Innovation Readiness in Healthcare Information Infrastructures

Key Resources to Enable Collaborative Digital Innovation

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Abstract
This paper describes key requirements for digital innovation readiness in the public healthcare sector. Collaborative innovation models, where internal and external innovators contribute their ideas and solutions put certain requirements to the organization and ICT infrastructure of health organizations. To explore these requirements, we conducted an empirical case study of a collaborative digital innovation project from its concept stage towards implementation. Our study identifies key technical and organizational resources needed to facilitate innovation, and it therefore has implications for what resources and capabilities need to become part of the healthcare information infrastructure to enable collaborative digital innovation.

Keywords
Innovation, collaborative innovation, digital, healthcare, information infrastructures, innovation readiness.

1 INTRODUCTION

During the last decade, a dynamic innovation ecosystem has emerged outside of the public healthcare sector. Entrepreneurs develop digital healthcare that utilizes e.g. wearables, self-monitoring and tele-health. Ideally, hospitals should relate to and benefit from this thriving innovative environment. Nevertheless, the transformative potential of innovation with digital technologies is difficult to realize in hospital settings [1] [2] [3] [4] [5]. Hospitals traditionally have siloed information systems catering for different functional areas with an immense number of localized and cross-cutting dependencies [6] [7].

Despite challenges in managing their existing digital infrastructures, hospitals need to foster innovation to meet the triple aim of improving health, enhancing care experience, and reducing per capita costs of healthcare [8]. This could happen by leveraging the dynamics of so-called open or collaborative innovation [9] [10]. Collaborative innovation is motivated by the assumption that active participation of a wide range of actors will increase the quantity and quality of innovations [11]. However, this entails accommodating third-party contributors in existing infrastructures. This may require changes to current ICT architectures, processes and governance arrangements. In this paper we seek to articulate the various aspects of opening up hospitals' ICT infrastructures to innovation, through examining the research question: "what does it take to foster collaborative innovation in established health information infrastructure?".

We draw on insights from the information infrastructure stream within information systems research. Digital infrastructures, and particularly digital platforms, are pivotal for collaborative innovation as they allow opening-up to third parties [12]. In the next sections we present related research, our empirical study, our key findings and their implications.

2 RELATED RESEARCH

2.1 Enabling Innovation in Digital Infrastructures

Complex, interconnected networks of systems have been called "system-of-systems" [13], "ultra-large scale systems" [14] or "coalitions of systems" [15] in order to emphasize their specific characteristics and challenges. We call them "information infrastructures" and draw on research that have studied the evolution trajectories of interconnected, distributed collections of systems comprised of both local systems and shared components.

The notion of infrastructure emphasize that these systems are shared, providing support to multiple different activities. They need to cater for a wide range of potential users and uses, both currently and in the future [16]. Moreover, they are open and evolving over time, as the pre-existing solutions, routines, and structures – the "installed base" – continuously evolve [17]. The solutions therefore have to be adaptive to the developments of practice [18]. At the same time, they have to be stable enough to reliably support activities that make use of them [19]. Balancing the need for flexibility and stability is a central dilemma for information infrastructures.

Aiming for innovation in existing large-scale infrastructures such as the ones that are in place in hospitals, entails conceptualising new technologies not as standalone objects, but as elements in larger infrastructural arrangements [20]. Working with infrastructures within healthcare is especially challenging because novelty has to link to historically built landscapes that are the outcome of intensive digitalization efforts undertaken during the last decades [21]. Furthermore, taking an infrastructural

perspective means paying attention to durability, permanence and to the investigation of strategies for effectively managing future evolution. The concept of the "long now" help us understand the forward looking concerns of infrastructural development, realizing that today's planning will effect tomorrow's sustainability and evolvability of infrastructures [22] [23]. This requires what Steinhardt and Jackson labelled "anticipation work" [24]. Anticipation of the future is not only about accommodating contingencies, it is also about providing the means for advancement, resources for "encouraging mutations, branching away from the status quo" [25]. Such an anticipatory or forward-looking orientation are thus crucial for ensuring innovation readiness of the information infrastructure.

