

Standardization as a Catalyst for Extending Resources and Capabilities in Service Systems Engineering: Findings from the omlox case

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(Smart) service systems have inspired the emergence of a new research area that builds on smart, connected products and networked business models with smart services and brings together various social-science and technological disciplines. However, the factors that lead to successful service systems engineering initiatives have remained underexplored, despite their increasing significance in industry. In particular, the role of standardization is unclear, even though it seems to be central to making smart products interoperable and to establishing innovative (smart) service systems. In an exploratory case study of the standardization initiative omlox, we set out to identify and investigate empirically the effects that standardization can have on engineering (smart) service systems. Our focus is to determine how standardization can assist a company in accessing external resources and capabilities for recombinant service innovation. The results reveal that compliance with a standard enables companies to tap into compatible solutions, data, and knowledge from external stakeholders and that participation in standardization initiatives can be a platform for identifying potential collaboration partners.

We conclude that standardization plays a major role in all phases of service systems engineering, from analysis to design and implementation.

1. Introduction

Surprisingly often, innovation is a recombination of existing solutions (Beverungen et al. 2018; Wiesböck and Hess 2020). Early on, Schumpeter (1934) established the theory of recombination, according to which a solution can be innovative “even if the content of the innovation looks or sounds familiar” (Cooke 2016, p. 1496). Since then, recombinant innovation has been investigated and applied in numerous contexts (Gallouj and Weinstein 1997; Hargadon and Sutton 1997; Zeppini and van den Bergh 2011; Cecere and Ozman 2014; Waltermann and Hess 2020; Saldanha et al. 2020).

Two intertwined themes currently drive recombinant innovation in industrial companies: First, technological advances have enabled an Industrial Internet of Things (IIoT)—the connection of (smart) physical things via communication technologies—to emerge (Yoo et al. 2010; International Telecommunication Union 2012; Wortmann and Flüchter 2015). With such advanced technologies, recombination has gained momentum in innovation research (Yayavaram and Ahuja 2008; Corrocher and Zir-



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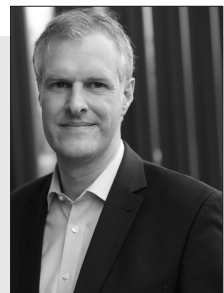
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ulia 2010; Schilling and Green 2011; Barnett 2011; Gruber et al. 2013; Guan and Yan 2016). Second, increasing numbers of service-related products by industrial companies (servitization) (Vandermerwe and Rada 1988; Bustinza et al. 2015), fueled by the increasing importance of the service sector to the economy (de Vries 2006; Probert et al. 2013; Chang and Chen 2016), has shifted the emphasis of recombinant innovation in terms of outcomes. While product innovation has a long tradition in research, service innovation has become a research topic in its own right (Perks et al. 2012; Witell et al. 2016; Chang and Chen 2016), while service systems engineering (SSE) (Böhmman et al. 2014) particularly focuses the study of service innovation that refers to the IIoT.

SSE views service from a socio-technical perspective and focuses on service innovation as an innovation process; the term “service innovation” can also be used to describe the outcome of an innovation process (Toivonen and Tuominen 2009; Witell et al. 2016). (Smart) service systems, as the main unit of analysis of SSE, is a new research area that brings together various social-science and technological disciplines (Beverungen et al. 2019a). In service systems, value is co-created by multiple actors who share and recombine their resources and form complex service exchange networks (Blau et al. 2009; Badinelli et al. 2012; Böhmman et al. 2014; Lusch and Nambisan 2015). A smart service system is a type of service system in which smart products are used as boundary objects (Beverungen et al. 2019b) to enable and facilitate context-based services and co-creation (Becker et al. 2013; Böhmman et al. 2014). Boundary objects are “objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites” (Star and Griesemer 1989, p. 393). Boundary objects can take any tangible or intangible form such as technical interfaces and tools, documents and models for development, and trade fairs and events (Petrik and Herzwurm 2020). Smart service systems refer to the IIoT since boundary objects can be physical devices that are digitally networked with other devices and information systems.

Over time, boundary objects become standardized, providing an infrastructure for participation (Hein et al. 2019) and becoming a basis for complementary innovation (Pauli and Lin 2019). Research on standardizations’ effect on innovation has focused on outcomes like economic growth (Ernst et al. 2014; Blind et al. 2018), commercial success of new products and services (Egyedi and Sherif 2010; Wiegmann et al. 2017), companies’ innovative capacity (Baron et al. 2014; Blind et al. 2017) environmental issues (Palmer et al. 1995; Porter and Linde 1995), and product and process quality (Dranove and Jin 2010; Mangiarotti and Riillo 2014). However, the micro-economic rationale for understanding the impact of standardization

on innovation and firm performance has been neglected so far (Foucart and Li 2021). In particular, how standardization affects a company’s service innovation process and whether developing standards should be actively integrated into (smart) SSE methods are areas that remain unclear.

We set out to examine the role of standardization in SSE, guided by two research questions: *How does complying with standards affect SSE?* and *How does participating in standardization initiatives affect SSE?* We answer these questions in an explanatory case study of the standardization alliance omlox¹. In addition to participation in the four-day omlox go-live event and extensive analysis of documents, we conducted nineteen semi-structured interviews with participants from companies that are actively involved with omlox. We used the SSE method proposed by Beverungen et al. (2018) as a conceptual basis for organizing and interpreting our data in the context of SSE since this approach includes patterns for recombinant service innovation (Beverungen et al. 2018).

This paper entails three major contributions: First, we contribute new insights into how standardization affects service innovation processes. Based on the omlox case data, we illustrate how both the resulting standard itself and participation in a standardization initiative gave the omlox participants access to external resources and capabilities that they used to augment various phases of their SSE initiative. Second, we provide empirical evidence on how the recombination perspective helps to clarify how service systems are engineered, and on the applicability and utility of the recombinant SSE method. Thus, we strengthen the promising but underdeveloped discourse on recombinant innovation in SSE (Beverungen et al. 2018; Li and Peters 2019). Third, we inform practitioners that standardization can be used for more than interoperability; since it can foster innovation it should be part of the innovation agenda. Our study maps experiences from more than sixty companies that have already been influenced by standardization, providing practitioners with a high degree of confidence when embarking on new strategic paths.

The rest of the paper is organized as follows. Section 2 reviews the theoretical foundations of recombinant innovation and (smart) SSE and discusses standardization’s role in innovation projects. Section 3 presents and justifies our research method, while Section 4 presents a case description and provides empirical results in terms of an SSE project. In Section 5, we discuss how standardization affected SSE in the case of omlox, and Section 6 concludes the paper.

