How to tame the Tiger – Exploring the Means, Ends, and Challenges in Smart Service Systems Engineering

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HOW TO TAME THE TIGER – EXPLORING THE MEANS, ENDS, AND CHALLENGES IN SMART SERVICE SYSTEMS ENGINEERING

Research paper

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Abstract

Smart service systems are like a tiger – they are difficult to tame. This is largely rooted in their complexity, which results from the involvement of multiple actors and the interaction of multiple disciplines. Smart service systems engineering requires the development of value propositions that integrate both smart products and smart services based on data analytics, cloud computing, and digital platforms. Therefore, a large variety of tasks must be performed to successfully engineer such systems. While academia has proposed different methods, techniques, and tools (means) to support these tasks, it remains unclear how smart service systems are engineered in practice and for what outcome (ends) the means are used for. This paper aims to address this shortcoming by conducting 14 in-depth interviews with experts who were involved in smart service systems engineering projects. Our qualitative data analysis resulted in an extensive set of means, ends and challenges that we were able to structure along the design dimensions value, process, and resource, as well as the overarching dimension of project management. Based on the interview data, we discussed the suitability of existing means, and approached the question whether it is necessary to leverage the adoption of existing methods in practice or rather to develop new, more practically useful methods instead. With this study, we contribute to academia by advancing our understanding of the suitability of methods for smart service systems engineering and call for creating and promoting toolboxes of easy-to-use and flexible means. Our insights are also helpful for practitioners to better assess challenges and ends for their smart service innovation initiatives.

Keywords: Smart service, smart service systems, service engineering, methods, means-end-analysis, project management.

1 Introduction

Connected products are smart if they can sense their own condition and surroundings, allow for real-time data collection, continuous communication, and interactive feedback. These facilities qualifies them for providing smart services (Allmendinger and Lombreglia, 2005; Wuenderlich et al., 2015). We already find examples of smart products and services in a variety of fields. In a business-to-business (B2B) context, for instance, digitally connected aircraft engines report status data in real-time, thereby enabling pay-per-use business models. Industrial products such as compressors, ventilation systems, and elevators are being upgraded with digital services for remote control, monitoring, usage-based billing and other services (Herterich et al., 2015). In a business-to-consumer (B2C) context, cars may analyze driving behavior based on sensor data, schedule workshop appointments, or provide optimized eco-feedback.

Such combinations of smart products and services are understood as smart service systems. Over the last 10 to 15 years, there has been a growing academic interest in understanding and conceptualizing such systems (e.g., Beverungen et al., 2019; Lim and Maglio, 2019). Existing academic works highlight the complexity and heterogeneity of such systems. We also find first attempts to provide guidelines, methods and tools that organizations can utilize in their smart service systems engineering (SSSE) projects (e.g., Abrell et al., 2016; Beverungen et al., 2018; Blaschke, 2019; Lim et al., 2015; Patrício et al., 2011; Poeppelbuss and Durst, 2019). However, there is only limited empirical knowledge on how organizations plan and pursue SSSE projects and which means, including guidelines, methods, techniques, and tools, they apply. Therefore, we attempt to contribute empirical insights into the means that organizations select for their SSSE projects, into the purposes they aim to attain by using these means (ends) and the challenges they face when applying them. We further try to identify the white spots of method support in SSSE projects and derive corresponding needs for research.

We consider the empirical investigation of SSSE projects as particularly timely, relevant, and interesting for the following reasons. First, SSSE projects tend to exhibit traditional dichotomies, including products and services, machinery and digital technologies, as well as systematic and sequential versus agile and user-centered approaches to project management. Therefore, it is interesting to reveal which means are helpful to organizations to balance corresponding tradeoffs, especially as existing methods for service engineering might not be suitable for SSSE (Marx et al., 2020). Second, SSSE projects tend to be inter-organizational and collaborative and they require resources and expertise (e.g., in software development, user experience design, and data analytics) that often cannot be covered by a single organization (Anke et al., 2020). Thus, we pose the following research question: *How do organizations engineer smart service systems?* In particular, we are interested in the ends they pursue, the means they select and apply, and the challenges they experience with applying them.

The remainder of this paper is organized as follows. In Section 2, we introduce the key concepts related to SSSE. Then, we present the methodology of our interview study. Section 4 presents our empirical insights on the ends and means used in SSSE projects, as well as on the related challenges. The paper closes with a discussion and conclusions in Section 5.

