farmacéutico	"Hay que separar los términos de receta y prescripción"
11/21/2008	Jornada de RE en el Context d'Europa	http://www.gencat.cat/salut/ticsalut/html/ca/dir1769/doc27331.html
11/29/2008	Correo Farmacéutico	"No es lógico que haya 17 modelos de receta electrónica incompatibles entre sí"
12/01/2008	119 - Informatiu	"Editorial: L'any que ens ve!"
12/07/2008	Diari de Girona	"Les farmàcies connecten amb els metges"
12/21/2008	Memòria CCFC	
12/23/2008	COFB	Acord amb el Col•legi pel projecte de recepta electrònica (carta que COFB adreça als seus membres)
02/24/2009	El Periodico	"Geli anuncia que la receta electrónica estará implantada en toda Catalunya a finales del 2009"
03/01/2009	El Farmaceutico	“Congreso Europeo de Oficina de Farmacia - Entrevista con Jordi Dalmases”
03/01/2009	El Farmaceutico	“Congreso Europeo de Oficina de Farmacia - La receta electronica un buen motivo de conversación”
03/06/2009	COFB	Conveni sobre certificats digitals amb el BBVA (carta que COFB adreça als seus membres)
03/09/2009	El Punt	"La recepta electrònica estarà implantada el juny d'aquest any a tota la demarcació"

Table A1. List of Documents Analyzed (cont.)

Date	Publication	Title
04/01/2009	Offarm (28:4)	"Infarma 2009: La salud no sable de coyunturas económicas"
04/22/2009	El Punt	"Les farmàcies del Camp i l'Ebre ja han dispensat més d'un milió de fàrmacs amb recepta electrònica"
05/31/2009	El Punt	"La recepta electrònica a l'Ebre"
06/01/2009	El Farmaceutico	"Farmacéutico del año: Joan Durán Pou"
06/01/2009	124 - [i] COFB	"Certificats per a l'e-recepta"
06/19/2009	El Punt	"Els metges de família, crítics amb alguns punts de la recepta electrònica"
07/21/2009	El Punt	"La recepta electrònica començarà a implantar-se després de l'estiu als hospitals de Tarragona"
08/01/2009	125 - [i]CoFB	Entrevista amb Marina Geli
08/07/2009	COFB	El Col•legi avisarà sobre alertes a través d'SMS
09/01/2009	126 - [i]CoFB	Entrevista amb Francesc Pla
10/06/2009	El Punt	"Més medicina, menys burocràcia"

About the Authors

Joan RODON is an Associate Professor in the Information Systems Department at ESADE Business School, Universitat Ramon Llull. His research focuses mainly on the processes of emergence and evolution of digital infrastructures. His research has been published in journals such as *European Journal of Information Syste*ms, the *Communications of the ACM*, the *Journal of Information Technology*, the *Information Systems Journal*, and the *Decision Support Systems*.

Leiser SILVA is an Associate Professor in the Decision and Information Sciences Department at the Bauer College of Business, University of Houston. He does qualitative studies that examine different aspects of Information Systems implementation and management, especially those related to power and politics. He is also interested in philosophical aspects that underpin qualitative research related to Information Technology. His research has been published in journals such as *MIS Quarterly*, the *Journal of the Association for Information Systems*, the *Information Systems Journal*, the *European Journal of Information Systems*, and the *Information Society and the Journal of Information Technology*.