Overcoming barriers of systemic innovations in a business network

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Abstract Systemic innovations expand the scope of development from certain products and services to complex solutions where complementary innovations are needed to occur at the same time. Intelligent technologies that build upon digitisation and enable remote monitoring and control and related services are an example of systemic innovations transforming manufacturing firms' business logics and requiring the involvement of the business network. The progress and success of such innovations may face various barriers, not only concerning the technology being developed but also the value creation and capture processes of the entire system. This paper explores intelligent technologies as a systemic innovation, identifies transformation-related barriers toward the open systemic innovation and characterises ways to overcome the barriers in a business network. A single-case study with a manufacturing firm and its business network involved the front end of a systemic innovation concerning the creation and development of intelligent materials and related business solutions. The results reveal barriers concerning the market, industry, solution and investments and propose ways to overcome them during the front end, and in anticipation of the back end, of the systemic innovation. The chapter shows novel empirical evidence on intelligent technologies as systemic innovations from a special case. It offers ideas for preparing the network-level changes at the front end of systemic innovations.

1 Introduction

Firms pursuing radical innovations do not settle merely with product and service innovations, but also seek value innovations that may significantly renew the logic of doing business (Berghman et al., 2012; Matthyssens et al., 2006). For example, manufacturing firms may experiment with intelligent technologies that enable the connectedness of products, equipment and entire processes with each other and related services as a possible means for extending or transforming the firm's business logic (Porter & Heppelman, 2014). Such innovations may be systemic, that is, innovations "whose benefits can be realised only in conjunction with related, complementary innovations" (Chesbrough & Teece, 2002, p. 128). In systemic innovations, development occurs throughout the entire system: it concerns not only technologies, products and processes, but also services, supply chains, business logic and even customers and markets. This paper focuses on intelligent technologies as systemic innovations and how they are used to transform industrial firms' business.

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In the case of systemic innovations, firms cannot drive the innovations alone, but depend on the other members in the business network, even though they cannot necessarily control them (Chesbrough & Teece, 2002). The business network includes other organisations, such as suppliers, customers, customers' customers, and various third parties, including software suppliers, consultants, service providers and other stakeholders whose involvement is required for the innovation to create value. While previous research on open innovation has focused mainly on collaborative inventing among the actors in the business network, the value creation and capture processes beyond invention deserve further attention (Chesbrough et al., 2018). As systemic innovations are particularly complex and require the commitment of the business network, their pathway toward value creation and capture in the market can be particularly challenging.

Radical technology shifts imply business logic changes that may threaten existing business models and, therefore, require completely new ways of working for the entire business network (Tongur & Engwall, 2014). New partner firms and collaboration may be needed—even within new industries—to create and capture value from the systemic innovation. Forming the business network and identifying a shared value proposition take place at the front end of the innovation (Reid & De Brentani, 2004; Takey & Carvalho, 2016); this is when ideas for the innovation are created and experimented with, strategies are formed, and before choosing the final solution concept for implementation. The front end of systemic innovations requires specific attention to identifying and coordinating the business network and preparing for the new type of business model in the network, which takes place before planning for the subsequent process phases (Takey & Carvalho, 2016). Previous research has not revealed the barriers and related changes in initiating the systemic innovations sufficiently, and more research has been called for in the domain of intelligent technologies (Tongur & Engwall, 2014).

The purpose of this chapter is to explore intelligent technologies as a systemic innovation, particularly in terms of the barriers experienced at the front end of the innovation and ways to overcome them. The idea is to view open innovation from the perspective of value creation and capture (Chesbrough et al., 2018), focus on stakeholders' experiences during the front end of the systemic innovation, and thereby tackle the emergence of new business logic, instead of focusing exclusively on product-related invention and R&D. The systemic approach of creating value is apparent in business networks and ecosystems as different actors bring their specific resources that need to be integrated into the system (Aarikka-Stenroos & Ritala, 2017). The goal is increased understanding of the implementation requirements of systemic innovations, specifically in the case of an intelligent technology to be adopted in a business network. The focus is on two research questions:

1) What kinds of barriers do stakeholders in the business network experience when involved in defining systemic innovation? and
2) How (i.e., through what kinds of changes) is the systemic innovation initiated in a business network?

The focus is limited to business-to-business (B2B) settings where manufacturing firms deliver products, services and solutions for customers and may drive systemic innovations, intelligent technologies in particular. This choice is motivated by the topicality of intelligent technologies and the systemic nature of their innovations, specifically in B2B contexts. Thus, consumer businesses are purposely excluded. Attention is directed at complex systemic innovations, i.e., situations where multiple innovations occur in parallel and depend on each other. As a contrast to single-firm innovations and firm–customer dyads, the focus is on business networks where multiple firms need to collaborate to define, complete, share and diffuse the innovation.

