Smart Service Innovation: Organization, Design, and Assessment

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Abstract

Background: The emergence of technologies such as the Internet of Things, big data, cloud computing, and wireless communication drives the digital transformation of the entire society. Organizations can exploit these potentials by offering new data-driven services with innovative value propositions, such as carsharing, remote equipment maintenance, and energy management services. These services result from value co-creation enabled by smart service systems, which are configurations of people, processes, and digital technologies. However, developing such systems was found to be challenging in practice. This is mainly due to the difficulties of managing complexity and uncertainty in the innovation process, as contributions of various actors from multiple disciplines must be coordinated. Previous research in service innovation and service systems engineering (SSE) has not shed sufficient light on the specifics of smart services, while research on smart service systems lacks empirical grounding.

Purpose: This thesis aims to advance the understanding of the systematic development of smart services in multi-actor settings by investigating how smart service innovation (SSI) is conducted in practice, particularly regarding the participating actors, roles they assume, and methods they apply for designing smart service systems. Furthermore, the existing set of methods is extended by new methods for the design-integrated assessment of smart services and service business models.

Approach: Empirical and design science methods were combined to address the research questions. To explore how SSI is conducted in practice, 25 interviews with experts from 13 organizations were conducted in two rounds. Building on service-dominant logic (SDL) as a theoretical foundation and a multi-level framework for SSI, the involvement of actors, their activities, employed means, and experienced challenges were collected. Additionally, a case study was used to evaluate the suitability of the Lifecycle Modelling Language to describe smart service systems. Design science methods were applied to determine a useful combination of service design methods and to build meta-models and tools for assessing smart services. They were evaluated using experiments and the talk aloud method.

Results: On the macro-level, service ecosystems consist of various actors that conduct service innovation through the reconfiguration of resources. Collaboration of these actors is facilitated on the meso-level within a project. The structure and dynamics of project configurations can be described through a set of roles, innovation patterns, and ecosystem states. Four main activities have been identified, which actors perform to reduce uncertainty in the project. To guide their work, actors apply a variety of means from different disciplines to develop and document work products. The approach of design-integrated business model assessment is enabled through a meta-model that links qualitative aspects of service architectures and business models with quantitative assessment information. The evaluation of two tool prototypes showed the feasibility and benefit of this approach.

Originality / Value: The results reported in this thesis advance the understanding of smart service innovation. They contribute to evidence-based knowledge on service systems engineering and its embedding in service ecosystems. Specifically, the consideration of actors, roles, activities, and methods can enhance existing reference process models. Furthermore, the support of activities in such processes through suitable methods can stimulate discussions on how methods from different disciplines can be applied and combined for developing the various aspects of smart service systems. The underlying results help practitioners to better organize and conduct SSI projects. As potential roles in a service ecosystem depend on organizational capabilities, the presented results can support the analysis of external dependencies and develop strategies for building up internal competencies.

Content Overview

Table of Contents

List of Abbreviations

A2A ... Actor-to-Actor
ADR ... Action Design Research
AI ... Artificial Intelligence
API ... Application Programming Interface
B2C ... Business-to-Consumer
BM ... Business Model
BMC ... Business Model Canvas
BMDT ... Business Model Design Tool
BMI ... Business Model Innovation
BOL ... Beginning-of-Life
BPMN ... Business Process Model and Notation
CAD ... Computer-Aided Design
CASD ... Computer Aided Service Design
CBA ... Cost-Benefit-Analysis
CEO ... Chief Executive Officer
CG ... Control Group
CJM ... Customer Journey Mapping
CORE ... Computing Research and Education Association of Australasia
CPS ... Cyber-Physical Systems
CRISP-DM ... Cross Industry Standard Process for Data Mining
DDBM ... Data-driven Business Model
DESRIST ... Conference on Design Science Research in Information Systems and Technology
DI ... Digital Innovator
DIN ... Deutsches Institut für Normung
DSL ... Domain-specific Language
DSM ... Digital service specific methods
DSR ... Design Science Research
DSRM ... Design Science Research Methodology
EG ... Experimental group
EOL ... End-of-Life
FR ... Functional Requirements
GPM ... General-purpose Methods
ICT ... Information and Communication Technology
ID ... Identifier
IEM ... Impact-Effort Matrix
IoT ... Internet of Things
IRR ... Internal Rate of Return
IS ... Information Systems
ISB ... Information Service Blueprint
ISO/IEC ... International Organization for Standardization/International Electrotechnical Commission
IT ... Information Technology

LCC .... Lifecycle Costing
LML .... Lifecycle Modelling Language
LNCS .... Lecture Notes in Computer Science
MBSE .... Model-based Systems Engineering
ME .... Method Engineering
MKWI .... Multikonferenz Wirtschaftsinformatik
MOL .... Middle-of-Life
MQTT .... Message Queuing Telemetry Transport
MVP .... Minimum Viable Product
NABC .... Need, Approach, Benefit, Competition
NPV .... Net Present Value
OEM .... Original Equipment Manufacturer
OMG .... Object Management Group
OPC-UA .... Open Platform Communications Unified Architecture
PLM .... Product Lifecycle Management
PS .... Project Sponsor
PSS .... Product-Service System
QR .... Quality Requirements
R&D .... Research and Development
REST .... Representational State Transfer
ROI .... Return on Investment
RQ .... Research Question
SBM .... Service Business Model
SBMC .... Service Business Model Canvas
SDL .... Service-Dominant Logic
SE .... Service Engineering
SEM .... Service engineering methods
SI .... System Integrator
SME .... Situational Method Engineering
SO .... Service Operator
SQL .... Structured Query Language
SSC .... Smart Service Canvas
SSE .... Service Systems Engineering
SSI .... Smart Service Innovation
SSSE .... Smart Service Systems Engineering
SysML .... System Modelling Language
TCO .... Total Cost of Ownership
UBI .... Usage-based Insurance
UCD .... User-centered Design Methods
UI .... User Interface
UML .... Unified Modelling Language
UX .... User Experience
VHB .... Verband der Hochschullehrerinnen und Hochschullehrer für Betriebswirtschaft
VPC .... Value Proposition Canvas

List of Tables

List of Figures

PART A - SYNOPSIS

1 Introduction

1.1 Motivation

The ongoing digital transformation is "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" (Vial, 2019, p. 118). It provides organizations of all industries ample opportunities for creating competitive advantage, including innovative smart service offerings. Examples of smart services can be found in consumer markets where car makers connect vehicles with digital platforms to analyze driving behavior based on sensor data, schedule workshop appointments, provide usage-based insurance, or give feedback on driving behavior (Beverungen, Breidbach, et al., 2019; Husnjak et al., 2015). In the industrial domain, manufacturers innovate by combining digitally connected machines and equipment with value propositions like predictive maintenance, remote service and control, fleet management, and pay-per-use models (Herterich et al., 2015; Heuchert et al., 2020).

Smart service innovation (SSI) inherently reflects the process of digital transformation, as it utilizes digital technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and cloud computing as enablers of new value-creating and revenue-generating opportunities (Demirkan et al., 2015; Parida et al., 2019; Sjödin, Parida, Jovanovic, & Visnjic, 2020) that change the value propositions and value creation processes of organizations (Vial, 2019; Wessel et al., 2021). SSI establishes smart service systems, which rely on physical objects with computation, data storage, sensors, actuators, and networking capability (Porter & Heppelmann, 2014). Such smart products serve as boundary objects between actors of the service system (e.g., service consumers and providers) and enable or facilitate mutual value creation (Allmendinger & Lombreglia, 2005; Beverungen, Müller, et al., 2019; National Science Foundation, 2014).

However, creating novel smart service offerings is challenging in practice, mainly due to the associated complexity and uncertainty. This may lead to situations described as *digital paradox*, in which "increasing revenues from digital services fail to deliver greater profits because of rampant cost increases" (Sjödin, Parida, Kohtamäki, & Wincent, 2020, p. 479). Some of the challenges identified are the lack of skills for digital innovation and solution design, technical interoperability problems, the management of multiple stakeholders, and unclear regulations regarding privacy and data ownership (Bonamigo & Frech, 2020; M. Ebel, 2021; Klein et al., 2018; Wolf et al., 2020).

Smart service innovation has become a central topic for information systems (IS) research over the last years (Beverungen, Breidbach, et al., 2019; Yang et al., 2021) with links to many other disciplines including services marketing (Wuenderlich et al., 2015), industrial marketing management (Sjödin, Parida, Kohtamäki, & Wincent, 2020; Sklyar, Kowalkowski, Tronvoll, & Sörhammar, 2019), innovation management (Maglio & Lim, 2016), and industrial engineering (Rabe et al., 2018). The information systems discipline is particularly suitable to study the systematic development of smart service systems due to its interdisciplinary nature (Böhmann et al., 2014). In this context, the term "service systems engineering" (SSE) is used to go beyond traditional service engineering "towards systemic, interactive and collaborative service innovation based on advances in IT" (Böhmann et al., 2014, p. 74) that adopts the ideas of service systems (Beverungen et al., 2018; Maglio et al., 2009) and service ecosystems (Vargo & Lusch, 2016, 2017; Vink et al., 2021). Höckmayr and Roth (2017) have formulated requirements for SSE methods that include, amongst others, the imperative to "address larger constellations within which multiple actors become joined over time and space" and to "acknowledge the role of knowledge and skills applied by various actors" in service innovation (Höckmayr & Roth, 2017, p. 5). Referring to digital transformation more broadly, Alt (2019) similarly calls for methodologies that cover an ecosystem-wide perspective and integrate aspects of business and technological change. Currently, there is little empirical research on performances by individual actors within such multi-actor settings, which has been identified as an open research issue in the context of digital transformation (Vial, 2019).

The existing SSE design knowledge for the systematic development of service systems includes reference process models with phases, activities, and methods to guide the development of service systems (Beverungen et al., 2018; DIN, 2019; Jussen et al., 2019). Studies show that organizations already employ iterative and agile ways of working to deal with complexity and reduce uncertainty but current SSE methods lack the support for multi-actor settings (Sjödin, Parida, Kohtamäki, & Wincent, 2020). Furthermore, the set of SSE methods is limited and should be extended through methods from disciplines such as business model innovation, user-centered design, and software engineering to cater for the various design tasks in SSI (Holler et al., 2018). During the design of service systems in the various stages, an ongoing assessment can improve the quality of service concepts (Turetken et al., 2019) and their business models (Tesch et al., 2017). However, there is currently little support for such assessments (Szopinski et al., 2019).

The purpose of this thesis is to address these gaps by focusing on three main topics: (1) *organization*, i.e., the involvement, contributions, and activities of different actors in SSI, (2) *design*, i.e., the suitability and combination of existing methods for SSI, and (3) *assessment*, i.e., the development of new methods for the assessment of services systems during their design. The research approach combines empirical research and design science approaches, which include the application of expert interviews, qualitative analysis, case studies, conceptual modeling, prototyping, and experiments for the evaluation of artifacts.

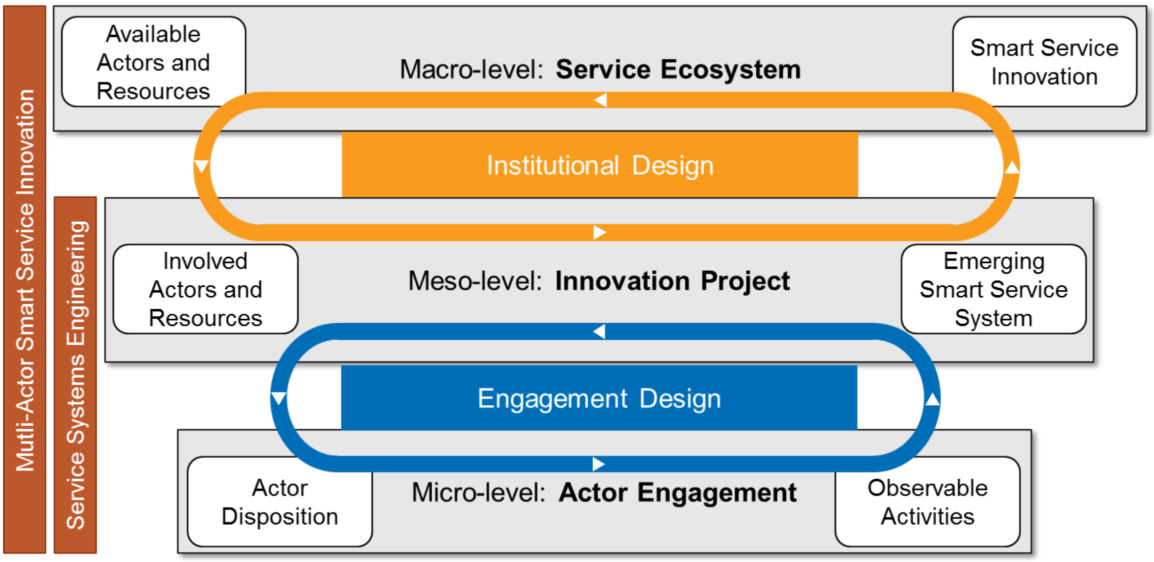

Figure 1.1: Multi-level framework for smart service innovation

To capture the empirical phenomena and organize the research findings, a multi-level framework perspective on smart service innovation (Figure 1.1) is established based on the work of Storbacka et al. (2016) and Grotherr et al. (2018). It describes the reconfiguration of resources by multiple actors in a service ecosystem towards a new value proposition on the macro-level. Depending on the need for different resources, suitable actors are involved (Institutional Design cycle). The collaboration of involved actors is facilitated by projects, which represent the meso-level of this framework. Projects can be understood as a configuration of actors, resources, and the rules of engagement. They form the context in which individual actors collaborate, e.g., by establishing project management mechanisms, enacting a development process, and distributing work. The establishment and adaption of the project create the context for the performances of individual actors (Engagement Design cycle). At the micro-level, actors conduct their work using methods that represent the knowledge and skills they consider suitable. The created work products are integrated into a smart service system as continuously evolving project results at the meso-level, which in turn enables the desired new value proposition for the target customers at the macro-level.

Contributions regarding the *organization* include a set of ecosystem roles that actors may assume, and innovation patterns, which describe typical configurations of actors and roles. In addition, a model that relates the performed activities of individual actors to the reduction of uncertainty at the project level is proposed. Regarding the *design*, methods for developing and documenting different aspects of the service system are gathered along with various challenges in designing services. It is shown that combining methods from different disciplines are both feasible and useful in SSI. To capture the variety of service system elements and their dependencies, the Lifecycle Modelling Language (LML) has been found to be suitable to fulfill the information needs of different stakeholders. Finally, the approach of design-integrated *assessment* is proposed. It is based on a meta-model for smart service systems, which allows the annotation of service elements with assessment-related information. An assessment model is derived from these annotations, which is updated whenever the service model changes. The instantiation of these models in tool prototypes and their evaluation shows that the application of such design-integrated assessment is beneficial in SSI.

The presented results contribute to the body of knowledge in smart service innovation as an overarching phenomenon as well as to service system engineering as an emerging discipline. Specifically, they can be used to enhance existing reference process models, such as the DIN SPEC 33453 (2019), which describes phases, activities, and methods for SSI. This thesis sheds light on the context, in which such process models are enacted, e.g., by linking activities to actors and indicating the required methods that guide them. Furthermore, the range of suitable methods to support these activities is extended. For practitioners, this research provides valuable insights for the organization of smart service innovation. On an operational level, the enactment of service innovation processes is supported by a better understanding of involved actors, their roles, and activities, as well as suitable methods for service design and assessment. Strategically, the presented results might assist the evaluation of external dependencies and planning of skill development within one's own organization.

1.2 Research Objectives and Research Questions

Service Systems Engineering (SSE) as an emerging discipline "seeks to advance knowledge on models, methods, and artifacts that enable or support the engineering of service systems" (Böhmann et al., 2014, p. 76). The overall goal of this thesis is to contribute to SSE by providing empirical evidence from real-world projects on the organizational setup as well as suitable methods for the design and assessment of smart services. Within this goal, the three research objectives with associated research questions are defined as follows:

Objective 1: Understand the organizational setup of SSI. The complexity of smart service systems and the variety of required elements for such systems require various competencies, which are typically not found within a single organization. Additionally, innovation processes are beset with various types of uncertainty. For instance, customer requirements are often not clear and have to be discovered. Therefore, it can be assumed that SSI requires the involvement of multiple actors (Lusch & Nambisan, 2015). This is in line with the S-D logic perspective of innovation as reconfiguration of resources in an ecosystem of actors. Understanding which resources they contribute, which activities they perform, and how they collaboratively reduce uncertainty, provides the context for enacting SSI reference process models. Furthermore, a better understanding of multi-actor SSI illustrates the complexity and need for collaboration in such innovation projects. For the first research objective, the following research questions (RQ) are defined:

- RQ 1.1: Which roles are assumed by the actors involved in SSI?
- RQ 1.2: Which actor-role constellations can be identified that reflect recurring SSI patterns?
- RQ 1.3: How does the involvement of actors change over time?
- RQ 1.4: How do involved actors reduce uncertainty in SSI projects?

Objective 2: Evaluate the suitability of existing methods for SSI. Depending on its role, any actor responsible for certain activities in SSI must find a suitable approach to perform these activities within the project constraints of quality, cost, and time. This requires a suitable development process and project management approach. While smart service systems have specific traits, the problem of designing complex systems under uncertainty has been addressed by other disciplines already. To avoid re-inventing the wheel, it is worthwhile to evaluate how existing methods including models, techniques, and notations are suitable for SSI and how they can be combined in a meaningful way (Marx et al., 2020). The variety of methods leads to a fragmentation of work products that impedes the establishment of an integrated view of the emerging service system. A promising solution for this issue is the Lifecycle Modelling Language, which is evaluated regarding its suitability for SSI. Within the second objective, the following RQs are defined:

- RQ 2.1: Which methods for service design are applied in practice for SSI?
- RQ 2.2: Which challenges can be identified with applied SSI means in practice?
- RQ 2.3: How can methods from different disciplines be combined to support SSI?
- RQ 2.4: Which information needs in the lifecycle of smart service systems can be fulfilled with the Lifecycle Modelling Language?

Objective 3: Develop methods for design-integrated assessment in SSI. To identify innovative value propositions for smart services, creativity methods are employed that typically result in many ideas. To select to most promising ones for further elaboration and justify the required funding, their financial impact should be assessed during the design process. Furthermore, it has been found that the assessment of service business models during their development improves their overall quality (Turetken et al., 2019). Currently, the research on how to integrate the assessment of service concepts into development activities is sparse. Therefore, the third research objective aims at the development of new methods for the design-integrated assessment of smart service ideas and their business models within SSI. It is addressed by the following two RQs:

- RQ 3.1: How can smart services be financially assessed?
- RQ 3.2: How can service business models be assessed?

1.3 Thesis Structure

This habilitation thesis consists of two parts:

Part A consists of six sections, with section 1 containing the introduction, research questions, research background, findings, discussion, and conclusion. In section 2, service-dominant logic, smart service systems, multi-actor smart service innovation, and service systems engineering are introduced as main foundational concepts and theories. Section 3 provides a summary of the research approach and the applied research methods. The key findings are presented in section 4. The discussion of these results in section 5 covers theoretical contributions, limitations, managerial implications, and directions for future research. Part A closes with conclusions in section 6.

Part B contains eight sections, which are original research papers. They document the details of the findings presented in Part A. Table 1.1 gives an overview of the included papers and the research questions they address. All papers are peer-reviewed and published in an outlet with a ranking of at least "C" according to VHB JourQual 3. Earlier versions of papers are documented in the footnotes.

Citation	**Title**	**Outlet**	**JQ3[1]**	**CORE[2]**	**Addressed RQs**
Anke, Pöppelbuß, and Alt (2020a)	It Takes More than Two to Tango: Identifying Roles and Patterns in Multi-Actor Smart Service Innovation	Schmalenbach Business Review[3]	B	-	1.1 1.2 1.3
Pöppelbuß, Ebel, and Anke (2021)	Iterative Uncertainty Reduction in Multi-Actor Smart Service Innovation	Electronic Markets	B	A	1.4
Anke, Ebel, et al. (2020)	How to tame the Tiger – Exploring the Means, Ends and Challenges in Smart Service System Engineering	European Conf. on Information Systems	B	A	2.1 2.2
Richter and Anke (2021)	Combining Methods for the Design of Digital Services in Practice: Experiences from a Predictive Costing Service	Wirtschafts-informatik	C	C	2.3
Anke et al. (2018)	Modelling of a Smart Service for Consumables Replenishment: A Life-Cycle Perspective	EMISA Journal[4]	C	C	2.4
Anke (2019)	Design-integrated Financial Assessment of Smart Services	Electronic Markets[5]	B	A	3.1
Zolnowski et al. (2017)	Towards a Cost-Benefit-Analysis of Data-Driven Business Models	Wirtschafts-informatik	C	C	3.2
Anke (2020)	Enabling Design-integrated Assessment of Service Business Models Through Factor Refinement	DESRIST	C[6]	A	3.2

Table 1.1: Overview of papers included in Part B

[1] German VHB JourQual 3 ranking list, https://vhbonline.org/en/vhb4you/vhb-jourqual/vhb-jourqual-3
[2] Computing Research and Education Association of Australasia (CORE) ranking 2018, https://www.core.edu.au/
[3] A previous version of this paper was published at the WI 2020 conference (Anke, Pöppelbuß, & Alt, 2020b)
[4] A previous version of this paper was published in the book "Smart Service Engineering" (Thomas et al., 2016), which contains the proceedings of the "Dienstleistungsmodellierung" conference (Wellsandt et al., 2016) and was selected by the editors for publication in the EMISA journal.
[5] An earlier version of this paper was published at the MKWI conference (Anke & Krenge, 2016)
[6] The International Conference on Design Science Research in Information Systems and Technology (DESRIST) proceedings are published in the Lecture Notes in Computer Science (LNCS) series, ranked "C" in JourQual 3.

2 Research Background

2.1 Smart Service Systems

In service science, a ***service system*** is defined "as value-co-creation configurations of people, technology, value propositions connecting internal and external service systems, and shared information (e.g., language, laws, measures, and methods)" (Maglio & Spohrer, 2008, p. 18). Service systems, e.g., individuals and organizations, can be combined to composite service systems to form higher-level value co-creation relationships and alliances, i.e., they can be nested and overlap. Service systems are dynamic as they compose, recompose, and decompose over time (Maglio et al., 2009; Vargo & Akaka, 2012).

Digital technologies enable novel service systems as operant resources such as information, skills, and knowledge can be combined and exchanged in new ways that create value for the involved actors (Barrett et al., 2015; Edvardsson & Tronvoll, 2013; Nambisan, 2013; Sklyar, Kowalkowski, Sörhammar, & Tronvoll, 2019; Wolf, 2020). It is achieved through digitization, i.e., encoding of analog information in digital formats (Yoo et al., 2010) that decouple information from physical mediums and devices (Lusch & Nambisan, 2015). Therefore, digital technologies allow to "liquefy and distribute resources" within a service system and allow involved actors to "quickly access and utilize resources needed for service exchange" (Barrett et al., 2015, p. 143).

In ***smart service systems***, smart products are a key digital technology that increasingly becomes part of value-creating systems (Figure 2.1). ***Smart products*** refer to physical objects with computation, data storage, localization, sensors, actuators, and networking capability that enable learning, decision-making and dynamic adaptation to usage situations based upon data received, transmitted, and/or processed (Allmendinger & Lombreglia, 2005; National Science Foundation, 2014). Smart products can be understood as boundary objects that integrate the resources and activities of actors in service systems (Beverungen, Müller, et al., 2019), and, thus, enable the co-creation of ***smart service*** in various forms (Boukhris & Fritzsche, 2019). Hence, smart service systems connect things and people, collect and process data, and thereby automate and facilitate value co-creation in actor-to-actor networks (Beverungen, Müller, et al., 2019; Boukhris & Fritzsche, 2019; Lim et al., 2018). This results in a wide array of potential configurations of smart service systems with different characteristics. To support their systematic description and comparison, taxonomies can be used (Brogt & Strobel, 2020).

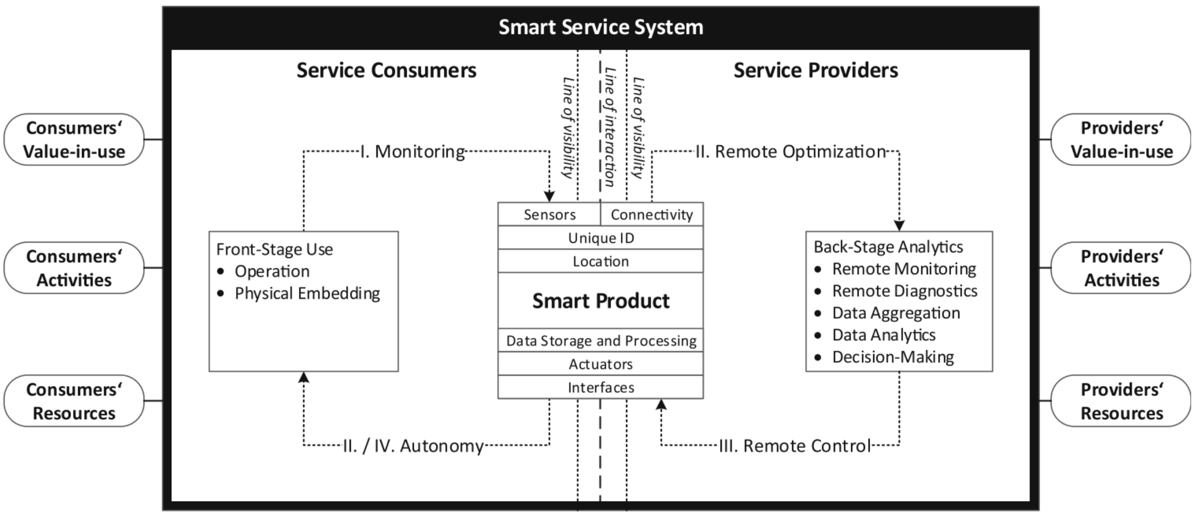

Figure 2.1: Conceptualization of smart service systems (Beverungen, Müller, et al., 2019)

A second research stream coming from industrial engineering conceptualized the integrated offering of goods and services as ***product-service systems*** (PSS) (Mont, 2002), which can enable new types of value propositions and business models (Tukker, 2004). The rising importance of information technology has extended this concept to smart PSS (Chowdhury et al., 2018; Pirola et al., 2020). A smart PSS is defined as "a PSS based on "networked smart products and service systems for providing new functionalities thus leveraging on digital architectures, Internet of Things, cloud computing and analytics" (Pirola et al., 2020, p. 2). Similarly, the concept of data-driven PSS (Zambetti et al., 2021) illustrates the infusion of digital technology into PSS, which brings them closer to the concept of smart service systems. From an information systems perspective, IoT has been found to enable new business models and product lifecycle support in the design of PSS (Basirati et al., 2019). As a result, PSS that are enabled with IoT and other digital technologies (González Chávez et al., 2020) are particularly relevant for industrial domains, in which existing equipment, machinery, or other technical products are augmented with services or even turned into services ("servitization"), which is expected to converge with the Industry 4.0 movement (Gaiardelli et al., 2021; Kohtamäki et al., 2019).

The integration of computational capabilities into physical components has led to the concept of ***cyber-physical systems*** (CPS) (Wiesner et al., 2017). A CPS is defined as "an intelligent system connecting the physical and the digital/cyber world through influence and control using sensors and actuators." (Martin et al., 2020, p. 14). They consist of "embedded systems, logistics and management processes, and Internet services for receiving, processing, and analyzing data from sensors, and controlling actuators connected by digital networks, and multi-modal human-machine interfaces" (Wiesner et al., 2017, p. 19). This "merging of the physical and virtual world" (Wiesner et al., 2017, p. 19), allows the continuous monitoring of the environment and feedback based on data analytics.

The distinction between smart service systems, (smart) PSS, and CPS has been part of recent discussions. Beverungen et al. (2020) point out that service systems are a framework for analysis and design, whereas PSS refers to a marketing perspective, i.e., they are a "marketable set of products and services capable of jointly fulfilling a user's need" (Goedkoop et al., 1999, p. 18). The relationship between PSS and CPS is "symbiotic" in the sense that they offer complementary perspectives: From a CPS point of view "the physical and ICT domains are complemented with service engineering for the development of the solution" (Marilungo et al., 2017, p. 359), while PSS "focuses on the bundling of tangible products and intangible services more from a business perspective" (Wiesner et al., 2017, p. 19). In line with this view, this thesis considers PSS as a special type of smart service, which is mainly found in industrial domains. CPS provide a technological perspective on smart service systems, which helps to better understand the relationship of physical and computational aspects for observing and affecting the environment through sensors and actuators (Wiesner et al., 2017).

2.2 Service-Dominant Logic

While service science is an interdisciplinary approach that aims at the design, engineering, and management of service systems, service-dominant logic (SDL) – or S-D logic – originates in marketing. SDL provides a theoretical grounding of service science and hence an analysis lens for service systems, particularly the co-creation of value through interactions by multiple actors (Akaka et al., 2019; Vargo & Lusch, 2004). The focus of SDL is on intangible resources, relationships, and value co-creation and thus departs from goods-dominant logic, which is centered on tangible resources, transactions, and value that is embedded in physical goods. SDL defines key concepts that are used throughout this thesis, including actor, resource, value, service, institutions, and service ecosystems (Figure 2.2).

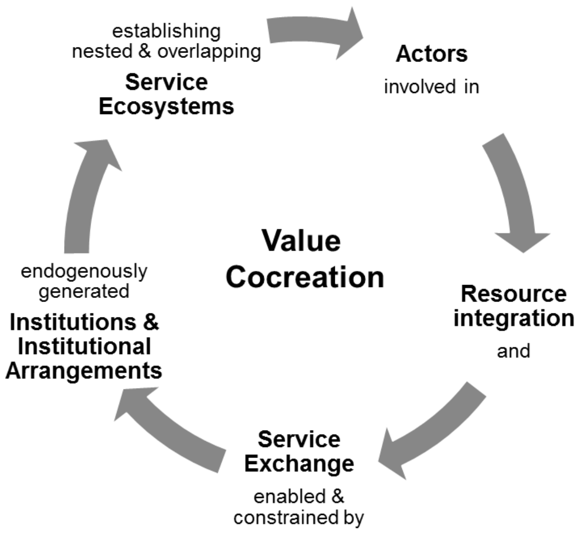

Figure 2.2: The narrative and process of S-D logic (Vargo & Lusch, 2016)

Actors denote any entity that is involved in service exchange, ranging from individual persons to firms, and even nations. This departs from traditional understanding with predefined labels such as consumers and producers, as value is understood to be cocreated for each other's benefit, rather than produced and consumed (Lusch & Nambisan, 2015). It also implies that value cannot be delivered by single actors. Instead, they only can make value propositions "as an invitation to engage [..] for the cocreation of value" (Lusch & Nambisan, 2015, p. 160).

