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Generative mechanisms for innovation in information infrastructures

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ABSTRACT

This paper investigates innovation in information infrastructures. The research question is, how can an information infrastructure provide generative mechanisms for innovation of ICT-based services? Building on a critical realist approach, the empirical evidence was a case study within an international airline, aiming to diversify its services. From the analysis it is proposed that there are two self-reinforcing mechanisms in information infrastructures. The first is the *innovation mechanism*, resulting in a new service. The second is the *service mechanism*, resulting in more users and profits. The two mechanisms feed on each other.

1. Introduction

This paper explores innovation from the perspective of information infrastructures. During the past decade innovation of ICT-based services has transformed several industries, such as financial services, telecom and IT, and media. Other sectors are following, for example the music industry and e-government. Innovation is not easy; it is hard to plan and manage (Tidd & Hull, 2003), it is socio-technical and non-linear (Janszen, 2000) and should be done mindfully (Swanson & Ramiller, 2004). As Christensen has shown, innovation is also paradoxical; the innovative company faces the danger of becoming a victim of its own success, as it develops a mindset that hinders new innovations (Christensen, 1997).

The IS research field has also during the past decade documented a significant transformation from applications to infrastructures. As defined by Hanseth an information infrastructure is "a shared, evolving, open, standardized, and heterogeneous installed base" (Hanseth, 2002, p. 2). Information infrastructures may be corporate (such as ERP supply chains), industry oriented (such as stock exchanges) or social (such as LinkedIn), but they share the attribute that no single actor can design and govern the structure. The key term in this concept is the installed base, which denotes the number of components and users in the information infrastructure. For example, the installed base of a national health system would consist of the

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health record databases, the users of the medical professions, the work processes, the VPN network, the vendors and maybe also the patient users (Braa, Hanseth, Mohammed, Heywood, & Shaw, 2007).

A key attribute of a successful information infrastructure is the self-reinforcing mechanism, illustrated with Gindley's figure below. An installed base attracts complimentary products. This makes the information infrastructure more attractive to users, and generates more use, which in turn increases the size of the installed base.

Compared to the traditional concept of information systems, the notion of information infrastructure offers two important advantages. First, it changes the object of study from a single application within a company to the world of large socio-technical networks. Second, it offers a new perspective on how such solutions are developed. While the stand-alone system can be designed and implemented, the information infrastructure is seldom designed from scratch; rather it is growing more organically from an existing base.

How do information infrastructures provide support for, or even generate, new innovations? Some information infrastructures are spectacular innovations, such as Internet based supply chain networks, inter-organizational health systems, FaceBook and eBay. At a more practical level, however, the relationship between innovation and information infrastructures is less well known. Information infrastructures certainly grow organically by more use, but they also grow by innovation. One assumption is that innovations can arise from new uses and combinations of existing technologies, but we do not know very much about the process by which innovative infrastructures are developed.

For example, will the often large number of actors and systems ("the installed base") constitute a hinder or a resource for innovation? How does a new innovation relate to the infrastructure? These issues call for more research on how successful infrastructures are developed. Thus, the main ambition is to understand the self-reinforcing mechanisms in the development and change of information infrastructures in more detail.

The research question is: how can an information infrastructure provide generative mechanisms for innovation?

This paper proceeds by a review of some central contributions on information infrastructure and innovation. Then, in section three, the research approach is briefly presented, while section four presents the case study. Findings are discussed in Section 5 and conclusions offered in the last section.

2. A brief review on innovation in infrastructures

Star and Ruhleder (1996) asserted that "infrastructure is a fundamentally relational concept. It becomes infrastructure in relation to organized practices" (p. 4). They defined information infrastructure in the following terms: It is *embedded* into other structures, *transparent* in use, has *reach and scope* beyond a single event, is *learned as part of a membership*, it links with *conventions of practice*, *embodies standards* to be able to plug into other structures, is built on an *installed base* and, finally, it becomes *visible upon breakdowns* (Star & Ruhleder, 1996).

Thus, understanding innovation in information infrastructures presents a set of challenges. First, information infrastructures are complex socio-technical structures, where an innovation is not a new technical component or system, but a new service in use. ICT-based service innovation often redefines the roles of the service provider and the users (Tidd & Hull, 2003). An illustrative and very successful example is the Internet bank. The real innovation of Internet banking is not the web software, but the *redefinition of roles*: The bank organization provides the technological infrastructure, the technology is available 24/7, and the customers are doing the transactions themselves. The actual innovation is the interplay between the providing organization, the new technology and the users.