The chapter next introduces how intelligent technologies have been considered in earlier research and frames them as systemic innovations requiring the involvement of business networks. Then, a case study on a manufacturer moving toward intelligent materials is introduced. The data collection deals with the early phase of a systemic innovation program carried out on the firm's engineering and construction business areas. The results reveal barriers on multiple levels concerned with the innovation and change requirements regarding the front end and in anticipation of the back end, of the systemic innovation. The contributions draw attention to the preparations made at the front end of the systemic innovation that already involves the business network actors.

2 Systemic Innovations in a Business Network

2.1 Digitalisation and Systemic Innovations

Through the increasing digitisation in industries, technologies and products are becoming more intelligent; they are "able to collect, process and produce information and even 'think' for themselves" (Rijsdijk et al., 2007). Companies may use intelligent components in their products (Rijsdijk et al., 2007), for example to acquire information about customers' goals and processes digitally (Weill & Woerner, 2015). They may also enhance their value creation processes through remote technologies and increased information technology support (Wünderlich et al., 2013; Momeni & Martinsuo, 2018), and enhance or complement their core offerings with smart and digitised services and product-service systems (Barrett et al., 2015; Coreynen et al., 2017; Wünderlich et al., 2013). Typically, intelligent technologies may be discussed through concepts such as smart technologies and services (Ehrenhard et al., 2014; Wünderlich et al., 2013), digital technologies (Pagani & Pardo, 2017), digital innovations (Nylén & Holmström, 2015) or digitisation (Coreynen et al., 2017).

Irrespective of the terminological differences, intelligent technologies typically deal with software and sensors embedded in technologies (materials, processes, systems or products) as well as the supportive information and communication technologies. They enable the collection, processing and use of technology and customer information through information systems, and subsequently improve value creation for involved stakeholders (Barrett et al., 2015; Porter & Heppelman, 2014; Rijsdijk et al., 2007). They also create an opportunity to use multiple business logics and channels to meet the customers' needs (Weill & Woerner, 2015). The properties of technology intelligence have been mapped to some extent already, particularly for consumer business (Rijsdijk et al., 2007).

The nature of intelligent technologies is quite all-encompassing – they may deal with the entire business system in a firm. Sensors, information technologies, software, the core manufacturing process, products, and complementary services are inherently connected throughout the system. Therefore, this study considers intelligent technologies as systemic innovations where the benefits of the entire system require parallel development of related additional innovations (in line with Chesbrough & Teece, 2002). Intelligent technologies have the potential to radically change how value is created, experienced, and captured (Davis et al., 2011; Porter & Heppelman, 2014), so they may also be considered as value innovations (in line with Berghman et al., 2012; Matthyssens et al., 2006). The systemic nature of the innovations in intelligent technologies draws attention to the need to coordinate work and cooperate throughout the innovation process. This coordination and cooperation become challenging in inter-organisational business networks, particularly with pioneering technologies that do not have established standards (Chesbrough & Teece, 2002).

2.2 Involvement of Business Networks in Open Systemic Innovations

With entirely new value constellations and business models, systemic innovations may cannibalise existing businesses and require resources and services from other organisations very early, at the innovation front end (Chesbrough, 2003). Involvement of possible partners in the business network could be useful to define, create and deliver the innovation successfully for commercial use. Stakeholders for a manufacturing firm may range from current and future customers; wholesales intermediaries; other material, component, product and service suppliers that offer complementary innovations; and research partners, consultants, and industrial designers, among others. Any of these stakeholders can have their different expectations, goals and contributions (Ritala et al., 2017) in creating the systemic innovation and growing it into a successful business.

The involvement of these kinds of stakeholders is common to open innovation (Chesbrough, 2003; West & Bogers, 2013), which has traditionally been considered from the perspective of technology invention and R&D (Chesbrough et al., 2018). However, in systemic innovations, it is not sufficient to concentrate on a product or technology—value must be considered more broadly, covering the entire system. Ecosystems emerge and evolve based on the stakeholders' voluntary participation, depending on their competencies and aspirations for value creation (Rohrbeck et al., 2009; Weill & Woerner, 2015). Particularly with digital innovations and service-related business logic changes, an ecosystem view with stakeholders' mutual value creation is emphasised (Barrett et al., 2015; Weill & Woerner, 2015), meaning that value creation and capture must be considered for the entire product-service system and all stakeholders involved.

Very commonly, such an idea of openness depends on how a particular firm wants to outsource activities, find external partners, use the partners' resources and capabilities and adopt innovations created by others (West & Bogers, 2013). The joint effort and proactive involvement of other firms in the business network are less frequently covered in the research. The focal firm's perspective is typically taken, in terms of accessing information from partners in the supply chain (Berghman et al., 2012), the firm's capabilities for networking (Eggers et al., 2014; Reid et al., 2015), and collaborating in inter-organisational relationships (Gemünden et al., 2007). As systemic innovations tend to represent radical transformation both for a focal firm and its broader network, any firms in the network will need to change their assumptions and worldviews (Reid et al., 2015), their "orientation" and competencies (Herrmann et al., 2007; also Talke, 2007), and the framing of their search in novel market and technical environments (Bessant et al., 2014). Ritala et al. (2017) emphasise the need to establish good knowledge-search and integration mechanisms to resolve network-level tensions that may emerge due to actor-specific knowledge and goals. Behaviours and attitudes among personnel will significantly affect the firm's capacity to carry out and benefit from their radical and systemic innovations (O'Connor & Rice, 2013).

