Governing e-Health Infrastructures: Dealing with Tensions

Completed Research Paper

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Abstract

In this paper we investigate tensions in large e-health infrastructure programs. Currently, there is a gap between the high expectations to e-health and the fragmented status of IT services. In response to this situation the health authorities in many countries has called for a strategy of central IT governance and enterprise architecture, but many large programs experience tensions. Our research question is, how can we understand and manage the tensions of large-scale programs in e-health?

The empirical evidence is a multilevel study of a national e-health Norway initiative, at three levels; national, regional and project. We find that the governance-architecture approach is not effective in balancing the tensions of e-health infrastructures. Our proposed solution is to differentiate between stable and unstable elements of the infrastructure; the stable elements can, and should, be managed top-down, while the unstable elements should be subject to local innovation and decentralised governance.

Keywords: E-health, tensions, governance, architecture, information infrastructure

Introduction

The main argument in this paper is that the current approach in national and regional e-health programs – a combination of enterprise architecture and centralized governance – lacks an understanding of the inherent tensions of information infrastructures. Dealing with these tensions requires new thinking.

The background is that most rich countries are in the act of rebuilding their e-health infrastructures. The reason is primarily increased pressures – from politicians and the public – for better and less costly medical services, and the expectations to the contribution from e-health, in respect to these aims, are formidable. For example, the e-health aims of the European Union are to (i) improve citizens' health by making life-saving information available, between countries when necessary, using e-health tools, (ii) to increase healthcare quality and access by making e-health part of health policy and coordinating EU countries' political, financial and technical strategies and (iii) to make e-health tools more effective, user-friendly and widely accepted by involving professionals and patients in strategy, design and implementation (EU Commission 2014).

While this may sound straightforward, anybody with knowledge of the current status of e-health will know that these aims are indeed challenging (Sauer and Willcocks, 2007; Currie, 2014; Klecun, 2016; Kohli and Tan, 2016). As expressed by the Estonian President Toomas Hendrik Ilves, Chair of the independent high-level e-health Task Force: "We know that in healthcare we lag at least 10 years behind virtually every other area in the implementation of IT solutions. We know from a wide range of other
services that information technology applications can radically revolutionise and improve the way we do things” (EU Commission, 2012, p.5).

A central task is to implement a set of key e-health services, such as electronic patient record (EPR), e-prescription, lab, radiology, and chart and medication systems. These solutions must be internally integrated, exchange data with hundreds of other clinical systems, and they also need to be able to communicate across health regions, and, eventually, borders. Preferably, they should also be designed to serve as platforms for innovation of patient oriented solutions and new technologies such as tablets, mobiles and sensors. The solutions will be used by tens of thousands of health personnel and millions of patients, and disruptions in operations or errors in data may cost human lives. All this requires a restructuring of current solutions, in particular the dismantling of IT silo systems into interacting solutions, connected by secure broadband services and run 24/7. Some researchers have argued that the complexity of these socio-technical systems exceeds the current methods of project management and software development (Sommerville et al., 2012.)

How should this challenge be governed in e-health? A combination of two approaches have been chosen in most countries:

- The establishment of an IT governance regime, in order to plan, prioritize and coordinate the various activities (Weill and Ross, 2004; ISACA 2012).
- The establishment of an IT architectural regime, consisting of enterprise architecture (EA), various standards and an implementation process (Ross et al., 2006; Open Group, 2011).

We suggest calling this the IT Governance-Architecture Approach. As argued by Tiwana (2014) IT architecture addresses the structural complexity of ecosystems, while governance deals with the behavioural complexity. The two approaches share some salient and mutually reinforcing characteristics, which justifies the term. First, it is based on top-down control: Both approaches assume that the best way to deal with complexity is centralised control. Second, it is holistic: It is the whole organisation (or infrastructure) that is targeted. Third, it is an integrated approach: Implicit in the two points above is the premise that, since everything-is-related-to-everything-else, integration is the key mechanism for dealing with relationships. Information systems should be integrated, and architectural and organisational governance mechanisms should be closely linked. A range of various technologies is available to support these solutions.

The results of implementing these principles in e-health are hard to assess, because there are a limited number of studies at a national level. The European Commission (2011) has documented slow progress in e-health, and large variations between the EU countries. At a programme level the British mega-programme, which was largely based on the governance-architecture approach, was a general failure, and was redesigned into a less ambitious and decentralised program (Currie, 2014; Klecun, 2016). In a longitudinal study in Denmark Aanestad and Jensen (2011) compared two national EPR initiatives; one top-down and integrated project and one small and emergent initiative, finding the latter the most successful. On the other hand, there are also successful examples of top-down approaches, such as the solution in Estonia (Aaviksoo and Saluse, 2010).

The starting point of our investigation is the observation made by several researchers that there are conflicting forces in e-health mega-programmes. For example, Sauer and Willcocks (2007) found that expectations exceed realities in these programmes, partly because they are oversold in order to ensure the necessary funding, and partly because the organisational and technical complexity make them extremely challenging. Currie (2014) identified a number of conflict issues in the British National Programme, such as tensions between clinicians and administrators, and between centralised governance and local needs. Hanseth and Bygstad (2015) found that the standardization strategy, which is central in most mega-programmes, often is deployed too rigorously; it may lead to increased complexity and, accordingly, is a hindrance to innovation. We argue that these tensions are not accidental, but associated to the

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1 For instance, enterprise service bus technology (Rosen et al., 2008) enables real-time exchange and conversion of data between systems, and a frameworks such as HIE/XDS (Dogac et al., 2007) support the sharing of patient records from different institutions and systems. Standards such as HL7 support semantic interoperability. These technologies are today widely used.
complexity and dynamics of large e-health infrastructures. Thus, they are not primarily symptoms of poor project management. Therefore, both theoretically and from a practice view it is important to understand tensions in e-health in more depth.

Our research question is: how can we understand and deal with the tensions of large e-health infrastructures?

To develop our argument we build on the information infrastructure research (Hanseth and Lyttinen, 2010), and a longitudinal case study of a large e-health infrastructure in Norway. Our conclusion is that in order to balance tensions we should adopt an architectural perspective, and differentiate between stable and unstable elements of the infrastructure; the stable elements can be designed and governed centrally, the unstable elements cannot.