Resources refer to anything that actors can draw on for support. They can be distinguished into *oper-and* and *operant* resources. Operand resources are acted upon and therefore have an enabling role. They are mainly static and tangible (Lusch & Nambisan, 2015), e.g., technical infrastructure. Operant resources act upon other resources to create an effect. They are typically dynamic and intangible. The most relevant type of operant resources is applied knowledge, i.e., include human skills and capabilities. Using resources provided by other actors is called ***resource integration***.

In S-D logic, ***service*** is understood as the process of using one's resources, including specialized competencies like knowledge and skills, for the benefit of another actor or the actor itself (Lusch & Vargo, 2016; Vargo & Lusch, 2004). SDL distinctively uses the singular term "service" to denote the process character of doing something beneficial instead of the plural term "services" that would imply units of output and, hence, a goods-dominant logic (Lusch & Nambisan, 2015).

The value co-creation between two actors is achieved through the mutual application of resources from their respective value networks (Figure 2.3). The service exchange is directed at solving problems and might involve products as a distribution mechanism. While money can be exchanged between the actors ("value-in-exchange"), the created ***value*** of the service is determined by the beneficiary, i.e., the customer, within the application of context ("value-in-use") (Vargo et al., 2008).

The coordination of service exchanges is supported by ***institutions***, which are rules, norms, and other aids for communication. They are created by actors through institutional work and combined into more comprehensive ***institutional arrangements***. Such arrangements provide the context for actor to actor (A2A) value co-creation, e.g., projects, buyer-supplier-relations, platforms, and regulation (Barile et al., 2016). Roles describe how generic actors can engage in institutions, which can involve institutional work, i.e., the creation, maintenance, and disruption of institutions (Vargo & Lusch, 2016).

Although the S-D logic conceptualizes actors as generic, it does not mean that all actors are identical (Vargo & Lusch, 2016). Instead, it refrains from assigning predesignated roles like producers and consumers to actors and encourages to characterize actors "in terms of distinctly constituted identities associated with unique intersections of the institutional arrangements, with which they associate themselves" (Vargo & Lusch, 2016, p. 3). ***Roles*** can be defined as "distinct technologically separable, value-added activities undertaken by firms or individuals" (Kambil & Short, 1994, p. 69) that reflect "clusters of behaviors expected of parties in particular statuses or positions" (Knight & Harland, 2005, p. 282). From an SDL perspective, a role can therefore be understood as the provision of certain resources by an actor within an institutional arrangement. While roles are usually assigned to individuals, they can also apply to organizations or other entities like groups, teams, or even networks (Story et al., 2011). Actors can have multiple roles simultaneously and the assignment of roles to actors can change over time (Dedehayir et al., 2018; Ekman et al., 2016).

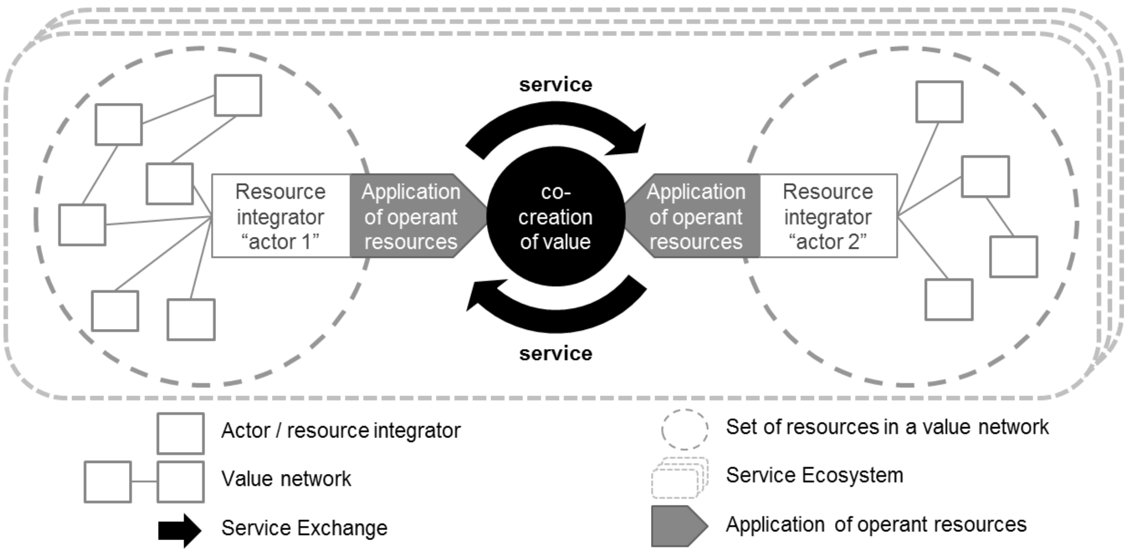

Figure 2.3: Service exchange view of value co-creation (Ehrenthal et al., 2021, p. 283)

Extensions of SDL introduce the notion of ***service ecosystems***, which are "relatively self-contained, self-adjusting system[s] of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange." (Vargo & Lusch, 2016, pp. 10–11). Such ecosystems may have multiple institutional arrangements that provide the context for service exchange. An ecosystem perspective further implies that networks of actors can be seen at various levels of aggregation as service systems and ecosystems can be nested and overlapping (Vargo & Lusch, 2016). Therefore, a service ecosystem can be viewed as a service system at a higher level of aggregation; or put differently as "systems of systems" (Storbacka et al., 2016, p. 3009).

Disentangling the levels of aggregation, Vargo and Lusch (2017) suggest distinguishing between dyadic exchanges on a micro-level (e.g., transactions and sharing) and more complex constellations of exchanges on a meso- (e.g., networks, industries, markets) and macro-level (e.g., society) of aggregation. Taking a multi-level perspective on phenomena is at the core of the microfoundations movement in strategic management and organization theory (Felin et al., 2015; Haack et al., 2019; Storbacka et al., 2016). Microfoundations locate "the proximate causes of a phenomenon (or explanations of an outcome) at a level of analysis lower than that of the phenomenon itself" (Felin et al., 2015, p. 587). That is, the actors, processes, and/or structures at the micro-level may interact or operate alone to influence phenomena at the next upper (e.g., meso- or macro-) level (Felin et al., 2015).

Grounded in S-D logic, Storbacka et al. (2016) adopt the microfoundational view to conceptualize actor engagement as a microfoundation of value co-creation in service ecosystems. They define ***actor engagement*** as both an actor's exchange-based and non-exchange-based resource contributions in an interactive process of resource integration within a service ecosystem, which is facilitated by the actor's disposition to engage (Storbacka et al., 2016; Storbacka, 2019). The framework of Storbacka et al. (2016) consists of macro-, meso-, and micro-levels (Figure 2.4). The macro-macro relationship of their framework defines value co-creation as an outcome of service exchange within the context provided by the institutional logic of a service ecosystem (Storbacka et al., 2016, p. 3009).

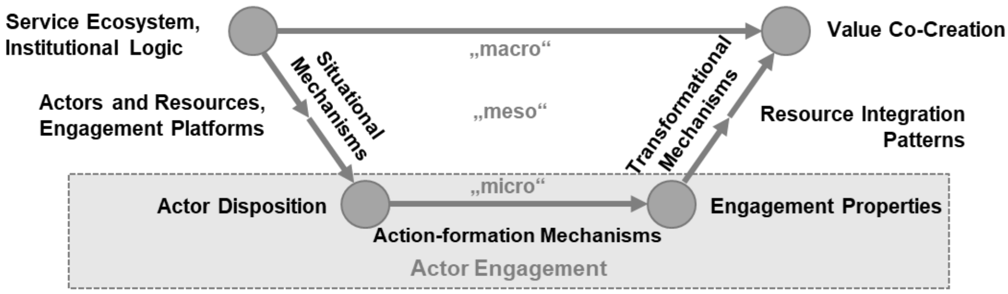

Figure 2.4: Actor engagement as a microfoundation for value co-creation (Storbacka et al., 2016)

Looking at the relationship between the levels, the institutional logic of a service ecosystem provides the macro-level context for the interaction of actors with their resources on engagement platforms at the meso-level. Engagement platforms can be understood as virtual or physical "environments containing artifacts, interfaces, processes and people" (Storbacka et al., 2016, p. 3011). They serve as intermediaries of connections between actors and thereby facilitate but do not participate in, actor engagement at the micro-level. Resource integration patterns emerge on the meso-level as a result of actor engagement on the micro-level. Finally, these lead to value co-creation by transforming the resource configurations of the actors in the service ecosystem (Storbacka et al., 2016).

2.3 Service Innovation in Ecosystems

Service innovation refers to the reconfiguration of resources or changes in structures and value-co-creation processes of the service system (Edvardsson & Tronvoll, 2013; Vargo et al., 2010), which lead to new practices that are useful and, hence, valuable, to actors in a specific context (Edvardsson et al., 2018; Edvardsson & Tronvoll, 2013; Lusch & Nambisan, 2015). When actors (e.g., service firms) innovate, they design resource integration mechanisms, which are supposed to support other actors (e.g., customers) in integrating and acting on available resources so that they can create value in new and better ways. This also means that service firms do not develop services (as units of output), but design and communicate new value propositions and develop and manage service systems.

The outcome of service innovation can influence multiple dimensions (Plattfaut et al., 2015), including the general service concept or value proposition, client interfaces or touchpoints, delivery system and use of technology (Jong & Vermeulen, 2003), business partners and revenue models (den Hertog et al., 2010), as well as institutions and institutional arrangements (Edvardsson et al., 2018; Koskela-Huotari et al., 2016; Vargo & Lusch, 2016). Although SSI focuses on the use of digital technology in service systems, it usually affects multiple other dimensions at the same time as it intends to establish new and better ways of co-creating data-driven value (Beverungen, Müller, et al., 2019; Djellal & Gallouj, 2018; Edvardsson et al., 2018; Maglio & Lim, 2018). Hence, the outcome of SSI can lead to a change in an actor's business model (Barrett et al., 2015; Paschou et al., 2020; Wuenderlich et al., 2015).

While service providers have traditionally driven service innovation independently, these firms increasingly require support from external actors to successfully develop new digitally enabled value propositions and corresponding resource integration mechanisms within their service ecosystems. Especially in the context of digital transformation, it is argued that service innovation no longer originates from within a single organization, but evolves from "a network of actors" (Lusch & Nambisan, 2015, pp. 155–156). In other words, actors recombine elements from both internal and external resources for service innovation (Beverungen et al., 2018).

Academia has just begun to investigate smart service innovation from a multi-actor perspective that goes beyond the single focal organization or the dyadic perspective of a provider and a customer actor, e.g., by identifying the roles of actors in service innovation processes (Ekman et al., 2016; Ostrom et al., 2015; Schymanietz & Jonas, 2020). Service innovation can lead to structural changes that fundamentally affect the relationship and interaction with customers (Abrell et al., 2016; Chowdhury et al., 2018; Jussen et al., 2019; Storbacka et al., 2016), e.g., by involving them as co-designers (Jonas, 2018; Martinez et al., 2010). Furthermore, the use of digital technologies in smart service systems often requires specialists in systems integration, user experience design, cloud computing, data analytics, or platform business, who are usually not available within a single organization (Djellal & Gallouj, 2018).

It is important to note, that neither the involvement of actors in innovation activities nor the roles they assume are static. For example, the role of the customer can change from a supplier of ideas, and creator of demands to a co-developer and tester, purchaser, and feedback provider (Dedehayir et al., 2018; Dörner et al., 2011). Similarly, consulting companies might be involved only in the early phases, while others, e.g., IoT platform providers participate at later stages (Dedehayir et al., 2018).

The interplay of cooperating actors at each stage of the innovation process influences events in subsequent stages (Jalonen, 2012). Within this context, Edvardsson et al. (2018) propose a conceptual framework of service innovation that considers the interdependencies between the agency of actors, social structures of the service ecosystem, and different ***states of the innovation process***. Their conceptualization emphasizes that service innovation must be viewed from the perspective of multiple actors and the institutional arrangements they are embedded (Edvardsson et al., 2018). Correspondingly, they distinguish between three states of the service innovation process:

- *Initiating*: formulate the intended value propositions that are attractive to other actors.
- *Realizing*: put the innovative value proposition into practice.
- *Outcoming*: market diffusion and scaling up, innovative value propositions become sustainable and the service providing actors can capture enough value to ensure their sustainability.

While service ecosystems are considered "emergent", actors can influence how they evolve. This is mainly achieved by reconfiguring institutional arrangements that guide how value is co-created within an ecosystem (Vargo et al., 2015; Vink et al., 2021). Actors that initiate or drive the innovation process may assume the role of "ecosystem orchestrator" and shape the design of such ecosystems (Lingens et al., 2021). In that view, service innovation involves a series of service exchanges between multiple actors to cocreate new resources, including institutional arrangements, towards to desired value proposition for the target customer (Vargo et al., 2015). Therefore, multi-actor service innovation can be considered an ecosystem state (Chandler et al., 2019; Edvardsson et al., 2018; Polese et al., 2021).

2.4 Systematic Development of Smart Service Systems

2.4.1 Value Proposition Design and Business Model Innovation

At the core of service innovation is the development of a ***value proposition*** that is attractive to the customer. Digital technologies impact how actors create and capture value. Such potentials can be yielded in service innovation through new value propositions, hence "business model innovation can be understood as value-proposition design." (Maglio & Spohrer, 2013, p. 667). A well-known technique for developing value propositions is the value proposition canvas (VPC) (Osterwalder, 2014), which relates customer problems and needs to potential elements of new services or products. The VPC has been successfully utilized for smart service business model development (Neuhüttler et al., 2018). It also serves as the foundation for methods that support the development of value propositions in smart services, e.g., the "Smart Service Canvas" (Pöppelbuß & Durst, 2019), and the "VdiP-developer" framework (Genennig et al., 2018).

Value propositions are central components of ***business models*** (BM), which describe "the value logic of an organization in terms of how it creates and captures customer value and can be concisely represented by an interrelated set of elements that address the customer, value proposition, organizational architecture and economics dimensions" (Fielt, 2013, p. 96). This definition highlights that business models include considerations of firm-level or network-level organization as well as economic aspects for all involved actors. The basic elements of a business model are their relationships according to Gassmann et al. (2014) are depicted in Figure 2.5. The target customer group ("Who") is at the center and connected to the offer ("What"), the value creation resources and their orchestration ("How"), and a revenue model for value capture ("Value").

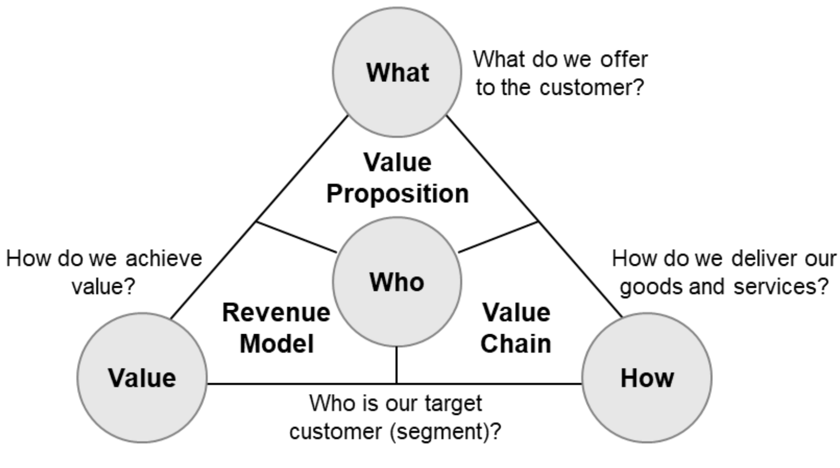

Figure 2.5: Basic elements of a business model (Gassmann et al., 2014, p. 91)

Business model innovation (BMI) aims to identify a viable combination of these elements. An analysis of existing business models has shown that many business model innovations result from the recombination, modification, or transfer of existing business model concepts (Gassmann et al., 2014). This finding helps to create design knowledge on business models, e.g., in the form of business model patterns. For example, the St. Gallen Business Model Navigator (Gassmann et al., 2013) supports ideation for BMI through 55 patterns, which include well-known examples such as "freemium", "pay-per-use", and "auction".

As smart services fundamentally rely on data-driven value co-creation, the category of ***data-driven business models*** (DDBM) is particularly relevant (Bulger et al., 2014). According to Hartmann et al.

(2014), DDBM is defined as “a business model that relies on data as a key resource”. Regarding the level of data usage, there is a spectrum of business model patterns that use little data and those that enrich all aspects of business models with data analysis (Schüritz & Satzger, 2016). The relation between the capabilities of CPS and suitable business model patterns for smart services can be illustrated in the domain of connected cars: 16 out of the 55 patterns in the St. Gallen Business Model Navigator were identified as applicable, including “Leveraging Customer Data” and “Two-Sided Market” (Mikusz et al., 2015) for services like roadside assistance or usage-based insurance (Husnjak et al., 2015). In a similar vein, Turber et al. (2014) propose IoT-based business models, which highlight the relevance of data in business models but also an ecosystem perspective in which multiple actors are collaborating.

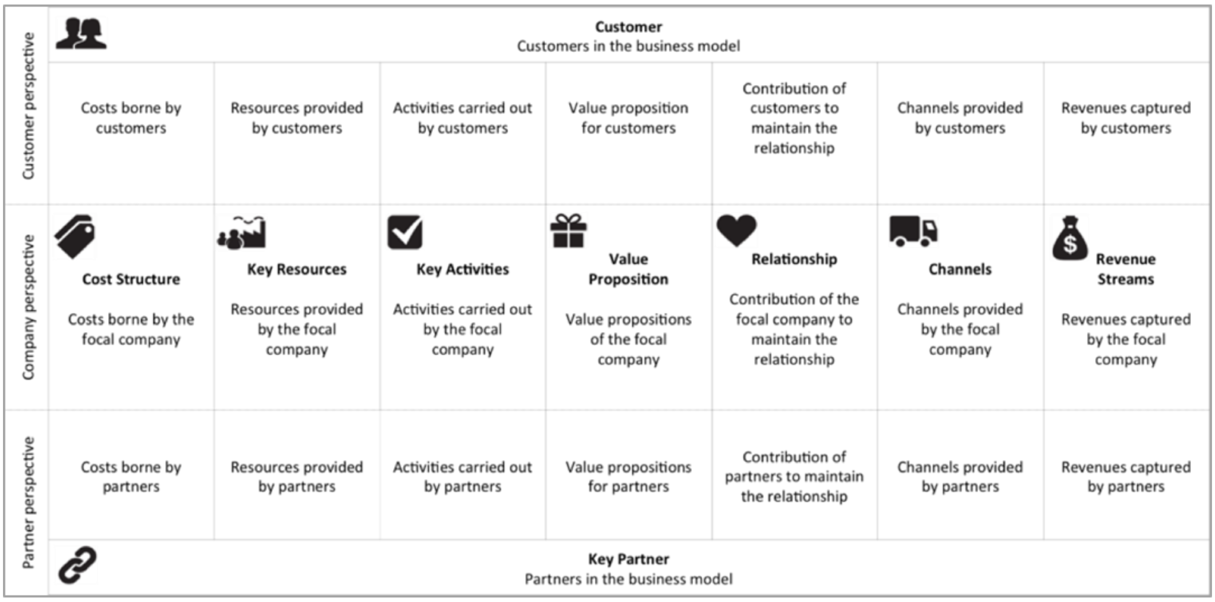

Figure 2.6: Service Business Model Canvas (Zolnowski, 2015)

Business models are also discussed in service research (H. Bouwman & Fielt, 2008; Fielt, 2012; Wieland et al., 2017). They can be understood as part of the formation of institutions, as they enable and constrain value co-creation between actors in an ecosystem (Wieland et al., 2017). Because of their characteristics, representations for service business models differ from representations for traditional business models (Ojasalo & Ojasalo, 2015). A service-specific representation is the Service Business Model Canvas (SBMC) (Zolnowski, 2015), shown in Figure 2.6. It is based on the well-known Business Model Canvas (BMC) by Osterwalder and Pigneur (2010) but highlights the integration of different actors within service business models and thus, allows focusing on the co-creation in the business logic. The SMBC focuses on the contribution to and benefit of each actor. This logic is applied in seven dimensions of the original BMC, i.e., “value proposition”, “relationship”, “channels”, “revenue streams”, “key resources”, “key activities”, and “cost structure”. The dimensions “customer segment” and “key partners” are extended as separate perspectives for these actors (Zolnowski, 2015).

Designing business models as strategic objects has been identified as an area, to which the information systems discipline can contribute through modeling, designing of artifacts, and computer-aided decision support (Osterwalder & Pigneur, 2013). For example, the emerging category of ***business model design tools*** (BMDT) indicates the growing software support for the definition and assessment of business models (P. Ebel et al., 2016; Szopinski et al., 2019), which allows for experimentation and thus facilitates business model innovation (Chesbrough, 2010).

2.4.2 Design Dimensions and Development Methods

Services, in general, are described along their traditional ***design dimensions*** of resources, process, and value (Figure 2.7). *Resources* refer to a human or technical capacity, which is required to perform a desired change of state in the external factor, i.e., the customer itself or a customer-controlled object. Resources may include assets, technology, competencies, people, and infrastructure. *Process* describes the steps that are performed by the provider and the customer to create the desired service, i.e., the co-creation of value. The *outcome* refers to the achieved state of the external factor as a result of the process, which is valuable to the customer. Some authors include the "market" dimension, which refers to the potentially reachable customers for the service at hand, and is therefore particularly relevant for business cases and competitive analysis (Leimeister, 2020, pp. 86–89).

Bullinger et al. (2003) name outcome, process, and structure as service design dimensions that need to be described using a product model, process model, and resource concept. For the design of service systems, these design dimensions can act as a high-level framework for organizing the work products that are created in an engineering process. Additionally, conceptual models for services rely on these design dimensions (Becker et al., 2010).

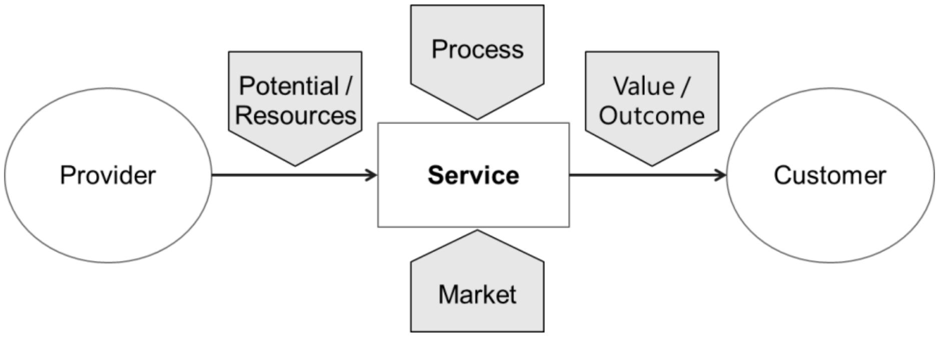

Figure 2.7: Basic design dimensions of services (Leimeister, 2020, p. 86)

To systematically develop complex systems from the initial idea for a value proposition to a production-ready system, collaborative work can be guided by ***methods***. They "cover the software development process and its contained activities, but also the artifacts that are to be produced, the tasks that need to be performed to achieve the development goals, the roles in an organization that participates in the development, the tools, techniques and utilities that are employed, as well as relationships between these concepts" (Engels & Sauer, 2010, p. 411).

Method engineering (ME) is a discipline dealing with the systematic design, construction, and adaptation of methods for the development of information systems (Brinkkemper, 1996, p. 276), and was later adopted for software engineering. As ME requires the consideration of methods on a meta-level, it provides the terminological basis of key concepts such as method, technique, tool, and notation (Brinkkemper, 1996). These concepts are applied for describing, analyzing, and improving (software) development processes. For that, meta-models for engineering processes are proposed to establish the links between the sequencing of activities as a process, the roles of the persons responsible for conducting these activities, and the techniques that can be used to structure the performance of activities (Engels & Sauer, 2010). Standards, guidelines, and notations are used to describe the structure of a certain artefact and can therefore be used for documentation of results, i.e., work products. A generic meta-model for software lifecycle is depicted in Figure 2.8.

It has been acknowledged that there is no "one-size-fits-all" approach to development processes, as the specifics of projects and organizations are never fully considered in standardized methods. ***Situational Method Engineering*** (SME) (Henderson-Sellers & Ralyté, 2010) suggests that the method for a specific (software) development endeavor should be created from existing – more or less formalized – parts which are called method fragments, method chunks (Henderson-Sellers & Ralyté, 2010), or practices (Jacobson et al., 2007). The selection and composition are driven by the actual context, which is described by "situational factors", such as team size, application size, stability of requirements, organizational culture, business risks, and legal aspects (Clarke & O'Connor, 2012).

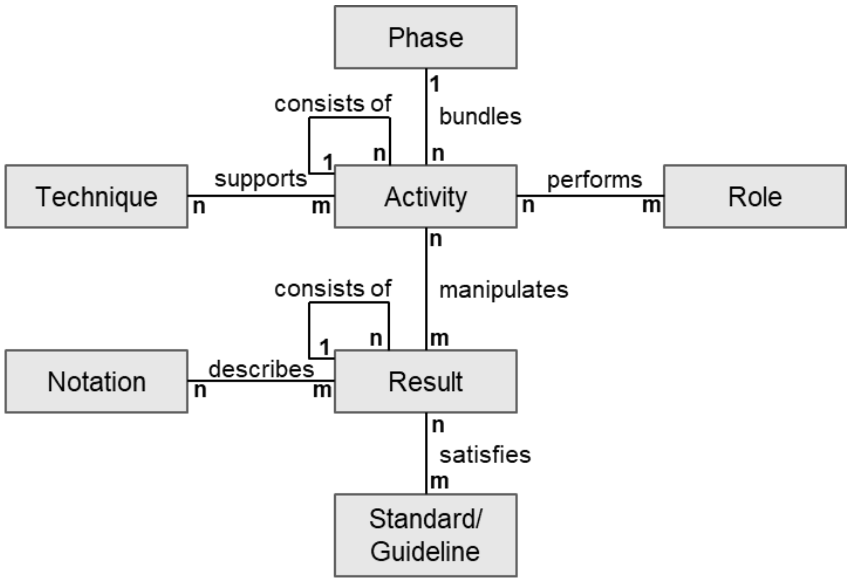

Figure 2.8: Generic meta-model for software lifecycles (Kneuper, 2018, p. 50)

As Alt (2019) points out, the transformation of organizations requires different sets of methods and techniques depending on the transformation level, consisting of software, processes, and value. With the focus on value in digital transformation, techniques like the BMC and methods like business model innovation are applied to guide transformation projects (Alt, 2019). With smart service systems consisting of a technical software-intensive system, a service process, and often an innovative business model, these perspectives must be covered by suitable development approaches (Pakkala & Spohrer, 2019). Therefore, methods from various disciplines may be applied in SSI, including service engineering, PSS engineering, software engineering, business model innovation, systems engineering, user-centered design, innovation management, and general management (Abramovici et al., 2015; Hagen, Kammler, & Thomas, 2018; Kuhlenkötter et al., 2017).

Selecting and combining suitable parts from existing methods can serve as a basis for the organization of SSI projects. Vink et al. (2021) call for the development of practical methods and approaches for collaborative service design in ecosystems. This shows both the growing awareness of such setups and the lack of methods to exploit their potential. From an SDL perspective, reference models, methods, and frameworks are institutional arrangements, as they provide norms, rules, and practices that enable and constrain the work of actors (Iden et al., 2020). As projects facilitate the resource integration and service exchanges between actors (Vargo & Clavier, 2015), they represent the meso-level in the multi-level SSI framework.

2.4.3 Service Engineering and Service Systems Engineering

Developing a service system that allows fulfilling the envisioned value proposition is a complex process. In the past, ***service engineering*** (SE[7]) has been established as "a technical discipline concerned with the systematic development and design of services using suitable procedures, methods, and tools" (Bullinger et al., 2003, p. 276). Service engineering aims to adapt methods for product engineering to make them useable for service development (Böhmann et al., 2014) and followed a rather traditional linear approach (Beverungen et al., 2018). However, these procedural models are not well established in practice (Hagen, Jannaber, & Thomas, 2018).

In the area of ***PSS engineering***, a large body of knowledge has emerged (Cavalieri & Pezzotta, 2012). As PSS and smart service systems share the characteristics of high complexity in both the engineering process and the resulting system, existing methods for PSS engineering may inform smart service innovation. Studies regarding the suitability of PSS engineering methods for smart PSS have found that methods and frameworks are applicable but need to be enhanced for better support of customer integration and specifics of digital technologies (Hagen, Kammler, & Thomas, 2018; Pirola et al., 2020).

To address the specific characteristics and potentials of smart services, methods need to consider the role of data as a resource and the use of digital technologies in service systems (Demirkan et al., 2015; Herterich et al., 2016). This has led to a call for the development of new service engineering methods, which also apply S-D logic, i.e., consider multi-actor value co-creation in service systems (Peters et al., 2016). Although improvement and adaption of existing methods for the digital age are ongoing, they do not yet sufficiently address the increased complexity and agility of smart services (Marx et al., 2020).

A recent study assessed 36 SE methods towards their suitability for smart services from a service, product, data, and software perspective and five phases of a development process (Marx et al., 2020), It found that only twelve methods consider smart services, while most methods focus on PSS. Regarding comprehensiveness, the service perspective is handled by all methods, while software and data are only considered in six and eleven cases, respectively. Concerning the development process, the requirements and design phases are covered the most, while idea generation, implementation, and delivery received far less attention (Marx et al., 2020). Only a single method (Freitag & Wiesner, 2018) covers all development phases but focuses on the service perspective. Another method partially covers all perspectives but is limited to the design phase (Verdugo Cedeño et al., 2018). Interestingly, both methods build upon Product Lifecycle Management (PLM) (Terzi et al., 2010), which provides a comprehensive foundation for designing and managing services around smart products (Kiritsis, 2011).

