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Abstract

In this paper we investigate the IT systems silo problem in e-health infrastructures. After three decades of user oriented systems development the health sector is characterized by system diversity and fragmentation. In response to this situation health authorities in the EU countries have called for a strategy of standardisation and integration; aiming to reduce complexity. It is assumed that this strategy will lead to less costly (through better co-ordination) and better health services (through more reliable data). Our research question is, how can we understand and manage the socio-technical complexity of large-scale integration in e-health?

Our empirical evidence is a large e-health programme taken by the Southeast Regional Health Authorities in Norway, in order to reduce the number of systems and user environments. In particular we investigated the implementation and integration of an electronic patient journal system for 12.000 users. Considering our findings, and building on infrastructure and complexity theory, we find that the current approaches to resolve silo integration are relatively effective in reducing organisational complexity, but they may increase overall complexity over time.

Keywords: IT Silo Systems, e-Health, infrastructures

1 Introduction

In his much cited article "Dismantling the silos: extracting new value from IT investments in public administration" (2001) Frank Bannister analysed the growth of silo systems in the public sector. A silo system was defined as the IT expression of Weber's theory of rational bureaucracy; serving a legally based hierarchy, implementing a set of rules and taking care of written records. Bannister argued that although the silo systems had served their initial purpose, they had become "the legacy of decades of introspective development" (p.65) and a serious hinder for developing a public sector that was expected to be more customer- and service oriented. He suggestions for dismantling included a re-conceptualisation of public services and a brand new IT architecture based on business objects.

Bannister's analysis still seems highly valid, but the context has changed: in most developed countries the pressures from politicians and the general public for better IT solutions have grown immensely, not least within e-health. Also, the knowledge of the transformative role of IT for organisations and societies has increased, both through research such as e-government (Irani et al., 2008) and digital infrastructures (Hanseth et al., 2012), and through the exciting examples from everyday life, as millions of people use their smart phones and tablets to exchange information on Facebook and track their blood pressure and bus arrivals on their apps. In addition, new technologies have arrived with the promise of solving the silo challenges, such as Enterprise Architecture (Ross et al, 2006), service oriented architecture (Rosen et al., 2008) and interoperability solutions.

In spite of these trends, the IT silo problem is still salient and basically unsolved in the e-health research (De Bri and Bannister, 2010; Van Weenstra et al, 2011). The challenges of the health sector are well documented (Sauer and Willcocks, 2007; Greenhalgh, et al., 2010; Hanseth et al., 2012; Currie, 2014), highlighting that the problem is systemic; to connect and integrate a diverse ecology of systems, organisations, users and patients. A report from the European Commission showed that the e-health sector in Europe has many plans, but relatively few successes (EU Commission, 2011).

Since the silo problem is socio-technical, resolving it requires more than purely technical solutions. At the heart of the problem is complexity, which we generally understand as an attribute of the scope and number of different but related parts of a whole. More specifically, Schneberger and McLean (2003) defined complexity as dependent on:

- *The number and variety of components:* the scope of the system is not only determined by the number of components, but is also greatly affected by the variety – the number of *types* of components.
- *The number and variety of interactions and interdependencies*: complexity increases with the number and types of interactions between components. It also increases with the number of interdependencies, i.e. when the change of state of one component affects the state of another.
- *The speed of change of the system*: the rate of change in space and time. The faster the system changes, the harder it is to understand and govern it.

In our digital infrastructure perspective the components may be both technical and social, and their interactions are often socio-technical. In a health context this refers to the diversity of organisational, human and technical elements in an unstable environment. It is crucial that new solutions decrease complexity, rather than increasing it. This has also bearings on how these large initiatives should be managed; in a traditional top-down manner, such as the British National Programme for IT (Sauer and Willcocks, 2007; Currie, 2014), or with a more organic approach. Investigating several large e-health projects, Larsen and Ellingsen (2010) recommended that development in inter-organizational settings should be carried out in small steps and with substantial influence by users and vendors. However, most mega-projects are not allowed the time to do this.

