PROCESS INNOVATION MEETS DIGITAL INFRASTRUCTURE IN A HIGH-TECH HOSPITAL

Research paper

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Abstract

Digitalisation is usually about process innovation with the use of IT, i.e. automating or informating organisational processes. However, redesigned processes are often misaligned with the underlying digital infrastructure. For instance, improving patient logistics with the help of IT is a key aim for current e-health initiatives, but has proven to be quite challenging in practice, and is sparsely dealt with in the literature. Our research question is, how can a process innovation initiative successfully interact with an underlying digital infrastructure?

Our empirical evidence is an in-depth case study at a new high-tech hospital in Norway. Building on a proposed framework of interaction between process innovation and digital infrastructure, we identify and analyse two governance and two architectural mechanisms. Theoretically, we contribute to the digital infrastructure research by proposing a configuration for successful process innovation, in a complex e-health context. For practitioners, we show that lightweight IT can serve as a mediating technology in the configuration.

Keywords: Process innovation, e-health, digital infrastructure, case study

1 Introduction

Digitalisation denotes a complex transformation, where the physical and the digital are entwined and configured in new ways. Digitalisation usually includes two key elements; the redesign (or automation) of a work process or service, and some innovative use of IT. For instance, Amazon redesigned the way we buy books, and a traffic *app* in a smart phone tells us when the next bus arrives. However, in many cases the process redesign and the underlying digital infrastructure are misaligned; i.e. they do not support each other. An example from e-health illustrates this.

A common complaint from hospital patient patients is that while the medical treatment was excellent, the co-ordination between different units was poor, and the information on schedule, waiting time and further actions was often lacking (Salazar et al, 2004; Norwegian Ministry of Health, 2015). For instance, a patient may consult a doctor on a disease and is asked to take a blood test or an x-ray. The doctor (or nurse) usually cannot book this, but has to send a requisition, which is treated by the lab or radiology department, and then a reply eventually arrives. Another example: A patient is offered medical treatment on a specific date in the morning. However, when arriving at 8, the patient is told that "you will be summoned", and then sits down to wait for many hours.

There are several reasons for these practices, but the two most important are that (i) patient flow has had a lower priority than medical treatment in the functional organisation of hospitals, and (ii) therefore the organisational processes and IT solutions were designed to support medical treatment, not logistics. From the patient and societal points of view, the costs are certainly high in terms of wasted time and goodwill, and both politicians and hospital managers have launched many initiatives to meet the challenge of poor patient flow.

Two main approaches has been:

- *A process initiative*, implemented under different names such as patient logistics or flow, patient careers, or clinical pathways. They cover somewhat different aspects, but the core idea is to adopt a process perspective (initially developed in industry), that focuses on redesigning and institutionalising a sequence of work tasks.
- *An IT initiative*, which focuses on integrating the many silo systems of hospitals, in order to support a more holistic patient flow.

Ideally, the two approaches complement each other; the process innovation approach presupposes that information from different systems is available when needed, and the IT approach assumes that if the information is available, it will satisfy the need of the process. However, the experiences of the past two decades show that this is more difficult than expected, and patient logistics is still one of the most challenging tasks in modern hospitals (Van Lent et al., 2012). While process redesign is challenging in itself, a particular problem is that the installed base of IT solutions represents a considerable challenge for redesigning processes. This is not only because the IT solutions are "poor" (which is actually true in some cases), but also because silo IT solutions support organisational silos. Breaking these up is therefore a double challenge, which is easily underestimated.

Our research question is:

- *How can a process innovation initiative successfully interact with an underlying digital infrastructure?*

In this study we investigate these issues in a high-tech hospital in Norway. High-tech hospitals are characterised by *digitalisation*, i.e. in addition to advanced IT support such as clinical systems and a host of medical-technical apparatuses, they are based on a digital infrastructure, which connects the various organisational and technical parts into one integrated whole. At least, that is the ambition. To develop our argument we propose a framework to understand how the two forces interact.

2 Two Theoretical Approaches and a Framework

We first discuss research on process innovation and digital infrastructures; then present our framework. Our context is large health care solutions.