Second, innovation in information infrastructures is seldom the work of a single entrepreneur, in contrast to the traditional Schumpeterian view: new services are usually developed in close interaction with partners and customers, and they are more often innovated in networks rather than labs (Abramovici & Bancel-Charensol, 2004). Fifteen years ago van de Ven described innovation as a collective process, including not only the entrepreneur, but also a variety of industrial and public actors (Van de Ven, 1993). The insight that innovations today more seldom take place within a single organization has triggered a strong interest in different forms of co-operative innovation processes (Bessant & Tidd, 2007). Andersson et al. found that architectural knowledge is crucial in inter-organizational innovation, in four dimensions: technology capability awareness, use context sensitivity, business model understanding and boundary-

spanning competence (Andersson, Lindgren, & Henfridsson, 2008). Other researchers have investigated the innovative capabilities of distributed and heterogeneous networks, and showed that innovations in this context may be regarded as a series of cognitive and social translations (Yoo, Lyytinen, & Boland, 2008). Cognitive translations include the creation of ideas into actionable artifacts, while social translations take place at the borders of different knowledge communities, where involved actors negotiate and mutually adapt a solution. While the cognitive translation process is relatively linear, the social translation process is much less predictable.

Third, research on information infrastructures has shown that the development trajectories of information infrastructures are hard to predict and control (Ciborra, 2000; Hanseth, 2007). Extensive case research showed that many of the key approaches from strategic IT management, such as strategic alignment, top-down planning, and project management, do not work as intended in the context of large information infrastructures. Rather, the authors assert that top-down approaches rather will increase the managerial problems of large information infrastructures, and instead they point to such concepts as *cultivation* and *care* in order to foster innovation and growth. Taking these ideas further Hanseth and Lyytinen pointed out that large-scale information infrastructures have a complexity that goes beyond traditional systems design. They proposed a full theory on the design of information infrastructures, focusing on how to foster the growth of an installed base, building on networks economics and complexity theory (Hanseth & Lyytinen, 2010).

The five design principles and the associated mechanisms are described in Table 1:

These key design principles exploit the dynamics of self-reinforcing mechanisms of growing information infrastructures, as illustrated in Fig. 1. The associated mechanisms illustrate that the crucial aspect of infrastructure growth is not functionality, but the interplay between technology and use. The guidelines do not, however, specifically address the dynamics of how new innovations are created and integrated.

Summing-up this brief overview: we know that the innovation process in information infrastructures is complex and non-linear, that it is essential to exployt the dynamics of self-reinforcement of the installed base and that it is a collective endeavour which is both cognitive and social. What we know less about, is the causal structure of innovation in information infrastructures, and how this is linked to the growth of the installed base. Thus, what we are looking for is a recursive structure of mechanisms, which links innovation and growth in more detail.

3. Method

3.1. Research approach

The general approach for this study was a critical realist case study (Easton, 2010; Sayer, 1992). Several researchers have argued that Critical Realism may enrich IS research (Mingers, 2004; Smith, 2006) and that it is particularly well suited to conduct longitudinal case studies where explanations are sought (Dobson,

Table 1
Design principles and mechanisms.

Principle (Hanseth & Lyytinen, 2010, p. 11)	Mechanism
1. Design initially for usefulness	Direct and short-term usefulness for a small target group will bootstrap the use
2. Draw upon existing installed bases	Extending existing structures will make it much easier for users to adopt new services
3. Expand installed base by persuasive tactics	Building user communities in parallel with technical development will increase use
4. Make it simple	A new user (and partner) will prefer a service that is easy to use
5. Modularize by building separately key functions of each infrastructure, use layering, and gateways	A modularized and layered structure makes it easier for others to extend the infrastructure

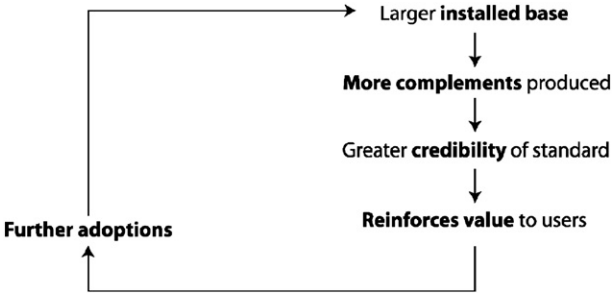

Fig. 1. Grindley's standards reinforcement mechanism. (Grindley, 1995).