2.2 Sources of Innovation in Healthcare

Hospitals are complex and risk averse environments that have traditionally struggled to innovate in networked information exchange and communications [26] [27] [28] [29]. Bygstad studied four cases in the health sector and found that: "the solutions of the future are not only hard to plan but also hard to envision, and emerge through interactions of diverse actors. That is why a third-party ecology is more innovative than a heavyweight IT department" [30]. Bygstad´s study articulated a distinction between "heavyweight" and "lightweight" information technology (idem). He suggested the use of the qualifier "lightweight" for mobile apps, sensors and simple solutions and the use of the qualifier "heavyweight" for large systems, and sophisticated solutions with advanced integration. Bygstad proposed that IT departments should focus on heavyweight technologies, letting external actors innovate with lightweight technologies.

King and Lakhani [31] (as cited by [32]) argued that open innovation is to be found when the knowledge needed to create or to select appropriate solutions to a problem is broadly held, while when such knowledge is concentrated internally we find intrafirm innovation to dominate. In a similar vein, Salge et al. argue that internal actors (from the clinical side or from the IT department side) may be well placed to identify problems related to clinical practice, to work out suitable solutions using digital technologies and to bring them in use, while external actors may be better placed to identify problems related to patient experience having the flexibility to experiment with different solutions. Overall, both third-party and internal initiatives are needed for hospital digital innovation [33].

2.3 Technological Innovation Potential

Current digital technologies allow modularization and decoupling, which can facilitate multiple contributors to expand established digital infrastructures. Specifically, the widespread use of web service protocols and APIs increase the level of decoupling, creating new opportunities to put together the initiatives of different parties [34]. The potentialities of technology allow conceptualising innovative solutions, moving quickly to proof of concept and small-scale piloting. Nevertheless, the transition to fully fledged implementations in hospital settings has proven to be very difficult. We aim to contribute to a better understanding of what such transition processes entail and require.

Currently the dominant model to map innovation processes includes a number of "maturity levels" or stages in a scale (technology readiness levels - TRL). This scale was introduced by NASA in the 1970s, but was modified since then (and extended from 7 to 9 levels) becoming a *de facto* standard for technology assessment in many industries [35]. It is widely used for innovation policy and governance. It is for instance central in EU's research program Horizon2020. Figure 1 presents the 9 different maturity levels.

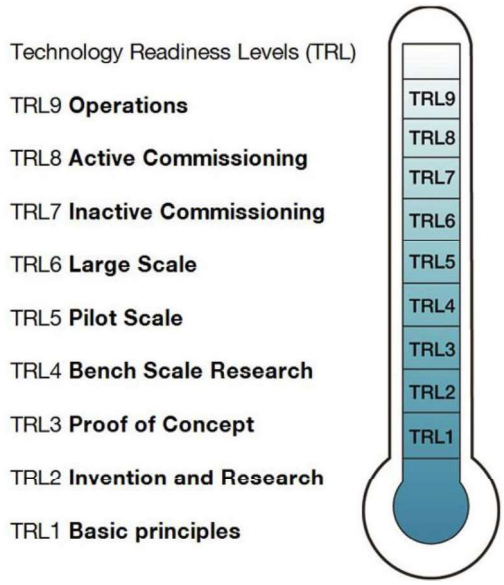

Figure 1. Technology Readiness Levels. Source: https://www.gov.uk/government/news/guidance-on-technology-readiness-levels

We will use this scale to give a temporal structure to the analysis of innovative collaborative projects.