1 Homepage of the omlox initiative: <https://omlox.com/home>

2. Research Background

2.1 Recombinant Service Innovation and Service Systems Engineering

While product innovation relates to the invention or improvement of an artificial object's features and attributes, service innovation focuses on co-creating superior value for benefactors and beneficiaries (Lusch and Nambisan 2015). At its core, service innovation is about improving the use of operant resources—the knowledge and skills—of the stakeholders involved in value co-creation, while physical objects, as operand resources, are physical manifestations of knowledge and skills (Sirilli and Evangelista 1998; Hipp and Grupp 2005; Vargo and Lusch 2008; Gallouj and Savona 2009). Focusing on value co-creation, service innovation is characterized by the central involvement of customers and external business partners in developing new value propositions and creating value (Gann and Salter 2000; Fosstenlökken et al. 2003; Dougherty 2004; Mina et al. 2014; Engel and Ebel 2019). While value co-creation has often been described as a dyadic interaction between a service provider and a customer (Lusch and Nambisan 2015), recent research takes a network or (eco-)system perspective (Frey et al. 2019), considering multiple actors as resource integrators that provide access to their operant and operand resources and access the resources provided by others (Vargo and Lusch 2008; Lusch and Nambisan 2015). For this reason, service innovation refers to orchestrating resources and activities in a service system involving multiple stakeholders (Chandler and Vargo 2011).

Given its conceptual focus on the integration of resources, service innovation is closely in line with the principles of recombinant innovation (de Vries 2006; Mina et al. 2014), which is based on the view that most innovations are based on recombining resources that were previously uncombined (Cooke 2016), as few innovations are fundamentally new (Wirth et al. 2015). An innovator today has access to an almost infinite number of pre-existing solutions that can be tapped into as resources, so there are virtually no limitations on the recombination process (Stuart and Podolny 1996; Fleming 2001; Keijl et al. 2016).

Recombinant service innovation can involve three fundamental mechanisms: dissociation, association, and addition (Beverungen et al. 2018). Dissociation describes splitting up an existing solution, isolating specific features, and transforming these elements into new value propositions (Gadrey et al. 1995; Cecere and Ozman 2014). Association refers to the development of a new value proposition through the combination (or association) of two or more existing elements (Fleming 2001). Addition refers to the introduction of a new element to an existing solution, resulting in a new value proposition (Tsur and Zemel 2007). Beverungen et al. (2018) proposed an agile method for SSE that includes all three mechanisms. This method consists of three phases: service system analysis, service system design, and service system transformation (cf. Figure 1). (A detailed list of the method's activities is presented in Appendix A.) The method was revised and extended as DIN SPEC 33453, published by the German Institute for Standardization (DIN) (DIN Deutsches Institut für Normung e.V. 2019).

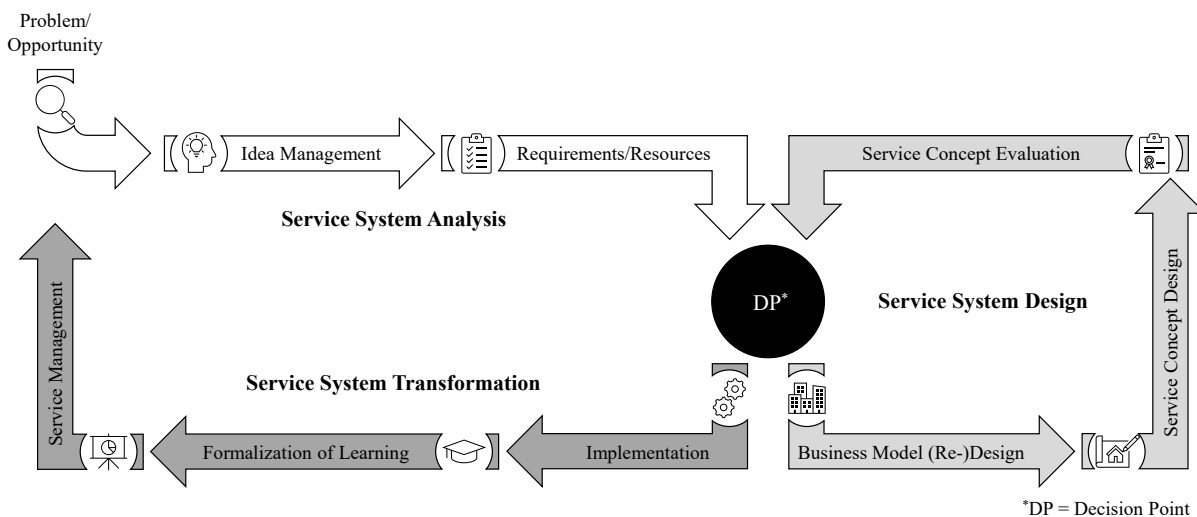


Fig. 1: Method of recombinant service system engineering

The need to understand recombinant service innovation has increased since the emergence of digital technologies “has dramatically boosted the number and accessibility of

resources” (Beverungen et al. 2019a, p. 2), creating additional opportunities for recombinant innovation (Yoo et al. 2010; Guan and Yan 2016). Digital technologies are

reprogrammable—that is, their functions can be changed and adapted to new contexts (Waltermann and Hess 2020)—and digital content can be stored, transmitted, processed, and displayed on any digital device (Waltermann and Hess 2020). These two properties facilitate decoupling content from physical media (i.e., resource liquefaction) so resources are available for recombination (Barrett et al. 2015; Lusch and Nambisan 2015). Digital technologies use smart products as boundary objects to establish smart service systems (Beverungen et al. 2019b) that can then provide new ways for stakeholders to integrate these resources.

Recombinant innovation requires the actors involved to store and access a diverse set of resources, process them internally, and recombine them with other resources in a new context (recombinative capability) (Carnabuci and Operti 2013; Cecere and Ozman 2014; Bessant and Trifilova 2017). Specifically, complex innovation requires a broad set of operant resources, such as knowledge and skills, that might be found externally (Bayona et al. 2001; Tether 2002; Piga and Vivarelli 2004). Service systems that can access and recombine a wide variety of operand and operant resources are more likely to generate innovative solutions (Gallouj and Weinstein 1997; Weitzman 1998), absorbing external resources through access (without transferring ownership) or by taking over the resource (transferring ownership) (Breidbach and Maglio 2015). These mechanisms suppose that all actors can overcome cognitive disparities and integrate and absorb resources efficiently (Cohen and Levinthal 1990; Beverungen et al. 2018).

2.2 Foundations of Standardization

Standardization is an essential part of research because of its substantial role in digital technologies' evolution (David and Greenstein 1990; Keil 2002; Nelson et al. 2005; Lyytinen and King 2006; Weitzel et al. 2006). Especially with the appearance of smart products and smart services, standards are often missing, even though their definition of common interfaces is of critical to cooperation between actors (Bongers et al. 2019). Generally, standards are intended to create interoperability between products, services, or other standards (Nelson et al. 2005; Lyytinen and King 2006), referring to a system's or a process's ability to exchange and use information or functionalities from other systems (Vernadat 2006). Organizations can alter the degree of interoperability on a technological level (e.g., architecture and infrastructure of IT), a conceptual level (e.g., syntactic and semantic differences of information exchange), or an organizational level (e.g., human and organizational behaviors) (Chen 2006; Vernadat 2006; Chen et al. 2008) to achieve consensus among actors in the ecosystem. Likewise, finally established standards prevent markets from fragmented solutions

(Keil 2002), reducing market uncertainty and prices (Funk and Methe 2001). As a result, standards are often seen as innovations themselves and, at the same time, as a vital foundation for further innovation (Serhan and Kabèche 2017).