2 Research Background

2.1 Smart Service and Smart Service Systems

In academia, we see a growing dedication to the concept of smart service since Allmendinger and Lombreglia (2005) first coined the term. Beverungen et al. (2019, p. 12) define *smart service* as "the application of specialized competences, through deeds, processes, and performances that are enabled by smart products." *Smart products* refer to physical objects with embedded systems and networking capability that enable the intelligent adaptation to customer needs and changes in usage situations (Allmendinger and Lombreglia, 2005). They are the central building blocks of the (Industrial) Internet of Things and cyber-physical systems (Serpanos and Wolf, 2018) and provide boundary objects between the provider and the customer for service provision (Beverungen et al., 2019). While the term smart service refers to the value proposition or offering towards the customer (e.g., a predictive maintenance offering), the smart product is the technical component of the socio-technical system that is involved in service provision. Such socio-technical systems can also be understood as *smart service systems*, which Beverungen et al. (2019, p. 12) define as "service systems in which smart products are boundary objects that integrate resources and activities of the involved actors for mutual benefit". With a stronger consideration of relevant technologies, Lim and Maglio (2018, p. 166) define smart service systems as service systems that control "things for the users based on the technology resources for sensing, connected network, context-aware computing, and wireless communications". According to the National Science Foundation (2014), such systems are expected to be "capable of learning, dynamic adaptation, and decision making based upon data received, transmitted, and/or processed to improve its response to a future situation." Similarly, Böhmann et al. (2018) describe that the digital transformation leads to service systems that are increasingly automated, interactive, open, and learning systems.

2.2 Ends in Smart Service Systems Engineering

Service systems engineering is "the systematic design and development of service systems" (Böhmann et al., 2014, p. 74). The development of service systems can be understood as "a process of using new ideas and new technology to develop improved or new services" (Plattfaut et al., 2015, p. 3), which results in a change of one or multiple system dimensions (Plattfaut et al., 2015). Therefore, conceiving or redesigning single or multiple dimensions of smart service systems can be understood as the *ends* of SSSE. While there are different approaches to conceptualize the dimensions of service or service systems (Becker et al., 2010; Beverungen et al., 2018; Bullinger et al., 2003; Heskett, 1987; Pekkarinen and Ulkuniemi, 2008), these can largely be condensed to the three main dimensions of value, process, and resource. The three dimensions also correspond to the three key concepts for new service development as proposed by Edvardsson and Olsson (1996). We consider them to be equally applicable to smart service systems, as the dimensions are agnostic to the use of specific technologies like smart products.

The first dimension is the *value dimension*. Edvardsson and Olsson (1996, p. 148) emphasize that the "main task of service development is to create the conditions for the right customer outcome." The outcome must be perceivable by the customer; otherwise, it would not be a customer value. Other terms that relate to the value dimension are 'offering' (Frei, 2008) or 'value proposition'. The value proposition provides a statement on the value that the service provider proposes to beneficiaries based on its skills and knowledge (Vargo et al., 2008). The value proposition is typically put down in a 'service concept', which is "a detailed description of what is to be done for the customer and how this is to be achieved" (Edvardsson and Olsson, 1996, p. 148). Hence, developing convincing value propositions requires a sufficient understanding of customer needs. In a market economy, the customer will finally decide to buy or not to buy a service offering based on her/his perception if she/he will receive a benefit or added value from the service (Edvardsson and Olsson, 1996). In this regard, it is also expected that innovative revenue models support the transition from transaction-based to more relation-based customer relationships (e.g., through pay-per-use and subscription models) (Oliva and Kallenberg, 2003).

The *process* dimension views service as "a process of a set of activities which take place in interactions between a customer and people, goods and other physical resources, systems and/or infrastructures representing the service provider and possibly involving other customers, which aims at assisting the customer's everyday practices" (Grönroos, 2006, p. 323). Hence, this dimension focuses on the interactions between the service provider and the customer as an external factor to co-create value together. Engineering these interactions is seen as a central research challenge for service systems engineering (Böhmann et al., 2014). Amongst others, this includes the design of adequate interfaces between providers and customers to ensure positive service experiences (Patricio et al., 2011). Following ideas of service blueprinting (Bitner et al., 2008), the distinction between front-stage and back-stage processes is also relevant to smart service systems, especially as automated back-stage processes for data analytics and data-driven decision-making gain relevance (Beverungen et al., 2019; Böhmann et al., 2018).

The *resource* dimension represents the configuration of the service delivery system (de Jong and Vermeulen, 2003) that provides the prerequisites for the service (Edvardsson and Olsson, 1996). The service delivery system defines how the resource base is organized, including human resources, technical resources, equipment, organizational arrangements, and supply chains for service delivery. In smart service systems, the use of information and communication technologies allows mobilizing resources in novel ways (Böhmann et al., 2014). Putting such technologies in place requires architectures for the overall smart service system and technical specifications for its components (e.g., smart products, connectivity devices, and sensors). Understanding the customer as a co-creator of value implies that parts of the smart service system's resources are external to the service firm at the customer's (and potentially also supplier's or partner's). Such external resources that cannot be controlled (Edvardsson and Olsson, 1996), leading to third party dependencies. In smart service systems, we especially see dependencies to partners or suppliers that provide access to digital platforms and marketplaces or cloud computing services. Using alternative notions for this dimension, Bullinger et al. (2003) refer to the resource dimension as the 'structure dimension' and Becker et al. (2010) label it 'potential dimension'.