Theoretical Lens: Information Infrastructures and Conflicting Forces

Hanseth and Lyttinen (2010) 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" (p. 4). A particularly important attribute of information infrastructures is that, in contrast to stand-alone applications and IT silo systems they include some inherent conflicting forces (Edwards et al. 2007; Rodon and Hanseth, 2015). The root of these tensions is complexity, which we generally understand as an attribute of the scope and number of different but related parts of a whole.

Information infrastructures include a variety of user groups, sub-systems and technical components, with complex interactions and many interdependencies, and they evolve through adoption of new users, innovation of new services, and inclusion of new partners (Henfridsson and Bygstad, 2013). Particularly in the complex world of e-health this creates tensions. In a longitudinal study of the large UK National Programme for IT Currie (2014) found tensions in several areas: centralized contracts with IT suppliers created tensions between central procurement and local needs; benefits realization was difficult because of uncertainties on who was responsible; the balance between privacy and availability of electronic patient records was never resolved, and, finally, clinical engagement was low, because many of them felt that the authorities were not interested in their opinions. In a Danish study, Vikkelsø (2007) found that the governance and auditing regime of health infrastructures created strong tensions between administrators and health personnel, for instance regarding professional autonomy and the evaluation of medical practices.

Theoretically, some studies have conceptualized these tensions as a duality; i.e. these tensions are seen as interdependent, complementary, mutually enabling, and constituent of one another (Tilson et al. 2010; Wareham et al. 2014). For instance, flexibility and variability are achieved by means of the stability granted by standards as the latter enable novel recombinations of digital components of infrastructures. This is also echoed in Star and Ruhleder’s (1996) statement; “An infrastructure occurs when the tension between local and global is resolved” (p.114).

Other studies have perceived these tensions as dualisms, i.e. conflicting forces that are pulling in opposite directions (Currie, 2014; Klecun, 2016). Hanseth et al. (1996) discussed the on-going tensions between standardization and flexibility of large infrastructures; in order to grow they need both standards (to stabilise and scale) and flexibility (to innovate and adapt). They argued that these forces cannot be optimized by must be balanced, and an informed balance requires insight in the specifics of the actual technologies and in distinguishing between different aspects of flexibility.

Tensions in information infrastructures: A framework

Building on extensive historical and social research Edwards et al.’s (2007) identified three basic tensions in cyberinfrastructures; time (short-term decisions vs. the long-time growth), scale, (such as between global interoperability vs. local optimization) and agency (such as processes of planned vs. emergent change). Edwards et al. (2007) conceptualised tensions as both barriers and resources to infrastructural development, and "should be engaged constructively; in particular, they should be leveraged for their contributions to long-term properties of infrastructural fit, equity, and sustainability” (p.29). We use
these three types as our analytical lens to assess the tensions of IT architecture and IT governance, as summarised in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Scale</th>
<th>Agency</th>
</tr>
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<tbody>
<tr>
<td><strong>IT Governance</strong></td>
<td>Between short-term usefulness and long-term evolution</td>
<td>Between centralized and decentralized control</td>
<td>Between planned and emergent action</td>
</tr>
<tr>
<td><strong>IT Architecture</strong></td>
<td>Between long-term, stable standards and dynamic flexibility</td>
<td>Between global scalability and adapting to local needs</td>
<td>Between tight and loose coupling</td>
</tr>
</tbody>
</table>

**IT Governance**

IT Governance is often defined as the institutionalization of decision rights on IT matters in an organization (Weill and Ross, 2004).

*Time:* Hanseth and Lyytinen (2010) described the development of infrastructures as dependent on two processes; bootstrapping (in the short term) and adaptation (in the long term): in order to succeed infrastructures has to be useful and profitable in the short-term, but also be prepared to grow with changing requirements and use over a long lifespan.

*Scale:* Governing large infrastructures is a balance between centralized and decentralized control. There is a tension between the autonomy of independent actors to seek generativity through distributed control vs. the centralized control that enables large-scale generativity (Tilson et al. 2010; Tiwana, 2014; Williams, 2016).

*Agency:* Some digital infrastructures are the result of planned development and implementation, but many have grown organically without central co-ordination, such as the Internet (Edwards, 2007; Hanseth and Lyytinen, 2010). In practice, most infrastructures grow by negotiations between planned and emergent action.

**IT Architecture**

IT Architecture in our context deals with the relationships between the components (both technical and social) of the infrastructure. Several researchers have investigated the tensions between stability brought by the installed base to enrol new actors and services, versus the flexibility to leverage unbounded growth of actors and services (Tilson et al. 2010; Tiwana 2014; Wareham et al. 2014).

The dominant paradigm in IT architecture is to think in terms of services, not systems. A service supports directly the business processes, and should - ideally - constitute the layer between technology and business. In an SOA, functionality is encapsulated, and standardized interfaces are available. There are various technical solutions for implementing SOA, for example a layered architecture and the Enterprise Service Bus (Zakareya and Irani, 2005).

*Time:* Standards, in a broad sense, are crucial for the growth of infrastructures, but must be balanced against the need for innovation and adaptation (Hanseth et al, 1996; Grisot and Vassilakopoulou, 2013). Research has documented tensions between the sensitiveness to local contexts with the need to standardize across contexts (Silsand and Ellingsen 2014; Hanseth and Bygstad, 2015). Platform architecture is one solution for balancing these needs; they consist of certain stable components (the platform itself), while others (the complements) are encouraged to vary in cross-section or over time (Baldwin and Woodard, 2008).

*Scale:* Information infrastructures should be scalable, i.e. being able to include more users and more user groups, but they should also be flexible enough to satisfy local needs (Edwards, 2007; Grisot and Vassilakopoulou, 2013). The sheer complexity of e-health makes this extremely challenging (Williams, 2016).
Agency: The basic tension is between tight and loose coupling (Parnas, 1972); tight coupling supports stability, while loose coupling enables change. Tight coupling allows for efficiency and control, while loose coupling allows for local change in components and organizational units. There is a tension between the top-down demands for integration with the bottom-up reliance on the installed base of systems and practices (Hepso et al. 2009).

Dealing with tensions

How do managers deal with these tensions? A limitation of the IT Governance-Architecture approach (Weill and Ross, 2004; Ross et al., 2006; ISACA, 2012) is that it is built on the experiences from managing large companies and IT projects, where the main challenge is to standardize and coordinate within a single organisation. In contrast, e-health infrastructures are much more harder to control, as they are more complex and encompass many different stakeholders (Hanseth and Lyttinen, 2010; Klecun, 2016). Also, they are not designed from scratch, but grow organically through innovation, adoption and scaling (Henfridsson and Bygstad, 2013). The extant normative literature do not deal with these issues in sufficient depth, and assume generally that holistically planned architectures, standardization and top-down governance are the only feasible approaches.