However, this relationship between standardization and innovation cannot be assumed to apply in all cases. As Blind et al. (2017) demonstrated, the influence of standardization on innovation depends on whether standards are voluntarily developed and adhered to collaboratively by market participants (formal standards) (Gupta and Lad 1983; Leiponen 2008) or developed and enacted by authorities like governments (regulations) (Blind 2012), and whether they are employed in a market of high or low uncertainty. In relatively stable markets, regulations have a positive effect on innovation (costs), and formal standards have a negative effect (Blind et al. 2017). In uncertain markets, this effect is reversed. Because of the technological complexity of digital technology and the high level of competition (Jalonen 2011; Sainio et al. 2012; Blind et al. 2017), digital technologies operate in a highly uncertain market and would benefit only from formal standards.

The standard development process can be market-based, committee-based, or a combination of the two in variable proportions (multi-mode) (Farrell and Saloner 1988; Wiegmann et al. 2017). In market-based standardization, single or multiple companies introduce competing solutions to the market, leaving their acceptance and distribution to the market (Farrell and Saloner 1988; David and Greenstein 1990; Besen and Farrell 1994; Funk and Methe 2001; Keil 2002). These solutions fight for market dominance and the winner often establishes itself as a standard (de facto standards). In committee-based standardization, a committee agrees on a standard that is introduced to the market afterward (de jure standards) (Farrell and Saloner 1988; David and Greenstein 1990; Besen and Farrell 1994; Funk and Methe 2001; Keil 2002). Committee-based standardization can be further differentiated (David and Greenstein 1990; Blind et al. 2017) based on whether the standards are developed by specialized standardization organizations like the European Telecommunications Standards Institute (ETSI) or the Institute of Electrical and Electronics Engineering (IEEE) (in which the market participants affected are often involved) or regulatory authorities like government agencies.

Engaging in the process of creating formal standards can help organizations distribute research and development expenditures, identify the simplest and most straightforward solution to a problem (Nelson et al. 2005), and reduce transaction costs (Nadvi and Wältring 2002). With such benefits and the increasing importance of digital technologies, standardization has become a form of

strategizing (Keil 2002). Organizations that participate in creating standards can gain competitive advantages and send positive signals to the market about their expertise (Lyytinen and King 2006). In contrast, organizations that support the wrong standards might get locked out of the market (Keil 2002; Lyytinen and King 2006).

Standards can also facilitate understanding and interaction between actors in a service system. Creating a common understanding and consensus between actors, especially those from diverse social backgrounds, is often challenging (Star and Griesemer 1989). Star and Griesemer (1989) introduced the concept of boundary objects to bridge these disparities, as they provide a joint structure while allowing each actor to adapt the object to their individual purposes. Initially, boundary objects are characterized by a certain degree of vagueness and flexibility, which can create obstacles to using them (Steger et al. 2018). Later, users agree on a set of rules or definitions, also known as standards, to achieve consensus (Star 2010), which usually lead to an infrastructure that limits a boundary object's flexibility (Weitzel et al. 2006). Thus, an infrastructure is a tool that is linked to activities and structures and invisibly supports a community of practice (Star and Ruhleder 1996; Pipek and Wulf 2009). However, not all boundary objects are integrated into infrastructure. Undefined boundary objects end up in residual categories, which outsiders often use to create new boundary objects (Star 2010).

Service innovation, particularly the field of platform research, has adopted the concept of boundary objects to describe the relationships between a service system's actors (Ghazawneh and Henfridsson 2013; Hein et al. 2019). Boundary resources are used to align platform owners' control with users' design capabilities, enabling third parties to create a diverse set of new value propositions by recombining the boundary resources provided and the actors' internal resources (Ghazawneh and Henfridsson 2010, 2013; Petrik and Herzwurm 2020). Hence, platforms are often considered as having a high degree of generativity, which is defined as the "capacity to produce unanticipated change through unfiltered contributions from broad and varied audiences" (Zittrain 2008, p. 70). Boundary resources are continuously shaped and reshaped through distributed tuning, which includes accommodations and rejections by the ecosystem actors (Eaton et al. 2015). In such ecosystems, where actors must regularly adapt and learn, standards become an essential part of the architecture since they can decrease uncertainty for other actors in the ecosystem and reduce cognitive disparity (Lusch and Nambisan 2015). Thus, balancing the amount of platform owners' control with third parties' degree of autonomy (Tiwana et al. 2010) can lead to the desired level of generativity and innovation (Pauli and Lin 2019). Despite the more advanced state of current research, the question

remains as to how standards affect the service innovation process itself.

3. Research Method

3.1 Case Description

As the field of open standards and the development of standards in the context of smart SSE is relatively new and evolving, we conducted an exploratory single case study (Walsham 1995; Klein and Myers 1999; Yin 2018). Case studies are particularly suitable for the underlying research question, as the standardization process is of high economic interest to companies in the industrial indoor-locating business that cannot be studied outside their natural setting, and the process of developing a standard is time-consuming but unique, forcing the study to focus on contemporary events that are not repeatable (Benbasat et al. 1987). Case selection and analysis followed a theoretical sampling approach (Glaser and Strauss 1967). To meet our research objective, the case had to be that of an initiative that developed an open standard that affects all horizontal layers of a typical smart service system. We chose the omlox initiative as a suitable case.

The omlox initiative is an ecosystem of companies that work together to specify an open standard, which enables interoperability between localization-related systems in the context of the IIoT. More than sixty companies with various business models, including pure sensor or machine manufacturers, software providers, consultancies, and companies that provided complete IIoT solutions, were involved in the development process. Within two years, they developed the omlox standard, which specifies how companies that provide or use location data can adjust their products and services to guarantee the interoperability of their systems. To reach this goal, the companies worked together in short, rhythmic cycles, regularly introducing their use cases—the initiative received over 100 use cases—and discussing their ideas, bringing them to life through prototypes, and testing their interoperability at specifically designed test sites. After the standard's release in mid-2020, the omlox initiative handed the specification over to an independent standardization association for its further management and distribution.

Participating companies were identified as a functional unit of analysis since they were involved in SSE processes, either by developing service systems entirely by themselves or by being part of another participator's SSE procedures. The cases also offered a wide variety of company types, which facilitated the results' generalizability. In addition to small and medium-sized enterprises (SMEs), large corporations that exceeded 250 employees

or operated in multiple countries were involved in creating the standard. With the standard's having been launched in the middle of the study, the research took place at the beginning of the standard's lifecycle.

3.2 Data Collection and Analysis

We collected data in nineteen semi-structured interviews with informants from seventeen companies, conducted between May 2020 until August 2020. Informants' positions varied widely, but all were mainly involved in the omlox standard-creation process, which was the central consideration for participation in the study. Each interview was conducted following Myers and Newman's (2007) recommendations for qualitative interviews. As Walsham (1995) and Yin (2018) recommended, an unbiased and non-judgmental form of listening was used. In addition, a 21-minute unstructured interview was conducted with a board member of the managing standardization association to develop a deep understanding of standardization associations. Table 1 provides informa-

tion about the informants. Since anonymity was guaranteed, their positions and organizational descriptions are generalized.