2.1 Process innovation

"All work is process work", wrote Michael Hammer (2015), and defined a business process as "a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer". Process innovation is admittedly a complex and non-linear phenomenon, but we can also understand it more concretely as "the reengineering of work through information technology" (Davenport, 1994). In practice, building on Zuboff's (1988) terms, this means usually to *automate* the whole or parts of a process to make it more efficient, or to *informate* it to help users solving problems. The process innovation literature has identified several innovation-enabling IS activities, such as infrastructure flexibility, collaboration with suppliers and distributors, project management and process analysis (Tarafdar and Gordon, 2007).

While business process redesign and business process management have a long tradition in industry and retail, process thinking has proven to be more challenging in the health care sector. However, process thinking has been introduced under several labels:

- *Patient careers;* the sequential steps of logistics and treatment, has been discussed since the 1960s (McKinlay, 1967).
- *Patient logistics,* the flow of patients through the health services (Van Lent et al., 2012)
- *Clinical pathways*, denoting the steps of treatment, seen from a medical perspective (Rotter et al., 2010).
- *Hospital supply chain management,* a more systemic view of the flow of all types of resources (De Vries and Huisman, 2011).
- *Patient oriented care,* focusing on the needs of the patient, rather than the clinicians (Meijboom et al, 2011).

These terms all address a "horizontal" view of the health care services or the hospital, complementing the "vertical" view of the highly specialized medical treatment. The key aim of these approaches is to support the flow of the patient through the various services and units.

In the larger picture of inter-organisational supply chains, previous research has shown that supply chain management in a health care setting is different from the industrial sector, but that existing concepts, models and supply chain practices can be extended to supply chain management in health services (De Vries and Huisman, 2011). The process e-health literature, however, address only sparsely the role of the underlying digital infrastructure.

2.2 Digital infrastructures

Digital infrastructure research offers a quite different perspective; it regards the interconnected networks of organisations, people and technologies as the key object. Hanseth and Lyytinen defined an information infrastructure as "a shared, open (and unbounded), heterogeneous and evolving socio-technical system (which we call installed base) consisting of a set of IT capabilities and their users, operations and design." (Hanseth and Lyytinen, 2010) The heterogeneous mix of people and technologies are built on the installed base. As the installed base grows its development and growth become self-reinforcing, through cultivation.

Evolution of digital infrastructures is different than process innovation; infrastructures are not "designed", but evolve through the combined actions of many stakeholders. Some researchers have identified generative mechanisms for this evolution, such as innovation, adoption and scaling (Henfridsson and Bygstad, 2013), denoting socio-technical networks of actions. For instance, the digital infrastructure of the South-East Health region of Norway (including our case hospital) had been growing for 20 years, and included around 4.000 different applications, each with a specific user group. Scandinavian research has identified *complexity* (organisational, technical and practices) as the key challenge of e-health infrastructures Ellingsen and Bjørn, 2014). In addition, a central theme has been the tensions between local needs and global standardisation (Bjørn and Kensing, 2013, Bygstad and Hanseth, 2016).

2.3 A Framework to Deal With Conflicting Forces

Research has shown that there are some inherent conflicts between process redesign and digital infrastructures (Beverungen, 2014; Rahimi et al., 2014). From a theoretical point of view these conflicts originate in the complexities of both structures. Process complexity originates from the number and dependencies of processes, but even more importantly from the instability; innovation and improvement usually means change of processes. Digital infrastructure complexity grows with the number of elements over time, where the installed base (Hanseth and Lyytinen, 2010) of interconnected systems and established routines becomes a force in itself, which is difficult to change.

From a more practical view we observe the conflicting forces in change initiatives that include IT solutions. First, the knowledge regimes are different; the process design community is business (or organisation) oriented, while the digital infrastructure community is mainly technology oriented. Second, the plasticity is different; while processes can relatively easily be redesigned, the inertia and path dependency of the installed base of infrastructures is well documented (Hanseth and Lyytinen, 2010). Third, the time perspective differs; process redesign is usually focused on innovation and time-to-market, while the digital infrastructure people are concerned about the need for a long-term and holistic architectural perspective.