Service systems engineering (SSE) is an emerging discipline that takes service systems as the basic unit of analysis and design and thus adopts a systemic perspective on service innovation. It addresses the engineering of (1) service architectures, (2) service systems interactions, and (3) resource mobilization and aims to provide models, methods, and artifacts to support these activities (Böhmann et al., 2014; Grotherr et al., 2018). Figure 2.9 depicts the main elements of service systems that are targeted by SSE, together with examples from smart service systems. While BMI helps to develop novel value propositions, SSE aims to engineer the service system that enables them.

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[7] SE is often used as abbreviation for Software Engineering. As both software engineering and service engineering are relevant in this thesis, it is important to note that software engineering will always be written out while SE always stands for service engineering.

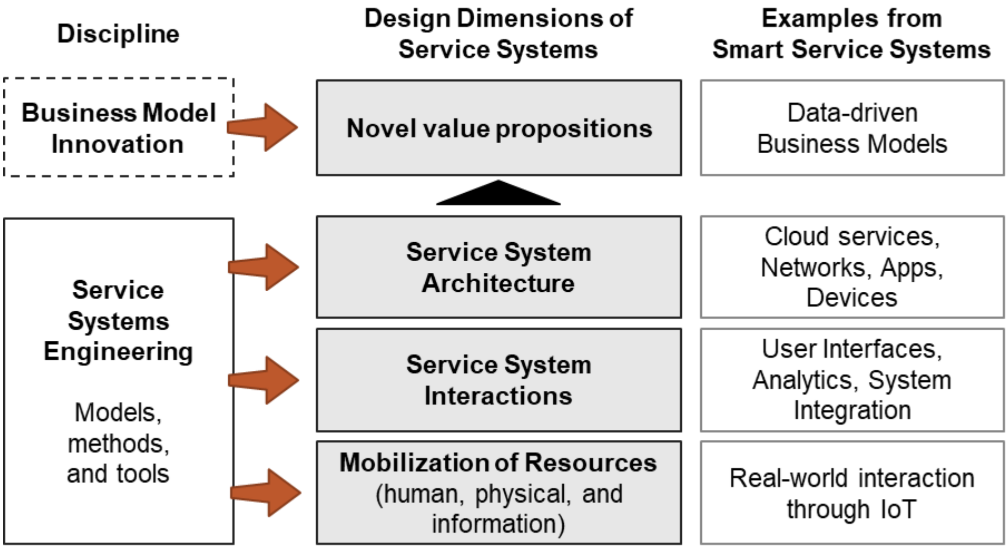

Figure 2.9: Service systems engineering (SSE) in context (based on Böhmann et al., 2014)

In the context of SSE, the potential of CPS regarding data acquisition and automation is identified as an enabler for service innovation (Böhmann et al., 2014) that leads to smart service systems. Several approaches have recently been proposed for SSE in the academic literature, e.g.:

- *Engineering of digitally-enabled service systems* combines the existing methods with a new approach for liquifying, unbundling, and re-bundling resources (Höckmayr & Roth, 2017),
- *Recombinant Service Engineering* (Beverungen et al., 2018) aims to create a class of methods for service systems through association, dissociation, and recombination of existing resources,
- *Multi-level design framework for service systems* (Grotherr et al., 2018) guides the process of iterative design and validation of design decisions through real-world interventions,
- *Smart Service Engineering* (Jussen et al., 2019; Moser & Faulhaber, 2020) integrates business model development and prototyping in ecosystems into a lightweight agile process, and
- *DIN SPEC 33454 „Development of Digital Service Systems“* (DIN, 2019) consists of design dimensions, phases, activities, and methods to support the conduct of activities (Figure 2.10).

Further SSE approaches consider specific aspects of smart service systems, e.g., data-driven value-creation (Lim et al., 2018), platforms (Adali et al., 2021), multi-actor value networks (Patrício et al., 2018; Reinhold et al., 2021), ecosystems (Immonen et al., 2016), and service architecture (Halstenberg et al., 2019). Another group of methods is dedicated to the specifics of smart service for manufacturing and industrial equipment (Freitag & Hämmerle, 2020).

Some development approaches use product models to document the current state of the developed system concept and show the interdependencies of system elements, particularly in methods that follow the model-based systems engineering (MBSE) approach (Halstenberg et al., 2019). A variety of modeling approaches have been proposed, which can be differentiated into general modeling languages and domain-specific languages: ***Modelling languages*** allow the description of complex systems and value creation structures in various domains, e.g., e3-Value (Gordijn, 2004), Business Process Model and Notation (BPMN), the System Modelling Language (SysML), the Unified Modelling Language (UML), and the Lifecycle Modelling Language (LML). As they are targeted at the description of different aspects of a system (Halstenberg et al., 2019), they are often used in parallel.

More recently, ***domain-specific languages*** (DSL) for smart service have been proposed (Huber et al., 2019; Lessard et al., 2020; Lüttenberg, 2020; Strobel, 2021). They are designed to capture the specifics of smart service systems through a meta-model, that is often expressed as UML class diagrams. This meta-model provides the abstract syntax, which may be augmented through a concrete syntax (notation), that represents the defined modeling elements visually.

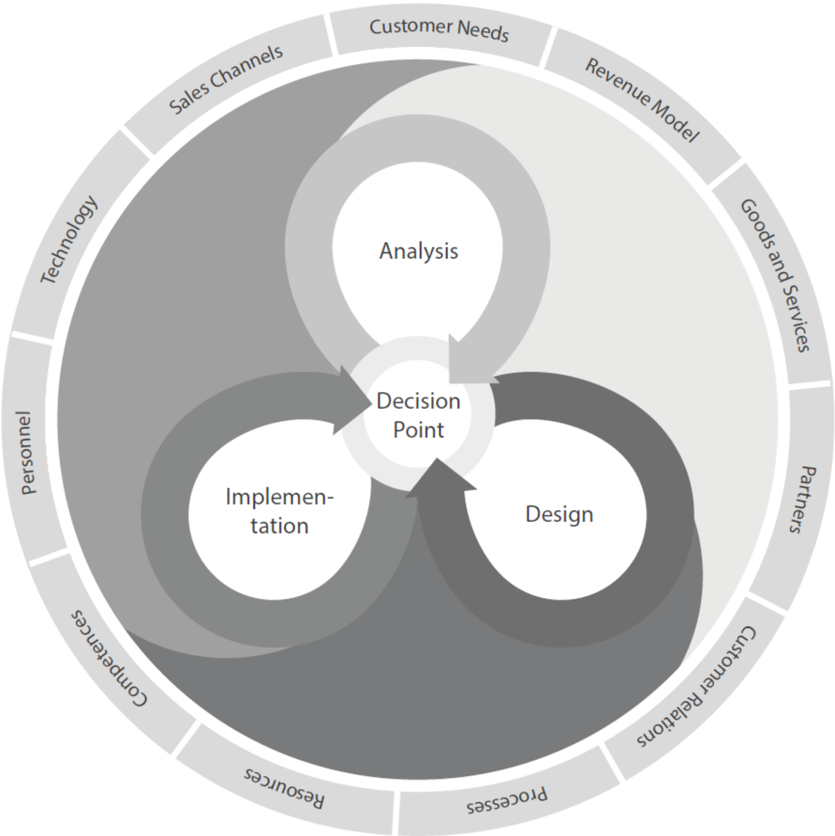

Figure 2.10: Reference process and design dimensions for digital service systems (DIN, 2019)

The plethora of methods in this space illustrates the ongoing effort of researchers to understand the specifics of smart service systems and address them in suitable development approaches. Notwithstanding this variety, most methods and process models highlight the importance of agility, i.e., they follow the principles of the "Agile Manifesto" (Beck et al., 2001). It contains a set of values and principles calling for the organization of development efforts in a highly iterative way with intensive customer involvement. Adopting agile practices helps to adapt to dynamics in the environment (Kuhrmann et al., 2021; Paez et al., 2020; Paluch et al., 2020) and thus address the complexity and uncertainty inherent to SSI (Ramirez Hernandez & Kreye, 2020; Sjödin, Parida, Kohtamäki, & Wincent, 2020).

Overall, it can be stated that the need for better guidance for the engineering of (smart) service systems is widely acknowledged. Agile process models and a variety of methods have been proposed that directly address the specifics of smart services. However, as many methods were developed without a certain process model in mind, the mapping of activities to suitable methods and techniques is not well understood yet. Additionally, the proposed process models and methods provide barely any information on how they are applied in multi-actor settings such as service ecosystems. This mainly refers to the question of how to organize work among multiple actors depending on their capabilities and the activities to be performed.

2.4.4 Assessment of Service Innovations

Various benefits can be created from offering smart services and data-driven business models, e.g., cost reduction, increased revenues, improved customer loyalty, and strategic benefits (Zolnowski et al., 2016), although not all of these expectations can be fulfilled (Hagen & Thomas, 2019). Successful smart service innovation must lead to sustainable advantages for all actors involved in value co-creation. To this end, service concepts should be assessed regarding their potential impact. Assessment methods require a model of the evaluation target, a set of evaluation criteria, and procedures on how evaluation-related aspects are gathered and combined into an overall assessment result. The complexity of the task is illustrated by Kim et al. (2016), who propose an evaluation scheme for PSS system models consisting of 94 evaluation criteria that cover both customer and provider perspectives in economic, environmental, and social dimensions along the complete lifecycle. This list is designed as a repository from which users can select suitable criteria depending on evaluation targets.

Business models are frequently used to develop and refine the business logic of a service idea, and thus impact the economic value of the service. Therefore, they lend themselves as a vehicle for assessment, which can guide both the design of the service but also the design of the business model itself. It has been argued that assessments of service business models should be performed in early lifecycle phases, e.g., to decide on which service idea should be pursued further and justify funding (Tesch et al., 2017). Determining cost and benefits have been found to have a high potential to influence business model design decisions (Turetken et al., 2019). As business models are qualitative (Zott et al., 2011), they need to be augmented with additional information to enable quantitative assessments. Meertens et al. (2014) propose a method for the assessment of business model alternatives through derived business cases. Other methods guide the concretization of cost and benefit (Gilsing et al., 2020) or evaluate digitalization opportunities through the financial assessment of new business models (Linde et al., 2021).

Research on service assessment methods is still nascent. For example, PSS engineering methods call for a "business analysis" to determine the financial impact but only a few PSS design models contain concrete activities for financial analysis (Lin & Hsieh, 2011; Marques et al., 2016). Pirola et al. (2020) identify the assessment of PSS concepts as one of the main but least addressed research streams for smart PSS. Their study focuses on tools that allow the quantitative and qualitative assessments of PSS concepts to foresee their economic and business value. The authors emphasize the relevance of PSS assessment for the management of risk and uncertainty using economic models, e.g., to predict costs at an early design stage. They acknowledge that the created value of smart PSS is distributed among multiple actors, which makes assessment using economic models difficult (Pirola et al., 2020). One of the most recent proposals for economic assessment is based on a PSS model, which is iteratively developed in a software tool (Medini et al., 2021). Using a simulation, the tool subsequently calculates the cost and revenue of the modeled PSS along its lifecycle for both the customer and the provider.

It can be concluded that the assessment of service ideas and business models is an under-researched area. While the importance of such assessments is recognized, the knowledge of methods and their integration in the design process is sparse and fragmented. In line with agile principles, several authors suggest that such assessments should take place early and repeatedly to create insights to support design decisions. Assessments should therefore be part of an iterative design process as proposed in recent frameworks for risk-oriented smart PSS engineering (Coba et al., 2020) and value-driven business model design (Sjödin, Parida, Jovanovic, & Visnjic, 2020).

3 Research Approach

3.1 Research Strategy

Building on the conceptual foundations presented in the previous section, a combination of research methods was applied to address the defined research objectives. As shown in Figure 3.1, the research strategy is based on two main approaches:

- ***Empirical research*** on the processes of developing service systems can provide valuable insights to inform SSE (Böhmann et al., 2014). Here, it is applied to establish an understanding of how SSI projects are organized and conducted in practice. Data is gathered through interviews with industry experts and analyzed using qualitative content analysis. Based on qualitative data analysis, these findings were used to conceptualize mechanisms such as the dynamics of actor-role assignments across different ecosystem states or iterative uncertainty reduction. Additionally, a case study was used to evaluate the suitability of LML to describe the emerging smart service system.
- ***Design science research*** (DSR) aims to develop novel artifacts to improve practices and performances (Hevner et al., 2004). DSR has been identified as particularly suitable for research in SSE (Böhmann et al., 2014) as it creates design knowledge and thus advances models, methods, and artifacts of SSE. DSR was applied to design a combination of methods from different disciplines that supports SSI. Additional artifacts were developed for the design-integrated assessment of services and their business models. These are meta-models to capture the relevant aspects, methods for calculating assessment results, and tools as instantiations of these concepts. Tool prototypes were used to show the applicability and evaluate the utility of the developed artifacts.

The following section provides a short description of how the selected research methods were applied.

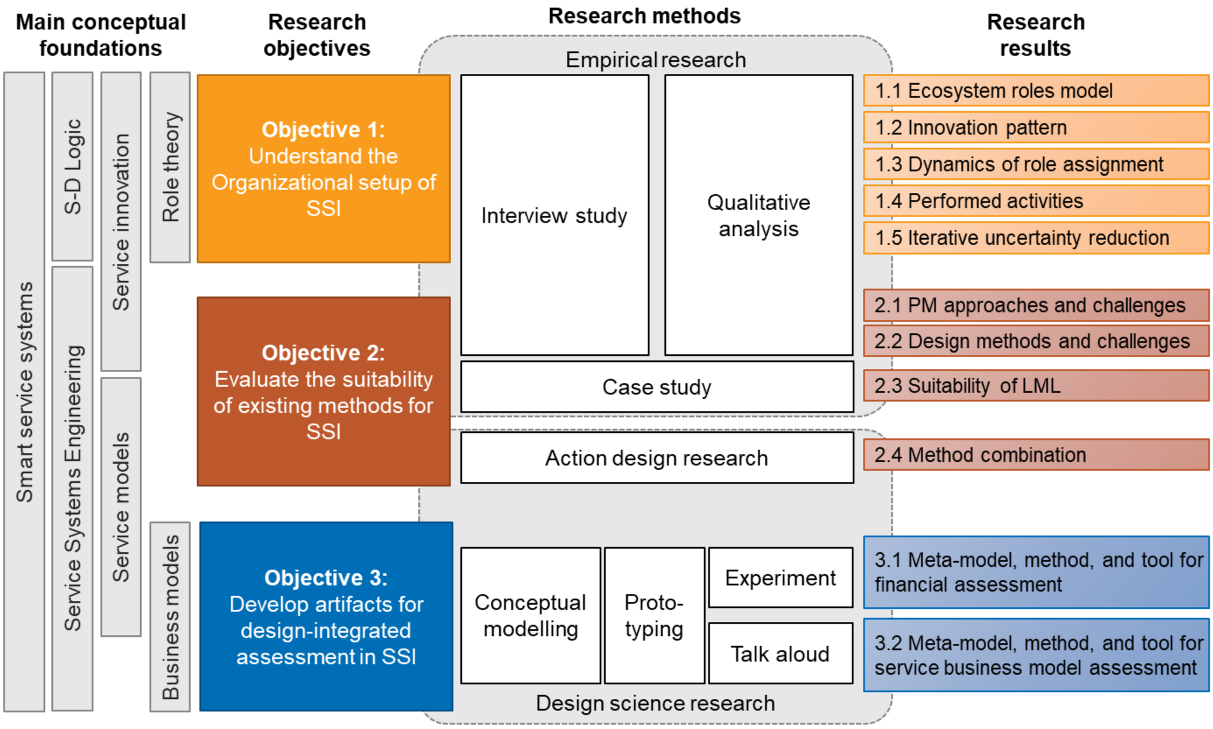

Figure 3.1: Overview of research approach

3.2 Applied Research Methods

3.2.1 Interview Study

Given the need for more theoretical and empirical work on smart service innovation (Djellal & Gallouj, 2018), an explorative approach to gathering insights on the organizational setup of SSI appears appropriate. It was decided to use an ***interview study*** with experts, who participated in real-world SSI projects. The interview study consisted of two rounds: In the first round, 14 interviews were conducted to gather insights from specific projects, particularly on the participating actors, addressed tasks, employed means, and challenges. In the second round, 11 additional interviews focused on the experience that experts had with SSI in general, i.e., without restriction to a specific project. The interviews were structured along the guidelines shown in Table 3.1 and lasted on average one hour.

Interview guideline in 2018	Interview guideline in 2020
1. Introduction of interviewer and expert, description of the expert's organization, expert's background, and his/her role in the organization. 2. Identification of smart service innovation projects, in which the expert was involved and selection of one project for closer analysis in the following sections of the interview. 3. Project initiation, including a general description of the project and the trigger for starting the project. 4. Project organization, including internal and involved external actors, the project management approach, employed methods, and specifications made. 5. Project outcome, including the value proposition, operational process design, and resource configuration of the smart service system.	1. Follow-up on the previous interview including a brief retrospective on the specific project from the initial interview. 2. Actors and roles that can be present in smart service innovation projects. 3. Multi-actor project management including methodologies, collaborative tools, and distribution/coordination of work across actors/roles. 4. Methods, techniques, and practices that are commonly used in smart service innovation projects.

Table 3.1: Abridged interview guidelines

3.2.2 Qualitative Data Analysis

The resulting interview recordings were transcribed and analyzed using ***qualitative content analysis***. As the first round of interviews had the character of a multi-case study, the approach proposed by (Yin, 2018) was used for the analysis. The main aspects of each project along the main sections of the interview guidelines were captured in case summaries. As three researchers were involved in this analysis, their individual findings were compared and consolidated. From these consolidated case summaries, the following aspects were extracted:

- Involved actors and their contributions
- Project management approaches
- Applied means for service design, i.e., for development and documentation
- Challenges in project management and service design

The analysis results were then compiled into overviews and structured into a set of contributions by actors, methods, notations, and challenges. The interpretation of these findings resulted in the conceptualization of a set of ecosystem actors (1.1), innovation patterns (1.2), the explanation of changing actor-role assignments in different ecosystem states (1.3), applied means for project management (2.1), and service design (2.2) along with their associated challenges.

The sample was extended by eleven interviews from the second round. A broader approach was chosen to gain insight into the experiences that experts made regarding SSI across various projects. The analysis and interpretation of this interview data were performed according to the methodology proposed by Gioia et al. (2013) as an approach to grounded-theory-based interpretive research. This resulted in a hierarchical data structure of 54 first-order codes, 21 second-order themes, and four aggregate dimensions that described the activities of actors in SSI (1.4). As an overarching core category, "iterative uncertainty reduction" was determined. In the subsequent interpretation of this core category, the multi-level framework by Storbacka et al. (2016) and microfoundations as a theoretical lens were applied. From this interpretation, the theoretical model of uncertain reduction at the meso-level resulting from performed activities of individual actors at the micro-level (1.5) was developed.

3.2.3 Case Study

Case studies help to explore complex phenomena in a real-world context when little previous knowledge exists (Rowley, 2002; Yin, 2018). As notations for smart service systems have barely been a topic of research so far, insights from case studies can contribute to incremental theory development. Therefore, the suitability of the Lifecycle Modelling Language was evaluated using a real-world case. The smart service system to be designed was the automated replenishment of consumables for 3D printing machines, which is an integral part of pay-per-use. The system consists of various physical, digital, and organizational elements with different lifecycles. For its design and operation, multiple internal and external stakeholders are involved. The evaluation was guided by the following process:

1. identify the main system elements and the relevance of their life cycles
2. derive information needs for different stakeholders that participate in the design and operation
3. analyze the scenario of automated replenishment of consumables for 3D printers
4. model the scenario using different LML diagram types
5. evaluate the model based on the elaborated information needs of different stakeholders

From these results, the suitability of LML (2.3) was assessed regarding the potential benefits that smart service life cycle models can provide for different stakeholders.

3.2.4 Design Science Research

DSR is an approach that helps to systematically design innovative artifacts and evaluate their utility. Such artifacts aim to improve current organizational practices and can take the form of constructs, (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations, which are implemented and prototype systems (Hevner et al., 2004; March & Smith, 1995). Different frameworks have been proposed to guide the design science research activities. Two of them have been used for research in this thesis, namely "Action Design Research" (Sein et al., 2011) and the "Design Science Research Methodology" (Peffers et al., 2007).

Action Design Research (ADR) aims to design artifacts in a real-world setting through systematic learning from the collaboration between practitioners and researchers. ADR is organized in four stages (1) problem formulation, (2) building, intervention, and evaluation, (3) reflection and learning, and (4) formalization of learning (Sein et al., 2011). ADR was applied to investigate the potential of combining methods from different disciplines, including those that were specifically designed for smart services but not used in practice yet. By actively involving researchers in a collaboration with practitioners, such methods can be transferred into practice. At the same time, the real-world project ensures the practical relevance of the resulting method combination. This designed artifact represents organizational knowledge of how digital service innovation can be supported by a set of existing methods.

Type	Methods		
General-purpose methods (GPM)	▪ 5 Why's ▪ 9-P Marketing Mix ▪ ABC-Analysis ▪ Brainstorming ▪ Conjoint-Analysis ▪ Environment Analysis	▪ Expert Interview ▪ How Might We-Questions ▪ Idea-Contest ▪ Interview for Empathy ▪ MoSCoW- Prioritization	▪ Nightmare Competitor ▪ Shadowing ▪ Stakeholder Analysis ▪ Stakeholder Map ▪ SWOT-Analysis
User-Centered Design (UCD)	▪ Customer Journey ▪ Digital Mock-Up ▪ Low-Resolution Prototyping	▪ Pains & Gains ▪ Persona ▪ Prototyping	▪ User Story Mapping ▪ Value Proposition Canvas
Service Engineering Methods (SEM)	▪ Customer Journey Mapping ▪ Job Mapping	▪ Minimum Viable Service	▪ Service Blueprinting
Digital Service-specific Methods (DSM)	▪ Information Service Blueprint	▪ Smart Service Canvas	

Table 3.2: Initial set of methods for the ADR project

For that, a list consisting of 30 methods from different disciplines was created, which serves as the basis for method selection in each iteration (Table 3.2). The majority came from the methods listed in DIN SPEC 33453 (DIN, 2019). Others were identified in a textbook on data-driven service engineering and management (Leimeister, 2020) or contributions from recent conferences on information systems.

The ADR project was conducted in a collaboration between a university and a German software company. This company aims to expand its product range with a new smart service that supports cost estimation for automotive parts. As an overall project structure, the DIN SPEC 33453 was chosen, which describes an agile process with the phases of analysis, design, and implementation (DIN, 2019). The project consisted of five iterations, each of which had a specific objective. Based on the objective and the results from the previous iteration, suitable methods were selected and applied. For the design of the final artifact, the chosen methods were extracted, the output of each applied method was identified and labeled, and the methods were connected based on their input-output-relation.

The ***Design Science Research Methodology*** (DSRM) by Peffers et al. (2007) is a widely used approach to DSR (Figure 3.2). It was applied in the development of new artifacts for the design-integrated assessment of services. As shown, the process is iterative as findings from evaluation and communication can (and should) lead to further development of solution objectives and artifact design.

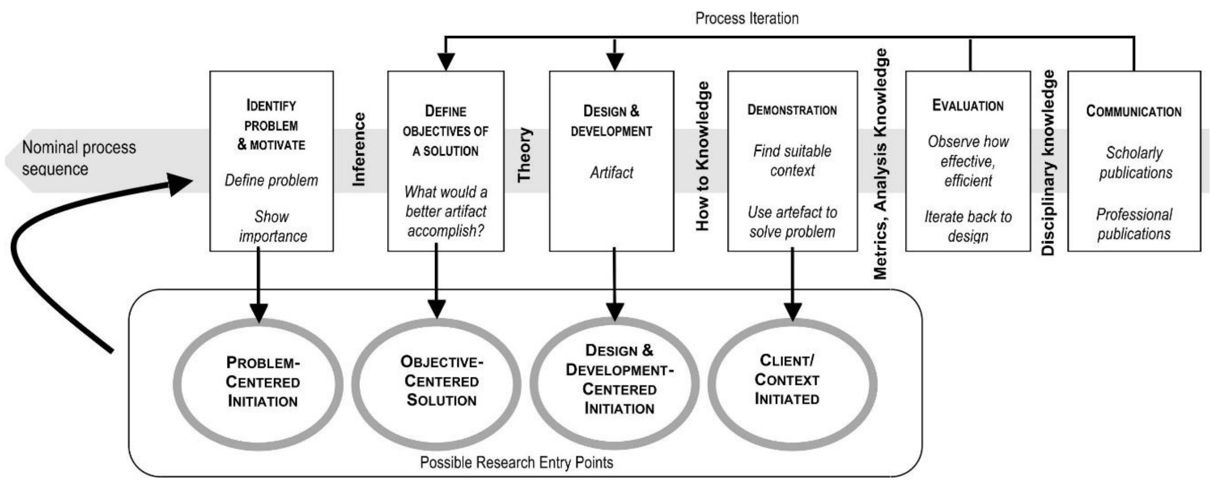

Figure 3.2: Design Science Research Methodology Process Model (Peffers et al., 2007)

While the DSRM process makes DSR more concrete, it does not prescribe any methods that should be applied to fulfill the individual steps. An exception is the evaluation step, where several approaches have been proposed and found their way into research practice (Sonnenberg & Vom Brocke, 2012; Venable et al., 2016). Therefore, suitable methods have to be defined for all other steps in the concrete design project. For an overview, the applied methods are provided in Table 3.3 which is organized according to the two research questions on financial assessment of smart services (RQ3.1) and assessment of service business models (RQ3.2) that constitute the overall topic of design-integrated, for which suitable artifacts are to be designed.

Phase	Smart Service Financial Assessment	Service Business Model Assessment
Identify problem & motivate	Literature review, especially on servitization and PSS engineering	Literature review, especially on data-driven business models
Define objectives of a solution	Requirement analysis based on characteristics of smart services and processes for their engineering	Requirement analysis based on business model design tools
Design & development	▪ *Models:* meta-modeling based on smart service characteristics, pricing models, and financial cash flows ▪ *Method:* Financial calculation based on techniques of capital budgeting ▪ *Instantiation:* Development of a prototypical web application	▪ *Model:* meta-modeling based on cost-benefit-analysis, effects of DDBM, and meta-model for financial assessment ▪ *Method:* Interaction Design ▪ *Instantiation:* Development of tool using a web-based rapid prototyping system
Demonstration	Lab experiment with 30 participants ▪ solved service design task with ideas brainstormed by participants ▪ the experimental group used the tool ▪ the control group used a spreadsheet	Usage of the prototype by 11 participants ▪ conduct nine assessment tasks ▪ talk aloud method during task performance ▪ rating through a survey after completion
Evaluation	▪ Apply meta-models to real-world cases ▪ Survey of participants on tool utility	*(not conducted yet)*
Communication	One journal paper (Anke, 2019)	Two conference papers (Anke, 2020; Zolnowski et al., 2017)

Table 3.3: Methods applied in the DSRM

The research resulted in seven artifacts that are linked, as shown in Figure 3.3. The links are created by using models in methods and subsequently their implementation in prototypes. Additionally, meta-models for smart services, financial cases, and business model assessment are integrated into a more comprehensive meta-model for service assessment. This integration shows how design knowledge can be accumulated, which DSR research often lacks (Vom Brocke et al., 2020).

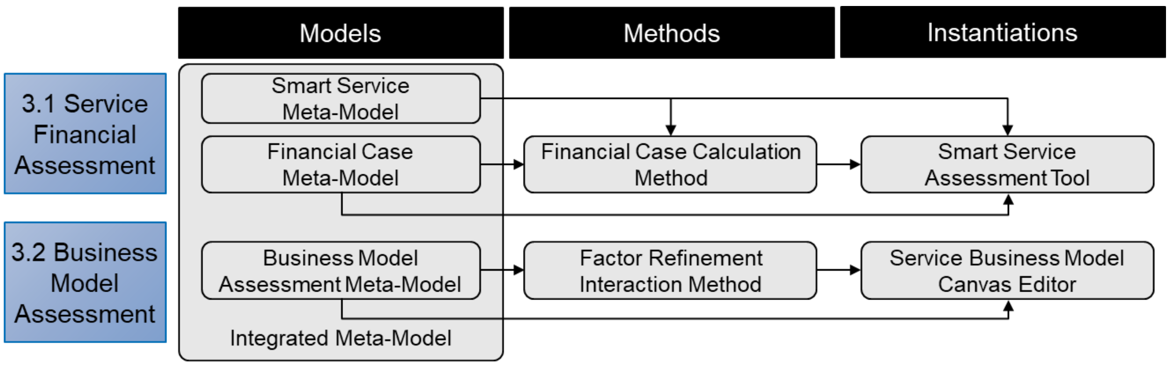

Figure 3.3: Designed artifacts and their relations

4 Summary of Findings

4.1 Overview of Research Results

SSI requires the collaboration of multiple actors that integrate their existing resources, e.g., knowledge, skills, software components, and infrastructure, to develop new resources and establish new resource integration patterns. An adapted version of the framework proposed by Grotherr et al. (2018) is used to explain key relationships in SSI and organize the research findings (Figure 4.1). At the macro-level, smart service innovation is created by multiple actors in a service ecosystem. These actors are loosely coupled by their ability to provide resources that are relevant for smart services. The collaboration as service exchanges between these actors takes place within an innovation project as an institutional arrangement, which represents the meso-level. As different resources are needed in the course of the project, the involvement of actors may be changed through the institutional design cycle. Project management activities are represented by the engagement design cycle that organizes the collaborative work. This includes the agreement of a project management approach and a collaborative development process. Depending on their roles and other contextual factors, actors use suitable methods and practices to perform activities toward different design objectives. These performances result in new or updated resources and patterns for their integration, which contributes to a smart service system that enables smart service innovation with the desired value proposition.