2.3 Means for Smart Service Systems Engineering

A plethora of *means* can be considered relevant to this study because smart service systems comprise a variety of service, software and hardware components, for which we can easily identify distinct design methodologies, methods, tools and further means, e.g., from the fields of software development or innovation management. We also see an increasing amount of research that specifically targets the intersection of digital transformation and service innovation, which is presented under several terms, including, for instance, service systems engineering (Beverungen et al., 2018; Böhmann et al., 2014), design of informatics-based services (Lim et al., 2015), and smart product-service-systems (Hagen et al., 2018; Zheng et al., 2019). Considering this stream of research, the majority of researchers obviously agree that SSSE poses new challenges and therefore, *means* need to be reconsidered (Böhmann et al., 2014; Hagen et al., 2018; Marx et al., 2020). They discuss various directions including, for example, the development of new means or the adaptation and integration of existing means. On the one hand, recent studies illustrate shortcomings of existing means for the development of (smart) service systems and call for more integrated methods and tools (Böhmann et al., 2014; Marx et al., 2020). Others also mention potential advantages of more agile development processes that rely on loosely coupled means (Beverungen et al., 2018). Despite the growing number of means for SSSE that are published in academic literature, it appears that they are hardly known or applied in practice Wolf et al. (2020).

In this study, we summarize the plurality of relevant concepts (e.g., methods, tools) under the umbrella of *means*, although we know that they are not equal concerning the ends they support or concerning their levels of abstraction or formality. We still introduce the following concepts briefly, as these provide a reference for the discussion of our empirical insights later. "A *method* is a set of steps (an algorithm or guideline) used to perform a task" (March and Smith, 1995). Methods consist of directions and rules and provide a structure (e.g., in the sense of a process with phases and milestones) for development activities and work products (e.g., models or instantiations) (Brinkkemper, 1996). A *technique* is a more fine-grained method in the sense of a procedure to perform an activity, e.g., how to apply a modeling notation (Brinkkemper, 1996). A *methodology* provides a set of methods, techniques, and guidelines, and with them, a general way of thinking or mindset towards the development endeavor (e.g., sequential vs. iterative, plan-driven vs. agile). Popular examples from software engineering are the waterfall methodology, the V-model, and the agile methodology (Beck et al., 2001; Maruping et al., 2009). *Models* express relationships among constructs. They "represent situations as problem and solution statements" (March and Smith, 1995, p. 256). To design the process dimension of a service system, for instance, process models of different levels of formality (e.g., Customer Journey Maps, Service Blueprints or Business Process Model and Notation (BPMN)) can be used, which "describe *how* the outcomes of a service are achieved" (Bullinger et al., 2003). *Tools* are digital (and possibly automated) means to support parts of a development process (Brinkkemper, 1996). As instantiations, they operationalize constructs, models, and methods (March and Smith, 1995). In contrast, *visualization tools* provide concise, easy-to-understand, and visually appealing frameworks to structure contents, e.g., in workshop settings. A popular example is the Business Model Canvas (BMC) by Osterwalder and Pigneur (2010).

3 Methodology

The objective of this interview study is to investigate how organizations develop smart service systems. To achieve this objective, we interviewed 14 experts who were involved in real-world SSSE projects.

During **data collection**, we followed a purposive, theoretical sampling approach (Eisenhardt, 1989; Yin, 2016), and defined criteria to identify and select suitable experts for our interview study. We selected interviewees from whom we expected to learn about interesting and relevant practical experiences that they made in SSSE projects. We also sought for variety within our sample, including experts from different types of organizations (e.g., service providers and IT consultancies), with different positions (e.g., project manager or product manager), and from both B2C and B2B settings. We intended to gather information-rich and plentiful data as well as a broad range of perspectives on the subject of our study (Yin, 2016). In the end, we identified 14 experts from 13 organizations located in Germany who were able to report on their practices, experiences, and challenges in SSSE projects.

Expert	Organization Pseudonym	Organization Description	Expert's Position in Organization	Duration
1	ENERGYPLAT	Digital platform provider for energy management	Head of Product Management	1:30 h
2	INSURANCE	Insurance company	Project Manager	1:04 h
3	CITYMOBIL	Utilities and public transport	Project Manager	1:29 h
4	GLOBALSYS	Global IT solution provider	Architect/Consultant	1:17 h
5	GLOBALSYS	Global IT solution provider	Program Manager	1:27 h
6	ENERGYTRADE	Digital platform provider for energy trading	Project Manager	1:11 h
7	ITSOLUTION	IT solution provider, software and consulting	Lead Architect	1:13 h
8	ITCONSULT	IT consulting	Program Manager	0:41 h
9	DIGIBUSINESS	IT and digital business solution provider	Project Steering	1:06 h
10	UTILCONSULT	Management consulting for utilities	Team Lead Digitalization and IT	1:14 h
11	PHARMACHINES	Machinery construction for the pharmaceutical industry	Product Manager for Service/Support	0:48 h
12	PACKMACHINES	Plant construction for packing food/non-food items	Head of After Sales Service	0:41 h
13	INTERNALIT	Internal IT provider of a machinery manufacturer	IT Solution Consultant	1:00 h
14	FIELDSERVICE	Field service management software	CEO	1:04 h