In this paper we investigate an ambitious initiative in Norway, which aims at integrating the IT solutions after a merger of the largest hospitals in Norway. Our research question is, *how can we understand and manage the socio-technical complexity of large-scale integration in e-health?*

Our methodological approach was a multi-level case study (Greenhalgh, 2010), where we investigated both the high-level policies and the practical challenges of implementing them. We present our results as "research light" work (Avison and Malaurent, 2014). This means that we do not develop new theory, but we focus on exploring and understanding a phenomenon which is important for IS community. Our contribution highlights that the current technical and governance approaches do succeed in reducing the organisational complexity resulting from IT silos. The overall complexity, however, in particular the technical and governance aspects, may increase in the longer run, because of an increasing number of inter-dependencies.

2 IT Silo Systems

Nobody ever said: *we need a silo system.* Rather, the term IT silo systems (also called stovepipe systems) was coined at a time when people realised that there was something wrong with the approach. Until then, silo systems were just ordinary systems, and in order to assess the topic with insight we need to know the reasons for building them.

Bannister (2001) described silo systems as the IT implementation of Weber's (1919) bureaucracy principles: they support the functional division of labour, organisational hierarchies and rule-based decision making. In the table below these principles are exemplified by e-government silo systems and e-health silo systems. The examples are very briefly described in table 1, but illustrate the key point.

Weber principle	**E-health silos**
Functional specialisation of labour	Specialised systems for each function: Patient care, labs, radiology, surgery etc.
A hierarchy of authority	Specialist department owns system
A system of rules which limit discretion	The application logic supports and records diagnoses and effects of treatment
Impersonality	The system returns same results regardless of user
A career structure based on technical competence	User rights follow competence or roles; doctors, nurses, lab personnel
A written records of activities	Data base for documentation, research and statistics

Table 1. Weber principles and silo systems

A reasonable reflection when assessing table 1 is that silo systems are sensible and support their users in conducting their tasks. They reflect the organisational structure and support decision rights. They are technically relatively straightforward; the user interface, the application logics and the database are closely integrated. Usually, these systems works well, are technically stable, and relatively easy to change when tasks or formats change. In short, *silo systems reduce local complexity*. Sound systems development methods, such as user oriented design and usability work, have been introduced in order to optimize the quality of such systems. Information Systems research has also documented that there is a web of people, knowledge, local routines and use patterns deeply embedded with successful systems (Coakes et al., 2000).

However, while the silo systems constituted a valuable resource for their users, they became a liability when the perspective changed to the interaction and cooperation between departments, and later between different organisations. The first change came when the *process perspective* (Harmon, 2010) was introduced in the 1980s, emphasizing that efficient workflow in an organisation should be organised as a process, not as functional divisions. The second change came with the advent of the Internet, which easily enabled cross-organisational communication, and gave rise to international supply chains and e-business. While silo systems integrate an organisation units vertically, the Internet links its millions users horizontally.

To some extent, the problem was solved within industrial production and retail by the implementation of ERP systems and business process management in the 1990s, and by electronically supported supply chains after 2000 (Turban et al., 2010). In the public sector the problem has been harder to address, for several reasons. The public sector is more regulated by law and influenced by politics (Bannister, 2001), and it may be argued that the complexities of government and health are much larger than in retail logistics. To take the example of e-health, a large university hospital has over 100 professions working there, several thousands of different diseases are treated, and new treatments, medicines and technical devices are arriving every year. Often, a new medical device has its own software and database, and - before you know it - you have a new silo system.

2.1 Proposed solutions

A number of approaches have been proposed in order to break up the silos. The approaches discussed below may not be exhaustive, but cover, in our view, the key issues.

Process thinking. One approach has been process thinking, as a parallel to the innovations in the private sector, such as process management with ERP and supply chains (Christensen et al., 2009). Currently, many initiatives within e-health are influenced by process orientation, in focusing on patient centred care and logistics. However, process management does not go easily with the specialist organisation and culture of hospitals, and it also requires technical solutions that are not silo systems.

Standards and interoperability. If different units and organisations shall be able to exchange information, standards and shared formats are needed, and many international standards are available in e-health, such as HL7. The European Union highlights standards and interoperability as the key approach (EU Commission, 2011). However, standards are means, not solutions, and some researchers have found that the emphasis on standards has actually been a hinder for the innovation of successful solutions (Hanseth et al., 2012).