3 METHOD AND CASE BACKGROUND

3.1 Case background

We conducted a case study [36] of the trajectory of a digital innovation initiative where a start-up company and a Norwegian hospital collaborated. The hospital offers multidisciplinary rehabilitation to patients following illness or injury and has a strong emphasis on research and innovation. The hospital is part of a regional health trust, where IT services are offered by a regional IT provider that we will here call HospitalPartner. The innovation initiative was initiated by a third party; an ICT company that was established by healthcare practitioners with the vision of facilitating and streamlining information flows in hospitals. Specifically, the initiative is about developing and introducing point-of-care information access tools enabling clinicians to read and register patient data on the move. These tools can improve efficiency of documentation work and support work optimization. The two main founders of the company conducted a proof of concept trial in 2015. The subsequent development of a prototype in the form of a mobile phone app was supported from different innovation support programs. In November 2016, the company contacted the rehabilitation hospital to present the concept and investigate the possibility of testing the prototype in the hospital. In December 2016 an initial test took place and hospital employees gave feedback towards adjusting the app to fit rehabilitation needs. During a

workflow simulation exercise, clinical workers performed different tasks measuring the time needed for task completion with and without the use of the new tool. This yielded evidence used to calculate the potential for time savings, and the hospital decided to work towards the deployment of the tool. This took more than two years (2017-2019) and revealed issues with the innovation readiness of the existing information infrastructure. In the Findings chapter we describe this phase in more detail.

3.2 Data collection and analysis

We gathered qualitative data through interviews, document analysis, as well as observations during meetings and presentations. We interviewed staff in the hospital's IT department (5 interviews) and staff in the ICT company (4 interviews), seeking to document key events along the process trajectory. We especially focused on the challenges of moving from conceptualisation, to proof of concept and then towards implementation in actual operations. In addition, we analysed status reports, project documents and presentations. Information on the existing ICT infrastructure was also gathered in a 4-year project between 2014-2018, where the hospital and HospitalPartner were partners (RFFHF no. 239050). Data collection was performed during the 2014-2019 period. The data analysis was performed from an infrastructure perspective informed by the literature on innovation (see section 2). Our concern has been to let empirical detail guide the development of insights. Thus, we started from the trajectories of the initiative studied and sought to understand how the initiative aimed to move from concept to prototype to pilot (i.e., from lower to higher readiness levels on the TRL scale), the challenges met along this trajectory and the infrastructural resources needed along this trajectory. Our analysis led to the identification of specific types of technical and organizational resources and capabilities that are required for innovation readiness, especially as regards facilitating the work of digital entrepreneurs.

4 FINDINGS

4.1 The innovation trajectory

The company's initial prototype was developed based on the start-up company initiators' work experience in the health sector and a series of observations at emergency wards in several hospitals. When the collaboration with the rehabilitation hospital started, the app was adjusted to better fit with the specific hospital's needs. During prototype testing, the mobile network was used instead of the hospital's network. Moreover, the app worked with mock data and without connection to any other IT system. When the hospital decided to work towards the deployment of the app, integration with the existing information infrastructure was needed. Specifically, it was important to exchange patient data between the Electronic Patient Record (EPR) system and the new app. A description of the EPR's API was provided by the EPR vendor on request, and the start-up company was able to develop an interface.

