Understanding Digital Innovation from a Layered Architectural Perspective

Jesper Lund and Esbjörn Ebbesson

> *Good ideas may not want to be free, but they do want to connect, fuse, recombine. They want to reinvent themselves by crossing conceptual borders. They want to complete each other as much as they want to compete.*
>
> Steven Johnson
> Popular Science Author
> In *Where Good Ideas Come From (2010)*

Managing successful digital innovation processes is a challenging task, especially when it involves heterogeneous actors with different sets of knowledge. By gaining a better understanding of how different architectural layers of digital technology interplay with digital innovation, we can be better prepared for managing the complex and messy processes that often arise when working with digital innovation. In this article, we therefore ask: How does the layered architecture of digital technology interplay with digital innovation processes? A case study approach was selected to studied events involving multiple actors in an innovation and development project called the Smart Lock project. The theoretical basis for our study is digital innovation from the perspective of knowledge exchange and relationships. A temporal bracketing strategy was used to support a process analysis of the case data. The article primarily contributes to the body of research concerning digital innovation and provides an example to practitioners of how digital innovation processes can be coordinated and managed based on the innovation at hand.

Introduction

The already challenging task of managing successful innovation processes has become even more so today, when innovation processes are becoming increasingly messy (Fagerberg et al., 2006; Ollila & Yström, 2016; Van de Ven et al., 1999). This is particularly evident in the case of digital innovation, which refers to the process of creating new configurations of digital and physical components to produce novel products and services (Henfridsson et al., 2009; Lund, 2014; Yoo et al., 2010). Amazon Kindle, Spotify, and Netflix are all examples of digital products and services enabled by digital innovation and illustrate how digital reconfigurations can reshape even the most mundane artifacts.

Digital products and services are built around digital technology, which can be categorized by layers consisting of *devices, networks, services,* and *content* (Yoo et al., 2010). As different architectural layers of digital technology require different knowledge, competencies, and resources, organizations often need to either set up or join innovation networks to be able to succeed with digital innovation (Lund, 2017). As a result, digital innovation processes are becoming more and more open, networked, and complex with an increased need for heterogeneous resources (Boland et al., 2007; Baldwin & von Hippel, 2011; Yoo et al., 2010; Yoo et al., 2012). Many organizations are therefore shifting from vertically aligned thinking, where one organization can handle all research and development by itself, to horizontally aligned thinking, where the firm looks outside their own organizational borders to acquire knowledge from other actors in order to stay innovative and competitive (Bogers et al., 2017; Chesbrough et al., 2006; Yoffie, 1997).

Reviewing current literature about digital innovation illuminates several challenges that can be found regarding digital innovation processes. One challenge concerns collaboration between organizations. The increasing complexity of products and services requires heterogeneous knowledge sources and assets in order for those products and services to become marketable (Bogers et al., 2017; Lund, 2014; Lyytinen et al., 2016).

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In digital innovation processes, individual firms or other actors (e.g., researchers) seldom have the power, resources, or legitimacy to innovate and produce changes by themselves. Therefore, it is important to understand the relationships between actors to better understand the dynamics of these processes. Relationships also influence boundary-spanning exchanges between actors in an innovation process that are tangible (e.g., money, industrial resources) and intangible (e.g., knowledge, experiences) (Bogers et al., 2017; Powell & Grodal, 2005; Simard & West, 2006). Research has also investigated how to mobilize a range of innovators with conflicting interests and different knowledge bases, where no one has control over the final product architecture or the digital infrastructure that supports the innovation (Lyytinen et al., 2016).

Although efforts have been made towards understanding the dynamics of heterogeneous innovation actors in development (Boland et al., 2007; Ollila & Elmquist, 2011; Svensson & Ihlström Eriksson, 2012), little can be found about how the actual digital technology at hand relates to the dynamics of digital innovation processes. By gaining a better understanding of how different architectural layers of digital technology interplay with digital innovation, we could be better prepared for managing the complex and messy processes that often arise when working with digital innovation (Lund, 2017; Yoo et al., 2010; Yoo et al., 2012).

In this article, we present an interpretative case study approach in which we have studied events involving multiple actors in an innovation and development project called the Smart Lock project. The case study is used to investigate the research question: *How does the layered architecture of digital technology interplay with digital innovation processes?* The aim of this article is to describe and explain how the architectural layers of digital technology interplay with the relationships and boundary-spanning exchanges in digital innovation processes. This work therefore contributes to the body of research concerning digital innovation and provides an example to practitioners on how digital innovation processes can be coordinated and managed based on the innovation at hand.