Table 1. Overview of expert interviews

We collected our qualitative interview data via phone between October 2018 to January 2019 (Table 1). The duration of the in-depth interviews was between 41 and 90 minutes. As we guaranteed anonymity to all interviewees, we only provide organization pseudonyms and the expert's position in this article. In our interviews, we followed a semi-structured interview guideline that also left room for additional ideas and thoughts of the experts in order to stimulate the experts to provide rich information on their project experiences and relevant context. Context was particularly important to us as we expected the intra- and inter-organizational conditions to have an important influence on the selection of means in SSSE projects. The interview guideline comprised the following sections with multiple open questions each:

(1) Introduction of interviewer and informant, description of the informant's organization, informant's background, and his/her role in the organization,

(2) Understanding of the term smart service; identification of SSSE projects, in which the informant was involved; selection of one specific project for closer analysis in the rest of the interview.

(3) Project initiation, including the trigger for starting the project.

(4) Project organization, including the general project management approach and actors involved.

(5) Means used to design the value dimension of the system as well as resulting documents.

(6) Means used to design the process dimension of the system as well as resulting documents.

(7) Means used to design the resource dimension of the system as well as resulting documents.

(8) Review of the project results, including key challenges and key successes.

We started our **data analysis** by organizing the interview recordings and metadata on a cloud-based data storage that was accessible to all authors. We relistened to the recordings of the interviews multiple times and used a shared spreadsheet file with summary sheets to capture the key findings from each interview. We labeled the SSSE projects as mentioned by the experts. For each interview, one of the researchers of our author team (usually the interviewer) was assigned as the responsible analyst. For all interviews, a second researcher performed plausibility checks by listening to the recordings and discussing his impressions with the responsible analyst.

Following a directed approach to qualitative content analysis (Hsieh and Shannon, 2005), we broke down the interview data of each expert into smaller fragments and coded them according to four deductively derived a priori themes of our coding template (King et al., 2018): the design dimensions of *value*, *process*, and *resource*, as well as the overall *project management approach*. We further coded the interview passages that were relevant to these themes with the terminology as used by our interviewees – in the sense of inductive open codes or in vivo codes (Yin, 2018). Based on an iterative process of coding (King et al., 2018), we clustered these newly derived codes (e.g., tight deadlines, the involvement of partners) to broader categories and sub-categories (e.g., collaboration, pricing, user interaction/user interfaces). Then, we assigned them to the three categories of *means*, *ends*, and *challenges*. Finally, we jointly conducted an analysis across all interviews and looked for linkages between the means, ends, and challenges. We summarized our findings in detailed memos in our cloud-based data storage.

4 Results

The experts in our sample reported on a broad range of SSSE projects, in which various service offerings were developed, ranging from mobility and vehicle charging services for citizens, remote support services for industrial equipment, to vehicle delivery tracking and energy management (Table 2). By focusing on one specific project in each interview, we learned about the project-specific context and included it into our analysis. This helped us in understanding the selection of the general project management approach, as well as the interplay between ends, means, and challenges.

Concerning the **project approach**, we analyzed the overall organization of the projects as mentioned by the experts, including the methodologies followed, roles, tasks, deliverables, phases, as well as tools for planning and controlling. In our interviews, we found two main types of approaches for project management, which are commonly distinguished, including (1) traditional sequential approaches (e.g., waterfall model), which focus on predictability, and (2) more recent agile approaches (e.g., Scrum), which are characterized by flexibility and adaptability (Sommerville, 2016). We clustered the approaches mentioned by the experts in these categories. If both types were used, which was observable in some projects, we assigned the category “hybrid” to them (Table 3). Furthermore, we grouped the project management challenges into the categories of planning, collaboration, and go-live (Table 4). Concerning the general project management approach, we saw an almost equal distribution of sequential, agile and hybrid methodologies across the projects that the experts told us about. However, experts who had used a *sequential* methodology often described them as unsuitable for their project in hindsight. For example, in project 3, the dynamics of the market and technological development required many changes of the project goals and planned activities. However, the project was supported by public funding, which formally required a sequential approach to project management. Experts 12 and 13 stated that they would choose agile methodologies for future advancements of the software.