In January 2017, the company and the hospital sent the first formal request to HospitalPartner, concerning a test server for running the further development and testing within the region's ICT environment and with real data. This required first that HospitalPartner prepared a Solution Design document and a Risk and Vulnerability Analysis, which were not generated until after the summer of 2017. The delays had several reasons. The major concern of HospitalPartner was to ensure secure operations for the existing infrastructure, and there was not sufficient capacity, nor adequate procedures in place to serve requests from this kind of innovation projects. In addition, large-scale infrastructure modernization programs and several critical incidents took up significant resources in the organization. While a test server was eventually granted (ready in October 2017), access to test data was more challenging. For internal testing, HospitalPartner would use copies of real data. This was legal since HospitalPartner is the formal data processing entity for the hospitals. However, such data could not legally be made available to an external actor such as the start-up company that had no formal role as vendor to the regional information infrastructure. The hospital made a decision to purchase the app and then enrol the company as a data processing partner in legal terms. Beyond getting access to test data to verify the integration, the app also had to be integrated with the regional solution for identification and access management (IAM), and the recently implemented enterprise mobile management solution (EMM) had to be used. Separate orders were sent for each of these, but the project again experienced long delays in getting responses. The orders were handled by several different sections within HospitalPartner (more than 10 groups and sections were involved). In the beginning of 2018, HospitalPartner revised its internal organization and processes and appointed a coordinator to oversee the various order processes. It was also decided that the hospital and not the company should be communicating with HospitalPartner, e.g. around the change requests emerging from testing. During the summer of 2018 testing could commence. Due to the legal status of test data as the hospital's data, the tests had to be conducted on-site in the hospital rather than on the company's premises, and with clinical staff present. This phase saw the need for a closer collaboration also with the EPR vendor. This brought a fourth actor into the collaboration and lack of timely and correct information delayed the project further. Traditionally, change requests to applications running in HospitalPartner's production environment were handled by the Change Management Board which met every three months. This governance model did not fit with the agile way the company's solution was developed, with frequent (often daily) changes. In the later testing stages, involving additional users also revealed new requirements, but due to concerns related to the formal process, several desired functionalities were postponed. Close to the final go-live, a critical problem with the interfacing of the EPR solution was discovered. A new change request was sent to HospitalPartner, who at that time had a two-months' change freeze period. However, half a year later (summer 2019), the solution was finally in small scale pilot use.

4.2 Infrastructural resources required

The trajectory shows a stretched-out process which has been frustrating for all participants. However, it also reveals what third-party innovation using mobile devices require from the existing information infrastructure. The trajectory shows how moving from "proof of concept"

towards operations requires an increasing scope of infrastructural resources. Some of these were related to technology: Information about current systems in use, access to a test setup including a system installation and test data, access to run on the internal infrastructure of the hospital, integration with the Identity and Access Management solution of the hospital, and information about updates happening to the infrastructure, which may have implications for the prototype. In addition, organizational arrangements to facilitate coordination among the actors were needed, as well as new governance arrangements matched to the agility and uncertainty of innovation projects.

As the solution transitioned from being just a concept to becoming a prototype and moving towards a pilot in actual use, new sets of such infrastructure resources were required. In Table 1 we mapped the resources against the readiness levels.

TRL	Use cases	Access to APIs of standard systems	Test Data (synthetic, masked or actual data)	Servers for test & development	Security services	Process mngt. Incl. formal agreements	Agile change mngt	Identity & Access Mngt.	Risk and Vulnerability analysis tools
1									
2-3	x								
4-6		x	x						
7-9		x	x	x	x	X	x	x	x

Table 1 Infrastructural resources mapped to the Technology Readiness Levels.

We see that most of the requirements for resources emerged in the later phases of the project. These requirements were related to the porting of a stand-alone prototype into a pre-existing information infrastructure. In our case study, the required resources were not in place as the innovation moved from stage to stage. The project (along with other innovation initiatives) stimulated the development of (some of) the required resources in HospitalPartner, who developed a proposal for building capacity, expertise and technology. The proposal suggests establishing a single point of contact and a standardized process for innovators, additionally to a set of technical resources.

The proposal sketches a development environment with servers, tools, databases, storage, and data access. Secure access to data from the central information systems (EPR/PAS, medical chart system, personnel system, and demographic information) is seen as crucial, however, for some projects, access to fictional or synthetic patient data is sufficient, while others need to interact with real data (e.g. if they seek to build up or verify data analysis capabilities). It is emphasized that the test platform (with real patient data) must have a sufficient security level. Also, a technical verification regime is needed to ensure that the third-party solutions adhere to the established procedures and that adverse security and performance aspects would not emerge when the solutions are scaled.