2001; Easton, 2010). The basic assumption of critical realism is the existence of a real world independent of our knowledge of it. Reality is conceived as being stratified in three domains. The *real* domain consists of objects, both physical and social, with capacities for behaviour called mechanisms. These mechanisms may (or may not) trigger events in the domain of the *actual*. In the third layer these events may be (or not) observed, in the *empirical* domain. Thus, structures are not deterministic; they enable and constrain events (Archer, 1995; Sayer, 2000).

Critical realism combines a realist ontology with an interpretive epistemology (Sayer, 2000); although a real world exists, our knowledge of it is socially constructed and fallible. This does not imply an epistemological relativism; since a real world does exist critical realism holds that some theories *approximate* reality better than others. This process of approximization is seen as a key part of scientific enquiry. It follows from this that critical realism does not aim to uncover general laws, but to understand and explain the underlying structure and mechanisms. This is done through *retroduction*; we take an empirical observation and hypothesize a mechanism that might explain that particular outcome. These mechanisms are associated with the *nature* of the object of study, not to the regularities of events. Thus, the aim of a critical realist case study is go beyond the chronology of events, in order to identify the generative mechanisms that produced the associations between events (Hedstrom & Swedberg, 1996).

Our object of study is an information infrastructure; a complex entity consisting of many elements. A key concept in critical realism is *emergence*, which implies that attributes of a higher level object emerge from the interplay of lower level objects, but are not derived from them. Following DeLanda we envisage an information infrastructure as an *assemblage,* i.e. "wholes characterized by relations of exteriorities" (p.10). The basic attributes of assemblages are (DeLanda, 2006):

- An assemblage is a social entity consisting of various types of components, which in themselves may be assemblages. An assemblage allows for interactions between components that are emergent, i.e. mechanisms whose behaviour cannot be explained by the properties of the component. For instance, the growth of an information infrastructure cannot be explained solely by the attributes of the technology, nor by the intentions of its users — but by the interplay of the various elements. The results may be unintended.
- A component is self-subsistent and may be unplugged from one assemblage and plugged into another without losing its identity. This happens for example when a person quits one organization and starts to work for another.
- A given component may play a mixture of material and expressive roles by exercising different sets of capabilities. Assemblages may increase their homogeneity by sharpening its boundaries (*territorialization*) or destabilising it (*deterritorialization*).

In an information infrastructure context we should conceive these structures as semi-stable. They are the result of relatively stable patterns of behaviour over time, but at the same time they are changing continuously, as the result of growth and change. For example, the behaviour of a user community will have some stable patterns (in spite of people joining or quitting), but it may also change its patterns of behaviour in interaction with a new service, at the higher level of assemblage.

3.2. Data collection

The case company, Norwegian Corp, was chosen for two reasons. First, it was a young and successful company, with a reputation for innovation. Second, the company was expanding its initial successful infrastructure of booking services into new ICT-based services, thus constituting a fruitful case to study innovation in infrastructures.

Data collection at Norwegian was conducted during a period of nineteen months during 2008 and 2009. Ten managers and specialists were interviewed, each circa 2 h, some of them twice. See Table 2 for details.

Some work processes were observed by the researcher, each of them for 2–3 h. In addition a large volume of technical documentation (business plans, project plans, contracts, and technical architecture documents) was analysed. The researcher was also a frequent customer of the services of the company during the research period, in order to have first-hand experience.

3.3. Data analysis

A critical realist analysis typically includes the following steps (Easton, 2010; Sayer, 1992, 2000):

- *Identification of events.* In a case study events are often identified by informants, and may appear sequentially. Events have causes, which we want to understand.
- *Identification of entities.* Entities may emerge from data, in a grounded way, or they may be embedded in a theoretical framework. Entities may be organisations, actors or systems, and have causal powers, i.e. they may cause events to occur.
- *Identification of mechanisms.* A generative mechanism is a causal structure that can trigger events. Whether a mechanism is triggered depends on context, i.e. other mechanisms.
- *Validation.* A proposed mechanism should be treated as a candidate explanation, and the data collection and analysis should be repeated until closure is reached.

A key step is the search for mechanisms. According to DeLanda (2006, p.34), we should build our explanations on two types of mechanisms:

- The *micro–macro mechanisms*, which explain the emergent behaviour, i.e. how different components interact in order to produce an outcome at a macro level.
- The *macro–micro mechanisms*, which explains how the whole enables and constrains the various parts.

This analysis is particularly relevant for understanding information infrastructures, because they are multi-level structures (or assemblages). Explaining behaviour in these structures requires sensitivity for what goes on at each level, and how the different levels interact.