Project	Smart Service	Project Description
1	Energy distribution network control service	Development of a digital service that stabilizes the energy distribution grid by predicting instabilities and incentivizing individual households to change their energy consumption behavior.
2	Diabetes prevention app	Customization of an app that uses blood sugar measurements, activity tracking and reporting for people to influence their behavior. The app is a 3rd party white-label solution offered by INSURANCE.
3	Electric vehicle charging	Development of a billing and access service to allow for a simple and cost-efficient charging of e-vehicles in the city of CITYMOBIL.
4	Fleet and maintenance management	Development of a system by GLOBALSYS for a manufacturer of commercial vehicles that enables the sharing of data between manufacturer and customers for fleet management and maintenance planning.
5	Smart parking service	Development of a service by GLOBALSYS for a large German city that combines multiple data sources to identify areas with a high probability of free parking space. Service also includes parking reservations.
6	Energy trading platform	Development of a tendering service as an alternative to expensive energy exchanges to improve own margin. It supports placing tenders in the marketplace, shows current tenders and market pricing.
7	Customer service for public transport	Development of a platform by ITSOLUTION for a municipal public transport organization, including services for end-users, e.g., master data management, ticket purchasing, subscriptions, etc.
8	Car delivery tracking	Customer-individual development of a digital monitoring service by ITCONSULT for the real-time tracking of car delivery.
9	Industrial doors remote support	Development of a remote support service for industrial doors by DIGIBUSINESS for the door manufacturer.
10	Intermodal public transport service	Development of a digital service (incl. app and information terminals) for citizens that provides alternatives based on location and destination with the integration of multiple modes of transport.
11	Virtual reality-based user train-	Development of a virtual reality training service using maintenance simulations of PHARMACHINES' products, which one of its customers triggered.
12	Remote support via video chat	Development of a video-chat-based remote support app to support customers in resolving incidents with PACKMACHINES' products.
13	Predictive maintenance	Development of a showcase of an availability-based business model as part of a governmentally funded consortium project.
14	Digital customer portal	Development and customization of software that FIELDSERVICE's customer in facility management can use to provide its customers with a customer portal (instead of paper-based documentation).

Table 2. SSSE projects mentioned by the experts

The experts' experiences with *agile methodologies* appeared to be more positive. Expert 1 said: "We decided to use an agile approach due to an uncertain specification, and Scrum allowed us to gather feedback regularly". However, he also mentioned that customer involvement in the Scrum methodology requires the availability of customer employees for planning and review. In project 6, a "Scrum-like" approach was chosen, in which the software development was organized in iterations ("sprints") based on a product backlog. However, the involvement of customers did not follow the rules of Scrum as the system integrator and service provider were "both large companies, which have their difficulties in working with Scrum". Instead, initial workshops with prospective customers were conducted to gather ideas and prototypes were used for validation and feedback with additional customers. However, the actual agile development was done without involving users. After the launch of the system, additional feedback was gathered from actual users of the system.

Methodologies	Description	Projects
Agile	Used an agile approach throughout the project	1, 2, 4, 6, 8
Sequential	Used a sequential approach throughout the project	3, 10, 12, 13
Hybrid	The project was conducted partly agilely and partly sequentially	5, 7, 9, 11, 14

Table 3. Employed project management methodologies

We also found the use of *hybrid approaches*, which often results from divergent expectations, methodologies or practices of the different actors involved in SSSE projects and which yield additional challenges. In the project described by expert 5, the implementation of the app was conducted in an agile approach, while the backend services were developed by another team using a sequential methodology. This caused friction as the backend team could not start without a complete specification of the interface, for which the app team required several iterations. Expert 9 stated that “every customer wants to work agile, but at the same time they want to know the result, budget and time in advance. Therefore, a customer requirement specification was developed [...] and a quote with a fixed price was made. From the outside view, this looked like a waterfall approach. Internally, an agile approach was used to develop the software based on Scrum”.

Category	Challenges	Projects
Planning	Tight deadlines; lack of time for preparation/analysis	4
	Uncertain/inconsistent management decisions	5
Collaboration	Involvement of partners	1,6
	Difficulties of involving customers in an agile approach	1
	Distribution and synchronization of work; maintaining consistency of work products	1, 5, 7, 9
	Getting access to and aligning work with stakeholders, e.g., partners, internal units	5, 6
	Common understanding and suitable level of detail	7
	Lack of technical knowledge at the service provider	7
	Achieving a common understanding of concepts (e.g., industry 4.0, smart service, etc.)	13
	Work of external project participants not delivered on time; threat of missing deadlines	1, 4
Go-live	Advancing app from prototype status to a productive and usable one	12
	Testing was time-consuming and required a lot of effort	12

Table 4: Challenges regarding project management

Across the three design dimensions, we were able to identify a large set of different ends and means that were used in SSSE projects. When analyzing the ends and means across all dimensions, we further distinguished between means for *developing* insights, ideas, and concepts, and *documenting* those as work products for further use in the SSSE project.

Our analysis of the **value dimension** yielded the ends *customer understanding* and *value proposition*. (Table 5). Almost all projects applied user-centric approaches to develop a customer understanding. Some projects were even based on customer ideas or the role of the product owner was transferred to the customer. Most commonly, interactive workshops, discussions, and Design Thinking methods were employed. Furthermore, one project made use of an internal platform that enabled the sharing of customer insights between employees. In other projects, expert interviews and field tests with selected customers were used. For capturing and retaining such insights, the experts of our sample used requirement specifications, personas, customer journeys, or epics and user stories. The experts also mentioned minimum viable products (MVP) or low fidelity prototypes to gather early feedback.