Digital Innovation

As a process, innovation can be defined as the invention, development, and implementation of new ideas (Garud et al., 2013). Traditionally, innovation is based on internal research and development to either develop or generate new products and services (Chesbrough et al., 2006). However, in many consumer-oriented markets today, it has become important to involve external knowledge sources (Cohen & Levinthal, 1990; Westergren & Holmström, 2012). By opening up innovation processes, external firms start to play an increasingly important role for organizations to exploit new markets (Chesbrough, 2003). This is especially evident within technology development fields, such as digital innovation (Powell & Grodal, 2005).

Digital innovation refers to the embedding of digital computer and communication technology into a traditionally non-digital product (Henfridsson et al., 2009). Digital innovation also refers to the process of creating new combinations of digital and physical components that produce novel products or services (Yoo et al., 2010). As a process, digital innovation is often characterized as a networked achievement involving many actors, including user communities, often with different intentions (Kallinikos et al., 2013; Van de Ven, 2005; Yoo et al., 2005). As digital innovation becomes more networked, it also drives a need for collaboration spanning organizational realms (Yoo et al., 2010). Hence, there is a growing acknowledgment that digital innovation is a collective achievement by many actors and stakeholders from different fields with diverse knowledge bases (Van de Ven, 2005).

Digital innovations that are driven by the heterogeneity of actors and their knowledge bases tend to redefine digital products and services. This is illustrated by how digital innovation can lead to the re-organization of entire industries and the generation of new business logics, which changes business models (Lyytinen et al., 2016). Such reorganization is reflected in the innovation networks that are formed by firms and other actors to disperse knowledge necessary to innovate (Powell & Grodal, 2005).

Digital innovation processes

Digital innovation processes that occur in heterogeneous networks are complex and messy (Lyytinen et al., 2016). These processes also differ from other forms of innovation due to the complexities within, and the interactions between multiple actors' relationships and social changes. The complexity becomes even more apparent when working with digitization of services and products (Lyytinen et al., 2016). Especially in fields of technological uncertainty, firms are more likely to look for actors outside their organizational boundaries to involve an innovation network. One explanation for this is that firms can share the resources needed for developing innovative technology by forming networks and

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therefore also share risks. Innovation networks have been shown to provide access to diverse sources of capabilities and information, and the interaction between the actors increases the innovation level at the individual firms. This is especially evident in young and small organizations that benefit more from these relationships compared to larger firms (Powell & Grodal, 2005). Successful external relations, such as inter-organizational relationships, therefore fuel growth and innovation within a firm.

From the perspective of information and knowledge, the knowledge work in innovation processes with heterogeneous actors is not just a matter of processing more knowledge. Instead, it can be seen as a process of transforming knowledge between actors. The transformation of knowledge in the interface between different actors and their respective knowledge areas can be seen as both an opportunity for, as well as a barrier against, innovation (Carlile, 2002). The trading zones that can potentially occur in these innovation processes enable actors with different knowledge and agendas to negotiate, collaborate, and learn from each other (Boland et al., 2007).

Knowledge work in innovation processes requires the involved actors to have the ability to make a strong perspective within a community, while concurrently taking perspectives of other knowledge communities into account. Boland and Tenkasi (1995) describe perspective making as a process whereby a community strengthens its own knowledge domain and practices. Furthermore, the process of perspective taking is described as an exchange, evaluation, and integration of knowledge that others possess. In its essence, it is about making knowledge accessible, for example, through representations or narratives (specifications, prototypes, etc.), so that individuals can engage in a process where they explore, acknowledge, and appropriate the knowledge of others while also making their own knowledge accessible.

The layered architecture of digital technology

To illustrate the configurable nature of digital technology from the perspective of digital innovation, the notion of architectural layers can be used. These layers consist of *devices, networks, services,* and *content* (Yoo et al., 2010). The architectural layers enable two important separations: the separation between service and device due to re-programmability and the separation between contents and networks as a result of homogenization of data (Yoo et al., 2010). The re-programmability enables digital devices to support a wide set of functions and the homogenization of data allows digital content to be used on almost any digital device. As a result, the digital technology of today is malleable and dynamic. This generativity characteristic of the technology enables functionality that can be added after a product is launched onto a market (Yoo et al., 2012; Zittrain, 2006). This is often exemplified by smartphones acting as platforms for apps. These apps turn smartphones into adaptable and changeable digital tools supporting a multitude of different uses.

Layered digital technology is an example of a modular architecture that enables new innovations by combining components from different architectural layers (Tiwana et al., 2010). Design decisions for components in each of the layers can normally be made with small considerations of other architectural layers. As a result, the modularity increases flexibility in a design (Henfridsson et al., 2014; Yoo et al., 2010).