The practical search for the mechanisms was conducted in the following steps. First, a time line was established, and important events were identified. Naturally, important business initiatives (such as the

Table 2
Informants at Norwegian.

Date	Informant	Key topic
March 2008	Business developer	Business models for Norwegian
April 2008	CIO	IT architecture and innovation
April 2008	Marketing consultant	Revenue management
May 2008	Bank manager	Establishing Bank Norwegian
May 2008	Sales manager	Innovation processes, internet sales
July 2008	CIO	Culture and management
August 2008	IT project manager	Project culture in Norwegian
Sept 2008	CIO	Call Norwegian project
Oct 2008	IT dept. manager	IT architecture and Call Norwegian project
Oct 2008	Project manager	Call Norwegian project and portal architecture
Jan 2009	Systems director	IT architecture
May 2009	Systems director	IT architecture and Call Norwegian
Dec 2009	CIO	Call Norwegian, business development

launch of a new business service) were seen as key events, but also events relating directly to the growth of the information infrastructure (such as bypassing the travel agencies) were identified as central.

Then the main entities were identified; the key actors and systems were identified, and a comprehensive analysis of business strategy and information infrastructure was conducted, focusing particularly on the interplay between different levels. For example, many interviews had focused on the detailed accounts of how the key actors had moved from ideas to designs and finally to solutions. These suggested causal links were checked, and then a process of forward and backward chaining was conducted. In particular, the researcher tried to investigate the interplay between different levels of infrastructure, in order to understand the causal relationships at work.

From this analysis a pattern, called the *innovation mechanism*, emerged. The mechanism was validated with more project data, and with earlier events at Norwegian. It was found to be consistent with the data, and was also analysed in relation to the other assumed mechanism in the infrastructure, namely the generic growth mechanism (Grindley, 1995). The two mechanisms were analysed as generative patterns of infrastructures, using DeLanda's (2006) framework; going from macro to micro (to explain innovation) and from micro to macro (to explain growth).

To ensure internal validity the preliminary findings were systematically reviewed, and rival explanations were assessed. Findings were also discussed with informants, and paper drafts were sent to key informants for comments. A number of issues were raised in this process, from correcting factual errors to proposing alternative interpretations. This discussion led to several changes to the manuscript.

4. The case study

Norwegian is an international airline carrier based in Norway. Its strong growth started in 2002, when it established a national network, helped by the government deregulation of the airline industry. Today the company has 1300 employees, 85 destinations in Europe and carried 9.1 million passengers in 2008. More than 85% of tickets are sold on the Internet (Norwegian.no). The company has pioneered the Scandinavian low-price airline market, and has been quite innovative. Some important events were:

2002: Introducing low cost airline in Norway
2003: Bypassing travel agencies, by Internet sales and print-out tickets with barcode identification
2004: Introducing the low-price calendar (this was internationally patented)
2005: Dialogue with 85% of customers is electronic
2007: Bank Norwegian is introduced
2008: Call Norwegian (part 1) is introduced
2010: Call Norwegian (part 2) is introduced

In 2007 the company decided to enter the banking market with Bank Norwegian. The CEO Bjørn Kjos commented at the start: "Today we have one of the most visited web pages in Norway, with 2–3 million visitors each month. We aim at coupling this traffic towards bank services." (E24, 4th May 2007). The initiative has been quite successful; in fact so successful that Norwegian will offer a mobile service Call Norwegian, based on the same thinking.

If we look closer at the company parts of the success may be explained by a particular IT architecture. It is illustrated and simplified in Fig. 2. The key elements are the web page for each service, the databases and "the bus." Each service constitutes an information infrastructure, with a number of registered customers. For the airline this is currently ca. 1 million, for the bank around 80,000, while the mobile company was starting up in the autumn 2008. In this paper the focus is on the development of Call Norwegian, as an extension to the established infrastructure.

The architecture allows the company to innovate on an existing infrastructure, in much the same way as Virgin and Amazon (Cai, Chung, & Su, 2008) have done. The traffic on the airline website may be routed to other services at very low marketing costs. Accordingly, extended infrastructure services, such as bank system and mobile system (from external providers) may be linked to the "bus" at low costs and in time windows of opportunity. It is essential that all communications with the customers are electronic, as a combination of web pages and email. Of course, this lowers transaction costs, but more importantly, it makes it much easier to enrol new customers into the infrastructure.