Ends		Means	Projects
Customer Under-standing	*Develop*	Feedback on current service, customer ideas, customer as product owner	1,4,11,12
		Workshops, discussions, Design Thinking	2,3,6,7,9,10,13
		Internal employee platform (prediction markets)	5
		Expert interviews, field tests with friendly customers/test users	1,3,6
	Document	MVP, paper-based prototypes	6,7
		Epics and user stories	1,2,5
		Customer journeys, personas	1,2,5,9,13
		Requirements specification	7,9,10,11,12,13,14
Value Proposition	*Develop*	Identify/prioritize actors/customers and their jobs/problems	2,3,6,11,12
		Understand the capabilities of existing system as a basis for new service	3
		Interactive discussion, workshops	6,7,9
		Check for legal hurdles (e.g., patents, privacy, regulatory)	1,12
	Document	Define process model	3
		Slides, whiteboards, bullet points	2,3,4,6,11,13
		Textual specifications	5,10,11,12
		Workshop documentation, according to structured innovation approach	9
		Business Model Canvas, Value Proposition Design, personas	1,3,6
		Use cases	9

Table 5: Means and ends in the value dimension

Category	Subcategory	Challenges	Projects
Customer Under-standing	*Market Dynamics*	Dependency on external developments, e.g., technological advancements	3
	Requirements	Unspecific customer requests	5
		Variety of customer requirements	13
Value Prop-osition	*Target Customer*	Decisions on customer segment/target group	2
	Customer Problem	Choosing a problem, which is to be addressed	2, 12
	Quality	Overall level of quality of service, i.e., functionality vs. price	3
	Legal	Unclear legal conditions, e.g., on billing methods, potential patent violation, regulatory compliance, ownership of data	1, 3, 12, 13
	Features	Defining the feature set for the initial launch, future releases, and prioritization of necessary vs. useful features in general	5, 6, 12
Value Capture	*Revenue Model*	Distribution of financial benefits	1
	Pricing Decisions	Finding a good pricing model, refining the pricing model	6
		Customers with different price expectations/perceptions	12
	Business Model	Difficulties in identifying suitable business models	6,10,12

Table 6. Challenges in the value dimension

An explicit definition of the service's value proposition was not done in all projects of our sample. Where it took place, however, customer jobs and problems were identified, workshops or discussions took place, or existing systems provided a basis for new service offerings. Definitions and models of the value proposition were mainly documented on slides, whiteboards or textual specifications. A few experts also mentioned specific methods like the Business Model Canvas or Value Proposition Design.

The experts mentioned manifold challenges when designing the value dimension (Table 6). As regards the *customer understanding*, the project teams had to deal with unspecific requests or a great variety of requirements. More challenges were found regarding the *value proposition*, including unclear ownership of data or the selection of the right customer problem to be addressed. In addition, the expert mentioned challenges regarding *value capture* mechanisms, including business models and pricing strategies, too.

The main ends in the **process dimension** are the design of *user interaction / user interfaces* as well as *background processes* (Table 7). A major part of the projects involved UX experts. Early test phases with customer feedback and adjustments as well as workshops and discussions aided the development. Prototypes, wireframes and click dummies were further means to model and document user interactions. Particularly customer journeys were considered helpful in designing both value proposition and user interaction. In some projects, other types of process models and textual descriptions were used to document the process steps. As regards the background processes, not all projects did consider them explicitly. Among those cases which did, textual descriptions, as well as formal modeling languages were used. However, only a few experts could provide details on means that helped to develop background processes. Only technical documentation or the expertise of the product owner were mentioned here.

Ends		**Means**	**Projects**
User Interaction / User Interfaces	*Develop*	Involvement of UX experts	1, 2 ,4, 6, 10
		Early testing and adjustment, improvement through feedback	1, 2, 3, 14
		Workshops, discussions, analysis	3, 6, 7, 8
		Definition of roles and permissions	1, 7
		Design guidelines	12
	Document	Prototypes, wireframes, click dummies, atomic design	1, 4, 5, 7
		Customer journeys, visualized customer process	1, 5, 6, 13
		Service journeys, process models, textual description of process	12, 14
Background Processes	*Develop*	Technical documentation including process definitions	9
		Domain expertise of product owner	6
	Document	Textual description, informal modeling of process steps	4, 6, 11, 12
		Formal modelling language (BPMN, UML, flow charts)	2, 3, 4
		Click dummies, modular standard screens	7, 14

Table 7: Means and ends in the process dimension

Category	**Subcategory**	**Challenges**	**Projects**
User Interaction / User Interfaces	*Touchpoints*	Unclear whether additional effort in user interface simplification will pay off	7
		Determine the suitable number of elements should on a page, i.e. amount of information that users can handle	7
Background Processes	*Process Design*	Capabilities and degrees of freedom in existing systems had to be matched to requirements for new service; change of either systems or requirements	3

Table 8: Challenges in the process dimension

In total, only two experts mentioned challenges that refer to the process dimension (Table 8). Expert 7 described challenges regarding user interfaces and touchpoint design. Expert 3 mentioned that he had to align existing systems with requirements of the new service system, resulting in change requests.