Although the architectural layers of the technology enable digital innovation, different actors from different fields are often required to cooperate. The different layers of technology require different resources, knowledge, and competencies. Therefore, organizations often need to collaborate in complex innovation processes involving heterogeneous actors in order to be able to succeed with digital innovation (Tilson et al., 2010; Yoo et al., 2012). As a result, digital innovation as a process often becomes complex and difficult to manage efficiently (Boland et al., 2007; Lund, 2014; Tiwana et al., 2010; Yoo et al., 2012).

Research Approach

Our research objective with this study is to describe and explain how the layered architecture of digital technology interplays with the digital innovation process. To achieve our objective, we used an interpretative case study approach (Walsham, 2006) in which we studied events involving multiple actors in an innovation and development project called the Smart Lock project.

Case background

The Smart Lock project ran for 13 months (Figure 1) and was an inter-organizational collaboration between four key partners that focused on improving wellbeing for senior citizens in a home care scenario in Halmstad, Sweden. The specific challenge that the project addressed was the uncertainty and feeling of insecurity that stems from not knowing if your door is closed and locked. The proposed solution to the problem was a digital lock and a monitoring system aimed to be used in

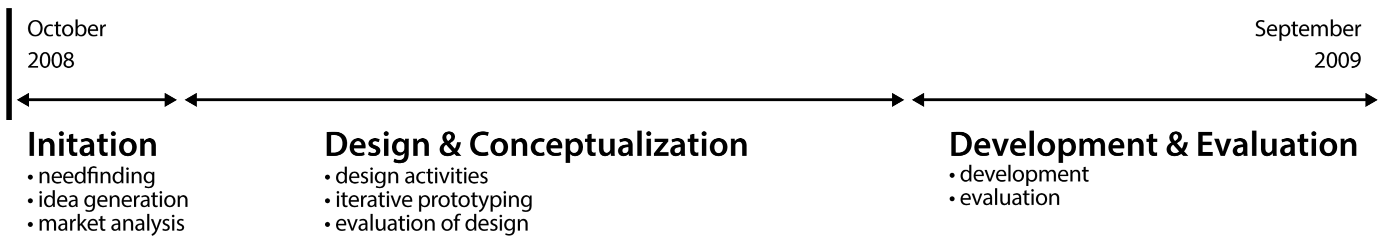

Figure 1. The three phases of the Smart Lock project

the senior citizens' homes. The four key partners in the project were a research group from Halmstad University (facilitation of co-design), the Alpha company (lock technology), the Beta company (wireless security), and a non-governmental organization (NGO) (expert domain knowledge). Furthermore, the municipality was seen as an important partner because they owned data concerning home visits to the seniors.

The digital innovation process consisted of three phases. The first phase included need finding, idea generation, and market analysis. Typical activities during this phase were workshops and focus groups involving seniors, NGO representatives, and representatives from Alpha and Beta. The NGO representatives and seniors were divided into two types of focus groups, representing the users:

1. A primary focus group of next of kin worked closely with the IT developers to generate ideas.

2. Two secondary focus groups, one with seniors and one with next of kin, acted as reference groups to evaluate ideas.

During the second phase, the primary focus group designed the actual device through mock-ups, scenarios, and iterative prototyping. Continuous evaluation of the design was done by the secondary focus groups. The researchers facilitated these activities and Alpha and Beta acted as advisors and "guests" in these sessions during which they answered questions and provided technical feedback to the focus groups. During the third phase, Alpha and Beta developed hardware and software based on requirements and prototypes delivered from the second phase. The high-fi prototype that was developed by Alpha and Beta were then evaluated through real-life testing. During the test, seniors and next of kin were able to test the prototype in their own homes for two weeks.

Data collection and analysis

A temporal bracketing strategy (Langley, 1999) was used to support a process analysis of the case data. This strategy specifically permits the creation of comparative units of analysis for the exploration of theoretical ideas. The approach can be especially useful if there is mutual shaping between concepts or multidirectional causality that will be incorporated into the theorization (Langley, 1999). Given that mutual influences (in this case, the influences of digital technology and innovation process dynamics) are difficult to study at the same time, it is easier to analyze data in a sequential process by temporarily "bracketing" one of the data streams. By decomposing data into successive periods, this strategy enables studies of how actions of one period lead to changes in the context that will influence actions in subsequent periods (Langley, 1999). The model of layered digital technology (Yoo et al., 2010) was used as a lens to structure data from the case. Changes in the architectural layers of the digital technology were used as key events to identify possible points of interest. These were then used as starting points for a temporal bracket that could encompass interesting and critical events in the digital innovation process, for example, changes in relationships or boundary-spanning exchanges between actors in the process. This analytical lens, together with the literature about digital innovation, was used to analyze the empirical findings.