The "ERP" solution. The basic idea is that one integrated software system "suite" (such as SAP) may solve the problem by offering all necessary functionality, including work process support. One example of such solutions is the EPIC systems, which is famously used by Kaiser Permanente and many other hospitals in the United States (Mccarthy et al., 2009). One may regards this solution as an extreme example of standardisation, by leaving all integration to the vendor. It has some practical and economic lock-in implications that many health authorities are uncomfortable with, since in practice it is hard to change to another vendor (Koppel and Lehmann, 2014). Also, with a stream of new medical technology apparatuses, it is hard to image that suite systems can integrate them.

Enterprise Architecture (EA). The idea of holistic architecture thinking was introduced by Zachman (1989), pointing to the increasing complexity of the IT portfolios of large organisations. The key to managing this complexity is classification, and the Zachman framework is a classification system to describe the knowledge about the enterprise and the IT services. Today a number of EA frameworks are widely used, for example TOGAF (2011) and Ross et al. (2006). The strength of EA thinking is that it links the value creation (i.e. business processes) in the organisation to the IT resources. There are some concerns, however, that EA initiatives tend to create a new IT bureaucracy and that the planning horizon becomes too long (Kemp and MacManus, 2009).

Service Oriented Architecture (SOA). One way to implement EA is by SOA, i.e. 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 (Zakareya and Irani, 2005) and the Enterprise Service Bus (Rosen, 2008). These solutions allow in principle for seamless integration of services and technology, but they are not easy to combine with existing silo systems. There are some quite successful SOA implementations, but also many failures. Some researchers have found that SOA is mostly used as technical tool, poorly connected to the business side (Hirschheim et al., 2010).

Data Warehouse. This solution provides access to the data from different databases, at a read-only basis. Data warehouses extract and normalise data from different sources, and make information available through (for example) BI tools with graphics and advanced query options (Chaudhuri et al., 2011). In this sense it does not solve the silo problem, but it makes information from the databases available.

Centralised governance. While governance of silo systems is often decentralized, the governance models for breaking up the silos are mostly top-down (Ross et al., 2006). This is done in order to take care of the overall digital infrastructure analysis, and to manage the co-ordination of current systems and projects. However, it also increases the managerial complexity at policy and project levels.

Will these solutions contribute to reduce overall complexity of the emerging large-scale digital infrastructures of e-health? We regard this as primarily an empirical question, and the evidence is inconclusive. There are both successes and failures, and the successes are highly dependent on context, such as competence and organisational culture (Rai et al., 2010; Greenhalg et al, 2010; Larsen and Ellingsen, 2010; Currie, 2014). We think it is fair to say that all these five approaches are used in the health sector in order to break up the silos. Often, they are combined, at least partly. This is also the case in the large e-health initiative we are investigating here.

3 Case and Method

The South-Eastern Norway Regional Health Authority (RHA) may be regarded as a governmental "holding company" for 13 hospitals, including the largest, Oslo University Hospital (OUS). RHA serves a population of 2,8 mill, and has 75.000 employees. IT Services is centralized, run by the company *HospitalPartner*, which is wholly owned by RHA. A 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 was reported to be around 3.000, while the newly merged Oslo University Hospital had around 800. 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 RHA decided in 2012 to start an ambitious programme called Digital Renewal, in the period 2013-18 with a budget of 5 bn. NOK (around 625 mill Euro). The main aims were *standardizing of work processes and technology*, operationalized through six sub programmes:

- *Clinical Documentation*: Standardizing electronic patient journal (EPJ) and other clinical systems within 2016.
- *Radiology:* Consolidating from several to one shared solution for x-ray, MR and CT within 2018.
- *Medical labs:* Consolidating from several to one shared lab system within 2018.
- *Digital co-operation*: Exchanging electronic messages on patient logistics between all hospitals (and also, to some degree, primary care).
- *ERP:* Shared solution with an ERP system and data warehouse
- *Infrastructure:* Shared IT platform and data centre

The mega-programme was organised and governed in a top-down structure, with a board for each sub-program. The many projects were run by professional project managers, with tight reporting and continuous risk management. As illustrated in figure 1 it was also organised as a learning program, with systematic assessment of the results. External consultants regularly produced audits.

The mega-program Digital Renewal
We investigated our case at two levels; the governance of the megaprogram, and one of the key projects. We studied two aspects of governance, the top-level aims and strategy, and the enterprise architecture initiative. The chosen project, DIPS, was studied in detail, both as implementation and as a learning experience, feeding back to the governance process.