The more empirical IS research has identified other approaches. For instance, in a study of a large IT transformation program from the banking sector Gregory et al. (2015) identified six types of tensions. They found that managers applied ambidextrous resolution strategies (defined as pursuing disparate things at the same time) to deal with them, i.e. balancing long- and short term goals, and local versus global needs. A more bottom-up approach was offered by Contantinides and Barrett (2015); in a study of an e-health infrastructure in Greece they investigated actors with different interests and interpretations, and suggested a collective action perspective and a polycentric approach (Ostrom, 2010). This implies that tensions are dealt with in a nested governance structure, where lower levels become part of a larger infrastructure without giving up their local needs and framing.

How can we deal better with these tensions in e-health mega-programmes? As Tiwana (2014) and Williams (2016) has argued, environmental dynamics influences greatly the interplay of governance and architecture. Therefore, an informed approach to this question requires that we understand the particularities of large e-health infrastructures and their political context.

Method

To study the phenomenon in depth and in context we chose a multilevel case study (George and Bennett, 2005; Hitt, 2007), which enabled us to investigate the interplay of policies, programs and projects. We studied the governance and development of a national e-health infrastructure in Norway over a period of six years (2009-2016), at three levels:

- **The national level:** we interviewed top executives and IT managers at the Ministry of Health and Directorate of Health, analysed plans and initiatives, and we followed the governance and development of the first national e-health service, the ePrescription solution in 2009 to 2013.
- **Regional level:** we investigated the development of a governance structure and regional IT architecture in the South-Eastern Norway Regional Health Authority from 2013 to 2016, organised as a mega-programme, “Digital Renewal”.
- **Project level:** we followed a large project over a period of two years, 2013-2015; the EPR implementation project at Oslo University Hospital.

Our starting point was the national policies for e-health, which was a salient public debate issue during these years and also presented some high-level IT governance and architecture issues. From there we chose the largest health region to investigate how policies were translated into IT strategies and governance structures, in the form of the Digital Renewal programme. In order to investigate how these initiatives unfolded into concrete projects and solutions, we selected the implementation of an electronic patient record system at the largest hospital in the country.
Data collection and analysis

In dealing with our research question we carefully combined two perspectives: First, we interviewed top health and IT managers and enterprise architects on their ambitions and conceptualisations. Second, we followed the implementation of these plans by interviewing selected project managers, software developers, clinicians and specialists.

We focused on relational information; the co-operation of sub-projects, the communication with vendors, the relationship to the overall Digital Renewal programme, and the social and technical dependencies between different units. Data was mainly from two sources. First, we collected data by interviewing 74 informants, some of them twice. Interviews were open, focusing on their experiences in the programme and projects. The main informant groups were managers at different levels, IT architects and developers, and medical personnel. Second, the sector was extensively documented with policy documents, regional policies, and project plans (feasibility study, main project directive, sub-projects directives), and project status information, such as status reports and on-going risk assessment. It was also well documented in technical terms, with a wealth of requirements specifications and IT architecture descriptions. See Table 2 below.

<table>
<thead>
<tr>
<th>Level</th>
<th>Interviews</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>Ministry of Health: Senior managers and executives</td>
<td>Ministry of Health: White paper: “One citizen, one journal”</td>
</tr>
<tr>
<td>2009-15</td>
<td>Directorate of Health: Senior managers, E-prescription project managers and architects</td>
<td>National ICT: A National SOA architecture</td>
</tr>
<tr>
<td></td>
<td>Consultants</td>
<td>Directorate of Health: The ePrescription project plan and ePrescription architecture</td>
</tr>
<tr>
<td>Regional</td>
<td>South-East Health Region:</td>
<td>The Digital Renewal Programme:</td>
</tr>
<tr>
<td>2011-15</td>
<td>- Vice chairman of the Board</td>
<td>Plans and status reports</td>
</tr>
<tr>
<td></td>
<td>- Programme manager</td>
<td>IT architecture documents</td>
</tr>
<tr>
<td></td>
<td>- Regional CIO</td>
<td>Requirements specifications</td>
</tr>
<tr>
<td></td>
<td>- Project co-ordinator</td>
<td>Minutes from Board Meetings</td>
</tr>
<tr>
<td></td>
<td>- Regional IT architects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- HospitalPartner managers</td>
<td></td>
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<tr>
<td></td>
<td>- HospitalPartner developers</td>
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<tr>
<td></td>
<td>- Vendor representatives</td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>The EPR project at Oslo University Hospital:</td>
<td>Project documents:</td>
</tr>
<tr>
<td>2013-15</td>
<td>- Project Manager</td>
<td>Plans</td>
</tr>
<tr>
<td></td>
<td>- Sub-project managers</td>
<td>Status reports</td>
</tr>
<tr>
<td></td>
<td>- IT architects</td>
<td>User requirements</td>
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<tr>
<td></td>
<td>- IT developers and consultants</td>
<td>IT architecture documents and blueprints</td>
</tr>
<tr>
<td></td>
<td>- Lab personnel</td>
<td>Vendor documents:</td>
</tr>
<tr>
<td></td>
<td>- Medical doctors and nurses</td>
<td>Product specifications</td>
</tr>
<tr>
<td></td>
<td>- Vendor representatives</td>
<td>Evaluation reports</td>
</tr>
</tbody>
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In multilevel analysis a key aspect is to understand the interactions between levels; in our case the interplay of national, regional and project levels. Following Hitt et al. (2007) we investigated top-down (management) influences and bottom-up (emergent) influences. Data were analysed in three steps (Miles and Huberman, 1994). First, we used the information from each informant and written documents to construct a chronology and rich picture of the programs, projects and their surroundings, and to document a case description. Second, we conducted a comprehensive analysis of the tensions of the case. Building on our framework we analysed tensions in time, scale and agency. In the temporal analysis we deployed forward chaining technique to explain intentions of stakeholders, while backwards chaining of events served to explain outcomes. Finally, we assessed the identified tensions, in order to identify and understand the sources. The analysis was iterative, and included feedback from our informants; in analysing tensions of scale we carefully assessed the overall architecture documents and then discussed their implications for local clinics with doctors and lab personnel. Their views were again discussed with
central architects. In understanding tensions of agency we analysed the governance regime in terms of policies and running decisions, compared with views from clinicians and local IT managers and developers. At the end of the research process we also discussed draft versions of this paper with key informants.