How do the two forces interact? The common approach is *projects*, where representatives for the two communities co-operate in planning and executing joint activities. Focal artifacts for co-operation are boundary objects, i.e. objects that inhabit different, but intersecting social worlds, and satisfy the informational requirements of both (Star and Griesemer, 1989). Typical boundary objects in our context are user interfaces, which mediate the interaction of a person in a process, and the underlying digital infrastructure. Thus, when process models are (re)modelled the need for information or IT services are included in the process steps. In order to accomplish this, boundary-spanning competence is critical. Tarafdar and Gordon (2007) found that IS competencies in Knowledge Management, Collaboration, Project Management, Ambidexterity, IT/Innovation Governance and Business-IS Linkages affected process innovations positively. Rahimi et al (2014) investigated the alignment between business process and IT governance, and found that the presence of mutual adjustment between business process and IT management functions was critical to support strategic and operational process and IT decision making.

At a more theoretical level Tiwana (2013) argued that two key mechanisms are available to deal with complexity in digital ecosystems; *architecture* and *governance*. Architecture denotes how the main elements are organised and interact, while governance deals with decision rights, who decides what. We build on these insights, and suggest a conceptual framework to understand the interaction between process innovation and digital infrastructure.

As Figure 1 shows we envision to different structures; on the upper part of the figure we show the redesigned processes, while the lower part shows the underlying digital infrastructure. Between them are two mediating mechanisms, governance and architecture. At a general level we can define the role of the mechanism in these terms:

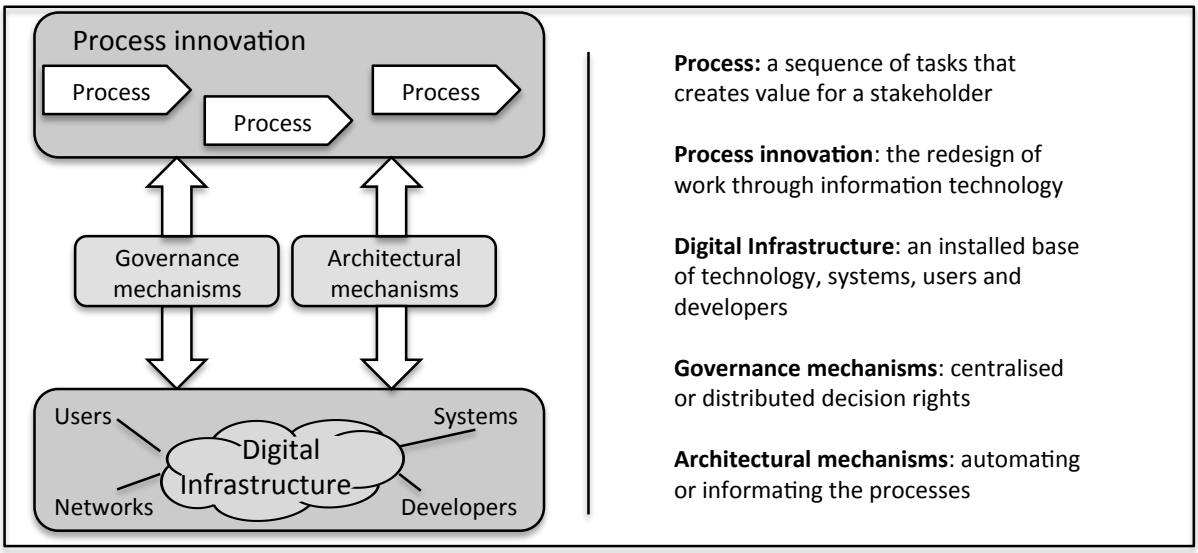

Figure 1. Framework

- G*overnance* mechanisms regulate who decides what, for instance whether the redesigned process should lead to changes in the digital infrastructure, or (the other way) whether new technologies in the infrastructure should lead to process changes. Governance mechanisms can be centralised or distributed.
- A*rchitecture* mechanisms deal with designing and implementing the technical solutions that support the processes. The nature of support can be automating (strongly structuring) or informating (providing more information for the user) the processes (Zuboff, 1988).

These definitions are our theoretical foundation, but in practice there are many unsolved questions. What is less known is under which conditions they will work, and how they actually cause outcomes. A more fine-grained investigation was needed.