In sum, the proposal (which is not yet operational) aims to introduce a timely, flexible and needs-oriented procedure for handling collaborative innovation projects while adhering to information security and privacy demands.

5 DISCUSSION

5.1 Need for test facilities beyond 'sandbox'

The Technology Readiness Levels model stipulates that an innovation needs to move through stages where it is further developed and concretized. Testing is the core activity that yields the required insight for this development. Also for digital innovation in the healthcare sector there is widespread agreement that a test facility is required. Often such test facilities are setup as so-called "sandboxes", i.e. as test environments that are self-contained and isolated from the production environment. While such an environment may be helpful for early-stage testing, our case shows that this is not sufficient for moving further. In the process of connecting to the actual production environment several new issues need to be addressed. For instance, access to existing patient data requires integration with other information systems. Also, access-handling is important – not only on routine use but during the development phase of a collaborative innovation project. The ongoing interaction with users is crucial, and this requires an ongoing experimentation with the new technology in a real-life or realistic setting. Thus, the test and development facilities need to be connected to the actual information infrastructure.

Collaborative innovation requires flexibility and ability to handle gaps in planning, since innovation exhibits more uncertainty than operations, and frequently unfolds through exploratory small volume solutions. Procedures are needed for granting and revoking access to the test environment. Furthermore, support is needed for handling agreements and contracts, and for ensuring adherence to public sector procurement regulations General API management processes, such as e.g. key distribution, activation and revocation, are also required. Even more importantly, the distribution of costs and benefits associated with development, publication and usage of APIs must be addressed, both among vendors offering APIs and innovators using them.

Not all digital health innovations are the same. Our case concerns an application intended for daily clinical work with patients requiring a tight integration with the existing information infrastructure. While this was not the first mobile device based project in the region, it was the first where patient data were accessed via mobile phones and thus required the highest security level. Still, we will argue that most of the needs that emerged were not specific to this particular application. Any digital innovation to be used in a hospital context will at some point require resources such as use cases validated in work settings, test data (either synthetic, masked production data, or actual production data), APIs to interface with existing applications, secure communication networks and encryption, identity access management (IAM). Furthermore, collaborative innovation requires a project setup that ensures adequate communication and coordination between the project and infrastructure provider and appropriate governance mechanisms.

5.2 The Infrastructure's Innovation Readiness

An information infrastructure perspective helps us to take the existing infrastructure into account when thinking of innovation. It indicates a perspective shift: from a concern with the innovation initiative as a standalone project that needs specific types of support, to a concern with how the pre-existing information infrastructure can accommodate novel additions [20]. The findings from this case correlate with earlier studies that emphasize how information infrastructures grow by extending the installed base [17]. However, this study goes beyond the majority of previous studies on the evolution of the installed base, by focusing on the shortcomings of the installed base that hinder its ability to evolve. The case revealed that the ability of the existing information infrastructure to accommodate extensions resulting from the collaborative innovation project was limited. Establishing test facilities of the sandbox variety is only a partial solution towards acceleration of innovation. Beyond that, a core concern of the regional healthcare trust should be to consider the "innovation readiness" of its information infrastructure. In order to accommodate innovation and to "future-proof" the critical information infrastructure there is a need to have in place the resources required, including capacity, expertise and technology. Innovations, both from internal and external sources require a deliberate facilitation that is not achieved without explicit and strategic action.

6 CONCLUSION

We expect that more innovative solutions will find their way into healthcare, such as mobile solutions, data analytics, sensor-based innovations and also, patient-oriented solutions. More attention to the infrastructure's innovation readiness will therefore be necessary. Facilitating the ongoing experimental utilization of these possible solutions, while not exposing the infrastructure to unnecessary risks, requires attention to the offerings of the existing infrastructure in terms of both technical and organizational capabilities and services. Increasing the innovation readiness of the public sector, including its ICT infrastructures will be crucial in order to meet future challenges.

7 REFERENCES

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8 ACKNOWLEDGEMENT

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