As the adoption and implementation of intelligent technologies may transform the way that value is created throughout the business network, different firms, both in the supply chain and more broadly in the business network, need to become part of the transformation. While sometimes intelligent technologies are discussed merely from one focal firm's perspective, this study is more concerned with a broader involvement from the business network. Intelligent technologies and related business networks appear in the consumer sector (Palo & Tähtinen, 2013; Rijsdijk et al., 2007; Vendrell-Herrero et al., 2017; Wünderlich et al., 2012) and in the industrial B2B environment that may also be connected with consumer businesses. This study focuses on B2B contexts.

2.3 Challenges in Implementing Intelligent Technologies in Business Networks

Previous research has investigated a variety of systemic innovations, including building information modelling (Alin et al., 2015; Lindgren, 2016), wind turbines (Andersen & Drejer, 2008), multi-storey timber house-building systems (Lindgren & Emmitt, 2017), energy-efficient housing (Mlecnik, 2013), electric vehicles (von Pechmann et al., 2015) and renewable energy (Kang & Hwang, 2016). These studies mostly agree on the challenges dealing with the implementation of the complex, systemic innovations and the significant effects they may have throughout the supply chains. Attention is drawn, for example, to factors relevant to the diffusion (Lindgren & Emmitt, 2017) and scale-up of the innovations (von Pechmann et al., 2015), as well as alignment of interests and sharing of knowledge in the business network (Alin et al., 2015; Andersen & Drejer, 2008; Kang & Hwang, 2016; Mlecnik, 2013). Of these examples, particularly building information modelling contains intelligent technologies in the B2B sector, and in construction in particular. Similar kinds of tensions, challenges of knowledge search, integration and goal alignment have also been identified in R&D networks more generally (Ritala et al., 2017).

Takey and Carvalho (2016) proposed a conceptual framework that sums up the key elements for the front end of systemic innovations. The four main elements in the framework are: mapping of the actors and positions in the network, mechanisms for coordination and collaboration, creation of new business models, and strategic business and venture planning as phases following from the front end. They point out that some practices in the front ends of autonomous innovations may be useful for systemic innovations, too. Concerning intelligent technologies, specifically, previous empirical research aligns reasonably well with the conclusions of Takey and Carvalho (2016), but with slightly different focuses and so far without a specific emphasis on the front end of the innovation. Examples of such empirical research are summarised in Table 1.

Table 1. Examples of previous empirical research concerning the adoption and implementation of intelligent technologies in business networks

Source	Method and context	Finding	Gap, need
Coreynen et al., 2017	Multi-case study, manufacturing SMEs in Belgium.	Reveals different pathways for digitisation (depending on where it is applied in the value chain) and, consequently, types of servitisation and related resource configurations.	Does not cover complex customer-specific solutions and related value delivery.
Ehrenhard et al., 2014	Single-case study and exploratory interviews, smart housing	Maps the primary and secondary actors, their roles and activities in the value network; identification of barriers for market adoption of complex multi-stakeholder technologies.	End-user view dominates; barriers not covered more generally in the (industrial) network.
Eloranta & Turunen, 2016	Multi-case study, large manufacturing firms, platforms for service-driven manufacturing	Reveals mechanisms to leverage complexity and three logics for their implementation: connecting actors, sharing resources, integrating systems.	The focus was on platforms dealing with service-driven manufacturing, not necessarily dealing with intelligent technologies.

Source	Method and context	Finding	Gap, need
Nordin et al., 2018	Single-case study with an SME offering solutions for smart home energy management	Identification of network management capabilities in an emerging smart technology field: context handling, network construction, and network position consolidation	Validation of the framework needed, also in different industries. The focus was on a startup; network management in established firms may be different.
Pagani & Padro, 2017	Multi-case study, five B2B industries	Identification of three types of digitalisation (activity links-centred, resource ties-centred, actor bonds-centred)	Validation and extension of the framework needed, also covering intra-organizational issues.
Tongur & Engwall, 2014	Single-case study, automotive industry	Characterisation of the business model dilemma stemming from a technology shift, consequently challenging the firm's entire logic of business.	The relationships between technological innovation, service innovation, and business innovation deserve further attention. Also, different technologies and industries should be studied.

The business network transformation regarding intelligent technologies is very strongly tied with the idea of service-oriented business models, and the change of these logics creates strategic challenges for the involved firms. The adoption of intelligent technologies may be quite demanding, as the traditional goods-centric logic may need to be replaced or complemented with the logic of services and may require business-wide service transformations (Coreynen et al., 2017; Eloranta & Turunen, 2016; Porter & Heppelman, 2014; Tongur & Engwall, 2014). In support of these findings in the B2B sector, the service-oriented business logic changes have also been experienced in the consumer sector (Palo & Tähtinen, 2013; Vendrell-Herrero et al., 2017).