The interviews lasted between 37 and 99 minutes, with an average length of 57 minutes and a median length of 56 minutes. The questionnaire was designed and repeatedly examined for target orientation, understandability, transferability, and completeness by the entire research team. Its first part consisted of questions about the informant, his or her company, and existing relationships to the standardization initiative to ensure the informant's significance in the investigation. What followed were questions about the omlox initiative, including its function as an ecosystem. Subsequent questions concerned the effects that the standard had on the company's SSE. The last part asked the informants about the standard's significance in terms of innovation and generativity. The researchers who were involved in the fieldwork conducted a pre-test to ensure its comprehensibility.

Tab. 1: Overview of interviews

#	Organization Description	Organization Size (employees)	Use Case		Duration
			Provision	Position of Informant(s)	
1	Software Provider	< 1,000	Active	CEO	0:56 h
2	IT Services & Consulting	> 10,000	Active	Product Manager	1:16 h
3	Sensor Manufacturer	> 10,000	Active	R&D Group Lead	1:04 h
4	Machine Manufacturer	< 50	Active	CEO	0:55 h
5	Machine Manufacturer	< 10,000	Active	Innovation Manager	0:56 h
6	Software Provider	< 50	Active	Project & Process Manager	1:12 h
7	Software Provider	< 50	Active	Product & Sales Manager	1:30 h
8	IT Consultancy	< 10,000	Active	Business Developer	0:58 h
9	IT Consultancy	< 10,000	Active	Head of Industry Solutions	1:35 h
10	Machine Manufacturer	> 10,000	Active	Head of Business Development	0:56 h
11	Software Consultancy & Vendor	< 50	Active	CEO	0:37 h
12	Consulting Laboratory	< 1,000	Active	Engineer	0:53 h
13	Machine Manufacturer	< 1,000	Passive	CEO	0:49 h
14	Industrial Navigation Specialist	< 50	Active	Head of Business Development	0:40 h
15	Software Provider	< 50	Active	CEO	0:47 h
16	Machine Manufacturer	> 10,000	Active	Project Manager	0:45 h
17	Sensor Manufacturer	< 50	Active	CEO	1:09 h
18	Machine Manufacturer	> 10,000	Active	Product Manager	0:56 h
19 + 20	Sensor Manufacturer	< 10,000	Passive	Head of Development IoT + Head of Development Technology	0:44 h
21	Standardization Association	< 50	Inactive	Board Member	0:21 h

The second part of data collection involved participation in the four-day omlox go-live event at the end of June and the beginning of July 2020, which gave the

researchers a broader and more detailed understanding of the standard's possible applications and challenges through direct observations. Speakers included the inter-

view partners and other participants in the initiative who explained how their companies could integrate and use the standard to their benefit. In addition, deep dives by multiple experts provided insights into the standard's relevance to industry. Gathering data in the form of such interactive webinars gave the researcher an additional opportunity to raise questions and observe the initiative from various perspectives. Critical statements were noted for further analysis.

Our data also included extensive documentation about the creation process, including the final specification of the standard, the use cases, and technical presentations. While the specification and technical presentations helped to clarify the standard's mode of operation and its implications, use cases illustrated the participating companies' interests in the standard. More than 100 use cases were collected throughout the standard's development process, each representing a participant's requirements for the standard's final version. While some companies engaged actively in providing use cases, others were more passively involved, focusing on the benefits such implications might have on their operations, products, and services. The documentation comprised 208 pages; with the interviews and the event participation, they ensured a necessary degree of triangulation (Flick 2014; Yin 2018).

For the final data analysis, we adopted the approach Corbin and Strauss (2015) proposed to establish a theory across cases that was founded on assertive and argumentative interpretations. The concept of theoretical sampling turned out to be indispensable to the whole analysis. Each interview was transcribed and analyzed to inform potential readjustments in the questionnaire for upcoming cases until no new information were gained by further data. While we were guided by the high-level method of recombinant SSE that Beverungen et al. (2018) proposed, we theorized using an inductive approach on a micro-level (Birks et al. 2013). With this modified but accepted form of inductive approach, we could examine the typical phases of a service innovation process (Birks et al. 2013).

The coding took place in three subsequent stages (Corbin and Strauss 2015). First, all transcripts were examined with open coding line-by-line to identify and describe underlying concepts while assigning them to more abstract categories. Axial coding was then used to refine and bring these categories into relationship with each other. Finally, selective coding was applied to include context and derive the work's theory. Throughout the coding, explanations and examples from Mayring (2015) and Saldaña (2016) were used for guidance. The analytical process was repeated until confidence and saturation were established (Corbin and Strauss 2015). In line with

Eisenhardt (1989), the process of collecting and analyzing data was highly iterative and executed with great care (Yin 2018).

4. Results

The standardization initiative omlox was formed to develop an industry-wide specification that providers can incorporate to engineer interoperable service systems. Companies worked together in short, rhythmic cycles, regularly introducing their use cases, discussing their ideas, bringing them to life through prototypes, and testing their interoperability at specifically designed test sites. The initiative received over 100 use cases that resulted in the final specification. Below we present our findings in terms of effects of standardization on the SSE method proposed by Beverungen et al. (2018). Participating in the standardization initiative offered input for a company, thus influencing the SSE, while complying with the resulting standard influenced the outcome of the SSE. Figure 2 offers an overview of the effects.

4.1 Service System Analysis

4.1.1 Step Problem/Opportunity

Employees involved in the standardization process returned to their organizations with valuable information and insights from the standardization initiative that can be used during a company's smart SSE to develop efficient and interoperable service systems. Those inputs bridge the gap between the standardization initiative and the corporations' SSE. We found four effects of how participating in standardization initiatives influences SSE in the step problem/opportunity: market and technological knowledge, the formation of collaborations, an additional data source, and access to plug & play solutions.

By providing a unique platform on which organizations could interact with each other, transfer information, and use for their own SSE, an ecosystem of companies that is active in a diverse set of business areas evolved around the omlox initiative, enabling each company to acquire market and technological knowledge from the others. Thus, participants came to understand more about ultra-wideband, one of omlox's core technologies, but they also found out whether customers demanded certain product features of other organizations.