The data concerning the case used for the analysis was collected over a period of two years, although the project only ran for 13 months. The extended period enabled us to gather data covering both the actors' everyday practices regarding their efforts to innovate IT products, as well as their practices after being involved within the innovation process. We discerned two types of data that were gathered during the project: process data and complementary data. The complementary data provided a contextual perspective of the gathered process data. The process data consisted of recordings of workshops, notes, and transcripts from meetings, mail conversations, project diaries, and notes taken by researchers during and after workshops with the users, the NGO, and the companies (Table 1).

In addition to the process data that was gathered, interviews were held to collect additional perspectives on the process data. The interviews were carried out with the users, the representatives from the companies, and the NGO to provide guidance and support to the process data. The interviews were conducted before, during, and after the project was finalized. Interviews took place both at Halmstad University in Sweden and at the companies' facilities. The interviews were recorded on digital media for transcription. Table 1 presents an overview of the data collection activities during the Smart Lock project.

Table 1. Data collection activities

	Type of Data / Activity	Number of Participants
Process Data	Workshop notes and recordings from 20 workshops	20
	Project documentation	–
	Notes from formal project meetings	–
Complementary Data	4 formal interviews with Alpha and Beta	2
	1 questionnaire	60
	2 group interviews with focus groups	8
	3 interviews with the NGO representative	1
	2 questionnaires regarding the week-long “real life” tests	16
	1 interview regarding the week-long “real life” tests	16

Furthermore, notes from meetings between actors in the process, field notes covering observations, archival documents, and reflections by researchers involved in the ongoing activities (such as workshops) in the innovation process were included in the analysis of the data.

The Smart Lock Case

This section describes key events from the Smart Lock case identified by examining the Smart Lock system based on changes in the layered architecture of the digital technology. Changes in architectural layers were then traced to the different concepts that were developed as well as events leading up to them. Figure 2 details the relationship between the main concepts that were developed during the innovation process and the timeline of the project.

Start up and initial concept
The project was initiated with a series of workshops where all three focus groups together with researchers and Alpha and Beta participated. The aim of the focus groups was to identify and prioritize problems relating to the everyday life of seniors and the next of kin from the perspective of secure living. The problematic areas that were identified through the workshops were then evaluated and ranked by a larger group of seniors and next of kin through a questionnaire, which also attempted to identify further needs and problems. The NGO

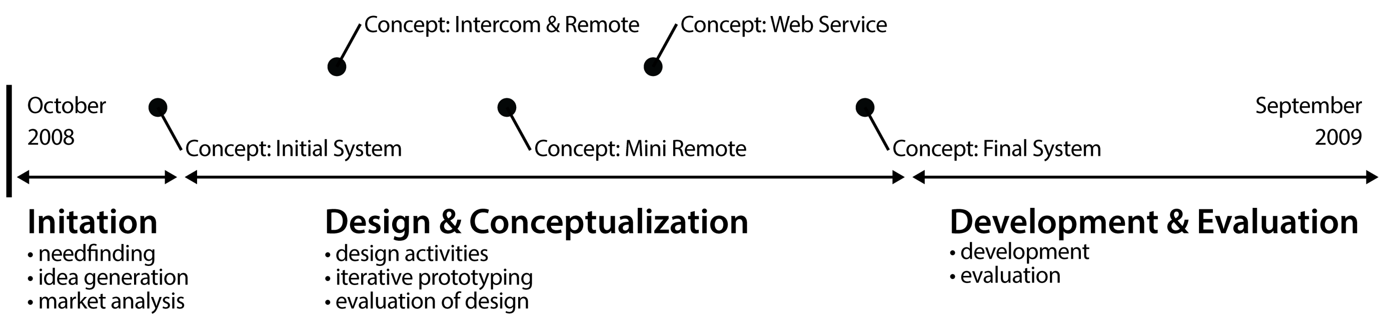

Figure 2. Key events from the Smart Lock case

played an important role during these initial activities, not only by contributing to the workshops, but also by enabling access to other user groups, such as other senior citizen interest groups and the church. These user groups were then involved when it was time to validate the results from the start-up workshops through the questionnaire.

The feedback from the questionnaire was used as input for the selection and development of ideas and concepts in the upcoming workshops within the Smart Lock innovation process. One primary area of concern, identified during the initial workshops and through the questionnaire, was the feeling of insecurity that a door might be unlocked. This insecurity was shared between the seniors and the next of kin. The seniors expressed concern about their own ability to get to the door to check it, while the next of kin worried about whether or not the door was indeed locked or not. This uncertainty resulted in the next of kin sometimes having to double-check that a door was locked. Taking both scenarios together, it was clear that the status of the lock was something that led to quite extensive travelling back and forth in the households. As an initial attempt to mitigate the problem areas, Alpha and Beta started planning the creation of a remote control.