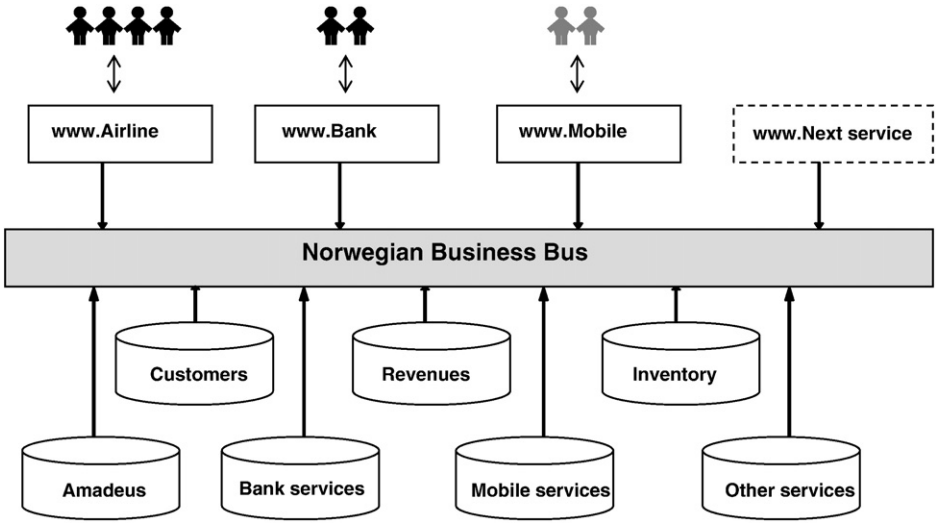

Fig. 2. Infrastructure at Norwegian.

4.1. Call Norwegian

The idea of a mobile company came in 2005, after the initial success of Norwegian. Where do ideas come from?

Said the Director of business development:

> "We had established a very flexible IT architecture, and we realized at the time that it would be possible to innovate new services on this. First we were just brainstorming rather freely; how could a combination of brand and technology generate new business? A GSM operator seemed to have some similarities with airline booking. Later, after the establishment of Bank Norwegian and the reward system in 2007, the idea had matured. We now focused much more on achieving synergies with the airline by providing an integrated set of mobile services for the traveller. We believe that the mobile phone will become more important as a terminal than the PC."

After a board decision in January 2008 a project was established. The main ambition of the project was to establish a number of mobile services:

- A mobile portal, with booking, payment and check-in services, plus content from many providers
- Broadband mobile access at airports and during flights
- GSM mobile services

In March a detailed Request for Information was sent to various telecom vendors, and a series of meetings were held in April. The business model was completed in May, and the contracts with the key vendors signed in August. The project was then organized with 5 sub-projects, illustrated in Table 3. Norwegian organized the project as close as possible to the future operations. The project was run by Norwegian Portal Director, acting as CIO in Call, using hired expert consultants in the planning and development phase.

The Director of Business Development commented:

> "When we started the project the solutions were only sketched out as architectural ideas and financial opportunities. We learned a lot from the meetings with potential vendors and content providers in the spring 2008, exploring a space of possibilities."

Said the Portal Director:

> "We focused on how to make money on new services, analysing which services we should provide ourselves, which we should buy and how they should be integrated. At the same time we are very

Table 3
The Call Norwegian project.

Sub-project	Technology	Responsible in operational phase
Mobile portal	Norwegian solution developed in .NET	Norwegian and partners' services
Airport services	Norwegian solution developed in .NET based on Radius server and infrastructure provided by Call Norwegian and Avinor	Avinor
Billing	NaviBilling by TeleBilling	TeleBilling
Network on board	Not yet decided	Norwegian and partner
GSM network (part 2, in 2010)	GSM	Network Norway

concerned about our architecture; it as an important ambition to maintain it as 'clean' as possible. We don't really go for cutting-edge solutions. Rather, we combine known and stabile components in new ways."

The technical solution is illustrated in Fig. 3. The central element is the Call Norwegian Business Bus and interfaces, and all communications go via the bus, as web services. This also includes communication with the Airline bus (CRM base) and the Norwegian Bank Bus (reward services). Most new services were bought, but a few was developed in-house, such as the purchasing and handling of wireless access at the airports.

The bus serves as a backbone for the various transaction systems such as billing, finance, GSM services, and Norwegian's shared CRM system. It also connects these systems to the sales and service channels, in particular mobile, web and email communications. Technically, the bus is a piece of .net software. It enables the company to expand the number of sales nodes (above) and the service nodes (below). In technical terms we might describe the function of the bus as bridging two different standards; the standards of World Wide Web with the standards of telecom and billing systems. This service oriented architecture allows the company to establish new nodes, and get rid of unneeded ones, in a very short time span, because the services are bought or leased, not developed.