The Case: Governing a Regional e-health Infrastructure

National level

Norway is a Scandinavian country with 5.2 million inhabitants who enjoy a high standard of living and public health services. The sector is governed by the Ministry of Health and Care, while the Directorate of Health is an implementing agency and health advisory. Primary care is supported by private GPs and municipal services. The hospitals are organised in four health corporations called Regional Health Authorities given the names Health North, Mid, West, South-East respectively.

Historically, IT strategies and decisions were attached to the individual hospital, and in spite of several initiatives, the overall IT portfolio within the hospital sector has remained problematic. Around 2005 the fragmented e-health solutions were brought to the attention of national media, through histories of poor patient treatment because of non-integrated IT solutions, and the practice of transporting X-ray images by taxi between hospitals. The political pressure on the sector increased, and the answer from the top health executives to the challenge was to establish a new governance regime. A high-level official commented:

“The main problem is the fragmentation of solutions, which has a historical explanation. Each hospital, each clinic – and even each clinician – has had the freedom to choose any solution that was available, during that past 30 years. These choices have often been made arbitrarily, dependent on which vendors were knocking on the door, or other local conditions. The result is hundreds of different solutions, which cannot exchange data, because of the lack of standards, and cannot communicate, because of the lack of integration. Today, this is a hindrance for patient oriented care, and a hinder for evidence based medicine. It is also expensive. There is only one solution, which is an overall consolidation to shared systems, and a standardization of data and processes. This requires the courage to establish a top-down governance, an integrated architecture and well-financed programmes to implement the strategy”.

Many top-ranking bureaucrats and health politicians shared these sentiments. In 2012 the Ministry published a white paper “One citizen – one record” that called for a national solution where patient data should be available for clinicians regardless of geography or institutional level. In 2012 the Directorate of Health established a relatively large IT division with the responsibility for the national e-Prescription (implemented during 2012-16) and Summary Care Health Record (implemented 2014-17) solutions. It also started to work on national policies and IT architectures. In 2016 the Directorate of e-Health was established to coordinate e-health initiatives at all levels.

Regional level: The Digital Renewal Programme

The South-Eastern Norway Regional Health Authority (“Health South-East”) may be regarded as a governmental “holding company” for 11 legal hospital organisations, including the largest, Oslo University Hospital (OUS). Health South-East serves a population of 2.8 million, and has 75,000 employees. IT Services is centralized, run by the company HospitalPartner, which is wholly owned by Health South-East and has around 1,300 employees. The long history of decentralized IT decisions had resulted in many well-working systems in each hospital, but also a fragmented portfolio of silo systems. The number of IT systems and applications was reported to be around 4,000; this situation was seen as a major hindrance for patient-oriented services and innovation, and was widely criticised by politicians and media.

As a response the Health South-East decided in 2012 to start an ambitious programme called Digital Renewal, in the period 2013-18 with a budget of 6 bn. NOK (around 700 mill Euro). The main aims were standardizing of work processes and technology, operationalized through six sub programmes:

- Regional Clinical Documentation: Standardizing and consolidating electronic patient record and other clinical systems within 2016, including chart and medication system, solution for chemotherapy treatment of cancer, birth/delivery record system, support for patient logistics, etc.
• **Radiology**: Consolidating from several to one shared RIS/PACS solution in 2018.
• **Medical labs**: Consolidating from several to one shared lab system within 2018.
• **Digital co-operation**: Exchanging electronic messages on patient logistics between hospitals outside the region and primary care, and the implementation of national solutions for information sharing like the ePrescription and Summary Care Record solutions.
• **Enterprise Management Support**: Shared solution with an enterprise system (SAP) and data warehouse
• **Infrastructure**: Shared IT platform and data centre

The mega-programme was organised and governed in a top-down structure, with central Programme Board, and a board for each sub-program. The many projects were run by professional project managers, with tight reporting and continuous risk management. External consultants regularly produced audits. The CEO of OUS, acting as the head of the Programme Board, commented:

> “The IT solutions have become extremely important for the whole health sector. We can see a parallel with the banking sector 20 years ago, which has dramatically changed the whole industry. It is very important to standardize our systems: A shared EPR system, together with shared lab and radiology systems will be operationally very important for patient safety, but also contribute to make OUS into one unified organisation.”

The program raised the level of ambitions regarding resolving the fragmentation problem. The key element in the strategy was not only to standardize each application but also to consolidate all installations of an application into a single shared installation (data base) for all hospitals. In the regional management jargon this was called *tidying up the fruit salad* (of systems). The program was clearly focused on individual applications, which should be implemented based on a so-called *best-of-breed* strategy. This strategy generated quite strong demands on information exchange between applications.

HospitalPartner had since 2010 developed an environment with strong integration competence. This included a quite sophisticated integration platform and an organisational unit, called the Integration Factory. The regional platform (see Figure 1) was based on an enterprise service bus technology: Microsoft BizTalk middleware. It was implemented on two levels:

- **Local level**: Internal communication between applications within one Hospital went through the local BizTalk platform.
- **Regional level**: All external communication between applications at different hospitals was routed through the local BizTalk platform and then to a central BizTalk platform. From there it was routed to other local BizTalk servers in the region or via National Health Network to other actors outside Health South-East.

As shown in figure 1 the central BizTalk platform (“SIKT”) linked the local hospitals (“Hospital A” and “Hospital B”), and with external actors through Norwegian Health Network (NHN). The central platform also included some central registers, such as Partner Register. The Integration Factory conducted all the programming on and format conversions on the platform.
The Digital Renewal program was generally well received in the press and in the sector. There were however some critical voices, primarily among hospital clinicians, among whom many felt left out of the process. One profiled doctor expressed it this way:

“The overall thinking in the programme is dominated by economists and consultants, and ignores the perspectives of the clinicians. In my view, they use the IT programme to implement a centralised corporate model in the region, instead of leaving the decisions to the clinicians that actually produce the medical services”.