"If I sit down and engage with omlox today and they give me input and then I give input to the hardware manufacturer again, and the hardware manufacturer again gives input to omlox, then a network is formed, where all people learn from each other." – Interview 7

A large majority of the informants pointed to the formation of unprecedented collaborations that they estab-

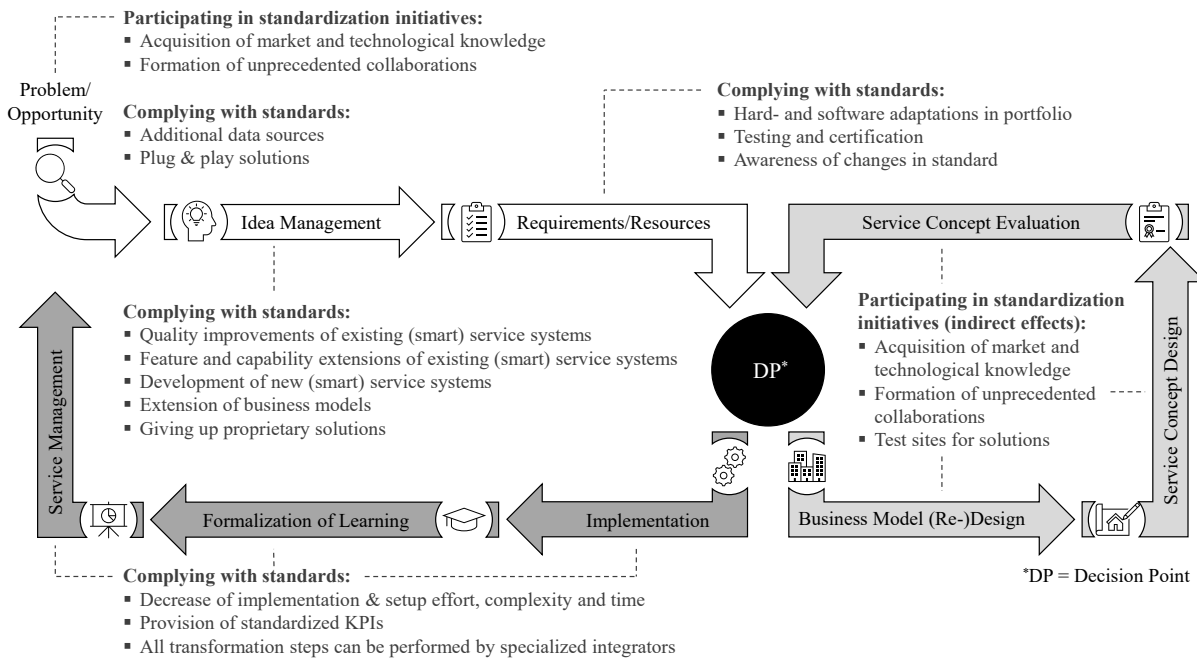


Fig. 2: Effects of standardization on service systems engineering

lished during the standardization process. In addition to collaborations that formed to work on certain topics during the initiative, cooperation emerged that crossed the initiative's borders. Here, omlox provided the initial opportunity to establish the first contact from which further business activities could evolve by:

"establishing contacts with other companies that are [in the initiative] and putting projects into practice that are likely also beyond omlox, where some have already been realized within the timeframe of omlox." – Interview 12

omlox's technological infrastructure also enables participants to use additional data sources. Data from various sensors/smart products that is transformed into a globally validated and standardized format becomes comprehensible to whoever needs it. This concept of sharing data within omlox's technological infrastructure was relevant to all informants:

"That means we know how the data arrives [and] whether it transfers, but also what the data stands for and how we can interpret it to gain direct, additional value from the information at hand." – Interview 12

Finally, not only data but complete solutions that require low implementation effort are exchanged. Such plug & play solutions, where providers can connect their solutions to existing infrastructure without having to set up and orchestrate their systems, enable them to use existing solutions instead of creating their own:

"[...] we don't need to develop everything ourselves. That means, for example, if one of our customers needs a heat map for its forklifts, that does not necessarily have to come from our company. Instead, we can create it relatively easily with the standard and with a partner in a plug & play manner." – Interview 18

With the dissemination of the standard and its rising possibilities for combining data sources and plug & play solutions, the opportunities for innovation are multiplying:

"It is often said that standards slow down innovation, especially when they are established. [...] But at this stage, you have to say [...] nothing slows down innovation. It is rather difficult when a standard is established for a longer time and just stays that way, even when it was state-of-the-art twenty years ago, [but] the creation of a standard is something that I believe favors innovation." – Interview 3

4.1.2 Step Idea Management

During the step of idea management, we found five additional effects regarding a company's service and product portfolio: quality improvements, feature and capability extensions, new solution developments, business model extensions, and abandonment of proprietary solutions. By using the omlox standard, participating companies hoped to achieve quality improvements in areas like accuracy, performance, productivity, reliability, security, transparency, and usability:

"As of today, when two [automated guided vehicles] come across each other, they have to drive slowly. If I know for sure that they are at this position, I could let them pass at full speed. That means I could solve things differently than I can solve them today with the current technologies in use." – Interview 5 regarding quality improvement in terms of performance

Another commonly mentioned manifestation was using omlox to extend existing service systems' features and capabilities. In this context, informant 2 described how he hoped to extend one of his company's service systems. Even though the company was already manufacturing first prototypes, it decided to integrate the specification belatedly because it would profitably extend the system's capabilities. While the system could track only the objects that were outdoors in the beginning, after integrating the omlox specification, it would be able to receive data whether the objects to be tracked were inside or outside. More than half of the experts expressed interest in such extensions of their existing products and services:

"So many partner companies are now pondering how they can expand their product ecosystem by using the standard in the direction of data control, AGVs [automated guided vehicles, or security solutions, adaptation to MES [Manufacturing Execution System] to map the process steps better. [...] Anyone can look at the standard. What data does the standard give me? How does that fit into my products? How can I extend my product, so it becomes even better?" – Interview 15

However, most experts also mentioned that complying with a standard enabled their company not only to create new features or capabilities for existing systems but also to develop new solutions from scratch. During the omlox initiative, an unprecedented locating system was developed that was used indoors, in manufacturing halls. When employees were passing close to each other, the newly created solution could track and trace those interactions, notifying employees when a close interaction was expected to occur. This system became tremendously important during the Covid-19 outbreak in 2020:

"We have now also quite rapidly developed an extension for distance detection and collisions—the corona-showcase—which was shown [at the omlox go-live event] and which did not exist in February. In April, it was ready." – Interview 15

Thus, the standardization initiative and the final standard build a foundation for an innovative scaling effect, enabling new and recombinant smart service system developments:

"I think certain new possibilities or ways can only be realized when I have standardized, harmonized information

because new technologies often start on a small scale. A manufacturer does something, or a small group develops something, but to achieve this scaling effect [...], I just need many manufacturers and many supporters [...]. The standard ensures that I can scale properly now and, when others join who have new ideas for the standard, start out small again." – Interview 21

Some of the informants associated the effects of standardization to an expansion of their organizations' business models. Even though most participants did not intend to extend their business models, some that were already in the process of doing so could make efficient use of the input factors the omlox initiative provided. Thus, a hardware manufacturer that produces material products intended to start providing additional software solutions that would offer complete systems to customers, so the customer would not long acquire software components from third parties. In this case, omlox was a helpful resource in the transformation process:

"We can gain experience with [omlox] to become a system provider because there is a system solution needed. We can also establish collaborations with other system providers that can a) support us and b) bring our components to the market." – Interviewees 19 and 20

Finally, companies that already provided holistic service solutions by themselves had to decide whether to keep or abandon their proprietary solutions. Most of these companies were convinced that proprietary solutions have downsides, while companies that create interoperable solutions can benefit in various ways:

"Some companies, and also us in the medium term, will have to give up on certain unique selling propositions or proprietary things, but at the end of the day, there will be something that will make things much easier for the end customer and the integrator—and then also for the manufacturers of systems or devices because there will be more choice and more competition. That is something we believe in." – Interview 3