3 Method

3.1 Method Approach

We chose an in-depth case study to investigate these issues, because the research question asked for a detailed investigation of a phenomenon in its real context (Yin, 2013). In selecting the case we followed Gerring's (2007) typology, and chose an *extreme case*, which is prototypical or paradigmatic of some phenomenon of interest.

Our selected case was a brand new hospital in Norway, the Østfold Hospital. It opened in the autumn 2015, and was presented as the most modern hospital in Europe, in its use of information technology and process orientation. Thus, it satisfied our key criteria; it was quite ambitious in both our objects of interest, and offered a unique opportunity to study the interplay of process design with digital infrastructure.

3.2 Data Collection and Analysis

We conducted an intensive study over one year, with interviews, observations and documents as our data sources. In line with our dual perspective we had a dual data collection strategy:

- To understand the patient logistics strategy we interviewed top managers in the health region and at the hospital, the CIO, line managers and clinicians. We also observed "whiteboard meetings" and the practical work at the emergency unit.
- To map the digital infrastructure we interviewed IT personnel at the Østfold hospital and the South-East Regional Authority and the IT Centre. We also interviewed vendors and consultants, and collected strategy plans, project plans, requirements specifications and status reports.

In order to develop *converging lines of inquiry* in a complex case (Yin, 2013*)*, we built - iteratively, as trends and topics emerged - on multiple sources. In total, we conducted 29 interviews, observed 6 sessions and collected 6 key documents. Se Table 1.

Type	**Managers**	**Clinicians**	**IT personnel and vendors**
Interviews	6	15	8
Observations	1	4	1
Documents	3		3

Table 1. Data collection

Data analysis was conducted in three steps, following a critical realist approach; from events we identified mechanisms, defined as a causal structure that causes an outcome (Bhaskar, 1998), and then

tried to understand the context under which the mechanisms were actualised (Pawson and Tilley, 1997). See Figure 2.

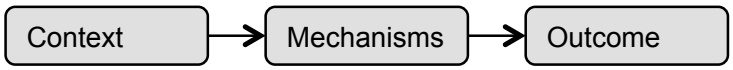

Figure 2. The CMO scheme

First we established a baseline of the process innovation initiative, and the digital infrastructure. Then we identified a large number of interaction episodes, and from these we identified four mechanisms; two governance and two architectural mechanisms (see Table 2). Finally, we used the Context-Mechanism-Outcome scheme to analyse the context, the interaction of mechanisms and the outcome. This allowed for a *configurational view* (El Sawy et al., 2010) on causality, which treats outcomes as a result of specific configurations, based on careful analysis of contingencies and mechanisms.

3.3 The Case

In 1999 the Norwegian Parliament decided to build a new hospital in Østfold County. Østfold Hospital is part of the South-East Regional Health Authority, which covers around half of the Norwegian population, and has 80.000 employees. The construction at the new site started in 2010, and the hospital opened in November 2015, with both somatic and psychiatric services, and 4800 employees (Fig 3).

The CEO of the hospital, Just Ebbesen, was a doctor and a pioneer in using IT to innovate and support clinical processes. He commented:

> "I had been engaged with the relationship of process innovation and IT the past 15 years, both theoretically and practically, and I knew what I wanted to achieve: hospital processes should be well defined and supported by information. The overall thinking was inspired by the theory of *value configurations* (Stabell and Fjellstad, 1999), so the Moss hospital[1] was designed as the *value chain* (dealing with the standardised high volume cases), the Østfold (Kalnes) hospital as the *value workshop* (dealing with complex diagnoses and treatment) we needed a comprehensive communication solution for the *value network* (including clinicians, staff, patients and municipalities)".

In 2011 he hired an energetic CIO with experience from production and retail, in 2012 a Process Director, and established a top management team aiming to build a hospital built on process thinking and advanced IT solutions. The process challenges included for example:

- Receiving emergency patients arriving with ambulances or by taxi, registering them, conducting triage and medical diagnoses, and requiring additional services such as lab tests or radiology.
- Allocating new hospitalised patient to wards and beds, and providing the necessary information to the staff, and to patient's family.
- Setting up a clinical pathway for each patient, and allocating various resources and services in calendars
- Ensuring that each patient received exactly the medicines that the doctor(s) had prescribed ("closed loop medication").
- Co-ordinating the discharge of patients with municipalities. For instance, the municipal care institutions required that information on an incoming patient should be sent before noon.
- Providing the kitchen with exact information on how many meals, dietary requirements, room numbers etc.
- Providing the cleaning department with timely information on which rooms to clean, and when.