The initial concept presented by Alpha and Beta, when viewed through the lens of Layered Digital Technology, is illustrated in Table 2. The idea was based around Alpha's existing "smart" lock solution, an engine-driven lock that could be opened or locked via a digital code transferred over Bluetooth. This enabled care personnel to use their cellphones instead of physical keys to open locks. The Smart Lock, combined with cameras and sensors, provided an opportunity for monitoring an apartment for, for example, movement, while also providing logs to see who had opened a door and when. Lock logs required GPRS to communicate updates from the lock to a server. This data was, in turn, accessible from a PC via TCP/IP.

Already during the first meetings with the senior and next-of-kin user groups, it became evident that the groups had quite different perspectives. For example, the groups wanted different features and had different visions of the primary use of the system. The next of kin wanted rich data regarding, for example, movements in an apartment, potential uses of cameras, and to know who visited and when. The seniors regarded many of these features as a breach of privacy. Also, a conflict of interest between the companies was identified. Beta was looking for more video and image features in the system due to possible synergistic effects with existing products, whereas Alpha was focusing on their own product features focusing on Smart Lock solutions.

In the first phase, the actors both informally and formally started to build relationships with each other. As the problem space of the project was quite uncertain, the user groups were essential for obtaining domain knowledge needed to guide the innovation process towards actual needs. However, the companies, which had a quite technology-driven approach towards what could be developed, highly influenced the initial features of the Smart Lock system. The innovation process was initially based on the ideas and components presented in Table 2. The actors involved were therefore the ones who could actually realize the ideas of a "smart" remote lock with features based on Alpha's and Beta's existing resources.

Design and conceptualization of the Smart Lock system
In total, 18 workshops with focus groups were conducted within the project. In these workshops, the primary focus group worked with the companies to refine ideas and conceptualize them. Techniques such as brainstorming, future scenarios, persona descriptions, design sketches, low-fi prototyping, and mock-ups were used.

Continuous evaluation of the design work was conducted by involving the two secondary focus groups. The outcomes from the needfinding workshops, the design,

Table 2. Initial Smart Lock system components

Content	Service	Network	Device
• Lock logs • Lock status	• Remote lock • Surveillance	• GPRS • Bluetooth • TCP/IP	• Remote control • Smart Lock • Cellphone • Cameras • Sensors • Server • PC

iterative prototyping, and evaluation workshops, were used as input for Alpha and Beta in the development phase of the project.

As different features and design solutions were discussed and materialized into conceptualizations, the components involved in the different architectural layers of the digital technology were changed. Different concepts utilized different components in different architectural layers of the digital technology. When one concept changed some components, this had a ripple effect throughout the layers.

During the second phase of the Smart Lock case, the relationships between Alpha and Beta were deepened and formalized. As described by one of the development managers, the relationships between the firms were strengthened as they started to share each other's competences:

> *"…we have become better and better at sharing and it has become so much easier to utilize each other's competences and we have started to share knowledge about technologies back and forth between the firms. Even though we worked at the same facility, we have been isolated from each other in the past. Now we have opened up and also started to use each other's components in our product lines…"*

The managers also elaborated on the importance of actually formalizing informal relationships:

> *"A co-operation between the firms seemed to be bound to happen, but it never did before we both joined this project. This was the starting point that made it all happen."*

During development meetings between Alpha and Beta, discussions of how to solve technical problems were increasingly common when engineers from the two companies met. According to the companies, these discussions led to potential problem solving for other development projects within both companies. Positive knowledge exchanges were therefore identified between the companies with spillover effects on other projects within the organizations.

The collaboration between the companies also led to synergetic effects, exemplified by the developing manager from Alpha stating that:

> *"We have opened up to each other and started to use each other's competence in other areas as well, such as when ordering components."*

This finding was in contrast to the next-of-kin focus group that wanted the possibility of buying both the services and the hardware directly from Alpha. The main reason for Alpha's stance regarding the business model was that they did not want to build up a sales and support organization targeted towards end consumers. Instead, they wanted to sell to municipalities that leased hardware and paid for the services. As no representatives were officially involved from the municipality, one important actor was missing to be able to realize the Smart Lock system.

The remote and intercom concept

During the design and conceptualization phase, several alternate concepts were developed by the focus group together with Alpha and Beta. The two main concepts designed were the remote and intercom and the web interface. When viewing the final remote and intercom concept from a layered digital technology perspective, it is evident that many of the core components stayed the same throughout the project (Table 3). Both the hardware and software were fully developed within the Smart Lock project. However, the remote control was mainly developed by Beta and was designed to be able to interact with the Smart Lock. The remote control could allow a user to lock and unlock the door, as well as seeing the current lock status. In a display on the remote control, a user could see and talk to the person at the door via an intercom mounted outside the door. The intercom was also developed by Beta using their proprietary technology for wireless audio and visual

Table 3. The components of the remote and intercom

Content	Service	Network	Device
• Photos of visitors • Video feeds • Lock status	• Remote lock • Video call	• Bluetooth • WiFi	• Remote control • Smart Lock • Intercom • Cameras

communication. The intercom sent a signal and a video feed to the user's remote control.