4.1.3 Step Requirements/Resources

For the step requirements/resources, two types of effects were identified during the investigation. The first type, individual requirements, is related to each company's ideas during the idea-management phase, as all newly generated ideas create requirements that must be considered to turn the idea into practice:

"Before we start the engineering of the product, when we define the specification of the products, we ask ourselves if it has to be compatible with omlox or not because this will drive a different set of requirements and a different set of engineering efforts." – Interview 4

The second type of manifestation that was identified is integrational requirements, which ensure the proper integration of the standard's specification into the organization's systems so they can comply with the standard. Only by doing so can a company guarantee the interoperability of its systems and ensure the amount of trust that is needed to transfer the standardization concept into practice successfully:

"So there will be some minor adjustments on the interface and probably also in the firmware [...] because the omlox interface is so close to our company's standard. If we had to connect another real-time locating system (RTLS) system—which would have had a different interface on its own, for sure—we would have had to do more." – Interview 11

After the release of the first version of the omlox standard in mid-2020, the specification was handed over to the PROFIBUS Nutzerorganisation (PNO), a market-independent committee that continues to manage and update the open standard. With changing versions of the updated standard, new requirements emerge for a company's SSE that must be implemented. omlox-compliant companies must always be aware of the specification's current state and, when changes occur, adapt their systems.

4.2 Service System Design

Fewer aspects of standardization directly affected the design phase of service systems than was the case in the previous phase of service system analysis, primarily because the final open standard cannot mandate that a company must design its products in a certain way. In other words, it is the outcome—the "what" and not the "how"—that matters during standardization:

"If I, for example, stay on the hub level [part of the omlox infrastructure], it is not important or mandated in which language the whole thing is written. [...] If somebody comes up and says, for example, 'I use an inefficient language, but I put a lot of computing power into my system,' then that is okay as long as they meet the functionalities [companies of the standardization alliance] require, it is fine." – Interview 12

Even though there were no direct implications of standardization observed, the design phase is still indirectly influenced by the input factors that arise from participating in a standardization initiative (section 4.1.1). For example, a company could use new collaborations in designing and testing their service systems. Generally speaking, the initiative provides a broad variety of input sources and resources that a company can use.

4.3 Service System Transformation

We observed significant effects of the omlox infrastructure on the service system transformation, especially

during implementation. Once an omlox infrastructure is established at the customer's site, additional service systems can be integrated. As a result, financial investments and set-up times for implementation projects are largely omitted, and initial investments become more promising to customers, as additional solutions can also be accounted for during the decision-making process:

"You have two types of customers: a customer who has already deployed an omlox infrastructure, so deploying our system is a minor investment the customer needs to make on top of this, [...] and a customer who does not have any localization infrastructure yet, who is interested in deploying our system, and whose main bottleneck will be deployment cost of this infrastructure. omlox will help us to justify that the investment required in the infrastructure can be materialized for different use cases." – Interview 4

The concept of system integrators also came into play. Integrators are companies that implement and manage a solution on the customer side. The integrator consolidates all standard-related capabilities, products, services, and systems to provide customer-specific solutions. Its objective is to use all available opportunities to design a customized solution that increases the client's satisfaction, solving his problem of being locked in to one vendor. At the same time, implementation efforts for participating organizations decrease significantly since the integrator can choose from a range of solutions and integrate them in a one-face-to-the-customer manner:

"[From my perspective as a system integrator], I have relationships with other participants. [...] I can map synergies much faster. I can create networks. When a company approaches me and says 'I would like to have this, this, and that,' I [...] might have a good connection to manufacturer A, manufacturer B, or whomever. Then I also have chip producer A on board, allowing me to say, 'Yes, we can do that. I can give you the complete package, I can equip your production hall. I can offer you hardware and software. I can integrate it for you. I can act as a general solution provider—everything from one source. You only need to talk to us. And as suppliers, we have the omlox-compatible companies on board.'" – Interview 9

While the integrator concept represents an additional sales channel for many organizations (which increases their chances of making a sale), integrators can provide a broad spectrum of solutions, deepening customer relationships. The integrator implements solutions and provides valuable feedback to the organizations, closing the loop and enabling each company to learn how to improve its service system. Many of the interviewees mentioned using key performance indicators (KPIs) to help them determine the effectiveness of their participation in the standardization initiative.

5. Discussion

This work's results illustrate the far-reaching effects of standardization on a company's (smart) SSE. The study was accompanied by the informants' broad agreement that standardization positively influences their companies' ability to innovate. Because of SSE's complexity (Anke et al. 2020), often only a few companies in a market have the necessary resources and capabilities to innovate (Powell et al. 1996). Therefore, the standard itself and participation in a standardization initiative can increase the degree of innovation by providing access to external resources and capabilities that were once unavailable. These external resources and capabilities can have several effects in the course of the SSE journey.

Organizations' initial motivation for complying with a standard is often to ensure their solutions' interoperability with those of other vendors so they can pool forces and jointly provide an entire service system. However, during the omlox initiative, several companies saw additional potential for innovation primarily because the standard led to a consistent infrastructure in which the necessary data from

external sources is available to be analyzed and recombined to create new value. Such an infrastructure also allows a company's own solutions to be set up easily in a plug & play manner. The companies avoid the cost-intensive development and implementation stage of their equivalent of this infrastructure, and the customer is more motivated to try out and procure the solutions, as the implementation effort is significantly reduced. Thus, standardization allows innovation through new resources and reduces the barriers to adopting innovative solutions. However, this innovative power of standards is contrasted by the service system's specific characteristics that are mandated for the companies. Compliance with standards imposes restrictions on individual solutions, additional expenses for testing and certification, and reengineering when changes occur. Companies must assess whether the advantages of the standard outweigh the disadvantages in each case and must build the capability to absorb the external resources, which is essential for complex service systems (Carnabuci and Operti 2013; Cecere and Ozman 2014; Bessant and Trifilova 2017).

Standards usually reduce variety and diversity by limiting customers' options (Brunsson et al. 2012a), which appears to contradict research that has demonstrated that recombinant innovation's potential increases through diversity, especially technological diversity (Fleming 2002; Miller et al. 2007) and institutional diversity (Stirling 2007). The reasons for this increased potential can rest on a more significant number of alternative recombination pathways (Weitzman 1998; Fleming 2002; Carnabuci and Bruggeman 2009), reduced risk of lock-ins

of suboptimal solutions that prevent further innovation (van Rijnsvoever et al. 2015), and increased resilience and flexibility for appropriate responses against unforeseen environmental changes (Stirling 2007; Negro et al. 2008). However, a high degree of diversity can also have negative consequences (van Rijnsvoever et al. 2015), such as increased effort required to keep track of all alternatives (Leten et al. 2007) and roadblocks to efficient assimilation (Sampson 2007). Recombinant innovation's potential seems to be highest at a balanced level of diversity (van den Bergh 2008). Accordingly, market participants' and policymakers' deliberate development, establishment, and compliance with standards could be a strategy with which to approach the optimal level of diversity. However, two conditions must be respected in this process: standards must be regularly confronted and expanded or replaced to promote innovation given increasing market dynamics and rapid technological progress (Brunsson et al. 2012b; Hanseth and Bygstad 2015), and the standard's effect on innovation can depend on the degree of market uncertainty and the identity of the standard setter (Blind et al. 2017). omlox fosters innovation in the uncertain IIoT market because it has been voluntarily developed by market participants.