[1] The Moss Hospital was part of the Østfold Hospital, situated around 30 kilometers away.

- Creating a real-time (graphical) logistics overview for management, to ensure an optimal flow of patient and use of resources

While these needs may sound straightforward, the reality is that each of them required a very careful design of the process, and that almost every step of the process was dependent on reliable information from various IT systems.

Figure 3: Østfold Hospital (Photo: HSØ)

Phase 1: Process modelling and IT piloting in old hospital 2013-15

The modelling and redesign of processes started in 2013, first in the emergency unit; later in ward. Around 25 clinicians and staff were allocated full-time to then project, plus a number of external consultants. A work group, consisting of clinicians, IT personnel, organisation development specialists and IT architects modelled 63 work processes, each of them in considerate detail, with "swim lanes" (for roles) and the need for IT support in each step. (Most of these work processes were sub-processes of 38 different clinical pathways). A separate group worked with the details of the Imatis solution, first working with process steps; later configuring the different views of the whiteboard.

The IT part was more challenging. The "regional package" consisted of more than 300 applications, maintained and run by the regional IT Centre. The key applications were the electronic patient record (EPR) system, lab system, radiology system and chart and medication system. The region was at the time running an e-health mega-program, Digital Renewal, aiming at integrating the most important (silo) systems[2] However, the integrated package was not ready, and progress was slow. After some heated discussions in 2012 the responsibility for parts of the start-up package was transferred in 2013 from the Digital Renewal program to the Østfold Hospital Project, because of the tight deadline in 2015. Both the lab system and the chart and medication system were new, and had to be integrated into the regional package at tight deadlines. An IT architecture team was established in Østfold, particularly to deal with the complex integration issues.

In addition, a new, more lightweight IT solution was specified to support logistics and communication; a system from Imatis. This was organised as a sub-project, with an external consultant as project manager, working with a group of clinicians who had modelled and redesigned many processes. The Ima-

[2] The large Digital Renewal program of the Health South-East had established a regional IT architecture with an integration framework built on Microsoft BizTalk, enabling a large number of systems to exchange data within and outside the region (see Bygstad and Hanseth, 2016). The 2010 and 2012 IT plans of Østfold Hospital included this package, with some local additions. Initially, the IT solution at Østfold Hospital was also governed by the program.

tis environment was strongly supported by top management, but the doctors, the IT departments, and the vendors were more sceptical. The CIO commented:

> "The link between processes and IT solutions were excellent, and the process modelling was very useful. But the solution was new to the regional IT Department, and integration with the clinical systems was demanding. I spent my days co-ordinating various vendors, the IT Operations and the doctors. A number of unresolved issues and questions popped up: who has the responsibility for technical integration (Vendors? The IT Centre? We?) The enormous amounts of clinical information from sensors and medical equipment – should everything be stored? And so on…"

The Imatis solution was based on lightweight IT[3], and used self check-in automats, mobile phones, tablets and electronic whiteboards, which were modelled in the processes.

Phase 2: Start-up at new hospital, Nov 2015

The start-up was successful, but narrowly so. The integration solution between the major clinical systems was complex, and some improvisation and shortcuts were done, and the lab solution was a pioneer installation, with an inexperienced vendor. The hospital was also a world test-case for implementing the chart- and medication system to be used not only at surgery units, but also in wards.

The Imatis solution included three main services:

- A solution for patient self check-in and dealing with queues
- A system for visualisation of patient flow and logistics, with whiteboards (see Figure 4)
- A message broker for distribution of messages to mobile phones and other units

Figure 4. Nurse using whiteboard, and Imatis services (Photo: HSØ)

As seen in Figure 4 the solution was extensive, and supported the flow of information between the major clinical systems, medical surveillance instruments, ambulance systems and the mobile terminals of both clinicians and patients. Access and security were role-based, enabling flexible use of equipment. Some of the whiteboards views were too rich, and were adjusted as personnel experienced daily use.