One hospital in the region had been excluded from the program; the new Østfold Hospital, which was under construction. It included several new IT solutions, partly from the program portfolio, but also a large, lightweight solution for patient logistics, with touch-screens and mobile technology. The interdependencies of physical and digital structures in the building project - and a non-negotiable start-up date in 2015 - had allowed the local management to run the project.

**Project Level: The DIPS project at Oslo University Hospital**

The largest project within the program, and the one given highest priority, was the implementation of DIPS (a Norwegian EPR system) at OUS, replacing older EPR systems in three hospitals with 12,000 users. The other hospitals in the region were already running DIPS. A shared medial record system for OUS was a requirement for making OUS work as one hospital. It was a quite urgent issue since the implementation of a shared patient portal that was assumed to enable information sharing ended in a spectacular failure in 2011 (including a hearing in the Norwegian Parliament). For these reasons, the projects priority was to get a standard version of DIPS up and running as soon as possible – the date was
set to October 20\textsuperscript{th} 2014. No additional functionality or adaptations were added, and only existing integrations between the existing patient record systems and others should be included in the project.

The Feasibility Report emphasized that the OUS EPR project was not primarily an IT project, but rather an organisation development effort. The main benefits were stated to be a shared EPR system for all users, and the standardization and restructuring of work processes. The budget was estimated to 685 MNOK (around 85 mill Euro).

The implementation project was organised with a steering group, project manager and project office, and eight sub projects. Around 400 participants were involved, a mix of employees of HospitalPartner, external consultants, DIPS employees, and many doctors, nurses and lab personnel from OUS. The project was very tightly run, with detailed activity planning and reporting at all levels, and continuous risk management. The steering group, headed by the CEO of OUS, was following the project closely.

The highest risks were assumed to be integration and data conversion. The integration risk was associated to technical complexity: 55 different systems should interact with the new EPR, with 345 interfaces. In order to mitigate the integration risks, the Integration sub-project was in charge of all integration.

Taking lab integration as example, the steps were:

- The lab technicians from three former hospitals with different labs met, weekly, with the IT integration staff in order to agree on terms and formats. A large Excel sheet with was used to consolidate more than one thousand lab elements (Lab technician: “In some cases we spent half a day fighting over the interpretation of one element”)
- The project IT staff designed the flow of data elements between the systems, as a specification. In some cases, the lab system vendor was asked to implement some changes
- The Integration Factory (which is part of HospitalPartner) programmed and tested these messages and calls, using standards such as HL7
- The Operations Centre at HospitalPartner conducted more tests, opened the necessary firewall ports, and set it into production

Conversion included the technical conversion of large amounts of patient information from three different EPRs into one, and it had to be done in one single operation, planned in the weekend of October 20\textsuperscript{th} 2014. Although the project was top-down controlled we observed a lot of lateral communication. For example, each sub program of Digital Renewal had an IT architect. Every week these had a shared meeting with the Health South-East chief architect, discussing current issues in the projects, but also more general topics. Informally, we also observed that employees from various sub-projects were engaged in discussions.

On October 20\textsuperscript{th} the new solution was set into production. 128 mill patient records and 160 mill lab tests for 2,8 mill patient were converted, using 278 TB of disc space. Then 12.000 users started using DIPS, helped by 870 super-users. With some minor problems the implementation was successfully conducted. A post-implementation survey revealed that the users, on the whole, were satisfied with the process and EPR solution.

The celebrations however did not last for long, since a long list of new challenges was waiting: stabilising and optimising the solution, implementing individual care plans into DIPS, and preparing for another set of integrations, where 65 candidate systems were suggested. This was accomplished during 2015, with the same project approach.

**Other projects and responses to tensions in 2015 and 2016**

The Digital Renewal project had been a success so far, but overall the program met several challenges. First, it was acknowledged that the various programs needed better coordination. Responding to these difficulties, the programme was re-organised in January 2015; the three programs Regional Clinical Documentation, Lab, and Radiology were merged into the Regional Clinical Documentation program and a new “design and architecture” unit was established to ensure compatible design decisions were made across all projects. In addition, higher priorities were given to the Infrastructure program to speed up its deliverables.
A more difficult challenge was that the consolidation strategy came under pressure. Both the Lab and the Radiology programs were focused on scale, i.e. specifying and implementing shared solutions for all hospitals. Further, the Lab program specified one solution covering “all” types of labs, i.e. medical biomedicine, pathology, microbiology, and blood bank. A preliminary version of the new lab system had been implemented in Østfold Hospital. This version did not include functions for the blood bank and covered only the basic functionality the other labs that the hospital needed. Accordingly, it could not be rolled out to the other hospitals.

The Radiology solution was planned to be first implemented in the Innlandet Hospital and then rolled out. The project has made it clear that the requirements of all hospitals regarding PACS (radiological images and their metadata) solution are similar. However, there is a considerable variety regarding the work processes (the RIS part) of the various radiology departments. These issues are partly due to differences between the departments. Some hospitals, for instance, need support for high-volume standard processes; others need careful tailoring for special cases. Norwegian radiology departments are quite advanced in rationalizing and automating radiological work processes. This automation has happened through a long time where work processes and RIS solutions have co-evolved. Accordingly, it has proven very challenging to develop one solution satisfying the requirements of all departments, and the same time ensuring that the solution is flexible enough to enable future changes in work processes. For these, reasons, one option being considered at the moment is to embark on different strategies for the RIS and PACS modules. It is believed that a consolidated PACS solution can be implemented fairly quickly, while the development of a consolidate RIS solution will take considerably more time.

The top management of the program, responding to these and other pressures, acknowledged that the strict top-down governance had its limitations. It was decided late in 2014 by the Program Board that a Regional Competence Centre for Clinical Solutions should be established in 2015 and that (more) local adaptation and innovation had to be allowed and supported. During spring 2016 a working group was established and given the task of proposing a strategy for how the Health South-East should organise activities related to new lightweight technologies, such as the Internet-of-Things.

These setbacks and challenges were not only postponing the implementations, but also raised doubts about the viability of the whole regional consolidation strategy; while there were several successful local implementations the regional solutions were contested. Adding to this, the Infrastructure program within the program aimed at delivering a homogeneous and integrated infrastructure, but will not do so until 2018 and the output from other programs is too urgent to put them on hold until the homogeneous infrastructure is in place. Thus, the situation for the program in spring 2016 was uncertain.

**Findings: Tensions in e-Health Infrastructures**

We will now look at how the strategy as well as the outcomes of the Digital Renewal program was related to central tensions, building on the framework introduced earlier. See Table 3 for an overview.