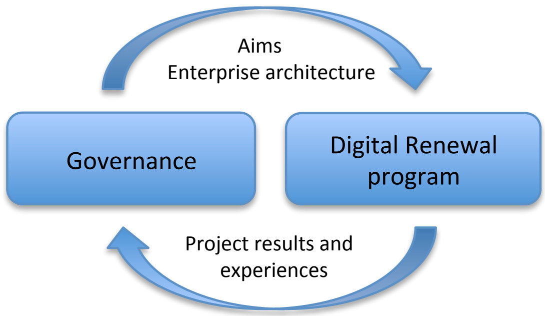

Figure 1. Governance and Digital Renewal Program

3.1 The DIPS project

The largest project within the Clinical Documentation Program was the implementation of DIPS (a Norwegian EPJ system) in OUS, replacing older EPJ systems in three hospitals with 12.000 users.

2012: The feasibility report

The Feasibility Report emphasized that the OUS EPJ project was not primarily an IT project, but rather an organisation development effort. However, is also highlighted that technical integration of DIPS with other systems was a major challenge. The main benefits were stated to be a shared EPJ system for all users, and the standardisation and restructuring of work processes. The budget was estimated to 685 MNOK (around 85 mill Euro).

The project was extremely important for RHA, OUS and even for the national health authorities. The merger of OUS had received some negative press in Norway, and the poor IT solutions were well known by the general public. For example, newspapers brought stories where x-ray images had to be sent by taxi from one hospital to another because of non-communicating IT systems. Thus, the stakes were rather high; the project not only provided a shared EPJ for OUS, but was in practice a test-bed for the organisational and technical architecture of the Digital Renewal programme.

2013-14: The implementation project

The implementation project was organised with a steering group, project manager and project office, and eight sub projects shown in figure 2. Around 400 participants were involved, a mix of employees of HospitalPartner, external consultants and 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 converting. The integration risk was associated to technical complexity: 55 different systems should interact with the new EPJ, with 345 physical integrations. In order to mitigate the integration risks, the Integration sub-project was in charge of all integration. Converting included the technical converting of large amounts of patient information from three different EPJs into one, and it had to be done in one single operation, planned in the weekend of October 20th 2014.

The project manager commented in June 2014:

> "This is a critical period, and we are keeping a tight schedule. At the moment the full configuration is not stable, due to many minor technical issues, but we are in control of these problems. We do, however, have too little insight in activities and decisions in the other programmes, such as Lab systems and Radiology, which may have large bearings on our own decisions. We lack an arena for on-going portfolio management".

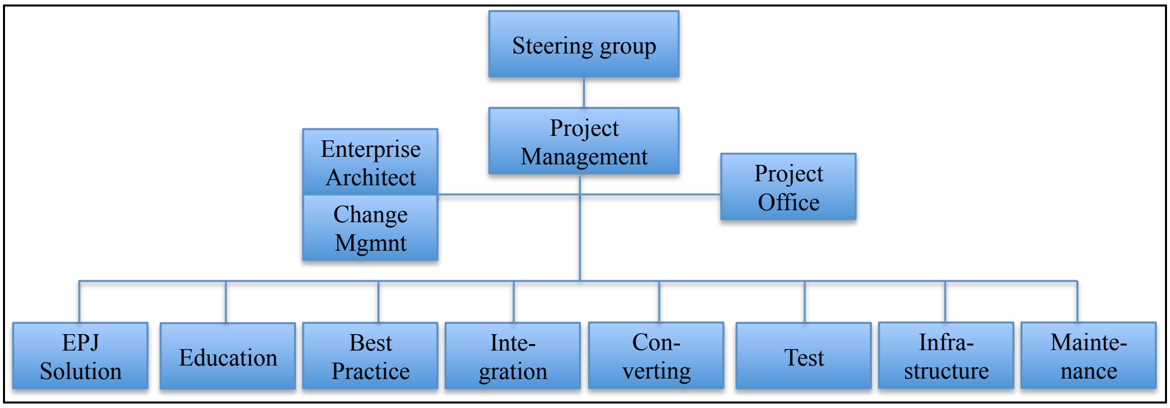

Figure 2. The DIPS project, with 8 sub-projects

October 2014: Start-up

On October 20th 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. The programme director commented:

> "We have established a shared electronic patient journal and patient administration for somatic, psychiatry and addiction treatment in OUS, making patient information available across all disciplines and geography, in one journal and one shared solution for test results. Patient safety is improved when all information is electronic. Electronic message exchange with the municipalities will improve patient logistics".