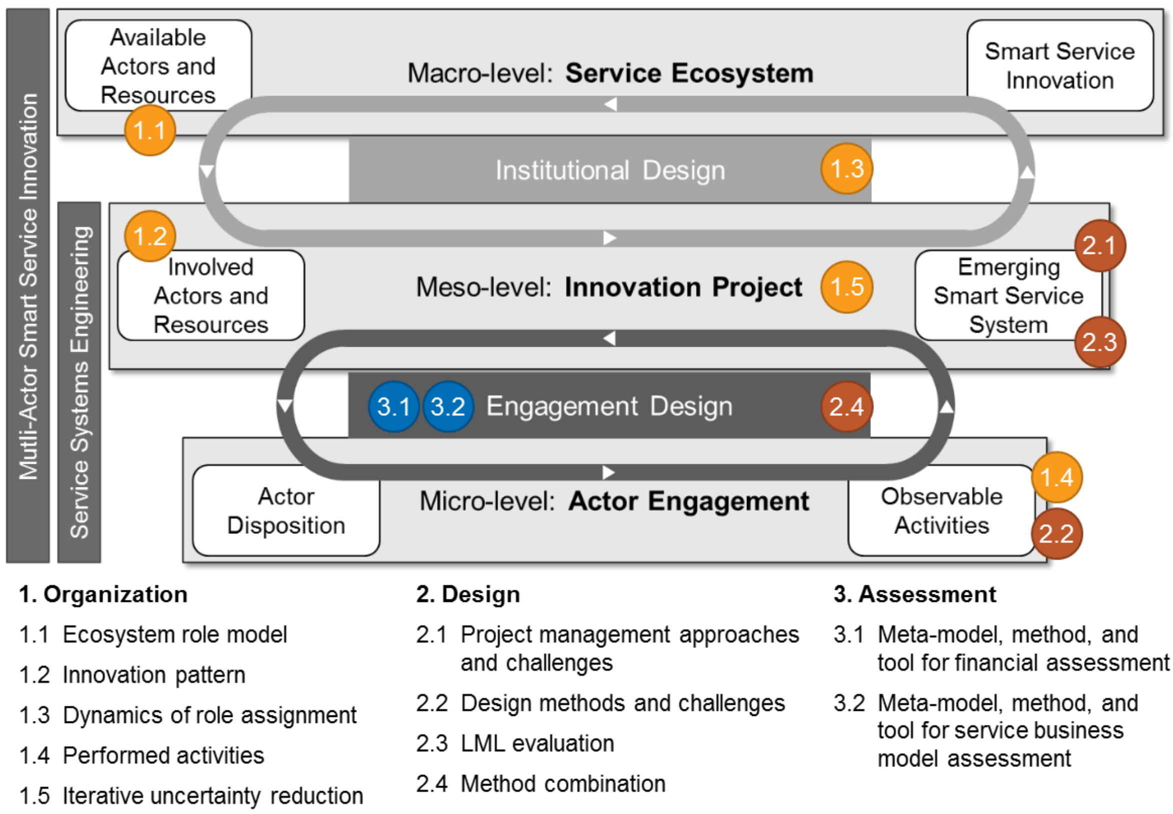

Figure 4.1: Mapping of research results to the multi-level framework

The research results are grouped into the three aspects of organization, design, and assessment. The aspect of *organization* deals with the involvement of actors and their activities. The *design* aspect focuses on applied methods, and challenges as well as the evaluation of LML and the proposal of a method combination. Finally, the *assessment* aspect relates to the evaluation of smart services and their business models, which is addressed through models, methods, and tools.

4.2 Organizational Setup of Multi-Actor Smart Service Innovation

The variety of contributions from the involved actors is described by the proposed ***ecosystem role model***. It consists of 17 roles, which are clustered into Primary and Secondary Roles (Figure 4.2). *Primary Roles* identify contributions that are required due to the characteristics of smart service systems and must be present in every project. *Secondary Roles* relate to more specialized contributions for which the demand is identified during a project. The set of roles is further systematized into different subsystems of the overall service ecosystem at different points in time. The *Engineering* subset refers to contributions that are needed for the development and implementation of the smart service system. The *Operations* subset begins with the launch of the smart service offering into the market and refers to the actual value co-creation with the intended target group.

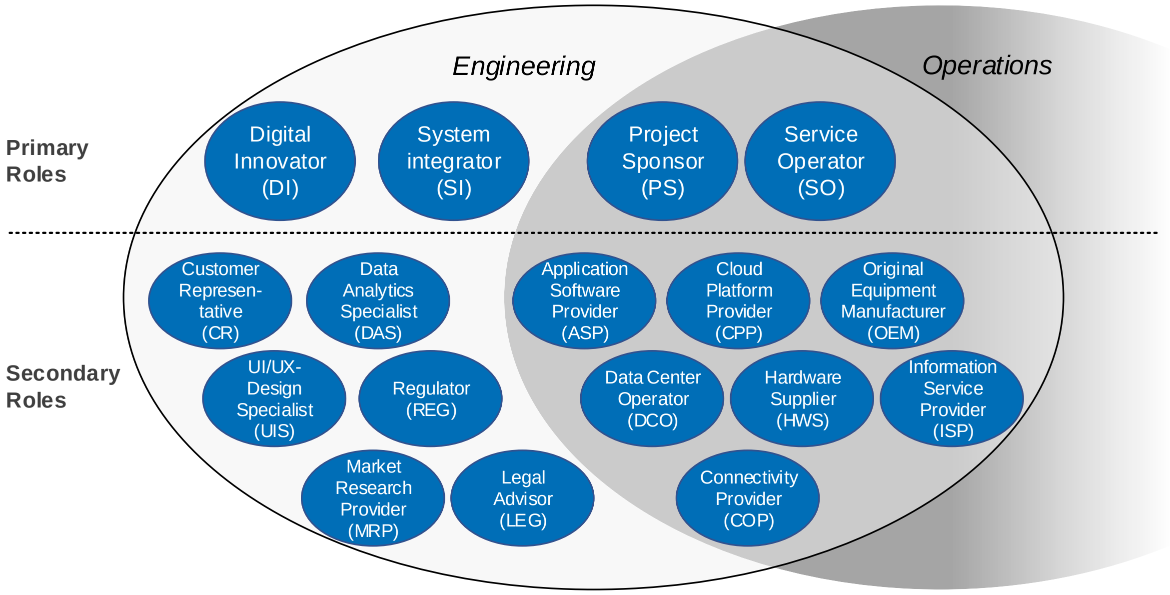

Figure 4.2: Roles and role groups from SSI projects

The need for certain competencies at different stages of innovation causes ***dynamics of roles and their assignment to actors*** in the service ecosystem that includes both the participation of actors as well as the changing roles of actors over time. The ecosystem states proposed by Edvardsson et al. (2018) are used to conceptualize this dynamic (Figure 4.3). In the "initiating" state of the ecosystem, one actor decides to develop a new value proposition for a certain target customer group. For that, various resources, e.g., infrastructure and knowledge, are needed, which are indicated by the roles highlighted as "required". By involving actors that provide the required resources, they assume the respective roles. With that, the project is enacted and transits the ecosystem to the "realizing" state.

The project acts as an institutional arrangement, which facilitates service exchange between the actors. Such exchanges result in the creation of new resources, e.g., software components, business models, or data analysis models. As a result of service exchanges, the new smart service system emerges. It aims to enable value co-creation in a configuration of actors, whose contributions are described using roles from the operation subset. The involvement of actors with suitable resources to fulfill the designated roles enacts the smart service system and changes the ecosystem state to "outcoming". This indicates that the service system is ready to integrate resources from the target customers and co-create the envisioned value proposition. It is important to note that the transition between states is fluent, as some actors, e.g., customers, are involved in multiple states, albeit possibly in different roles.

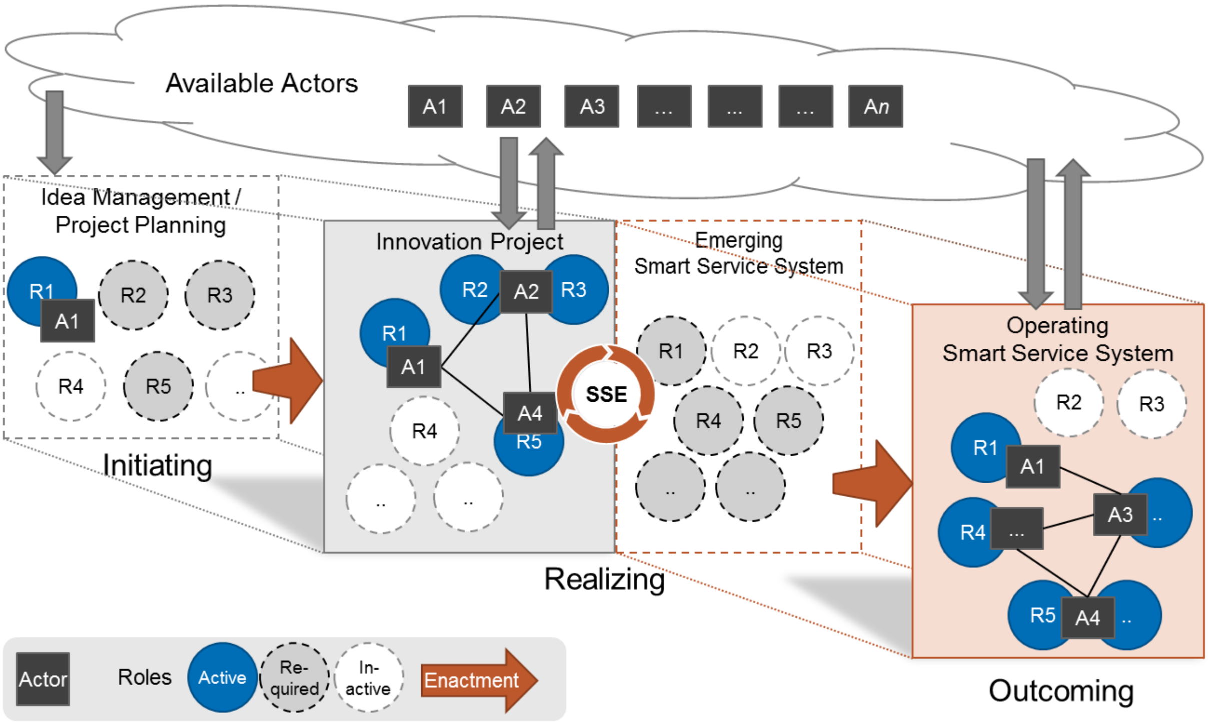

Figure 4.3: Dynamics of actor involvement in different ecosystem states

To illustrate the dynamics of actor-role assignments, the case of a fleet management and maintenance service is used (Anke, Pöppelbuß, & Alt, 2020a). As illustrated in Figure 4.4, actor P4 planned to provide these new smart services around its commercial vans. At the initiating state, P4 identified various competencies required to realize his service idea, e.g., those of a Digital Innovator, a System Integrator, and a UI/UX Design Specialist. For the transition into the realizing state, these required roles had to be filled with actors. Altogether, these actors and P4 were supposed to form the Engineering subsystem that collaboratively works on the design and implementation of the new service idea. Two external System Integrators (E12, E13) were chosen, and a design agency (E14) was hired for the UI/UX design. The fleet management functionality was delivered by an external Application Service Provider (E16). They also worked together with P4 on interfaces for the integration of fleet management functionality.

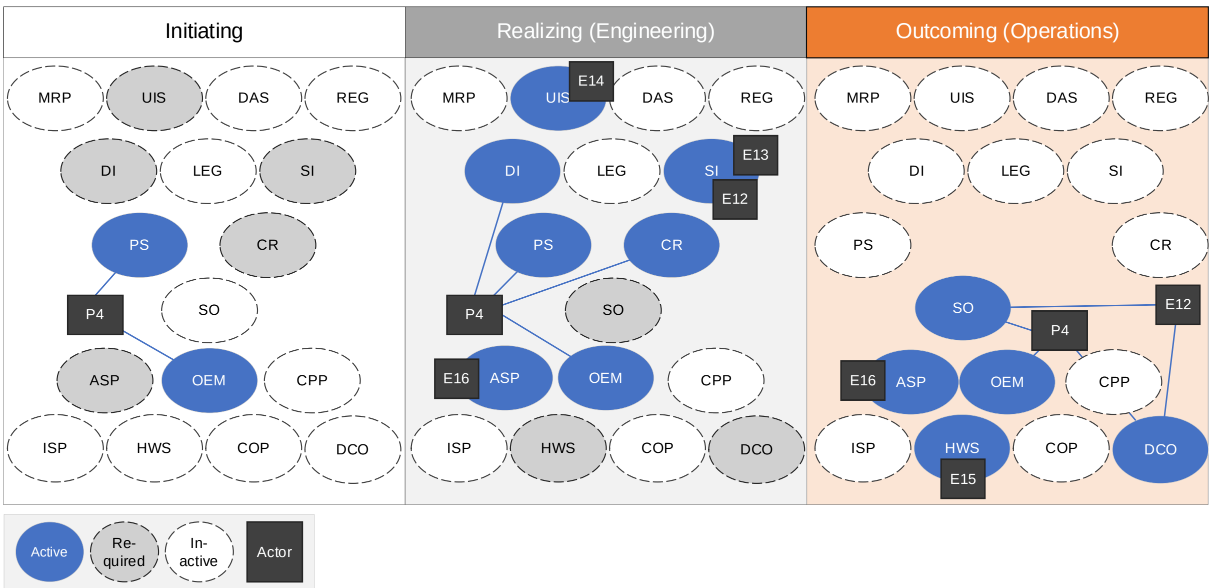

Figure 4.4: Actor-role assignments in different states of service innovation

As the actor P4 itself intended to use the service for its internal maintenance operations, it also assumed the role of the Customer Representative. Due to its innovation capabilities and domain expertise, actor P4 also took over the Digital Innovator role and developed the value proposition and business model. During the project, the actors determined additional competencies required for Operations, e.g., Service Operator, and Data Center Operator. The launch of the service offering marks the transition to the outcoming state. For that, the required roles of Data Center Provider and Service Operator had to be filled with actors. In this case, parts of the systems were operated and managed by actor P4 itself and other parts by E12. Therefore, these two actors shared the roles of Service Operator and Data Center Operator. In the outcoming state, some of the roles from the realizing state became inactive as their project work was finished.

This example shows that relevant resources regarding knowledge on markets, IT, and digital innovation are distributed among the participants of the project. In the analysis of actor-role assignments and a reflection of the underlying dynamics during the service innovation processes, four typical constellations are identified that are called ***smart service innovation patterns***, which are *Provider-driven development*, *Joint development*, *White Label Solution*, and *Forward Integration* (Table 4.1). These patterns indicate a certain strategic setup of an SSI project and the associated distribution of the business risk. Patterns also allow the analysis and design options of existing service ecosystems, e.g., regarding potential setups under given competencies per organization. This might help to derive strategic objectives regarding the establishment of new competencies or strategic alliances with key partners.

Name	Characteristics
Provider-driven Development	▪ Service innovation at the provider organization with the designated Service Provider role, possibly in collaboration with (future) customers ▪ IT-related competencies are often not available internally ▪ High dependency on external know-how, especially from IT provider organizations (System Integrator role), who are only responsible for the technical implementation ▪ Provider organization needs strong innovation and project management capabilities ▪ Entrepreneurial risk at the provider organization
Joint Development	▪ Service innovation is driven by a provider organization together with an external actor with the System Integrator role ▪ Both actors assume the Digital Innovator role together ▪ Lower requirements for innovation and project management capabilities at the provider organization due to external support ▪ Entrepreneurial risk at the provider organization
White Label Solution	▪ An actor with strong IT capabilities (i.e., an IT provider organization) develops, builds, and runs an innovative value proposition on its own ▪ The IT provider organization offers a white-label solution for a common problem to (multiple) provider organizations ▪ Provider organizations assume the Service Provider role and market the value proposition to their customers, i.e., they offer services with minimal effort for new service development ▪ The IT provider organization often follows a platform approach to provide customizable solutions for different provider organizations using reusable building blocks ▪ Entrepreneurial risk shared between IT provider organization and provider organization
Forward Integration	▪ IT provider organization develops, runs, and offers smart service systems by itself ▪ This actor covers most of the relevant roles through internal resources and competencies ▪ The actor may target markets of former customers ▪ Entrepreneurial risk is at the IT provider organization

Table 4.1: Smart Service Innovation Patterns (based on Anke, Pöppelbuß, & Alt, 2020a)

Due to the characteristics of both the type of system and the development process, actors involved in SSI are confronted with uncertainty and complexity. Uncertainty mainly relates to the multi-actor nature of SSI, where the outcome in terms of changes to the smart service system is difficult to predict. Therefore, smart service innovation uncertainty is conceptualized as a property of the meso-level, which refers to both the actor-to-actor network within a project and the smart service system with its changed resource integration patterns as the outcome. Actors influence future innovation activities by making decisions about what needs to be done in the project and who takes over responsibilities for work packages, e.g., by assigning tasks or subcontracting additional actors. Hence, the resource integration patterns of the project understood as actor-generated institutions (Vargo & Lusch, 2016), change through the joint project work, too.

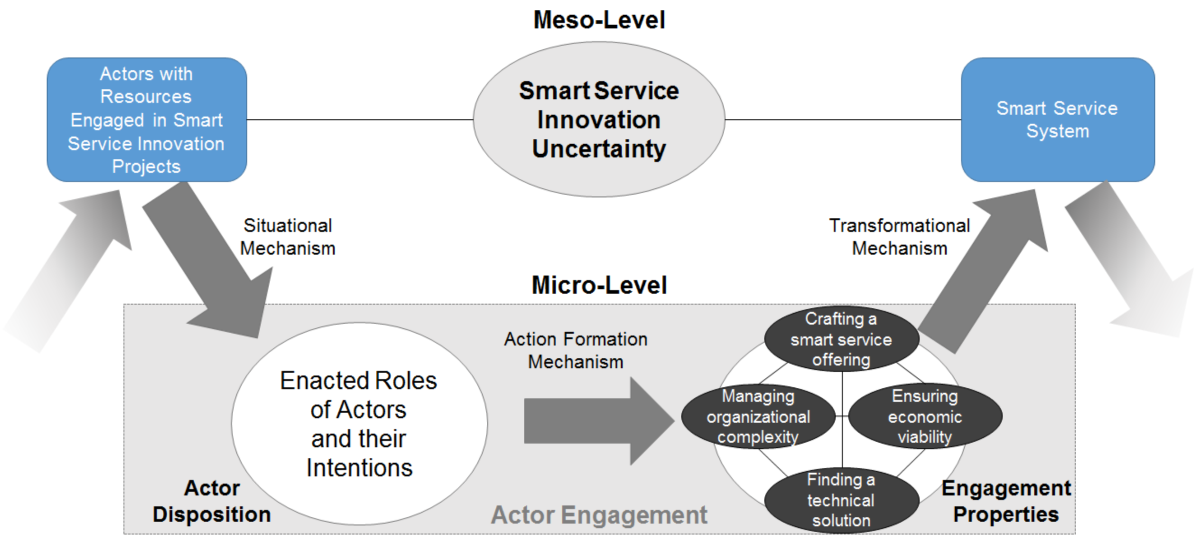

Figure 4.5: Theoretical model of iterative uncertainty reduction in smart service innovation

The theoretical model of ***iterative uncertainty reduction*** (Figure 4.5) aims to explain the behavior of actors in SSI projects to handle uncertainty. Considering the current conditions of uncertainty relevant to a project, the involved actors perform activities generating a new configuration of resources which is usually supposed to reduce uncertainty. The project set-up provides the conditions for actor engagement on the micro-level (situational mechanism), which influences the intentions and the roles that the actors enact during project work as actor dispositions. They are turned into action in the specific project context (action-formation mechanism). The collective action of all actors leads to the emergence of a new smart service system or changes to an existing smart service system (transformational mechanism), which can, in turn, be the outset of future innovation activities, as reflected by the fading arrows in Figure 4.5.

The theoretical model conceptualizes the actor's activities as engagement properties. The connections between these activities emphasize that they are interdependent. For example, involving users as part of *exploring and empathizing* causes additional *multi-actor complexity* that needs to be managed. Similarly, the design of a certain *technical solution* requires specialists that must be involved in the project but also influences the *economic viability* of the overall service system. Furthermore, the technical solutions are dependent on the service offering to be delivered. The interdependencies are not limited to the micro-level, but also affect the actor-to-actor network of the project on the meso-level and, hence, the smart service innovation uncertainty as a property of that level.

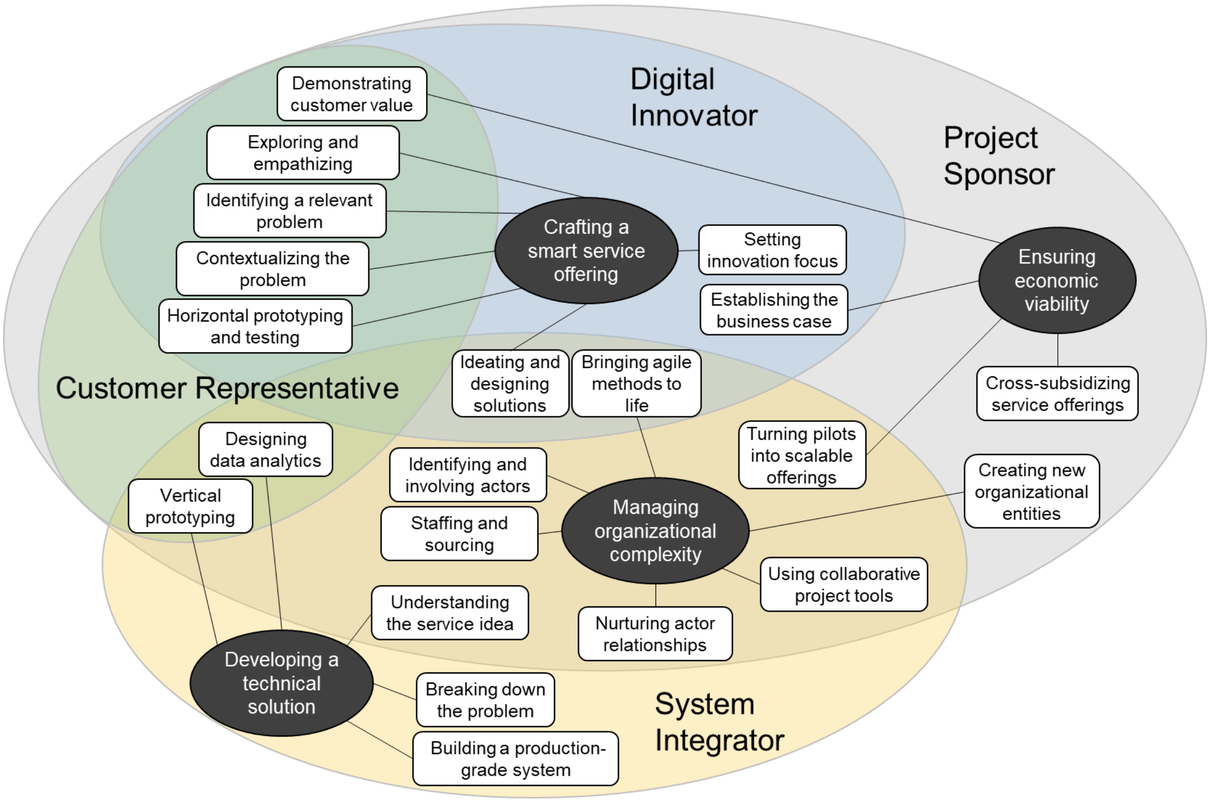

Figure 4.6: Activities of main roles in smart service innovation

The main ***activities that actors perform*** to successfully carry out smart service innovation together are (1) *managing multi-actor complexity*, (2) *crafting a smart service offering*, (3) *developing a technical solution*, and (4) *ensuring economic viability*. These activities are conducted by different actors, which assume the roles of Project Sponsor, the Digital Innovator, and the System Integrator. Furthermore, actors with the Customer Representative role also appeared to contribute to smart service innovation, which reflects customer involvement as a key characteristic of agile project management approaches. As shown in Figure 4.6, these main activities are aggregated from various sub-activities. In line with the expected high degree of collaboration, these are performed jointly by multiple actors. For example, the sub-activity "identifying a relevant problem" is conducted by the Digital Innovator together with the Customer Representative and the Project Sponsor. Other sub-activities are done by single actors, e.g., "Creating new organizational entities" (Project Sponsor) or "Building a production-grade system" (System Integrator). In contrast, "Bringing agile methods to life" and "Ideating and designing solutions" require the collaboration of all four roles, which underlines the importance of these activities.

While the activities and sub-activities describe *what* is being done by *whom*, it does not state *how* these activities are conducted in SSI projects. This is covered in the next section, which reports on the results regarding the suitability of methods for SSI, and how they can be combined.

Citation	Title	Outlet	Addressed RQs
Anke, Pöppelbuß, and Alt (2020a)	It Takes More than Two to Tango: Identifying Roles and Patterns in Multi-Actor Smart Service Innovation	Schmalenbach Business Review	1.1 1.2 1.3
Pöppelbuß, Ebel, and Anke (2021)	Iterative Uncertainty Reduction in Multi-Actor Smart Service Innovation	Electronic Markets	1.4

Table 4.2: Included publications of the findings summarized in section 4.2

4.3 Conducting Smart Service Innovation Projects

The organization of SSI projects requires agreement on how the collaborative work is to be organized and performed. Using an extended version of a generic software lifecycle meta-model presented in section 2.4, links between the organizational setup, the development process, its methods, and the (emerging) service system can be established (Figure 4.7). In this conceptualization, the process is defined as a sequence of activities, that can be bundled into phases. The performance of activities uses and/or creates new work products, which represent the current state of the service system regarding a certain design objective. Methods are linked to activities by proposing techniques for the performance of activities, and notations for the work products. Activities are performed by roles; which actors assume if they possess the required resources or capabilities.

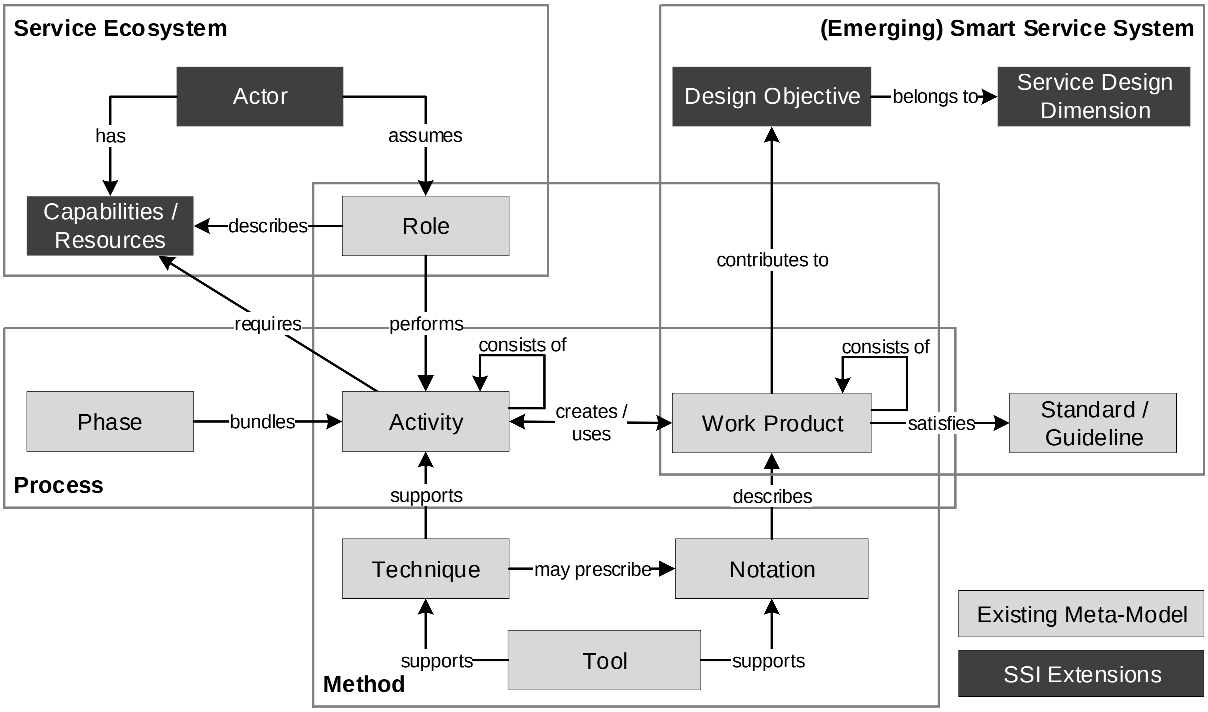

Figure 4.7: Extended conceptual model for multi-actor service systems innovation processes

4.3.1 Development Processes and Project Management

As shown in section 4.2, the actors assuming key roles of Project Sponsor, Digital Innovator, Customer Representative, and System Integrator are highly interdependent. Establishing and maintaining efficient collaboration within the innovation process is addressed by the *"managing multi-actor complexity"* activity. It consists of various sub-activities like "identifying and involving actors", "staffing and sourcing", and "bringing agile methods to life" (Figure 4.6). These activities are not only determining which actors participate in the project at a given point in time but are also setting the common ground for collaboration. Actors involved in management often have the Project Sponsor or the System Integrator roles.

Concerning the ***project management approach***, two main types were found: (1) traditional sequential approaches, e.g., the waterfall model, which focuses on predictability, and (2) more recent agile approaches, e.g., Scrum, which is characterized by flexibility and adaptability (Sommerville, 2016). If both types were used, which was observable in some projects, the category "hybrid" is assigned to them (Table 4.3). While there is almost an equal distribution of methodologies across the projects, experts who had used a sequential methodology often described them as unsuitable for their project in hindsight.

Methodology	Description	#Projects
Agile	Used an agile approach throughout the project	5
Sequential	Used a sequential approach throughout the project	4
Hybrid	The project was conducted partly agilely and partly sequentially	5

Table 4.3: Employed project management methodologies

Additionally, experts reported on various ***challenges regarding project management***, which were grouped into the categories of planning, collaboration, knowledge, and go-live (Table 4.4) along with the number of projects grouped by methodology. It illustrates the variety of problems that occurred in the management of SSI projects. The results also indicate that most challenges are occurring are not specifically associated with the employed project management approach. Instead, many challenges are related to collaboration, i.e., involving external partners appropriately, creating a common understanding, distributing work, and receiving contributions on time. These challenges can be summarized as being related to multi-actor complexity. Furthermore, the challenges show acquiring suitable knowledge related to data-driven approaches, agile methods, software development, and modern infrastructure from external and internal sources is difficult. It is notable, that very little of the reported challenges are related to the implementation and launching ("Go-Live") of services.