Both Alpha and Beta reported that they gained a deeper understanding of their respective target groups by working with the focus groups. The development manager of Alpha said:

> *"I feel that we have a much clearer picture of the use context and how the system, in this case, will be used."*

This knowledge could be traced both to how the Smart Lock solution was designed, but also to modifications in Alpha's current line of products and upcoming products. One representative from Beta said:

> *"We have some ideas from the workshops that we really find interesting and have specified for our next revision of our product."*

During the workshops, the companies and the primary user group changed their understanding of the problem by, for example, taking the perspective of caretakers situations, but also regarding what possibilities technology either offered. One representative from Beta said:

> *"We have gained a greater understanding regarding how they (the users) think and how they want things to work and function."*

When the companies gained knowledge and better understood the user groups' needs, the concepts changed as a result. This created a better outcome according to the development manager of Alpha:

> *"Due to the number of people and the thoroughness of the process working with the problem situation, this is so much better than if only developers had worked with it the same amount of time. The prototype will be much better than what it normally would have been."*

The web service concept

The web service concept complemented the Smart Lock intercom and lock. This concept was designed as a web portal for next of kin. The concept utilized all components of the intercom and lock, which spanned all architectural layers of the technology (Table 4). The web service also added additional features to the Smart Lock system, which had ripple effects on the requirements of the hardware. The web portal presented logs and history of when the door was locked or unlocked. It also showed if the lock interaction was initiated by the remote or by home care personnel. Furthermore, the system could present photos from the video intercom as well as handling alarm functionality where an alarm could be sent via SMS or email.

Different kind of sensors was used in the initial design to enable surveillance of a senior's movements. This was especially sought after from the next of kin. However, due to privacy issues identified by the secondary focus groups, the project excluded healthcare monitoring features via camera and sensor technology. Also, several alarm functions were removed for the same reason. When surveillance services were removed from the concept, sensor components were also excluded. Even so, to build the system based on the smart lock, remote and intercom, and web system, included a multitude of components that spanned over four architectural layers of digital technology.

When sensors and surveillance were excluded from the Smart Lock system, the core competence of Beta was no longer sought after. Also, their business incentive to participate was weakened. Therefore, they became a supplier of basic technology such as video and audio. A change in the innovation process dynamic was imminent when Beta took on this subcontractor role to Alpha.

Table 4. The components of the conceptualized Smart Lock web service

Content	Service	Network	Device
• Photos of visitors • Personnel logs • Visitor logs • Lock logs • Lock status	• Activity alarm • Inactivity alarm • Remote lock • Video call • Surveillance	• GPRS • Bluetooth • TCP/IP • WiFi	• Remote control • Smart Lock • Cellphone • Intercom • Cameras • Sensors • Server • PC

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The mini remote concept

During the development of the intercom and the remote, a spinoff product from the project was initiated by Alpha. A mini remote was conceptualized that consisted of only the remote lock service, somewhat similar to a remote car lock device. Few components were needed, which mitigated complexity issues (Table 5). This enabled Alpha to develop the mini remote product without involving any other actors.

Development and evaluation of the final system

In the development phase of the digital innovation process, Alpha and Beta designed the hardware and software for the Smart Lock system with only a few interactions with other actors in the process. One new actor had to be brought in informally to the innovation process before the start of the field trials. As the municipality had caregiving personnel visiting the test subjects, data that they were in control of had to be incorporated into the test. The system registered when a caregiver arrived to visit a senior, and the data was also visible through the Smart Lock web solution. As the Smart Lock system was dependent on the data controlled by the municipality, they had to be involved as an actor. This meant that Alpha in particular became dependent on resources owned by the municipality (the data about personnel).

A field trial of the entire Smart Lock system (Table 6) was conducted over the course of two weeks. Two questionnaires, one for each week, were used to gather data. In addition, interviews with seniors and next of kin were conducted at the end of the trial. The Smart Lock system was deemed successful in the evaluation. For example, seniors with physical disabilities who had trouble moving around in their apartment found the remote control very helpful. Another example concerned the relief of stress that next of kin felt by always being able to see who had been at their parents' home and when. This information also helped in their communication with the caregiving organization. Finally, there was a high degree of willingness to pay for the innovation from next of kin, which showed great commercial potential.