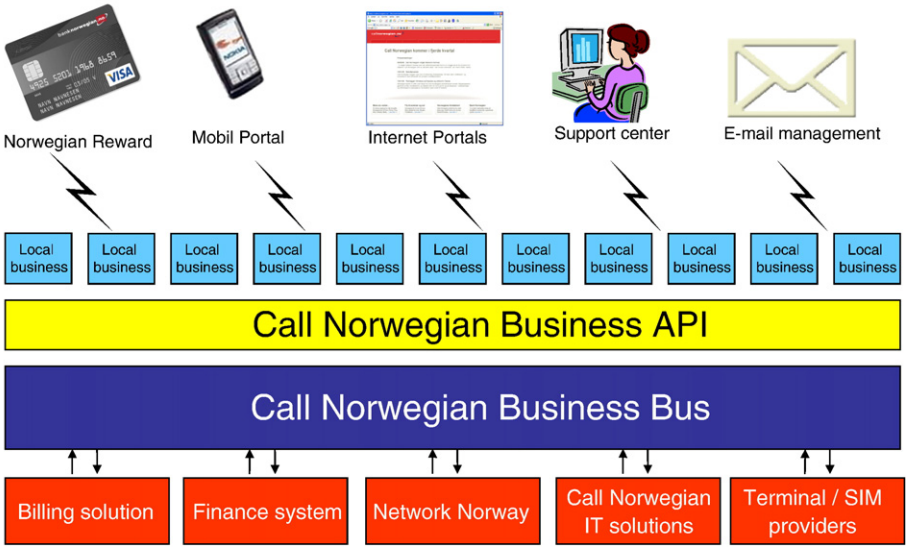

Fig. 3. Call Norwegian infrastructure (courtesy of H.-P. Aanby).

Seen as an information infrastructure we may describe it as a heterogeneous network, consisting of a large number of actors, connected to the business bus.

- Users will access the services via the mobile portal. One minor (but exciting) innovation is using the mobile phone to check-in and boarding, by providing a link to a ticket barcode, which may be read electronically right from the mobile screen.
- The providers of services include TeleBilling, who provided billing, Avinor who provided airport broadband, Network Norway, who provided GSM services, and Norwegian, who provided travel and profile services.
- A large number of content providers, who will provide news and travel information. A potential new service is location and context based information to travellers.

The complexity of integrating these very specialized services may appear large, but the bus structure and web services simplify the technical solutions. This is an ongoing struggle; keeping the architecture "clean", i.e. avoiding direct communication between services (omitting the bus) is essential for the sustainability of the solution. The pressures of project deadlines is obviously a threat to this aim, and the IT architect of Norwegian emphasized that "my first and top priority is protecting the integrity of the bus structure, no matter how important a project deadline is".

More fundamentally, though, in the context of information infrastructure innovation, is which socio-technical mechanisms are active in the extending of this infrastructure?

5. mechanisms for innovating in the infrastructure

5.1. Returning to the research question: how can an information infrastructure provide generative mechanisms for innovation?

Following DeLanda's call of investigation of both macro–micro and micro–macro mechanisms; what we are looking for is a recursive structure of mechanisms. This structure should explain how the information infrastructure is generating innovation, and also how the innovations are modifying the information infrastructure. Further, these mechanisms should be "external", in the sense that their capabilities are not decided from the components' internal properties. For example, an IT architecture may have certain properties, such as being layered. This property is quite important, but it is not a mechanism. A mechanism emerges from the relationship between the IT architecture and some other component, where the IT architecture *plays a role* in a larger context. For example, the IT architecture may allow someone to produce a new service. This does not (in itself) change the layer structure of the IT architecture, rather its ability to play different roles in different settings is more related to its interfaces.

5.2. Macro–micro mechanism

Several of the interviewees used the expression of *space of possibilities*, as the starting point for innovation. What constitutes this space? The respondents gave different answers. Some emphasized the business opportunity by logic of analogy; that a successful service (such as airline booking) is *similar* to the business of a mobile operator. Another informant pointed to the modularization and layers of the IT architecture, while a third informant emphasized the role of external partners in idea generation.

When examined more closely, the space of possibilities more fundamentally has to do with patterns of assembling different components into new services. The point is that these new services emerge through new combinations of components in way that generate a self-reinforcing mechanism. This mechanism was also identified (although at a business level, not service level) by Davenport and Short (1990). It is also a parallel to the *learning mechanism* in information infrastructures, as described by Hanseth and Braa (2001).