Category	Challenges	#Agile	#Sequential	#Hybrid
Planning	Tight deadlines; lack of time for preparation/analysis	1		
	Uncertain/inconsistent management decisions			1
Colla-boration	Involvement of partners	2		
	Dependency on external actors	2	1	
	Difficulties of involving customers in an agile approach	1		
	Distribution and synchronization of work; maintaining consistency of work	2		2
	Getting access to and aligning work with stakeholders, e.g., partners, internal units	1		1
	Achieve common understanding and suitable level of detail			1
	Confronting functional departments with too many technical details			1
	Achieving a common understanding of concepts, e.g., industry 4.0, smart services		1	
	Work of external partners not delivered on time; threat of missing the deadline	2		
Knowledge	Need for external know-how, e.g., software development and analytics	1	1	1
	General lack of digital transformation/innovation knowledge/skills	1	1	
	Lack of technical knowledge at the service provider			1
	Training of employees, e.g., infrastructure, data-driven approaches, sales	2	1	
	Team members or customers not familiar with an agile approach	2		
Go-live	Advancing app from prototype status to a productive and usable one		1	
	Testing was time-consuming and required a lot of effort		1	

Table 4.4: Challenges regarding project management

4.3.2 Methods for the Design of Smart Service Systems

The actual design of service systems is addressed by two activities: First, *"crafting a smart service offering"* deals with the development of a service concept, that is valuable to both customer and provider. Hence, the Project Sponsor is engaged in these activities, together with the Digital Innovator that often provides in-depth knowledge on innovation management methods. If agile principles are applied, a Customer Representative has to be involved in these activities. Actors of all involved roles take part in the ideating and designing of solutions. This highlights that the development of service concepts and their technical implementation are interdepended, i.e., service ideas are checked for technical feasibility, while technical opportunities enable new service features.

Second, "*developing a technical solution*" covers the design and implementation of the technical system that underlies the service concept. This is done by the System Integrator, a role that is often assumed by external companies. They collaborate with the Project Sponsor to understand the ongoing service concept development and work with the Customer Representative on prototypes. Finally, they are also responsible for building a technical system that is ready for productive use.

	Design Objective	***Means for Development*** *(Techniques / Practices)*	***Means for Documentation*** *(Work Products and their Notations)*
Value Dimension	*Customer Understanding*	▪ Feedback on current service ▪ Customer ideas, customer as product owner ▪ Workshops, discussions, Design Thinking ▪ Internal platform (prediction market) ▪ Expert interviews, field tests with test users	▪ MVP, paper-based prototypes ▪ Epics and user stories ▪ Customer journeys, personas ▪ Requirement specifications
	Value Proposition	▪ Identify/prioritize actors/customers and their jobs/problems ▪ Understand the capabilities of existing systems as a basis for new service ▪ Interactive discussion, workshops ▪ Check for legal hurdles (e.g., patents, privacy, regulatory)	▪ Slides, whiteboards, bullet points ▪ Textual specifications ▪ Workshop documentation according to a structured innovation approach ▪ Business Model Canvas, Value Proposition Design, personas ▪ Use cases
Process Dimension	*User Interaction / User Interfaces*	▪ Involvement of UX experts ▪ Early testing/improvement through feedback ▪ Workshops, discussions, analysis ▪ Definition of roles and permissions ▪ Design guidelines	▪ Prototypes, wireframes, click dummies, atomic design, modular standard screens ▪ Customer journeys, Service journeys ▪ Process models ▪ Textual description of process steps
	Back-ground Processes	▪ Technical documentation ▪ Process definitions ▪ Domain expertise of product owner	▪ Textual description ▪ Informal modeling of process steps ▪ Graphical models (BPMN, UML, flow charts)
Resource Dimension	*Technical Concept*	▪ Review of existing components, compliance with existing architecture/equipment ▪ Define new components, comply with architectural guidelines, 12-factor cloud apps ▪ Traditional system specification, derivation of technical requirements ▪ Iterative implementation on a test platform	▪ Vertical prototypes ▪ IT architecture model, microservices ▪ UML models ▪ ArchiMate models ▪ Interface definitions ▪ User stories and epics

Table 4.5: Aggregated set of means for different design objectives in real-world SSI projects

Both activities are targeted at different design objectives, i.e., the involved actors collaboratively make decisions on aspects of the service system. Each design objective can be related to one of the design dimensions value, process, and resource. In the interview study, a set of design objectives ("end"), and the ***used methods, techniques, and notations ("means")*** were identified and grouped along design dimensions and design objectives (Table 4.5). The results represent the view of practitioners, which are categorized based on the aggregated responses. Not surprisingly, the responses do not always match the respective category as terminological precision is not usually required in real-world projects. Instead, participants relied on their experience and selected means from different disciplines. By making such choices, they implicitly expressed that they consider these means suitable for the task at hand.

	Design Obj.	Category	Challenges
Value Dimension	*Customer Understanding*	*Market Dynamics*	▪ Dependency on external developments, e.g., technological advancements
		Requirements	▪ Unspecific customer requests ▪ Variety of customer requirements
	Value Proposition	*Target Customer Problem*	▪ Decisions on customer segment/target group ▪ Choosing a problem, which is to be addressed
		Quality	▪ Deciding the level of quality of service, i.e., functionality vs. price level
		Legal	▪ Unclear legal conditions, e.g., on billing methods, potential patent violation, regulatory compliance, ownership of data
		Features	▪ Defining the feature set for the initial launch, future releases, and prioritization of necessary vs. useful features in general
	Value Capture	*Revenue Model*	▪ Distribution of financial benefits
		Pricing Decisions	▪ Finding a good pricing model, refining the pricing model ▪ Customers with different price expectations/perceptions
		Business Model	▪ Difficulties in identifying suitable business models
Process Dim.	*User Interaction / User Interfaces*	*Touchpoints*	▪ Unclear if additional efforts in user interface simplification will pay off ▪ Determine the suitable number of elements should on a page, i.e., the amount of information that users can handle
	Background Processes	*Process Design*	▪ Capabilities and degrees of freedom in existing systems had to be matched to requirements; change of either systems or requirements
Resource Dimension	*Technical Concept*	*System Architecture*	▪ Number of connected products, amount of transmitted data unknown ▪ A load-aware mechanism for data collection and transmission ▪ Cross-system identity management ▪ Enabling/extending the underlying platform for new requirements ▪ Determining the required data and data quality
		System Integration	▪ Getting the system running globally, consideration of country-specifics ▪ Integrating devices; implementing protocol adapters ▪ Integration of existing systems; data access in heterogeneous systems ▪ Missing/incomplete documentation of hardware and external systems
		Technology Choice	▪ Low maturity technology stack ▪ Selection of communication technology, e.g., MQTT vs. OPC-UA ▪ Selection of cloud / IoT-platform provider

Table 4.6: Identified challenges in real-world smart service innovation

Working towards the design objectives mentioned above resulted in various ***challenges in the design*** (Table 4.6). Most of the identified challenges relate to ends with applied means. This could be due to a lack of method knowledge or poor application. In contrast, for the end "Value Capture", no means but several challenges were found. This gap is addressed by the new approach for design-integrated assessment (see section 4.4).

While there a variety of methods from different disciplines could be identified, there were no methods applied in real-world SSI projects that were specifically designed for smart services. This raises the question of how to ***combine methods from different disciplines*** to enable the reuse of existing methods and the transfer of new methods to practice. Potentially suitable methods for SSI can be categorized as "digital service specific methods" (DSM), "service engineering methods" (SEM), "user-centered design methods" (UCD), and "general-purpose methods" (GPM). Each set of methods can be applied for different purposes. Methods of the GPM category are the most general ones, e.g., from social research or marketing, and management. UCD methods are often used in agile projects to ensure that the resulting products are accepted by the user. While UCD can be applied to any kind of technical or digital product or service, SE methods are targeted at the engineering of services. Finally, DSM consider the specifics of digital services, such as data, devices, and analytics.

Within a real-world project based on the action design research approach (see section 3.1), a set of methods from different disciplines was chosen and combined to develop a service for "predictive costing" in the automotive industry. The resulting method combination is depicted in Figure 4.8. It shows which methods are combined in a meaningful way in a realistic case. The linking of methods is organized based on the input-output-relations, i.e., a method takes the result from the preceding method as input and produces an output that fits the subsequent method. The designed method combination highlights the central role of the Smart Service Canvas (Pöppelbuß & Durst, 2019) to establish a connection between customer, value, and ecosystem perspectives for smart services. Various methods from other disciplines help to elaborate the details of these perspectives.

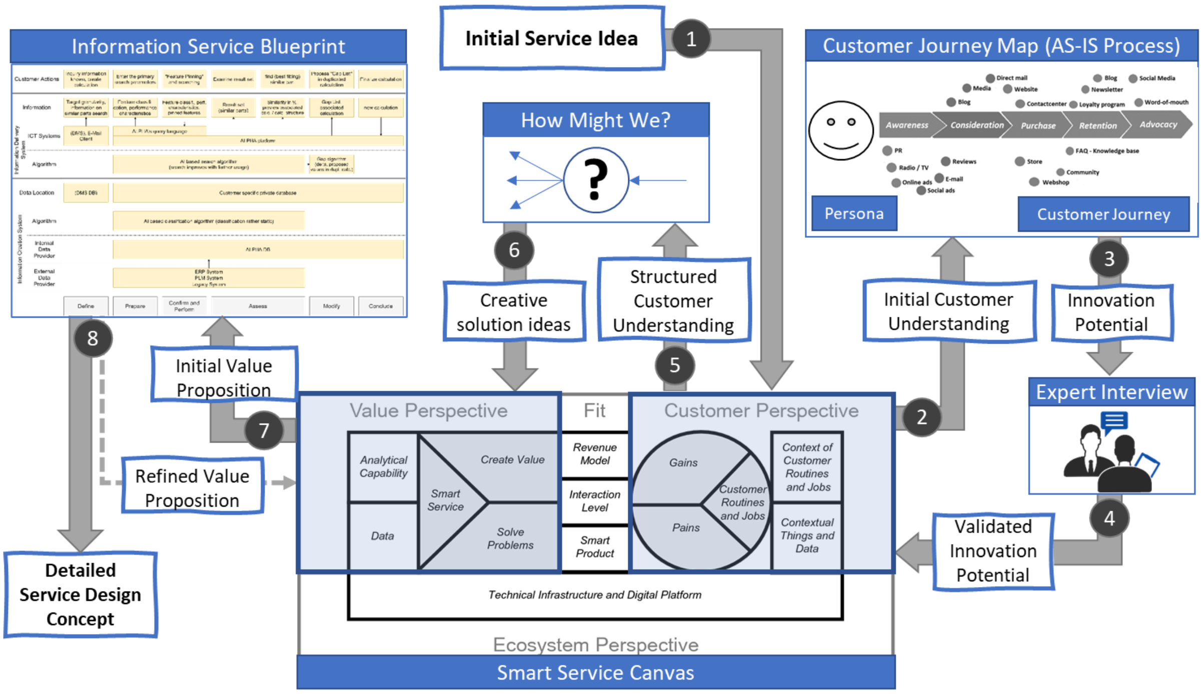

Figure 4.8: Combination of methods for iterative service innovation (Richter & Anke, 2021)

The method combination is by no means the only or the best possible combination. Instead, it shows that methods from different disciplines are suitable for SSI, and they can be combined beneficially. This finding underscores the reusability of existing method knowledge for SSI but also the necessity to guide the selection and combination of methods for a given situation.

4.3.3 An integrated, lifecycle-oriented Model of Smart Service Systems

Smart service systems consist of many elements that need to work together to enable the intended value proposition. Within the SSI project, development activities create and update work products that capture the design decisions made in the process. These work products represent diverse system elements that contribute to design dimensions. As shown in Table 4.5, work products are documented in different forms and notations. It illustrates the interdisciplinary character of SSI projects, where the methods from many disciplines are applied by the involved actors.

However, this leads to two challenges: First, using multiple representations of different service system aspects results in a fragmented view of the emerging smart service system along its design dimensions. This is reflected in some of the collaboration challenges displayed in Table 4.4, e.g., "maintaining consistency of work" and "achieving common understanding and suitable level of detail". Second, none of the identified notations explicitly consider the lifecycle of individual system elements. This is particularly relevant in later stages of the service operation, where changes in processes, updates of software components, or replacements of physical parts may impact other system elements. Making these dependencies explicit helps to manage risks by understanding the impact of changes. This is valuable for planning and conducting system modifications in a way that reduces the impact on system availability.

Experts mention the use of the Unified Modelling Language (UML) as a notation to describe the processes and resources of the system to be designed (see Table 4.5). However, UML does not support the modeling of lifecycles and has no built-in semantics for system elements. A recently proposed variant of the System Modelling Language (SysML) is the Lifecycle Modeling Language (LML) (LML Steering Committee, 2015). It aims to support the management of complex systems throughout their lifecycle by providing a simple graphical notation and semantics to the modeling elements, e.g., asset, action, requirement, cost, and decision (LML Steering Committee, 2015). LML allows expressing both structure and behavior of systems through dependencies and hierarchical refinements between the elements. Therefore, systems can be viewed from multiple perspectives at different levels of granularity.

The suitability of this language for the modeling of smart services was evaluated in a case study on the replenishment of consumables (filament) for 3D printers. The information demands of different stakeholders at the service provider have been identified (Table 4.7), and distinguished by the lifecycle phases beginning-of-life (BOL), middle-of-life (MOL), and end-of-life (EOL), as proposed by Kiritsis (2011).

Department	BOL needs	MOL needs	EOL needs
Marketing	customer needs, prices	customer satisfaction, customer number	next-generation products, recycling demands
Development	system requirements, solution approaches	identified problems and bugs	technical migration paths to the next version
Finance	planned revenues and development cost	operating cost and actual revenues	cost for warranties and recycling
Procurement	type of items for procurement, planned lead times, potential suppliers	quantities and times for the provision of intermediate consumption	*(no information needs identified)*
Logistics	required stock space, lead time, package sizes, quantities	Items to be delivered quantities and dates	removal of old equipment from customer sites and/or recycling
Customer Support	contact channels, availability, languages, response times	current incidents / tickets	*(no information needs identified)*

Table 4.7: Information needs of different stakeholders by life cycle phase

Using a CPS perspective of this smart service system helped to assign suitable LML modeling elements, e.g., activities, inputs/outputs, assets, and conduits. A high-level model of the smart service system and its lifecycle phases with data elements and infrastructure (Figure 4.9) was created using the Innoslate[8] tool. Activities with a "decomposed" label indicate that further refinements are available for these elements. Further refinement of elements in hierarchies led to up to five levels of abstraction in the resulting model. This facility is helpful to capture additional details during the development of the service concept. At the same time, a good overview was still provided at higher levels of aggregation.

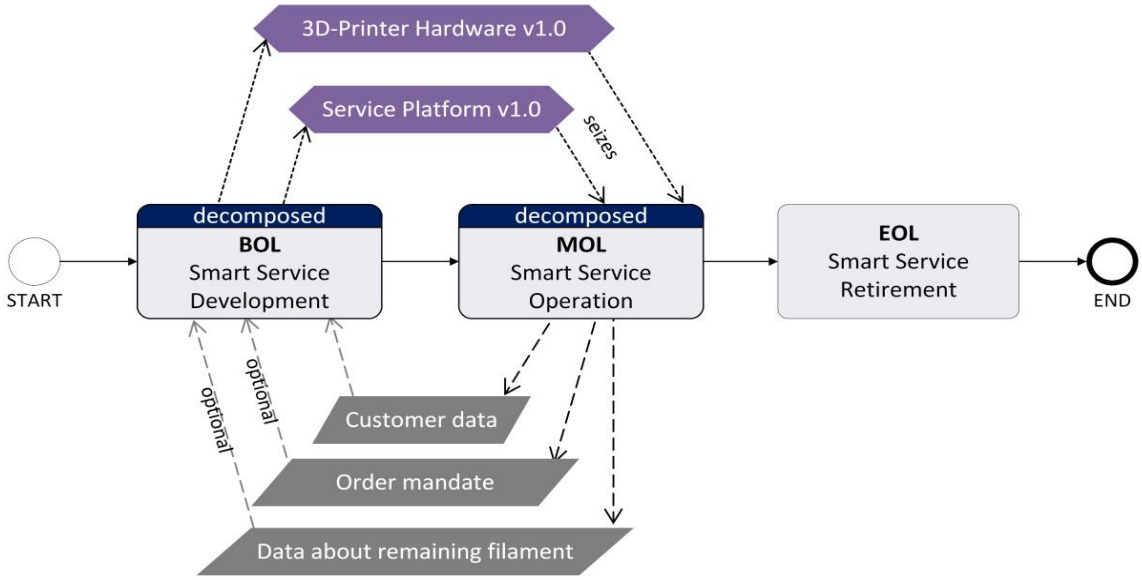

Figure 4.9: Top-level model view of smart service for consumables replenishment

Overall, the evaluation of the model found that LML is a powerful approach that allows capturing of the various elements and relationships of complex smart service systems. These dependencies are valuable for risk analysis as they help to understand the effects of changes. While it allows to model lifecycle aspects of the system, the strengths of the modeling approach lie in the collaborative design support at design time, i.e., the BOL phase. In contrast, the information needs at the MOL phase are not well addressed. This is mainly due to the lack of dynamic data that relates to individual instances of the system rather than the general system concept. Additional tools are required to create digital twins for operational systems from LML models and update relevant attributes with real-time values.

Citation	Title	Outlet	Addressed RQs
Anke, Ebel, et al. (2020)	How to tame the Tiger – Exploring the Means, Ends and Challenges in Smart Service System Engineering	ECIS	2.1 2.2
Richter and Anke (2021)	Combining Methods for the Design of Digital Services in Practice: Experiences from a Predictive Costing Service	Wirtschafts-informatik	2.3
Anke et al. (2018)	Modelling of a Smart Service for Consumables Replenishment: A Life Cycle Perspective	EMISA Journal	2.4

Table 4.8: Included publications of the findings summarized in section 4.3

[8] https://www.innoslate.com/systems-engineering/

4.4 Approaches for the Design-integrated Assessment of Smart Services

SSI aims to develop smart service systems that create value for the involved actors. Practitioners have reported various challenges when designing the value dimension in service systems, e.g., finding a promising target group and customer problem, distribution of financial benefits, finding a pricing model, and developing suitable business models in general (Table 4.6). While customer value is often part of service design, the provider value must be separately assessed. This is captured in the activity "**ensuring economic viability**", which consists of the sub-activities "Demonstrating customer value", "Establishing the business case", "Turning pilots into scalable offerings", and "Cross-subsidizing service offerings". These sub-activities require an understanding of the financial implications that concrete service might have, e.g., in terms of expected costs, savings, and revenue. To calculate these, various details like prices, usage intensity, and customer group size need to be defined. As not all assessment-related aspects are expressible in quantitative terms, also strategic criteria need to be considered. However, no specific means for development and documentation were identified to support activities for designing the value capture in the interview sample (see Table 4.5). This indicates a lack of methods and tools that support the assessment of smart services and service business models.

4.4.1 Meta-Modelling for Smart Service Assessment

A prerequisite for the assessment of service ideas and business models is a suitable model, which captures the relevant information. To support calculations and analyses on the models, they need a common basis. This can be provided by a meta-model that acts as an abstract syntax. Concrete models for services and their business models are instances of this meta-model. The challenge is to define meta-models in a way that balances expressiveness and simplicity. *Expressiveness* refers to the ability to capture the main elements of a service concept and its assessment-related information. *Simplicity* aims to keep the number of model elements low to make models easy to modify and comprehend. Furthermore, assessment results are sufficient to be rough estimates, as only basic aspects of the system are known in the early stages of development.

The service business model addresses the design dimension "Market" and contains the fundamental business logic of service. For the ***assessment of business models***, a cost-benefit analysis was used as the underlying approach. Based on empirically identified effects of data-driven business models, a meta-model was developed to qualify each factor (which are typically represented by "post-it" notes in physical settings) on an SMBC as revenue, cost, savings, or non-financial effect (Zolnowski et al., 2017). All effects are represented by a few attributes that capture the information required for calculations.

A different but complementary approach to the assessment puts the service architecture in the focus of a ***financial assessment of smart services***. For that, a meta-model for smart services was proposed to allow for early-stage financial assessment (Anke, 2019). The central element is the offer (the service), which can be consumed by multiple customer groups. To provide the service, functions are used to describe the most basic features. The invocation of these functions can trigger the execution of external services or the request for data from IoT devices. Data from connected devices can be described using data points. Based on their sizes for requests and responses, the overall data volume can be determined. As offers, functions, external services, and device data can be flexibly combined, the meta-model also utilizes the principle of recombinant service engineering (Beverungen et al., 2018). A financial case can be derived using the data provided by attributes in the model. The integrated meta-model for both aspects is shown in Figure 4.10 as a UML class diagram.

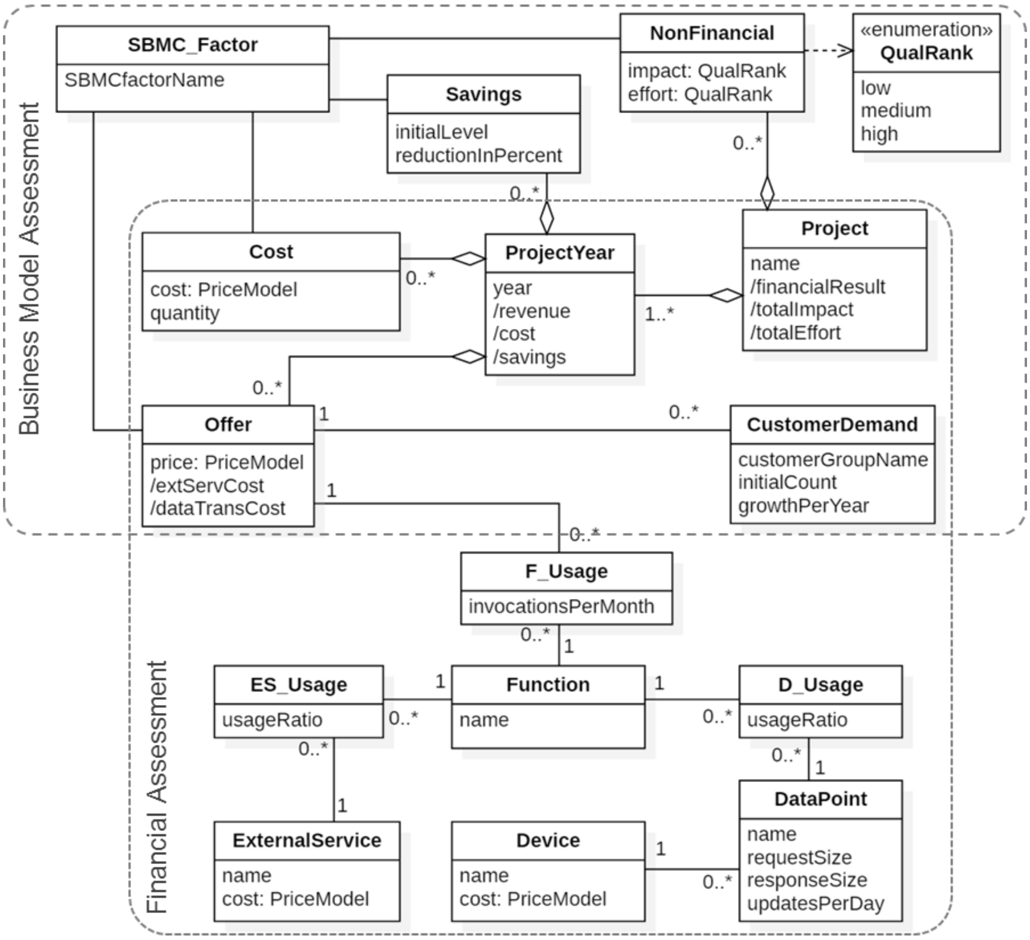

Figure 4.10: Integrated meta-model for the assessment of smart services and their business models

4.4.2 Methods and Tool Prototypes for Design-integrated Assessment

Based on the meta-models, two tool prototypes were developed to show the applicability of the meta-model and provide a basis for demonstration and evaluation. They allow users to create and modify models that capture the current decisions on the service concept. Specifically, these tools were designed to fulfill the following requirements:

- assessments must be possible in the early stages of the design with incomplete information,
- the addition and modification of elements, properties, relationships, quantities, prices, and costs must be possible in any order,
- the representation of models and assessment results must be comprehensible for users from different disciplines.

The ***"Service Business Model Canvas Editor" prototype*** supports the assessment of service business models. As business models are typically developed on a canvas-style board, the SBMC (see Figure 2.6 in section 2.4.1) was chosen as the core metaphor for the editor. The key challenge for this task is to connect the qualitative perspective of canvas-based business models like the SBMC with quantitative assessment. Therefore, an interaction method called ***factor refinement*** was developed for this purpose. The user can add factors ("post-its") to the different areas of the canvas to develop the business model qualitatively. Clicking on a factor opens a dialog box where its impact can be categorized as cost, revenue, savings, or non-financial. Depending on the choice, assessment-related information can be entered according to the attributes of the underlying meta-model (Figure 4.11). A quick preview of the impacts of the individual factor is already given based on the provided data.

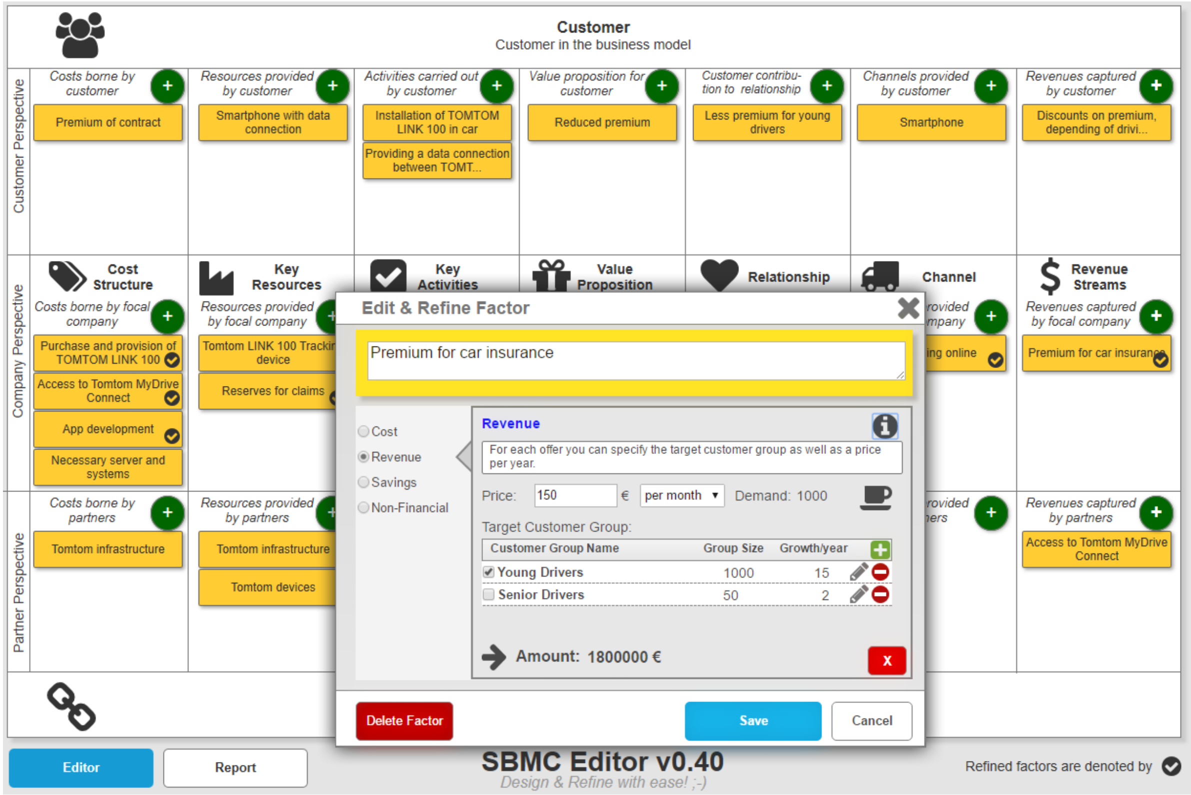

Figure 4.11: Service Business Model Canvas editor

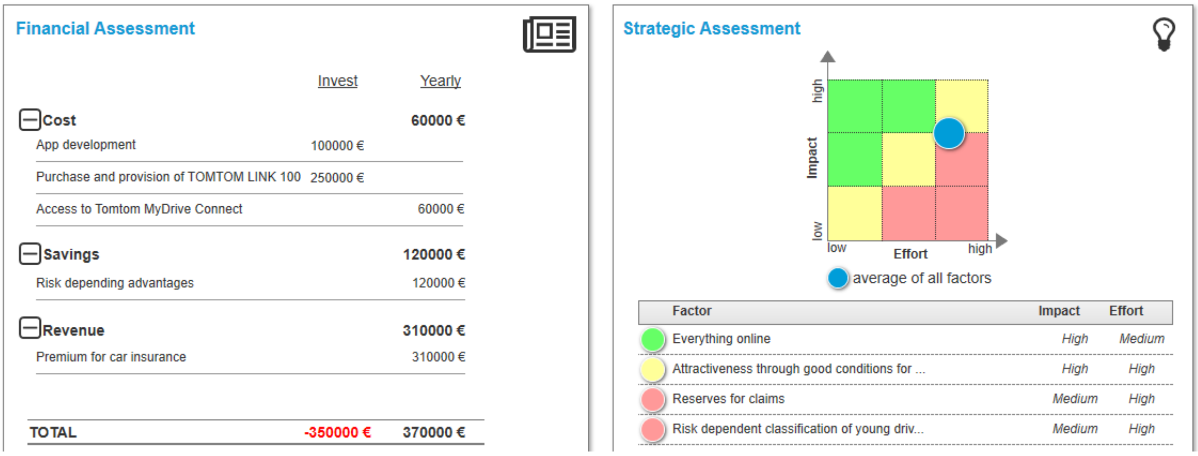

Figure 4.12: Report view of the SBMC editor

A detailed presentation of the assessment results is available in the report view, which is organized into financial assessment and strategic assessment (Figure 4.12). It contains always the most up-to-date aggregation of all refinements made to the factors in the business model. The financial assessment consolidates data from factor refinements of the types of cost, savings, and revenue. All categories are collapsible to show or hide the individual items. The strategic assessment uses a simple impact-effort matrix, in which a blue circle indicates the average position of all factor refinements that have been classified as "non-financial". Users can switch back and forth between the editor view and the report view to get a better understanding of the business model they are developing for their service idea.