The participating companies also saw substantial benefits from participating in the standardization initiative. While the standard establishes the mostly passive basis for resource exchange, the initiative led to active knowledge exchanges and collaborations. The spectrum of participants in the omlox initiative ranges from hardware manufacturers to software providers, consultancies, and mixtures of all these. Even organizations that were already able to offer complete service systems became involved because they saw the initiative as an opportunity to avoid a fragmented market and foster innovation by leveraging existing resources. During the initiative's day-to-day operations, this diverse field of actors worked together closely, sharing their knowledge of the market and technology. Some organizations also worked on a common idea in partnership. Research has highlighted the importance of such alliances on recombinative innovation (e.g., Quintana-Garcia and Benavides-Velasco (2008); Cecere and Ozman (2014); van Rijnsvoever et al. (2015)), as they provide external resources and capabilities that, combined with the companies' internal resources and capabilities, lead to new solutions (Powell et al. 1996).

Research on such alliances has identified technological proximity or distance as an important influence on innovation (Nooteboom 1999; Gilsing et al. 2008a; van de Vrande 2013), where the relationship can be described as an inverted U (Guan and Yan 2016). While close proximity can reduce the novelty value (Mowery et al. 1996a), a great distance can reduce the companies' capability to absorb external resources (Nooteboom et al. 2007a). Thus,

the optimum is seen in a balance (Mowery et al. 1996b; Nootboom et al. 2007b; Gilsing et al. 2008b). We argue that a standardization initiative with a carefully selected committee (van Rijnsoever et al. 2015) could be a means to find such partners and nurture innovation. United by a common interest, technological proximity is a given, but numerous actors with different backgrounds and expertise are involved, which allows companies to find partners that are not too technologically close to their own capabilities (Bar and Leiponen 2014). Through close cooperation within the standardization initiative, the alliance partners were also able to build a level of trust, promoting cooperation. Building such alliances had a positive impact on service systems analysis and the design phase.

Overall, harmonized standardization can have a positive impact on a company's service innovation. The standard itself supports interoperability and provides an infrastructure through which resources can be exchanged, while participating in standardization initiatives creates access to new resources and supports the search for alliance partners. However, additional efforts, restrictions, and the danger of reducing diversity too much are potential disadvantages. We argue for considering

recombination and standardization in SSE and integrating them into the service innovation process. Thus, we propose extending an existing SSE approach (Beverungen et al. 2018) with a standardization phase (Figure 3). We adapt the process as we observed it in the course of the omlox standard development initiative. In the first step, each participant expresses its needs and requirements regarding the standard by introducing new use cases. This procedure encourages companies to adapt the standard and ensures far-reaching value of the standard's technology, which fosters innovation. Next, the use cases are evaluated and prioritized based on their relevance to most participants. While during the omlox initiative, a backlog was established to manage such use cases, each standard-development organization can determine such instruments for itself. In the third step, the chosen use cases are integrated and tested in the participants' systems. After successful integration, the attributes are officially documented and anchored in the standard. This process is iterative so the standard can continue to promote innovation through appropriate adaptations in the future.

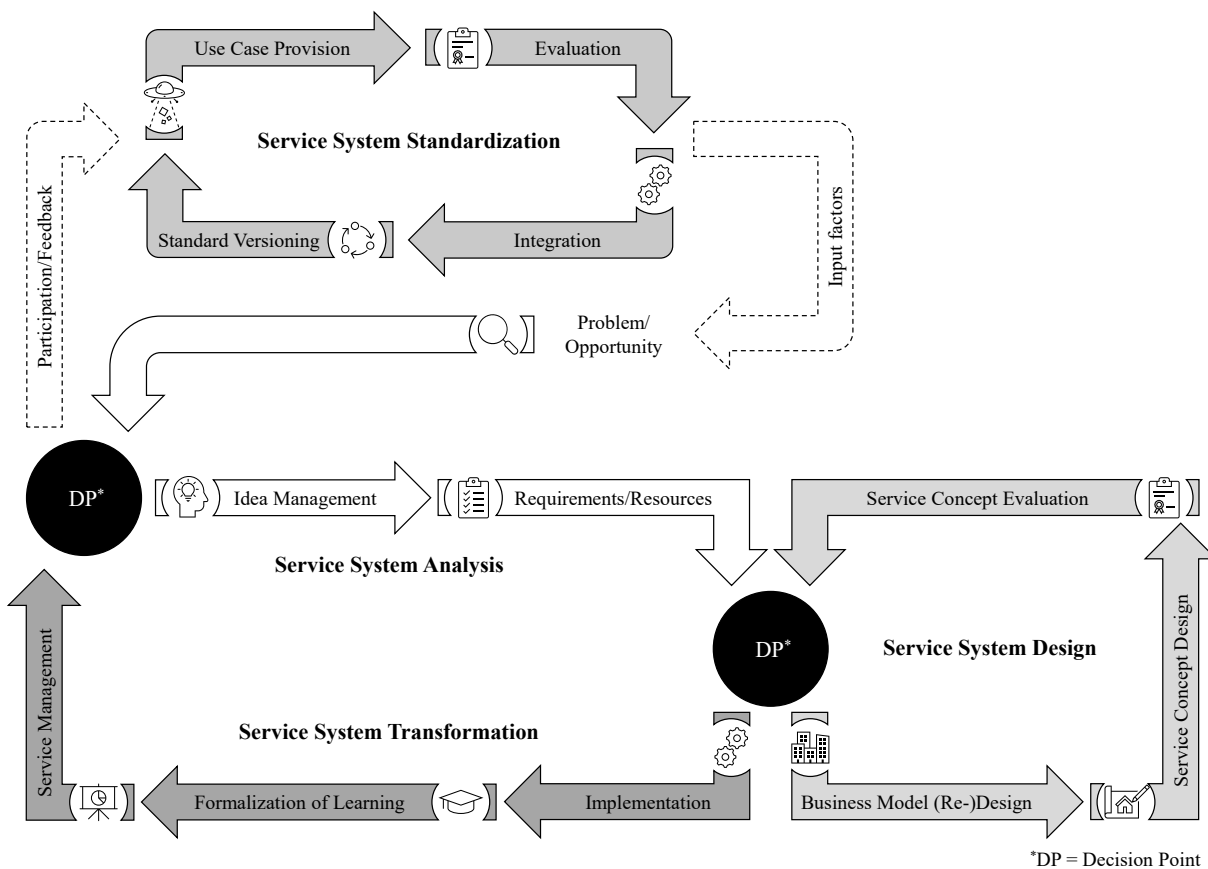


Fig. 3: Modified recombinant service system engineering approach by Beverungen et al. (2018)

6. Conclusion

This study demonstrates how standardization can affect (smart) SSE and innovation. In addition to the primary purpose of establishing interoperability between systems, complying with standards and participating in standardization initiatives can improve how companies engineer their (smart) service systems throughout all phases of the engineering process. In this sense, the purpose is not to determine “*how to engineer*” but “*how to use necessary resources for engineering*.” Through standardization, companies have access to external resources and capabilities that foster recombinative innovation and may find support for new opportunities, such as more efficient implementation and management of a service system.