When companies transform the business model, intelligent technologies will have implications on the configuration of resources (Coreynen et al., 2017) and the use and linkages of digital resources (Pagano & Padro, 2017). In particular, companies may need to consider what kinds of platforms they want to use to leverage the resources from the network (Eloranta & Turunen, 2016). Notably, the involvement of the network actors is affected, requiring the identification of the network actors and their activities (Ehrenhard et al., 2014), defining portfolios of activities for network management (Nordin et al., 2018) and coordination of activities between actors (Pagano & Padro, 2017). Thus, both the resource configurations and the network management may be challenging, as individual firms cannot control their network partners or fully know their interests (also Ritala et al., 2017).

The above empirical studies reveal that intelligent technologies (mainly through digitalisation) may take various paths in business networks. The adoption and use of intelligent technologies may be very challenging, mainly due to the business logic change. Network-level management needs to be considered, and barriers are experienced in various ways. However, the studies most frequently view the obstacles and challenges solely from the focal firm’s perspective and do not acknowledge the other network actors’ viewpoints. In particular, the end-users' adoption of the intelligent technology may face barriers regarding end-users' familiarity with the technology, the lack of standardisation and poor compatibility of technologies and services in the system, the price of the new technology solution, and the lack of support from government and regulations (Ehrenhard et al., 2014). Further knowledge

is needed, particularly concerning very complex solutions, mature firms' networks, both intra- and inter-organisational issues, and various industries.

3 Case Study

3.1 Intelligent Materials for Construction and Engineering Industries

To enable an in-depth analysis of the sophisticated systemic innovation of intelligent technologies in its specific business context, the case study method was adopted as the research strategy. The case study was carried out with a large, international industrial manufacturer, referred to here as MaterialCo. The firm has sales of over 10 BEUR, more than 15,000 employees, and its headquarters are located in Northern Europe. It manufactures metallic raw materials and components and designs and delivers assembled systems and sophisticated solutions to customers internationally. It has two primary market segments—construction and engineering—each served through a dedicated business area in the firm. The engineering business area covers components, products and systems created from the raw materials for other manufacturing firms, and the construction business area delivers structural components and systems for building and infrastructure construction firms. Due to the international market, the company faces similar kinds of market and institutional conditions as its competitors. At the same time, the Nordic home market has an ongoing trend of digitalisation in industries, which created excellent opportunities for experimenting with new technologies.

MaterialCo has been involved in creating an intelligent material to enable storing and communicating information about the material, product and manufacturing process and distributing this information throughout the supply chain for the full lifetime of the material. In this chapter, this intelligent material is used as an example of systemic innovations since it represents a strategic, radical innovation. It would require complementary innovations and involvement of the business network. Already the front end of the systemic innovation required initiating various development and experimentation projects. The firm expected that the number of projects and involvement of other firms would increase over time, thereby increasing the complexity of the innovation task.

The systemic nature of the solution mainly requires innovating all aspects of the material and information flow throughout the business process. MaterialCo could add intelligent features to component materials by various identifiers (such as sensors or radio frequency identification) and use them to enable technology-supported information flows in the supply chains for both business areas. The use of modern information systems and analytics could enable reading, replicating, updating and using the same information across firms involved in the specific supply chain. Delivering value in the business network would require defining new kinds of commercial offerings, sharing information throughout the supply chain and active cross-firm collaboration.

When data for this study were being collected, MaterialCo was exploring the technologies and partner organisations that could be involved in the future commercial business. Therefore, this study deals with the early phase of systemic innovation. The firm later proceeded with the innovation in various areas to the design and testing phases, followed by market experimentation.

Data collection took place within the focal firm and its two market segments in the early phase of the systemic innovation. Interviews were held with 27 people, including selected customer and partner firms in the engineering market (n = 12) and construction (n = 11), and managers within MaterialCo (n = 4). Additionally, we organised four workshops with the

firms involved in the business network and meetings with the contact person from MaterialCo to validate the results and promote the innovation work. The data collection was carried out in DIMECC's (Digital, Internet, Materials & Engineering Co-Creation ecosystem in Finland) research program (Future Industrial Services) and is explained in more detail in Martinsuo (2019).

3.2 Front End of the Systemic Innovation

The early phase of the development at MaterialCo included a visionary phase of strategising and starting new projects to develop and experiment with the technologies and to design intelligence into commercial solutions. The process and structure for the systemic innovation were emergent and informal, and only some technology-related and business-design tasks were specified as separate projects. MaterialCo invited some stakeholder firms to collaborate, co-develop and experiment in some projects to enable the application design and market piloting related to the intelligent materials. As MaterialCo is a market leader in its home markets and has a good reputation, it was in a strong position to pique the interest of potential partner firms to get involved in systemic innovation. These companies in the business network participated in the development work as a result of their interest in growing their business and to achieve a first-mover advantage in the field.