We may illustrate this process in Fig. 4.

The established information infrastructure (of Airline and Bank) offered a space of possibilities, constituted of the following elements:

- A large user group (ca 1 million individual customers), represented in the central CRM system
- An IT architecture, where components may be reused

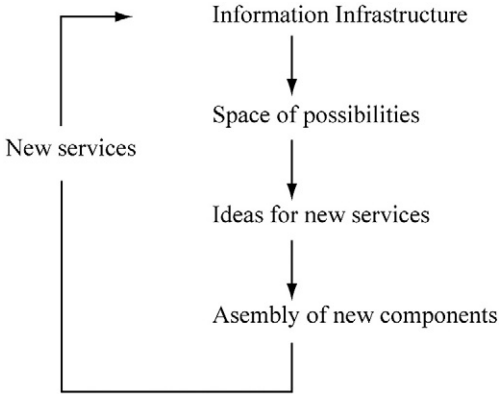

Fig. 4. The innovation reinforcement mechanism.

- A (limited) number of key persons with a thorough knowledge of the dynamics of the information infrastructure, including a strong technical knowledge of the IT architecture.

The next step was to combine these elements into ideas, and from there to assemble the components into new services. More than 30 different companies from telecom and IT were involved in these talks. The Portal Director described the process in these terms:

> "Based on the overall architecture we decided which components to build, reuse, buy or outsource. We involved various actors, such as IT, Sales, Marketing, expert consultants and external vendors. Contracts with vendors were signed and integration specifications made. The design and development process was iterative, producing design sketches, arranging workshops, evaluating new builds, optimizing and testing."

In this description we recognize the findings of Andersson et al. (2008), that inter-organizational innovation requires a demanding set of architectural knowledge. For example, the operator of the billing services had to a) understand the inner workings of both Norwegian's corporate bus architecture and the Telebilling system and b) be able to implement a solution which connects these two resources.

5.3. Micro–macro mechanism

At the end of this process, illustrated with the upward arrow ("New services") in Fig. 4, we find the micro–macro mechanism. As the information infrastructure has generated a new service, this will extend the information infrastructure. Technically, this will in realized the form of a new bus with web service interfaces, a set of new databases and a new set of terminal devices. The extension of the information infrastructure will further include the vendors and operations, and the thousands of new customers.

The extended information infrastructure will increase the space of possibilities. To get the full picture we may extend the figure with another feedback loop, the self-reinforcing mechanism of services.

As illustrated in Fig. 5 the information infrastructure has two self-reinforcing mechanisms. First, there is the innovation reinforcement mechanism, which was described above. At macro (infrastructure) level the result of the mechanism is a new service which extends the information infrastructure. The second mechanism is the service reinforcement mechanism, which is built on Grindley's standard's model, described in the Introduction. The result of this mechanism is more users to the information infrastructure.

The result is also a financial profit, which may be used to invest in more innovation. This closes the double loop. The innovation loop provides new services in the information infrastructure, which in turn (in the service loop) creates more profits. And so on.

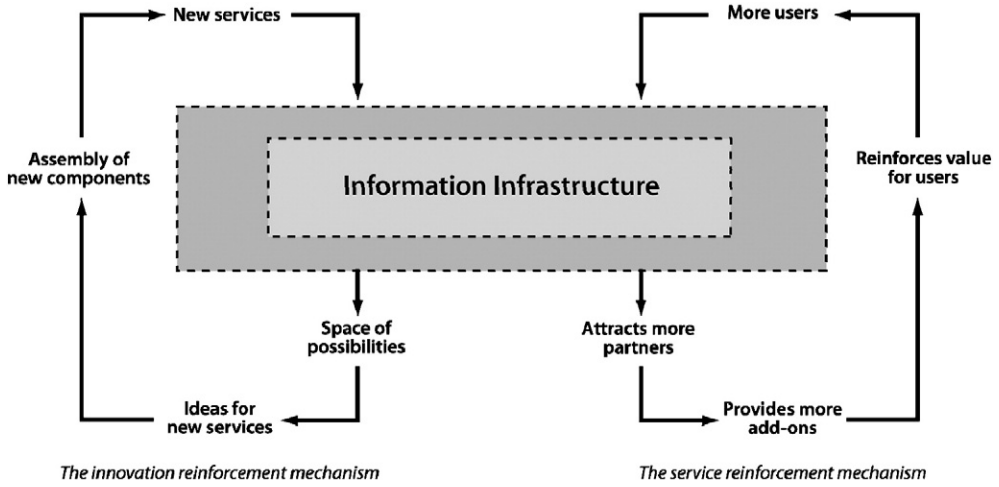

Fig. 5. The double set of self-reinforcing mechanisms of information infrastructures.