Ends		Means	Projects
Technical Concept	*Develop*	Review of existing components, compliance with existing architecture/equipment	1, 2, 6, 8, 12
		Define new components, comply with architectural guidelines, 12-factor cloud apps	1, 2, 4, 8
		Traditional system specification, derivation of technical requirements	3, 9
		Iteratively integrated and implemented on a test platform	7
	Document	Vertical prototypes	4
		IT architecture model, microservices	2, 4, 6, 7, 13
		UML, ArchiMate, interface definition	1, 4, 7
		User stories and epics	1, 4, 5, 6

Table 9: Means and ends in the resource dimension

In the **resource dimension,** the experts mentioned several means to develop and document the technical concept of smart service systems (Table 9). Looking at the *development of technical concepts*, it became transparent that a large part of the projects was based on existing systems or at least reliant on the integration of existing components. In addition, the actors involved in the projects had to develop new components, where predefined architectural guidelines and design approaches had to be respected. In some projects, traditional system specifications and the derivation of technical requirements were used also used for developing the technical concept. The *documentation of the technical concept* was done in a variety of ways. For instance, the experts used structured ways of modeling, e.g., notations like UML, ArchiMate or interface definitions. User stories and epics were also used for documenting a technical concept. In project 4, even the whole range of different means that we coded were used.

Category	Subcategory	Challenges	Projects
Technical Concept	*System Architecture*	Future number of connected products, data amount for transmission, etc.	9
		Load-aware mechanism for data collection and transmission	12
		Cross-system identity management	4
		Enabling/extending the underlying platform for new requirements	1
		Determining the required data and data quality	13, 14
	System Integration	Getting the system running globally, consideration of country-specifics	8
		Integrating devices; implementing protocol adapters	1
		Integration of existing systems; data access in heterogeneous systems	1, 2, 7
		Missing/incomplete documentation of hardware and external systems	4, 7
	Technology Choice	Low maturity technology stack	9
		Selection of communication technology, e.g., MQTT vs. OPC-UA	12
		Selection of cloud / IoT-platform provider	9, 13
Human	*Knowledge*	Need for external know-how, e.g., software development/ analytics	8,9,13
		General lack of digital transformation/innovation knowledge/skills	2,3
		Training of employees, e.g., infrastructure, data-driven approaches, sales	2, 4, 13
	Organization	Team members or customers not familiar with an agile approach	1, 4
		Dependency on external actors	1, 3, 6
		Confronting functional departments with too many technical details	9

Table 10: Challenges in the resource dimension

Challenges regarding the resource dimension (Table 10) are mostly related to the integration of external systems, services or devices. Hence, the experts frequently mentioned challenges concerning accessing, handling and processing data. They also mentioned challenges that we clustered to the category "human". Here, we identified issues like insufficient knowledge, inadequate application of methods, and difficulties with the coordination of work between different actors.

5 Discussion and Conclusions

In our study, we explored how organizations engineer smart service systems in practice. We interviewed 14 experts that were involved in real-life SSSE projects to generate our empirical insights, which we structured along the value, process, and resource dimensions of smart service systems, and the project management approach as an overarching category. To the best of our knowledge, we are among the first to provide such broad empirical insights that nurture the improvement of methodologies for SSSE. Thereby, we contribute to extending the current academic discussion beyond conceptualizing smart service systems and describing their features (Beverungen et al., 2019; Lim and Maglio, 2018).

Concerning SSSE project management, we saw a mix of sequential, agile and hybrid methodologies across the projects that the experts reported, but also a movement towards more agile project management. Some experts were unsatisfied with the sequential approaches and already decided that they would switch to more agile approaches in the future. We also saw that the selection of traditional sequential approaches was either enforced by external circumstances (e.g., public funding) or a result of maintaining old work practices, mostly at organizations with no or little experience in software engineering. Hence, it appears that agile approaches are more suitable for SSSE projects than sequential approaches. Recently suggested procedure models for SSSE, including recombinant service engineering (Beverungen et al., 2018) and the DIN SPEC 33453 for the development of digital service systems also argue in favor of agile methodologies. However, even using agile approaches, project management challenges remain. These challenges mainly refer to the collaboration among a diverse set of project participants that SSSE projects typically involve (Anke et al., 2020). Sometimes, the different project management cultures of actors clash in an SSSE project, leading to the hybrid approaches that we identified. Such hybrid approaches are likely to cause friction and misunderstandings. Sometimes, the actors even choose approaches that could be understood as tayloristic strategies, where they utilize their own routines only for their part of the overall project work and do sequential hand-overs of project steps instead of following a uniform, integrated and iterative methodology for the whole project.