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.

3.2 Method

We conducted the case study during 2013-14. It was designed as an intensive, multilevel case study (Greenhalgh et al. 2010) where we engaged with the project for 22 months, in order to conduct an in-depth analysis. The reason for choosing DIPS was that it could be seen as a *typical case* of an e-health mega programme, which is considered useful for generalising (Gerring, 2007), with state-of-the-art technology and organisational thinking, It presented a case for studying the organisational and technical challenges of large-scale integration. It was a head-on and ambitious initiative designed to solve parts of the IT silo problem.

Data collection

In dealing with our research question and our multi-level approach 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, users 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, the project was extensively documented with 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. Second, we collected data by conducting 64 interviews, several informants were interviewed two or three times in order to follow a particular development over time. Interviews were around one hour, open, and focusing on the informants' running experiences in the programme and projects. The main informant groups were general managers (12) at different levels, project managers (4) IT architects (11), IT developers (5) medical personnel (12), lab personnel (3) and vendors (3).

Data Analysis

Data were analysed in three steps (Miles and Huberman, 1994), as shown in table 2. First, we used the information from each informant and written documents to construct a rich picture of the project and its surroundings, and to identify key issues related to integration. Then we analysed each integration issue - such as governance, interactions between actors, technical solutions, perceived problems and challenges, and discourses - more systematically – using data displays and data reduction techniques.

Step	Task	Output
Construct rich picture	Identify key events and issues in the data material	Case description
Analyse integration issues	Analyse technical solutions, governance, interactions between actors, and problems	Table 3
Assess overall complexity	Analyse the number of types of components, types of links, and speed of change	Table 4

Table 2. Data Analysis

Finally, we assessed the overall complexity of the approach, in the short and the long run, using Schneberger's three criteria of components, interactions and speed of change. We conducted the assessment in two dimensions: in the *space* dimension we analysed the topology of the sociotechnical network, i.e. the number of technical and social nodes, and the number (and types) of links and integrations. In the *risk* dimension we assesses the pace of changes; the current and future introduction of new systems and users, and the associated need for changes in the links, such as messages and security mechanisms.

4 Findings

We present our observations in five topics, as summarized in table 3.

Overall IT solution

The RHA system strategy was a hybrid between suite and "best-of-breed", enabled by an advanced enterprise bus solution. The DIPS solution and the regional integration platform may be seen as the lynchpin of the Digital Renewal programme. The implementation of DIPS standardized the EPJ systems in OUS for 12.000 users, and in the region for around 50.000 users, allowing for easier data exchange and sharing, and potentially for better process support. The regional integration platform enabled the seamless data flow between DIPS and 55 different systems, and laid the foundation for later integrations. Regarding functionality DIPS did not contribute much new; it merely presented a new interface, which some users liked, but others found to be poorer than the old ones. However, regarding the silo problem DIPS replaced 3 other EPJs, and the integration platform opened the key systems (EPJ, lab and x-ray) for horizontal use.

Topic	Observations
Overall IT solution	The DIPS solution and the regional integration platform may be seen as the lynchpin of the Digital Renewal programme. It was a conscious attempt to deal with the silo problem in a systematic way.
Governance approach	The project was basically a top-down approach, but with many lateral interactions. These interactions were not only a co-ordination mechanism, but also served as a learning arena and a channel for important discourses
Short term and long term	We observed a tension between two perspectives, one focused on vision (the architects) , and one focused on deadlines (the project managers).
The core technical solution	The system strategy was a hybrid between suite and "best-of-breed", enabled by an advanced enterprise bus solution.
Integration	Integration as a continuous process. New systems and user groups will be integrated more or less continually. The Integration Factory was established to support this.