Discussion

The Smart Lock case shows an example of a heterogeneous set of actors with different agendas, perspectives, and conflicting interests working together innovating digital products and services. This case illuminates the need for cross-organizational collaboration in digital innovation, something that earlier research also indicates (Bogers et al., 2017; Boland et al., 2007; Power & Grodal, 2005; Yoo et al., 2010). While viewing the Smart Lock system from a layered digital technology perspective, the complexity becomes apparent. The complexity is also mirrored in the innovation process itself. Even though complexity in digital innovation has been showcased before (e.g., Lyytinen et al., 2016), this article aims to describe the nature of the complexity to enable ways to address it. Furthermore, this article provides new insights regarding the interplay between layered digital technology and digital innovation dynamics.

Table 5. The components of the mini remote

Content	Service	Network	Device
• Lock status	• Remote lock	• Bluetooth	• Remote control • Smart Lock

Table 6. The components of the finalized Smart Lock system including all products

Content	Service	Network	Device
• Photos of visitors • Personnel logs • Visitor logs • Lock logs • Lock status	• Activity alarm • Inactivity alarm • Remote lock • Video call • ~~Surveillance~~	• GPRS • Bluetooth • TCP/IP • WiFi	• Remote control • Smart Lock • Cellphone • Intercom • Cameras • ~~Sensors~~ • Server • PC

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When studying the innovation process from a layered digital technology perspective, five major changes in the conceptual representations could be discerned. The changes towards more stable concepts in the innovation process were all superseded by a flux of diverging designs, and in some cases actors, in what could be interpreted as a malleable initial phase of the digital innovation process. During this phase, new actors were connected to the process that opened up additional opportunities for trading zones. This phase also opened up new perspectives to Alpha, Beta, and the focus groups, which was already part of the process. This initial phase was followed by a concept development phase, where several concepts were created. Following this initial phase, where a concept development phase was several concepts were created. The formalization of concepts enabled the representatives from Alpha and Beta to bring these back to their own developers. It also opened up discussions about what additional resources that were needed or made obsolete based on the concepts. These discussions on how to realize the stable concepts put the innovation process back into a malleable state by inviting, strengthening, or diminishing the roles of the different actors. This is illustrated by the previous example of connected interest groups, as well as the municipality, but also by how Beta took the role of a subcontractor after sensor and surveillance technologies were removed based on user feedback.

The empirical findings illustrate how the process changed back and forth from a formalized and malleable phase during the Smart Lock case. The dynamic movement between malleable and formalized phases started from the initial stable concept. It then continued throughout the design work during the conceptualizations phase, until the stable concept of the finished smart lock system was formalized. In the malleable phase, heterogeneous external actors might be beneficial in order to bring in innovative ideas and designs. The heterogeneous actors' role in innovation is beneficial for innovation and firm growth, especially for young and small firms (Powell & Grodal, 2005). Arguably, this was the case in the Smart Lock project. All actors involved contributed with insights and resources that shaped the Smart Lock concepts. In the Smart Lock case, the malleable phases consisted of a wide design perspective to explore the innovative potential in ideas and concepts generated by the focus groups along with developers. In the formalized phase, ideas were materialized into concepts, mock-ups, and prototypes. The materializations were then discussed from both a business and user perspective. The business perspective included discussions about business models and opportunities to launch the concepts as products on a market. The user perspective concerned design and usability issues, as well as handling the conflicting interests between the different user groups.

When analyzing the empirical insights based on a layered architectural perspective of digital technology, the following insights can be discerned. A specific set of actors is needed to provide different perspectives and insights important for a digital innovation at hand. In the Smart Lock case, different user groups, together with researchers and the companies, provided a heterogeneous mix of competences and perspectives that highly influenced the concepts developed during the innovation process. The different actors all contributed with expertise to different architectural layers of the digital technology. Researchers together with the user groups primarily contributed to the content and service layers, whereas the firms primarily had knowledge and competence on the device and network layer. Even if all actors were involved in discussions concerning all architectural layers, the firms specifically wanted domain knowledge from the users to be able to develop relevant Smart Lock concepts. At the same time, their own expert knowledge was founded in the device and network layers. Based on these insights, we deem it important to identify, mobilize, and actively involve actors with knowledge and expertise in relation to all the architectural layers of digital technology. These insights can help innovators to plan for and mobilize a set of relevant actors for digital innovation.