Our interview data showed that practitioners employ a wide array of means to address the various ends across the design dimensions, which underlines the complex nature of SSSE projects. Here, we found traditional requirements specifications, but also user stories, customer journey maps, and personas as frequently used means. A large part of the project work is also documented in simple texts or on PowerPoint slides. Popular visualization tools like the Business Model Canvas and Value Proposition Design were only mentioned by a few experts. Rather formal techniques (e.g., notations like BPMN, UML, and ArchiMate) are only used for background processes and technical concepts. We also noted that experts from IT firms reported on a larger number and variety of methods compared to the experts from more traditional industries. Hence, only a small share of the available range of methods and tools is adopted in practice. Mostly, these are generic means (e.g., workshop discussions, personas) and hardly any SSSE-specific methods or tools. This leads to the question of whether adequate and specific methods and tools are still to be developed for SSSE or if we rather witness issues with disseminating the means and training of employees in applying them. Several researchers argue that there still is a need for better methods (Hagen et al., 2018; Marx et al., 2020). Furthermore, there is a call for the better integration of methods across different design dimensions. As a way forward, Marx et al. (2020, p. 12) suggest to "increasingly integrate a service systems view into smart service engineering." Böhmann et al. (2014, p. 76) similarly see the need for new and better means to develop service architectures that also "enhance the possibilities for modularization, standardization, contextualization and re-configuration of service components and resources, as well as for modeling and simulation of the behavior of service systems and their key actors." While these directions may sound reasonable from an academic perspective, they are also likely to result in even more complex methods and tools, which, in turn, will not be adopted easily by practitioners. Wolf et al. (2020) have already identified the unawareness of SSSE methods as a problem in practice. Beverungen et al. (2018) also see issues in the methods' complexity, their lack of usability as well as their ignorance of external resources from customers and other third parties. According to our interview data, the means that have found their way into practice are mostly easy-to-use visualization tools like the Business Model Canvas or common methods or techniques from software development like UML, personas, and user stories. While the better integration of methods, techniques and resulting work products appear to be an attractive goal, our results rather indicate the need for creating and promoting toolboxes of easy-to-use and flexible means. Beverungen et al. (2018, p. 389) highlight a similar dilemma between consistency and flexibility: “While a close integration seems favorable to design service systems consistently, loose coupling could keep the design of service systems more agile, by decoupling them from more inflexible product development processes.”

Therefore, **future research** is needed to develop such toolboxes of loosely coupled means for SSSE, which does not necessarily mean that a lot of new methods or techniques are needed. Researchers should continue analyzing the effectiveness and efficiency of identified means for SSSE, especially considering the support for inter-organizational collaboration and balancing flexibility and consistency across the design dimensions. Means could be categorized into (1) *established*, i.e., they are suitable and successfully applied in practice, (2) *available*, i.e., suitable to address identified challenges but not yet applied in practice, and (3) *missing*, i.e., there are no means to address the identified challenges. Means of the category ‘established’ can become part of the set of means to support SSSE and prevent ‘reinventing the wheel’. For means of the category ‘available’, it should be investigated why they are not applied in practice. Challenges for which no methods or techniques exist indicate a need for additional research. A further avenue for future research is the elaboration of skill-role maps that cluster several means into distinct skills, which, in turn, can be assumed by an organization or individual in an SSSE project. In the long term, both practitioners and academics alike will benefit from a well-aligned and consolidated set of means and roles that guide complex SSSE projects, and, thus, help to tame the tiger.

Due to the exploratory character of our study, the following **limitations** must be considered. First, our results are grounded in data from only 14 interviews. While the experts covered a broad range of SSSE projects in diverse settings, these can neither be considered comprehensive nor representative for SSSE projects in general. Second, we only interviewed one expert per case, which limits our available information to her/his perspective. Third, the proposed categorization of ends, means and challenges resulted from our subjective interpretation of the interview data. Although we discussed our codings intensively, other researchers might have come to different categorizations. Fourth, we were not able to assess the influence of certain project management setups and the use of specific means on project success as most SSSE projects in our sample were in the late stages of engineering or the early stages of market tests. Hence, our results cannot offer a normative set of means in the sense of best practices.

The **practical implications** of our findings relate to project management and the ends, means, and challenges of SSSE projects. First, SSSE projects are conceived as complex projects where the to-be state of the smart service system as a socio-technical whole is difficult to be fully conceptualized early on. The experts’ statements largely recommend the use of agile methodologies to deal with this uncertainty and to warrant new smart service offerings that are likely to meet actual customer demands. However, such methodologies might be unfamiliar to traditional product-centric businesses, and employees need to be trained accordingly. Furthermore, practitioners need to be aware that SSSE projects require inter-organizational setups. They do not only have to collaborate with customers but also with various partners and suppliers (Anke et al., 2020). Hence, organizations need to understand their role in the SSSE project and ensure that inter-organizational project management is pursued with adequate communication and collaboration tools. Second, the ends that we identified can serve practitioners as a preliminary checklist for the different areas that need to be addressed in SSSE projects. However, it can only be a starting point as important aspects, like the role of human resources in the smart service system, appear to be largely overlooked so far. While the ends provide a list of what has to be done, the identified means tell how it can be done, and, hence, these can also serve as an inspiration to SSSE project managers. Here, we recommend practitioners to broaden their repertoire of methods and tools, try out if they are useful, and serve as a multiplicator of suitable methods and tools through their inter-organizational project work. The challenges that we identified illustrate the things that can go wrong in SSSE projects, and thereby also provide some hints for preventive action (e.g., dealing with legal issues). Concluding, practitioners should be aware that SSSE projects are not mere hardware and software implementation projects, but inter-organizational, collaborative and human-centered endeavors. They need to be managed accordingly and the method and tool support used in practice should promote a corresponding mindset.

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