The customer and partner firms had some previous experience with intelligent technologies and were eager to voice their requirements and opinions. Even if the front end of innovation proceeded in an unstructured manner, the stakeholders shared the strategic interests concerning intelligent materials: efficient distribution of material-related data over the supply chain; the possibility for automated as well as manual reading of these data; new information system linkages between firms; and the opportunity to monitor the material/component data throughout the solution's lifetime. The interviewees foresaw a possibility to use modern information technologies proactively, develop a shared platform for information sharing and activate new business for all firms in the business network.

The interviewees anticipated that an advanced version of intelligent materials would imply "self-awareness," increased automation and dynamics in functionalities and processes, and even self-correction capacity. Still, it would take a long time to achieve this. Although the technical readiness was already sufficient, commercialisation of practical solutions would require a lot of development effort. With the slow pace of development in the construction and engineering industries, the requirement of transforming companies' network positions, relations in the supply chain and business models would be risky, not only for MaterialCo and its customers but also for other firms in the business network.

4 Barriers for the Systemic Innovation in the Business Network

Various challenges were discussed concerning the adoption and use of intelligent materials in the business network, mainly dealing with the value creation and capture of intelligent technology. The challenges were first coded inductively with detail and, then, categorised into barriers concerning markets, industry, solutions and investments. As can be seen, the identified barriers do not deal with technology or R&D as such. In fact, many interviewees expressed that the majority of technologies for intelligent solutions are already available. Instead of technical challenges, the value creation and capture for different stakeholders causes barriers. Furthermore, other issues were discussed by the interviewees, but only to a lesser extent. Table 2 summarises some examples concerning the identified barriers, which are discussed in further detail below.

Table 2. Example quotes from interviews concerning the barriers to adopting the systemic innovation

Barrier	Link to value	Example quotes
Insufficient market pull	Mechanisms of value capture among customers	"The customer's buyer never emphasises the positive things [about our solutions], but they'd rather say something about what the competitors do better so that they can get a reduced price. In reality, we should get the feedback from the operators and designers and users, technical people [of the customer firm]." [MaterialCo]
	Perceived threat of (previous) value destruction	"They [customers] really do not have such capabilities [that would be required for these systems]." [construction]
		"The value [of the intelligent solutions] comes indirectly to the customers when utilising the information. But it is difficult to imagine how they understand the value of knowing where the material has come from." [engineering]
		"I guess we all have some sort of resistance to change and fears toward new things if you do not necessarily know what the change means to you." [engineering and construction]
Insufficient industry readiness	Competing solutions for creating the same value	"Well, all firms are competitors, I mean, these machine builders, and it is a severe competition. There is no standardisation whatsoever [in a certain domain], nothing matches between competitors. Every firm wants to keep these applications and interfaces to themselves. It would be the customer's benefit to open up these interfaces [but it is not happening, yet]." [engineering]
	Perceived value of the status quo	"In the construction business, it is often so that 'if nobody else does this, why should we.' And 'this is how we have always operated.' And 'we are doing quite well like this.'" [construction]
Pervasive character of the solution	Systemic nature of value – the complexity of value creation before value capture	"There are still customers that want [systems operating with a traditional logic], with no intelligence at all. The ocean is full of these, so it is impossible to compare the information from intelligent systems to the manual ones [to motivate broader use]." [engineering]
		"Still today we many times face the situation that these interfaces [requiring different companies' collaboration] are not well enough designed, and then we have to ponder what to do. If the project manager would think about them in advance, it would be much easier." [construction]
Investment requirement	Cost of the created value	"Of course, it deals with who has the money, who is going to make the investment. Is that firm getting the benefits or extra value?" [construction]
	Separation of benefits and costs to different stakeholders	"Often in these apartment building sites, it is the grandmothers who think what this costs [and make the decisions]." [construction]

Interviewees expressed **various customer and market-related issues** as the most common potential barriers to adopting intelligent materials and related solutions. They emphasised that all customers are different, different markets demand different solutions, and the specific circumstances of customers would need to be adequately understood to design suitable solutions. Customers were described as somehow reluctant or slow to accept and use the intelligent materials (as opposed to a willing and abile). Interviewees described this, for instance, by doubting customers' knowledge on what they need, the usefulness of the technologies, and ways to benefit from the technologies. Some interviewees described occasions where customers were not able to procure service-enhanced solutions, or they could not utilise the solutions in the right way for their benefit. Customers' actions can even

cause problems if they do not understand the interplay between technical systems and the stakeholders involved in the business network, or if they do not communicate and give feedback on time. Some interviewees also discussed various third parties, such as software and service providers, who were not yet ready or willing to use intelligent systems. In a global industry, the market issues become even more complicated, as customers in the different geographic areas may vary in their technological readiness.