Our study contributes to the emerging literature on (smart) service systems in three ways. First, we demonstrate how standardization affects and improves access to external resources and capabilities, which is one of the bases for recombinant innovation (Carnabuci and Operti 2013; Cecere and Ozman 2014; Bessant and Trifilova 2017). Second, we add empirical evidence to the promising but underdeveloped discussion on adapting a recombinant innovation perspective in SSE (Beverungen et al. 2018; Li and Peters 2019). Third, we create awareness among practitioners that standardization can foster innovation and should be part of their innovation agendas.

While our study spanned several months, the actual standardization procedure extended over a much longer period. While our evidence on the initiative is comprehensive, our evidence on the standard’s impact is limited in that it might overemphasize the earlier phases of the (smart) SSE process. Longitudinal studies may be useful in further elucidating the latter phases of a standard’s life cycle.

With the far-reaching influence that external factors may have on a company’s (smart) SSE, further research efforts could intensify this exploration by elaborating on where and how companies might use additional resources that enable them to establish or improve their (smart) SSEs. For instance, the role of political or cultural incentives might be another aspect of our case study to consider. Another option may be to link the field of (smart) SSE to other research areas that have not yet been considered.

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Appendix A Detailed description of the steps of the Recombinant service systems engineering method by Beverungen et al. (2018)

Tab. A. 1: Recombinant service systems engineering method by Beverungen et al. (2018)

<p>1. Problem/ Opportunity Recognition</p> <p>Formulate new service objectives/ strategy</p> <p>Analyze the situation of market, company, and environment</p> <p>Identify target groups/ customers</p> <p>Identify and prioritize customer’s current and future needs, wants, and demands</p> <hr/> <p>2. Idea Management</p> <p>Generate and collect ideas</p> <p>Consider recombination of resources in existing service systems or generate new ideas</p> <p>Evaluate and preselect ideas</p> <p>Design basic functions/ initial service concept</p> <p>Define basic value propositions in line with customers’ needs, wants, and demands</p> <p>Check initial concept with involved departments and perform feasibility and profitability analysis</p> <p>Analyze market conditions and potential of ideas, considering customers/ customer needs and competitors/ existing similar or related solutions</p> <p>Analyze required partnerships and incentives</p> <p>Select the idea(s) that will be developed in detail</p> <hr/> <p>3. Requirements Analysis + Resource/ Solution Identification</p> <p>Identify and analyze market and customer requirements/ requirements to satisfy customer needs at every level</p> <p>Identify and analyze legal, economic, social, and cultural restrictions/ requirements</p> <p>Identify and analyze company requirements</p> <p>Develop and analyze use cases (use hypotheses)</p> <p>Identify capabilities, tasks, and resources required (incl. customer) for providing products and services</p> <p>Identify and recombine resources in current service systems, consider access to external resources, and transfer of ownership of physical goods</p> <p>Align requirements and device service specification</p> <hr/> <p>Decision Point</p> <p>After Service System Analysis: decide to proceed or not to proceed</p> <p>Decide to proceed with Service System Transformation (transfer, association) or with Service System Design (addition, dissociation)</p> <hr/> <p>4. Business Model (Re-)Design</p> <p>Design business model based on agreed resources, responsibilities, capabilities, and specifications</p> <p>Select development partners and define their responsibilities</p> <p>Identify and evaluate risks</p>	<p>Evaluate costs and functional performance of the business model</p> <p>Define design principles and estimate them with quantitative measures</p> <hr/> <p>5. Service Concept Design</p> <p>Segmentation into service components/ modules and specification of segment/ modules</p> <p>Plan tasks and assign responsibilities for design (involve customers as co-designers)</p> <p>Design value proposition and (internal and external) resources in the service system</p> <p>Design business process and plan process organization and interfaces (incl. partners and customers)</p> <p>Design physical goods, if any</p> <p>Design and implement technical infrastructure, including information systems and data</p> <p>Design resource plan for service provisioning (internal & external, incl. partners and customers)</p> <p>Create alternate design concepts for the service, and each component</p> <p>Define marketing and communication concept</p> <p>Define pricing, distribution, and sales concept</p> <p>Define performance indicators for each module</p> <p>Purchase any required equipment</p> <p>Synthesis of components</p> <hr/> <p>6. Service Concept Evaluation</p> <p>Evaluate conformity with requirements</p> <p>Develop a pilot and testing plan</p> <p>Conduct tests (performance, technical, and human factors, continuity or process, marketing)</p> <p>Conduct (partial) pilot runs</p> <p>Examine saleability of new service and determine potential customers’ acceptance</p> <p>Apply required changes (fine-tuning)</p> <hr/> <p>Decision Point</p> <p>After each Service System Design cycle: decide if the prototype is viable (proceed with Service System Transformation) or if further design is required (proceed with Service System Design)</p> <hr/> <p>7. Service Concept Implementation</p> <p>Define backup plans for implementation</p> <p>Define and detail introduction and implementation plan incl. responsibilities and core components</p> <p>Specify operational standards, instructions, schedules, rules, and outputs of the system</p> <p>Transform existing service systems incl. resources, people, business processes, information systems</p> <p>Implement internal and external communication and information measures and marketing</p>
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Train and motivate staff
 Ramp up, roll-out, market implementation, customer-specific production
 Monitor start-up

8. Formalization of Learning

Monitor and document the service systems engineering process
 Consolidate and formalize distributed knowledge to strengthen core competencies

Feedback loop to following start phase

9. Service Management

Monitor, measure, and assess the performance
 Improve performance
 Design modification

Appendix B Overview secondary data

Tab. B. 1: Overview of secondary data

Title	Description	Pages
LoTUS: Workshop presentation	Presentation reflecting the standardization alliance members' votings on topics like marketing strategies, working-group strategies, core member/ affiliate partner & user definition, meet & greet planning, architecture configuration	23
omlox: System integrator proposal	Presentation introducing and explaining the role of a system integrator	15
omlox: Use cases	Spreadsheet defining 100 relevant use cases for omlox, classified by category, value proposition, and priority. Ex.: Category: Location-based services; Subcategory: Geofencing; Role (who): Operator; Wish (what): Wants only compulsory working instructions to be displayed on a monitor, should be relevant for the actual job and working station, no paper instructions; Benefit (why): Reduction of paper consumption, always actual working instructions on display (no old versions), only working instructions for a specific station, easy handling for the employee; Priority: 27	62
omlox: Real-time tracking presentation	Presentation exemplifying the value propositions omlox is providing, illustrating the benefits of real-time tracking	21
omlox: Concept presentation	Technical presentation demonstrating in detail the general concepts and use case examples as well as their implementations. Including a worldwide partner overview.	38
omlox: Specification UWB zone	The official omlox core zone specification version 1.0 for PROFIBUS and PROFINET	45
omlox: Press information	An official press statement announcing the omlox standard	4
Σ		208

Keywords: Smart Services, Service Systems Engineering, Standards, Service Innovation, Recombinant Innovation, Case Study