[3] We define lightweight IT as a knowledge regime, driven by competent users' need for solutions, enabled by the consumerisation of digital technology and realized through innovation processes (Bygstad, 2016).

Phase 3: Stabilising solutions (Jan 2016-August 2016)

Several challenges were addressed in the months following the start-up. Local champions were active in motivating users in the new environment. For instance, the interplay between the emergency unit and the wards had been unsatisfactory, where the emergency co-ordinator used to call all wards to find an available bed. With the whiteboard solution she had now a visual overview of all available beds – provided that the wards had updated the situation. When this was routinized, the whole atmosphere in the wards improved a lot, because the telephones stopped ringing. "It is a completely new work situation for me", said the co-ordinator, "because the whiteboard enables me to have full overview and control of the process".

A key process indicator at a hospital is the average time of patients staying, which had increased from 3.2 in the old hospital to 3.6 days. The reason was assumed to be that the discharge process was not optimal, because the status of the patients was not changed immediately. As a consequence, available rooms were not cleaned in time. Both problems were rooted in the fact that tight logistics require a very disciplined updating of systems, and several initiatives were taken to improve on this.

A number of other issues emerged, but overall the situation in the autumn 2016 was satisfactory; a very innovative hospital had been established, for the benefit of both patients and clinicians. However, the ride had been pretty bumpy. Our key research interest was to identify the mechanisms explaining both the bumps and the success.

4 Findings

Building on our proposed framework we analysed the case in terms of governance and architectural mechanisms. Findings are summarised in Table 2. We deal with each mechanism by analysing the conflicting forces.

Type	Mechanism	Conflicting forces	Solutions
Governance mechanisms	Integrated project	Process design initiative vs. IT centre	Integrated approach: both processes and IT
	Process innovation	Process innovation vs. user habits	Soft implementation
Architectural mechanisms	System integration	Short-term hospital needs vs. regional architecture	System integration conducted at Østfold
	Lightweight IT	Lightweight IT vs. heavy-weight IT	Extensive solution (but not complete) with loose coupling to heavyweight

Table 2. Findings overview

4.1 Process design initiative vs. IT centre

The Østfold project was organised as one integrated initiative, including both physical structures, organisation and IT services. This meant that the physical architecture, the process redesign, and the supporting IT solution were all integrated in one project. The arrangement was unusual, but it gave the top management a strong negotiating position. The CEO commented:

> "If the responsibility for the IT solution had not been transferred to us in 2013, we would never have kept the deadline. Regionally, there were simply too many cooks. We had to simplify things to get the solutions running."

Through the project Østfold Hospital mobilised a large number of clinicians, administrative personnel, external consultants and local IT staff to work together to support the logistic and clinical processes with IT services. The extensive Imatis solution had to be detailed to give sufficient support, and workshops were regularly held to connect technology and tasks. Then, practical solutions with electronic whiteboards, mobile phones and tablets had to be found, dealing with many vendors.

During the project there were tensions between the project team in Østfold and the IT Operations Centre in Oslo. For the Østfold team the IT Centre was slow in responding to requests and changes, and also lacked the necessary competence with the lightweight Imatis solutions. Seen from the IT Centre the Østfold project was one of many on-going initiatives, and their expectations were often perceived as unreasonable. Tensions were gradually resolved, and the Integration Factory at the IT Centre in Oslo accomplished the demanding interplay between the Imatis lightweight solution and the regional infrastructure.

4.2 Process innovation vs. user habits

The process modelling was a fruitful joint learning arena for the clinicians and IT personnel. It resulted in an overall logistics view of the hospital, including the reception of patient from ambulances or municipalities, the flow between the medical and ward units, and the discharge of patients. It also resulted in careful redesign of many processes, supported by the new IT solutions. For instance, a new routine was the *whiteboard meeting*, a short stand-up daily meeting of doctors and nurses. The whiteboard shows a list of the current patients at the ward; the medical condition of each one is discussed, and it is decided who shall be discharged and who needs further treatment. The decisions are recorded immediately by touching the screen and changing status.