The ***"Smart Service Assessment Tool" prototype*** aims at the early-stage financial assessment of smart service ideas, which helps decide on the services to pursue further. It also relies on an editor to create and manipulate the business model, and the aggregation of assessment-related information.

Providing a rough financial case for a service idea can also help to justify the funding for the efforts required for the further development of the service system. The tool shows how the instantiated meta-model can describe the basic elements of a service architecture (devices, data, external services, functions, offers, and customer groups). These elements and their links are enhanced by quantitative data on prices, cost, frequencies, data volumes, growth rates, etc. (Figure 4.13).

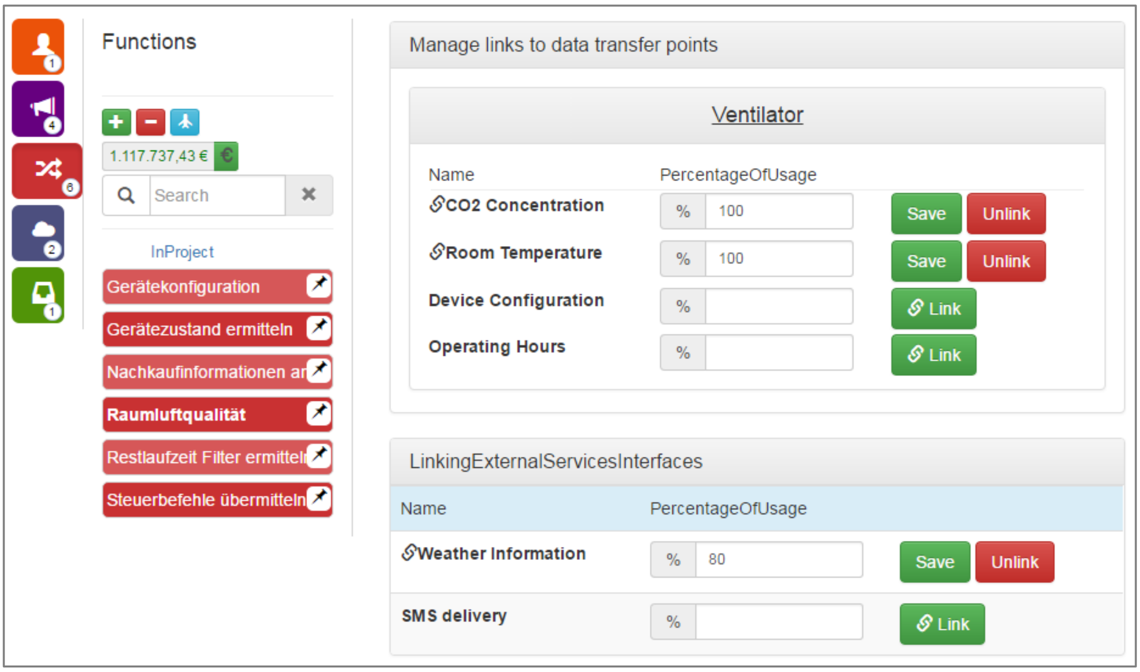

Figure 4.13: User interface of the Smart Service Assessment Tool

The built-in ***financial case calculation method*** transfers the data from these model elements and creates a payment series for the desired number of planning years. Whenever the service model is changed, the financial model is automatically updated to show the impact of the changes made. For example, the tool allows defining functions that can be part of different service offers. These functions in turn might require data from smart products or the invocation of external services. As both the transmission of data and the use of external services may incur costs, these are factored in the financial case that is calculated in the background. The detailed results can be viewed as a report that shows the revenue and cost items per year. The overall financial result is displayed in the editor view to provide instant feedback on changes in the service model.

4.4.3 Integration of Tools in the Development Process

As outlined in section 2.4.4, assessments should ideally be conducted as part of the development process as assessment results may guide decision decisions towards better value creation. The presented tool prototypes support agile process models with short feedback cycles by facilitating the change and adaptation of models whenever new design decisions are made. The tools are intended to be used in collaborative settings, e.g., workshops, so multiple actors to include their inputs and insights (Figure 4.14). This enables the fast and iterative modeling of service architecture and business models including their attributes, e.g., quantities, prices, and usage behavior. Models can be iteratively modified as often as required. Each change leads to a recalculation of the assessments, which can be incorporated into the design process. At the same time, it serves as documentation of the development status over various workshop sessions and thus avoids the loss of contributions. The iterative development is continued until the team decides on the continuation or rejection of the service idea or business model.

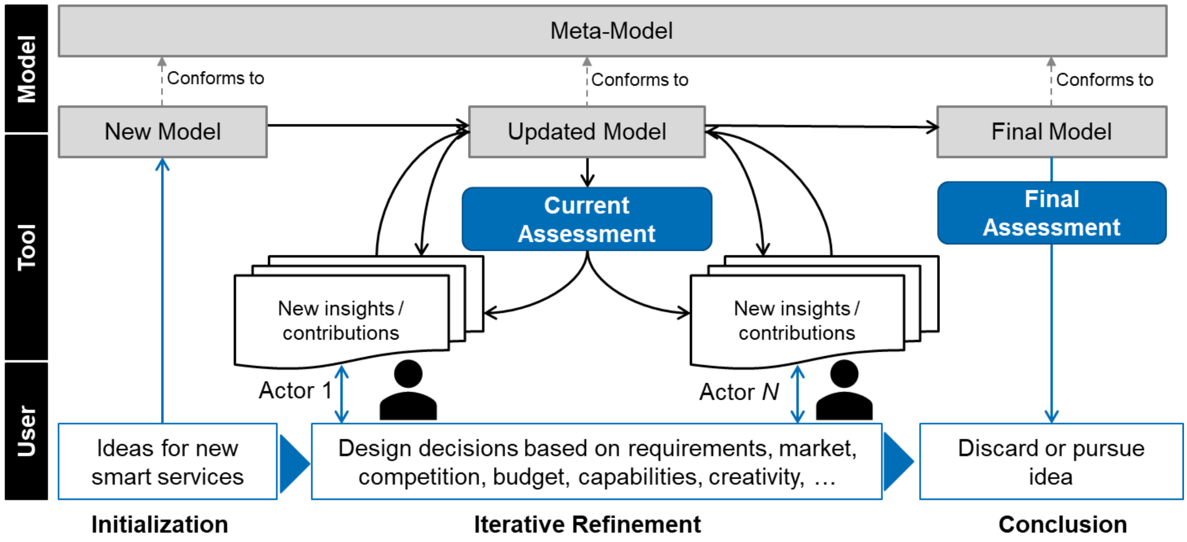

Figure 4.14: Tool-based approach for design-integrated assessment

The utility of these tools as an approach for design-integrated assessment was evaluated using a combination of an experiment, the talk aloud method, and two surveys. The results for the "Service Business Model Canvas Editor" tool showed a strong indication that the tool was not only helpful, but participants also prefer it over Excel, which is typically used for such tasks. Furthermore, participants indicated almost unanimously that assessment of business models should be tool supported. Therefore, it can be concluded that the efficacy and utility of the tool are considered positive within this sample of users. This is supported by a statement, in which respondents expressed that they understood the concept of refinement. Regarding the "Smart Service Assessment Tool", it was found that using the tool prototype is not obstructive, i.e., the tool was not hindering the design process within the experiment. Instead, the responses of participants indicated that tool support is perceived as helpful, i.e., they saw not only a benefit of having a tool in general but perceived this particular tool as helpful for the task at hand. This indicates that the general approach of the tool-based design was accepted and appreciated by the group of participants. More specifically, the structuring of smart service systems based on the underlying meta-model was considered a major benefit.

The evaluation of tools indirectly provided an evaluation of the meta-model as a central artifact. The results indicate that the refinement options are not considered too complex. However, the results also show that at least for some participants important input possibilities for the assessment were missing. Further research is required on whether this is due to a deficit in the model or usability deficits in the tool prototype. The presentation of reporting results is generally understood, however, there is considerable variance in the replies, which also requires further analysis.

Citation	Title	Outlet	Addressed RQs
Anke (2019)	Design-integrated Financial Assessment of Smart Services	Electronic Markets	3.1
Zolnowski et al. (2017)	Towards a Cost-Benefit-Analysis of Data-Driven Business Models	Wirtschafts-informatik	3.2
Anke (2020)	Enabling Design-integrated Assessment of Service Business Models Through Factor Refinement	DESRIST	3.2

Table 4.9: Included publications of the findings summarized in section 4.4

5 Discussion

5.1 Contributions

In this section, key findings are derived from research results and put in the context of related research. Each key finding is assigned to a research question, as indicated by its ID.

Key Finding 1.1: SSI ecosystems can be structured by a set of roles and actors that assume them by providing the resources that are defined by the respective role.

The proposed set of *ecosystem roles* (RQ1.1) describes typical resources that actors provide in SSI. It extends the knowledge of how technology-driven value co-creation in ecosystems is organized, as an ecosystem role expresses a set of resources that is relevant for SSI. Existing ecosystem models on this topic consider cloud computing (Floerecke et al., 2020), retail (Böttcher et al., 2021), automotive (Kaiser et al., 2021), and IoT in supply-chain management (Papert & Pflaum, 2017). As these ecosystem models overlap with SSI, future research may aim to consolidate the individual models. This will lead to a better understanding of core roles that are relevant for digital services across different industries, as put forward by Riasanow et al. (2020). These ecosystem models take a broader view and cover all the roles that generally exist in a specific industry or technology-centered ecosystem.

Key Finding 1.2: Innovation patterns represent typical assignments of roles to actors and can be used for the analysis and design of SSI ecosystems.

Typical constellations of roles (RQ1.2) that actors assume in the realizing state of the ecosystem have been conceptualized as four *innovation patterns*. This goes beyond existing research that identifies innovation patterns based on actors, rather than roles (den Hertog, 2000). As patterns represent a set of roles that actors assume, they indicate the combination of provided resources. These contribute to the understanding and implications of multi-actor value constellations. For example, it enables the analysis and evaluation of the following three aspects: (1) the identification of emerging business models in SSI, e.g., white-label solution provider; (2) the strategic analysis of external dependencies of organizations on external partners versus the development of internal capabilities to assume certain roles, and (3) the impact of applying these patterns for the establishment of SSI ecosystems.

Key Finding 1.3: The evolution of a service ecosystem is driven by the changing needs for resources along the innovation process, which causes actors to assume, change or leave roles.

The *dynamics of role assignments* (RQ1.3) based on ecosystem states provide a framework to align major phases of reference models with ecosystem configuration, e.g., which resources (described as roles) are required at which point in time and which activities are to be performed. This is in line with recent research, that identifies the *distance to knowledge* as a driver for the involvement of external actors in ecosystems (Lingens et al., 2021). As dynamics of role assignments also influences the emergence and adaption of the ecosystem structure, another perspective of roles has been established to describe the activities and influences that actors have on the adaption of the ecosystem. The actor with the largest influence on ecosystem structure can be assigned the role of "initiator" (Ekman et al., 2016) or "orchestrator" (Lingens et al., 2021). It is also shown that ecosystems are partly emergent and partly the result of explicit design decisions (Lingens et al., 2021). Similarly, Dedehayir et al. (2018) propose a set of roles in innovation ecosystems based on the type of value contribution. The key role is the "ecosystem leader" that attracts, links, and coordinates the other actors in the ecosystem.

Key Finding 1.4: Activities performed by individual actors collectively reduce uncertainty at the project level.

The theoretical model of *iterative uncertainty reduction* (RQ1.4) identifies the main activities that actors perform in SSI projects. The model explains the interdependency between actor engagement at the micro-level and the design of the SSI project. The performed activities of actors do not only affect the emerging smart service system and its properties but also the SSI project itself, e.g., by changing the involvement of actors or adopting new methods for service design. While the four main activities *managing organizational complexity*, *crafting a smart service offering*, *developing a technical solution,* and *ensuring economic viability* have been identified regarding their effect on uncertainty management, they are not limited to that purpose. They may serve as a foundation of a methodological framework as they also have sub-activities and relations to roles that reflect empirically grounded specifics of SSI.

Key Finding 2.1: Methods from other existing disciplines are generally applicable for SSI.

Conducting SSI projects requires the coordination of multiple actors. The result of their work must be integrated and contributes to the emergence of the new smart service system. To manage these collaborative efforts, a great variety of *methods from different disciplines are applied* (RQ2.1). The variety of identified methods illustrates the interdisciplinarity and complexity of SSI. However, it also shows that at least some of the existing methods are indeed suitable for such contexts, which allows reusing existing knowledge in future methodologies for SSI.

Key Finding 2.2: Existing methods do not address the specifics of SSI sufficiently, which impedes development effectiveness.

Practitioners reported on several *challenges* (RQ2.2) in SSI projects. Most challenges are related to the complexity of multi-actor project management, the development of sustainable business models, and specific technological problems. Notably, in the investigated sample of projects, no methods were applied to support the design objective “value capture”. It can be concluded that existing methods work well with aspects that are not specific to smart service systems and their innovation process.

Key Finding 2.3: Combining methods from existing disciplines with methods that were specifically designed for smart services is both feasible and beneficial for SSI.

The emergence of smart service systems has led to the design of new methods and the enhancement of existing methods that consider the specifics of such systems (Marx et al., 2020). Introducing specific methods in practice is easier if new and existing *methods can be combined* (RQ2.3) in a suitable way. A working combination of methods was determined, which uses the Smart Service Canvas (Pöppelbuß & Durst, 2019) as the central element. This combination of methods builds on the ideas put forward in Situational Method Engineering (Henderson-Sellers & Ralyté, 2010) and the empirical findings on hybrid methods that combine agile and traditional practices (Kuhrmann et al., 2021).

Key Finding 2.4: LML is well suited to express the specifics of smart service systems, particularly in cases where complex smart products are designed as part of SSI.

The application of methods from different disciplines creates a variety of work results. The *evaluation of LML* (RQ2.4) indicates that it is suitable to capture the specifics of smart service systems in an integrated model, which can serve the information needs of most stakeholders along the lifecycle. This finding is supported by other research, that applies LML to the design and management of PSS and IoT-based smart services (Hefnawy et al., 2016). LML is useful when new smart products are designed together with their services but might be too complex if existing smart products are mainly considered as a data source. Finding suitable notations for smart service system models is an ongoing effort. For example, a domain-specific modeling language proposed by Huber et al. (2019) captures the specifics of smart service systems even better but does not explicitly support lifecycles.

Key Finding 3.1: The designed meta-model is suitable to link service architectures and business models with assessment-related information.

Activities to ensure economic viability are considered to be highly relevant to SSI. To reduce uncertainty and drive the development of service concepts they should be assessed regularly. As the result of RQ2.2 shows, there is a lack of methods to guide such activities in practice. The results of this research extend the set of methods for SSI through an approach for design-integrated assessment of smart services (RQ3.1) and service business models (RQ3.2). The main artifact is a meta-model that captures the specifics of smart service architectures, business models, and assessment-related information. As these meta-models explicate a generalized structure of smart service systems, they can facilitate discussions on their nature and may be used as abstract syntax for domain-specific languages (Huber et al., 2019; Lüttenberg, 2020).

Key Finding 3.2: Tools for the assessment of smart services and their business models enable design-integrated assessment with incomplete information.

Prototypical *tool implementations* allow the instantiation and manipulation of models for concrete cases. As these model instances comply with the underlying meta-model, financial and strategic assessments can be continuously updated on every model change. This instant feedback is provided to the users, which may use the tools in collaborative settings, such as workshops. Implementing these tools required the development of two additional artifacts: (1) a *calculation method*, which derives financial results (RQ3.1) from the current model instance, and (2) and the *factor refinement interaction method*, which enables supplementing qualitative business model items with qualitative details for assessment (RQ3.2). The evaluation of these tools demonstrated their benefit. They address the identified gap in providing assessment-related information in the design process (Turetken et al., 2019) and can improve the assessment functionality of BMDT software, which is still underdeveloped (Szopinski et al., 2019).

5.2 Limitations

All presented individual research results are subject to their limitations, which are described in the respective paper. However, some general limitations are inherent to the qualitative research approach and the exploratory nature of this study.

- ***Generalizability:*** As it is difficult to get access to experts with real-world experience in SSI, the interviewees for the study were recruited from personal networks. While the number of experts was relatively high and covered a broad range of cases, these can neither be considered comprehensive nor representative of SSI in general. Furthermore, there was mostly only one interviewee per case or organization, which does not allow for an in-depth analysis of complex ecosystems. As the topic is broad and emerging, it is difficult to detect limits of applicability, e.g., regarding types of systems, levels of human integration, and industry specifics. For example, a different set of cases will likely lead to a modification to the set of roles and activities.
- ***Data Interpretation:*** Conceptualizing and theorizing from qualitative data requires the interpretation of data by researchers, which is inherently subjective. While this was mitigated through the involvement of multiple researchers in the analysis and interpretation of data, researchers with other backgrounds may have come to different interpretations.

- ***Artifact evaluation:*** A large share of test persons that participated in the evaluation of proposed artifacts for design-integrated assessment were students. While they do represent potential users, professionals with more experience might have given different responses. Additionally, the tool implementations were only prototypes and thus not optimized for usability. An optimized experience might have helped some of the users complete their tasks.
- ***Non-normativity:*** The influence of certain innovation patterns, management approaches, or employed methods on the overall project success has not been investigated. Most SSI projects in our sample were in the late stages of development or the early stages of market tests. This implies that the presented results should not be conceived as normative in the sense of common, good, or best practices.

Overall, the results are explorative and provide initial empirical insights into real-world SSI projects. Future research may use larger sample sizes, quantitative approaches, and/or a more specific selection of smart services cases based on taxonomies (Brogt & Strobel, 2020) to yield more robust results. Investigating further examples of smart service innovation processes and going beyond the realizing state of such processes might lead to the identification of additional roles. In particular, the outcoming state of service innovation was not in scope. The analysis of cases that are in the operational state will likely provide insights into the success of the respective SSI projects including the suitability of chosen methods and practices.

5.3 Managerial Implications

Practitioners should be aware that SSI 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 tools used in projects should promote a corresponding mindset and build up suitable capabilities. The presented results are therefore relevant regarding (1) innovation management, (2) agile methods for service innovation, and (3) economically viable service offerings.

First, the presented roles and activities describe how actors engage in SSI and thus provide a basic idea about the necessary resources, skills, and processes for the ***management of smart service innovation***. This does not only guide the setup and conduct of such initiatives but also highlights potential dependencies on other actors. As SSI takes place in multi-actor settings, it is key to identify and maintain relationships with relevant partners that complement the resources of one's organization. From a strategic perspective, the different actors need to decide which of the required resources they want to build up internally and which ones are to be sourced externally. The identified assignments of roles to activities and innovation patterns can help to analyze ecosystems and may guide sourcing decisions.

Second, the conceptualized mechanism of iterative uncertainty reduction emphasizes the importance of an iterative process for SSI. While uncertainty is an inherent part of any innovation, the awareness of the various sources of uncertainty as well as possible approaches to handling them may improve the innovation process (Jalonen, 2012). The experts consistently recommend the use of ***agile methodologies*** to gradually reduce uncertainty. They also expect that following agile methodologies increases the likelihood that new smart service offerings are designed in a way that they meet actual customer demands. However, such methodologies might be unfamiliar to traditional product-centric businesses, and employees need to be trained accordingly. The presented design dimensions and design objectives can serve as a preliminary checklist for the areas that need to be addressed in SSI projects. The identified means suggest potential methods that can be employed in the development process to guide the performance of activities. Practitioners should use these lists as inspiration to broaden their repertoire of methods and tools and serve as a multiplicator of suitable methods and tools through their collaborative project work. The identified challenges illustrate what can go wrong in SSI projects, and thereby provide hints for preventive action, e.g., dealing with legal issues.

Third, it cannot be overstated that smart service offerings need to solve a relevant problem of a customer, which is also ***economically viable*** for the service provider. Practice-oriented literature on business model innovation describes a continuous testing and experimentation process that distinguishes between desirability, feasibility, and viability in the progress of scaling business ideas (Bland et al., 2019; Osterwalder et al., 2020). As progress is made, the focus shifts more towards assessing and ensuring viability. Hence, it is important to keep a balance of customer needs, technical feasibility, and provider value when crafting a service offering as reflected by our set of aggregate dimensions. That is, looking at *crafting a smart service offering* in isolation only addresses the issue of "desirability". This needs to be combined with assessing feasibility, to avoid putting a lot of effort into service ideas that cannot be realized. If services are built from a technical perspective (*developing a technical solution*) without involving the customer, the Project Sponsor risks creating a service offering that fails to address customer needs. Finally, *ensuring economic viability* is needed to ensure that costs for building and operating the smart service systems are exceeded by benefits at the provider, which can take the form of revenue, savings, or strategic benefit (Zolnowski et al., 2017). The proposed approaches for design-integrated assessment can provide practical support for considering these aspects, especially when they are integrated into BMDT software.

5.4 Directions for Future Research

Research on SSI is hampered by multiple theoretical and conceptual weaknesses that future research should address. These consist of (1) conceptual and terminological inconsistencies in smart service systems and their characteristics, (2) lack of systematics in the methods for SSI and their combination, i.e., an SSI methodology, and (3) a theoretical grounding that explains the embedding of methods and processes of SSE into the organizational arrangement multi-actor SSI. In this section, these are elaborated in more detail, which includes research directions that result from the findings of this study.

5.4.1 Consolidate the Conceptual Foundations of Smart Service Systems

What are smart service systems after all? While the variety of partly overlapping conceptions of the term can be explained by advances in different scientific communities, the often overlooked inconsistencies limit the effective transfer of knowledge between different disciplines.

The conceptualization of the term "service system" itself has changed over time. A recent literature review by Brozović and Tregua (2022) has traced the conceptual evolution of service (eco)systems as follows: Initially, service systems were considered in *service management* with customers, employees, resources, and technology as constituents and service quality as target outcome. Later, the focus shifted to service systems as *value constellations* of people, processes, technologies, and knowledge that interacted to create value. In the third phase of the evolution, the *service ecosystem* notion was adopted to highlight the resource integration between actors that are constrained and facilitated by institutions and institutional arrangements (Brozović & Tregua, 2022). It can be seen that the second interpretation originates in service science and is used in current definitions of smart service systems, e.g., by Beverungen, Müller, et al. (2019). The third interpretation is rooted in S-D logic and provides a more generic perspective of value creation in dynamic multi-actor environments (Vargo & Lusch, 2016).

Various streams of research have adopted the term service system and extended it to highlight the special type of digitally enabled services that are based on smart products, e.g., (smart) service systems, (smart) PSS, and CPS (Martin et al., 2020). The diversity of terms and their meanings may lead to conceptual mismatch as the underlying definitions are not always clearly stated. Sometimes they are even used interchangeably, particularly when researchers contribute to neighboring disciplines without being aware of ostensibly subtle differences. Although each term highlights different aspects, they all share a common conceptual core which is yet to be made explicit in literature (Martin et al., 2020).

Achieving a consolidated conceptual understanding does not imply that all smart service systems should be considered the same. Instead, their characteristics should be further investigated and systematized. The current understanding of smart service systems appears to be appropriate for networked value co-creation. It has little focus on the engineering of the smart product, which is mainly considered as a data source, customer touchpoint, or "boundary object" (Beverungen, Müller, et al., 2019). Examples include carsharing, smart home solutions, diabetes prevention, etc. The common characteristic is the utilization (rather than the engineering) of existing, standardized hardware components and products, a focus on customer experience, scalable business models, and a focus on business-to-consumer (B2C) relations. In industrial domains with complex technical equipment and machinery, CPS and PSS are more often applied as a conceptual foundation. This is emphasized by the transformation of product-centric business models to service-centric business models through "digital servitization" (Gebauer et al., 2021). The engineering and manufacturing of the smart product is often an integral part of the core business in these cases. Therefore, product engineering aspects, lifecycle considerations, and even formal certifications are highly relevant in the innovation process. Examples include pay-per-use for air compressors, predictive maintenance for elevators, and fleet management for trucks.

To capture the variety of (smart) service systems they should be classified based on their characteristics, e.g., through taxonomies (Azkan, Iggena, et al., 2020; Brogt & Strobel, 2020) or archetypes (Rapaccini & Adrodegari, 2022). The classification of service systems is also helpful to identify "situational factors" (Clarke & O'Connor, 2012) that guide the selection of methods based on the characteristics of the envisioned system. Understanding and structuring the varieties of smart service systems is the basis for designing suitable development methods, that are "smart-enabled" (Pirola et al., 2020). These issues can be addressed by the following research objectives:

- determine the common constituents of currently overlapping but distinct concepts, e.g., of (smart) service systems, service ecosystems, CPS, and (smart) PSS,
- systematize the different variants of smart service systems, e.g., using taxonomies, to provide a common language and reference framework for situational factors in SSI.

5.4.2 Develop a Methodology for Smart Service Innovation

As the presented results show, there is a large set of processes, methods, practices, and notations that are used or suitable for the systematic development of smart service systems and related systems. Still, there is no common methodology for smart service innovation, which unifies the existing approaches.

Broadly speaking, SSI combines digital service engineering from a marketing perspective with technical system engineering to create the underlying smart service system that enables the desired value proposition (Pakkala & Spohrer, 2019). To guide this development, practitioners use many methods from different disciplines. This variety results from the different design objectives in smart service systems but also due to the variety of competence levels and professional backgrounds of the involved actors.

As developing smart service systems is a rather novel task for most practitioners, it is not surprising that they try to capitalize on the methods they already know. While certain methods and practices are suitable for SSI, barely any of the identified means were specifically designed for SSI, which confirms findings by Wolf et al. (2020). Academia on the other hand provides a variety of engineering methods for software, services, PSS, and CPS, which are partly updated for smart service systems (Hagen, Kammler, & Thomas, 2018; Marx et al., 2020).

The design of development processes is a field of tension between flexibility and control (Harmsen et al., 1994). *Flexibility* describes the degree of freedom in a method that allows for adaptation to specific situations during the application of the method. *Control* refers to the level of guidance in the application of the method. These lead to a spectrum of controlled flexibility as depicted in Figure 5.1.

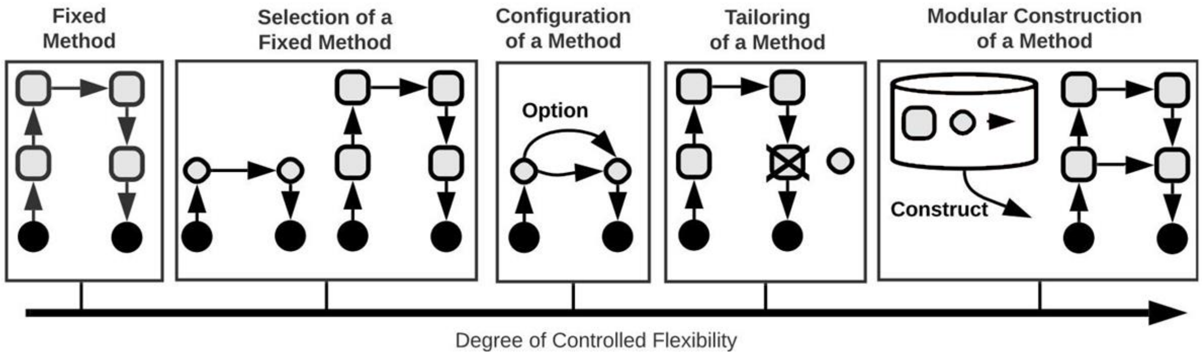

Figure 5.1: Degree of controlled flexibility in methods (Gottschalk et al., 2021, p. 263)

Against this background, the following insights should guide the development of an SSI methodology:

1. there is a variety of smart service systems, whose characteristics determine the suitability of individual development methods in a project context,
2. the different design objectives in smart services systems require an interdisciplinary approach to the development and integration of methods from these disciplines,
3. the work towards different design objectives is performed by multiple actors that need to collaborate and effectively develop the new service system.

Based on these characteristics, SSI requires a high degree of flexibility, which could be provided by two basic approaches for methodologies: (1) reference processes, and (2) loosely coupled practices.

Reference processes are a source of information that can serve as a starting point for concrete processes. They cover a wide range of potential uses in the target domain and aim for completeness. This is achieved by a well-defined structure of work products, modeling techniques, and activities with defined relation to work products as inputs and outputs, roles, etc. To be adaptable for concrete situations, they need to offer configuration options.

Besides the DIN SPEC 33454, which has been covered earlier, another reference process model for smart services has been proposed by Frank et al. (2020). It covers the main processes of planning, developing, performing, and billing. Each process is further detailed into sub-processes, process steps, and sub-process steps. Each of the 126 sub-steps is further described through inputs, outputs, suitable methods, and responsibilities. Depending on the level of adaptability, reference processes take the "method with options" or "tailoring a method" degree of controlled flexibility. Thus, reference process models are suitable for projects with strict compliance requirements (e.g. medical systems, safety critical applications) and/or mechatronics systems, where it is difficult to rapidly modify physical components, e.g. for industrial PSS (Müller, 2013). The benefit of reference processes is the complete coverage of the problem and the very good guidance of users. Drawbacks include the high complexity and the high effort to implement them in an organization, as all participants are required to learn them.

The approach of ***loosely coupled practices*** complies with agile principles, which recommend project teams adapt their way of working whenever they consider this as necessary. It represents the "modular construction of a method" degree of flexibility. This approach requires mechanisms for the description and combination of practices. For example, SME allows reusing existing practices (or "method fragments") from different disciplines that are collected in a method base. Concrete methods are then constructed by selecting and combining these practices (Jacobson et al., 2007). A large-scale survey of software engineering in practice shows that organizations use customized methods that combine traditional and agile practices, which result in so-called "hybrid methods" (Tell et al., 2019).