Table 3: Observations

The governance approach: Top-down, with lateral interaction

In contrast to earlier IT initiatives in the hospitals the programme was planned and run in a top-down manner, with the CEO of OUS acting as the head both the Programme Board and of the steering group of the EPJ project. In an interview he 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. The previous management of RHA and OUS had not done much in order to integrate the solutions, and when I started in 2011 I gave this a top priority. It is very important to standardize our systems: A shared EPJ 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 project was top-heavy, with many managers and tight control mechanisms, with a continuous risk management. When the first schedule problems occurred during the autumn 2014 –the Integration sub-project was one month late by November – it was placed on the top watch-list, and more resources were allocated in order to solve the problem.

We observed, however, 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 RHA 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.

Short-term and long-term perspective

We observed a tension between two perspectives, one focused on vision, and one focused on deadlines. In particular, the IT architects represented the vision, while project managers were concerned about deadlines. RHA had started an enterprise architecture initiative, and the IT architects were building on a TOGAF approach, where the aim was to establish a holistic model of RHA, integrating work processes, services, applications and infrastructure. One IT architect expressed concerns that the different projects were developing sub-optimal solutions, because decisions were taken without relating to an overall policy and model. Project managers, on the other hand, pointed out that since the overall model was not available, they needed to take the necessary decisions in order to keep their deadlines.

These tensions were generally acknowledged. One experienced manager commented:

> "All current projects in the programme are a compromise between the visionary and the pragmatists. The visionaries talk about work processes and innovation, while the pragmatists are concerned with systems, integration and deadlines. The pragmatists tend to win, since all important projects are in a hurry."

The core technical solution: Integration platforms

The main technical challenge was to integrate 55 existing systems, i.e. lab, radiology and other medical systems, with the new EPJ. Taking the lab systems as an example, the new solution required that (i) lab orders made by the doctor from the EPJ, were routed to different lab systems, depending on type of order, and (ii) the results from different lab systems were presented in a shared format back in the EPJ. This required the routing and transformation of a large number of message types, while observing security and privacy regulations.

The key technical solution was called "Regional Integration Platform", based on an enterprise service bus technology: Microsoft BizTalk middleware. It was implemented on two levels:

- Local level: All internal communication between applications within one Hospital will go through the local BizTalk platform

- Regional level: All external communication between applications at different hospitals will be routed through the local BizTalk platform and then to a central BizTalk platform. From there it will be routed to other local BizTalk servers in RHA or via National Health Network to other actors outside RHA.