<table>
<thead>
<tr>
<th>Table 3. Tensions in the case</th>
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<tr>
<td><strong>Scale</strong></td>
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<td><strong>IT Governance</strong></td>
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<tr>
<td><strong>IT Architecture</strong></td>
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</table>
Tension 1: Scale

The Norwegian e-health infrastructure had been growing for at least 25 years, resulting in a large number of “IT silo systems” that were reasonably well adapted to their users, but poorly integrated. At a high (national and regional) level it was “obvious” that local variations (previous to the Digital Renewal programme) were a hindrance for scaling. In theory, a service oriented enterprise architecture (Ross et al, 2006) should provide a smorgasbord of services, allowing clinics to configure their own solutions. However, the available vendor solutions were mainly “silo” applications (EPR, lab, radiology etc.), which in practice meant that “standardization” meant application standardization (“tidying up the fruit salad”). Moving from a silo structure to an integrated architecture was quite challenging, and the key approach chosen by Digital Renewal was to reduce the technical complexity by standardization; systems, formats, protocols, work processes.

At the level of local hospitals and clinics the attitude was more mixed. Many medical units with special needs felt that standardization was going too far, both in terms of work processes and technology. Most of them had been using IT solutions since the early 1990s, and had developed well-working routines supported by IT solutions from vendors with a long history of close cooperation. For instance, the former National Hospital (now part of Oslo University Hospital) treated several rare diseases, and for these purposes had developed tailor-made solutions with IT vendors. The regional procurement processes had not covered this in sufficient detail.

The Director of the Programme reflected on this in late 2015:

“In principle, everybody favours standardization, and have no problem in recognising that there are large benefits – economic, organisational, technical – in establishing shared and scaled solutions. However, nobody likes to be standardised. It is the others that should standardise.”

Analysing the consolidation and standardisation process we note that, although the EPR and integration framework project was successful, regionalisation was more difficult than expected. This was vividly illustrated by the problems with the lab and radiology systems, which had been specified and acquired as parts of the new regional architecture. While implementing shared applications at large scale (i.e. at the regional level) was the overall aim of Digital Renewal, we see that different strategies for achieving this were adopted. First, implementing the required IT solutions at Østfold was moved out of the program. Further, the strategy for achieving a regional EPR solution was based on a stepwise process over several years. The Lab and Radiology projects, however, were planned and conducted more strictly in line with the program principles; specifying, implementing and rolling out a shared solution. Compared to the existing situation, these projects expanded the scope of the applications in both reach (i.e. the number of hospitals sharing the solutions) and range (i.e. the functionality and use areas supported by the solutions).

Tension 2: Time

The current efforts in the Digital Renewal programme clearly illustrate the tension between short-term local needs and the need for long-term planning. The time perspective was greatly extended by the new architecture of the Digital Renewal programme, because restructuring the IT silo landscape takes at least a decade. Integration of a large number of systems created an ever-larger number of dependencies, which greatly affected the planning and scheduling of projects. For example, at the initiation of the program in 2012 the Lab and Radiology systems of OUS were considered unsatisfactory as regional solutions, and new ones were planned. However, the new EPR (DIPS) was implemented and integrated with the old ones, in order to keep the schedule. When the new Lab and Radiology systems will be introduced in 2017, the physical integrations must be reprogrammed. And when the new (and completely different) DIPS version is introduced in 2018 or later, the same must be done. This is expensive, time-consuming, and requires a both detailed scheduling but also long-time planning. At the same time, however, the long-term focus of the consolidation strategy was in conflict with the critical situations at Østfold Hospital and OUS. In these two cases, achieving short-term results had to be given highest priority.

The tension of different time perspectives was strongly felt more broadly at local hospitals and clinics. The program soaked up all IT resources, while there was an increasing pressure for new solutions at many
clinics. For instance, new Medical-Technical equipment (for surgery, radiology, diagnostics and many other purposes) was continuously introduced by vendors, and acquired by clinics. (It was estimated that Oslo University Hospital in total had a portfolio of 25,000 units). Bundled with the equipment were usually software and databases, which needed to be integrated with existing systems. When requests for integration resources were rejected (“because for the time being we need to focus on the Digital Renewal programme”), some clinicians asked angrily why the IT people should deny patients new treatments. This may seem an overreaction, but there is a risk that when the architecture is finally implemented after a decade of struggles, it consists of obsolete technologies.

**Tension 3: Agency**

The Digital Renewal programme was heavily centralized, with a tight governance structure, in line with the governance-architecture approach. The top managers of the Health Region (and all the CEOs of the hospital units) were controlling the program, with monthly meetings in the Programme Board. Each program director reported (in red/yellow/green status flags) the status of each project. The programme was staffed with a program director, and the key regional programme (Regional Clinical Solution) had established an IT architecture group, aiming a holistic view and management of the interplay of systems. The decisions taken in this governance structure were, according to our observations, taken in long consensus processes, involving managers at various levels, IT specialists, vendors, consultants and selected clinicians. These processes were not purely hierarchical, but to a large degree lateral; they included both informal communication between different units, and cross-disciplinary arenas such the IT architecture group.

However, we observed that many clinicians felt left out of the process. There was hardly any organised opposition, but rather the view that what looks smooth from the top of the organisational pyramid is much more complex on the ground. One profiled doctor described the governance of Digital Renewal this way:

“It looks fine and tidy at the top, but a number of issues are problematic: the hospitals are quite diverse and need different solutions, but now everybody has to use the same; the procurement regime is working poorly, and often leads to wrong decisions; the regional management decide the investments, but benefits realization must be conducted at hospital level. Personally, I would prefer that decisions were taken by the hospitals and clinics, and solutions were adapted to local needs. OK, it might mean some sub-optimization, but the consequences of mistakes would also be much smaller.”

**Summing-up tensions: Stable and unstable elements**

So how did the IT Governance Architecture approach of Digital Renewal deal with these tensions? On the governance side the pressures on top managers were considerable, as the continuously changing infrastructure required frequent decisions, and made it difficult to establish a stable governance regime. The Digital Renewal environment was intensely busy; the calendars of managers were so packed with meetings that new appointments had to be scheduled several weeks later.