5.4. Validation

Arguably, there are a number of other potential mechanisms that might have been derived from the Norwegian case. For instance, one might hypothesize that the *market mechanism* (balancing demand and supply) might explain the innovation of new services, or that *entrepreneurial drive* from key actors was the key. What makes a mechanism more plausible than another? The short answer is that we should choose the mechanisms that offer the strongest explanatory power in relation to the empirical evidence (Sayer 1992, 2000). In the analysis of the Norwegian case, a systematic review of several alternative and rival mechanisms was conducted, including the two suggested above. The result of this analysis was that although several mechanisms are at work, only the innovation mechanism is consistent with the whole data material, including feedback from key informants.

5.5. Implications

The practical implications of self-reinforcing service mechanism have been described by other researchers, in the form of guidelines for information infrastructure design (Hanseth & Lyytinen, 2010). The practical implications of the self-reinforcing innovation mechanism are more elusive, but the case highlights two relevant aspects.

First, a successful information infrastructure constitutes a considerable resource for ICT-based service innovation. The innovation mechanism and the Call Norwegian case, illustrate how these resources may be assembled into new innovations. One should however not interpret this as a friction-free process, because the whole information infrastructure may be set under pressure as it expands, both in terms of IT architectural and business complexity. As described in Section 4.1, there was an ongoing struggle in the Norwegian case, between architectural "cleanness" and short-term business goals, in particular as external components were integrated into the structure. Using DeLanda's (2006) terms, we might characterize it as a struggle between territorialisation (increased homogeneity) and deterritorialisation (destabilising). It remains an open question whether it is possible to maintain the architectural cleanness over time, as more components and partners increase complexity.

Second, as described by Yoo et al. the innovation process in networks is both cognitive, social and non-linear (Yoo et al., 2008). It is cognitive, in the sense that it requires an in-depth architectural knowledge, as described above, and the ability to integrate technical innovation with marketing skills. It is social, in the sense that it relies on trusting a number of independent actors and partners, in order to conceptualize and design solutions. And it is non-linear, because it is an ongoing iterative process. As the Norwegian case shows, the information infrastructure is semi-stable and evolving; some initiatives fail to attract customers,

and some partners are replaced by others. In line with other information infrastructure research (Hanseth, 2007) our findings illustrate that ICT-based service innovation cannot be planned and managed in detail. But the innovation mechanism may help organisations to facilitate the innovation process in a structured way. For IT managers, this implies that is may be more productive to focus on facilitation of capabilities rather than tight project control.

6. Conclusion

This paper investigated innovation in information infrastructures. The research question was, how can an information infrastructure provide generative mechanisms for innovation of ICT-based services? Building on a critical realist approach, the empirical evidence was a case study within an international airline, aiming to diversify its services. From the analysis it is proposed that there are two self-reinforcing mechanisms in information infrastructures.

The first is the *innovation mechanism*, resulting in a new service. This consists of the following steps: A space of possibilities in the information infrastructure architecture and operations creates new ideas for services. Together with external partners these may be developed into innovations, which will be included in the information infrastructure as new services. The new services and components in turn increase the space of possibilities.

The second is the *service mechanism*, described by Grindley (1995) and Hanseth (2002), resulting in more users and profits. The information infrastructure provides a number of cheap and easy-to-use services. This attracts more partners with their add-on services, which increases the value of the information infrastructure, and thus attracts more users. This growth generates a profit which may be used to invest in new innovations. The two mechanisms feed on each other. The service mechanism increases the installed base, which will increase the space of possibilities. This may trigger the innovation mechanism, which in turn will increase the installed base through new services.

There are certainly limitations to these findings. Being a critical realist case study, the findings relate to the mechanisms of the object of study, not to the regularities of events. However, although the proposed mechanisms were carefully identified, analysed and validated, they retain the status of *candidate* mechanisms; to be investigated and (in)validated by further research. This research should study innovation mechanisms in similar or other types of information infrastructures, both to test the validity of the suggested mechanisms and to discover others.

Lastly, a brief comment on the usefulness of critical realism as a methodological approach. The author believes that this approach enhanced the case analysis by giving it more ontological depth. Going beyond the level of events allowed for a more careful analysis of the information infrastructure and the identification of generative mechanisms. In particular, the recursive nature of these mechanisms explains the growth and innovation of information infrastructures in more detail.

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