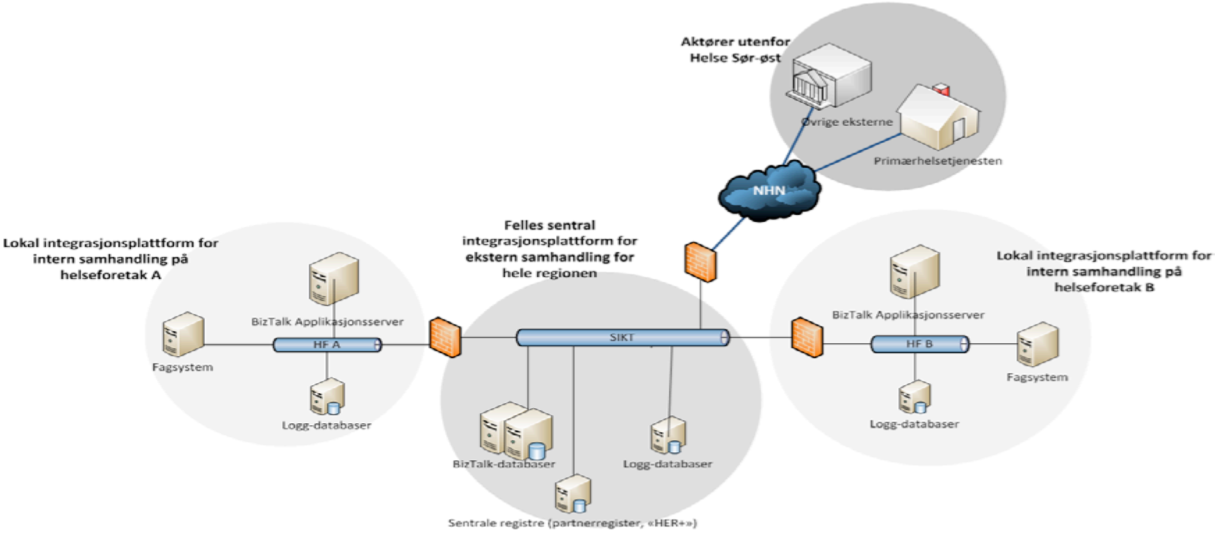

Figure 3. Topology for local and regional BizTalk platforms

The enterprise bus solution offers a number of advantages for integrating the 55 systems. First, it serves as a routing device; it supports the routing of messages and calls, so the addressing is not the responsibility of the applications. Second, it supports the transformation of formats. In the OUS implementation, it handles (for instance) the exchanges of HL7 messages from DIPS, transforming them to the national KITH standard for the lab and x-ray systems. It also scales well. For legal and privacy reasons there is one bus platform for each hospital, so HospitalPartner operates 13 local BizTalk platforms, but they are all run at the data centre. As shown in figure 3 the central BizTalk platform ("SIKT") links the local hospitals ("HF A" and "HF B"), and with external actors through Norwegian Health Network (NHN). The central platform also includes some central registers, such as Partner Register.

The integration platform is important for the future development. The implementation of DIPS is not the end of integration, but rather the first of a number of integration projects. The next project will be the new Lab solution, which will replace the current three lab systems at OUS with a completely new one. Then the new Radiology solution will come, and probably several others. This makes integration a continuous effort. Acknowledging this, HospitalPartner has established an organisational unit called the *Integration Factory*, with more than 20 specialized developers. The Integration Factory is a specialised programming unit for dealing with the BizTalk solutions; it receives order from the on-going projects, and programmes the formats and routing of messages and web services.

Integration as a continuous process

Integration is both a state and a process. In this case integration was much more than a technical task. Broadly, the integration process consisted of these steps, with lab integration as example:

- 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
- 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

This process took place for all the 55 integrated systems, and was the main reason for the project running two months late by January 2014. The main reason for the delay was the first of these steps, because it was quite time-consuming to agree on terms and formats. One lab specialist commented:

> "It was a demanding process to agree on requirements, because the routines of the three hospitals are quite different. For example, an emergency department needs another solution than a hospital without such a unit. We understand the need for standardisation, but we used to have a tight cooperation with our vendor, and the new solution means compromises and poorer operational support".

On the technical side, the Integration Factory was undoubtedly a great success. It combined highly skilled technical work on the bus architecture with the detailed knowledge of the various systems. In the longer run, however, it also raises concerns, because it makes quite complex integration a permanent feature of the IT environment, institutionalized with the Integration Factory. With the chosen strategy for IT architecture this was a sensible solution, but it was quite expensive and required top competence.

5 Discussion: Increasing or decreasing complexity?

We here assess whether the current approach of e-health integration, as a combination of standardisation, product suites, with EA and SOA technologies, is reducing or increasing the overall complexity. We illustrate our findings with the DIPS project, but our assessment entails the general approach.

We assess complexity as implications of our findings: first we analysed the topology of the sociotechnical network, i.e. the number of technical and social nodes, and the number (and types) of links and integrations (Schneeberger and McLean, 2003). Then we assessed the pace of changes; the current and future introduction of new systems and users, and the associated need for changes in the links, such as messages and security mechanisms. An overview of the analysis is offered in table 4.

The number and variety of components

As table 3 illustrates, the implications for complexity varies a great deal. At a hospital level (OUS) the organisational complexity was reduced in several ways: the solution enables health personnel to access clinical information across the various units (no more taxis with x-ray images), and patient information can be handled more consistently throughout the health region. This contributes to greater patient safety, and to more efficient processes. From an IT perspective, the solutions resulted in a less complex portfolio of core systems. It was, in this sense, a major contribution to reduce the silo problem.

Complexity aspect	**Implications for complexity**
The number and variety of components	Complexity was reduced: The number of different systems was reduced through standardisation, and the same applies to the number of system specific user groups.
The number and variety of interactions and interdependencies	The number of technical and social links was increasing, in particular in the technical architecture, and in the development environment.
The speed of change of the system	The speed of change was high, and integration was becoming a permanent process. Governance put considerable pressure on managers, but there were also many lateral interactions.
Overall assessment	*The overall complexity was decreasing in the short term, but may increase in the longer term.*

Table 4. Key issues

We also observed that the project was quite professionally run, with strong hierarchical management, but allowing for a lot of lateral communication. It was an expensive project, but well balanced in these two respects, as is recommended in recent software engineering and project management literature (Sommerville et al, 2012). There were some warning signs in the form of "project fatigue" and an on-going competition on specialist participation in projects, but on the whole we think that the approach has been successful, also in terms of reducing complexity.