In practice, however, these process innovations were met with resistance from many clinicians. One sub-project manager commented:

> "People are emotionally connected to applications, i.e. they are used to the GUIs, the logics and the routines supported by the systems. In contrast, people feel much less loyalty to a process, which in many cases is imposed from the outside, and makes them feel insecure in conducting their habitual work".

This applied for instance to the doctor's use of solutions; they were used to using the Electronic Patient Record system, and preferred to use it also for tasks where the Imatis solution required input. This was not actively opposed.

4.3 Short-term hospital needs vs. regional architecture

The high priority and fixed deadline of the Østfold hospital had led to a situation where the responsibility for systems integration was transferred from regional level to the local project. This meant that the core clinical systems, such as the EPR, lab, radiology and chart- and medication systems were configured and tested by the project. The definite deadline required fast decisions and action, and many of the more complex regional issues, such as scaling and flexibility, were postponed. The result, as shown in the "big-bang" start-up in November 2015, was relatively successful. But the CIO reflected:

> "We have to acknowledge that while lean processes are beneficial for the clinicians, one consequence is increased complexity in the IT solutions. This leads to challenges in keeping up stability in IT operations and maintainability in our systems. But so far the solution works".

The IT Centre did not appreciate the many technical shortcuts conducted by the Østfold team, which would cause technical debt and might create problems at a later stage. For instance, after the Østfold implementation doubts were raised whether the lab solution was scalable to a regional level.

4.4 Lightweight IT vs. heavyweight IT

The most innovative and prestigious solution in Østfold was the Imatis solution, partly illustrated in Figure 4. The Imatis solution was an example of what has been called lightweight IT (Lacity and Willcocks, 2015; Bygstad, 2016); i.e. commercially available IT components, relatively easy to implement, and loosely coupled to the heavyweight systems. The Imatis solution showed how lightweight IT could mediate effectively between the processes and the existing digital infrastructure; in fact, most of the redesigned processed were informated by the solution. However, the interaction between lightweight IT and heavyweight infrastructure was demanding, and the most ambitious process aim failed for this reason.

The planned *multi-booking* solution aimed at solving one of the key process issues, namely to book the necessary resources for a clinical pathway based on a specific diagnosis. For instance, if a patient is diagnosed with breast cancer, a multi-booking system would (automatically) generate a detailed schedule for the patient, including oncologist consultations, x-ray, surgery, and other activities. The benefits would be considerable, both for the patient and for internal logistics. Unfortunately, the solution failed; although satisfactory software was tested, integration with the EPR systems proved too difficult, partly because of conflicting vendor interests.

5 Discussion

In many ways the Østfold Hospital was an impressive innovation project on a large scale, showing that process innovation can be excellently supported by the digital infrastructure, while also extending the infrastructure. It also shows how Stabell and Fjeldstad's (1998) concept of *value network* can be effectively utilised in an e-health context. Connecting the large number of actors (clinicians in various departments, hospital staff, patients and their families, municipal institutions, ambulances) into a network built on whiteboards and mobile equipment, can greatly improve logistics. This was achieved through *visualisation*, rather than automation; various actors (such as the emergency unit co-ordinator wanting to allocate patients to ward; the kitchen preparing meals; the patient waiting in a queue; the municipal care home planning reception of patients) were supplied with the necessary information at the right time, and could act rationally on it.

The solution was not just "implemented" top-down, rather it was the result of on-going innovation and negotiation. The character of these processes is the key to our theoretical contribution.

5.1 Contribution to Digital Infrastructure Theory

In accordance with critical realism (Pawson and Tilley, 1997) we theorise our finding through the CMO scheme; in a specific context, some mechanisms may cause certain outcomes. This implies that both context and mechanisms are necessary factors in explaining the outcome.