The second most apparent barrier relates to **insufficient readiness at the industry level**. When the intelligent technologies are taken into use, and standard solutions do not exist yet, the tradition in the industry meets the future. Interviewees discussed global competition and the difficulty of getting information about competitors' actions. Still, at the same time, they were also concerned about the threat of confidential information flowing to competitors. The reluctance and slowness (as opposed to interest and willingness) of stakeholders in the industry to accept and use the systemic innovation deals mainly with the complexity of the network and the deeply rooted habits of the industry. Both engineering and construction industries have their established routines, which may be hard to break in a business network. The attitude of "this is the way in which we have always operated" may prevail, and there may be resistance to change. It may even be unclear who should be treated as the customer, and which firms should collaborate to convince customers of intelligent solutions. As all firms have their strategies and expectations, and standardisation has not yet taken place, whose ideas should be followed? Some interviewees described that the complexity of the business network is reflected to structural arrangements within firms in the network. In a new network it is not clear who within the firm should collaborate together and with a specific partner.

Another actively discussed barrier relates to the **pervasiveness of the solutions** developed based on intelligent systems and their necessary interplay with existing legacy systems. The variety of existing systems is already extensive, and when technologies evolve rapidly, firms may be unwilling to take up new systems before they are standardised and well established. The intelligent technologies imply transformations almost everywhere in the business system, and this overwhelming transformation is not easy to absorb. Interviewees discussed the difficulty of communicating the benefits of the new solutions, the ongoing technological insecurities, the invisibility of indirect earnings and the time required for demonstrating the benefits. Also, the need to connect new solutions with old systems was experienced as a challenge, particularly as there are no interface standards, and the solutions may involve different firms in the business network for each customer. With intelligent technologies, each solution has its business network; thereby, all customer solutions require unique approaches and involve unique risks.

Interviewees pointed out the **investment requirements** for all stakeholders concerning intelligent materials. Due to the front-end phase of the innovation, it was not at all clear who would pay for the required investment and how the costs and income would be shared across the network. Many interviewees discussed that the novel earning logics of solutions would change selling routines, and customers' purchase patterns may not yet acknowledge service-oriented procurement. Customers are typically very price-conscious and may find it challenging to compare traditional goods-centric prices to service-centric prices. Moreover, the provision of services is labour-intensive, calling for human resource-related investments. As it is quite uncertain how intelligent solutions are adopted, this can cause significant risks for suppliers.

Furthermore, various other challenges and barriers were discussed, each to a lesser extent. In particular, the service orientation typical to solutions is worth mentioning. As the business logics change toward services, the interviewees felt that the increased person-dependency and the novel earning models could become barriers for customers and partner

firms. The current ways of working, with their long histories, may seem easier and safer, whereas service-oriented logics will require a lot of development and education throughout the business network. Various technical details were also discussed, reflecting the necessity to develop such technical enablers and conditions that make it possible for customers and other stakeholders to benefit from intelligent materials.

5 Network-Related Changes at the Front End of the Systemic Innovation

Most of the required technologies concerning the intelligent materials already exist and primarily need refinement, application development and information solution development to facilitate the novel type of value creation and innovative connections with each other and to be offered as a complete solution. Four themes recurred when discussing network-related changes in initiating the systemic innovation (see Figure 1): foresight of the solution life cycle, changes in the solution design approach, changes to the earning logics, and optimising the performance of the solution for the customers. These themes convey the need for firms to collaborate differently very early on and to anticipate various aspects of the future business over its possible long-life cycle.

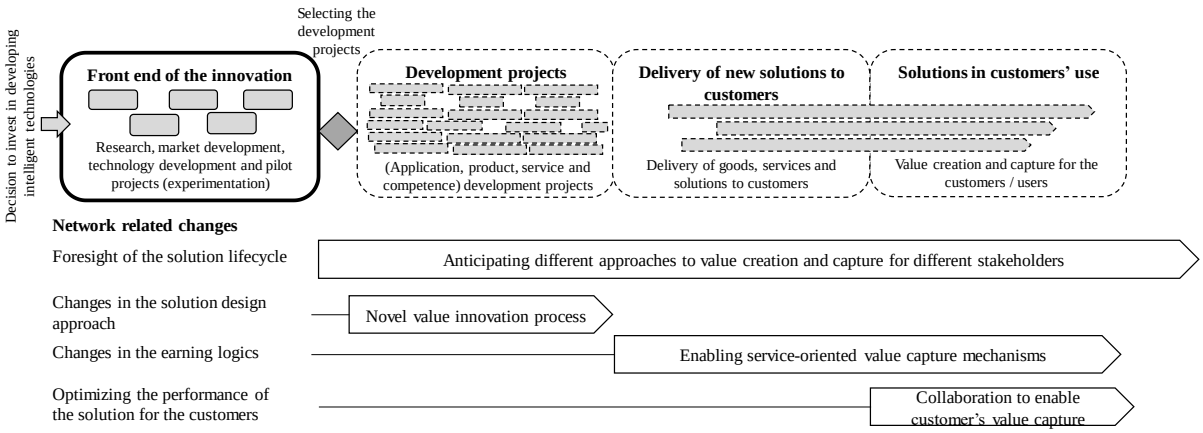

Figure 1. Overview of network-related changes at the front end of the systemic innovation