In the area of smart services, Giray and Tekinerdogan (2018) build an SME-driven approach for constructing a method based on the ISO/IEC 24744 standard as a meta-model for method fragments. They show how the constructed method changes depending on the defined situation factors, e.g., team size, experience, the existence of backend services, and IoT devices. Similarly, Gottschalk et al. (2021) propose an approach for constructing a business model development method based on SME, which contains methods building blocks for the discovery, development, and validation of business models. Creating an inventory of suitable method fragments or practices can be achieved by collecting them in real-world projects, as proposed by Holler et al. (2018) for the development of digitized products, or by breaking up existing integrated methods and reference models to separate the included practices, as proposed by Jacobson et al. (2017) for IoT-based solutions.

While various suitable methods and practices exist, there is a lack of guidance for their selection and combination for SSI, i.e., an SSI methodology. This should ideally link the activities to be conducted for a certain design objective with suitable methods and the roles of actors that are responsible for their performance. To achieve that, three main research objectives should be addressed in the future:

- identify the main design objectives of smart service systems, e.g., business model, service architecture, data analysis procedures, and customer interfaces,
- determine a set of suitable methods and practices to guide the development activities that address these design objectives,
- develop mechanisms that allow the selection and combination of suitable methods and practices for a specific situation.

The collaborative development of complex systems requires a consistent understanding of the current system concept, which is facilitated by suitable models. Some of the existing methods and practices include notations, e.g., service blueprint or business model canvas. While they individually contribute to the respective design objective, they lead to a fragmented model of the overall service system concept. Additionally, the relevance of managing the lifecycles of individual components in smart service systems is often overlooked, especially in the IS field. Recent contributions from industrial engineering on lifecycle management for PSS could add this important perspective (Wellsandt et al., 2018). Modeling of lifecycles needs to be extended to also support dynamic data from individual smart product instances that cater to the needs of stakeholders for the management of the smart service system, i.e., the MOL and EOL lifecycle phases.

Future notations and modeling languages are needed to serve the demands of diverse stakeholders along the lifecycle of such systems by providing different views on an integrated model. Additionally, they should be lightweight and open to rapid changes in the beginning but sufficiently precise for interpretation by machines, e.g., for assessments. The following research objectives address these issues:

- develop a concept to integrate the different views on the emerging service system concept,
- evaluate mechanisms that enable the consideration of lifecycles, including dynamic data,
- extend modeling languages to serve as a basis for design-integrated assessment,
- develop prescriptive knowledge that links situational factors to the applicability of certain methods and practices.

5.4.3 Establish a Theory of Smart Service Innovation grounded in S-D Logic

One of the challenges in the investigation of SSI is the lack of a conceptual link that embeds SSE into an organizational context, in which multiple actors collaboratively apply SSE methods and processes. This research indicates that S-D logic is a suitable lens to explain both the mechanisms of value co-creation in smart service systems and the collaborative process that leads to its emergence (Ehrenthal et al., 2021). The missing link could be SDL-grounded conceptualization of SSI projects as institutional arrangements, in which actors provide resources to collaboratively design smart services using suitable methods and practices provided by SSE. For that, the constituents of SSI and their relationships need to be expressed in S-D logic constructs (Ehrenthal et al., 2021), thus allowing for embedding conceptual and empirical inquiries more holistically into this framework (Brust et al., 2017).

Various SSI-related concepts have been devised recently based on S-D logic, e.g. Service Dominant Architecture (Weiß et al., 2018), Data Ecosystems (Azkan, Möller, et al., 2020), Service-oriented business models (Pfeiffer et al., 2017), and Open Innovation (Windasari & Lin, 2021). Additionally, service design as an SSI-related discipline has been extended toward service ecosystem design, which aligns better with SDL (Vink et al., 2021). These extensions are described by the conceptual building blocks Actor Involvement, Processes, Design Material, and Purpose (Figure 5.2). The proposed levels of alignment with SDL relate to the evolution phases of the term "service system" (see section 5.4.1).

In this research, S-D logic has been used as a lens to study the phenomena related to SSI. It was shown that SSI projects are higher-order service systems, which consist of individual actors that represent service systems themselves. Projects can be understood as institutional arrangements, as they facilitate and constrain service exchange among the participating actors. The applied SSE methods and processes can be viewed from two perspectives. First, they are part of institutional arrangements by establishing concrete rules for distributing work and the integration of work results. Second, they represent operant resources of actors as the mastery of methods requires skills and knowledge that actors contribute to the SSI project by assuming roles that represent a set of typical resources required for SSI. In fact, the possession of these skills is the reason they engage in such projects in the first place.

The dynamics in SSI, where actors dynamically assume, leave, or change roles, can be explained using the S-D logic concept of service ecosystems with the project as an engagement platform (Lusch & Nambisan, 2015). The configurations of involved actors and their activities for recombining and creating resources change over time. This leads to an emerging smart service system concept, which in turn is a blueprint for a future configuration of actors and resources. Hence, the desired smart service system emerges from a service ecosystem that is evolved through the engagement of the involved actors. The concept of ecosystem states is used to distinguish the realizing state, which roughly relates to the "development" from the outcoming state, which can be understood as "operations". However, the transition between these states is fluid and may not be directly related to traditional milestones such as "project start" and "service launch". From a macro-level perspective, SSI represents a state in the evolution of a service ecosystem.

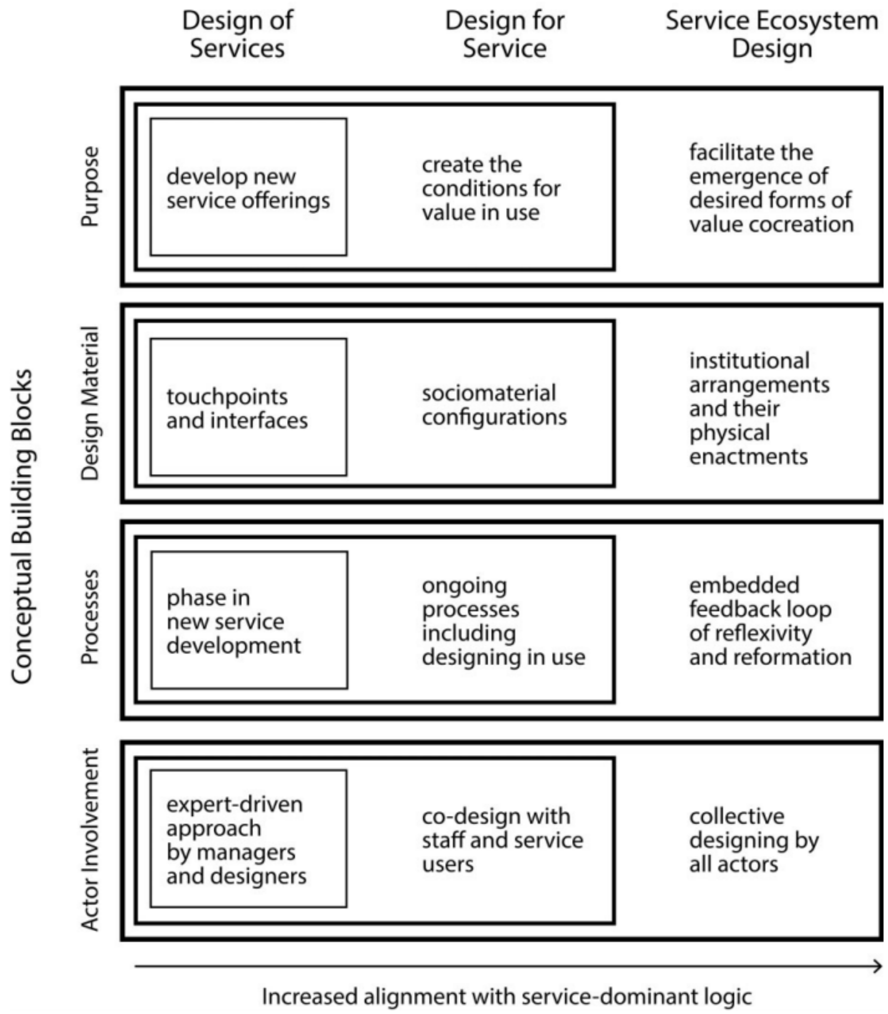

Figure 5.2: Conceptualizations of service design (Vink et al., 2021, 173)

An SDL-grounded theory of SSI can answer the call for midrange theories that link the meta-theoretical character of SDL with empirically accessible phenomena (Vargo & Lusch, 2017). It could establish a common ground to analyze and design the institutional arrangements that serve as an engagement platform for actors in different states of the service ecosystem. These institutional arrangements may also be used to conceptualize the embedding of SSE in projects and their development processes. Therefore, research objectives for establishing an SDL-grounded midrange theory of SSI may include:

- identify and classify operant and operand resources in SSI, e.g. based on ecosystem roles,
- identify the institutions that make up the institutional arrangement at the realizing state, e.g., projects, and at the outcoming state, e.g., service platforms,
- identify actor engagement that can be classified as institutional work, e.g., agreement on jointly used methods, practices, and modeling notations to advance the project organization,
- develop prescriptive knowledge, e.g., design principles, that guide the establishment of service ecosystems and their institutional arrangements for value co-creation.

6 Conclusion

Smart service innovation is a topic of high relevance in both practice and academia. While practitioners are keen to seize the potential of digital technologies for service innovation, they often struggle to successfully design viable smart service systems. Research in disciplines like information systems, marketing, industrial engineering, and innovation management has developed various principles, models, methods, languages, and tools that are (potentially) applicable to SSI. Understanding the characteristics of smart service innovation is the prerequisite for building on the foundation of existing means that could support the analysis, design, implementation, and management of smart services.

This thesis contributes to the systematic development of smart service systems by advancing the understanding of smart service innovation through empirical insights into the structure, organization, and conduct of real-world SSI projects. The evidence presented in this thesis confirms previous research suggests that SSI projects are interdisciplinary multi-actor settings, which are beset with complexity and uncertainty. The involved actors apply a broad spectrum of methods from various disciplines and face various challenges in project management and service design. Based on the empirical findings, different conceptual results have been elaborated, e.g., to characterize contributed resources of actors using a set of roles, explain the dynamics of their involvement during the project using ecosystem states, and the activities they perform to reduce uncertainty in the innovation project. Additionally, typical constellations of actor-role-assignments have been conceptualized as innovation patterns. Conducting SSI projects based on suitable methods from different disciplines is the focus of service systems engineering. The presented results do not only show the diversity of methods used in practice but also show how they can be combined in a suitable way. The variety of work products resulting from the application of different methods leads makes it difficult to gain an overall understanding of the current state of the development. The Lifecycle Modelling Language is suitable to fulfill the needs of different stakeholders through its ability to integrate different perspectives of smart service systems into consistent views. Activities to ensure economic viability can contribute to the uncertainty reduction but they lack suitable methods. Therefore, meta-models, methods, and tools were developed that enable the assessment of services and their business models as part of the design process, rather than at the end.

These findings progress the understanding of smart service innovation and serve as a foundation for improved methodologies and design theories, especially related to a better embedding of service systems engineering into multi-actor service innovation. Practitioners can benefit from these results for the setup and conduct of their innovation projects, as well as for strategic considerations of their capabilities, partnerships, and dependencies.

It can be expected that further research will create design knowledge that guides practitioners in the challenging task of systematically designing smart service systems. This will help organizations exploit the potential of digital technologies for the creation of innovative value propositions and gain a competitive advantage. On a larger scale, smart services may transform the way people interact with each other, create value, and improve their lives. The systematic investigation of these phenomena has just begun and will remain a fascinating topic for academics of several disciplines in the years to come.

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PART B - PUBLICATIONS

7 It Takes More than Two to Tango: Identifying Roles and Patterns in Multi-Actor Smart Service Innovation

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Abstract: Smart service systems enable innovative value propositions based on smart products and data-driven value creation. Grounded in service-dominant logic as our theoretical lens, we argue that smart service innovation takes place in ecosystems of collaborating actors, as a single actor does not possess all required resources and competencies. We empirically explore smart service innovation using an interview study of 14 experts who were involved in real-world smart service systems engineering projects. As a result, we conceptualize 17 roles that describe the resources and competencies required for smart service innovation at an abstract level. Through the analysis of actor-role constellations in our sample of projects, we further identify four patterns that exhibit different strategic approaches to smart service innovation. Our results advance the theoretical understanding of smart service systems through an empirically grounded systematization of roles, which reflect the resources and competencies required for smart service innovation. With this study, we shed light on the multi-actor and inter-organizational settings of service innovation processes, which have been under-researched so far. Our insights are further helpful for practitioners, who participate in the smart service innovation and who need to analyze their strategic position in service ecosystems.

Keywords: Smart service systems, service ecosystems, roles, service-dominant logic, inter-organizational projects, service systems engineering

JEL codes: M15, L86, O32, O30

7.1 Introduction

In today's digitally connected world, more than ever, service innovations result from the interactions between multiple actors. While we have traditionally seen the service provider as a rather independent actor in the driver's seat of service innovation processes, we now recognize that these firms require an increasing amount of help from external actors to successfully develop new digitally-enabled value propositions and corresponding resource integration mechanisms within their service ecosystems. Especially smart service systems, which enable value propositions based on smart products and data-driven value creation, illustrate that resources and competencies from a whole network of actors are required to put them in place. A narrow focus on dyads of service providers and customers with static roles is not adequate anymore – if it ever has been. Hence, it takes more than two to tango as digital technologies bring new actors into play who are, amongst others, specialized in systems integration, user interface design, cloud computing, data analytics, and platform business.

The value proposition of a smart service system is "preemptive in its behavior, adaptive to customer needs and contexts, thereby exceeding traditional offerings concerning both perceived customer value and provider efficiency" (Beverungen, Breidbach, et al. 2019, 1201). Smart products have been conceptualized as a constituent component of smart service systems (Beverungen, Müller, et al. 2019) as they can sense their condition and surroundings, allow for real-time data collection, continuous monitoring and communication, remote control and interactive feedback (Allmendinger and Lombreglia 2005; Wuenderlich et al. 2015). Smart service systems already exist in various industries including manufacturing, logistics, mobility, and healthcare as well as in private living (Beverungen, Breidbach, et al. 2019). Examples include performance-based contracting for aircraft engines and industrial compressors in business-to-business (B2B) settings as well as home automation and driving-behavior-aware car insurances in business-to-consumer (B2C) settings.

It is evident from these examples that digital technologies are important enablers and drivers of service innovation through smart service systems (Nambisan 2013; Lusch and Nambisan 2015; Beverungen, Breidbach, et al. 2019). They are also a key reason why corresponding smart service systems engineering projects increasingly involve multi-actor collaboration because the required knowledge and expertise on the use of digital technologies and the access to digital infrastructures are often not fully available by a single actor (Porter and Heppelmann 2015; Ekman et al. 2016; Floerecke and Lehner 2016; Sklyar, Kowalkowski, Tronvoll, et al. 2019). Furthermore, the use of digital technologies in smart service systems often goes hand in hand with structural changes to business models that affect the relationship and interaction with customers as well as the nature of value capture through revenue streams, e.g., pay-per-use and subscription payments instead of transaction-based product and service sales (Abrell et al. 2016; Storbacka et al. 2016; Chowdhury et al. 2018; Jussen et al. 2019). Therefore, incumbent actors also frequently need support from external actors in service innovation processes to envision and implement such changes in their network with customers, partners, and other actors.

The service-dominant (S-D) logic provides an appropriate theoretical lens to analyze multi-actor service innovation processes (Vargo and Lusch 2004; Ekman et al. 2016). According to S-D logic, actors do not develop services, but "they design and communicate new value propositions [and] develop and manage service systems capable of realizing the new value propositions" (Edvardsson and Tronvoll 2013, 21). S-D logic conceptualizes all market participants as generic actors who are involved in actor-to-actor (A2A) exchanges. Service innovation is understood as a collaborative process occurring in networks of actors, which are also referred to as service systems or service ecosystems (Edvardsson and Tronvoll 2013; Vargo and Lusch 2016). During service innovation, actors of the service ecosystem reconfigure their diverse resources and change institutional arrangements to provide new value propositions. (Edvardsson and Tronvoll 2013; Lusch and Nambisan 2015; Edvardsson et al. 2018). Ekman et al. (2016) further illustrate that the actors do not assume static roles (like customers or providers) but may assume several roles simultaneously and also actively change roles in the network of actors over time.

In line with S-D logic, we understand service innovation as the overall process from initiating the development of a new value proposition with an initial idea to its successful commercialization in the market. In this process "firms have a coordinating role" (Edvardsson et al. 2018, 90) and possess agency. They use their available resources, creativity, and strategic intent to initiate and create new value propositions. In our context of smart service systems, we refer to *smart service innovation* for the overall process from the first idea to market diffusion and *smart service systems engineering (SSSE)* for the deliberate activities of actors that aim at realizing new value propositions (Böhmann et al. 2014; Demirkan et al. 2015; Beverungen et al. 2018). SSSE is often organized in projects to consider cost, time, and quality as constraints. Such SSSE projects, which we consider to cover the "realizing" state of service innovation (Edvardsson et al. 2018, 98), are the unit of analysis in this study. In particular, we are interested in the various roles that actors assume in these projects as those reflect the necessary resources and competencies that are required to realize smart service systems. We also expect them to make institutional arrangements and strategic dependencies between actors visible.

Existing service research provides already some insights into multi-actor constellations in service ecosystems and service innovation (Ekman et al. 2016), but is very limited as regards the collaboration of actors in SSSE projects in particular. Studies of value co-creation between actors in technology-enabled service systems mostly examine existing and operational service systems (e.g., Breidbach and Maglio 2016), but do not address the projects in which such smart service systems are developed in the first place. Correspondingly, Dreyer et al. (2019) identify customer involvement in the engineering, operation, and improvement of smart service systems as a still under-researched field. They also show that the integration of further actors (e.g., partners or suppliers) has not even been discussed in the context of smart service systems. Furthermore, existing research seems to disregard that smart service systems can provide new entrants holding distinct resources (e.g., IT firms) with the opportunity to change institutional arrangements in service ecosystems fundamentally. That is, IT firms might not only engage in exchange relationships as a supplier of digital technologies but instead initiate and drive the development of innovative smart service value propositions themselves. Examples include Deutsche Telekom's smart parking solution "Park & Joy"[9] and the connected car platform "Drive"[10] by AT&T that leapfrog municipalities and automobile OEMs.

Therefore, we intend to advance our understanding of multi-actor smart service innovation through this qualitative-empirical interview study, which is grounded in S-D logic. In particular, we contribute through the analysis of actor-role constellations in SSSE projects. In this study, we pursue the following research questions:

- RQ1: Which roles are assumed by the different actors involved in SSSE projects?
- RQ2: Which different actor-role constellations can be identified in SSSE projects that reflect different patterns of smart service innovation?

Based on the data from interviews with 14 experts, we develop a set of roles that different actors assume in SSSE projects. Our study investigates actors at an organizational level and conceptualizes their distinct contributions (in terms of resources and competencies) as roles. With a dedicated focus on the SSSE projects, the formation process of the underlying A2A relationships is out of scope, as we consider these to be highly path-dependent with determining factors that go beyond single projects (Sydow 2009; Aaltonen et al. 2017). Furthermore, we do not analyze the "outcoming" state of service

[9] https://www.parkandjoy.de/
[10] https://drive.att.com/

innovation that follows after the completion of the SSSE project (Edvardsson et al. 2018). Hence, the set of roles that we contribute reflects the resources and competencies that the realization of smart service systems requires.

Besides the conceptualization of roles, we also uncover their assignment to actors and thereby explain the division of labor in SSSE projects. It becomes visible which contributions are frequently sourced from actors that are external to the focal service provider. Finally, the analysis of the different actor-role-assignments across the SSSE projects allows us to derive smart service innovation patterns that reflect distinct strategies of utilizing and changing institutional arrangements in the service ecosystem. With our study, we contribute to the "clear priority" for theoretical and empirical research on smart service systems, which have so far mainly been envisaged from a practical and descriptive perspective (Djellal and Gallouj 2018, 17).

The remainder of this paper is organized as follows. In Section 2, we introduce the theoretical background with key concepts related to S-D logic and smart service systems, as well as actors and roles in service innovation and business ecosystems. Then, we explain our research method in Section 3. Section 4 presents our findings from the interviews, including the proposed conceptualization of roles in SSSE projects and actor-role constellations, which explain different smart service innovation patterns. The paper closes with a discussion (Section 5) and conclusions (Section 6).

7.2 Research Background

7.2.1 Service Innovation with Smart Service Systems

In this study, we adopt the service-dominant (S-D) logic as our theoretical grounding of service and service innovation. In S-D logic, *service* is understood as the process of using one's resources, including specialized competencies like knowledge and skills, for the benefit of another actor or the actor itself (Vargo and Lusch 2004; Lusch and Vargo 2016). S-D logic also distinctively uses the singular term *service* to denote the process character of doing something beneficial instead of the plural term *services* that would imply units of output and, hence, a goods-dominant logic (Lusch and Nambisan 2015). Furthermore, the S-D logic does not distinguish between producers and consumers but adopts a generic A2A perspective on value exchange that dispenses with such pre-designated roles (Vargo and Lusch 2011; Lusch and Vargo 2016). Following this argument, "*all actors* fundamentally do the same things: *integrate resources* and engage in *service exchange*, all in the process of *cocreating value*." (Vargo and Lusch 2016, 7).

Service innovation refers to the reconfiguration of resources or changes in structures and value-co-creation processes of the service system (Vargo et al. 2010; Edvardsson and Tronvoll 2013), which lead to new practices that are useful and, hence, valuable, to actors in a specific context (Edvardsson and Tronvoll 2013; Lusch and Nambisan 2015; Edvardsson et al. 2018). Thus, when service firms (or more generally: actors) innovate, they design resource integration mechanisms, which are supposed to support other actors (e.g., customers) in integrating and acting on available resources so that they can create value in new and better ways. This also means that service firms do not develop services (as units of output), but, according to the S-D logic, design and communicate new value propositions and develop and manage service systems.

Such a service system lens is appropriate for studying service innovation as it goes beyond traditional perspectives that are grounded in technological product inventions (Edvardsson and Tronvoll 2013). A system perspective further implies that "value creation takes place within and between systems at various levels of aggregation" (Vargo and Lusch 2008, 5). While there are different conceptualizations of these levels, it appears meaningful to distinguish between direct exchange among dyads of actors (reflecting a micro-context) and direct and indirect exchanges in more complex constellations (e.g., triads and networks) of actors (reflecting a meso- or macro-context) (Chandler and Vargo 2011; Ekman et al. 2016). Vargo and Lusch (2016) also use the term *service ecosystem* to describe such networks of actors. Hence, to understand service innovation, S-D logic requires us to pay attention to the multiple actors, resources, and institutional arrangements at different levels instead of only focusing too narrowly on innovative offerings or the innovation process (Edvardsson et al. 2018).

Digital technologies provide multifaceted potentials for service innovation because operant resources such as information, skills, and knowledge can be combined and exchanged in novel ways that create value for the actors involved (Edvardsson and Tronvoll 2013; Nambisan 2013; Barrett et al. 2015; Sklyar, Kowalkowski, Sörhammar, et al. 2019; Wolf 2020). Digital technologies "liquefy and distribute resources" through the A2A-network of a service system and also allow actors to "increase resource density to quickly access and utilize resources needed for service exchange" (Barrett et al. 2015, 143).

We increasingly refer to *smart service systems* when digital technologies are combined with individuals and organizations to share resources and co-create value (Djellal and Gallouj 2018). In smart service systems, smart products are a key digital technology that increasingly becomes part of changed, new, and useful value-creating systems. *Smart products* refer to physical objects with embedded systems, sensors and actuators, and networking capability that enable learning, decision-making and dynamic adaptation to usage situations based upon data received, transmitted, and/or processed (Allmendinger and Lombreglia 2005; National Science Foundation 2014). Smart products can be conceptualized as boundary objects that integrate the resources and activities of actors in service systems (Beverungen, Müller, et al. 2019), and, thus, enable the co-creation of smart service. Accordingly, the "attribute *smart* […] highlights that digital technology allows for the transformation of service systems into smart service systems." (Beverungen, Breidbach, et al. 2019, 1202). Digging deeper into the distinctive attributes of smart services and their relationship to smart products, Boukhris and Fritzsche (2019) derive five dimensions that impact the "smartness of services", including the richness of data, the knowledge-intensity of the decision support engine, the level of sophistication of the outcome delivered to the beneficiaries, the architecture of the stakeholders, and the automation level of processes.

Despite the many works that put digital technologies and smart products center stage and push relevant social structures into the background, Beverungen, Breidbach, et al. (2019, 1202) posit that "smart service systems need to be understood as complex, open, and dynamic sociotechnical systems." Correspondingly, we see the need to better understand the interplay between people, organizations, and technology along with the different states of the system. In particular, we are interested in those actors that deliberately change service systems through service innovation, or *smart service innovation* to be more precise.

7.2.2 Actors and Roles in Service Innovation

It has already been argued that service innovation no longer originates from within a single organization, but rather evolves from "a network of actors" (Lusch and Nambisan 2015, 155–156). Put differently, actors recombine elements from both internal and external resources for service innovation (Beverungen et al. 2018). Accordingly, Edvardsson et al. (2018, 99) conceptualize service innovation as a phenomenon that takes place in *service ecosystems*, which are defined as "relatively self-contained, self-adjusting system[s] of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange." (Vargo and Lusch 2016, 10–11). The service ecosystem perspective emphasizes that service innovation is a "phenomenon embedded in social structures and taking place within social systems, in which actors adopt certain social positions and roles to interact and recreate social structures" (Edvardsson and Tronvoll 2013, 20).

Generally, *roles* can be understood as "distinct technologically separable, value added activities undertaken by firms or individuals" (Kambil and Short 1994, 10) that reflect "clusters of behaviors expected of parties in particular statuses or positions" (Knight and Harland 2005, 282). Role theory usually assigns roles to individuals (Janowicz-Panjaitan and Noorderhaven 2009; Rese et al. 2013), but they can also apply to other actors such as teams, groups, organizations, or networks (Knight and Harland 2005; Avelino and Wittmayer 2016). This is also in line with S-D logic, where the generic actor can refer to any kind of economic and social entity like, e.g., firms, individuals, households, or nations (Lusch and Vargo 2006; Vargo and Lusch 2008).

While the S-D logic conceptualizes actors as generic, it does certainly not mean that all actors are identical (Vargo and Lusch 2016). It is mainly that the S-D logic refrains from assigning predesignated roles like producers and consumers to actors. Instead, it encourages us to characterize actors "in terms of distinctly constituted identities associated with unique intersections of the institutional arrangements, with which they associate themselves." (Vargo and Lusch 2016, 7) Moreover, actors can assume multiple roles simultaneously and the assumption of roles can be subject to dynamic changes over time (Ekman et al. 2016).

To better understand the distribution of roles in service ecosystems and across different states of service innovation, Ekman et al. (2016) present a typology of generic actor roles that distinguishes between provider and beneficiary roles as well as between active and passive roles, all of which can be assumed by different actors simultaneously. They further see the possibility of inactive actors in the wider service network, who "decline or ignore the invitation to cocreate and hence choose not to participate" (Ekman et al. 2016, 52). Ekman et al. (2016) also conceptualize an initiator role that triggers service innovation within a service ecosystem. The actors who hold this role give the initial "invitation to co-create" by engaging in "new service development as a means to be able to offer a new value proposition" (Ekman et al. 2016, 54).

Also grounded in S-D logic and specifically considering the collaboration of internal and external stakeholders as actors in service innovation, Jonas and Roth (2017) conceptualize a continuum of four *modes of stakeholder integration*. This continuum ranges from low to high stakeholder integration with the four modes of (1) passive integration, (2) reactive integration, (3) mutual integration, and (4) pro-active initiative. Their empirical results from case studies (Jonas et al. 2016; Jonas and Roth 2017) exhibit higher degrees of integration almost only for stakeholders internal to the focal organization (e.g., top management). As regards external stakeholders, they find that it is mainly the customers and users who are (only passively or reactively) integrated at the very beginning (e.g., interviews) and the very end (e.g., testing) of the innovation process, especially by the service providers' sales personnel. They only see very limited evidence for the integration of other external stakeholders at all, including, e.g., suppliers and external service providers.

Finally, the S-D logic not only argues for an A2A perspective, but also for a dynamic view of service innovation (Edvardsson et al. 2018, 87). Correspondingly, Edvardsson et al. (2018) distinguish between three states of the service innovation process, including initiating, realizing, and outcoming. The initiating state mainly focuses on formulating intended value propositions so that they are attractive to potential customers and other actors. The realizing state is about putting the innovative value proposition into practice. The outcoming state refers to market diffusion and scaling up so that innovative value propositions become sustainable and the service providing actors can capture enough value to ensure their sustainability. Similarly, Ekman et al. (2016) illustrate the dynamic development of actor and role constellations from initial new service development via pilot implementations and service diffusion to network evaluation and service refinement. In their method for recombinant service systems engineering, Beverungen et al. (2018) distinguish between the three phases of service system analysis, design, and transformation.

Although service ecosystems can be understood as being subject to continuous reconfigurations because the different actors can change roles and resource configurations at any time, the existing conceptualizations and case studies following S-D logic still indicate that service innovation (or new service development) is typically conducted as a deliberate initiative that mainly covers the initiating and realizing state. That is, an actor initiates the service innovation endeavor (in the initiating state) and then sets up a dedicated project for designing the value proposition (in the realizing state). The project will usually involve various internal stakeholders (Jonas et al. 2016) but can also explicitly rely on contributions from external actors (Ekman et al. 2016; Beverungen et al. 2018). In the latter case, Sydow and Braun (2018) also use the term inter-organizational projects (IOPs) for those projects that are carried out in inter-organizational teams.

7.2.3 Roles in Innovation and Business Ecosystems

Apart from works grounded in S-D logic, there are further contributions from other research streams, especially innovation and business ecosystems, which conceptualize roles and develop ecosystem models. Dedehayir et al. (2018), for instance, conceptualize roles during the preparation, formation, and operation of innovation ecosystems, which they broadly define as "heterogeneous constellations of organizations, which co-evolve capabilities in the co-creation of value" (Dedehayir et al. 2018, 2). They present four groups of roles with eleven roles in total, including (1) leadership roles (e.g., Ecosystem Leader), (2) direct value creation roles (e.g., Supplier and User), (3) value creation support roles (e.g., Expert), and (4) entrepreneurial ecosystem roles (e.g., Entrepreneur and Sponsor).