The basic governance and architecture mechanisms of ecosystems (Tiwana, 2013) and digital infrastructures (Hanseth) are well documented in research. Considering our findings we think that a reasonable interpretation of the Østfold case is that large-scale IT-enabled process innovation in a hospital was successful by a specific *configuration* (El Sawy et al, 2010) of context and mechanisms:

- The context of a brand new hospital, with some autonomy from the installed base of the regional infrastructure, offered an opportunity of innovation for an ambitious and able top management group to leverage the available mechanisms:

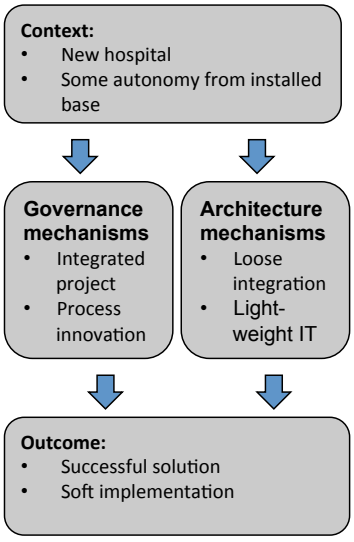

Figure 5: Configuration

- The governance mechanisms of process orientation and an integrated project allowed the managers to (i) design key processes for better patient flow and (ii) implement the new processes and technical solutions as mutually supporting elements.
- The architecture mechanisms of systems integration and lightweight IT allowed the managers to (i) connect to the existing digital infrastructure and (ii) to connect processes and infrastructure loosely, by innovative deployment of lightweight IT (Figure 5).

The attributes of lightweight IT were important, in the sense that the processes were not *automated*, i.e. strongly structured by IT, but rather *informated* (Zuboff, 1988*)*. This meant that clinical personnel were equipped with relatively flexible IT tools, such as mobile phones and electronic whiteboards, to support their tasks, but in a problem-solving way. The lightweight tools could also be reconfigured by local IT staff if needed. Therefore, lightweight IT is a part of our suggested configuration, enabling incremental design and implementation.

An important aspect is how the governance and architectural mechanisms interact, and may reinforce each other. For instance, in the Østfold case an obvious success factor was that the integrated project supported the technical solutions much better than a regional project would have done, and vice versa, the success of the lightweight architecture increased the legitimacy of the project.

Would the same have been feasible in another context, for instance in an established hospital? It is possible, but evidence from many failed similar initiatives (Ellingsen et al, 2013; Bjørn and Kensing, 2013) suggests that it would have been much more challenging. Our contribution to digital infrastructure theory (Hanseth and Lyytinen, 2010) is therefore *configurational* (El Sawy et al., 2010): it shows a causal pathway for extending infrastructure theory by a context of loose coupling, but with sufficient governance and architectural links to the larger infrastructure. We also extend the Scandinavian e-health research by proposing an alternative approach for dealing with the complexity issues.

5.2 Contribution to Practice

The practical contribution can be summarised in the following.

First, connecting process innovation and digital infrastructure is necessary for the success of such initiatives, but the case illustrates that large digital infrastructures cannot be "designed" top down, but evolve through governance and architectural growth. As illustrated in the Østfold case a careful use of the governance and architectural mechanisms may enable beneficial solutions.

Second, the role of lightweight IT shows how an intermediating technology, relatively loosely coupled to the digital infrastructure, offers the agility and flexibility to support process innovation. It also shows a way forward, to more platform-oriented solutions (Tiwana, 2013) in e-health, in the sense that it decouples lightweight interfaces from the main applications.

Finally, competence is critical. In the Østfold there was a fortunate mix of competences; a visionary CEO, a process oriented director of development, and a hands-on CIO, who worked equally enthusiastic with architectural issues as with mobile phone configurations. Also, the technical teams both at the hospital and at the Data Centre worked hard to solve problems, and gradually acquired the necessary competence.

6 Conclusion

Digitalisation is a convenient term, but denotes an extremely complex transformation, where the physical and the digital are entwined and configured in new ways. It includes usually both process innovation and a changing digital infrastructure. In this paper we investigated the interaction of these two forces in a high-tech hospital.

Our main contribution is a new *configuration* of how process innovation in e-health can successfully interact with a large existing digital infrastructure; the key is an integrated project with relatively loose

coupling to the digital infrastructure, but still allowed to draw on its resources. This configuration is not smooth; it requires on-going negotiation between conflicting forces, and it requires the courage to accept a less streamlined development. This, however, is perhaps the characteristic of digital innovation?

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