After the formalization of a concept, the firms started to discuss possible ways of launching the future digital innovation on the market. The role that the firm played in bringing the Smart Lock concepts to market differed with every concept. In the initial Smart Lock concept, both firms utilized already existing products and services into the concept. This meant that, for example, Beta had the opportunity to reach new markets with their alarm and surveillance products and services. Further down the road, Alpha took the role of owner of some of the concepts that included the use of their existing business model. This changed the role of Beta to a supplier of components instead of a partner to Alpha. A similar phenomenon was identified when the municipality had to be incorporated into the process to enable the launch of feature that incorporated data owned by the municipality. Based on these insights, we argue that digital innovation processes need to be managed in ways that enable a fluent movement between malleable and formalized phases.

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In the initiation of both malleable and formalized phases, there was a stronger need for relationship facilitation. In the malleable phase, new actors were involved in the Smart Lock case that had to find their place and role in the innovation process. This was especially evident with the user groups. To enable successful ideation and concept creation, heterogeneous users are beneficial for innovativeness (Bogers et al., 2017; Ollila & Yström, 2016; Powell & Grodal, 2005), which could also be observed in this case. However, to reap the benefits of heterogeneity in the innovation process, facilitation between actors had to be done by the researchers. A similar phenomenon has been identified in other cases of digital innovation as well. In these cases, heterogeneous actors required relationship facilitation to provide trading zones to support the exchange of ideas and perspectives (Ebbesson & Ihlström-Eriksson, 2013; Svensson et al., 2010). In the formalized phases, new actors had to be involved, and in some instances, the actors' role changed. An example of relationship facilitation in the Smart Lock case was when Beta shifted role to a subcontractor instead of a partner during the formalization of the web service concept. This facilitation was needed to mitigate problems with the innovation process and support the successful development of the Smart Lock system. The facilitation was also needed when new user groups, with no prior connection to Alpha or Beta, was connected to the innovation process. Furthermore, there was a need for facilitation to create an interface, or an arena, where the actors could meet. Similar findings are reported by Ollila and Elmquist (2011).

Based on these findings, we argue for the importance of relationship facilitation in the initiation of malleable and formalized phases to support digital innovation. Furthermore, perspective making and perspective taking can enable trading zones where actors can negotiate, collaborate, and learn from each other (Boland et al., 2007). As innovation processes require involved actors to make a strong perspective within a community, while concurrently taking perspectives of other communities into account, the empirical findings illustrate the importance of perspective making and taking during the malleable phases of digital innovation. As described by Boland and Tenkasi (1995), perspective making is a process whereby a community strengthens its own knowledge practices and domain. The process of perspective taking is essential to making knowledge accessible, for example, through representations and concepts. These representations allow actors to engage in a process where they can explore, acknowledge, and appropriate other's knowledge while also making their own knowledge accessible.

Conclusion

As shown in this article, a layered architectural perspective can be used to gain insights about how digital technology interplays with digital innovation. Actors, resources, and knowledge related to the different layers influence the digital innovation process, not only in the initial phases but throughout the whole process. Furthermore, as highlighted in the empirical findings, changes in the architectural layers affect the dynamics of the digital innovation process by creating a need for malleable and formalized innovation phases.

This article adds to earlier research about the complexity of digital innovation and suggests that a layered architectural perspective can provide valuable insights concerning how innovation processes within this domain can be coordinated and managed. Based on the insights presented in the discussion, we argue that it is important to identify, mobilize, and actively involve actors with knowledge and expertise in relation to all the architectural layers of digital technology. These insights can help innovators to plan for and mobilize a set of relevant actors for digital innovation. By analyzing ideas for new digital innovations based on a layered architectural perspective, firms can assess the viability of initiating actors and stakeholders that can support a successful digital innovation process. Furthermore, the interplay between the layered architecture of digital technology and digital innovation processes suggests a need for boundary-spanning exchanges in malleable phases and a need for formalized relationships in formalized phases of the innovation process.

Based on these findings, future studies are suggested to investigate in greater detail how digital innovation can be managed successfully. Questions such as what innovation activities are needed to enable digital innovation could be interrogated to further explore the phenomena and address the complexity of digital innovation.

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Citation: Lund, J., & Ebbesson, E. 2019. Understanding Digital Innovation from a Layered Architectural Perspective. *Technology Innovation Management Review*, 9(2): 51–63. http://doi.org/10.22215/timreview/1218

Keywords: digital innovation, collaborative innovation, concept development, innovation process, digital technology

Academic Affiliations and Funding Acknowledgements

Technology Innovation Management (TIM; timprogram.ca) is an international master's level program at Carleton University in Ottawa, Canada. It leads to a Master of Applied Science (M.A.Sc.) degree, a Master of Engineering (M.Eng.) degree, or a Master of Entrepreneurship (M.Ent.) degree. The objective of this program is to train aspiring entrepreneurs on creating wealth at the early stages of company or opportunity lifecycles.

- *The TIM Review is published in association with and receives partial funding from the TIM program.*