Some changes dealt with the use of the solution broadly. A few interviewees pointed out the need to develop **foresight of the solution life cycle** much beyond the solution delivery. This life-cycle view emphasises that various stakeholders have their specific expectations of value, that such value is created and captured differently over the value chain, and that the versatility of expectations needs to be anticipated at the front end of the innovation. According to interviewees, the suppliers cannot just concentrate on delivering the solution as cheaply as possible and then forget about it. In reality, they need to understand and foresee the years or even decades of solution use, as the years of solution use will eventually determine the life-cycle costs and benefits of the solution. As one interviewee explained: "A lot of this material can be recycled and re-used. . .. Monitoring of material wear and fatigue in demanding-use contexts will be really useful. And how about material sorting and recycling at the end of life? A lot of small firms have their money tied to these materials, so they would benefit if you could control it better" (construction and engineering). The interviewees anticipated that intelligence was relevant not only during the solution use but also for dismantling and recycling of the materials after use.

Some changes dealt directly with developing solutions using intelligent materials. Many interviewees felt that the entire **approach to solution design is changing** and it should

no longer deal with technical planning only, but also planning of applications, new processes, use and maintenance for the customer. Solution design occurs right after the front end of innovation, and the specific need is to identify the right value propositions for the right stakeholders. Each development project may require its particular value innovation for the complete systemic innovation to become successful. One service provider explained this through an example from their perspective: “If we think about these remote solutions, so far it has been very few instances where the maintenance of the solution has been considered during design and construction. . .. It might be completely new construction, just commissioned, and we [the service provider] start discussing if it is possible to connect this to a remote monitoring system. Then we start to think and invite the contractor back to implement the changes… This collaboration could happen much earlier” (construction). Indeed, the solutions that use intelligent materials are not really in the hands of the focal firm alone; customers and their possible other partners need to be involved during solution design.

Solution development would often also imply **changes to the earning logics** of the solutions. It is possible that product-centric pricing and earning is no longer likely with intelligent technologies but, instead, earning takes place over time, through use and availability. This may imply a service-oriented value capture logic and the need to involve completely new kinds of partners in the business network. In particular, the service-provider firms discussed that the system itself “does not really cost anything,” referring to a very low technology cost. In contrast, the cost of design and installations for remote monitoring, the cost of having unique processes for different customers and alternative costs of on-site monitoring can be substantial. Various firms get involved in such services over time. Interviewees described the possibility of using monthly availability-based pricing or performance-based pricing (e.g., based on energy or material consumption, or based on their reduction due to the remote solution). Still, they also indicated that the company networks create challenges for earning. One service provider offered examples of various stakeholders involved in installing water monitoring systems in construction: “Everybody knows that the maintenance always costs something. But the system itself does not cost much. . .. If the customer wants to follow up their water consumption themselves, someone needs to manage the customer information. What if it is a rental flat? There is a property owner, and there is a facility maintenance firm, people move, users change. . .. This causes certain challenges, legal and other” (construction).

Attention was given to the customer’s view to value, particularly in terms of **optimising the performance of the solution for the customers.** For the systemic innovation to succeed, the business network needs to keep sight of the customer’s value capture when the solution is in use. Many interviewees discussed how the customers could utilise the information concerning the intelligent materials and, consequently, optimise their operations for efficiency, flexibility and customer satisfaction. The ability to follow the material flow on-line, anticipate needs and problems and communicate this information to the right stakeholders may be crucial for the customers' business performance. In many cases, intelligent materials would require that many firms are committed to supporting the customer-specific solutions. "Identification of these materials will be really relevant. It deals with reclamations, the correct use of the material, the location, its history. . .. Sometimes we find that the complaint concerns another firm’s material, not ours” (MaterialCo). The long-term view to solution use introduces novel uncertainties to the business network, as it is not fully known how technologies, customers' businesses and ways of working will evolve.

Customers have not yet been very active in demanding intelligent solutions. However, their willingness to participate in experimenting with the new technologies is relevant and an early step to promoting customers’ solution acceptance. Interviewees offered examples of this kind of experimentation in both market segments. Although customers often want to

control the information flows concerning their products and solutions, it is challenging to anticipate what happens concerning intelligent materials in their use. For example, customers may lack the necessary knowledge and capabilities on intelligent materials and, therefore, they will need the support of other firms, particularly during early experimentation. Some interviewees characterised that intelligent materials will transform the industry, in terms of reconfiguring the stakeholders' relationships, network positions and roles and changing the industrial culture. The interviewees discussed various make-or-buy alternatives since it is not clear which firms will eventually orchestrate the business network for intelligent materials. They also pointed out that novel entrepreneurial firms may take essential positions in the network. The interviewees were not sure which firms would take leadership in the change, or how the networks will be configured. Still, they saw that even alternative network configurations are possible, as long as some focal firms dare to drive the transformation.