The number and variety of interactions and interdependencies

However, integration tends to reduce complexity in some aspects, while increasing it in others (Ellingsen and Monteiro, 2005). While the regional integration platform was well designed and organised, it presents some salient challenges. It is well prepared for more integration, both technically and organisationally, but its position in the overall architecture is more problematic. There are two reasons for this, one technical and one conceptual. Technically, it has quickly become the stable centre in an unstable environment, characterized by continuous integration. In the coming years it will integrate new lab and imaging systems, a completely new version of DIPS will come in two or three years, and a large number of other existing and new applications will need to be integrated. This will inevitably lead to more complexity, as new nodes and more types of messages will need to be managed. Over time this may threaten the stability of the solution.

More conceptually, the centrality of the integration platform means it institutionalized the idea that health IT is about *applications* that should be integrated. It did not address the silo problem as a work process problem, but as a basically technical issue. A clear indication is the tension between the IT architects and the project managers in the OUS case, where the architects argued (in line with TOGAF thinking) that process design and innovation should guide IT solutions. This was in contrast to the chosen approach, where in fact infrastructure and systems to some degree constituted the premises for work processes. This is not particular for OUS, but an international characteristic for e-health solutions (Villa et al, 2007).

The speed of change of the system

The speed of change was high, as can be expected by mega-projects: the rebuilding of a silo structure to a horizontal, integrated solution put a lot of pressure on the organisation and its environment. There are several symptoms of this: (i) the queue of other systems waiting to be modified and integrated, (ii) the large number of users to be educated and supported, showing some signs of *project fatigue* and (iii) the increasing complexity of the IT operations.

On the governance side the pressures on top managers are considerable, as the continuously changing infrastructure requires frequent decisions, and makes it difficult to establish a stable governance regime. As noted by other researchers (Sauer and Willcocks, 2007; Currie, 2014), the scale and unpredictability of health mega-projects makes traditional project management techniques insufficient. In the same line, the observed tensions in the DIPS case between the short-term concerns of project managers and the long-term objectives of the enterprise architects, is not primarily a symptom of conflict, but rather of decision overload.

In this situation we think it is important that experience and results feed back, not only to top managers but also to other organisational levels. We observed a great deal of lateral communication, for example between developers, IT-architects and middle managers, which served as feed-back loops and learning arenas, in addition to the formal structure. In a fast-changing environment this contributes to reducing decision overload.

Overall assessment

We think is fair to say that the overall complexity is decreasing in the short term, but may increase in the longer term. The approach is decreasing organisational complexity, and in the short and medium time perspective the increased technical complexity is manageable through advanced integration technology and specialised expertise. In the longer perspective there may be more concerns. Governance complexity increases mainly because of the increasing number of dependencies, and the speed of change. At a technical level the increasing integration is likely to threaten stability, because the causes of potential failures will multiply in these *coalitions of systems* (Sommerville et al., 2013), and costs will inevitably rise.

Further research should therefor investigate complementary and alternative solutions to the IT silo problem. Strategies for reducing complexity typically include *modularizing* and *loose coupling* (Parnas, 1972), or, in other terms, trying to make it simple by reducing the number of relationships. In practice this will mean to integrate less, and to integrate more loosely. The question, then, is: how do we sort out what can remain as IT silos, and what can be more loosely integrated? Can we rethink the silo problem by a looser coupling between clinical systems and work process support? The welcome benefits from this approach would be (i) that process support could be designed much closer to the clinicians and (ii) that the clinical silo systems could continue their life as – silos.

6 Conclusion

In this paper we addressed some key issues and challenges of the silo system problem in e-health, i.e. the large number of non-integrated applications. We researched the following question: *how can we understand and deal with the socio-technical complexity of large-scale integration in e-health?* From our empirical research in a large e-health initiative in Norway, our conclusions are: the current approaches to resolve silo integration are relatively effective in reducing organisational complexity, but they tend to increase overall complexity over time. Further, we find that the governance of such megaprojects quite demanding, requiring co-ordinating and learning feedback loops at different levels. We sketch a research agenda for an alternative approach, proposing a looser coupling of clinical and process support systems.

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