We identify two phases of governance. In the first phase (2013-14) the programme was organised after the various applications, such as EPR, lab and radiology, with tight and centralised control. This created various tensions, such as between standardization and local needs, between SOA thinking and vendor’s silo solutions, and between the five programs that needed more coordination. In the second phase (2015-16) the programme learned from these tensions, and revised parts of the implementation strategy. This did mitigate some problems, but not the really difficult ones. The hardest issue was the standardization strategy, where it gradually surfaced that the needs of hospitals were so variable that the whole architecture was misaligned with these needs.

Assessing the situation in 2016 (see Table 4) we found that there were significant differences between system areas of the programme. The EPR and integration framework had stabilised both in IT architecture and governance; the solution was generally accepted by clinicians and scaled well regionally with the integration framework, and the system governance regime was perceived as legitimate. In contrast, the Lab and Radiology areas were unstable; the architecture was contested (the solutions did not satisfy the diverse needs of the hospitals), and central governance was challenged. The Chart and
Medication solution was even more unstable, with many local solutions, and general doubts on the feasibility of the regional solution. The same applied to patient logistics, which with the coming of lightweight IT technology had emerged as an area of intense innovation at the Østfold Hospital.

<table>
<thead>
<tr>
<th>System area</th>
<th>Governance</th>
<th>Architecture</th>
<th>Status of installed base</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPR</td>
<td>First local, then regional governance</td>
<td>Gradual regional implementation over several years</td>
<td>Stable</td>
</tr>
<tr>
<td>Integration framework</td>
<td>Regional governance</td>
<td>Regional solution with Integration Factory</td>
<td>Stable</td>
</tr>
<tr>
<td>Radiology</td>
<td>Regional acquisition, local resistance</td>
<td>Chosen solution in test in one hospital</td>
<td>Unstable and contested</td>
</tr>
<tr>
<td>Lab</td>
<td>Regional acquisition, local resistance</td>
<td>Chosen solution in production in one hospital</td>
<td>Unstable and contested</td>
</tr>
<tr>
<td>Chart and Medication</td>
<td>Regional governance, many hospitals hesitating</td>
<td>Local implementations</td>
<td>Very unstable</td>
</tr>
<tr>
<td>Patient logistics</td>
<td>Local governance</td>
<td>Innovative solutions in Østfold Hospital, fragmented in other hospitals</td>
<td>Very unstable</td>
</tr>
</tbody>
</table>

This situation puzzled the management of the Digital Renewal program, because the whole program was based on the same principles of holistic architecture and governance. Why were the results so variable?

We think there is a simple answer to this question, namely that some of the areas were (for historical reasons) more mature and stable than others. This stability was not only the result of the implementation strategy, but related to the institutionalisation of a particular socio-technical solution, or the installed base. For instance, the EPR area had stabilised around a set of capabilities that clinicians expect, with relatively few large vendors. In contrast, the patient logistics area was immature, with a lot of on-going innovation with lightweight technology at many vendors. We think this distinction is the key to our overall research question, on how to deal with tensions.

**Discussion: Dealing with tensions**

Building on our empirical evidence and the information infrastructure literature we propose two principles for dealing with the tensions of large e-health infrastructures. Then we discuss the practicalities in implementing them.

**Principle 1: Tensions cannot always be resolved, but should be acknowledged and balanced**

Some information infrastructures are the result of planned development and implementation, while others have grown organically without central co-ordination, such as the Internet (Edwards, 2007; Hanseth and Lytinen, 2010). In practice, most information infrastructures grow by a mix of planned and emergent action, as various actors promote their short and long-term interests. This was also the case of the Norwegian e-health infrastructure, as described in the previous sections. As illustrated in our case, governing this balance is challenging, partly because no actor is in full control and managers need to choose which levers to pull.

We have shown how the key tensions of time, scale and agency are fundamental to information infrastructures, and documented that the IT governance and architecture literature do not deal sufficiently with them. Our first proposed principle is that these tensions cannot always be resolved, but should be acknowledged and balanced. This is in line with the analysis of Gregory et al. (2015). Acknowledging tensions has two implications. First we need to reframe our understanding of the challenge; it is not to “design and build” large structures, but rather to engage in an on-going “brownfield”
project, where the installed base of technologies and organisations play a significant and even decisive role. Second, we need to rethink our IT architecture and governance approach.

**Principle 2: To find the right balance, we should differentiate between stable and unstable elements in the infrastructure**

E-health infrastructures are complex objects that require sensitivity for context and the specifics of technologies. Dealing with tensions is usually seen as a question of balance, requiring sensitivity for context. However, the balance should not be in the form of negotiated compromises; rather it should be based on an understanding of the different elements in terms of stability and change: stable elements should be governed differently than unstable elements (Hanseth et al., 1996, DeLanda, 2004). The right balance should therefore not be based on compromise, but on an understanding of what is suitable for top-down architecture and governance, and what is not.

Hanseth et al. (1996) argued that there is a basic tension between standardization and flexibility, where standardization enables large-scale growth, but often conflicts with the need for flexibility as the environment changes, both flexibility in use and flexibility in design. This leads to a key question; what should be standardised and what should be allowed to change? The answer is simple: we should standardise the elements that have stabilised. The purpose of standardization is to hinder unproductive variety, or, if you will, to stop innovation (but may enable innovation at a higher level). However, if we try to standardise unstable elements, we risk halting innovation too early, and we risk local (and justified) resistance.

This requires an architectural approach to governance. Architecture is about the relationships between the components of the infrastructure. Tightly coupled and integrated systems are harder to change than loosely coupled and modularized ones; accordingly a tightly integrated system will necessarily be stable. So a strategy emphasizing tight integration is appropriate in contexts where the system does not need to be changed. Correspondingly, if a system needs to change, it should be well modularized and be composed of loosely coupled components. Balancing the forces of scale versus local needs requires an understanding of the stable elements of the infrastructure; the basic information is more stable than applications, and applications are more stable than GUIs and user equipment.

Summing-up, the basic balance of architecture is between tight and loose coupling (Parnas, 1972); tight coupling supports stability, while loose coupling enables change. The principle is therefore; **stable elements should be integrated and governed top-down. Unstable elements should be allowed local governance, with loose coupling.**

**A framework for architecture and governance**

The proposed framework is not a method, but a high-level guideline for implementing the two principles introduced above, in the context of e-health solutions. For each step we exemplify and discuss the empirical evidence from our case, and other e-health cases.