6 Conclusions

This study has explored intelligent technologies as a systemic innovation, particularly concerning the barriers and required changes at the front end of the innovation. The qualitative investigation of a single case centred on a manufacturing firm that pursues increased intelligence in its offerings, changing many aspects of its offerings and operations, and also requiring its partner firms to revise their practices, services and processes. With this study, the intent was to understand the implementation requirements of systemic innovations, specifically in the case of an intelligent technology to be adopted in a business network. Systemic innovations are particularly interesting for open innovation research as they not only cover product-related invention and R&D but also more generally renew the logic of value creation and capture for many of the stakeholders involved in the innovation.

The first research question asked, “What kinds of barriers do stakeholders in the business network perceive when involved in defining the systemic innovation?” Where previous research has identified barriers for adopting intelligent technologies, particularly from the end-users perspective in consumer business (Ehrenhard et al., 2014), this study added a broader view of the participating business network. It emphasised the supply chain connectedness, also between industrial and consumer businesses. Similar to Ehrenhard et al. (2014), standardisation and compatibility issues emerged as part of the pervasive character of the intelligent solution as a potential barrier. However, in industrial contexts, the legacy and history of systems cause further challenges, as they may slow the diffusion of the novel systems. Also, the findings revealed barriers concerning markets (insufficient and dispersed market pull), industry (insufficient industry readiness), and investments (investment requirement), thereby suggesting that systemic innovations must be seen at multiple levels, each requiring different actions. The barriers at the front end of systemic innovations need to be seen as **issues to be analysed and resolved** through various actions, within single firms and the business network and in the industry more generally. It is not sufficient to respond and react to adoption and diffusion barriers later in the process; instead, businesses must anticipate them proactively at the front end of the systemic innovation.

The second research question inquired, “How (through what kinds of changes) is the systemic innovation initiated in a business network?” The findings align with previous research in the need for openness, collaboration and networking (e.g. Eggers et al., 2014; Gemünden et al., 2007; Reid et al., 2015), but as a contrast to the focal firm’s perspective (West & Bogers, 2013), the attention was drawn to the proactiveness of various actors in the business network (Barrett et al., 2015; Weill & Woerner, 2015). While previous research has emphasised the general need to align the network actors' interests (Andersen & Drejer, 2008;

Mlecnik, 2013), this study explains what this alignment might mean when anticipating the life cycle of intelligent solutions. Namely, the four recurring themes concerning the changes of systemic innovations deal with the **business design at the front end** and **anticipation of the back end of the intelligent solution**, particularly in terms of the value creation and capture for various stakeholders**.** Changes in the solution design approach and earning logics are issues typically requiring attention at the innovation front end. For systemic innovations, these are multi-organisational issues instead of issues concerning a focal firm only. The networked approach to designing the systemic innovation will have significant implications on the actual innovation project in terms of specifying the roles and responsibilities within the network, configuring the entire network, specifying the value propositions for each participating stakeholder and cost and profit-sharing. In this way, this study has offered empirical evidence concerning some of the issues covered in the conceptual analysis of Takey and Carvalho (2016).

Foresight of the solution life cycle and optimising the performance of the solution for the customers dealing with the backend of the innovation (i.e., the use of the innovation after the innovation project) need to be anticipated when planning the systemic innovation. These, too, were discussed as networked efforts requiring the joined forces of firms in the business network. As the value creation and capture for stakeholders occurs differently over the solution life cycle, the anticipation of the life cycle draws attention to knowledge availability, search and integration (Ritala et al., 2017). What knowledge is available about the customers' and other stakeholders' operating conditions *in the future*, when the solution is in use*?* While knowledge processes between stakeholders were purposely not investigated in this study, the findings revealed inherent uncertainty concerning the solution life cycle, outlining challenging conditions for the pursued life cycle foresight and inviting future research.

Besides these themes, the findings emphasised that the systemic innovation required the reconfiguration of stakeholders' involvement and relationship, possibly changing the industrial culture and landscape. While previous research has discussed the transformation in the business logic through intelligent technologies in other contexts (Tongur & Engwall, 2014), this study offers further insight through the versatile usage options of the intelligent materials without restricting the analysis to a particular industry.

Qualitative single-case studies seek understanding of a selected phenomenon in a specific context. This case study is limited through the choice of the focal firm and its business network, as well as the choice of intelligent materials as an example of systemic innovations. To facilitate learning from the case, an extreme and informative case was purposely chosen, and its background and features have been characterised.

Empirical research concerning systemic innovations, in general, and intelligent technologies, in particular, is still young. This encourages scholars to explore different types of systemic innovations in different contexts more broadly. Forthcoming research should not only cover innovation management and diffusion and network management but also more fine-grained aspects of the innovation process. The findings in this study, for example, draw attention to the design of the systemic innovation and the anticipation of the life cycle of the solution as issues that have not yet been covered sufficiently. This study has also emphasised the different levels of analysis concerning the barriers: solution, firm, market and industry. All of them may open up novel avenues for further research concerning the ways that the barriers can be overcome and how systemic innovations could be promoted.

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