**Step 1: Identify the stable elements of the e-health infrastructure**

We regard the stable elements as the organisational and technical entities that are institutionalised. Stable elements persist over time, both structurally and in terms of use. In banking the stable elements are customers and accounts; in airlines the stable elements are flights and bookings. In the mature solutions of banking and airlines these are implemented as large transactional basic registers; shared international solutions such as Amadeus (Radulovic, 2013) and SWIFT (Scott et al., 2010). The less stable elements, such as marketing activities and customer interfaces are quite loosely coupled to the central solutions, and subject to local innovation and change.

In the less mature e-health sector the situation is more complex and under-analysed. There are few well-established central registers, and standardization initiatives abound, often without regard to the stability/instability of the actual elements. This is a key source of the observed tensions in the sector, because (i) the lack of a central defined core tend to make all systems equally important, and (ii) over-ambitious standardization plans tend to be insensitive to local needs, and (iii) central governance tends to choke local innovation.
It is therefore essential to understand what are the stable elements in health care. This may not be straightforward, but could be approached either from the point of medicine (for example Donabedian’s (1966) well-known scheme for health care quality) or from the point of informatics. Taking our Digital Renewal case we suggest the following analysis, built on the parallel with banking and airlines.

The most stable elements are core patient information, and some other basic registers, such as medicines and prescriptions. Medium stable elements are well-established routines, such as lab and radiology, with their associated systems. Less stable elements are patient treatment procedures and their associated systems, such as chart and medication systems, which is an arena for continuous improvement. Least stable are patient logistics, which is a typical innovation arena, with new lightweight technology. From the informatics side we know that work processes are subject to change and innovation (Christensen 2006, Erl et al, 2015). In the Digital Renewal program we observed a clear pattern; when unstable elements were subject to standardisation, tensions emerged. For instance, standardising EPR was relatively straightforward, while chart and medication systems were consistently challenging. In the same line, new solutions based on the Internet of Things and mobile devices are good example of what is highly dynamic.

Step 2: Assess architecture: standardise stable elements

E-health systems are mostly clinical (process) systems documenting treatment; they are not patient-centric. The silo structure of these systems implies that they include both stable and unstable elements; basic registers, medical treatment processes, logistics and user interfaces. In the case of the radiology system we observed that the relatively stable PACS part (medical images and their meta data) can be standardised, while the more unstable process support (RIS) was much harder. The central system in our Digital Renewal case was the EPR, which is predominantly a collection of texts written by doctors. The “patient record” is therefore no parallel to the accounts in banking or bookings in air travel. There are some initiatives to develop such a record, in the form of a “summary care patient record”, but the results are modest so far

We illustrate our argument by following proposal for our case organisation, where we argue that the most stable elements (core patient information) should be standardized; the medium stable elements (lab and radiology) should be standardized, but slowly and step-wise; solutions for the less stable elements (treatment processes) should be adapted locally, and that the least stable elements (logistics) should be subject to local innovations. Se Table 5.

<table>
<thead>
<tr>
<th>Degree of stability</th>
<th>Examples</th>
<th>Recommendation</th>
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<tbody>
<tr>
<td>Most stable</td>
<td>Core patient record</td>
<td>Standardise</td>
</tr>
<tr>
<td>Medium stable</td>
<td>Lab, radiology</td>
<td>Standardise slowly</td>
</tr>
<tr>
<td>Less stable</td>
<td>Treatment, chart and medication</td>
<td>Local solutions</td>
</tr>
<tr>
<td>Least stable</td>
<td>Logistics, lightweight IT</td>
<td>Local innovation</td>
</tr>
</tbody>
</table>

Step 3: Assess IT governance: central governance of stable elements

It follows from this analysis that it is the stable elements that should be centrally governed. The principle is simply that IT governance should not follow organisational structure, as is the custom, but rather architectural structure.

In our Digital Renewal case the governance was top-down and centralised for both stable and unstable elements. This created tensions that were quite difficult to deal with, because the governance regime lacked a strategy for local initiatives and innovation. The solution is not to allow free local innovation, but to establish a governance regime built on architectural, not organisational, principles. Simplified, the regime would (following the principles of Weill and Ross, 2004) define a central governance core at national level, with key systems, and a limited set of technical standards and security mechanisms; and a regional governance core accordingly. For both levels, access to registers would be defined and regulated.

When the stable elements are defined, and a governance regime is established, it is much easier to acknowledge that local units (hospitals, clinics) are free to deal with the more unstable and short-lived elements. These should be loosely coupled to central registers. For instance, if a hospital wants to develop
and implement a lightweight app to support its emergency unit, the decision should be taken locally, and a vendor should be enabled to access clinical systems through APIs or middleware solutions.

A governance regime built on architectural offers some clear advantages. First, it allows the central actors to concentrate on the key resources, and establish a robust core architecture. This also helps to reduce the managerial overload and project risks. Second, it defines and supports a local innovation arena, where innovative clinicians and vendors may explore and exploit the opportunities offered by the advances of medical and information technologies for the best of the patients.

**Limitations**

We acknowledge limitations of this research (a single, albeit extensive case study) and our proposed solutions. In particular we realise that our recommendations are high-level and contingent, in the sense that their usefulness is dependent on context. We also recognise the need to carve out a more precise definition of stable and unstable elements.

Briefly, we point to two possible avenues for further research: first, there is need for more in-depth investigations of national infrastructures, preferably comparative studies. Such studies offer a potential for fruitful co-operation with health authorities and industry vendors, and could be conducted as action research or as engaged scholarship (van de Ven, 2007) to develop more knowledge. Second, to make this research more accumulative we need more meta-studies or case surveys in the e-health field.

**Conclusion**

In this paper we researched the following question: *how can we understand and deal with the tensions of large e-health infrastructures?* Our empirical evidence was a multi-level study of a large e-health infrastructure program, where we investigated tensions in IT architecture and governance. It is hardly controversial that in a complex world of tensions and paradoxes, it is necessary to find sensible balances. The difficult question, in the case of e-health infrastructures, is which principles should guide the balancing.

The answer is that we need to acknowledge the inherent tensions in these structures, and understand how they can constitute a basis for new thinking in terms of architecture and governance. The key solution is to differentiate between stable and unstable elements of the infrastructure; the stable elements can, and should, be managed top-down, while the unstable elements should be subject to local innovation and decentralised governance. We offer a simple step-wise analytical framework to help e-health policy officials and IT practitioners to analyse and manage their infrastructures.

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