With a strong focus on the digital technologies that are also potentially relevant for smart service systems, we find additional and rather specific ecosystem models that devise roles, too. Papert and Pflaum (2017) present an ecosystem model with 19 roles for the realization of Internet of Things (IoT) services in a supply chain management context. They further structure their ecosystem into a central part, which includes the Solution Integrator as a key role, and two sub-systems for applications (including roles such as Application Developer and Middleware Provider) and smart products (including roles such as Product Manufacturer and Embedded System Provider). Floerecke et al. (2020) developed and revised the Passau Cloud Computing Ecosystem Model (PaCE), which comprises 31 roles for market actors, grouped into the five categories of client (End Customer), vendor (e.g., Network Operator), hybrid (e.g., Service Integrator), support (e.g., Training Provider), and environment (e.g., Legislator). Riasanow et al. (2020) analyzed the similarities of digital ecosystems in the automotive, blockchain, financial, insurance, and industrial IoT industries using conceptual modeling and large-scale cluster analysis. They define generic roles for each of the five industry-specific ecosystems and identify a core cluster of roles that are common across all five industries. This core cluster includes organizations that provide cloud infrastructure, platform and application services as well as data protection and security services.

These ecosystem models generally take a broader view on ecosystems and cover all the roles that generally exist in a specific industry or technology-centered ecosystem. However, they do not dedicate their attention to the specific roles of actors involved in service innovation when jointly designing a new value proposition in SSSE projects. Following Adner (2017), we also conclude that they rather take the view of "ecosystem-as-affiliation", which focuses on actors, as compared to "ecosystem-as-structure", which focuses on the activities that need to be "undertaken in order for the value proposition to be created" (Adner 2017, 44).

7.3 Methodology

7.3.1 Data Collection

To investigate the roles of the multiple actors that engage in smart service innovation, we conducted an interview study. As there still is a need for more theoretical and empirical work on smart service systems in general (Djellal and Gallouj 2018) and we consider existing insights into the interaction of multiple actors during SSSE projects as very limited, we infer that a qualitative study that intends to build and extend theory is an appropriate research strategy.

In our study, we interviewed experts who were involved in real-world smart service innovation processes. The experts represent actors on both the level of the human individual and the level of the firm that they work for. During the interviews, we expected them to provide us with insights into a specific service ecosystem that they and their organizations were involved in. In particular, we were interested in the roles that the different actors enacted during SSSE projects. We intended to generate information-rich data and to capture a multiplicity of perspectives on practices, experiences, and challenges in service innovation processes.

To identify appropriate experts, we followed a purposive, theoretical sampling approach (Eisenhardt 1989; Yin 2016). We as researchers approached those people in our wider personal network from whom we expected to learn about interesting and relevant practical experiences that they had made in smart service innovation processes. Hence, we selected those from whom we knew that they deal with the realization of smart service systems. However, we first learned about the exact SSSE projects during the interviews and the experts were free to choose about which projects they wanted to provide detailed information. Hence, we did not select experts based on specific project characteristics. We also deliberately refrained from interviewing fellow researchers as we were interested in the role constellations and dynamics from real-world service innovation processes. When approaching the experts, we sought for variety within our sample, including experts with different positions (e.g., consultant or project manager) from different types of organizations (e.g., service providers and IT consultancies) and various industries with both B2C and B2B settings. Thereby, we intended to cover different actor perspectives, e.g., actors that we expected to be initiators and drivers of service innovation as well as further actors that were involved as less active subcontractors or similar. We continued our data collection until we as research team jointly gained the impression of a sufficient theoretical saturation; that is, we felt it unlikely to learn about fundamentally new types of actors and roles through continuing with further interviews. In the end, we interviewed 14 experts from 13 organizations located in Germany (Table 7.1). All experts were employed at these organizations; there were no freelancers involved in this study. We conducted the interviews via phone from October 2018 to January 2019. They lasted between 41 and 90 minutes. All interviews were audio-recorded and selected sections were transcribed for detailed analysis. We only provide organization pseudonyms and the expert's position in Table 7.1 as we guaranteed anonymity to all interviewees. As an indication of the company size, we provide their number of employees in the following five categories: A: <50; B: 51-250; C: 251 to 1000; D: 1001 to 10000; E: >10000.

During the interviews, we followed a semi-structured guideline that covered the following sections with several questions each:

4. *Introduction* of interviewer and expert, description of the expert's organization, expert's background, and his/her role in the organization.
5. Identification of smart service innovation processes that the expert was involved in and the *selection of a specific SSSE project* for closer analysis in the following sections of the interview.
6. *Initiating state* of the smart service innovation process, including the initiating actor and triggering impulse for starting the SSSE project.
7. *Realizing state* of the smart service innovation process, including organization of the SSSE project, involved internal and external actors, overall project management approach, work contributions, approaches, and method use of the different actors.
8. *Outcoming state* of smart service innovation process, including the resulting value proposition and resource configuration of the smart service system, potential market diffusion, and scale-up by the time of the interview.

With this interview guideline, we provided a general orientation for the interview but also left some flexibility for additional insights and thoughts of the experts. Our rationale was to stimulate the experts to provide rich information on the smart service innovation processes and corresponding SSSE projects, the involved actors, their work contributions to the projects, and relevant context. Following the S-D logic as described above, our interview guideline did not include predefined conceptualizations of roles but we asked open questions to ensure that we identify and characterize actors in terms of their "distinctly constituted identities" (Vargo and Lusch 2016, 7). With this interview guideline, we also strived for identifying the actors' roles with the perspective of "ecosystem-as-structure" (Adner 2017, 44) by putting our focus on the activities and work contributions that the different actors render for the development of the smart service system.

7.3.2 Data Analysis

During data analysis, we followed the steps of compiling, disassembling, reassembling, and interpreting according to Yin (2018). As for the first step, we organized the interview recordings and interview metadata in a cloud-based data storage that was accessible to all researchers. We listened to the recordings of the interviews multiple times and used a shared spreadsheet file with summary sheets for each interview. In these summary sheets, we captured our key insights along the sections of the interview guideline. We also added labels for the specific SSSE project that the expert selected and reported on as well as memos with our initial thoughts and insights from the interviewer's perspective. 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 also listening to the recordings and discussing his impressions with the responsible analyst at the different steps of data analysis as described in the following.

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

Table 7.1: Overview of Expert Interviews

In the *disassembling* step, we broke down the interview data of each respondent into smaller fragments and specifically tried to identify the text passages in which the experts reported on the involvement of multiple actors in the SSSE project. We selectively transcribed the relevant fragments of interviews and used descriptive codes to label the actors that we were able to identify. Here, we coded actors on the level of organizations (and not human individuals) as all experts naturally reported on the SSSE project from the perspective of the firm they represent. In each project, we assigned an ID to specific actors that we were able to identify. When assigning the IDs, we took the perspective of the designated service provider in a project and distinguished between three types of actors: customers (both individuals and organizations; type C), provider organizations (type P), and external organizations (type E). To distinguish the different actors across all SSSE projects of our sample, we denoted them with 1...*n*. For instance, in project 1 we identified actors C1, P1, as well as E1, E2, E3, E4, and E5 from our interview with the expert who was employed at organization E1. In this step, we further used descriptive codes to describe the specific activities, resources, and competencies (including knowledge and skills) that these actors (e.g., the competence for user interface design) brought into the SSSE projects. While coding, we tried to stick closely to the terminology as used by our informants (in the sense of open codes or in vivo codes; Yin 2018). We summarized our findings in detailed interview memos that gave descriptions of the overall service ecosystem as described by the experts including the actors that we were able to identify as well as an initial conceptualization of their role, which we derived from their activities, resources, and competencies. We also created graphical sketches to depict the service ecosystem structures.

As for the *reassembling* step, we compiled an overview of all actors and roles that we derived from the previous step and searched for similarities and differences. We constantly compared our interview memos and codes across the different SSSE projects as recommended by Yin (2018). Precisely, we revisited each interview and checked if roles from the other interviews were also present and by which actors they were enacted. We also examined if the assignment of roles to actors differed. Based on the iterative process of comparing and discussing, we jointly grouped similar competencies and resources into a consolidated set of roles that we applied across all interviews. During this process, we added new roles when we identified competencies and resources that we had not covered before. We also rearranged, merged, and split up roles when considered necessary. In the end, we updated the graphical sketches and interview memos so that they corresponded with the final, consolidated set of roles.

In the *interpreting* step, we then went on with further condensing our findings and searching for possible explanations of the different constellations of actors and roles in the various service innovation processes. Here, we first systematized the set of roles into different groups of roles (Primary and Secondary Roles; Engineering and Operations subsystems) which were, amongst others, inspired by the corresponding actors' degree of involvement (Ekman et al. 2016; Jonas and Roth 2017) and different states of the innovation process (Edvardsson et al. 2018). Second, we also were able to derive different smart service innovation patterns based on similar actor-role constellations in SSSE projects (also reflecting different institutional arrangements in service ecosystems; Vargo and Lusch 2016).

7.4 Results

7.4.1 Identified SSSE Projects

The experts in our sample reported on a broad range of service innovation processes and corresponding SSSE projects. The value propositions to be developed comprised, for instance, mobility and charging services for electric vehicles, remote support for industrial equipment, car delivery tracking, and energy management (Table 7.2). The target customers of the new value propositions were anonymous consumer markets (e.g., public transport passengers in project 10), rather well-defined customer segments (e.g., users of electric vehicles in project 3) or even specific individual actors (e.g., project 8 with a customer-specific development of a car delivery tracking service by ITCONSULT). Depending on whether the value proposition was targeted at consumers or businesses, we marked the value proposition as either business-to-business (B2B) or business-to-consumer (B2C) in Table 7.2.

All SSSE projects in our sample utilize data from the IoT as part of the designated value creation. However, smart products have different functions in the resulting smart service systems. First, in most of the B2B projects, the smart product is in the focus and digital services are built around it (e.g., in projects 4, 9, 11-14). These projects mainly support the digital servitization of manufacturers (Sklyar, Kowalkowski, Tronvoll, et al. 2019), in which the value propositions move from a focus on tangible goods towards integrated solutions and service offerings (e.g., through a pay-per-use business model for industrial equipment and machinery). Second, smart products provide access to high-quality real-world data. This data is combined with other data to enable or at least improve the value creation efficiency of service systems. Examples include smart parking (project 5), energy distribution network control (project 1), and self-service charging for electric vehicles (project 3). Third, smart products are used by actors to optimize their business processes and collaboration with other actors (projects 3, 8). The different approaches to utilizing smart products as key resources in smart service systems can also be pursued in combination. This is especially visible from those cases where actors are both providers and users of their service offerings, e.g., when charging the cars of the firm's fleet (project 3) or the firm's service department uses a remote support service to reduce on-site visits for servicing industrial doors (project 9).

No.	Value Proposition (Type)	Project Description
1	Energy distribution network control (B2B)	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 (B2C)	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 (B2C)	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 main-tenance management (B2B)	Development of a system by GLOBALSYS for a manufacturer of commercial vans. It enables the sharing of data between the manufacturer and customers for fleet management and maintenance planning.
5	Smart parking service (B2C)	Development of a service by GLOBALSYS for a large German city that com-bines multiple data sources to identify areas with a high probability of free parking space. The service also allows reservations of parking spaces.
6	Energy trading platform (B2B)	Development of a tendering service as an alternative to expensive energy exchanges to improve the trader's margin. It supports placing tenders in the marketplace, shows current tenders and market pricing.
7	Customer service for public transport (B2C)	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 (B2B)	Customer-individual development of a digital monitoring service by ITCONSULT for a car manufacturer that allows for the real-time tracking of car delivery.
9	Industrial doors re-mote support (B2B)	Development of a remote support service for industrial doors by DIGIBUSINESS for the door manufacturer.
10	Intermodal public transport service (B2C)	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 training service (B2B)	Development of a virtual reality training service using maintenance simulations of PHARMACHINES' products, which one of its customers triggered.
12	Video chat remote support (B2B)	Development of a video-chat-based remote support app to support customers in resolving incidents with PACKMACHINES' products.
13	Predictive main-tenance (B2B)	Development of a showcase of an availability-based business model as part of a governmentally funded consortium project.
14	Digital customer portal (B2B)	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 7.2: Overview of SSSE Projects

7.4.2 Roles of Actors in SSSE Projects

Our analysis of the 14 SSSE projects led to the conceptualization of 17 roles in total. Table 7.3 and Table 7.4 provide an overview of all roles that we identified from our interview data. The column *Projects* indicates in which projects the respective role was identified as being actively involved in the SSSE project.

We clustered the set of roles into Primary and Secondary Roles (Figure 7.1). ***Primary Roles*** identify contributions that are usually required due to the characteristics of smart service systems. They were mentioned by almost all interviewees as being involved in the SSSE projects with few exceptions. ***Secondary Roles*** relate to more specialized contributions for which the demand is identified during a project. Therefore, they were not always present, as can be derived from our interview data. For example, not all smart service systems were built using a cloud platform, so the role *Cloud Platform Provider* was not always required. Moreover, although irritating at first sight, it is not uncommon that SSSE projects were completed without involving actors with the role of a *Customer Representative*.

We further systematized the roles concerning their relation to different states of the service innovation process and, hence, to different subsystems of the overall service ecosystem at different points in time. The ***Engineering*** subsystem refers to contributions that are needed during the SSSE project for the development and implementation of the smart service system (i.e., the realizing state of service innovation). The ***Operations*** subsystem begins with the launch of the smart service offering into the market and refers to the actual value co-creation with the intended target group (i.e., the service customers in the outcoming state of service innovation). This systematization helped us to depict the contributions of actors with multiple roles in both the Engineering and Operations subsystems (e.g., actors who held the Service Operator role in both systems or actors who moved from the Customer Representative role during Engineering to a Service Customer role in Operations). In this study, our focus is on the *Engineering* subsystem and so is the focus of the presented set of roles. Nevertheless, we found that several roles continue to be relevant during *Operations*, and, hence, they are placed at the intersection of both subsystems (Figure 7.1). However, we can certainly expect that there are more roles relevant to the Operations subsystem (and which could be added to the right-hand side of the set diagram), some of which we did not even learn about in our investigation of the Engineering subsystem.

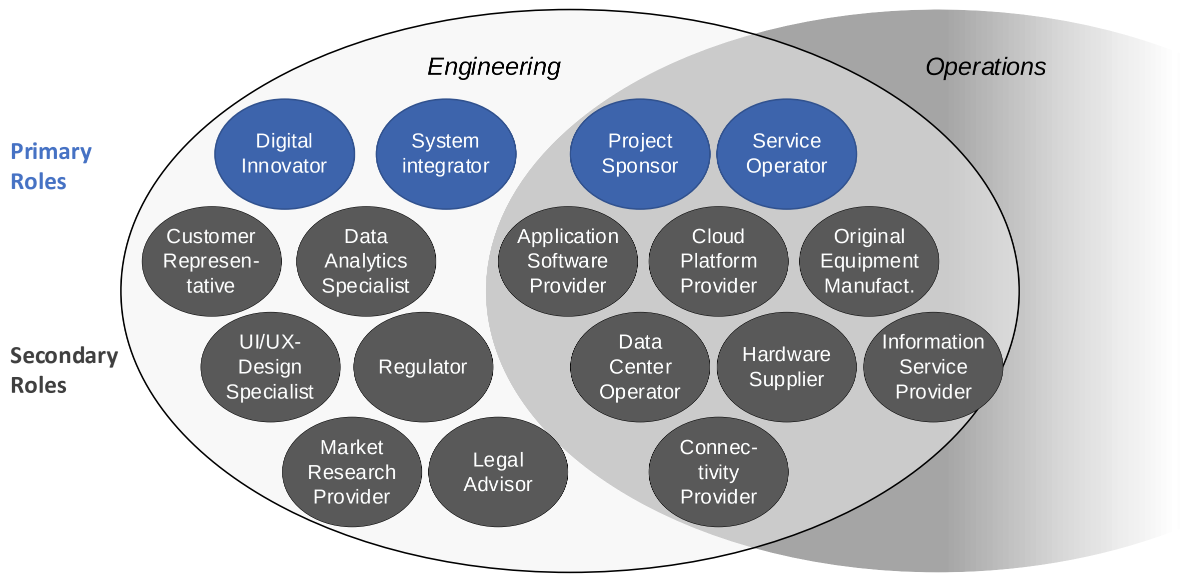

Figure 7.1: Proposed Set of Roles in SSSE Projects

Primary Roles

The four Primary Roles that we identified as being relevant to all SSSE projects are the Project Sponsor, Digital Innovator, System Integrator, and System Operator. The Primary Roles contribute competencies and resources that address the core characteristics of smart service systems, namely enabling innovative value propositions using digital technologies. The actor assuming the *Project Sponsor* role is usually the initiator of the SSSE project who intends to develop a new value proposition. Usually, it is also the same actor that intends to successfully market this value proposition afterward in the role of the Service Provider (which is present in Operations). The ***Digital Innovator*** role is only present in the Engineering subsystem and responsible for developing new ideas into value propositions and business models utilizing the capabilities of digital technologies. The ***System Integrator*** role oversees the design and implementation of technical resources of the service system during Engineering, for which the ***Service Operator*** becomes responsible to run and maintain during Operations. We did not identify a Service Operator role in three of the 14 projects. We assume that was the case if projects were still in the earlier stages of Engineering. Another reason might be that interviewees are typically only aware of a subset of activities and actors. So even if there were actors with a Service Operator role present in a project, the interviewee might not have reported on it. Thus, we still consider it as a Primary Role as the technical components of the smart service system need to be operated and maintained to enable the intended value proposition. Table 7.3 shows all Primary Roles along with the projects in which the corresponding activities were identified.

Role Name	Key	Activities in the Service Ecosystem	Projects
Project Sponsor	PS	▪ Initiates, sponsors, and often manages the overall project ▪ Operates and offers the service towards the Service Beneficiary after completion of the SSSE project	1-14
Digital Innovator	DI	▪ Provides methodological support for the innovation process ▪ Facilitates the creation of service ideas ▪ Designs business model	1-14
System Integrator	SI	▪ Develops technical concept, e.g., system architecture ▪ Develops front-end, e.g., apps, and backend services, e.g., cloud analytics and other software components ▪ Integrates existing systems, services, and devices	1-14
Service Operator	SO	▪ Operates the technical part of the smart service system ▪ Performs application management, e.g., ensures the availability and compliant operations of the system	1-9, 12, 13

Table 7.3: Identified Primary Roles in SSSE projects

Secondary Roles

The 13 Secondary Roles can also be subdivided into roles that are exclusively relevant to the Engineering subsystem and some that span both the Engineering and Operations subsystems. The former comprises six roles including the Customer Representative, Market Research Provider, UI/UX-Design Specialist, Data Analytics Specialist, Legal Advisor, and Regulator.

The *Customer Representative* role represents the target user (usually referred to as the customer by the interviewees) of the new value proposition. We found a varying degree of involving this role. For example, INTERNALIT (project 13) invited potential customers to take part in focus group discussions early on. In project 7, users of the public transport service were represented through a passenger advisory board. In contrast, the electric vehicle charging service (project 3) was first designed and implemented without end-user involvement. Only in later project stages, paid testers were asked for feedback. Projects 10 and 12 even did not involve the Customer Representative role at all. In project 10, the transport service was developed without the involvement of (potential) future users. However, after it turned out to have low market acceptance, the provider tried to get in contact with passengers to gather insights for improvements. In project 12, PACKMACHINES developed the video-chat service together with a software development firm without involving their customers. They started gathering feedback first when they presented the initial version of the smart service system in sales appointments. Generally, in projects where the SSSE project is initiated by a manufacturer in a B2B setting (holding the Project Sponsor role), customer involvement appeared to be less intensive or non-existing during the project. The interview data suggest that the manufactures (e.g., PACKMACHINES in project 12) preferred to have a working prototype before they involve customers.

An actor with the ***Market Research Provider*** role offers services to gain customer insights, which help to shape the characteristics of the intended value proposition of the smart service system. For the smart parking solution developed in project 5, a tool called "prediction markets" was used to collect opinions (votes) on features and pricing of the service from a large set of users. Another example is the diabetes prevention app in project 2, which was tested with many potential users by an external test provider to gain feedback on the usability of an app prototype. ***UX/UI-Design Specialists*** take care of user experience (UX) and user interfaces (UI). They support a user-centered approach to the design of technical systems. Consequently, they focus on interaction design and touchpoint management (e.g., through modeling customer journeys). The ***Data Analytics Specialist*** role denotes a set of competencies related to storing, processing, and analyzing large amounts of data. For example, in project 8, a specialist company was hired by the Project Sponsor to take on this role. ***Legal Advisors*** provide help with designing contracts, privacy statements, and other legal issues regarding the planned service. In project 6, a law office was involved to elaborate on the terms and conditions as well as a privacy statement for the designated energy trading platform. ***Regulators*** are responsible for the approval of service concepts that operate in regulated markets, e.g., energy, banking, or medical services. For example, in project 1, the planned service for energy distribution network control needed the approval of the German Federal Network Agency.

The other seven Secondary Roles are relevant to both Engineering and Operations. These are the Original Equipment Manufacturer (OEM), Hardware Supplier, Connectivity Provider, Cloud Platform Provider, Data Center Operator, Application Software Provider, and Information Service Provider. The *OEM* manufactures physical goods, equipment, and machinery, which usually need to be connected to the Internet to become part of the smart service system. Examples of OEM products in our sample include energy equipment for private homes (project 1), charging points for electric vehicles (project 3), commercial vehicles (project 4), and industrial doors (project 9). ***Hardware Suppliers*** offer various devices, such as communication modules or sensors to retrofit existing OEM products or physical facilities and environments (i.e., the servicescape) with computational capacity, sensors, communication capabilities, and other computing equipment. Thereby, OEM products are transformed into smart products and servicescapes into smart environments. For example, in project 5, parking sensors were installed to detect available on-street parking spots. ***Connectivity Providers*** typically are telecommunication operators who offer data transmission services such as mobile data plans. These are used to communicate with smart products once they are deployed. ***Cloud Platform Providers*** offer an infrastructure to operate software components. Some of them might include higher-level services for IoT-applications, e.g., device management or analysis of data streams. ***Data Center Operators*** provide and manage technical computing infrastructure, including computation, storage, and networking, which are needed as runtime environments for platforms, services, or software components (projects 1, 3, 4). ***Application Software Providers*** offer individual or standardized software products, which are typically integrated into the smart service system. Examples include a fleet management application (project 4) as well as applications for public transport information and ticketing (project 7, 10). The *Information Service Provider* delivers data that can become part of the data value chain in a smart service system. This role was needed in project 1 for ensuring access to information on energy prices. Table 7.4 shows the list of Secondary Roles along with the project in which the respective activities were found.

Role Name	Key	Activities in the Service Ecosystem	Projects
Customer Representative	CR	▪ Informs the project as a target customer of the value proposition ▪ May be involved at various stages of the project, e.g., to provide feedback during development	1, 3-9, 11, 13, 14
Market Re-search Provider	MRP	▪ Provides customer insights, e.g. through a collection of feedback on prototypes or service concepts	2, 5
UI/UX Specialist	UIS	▪ Designs customer journey and user interactions ▪ Designs wireframes and mockups ▪ Supports implementation of frontends	1, 2, 4, 6, 7, 13
Data Analytics Specialist	DAS	▪ Designs and implements big data solutions ▪ Expert for data analysis, machine learning, etc.	8, 13
Legal Advisor	LEG	▪ Provides advice regarding legal aspects of services and contractual relationships between actors	6
Regulator	REG	▪ Evaluates and approves service concepts regarding their compliance with regulatory requirements	1
Original Equip-ment Manufacturer	OEM	▪ Designs and produces physical products and equipment that are part of the service system	1, 3, 4, 8-13
Hardware Supplier	HWS	▪ Supplies sensors, communication modules, and other hardware components	4, 5, 9
Connectivity Provider	COP	▪ Provides services for connecting smart products in the field, e.g., cellular networks	5, 8, 9, 12
Cloud Platform Provider	CPP	▪ Provides application-independent functionality in the cloud, i.e. in a Platform-as-a-service Model (PaaS) often with focus on IoT	1, 2, 5, 6, 9, 13, 14
Data Center Operator	DCO	▪ Provides and operates IT-infrastructure, e.g. computation, storage, and network transfer	1-4, 12
Application Software Provider	ASP	▪ Develops and/or runs existing application software systems that must be integrated	2-7, 10, 14
Information Service Provider	ISP	▪ Provides information for data-driven value creation, e.g., weather forecasts, energy prices	1

Table 7.4: Identified Secondary Roles in SSSE Projects

7.4.3 Ecosystem Dynamics in Service Innovation

As indicated by the previous distinction between Engineering and Operations subsystems, the interview data also allowed us to describe some of the dynamics of roles and their assignment to actors during service innovation processes. As we cannot illustrate the dynamics of all SSSE projects in this article, we provide the example of project 4 (Figure 7.2). Actor P4 planned to provide fleet management and maintenance services around its commercial vans. At the initiating state of the service innovation process, P4 identified various competencies required to realize this concept, e.g., those of a Digital Innovator, a System Integrator, and a UI/UX Design Specialist. For the transition into the realizing state, these required roles had to be filled with actors. Altogether, these actors and P4 were supposed to form the Engineering subsystem that collaboratively works on the design and implementation of the new service idea. Two external System Integrators (E12, E13) were chosen and a design agency (E14) was hired for the UI/UX design. The fleet management functionality was delivered by an external Application Service Provider (E16). They also worked together with P4 on interfaces for the integration of fleet management functionality. As the actor P4 itself intended to use the service for its internal maintenance operations, it also assumed the role of the Customer Representative. External target customers were fleet managers, but their involvement in this phase is unknown, which is why we do not include them here as additional Customer Representatives. Due to its innovation capabilities and domain expertise, the actor P4 also took over the Digital Innovator role and developed the value proposition and business model. During the SSSE project, the actors also determined additional competencies required for Operations, e.g. a Service Operator, and a Data Center Operator. The initial launch of the service offering marks the transition to the outcoming state of the service innovation process. For that, the required roles had to be filled with actors that take on the roles of the Data Center Provider and Service Operator. In this case, parts of the systems were operated and managed by actor P4 itself and other parts by E12. Therefore, these two actors shared the roles of Service Operator and Data Center Operator. In the outcoming state, some of the roles from the realizing state became inactive again as their project work was finished. In this state, two additional roles of Service Provider and Service Customer become active. However, as our study focusses on the Engineering subsystem, they are out of scope and only mentioned for consistency here.

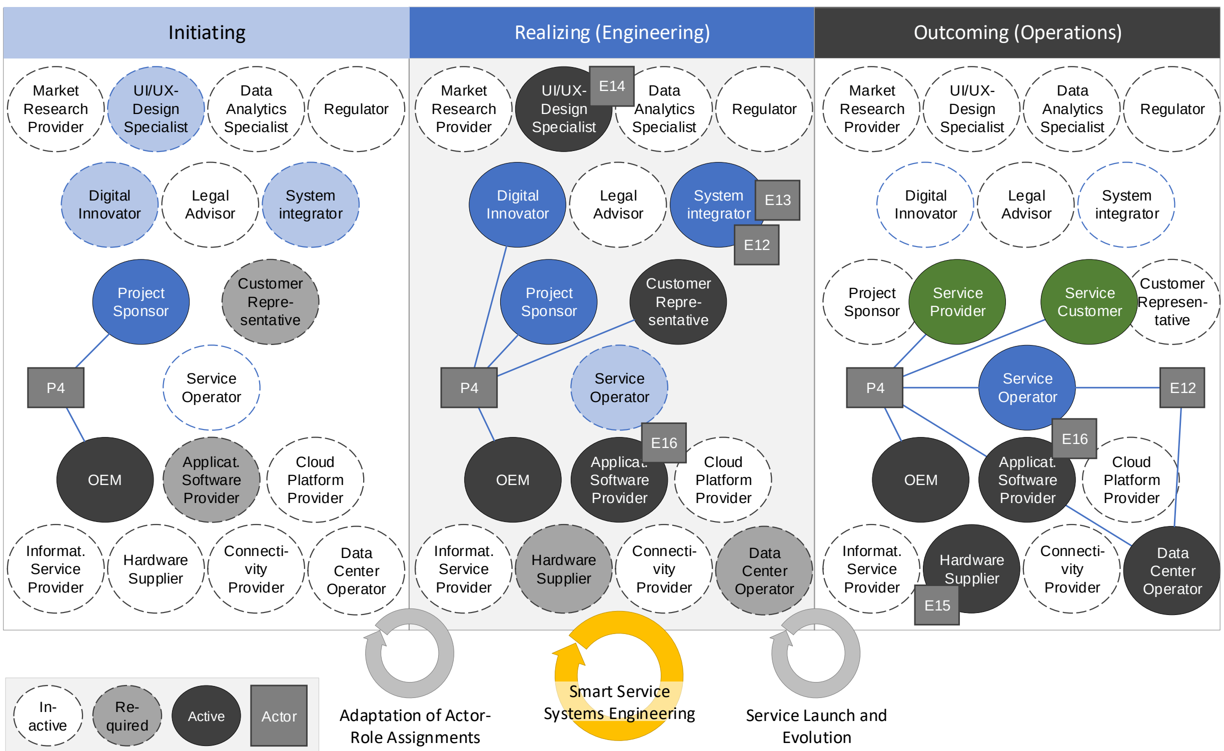

Figure 7.2: States of Service Innovation in a Service Ecosystem

7.4.4 Actor-Role Assignments in the SSSE Projects

Our comparison between the different interviews showed that some actors accumulated quite a few roles in SSSE projects whereas the same roles were spread across many actors in other projects. Hence, specific actors can assume one or more roles. Equally, there were SSSE projects, where multiple actors were assigned to the same role. Furthermore, we found that not all 17 roles were present in all 14 projects. There are even some roles that were present in a single SSSE project only. Considering the distribution of roles across actors, we saw that all projects required multiple competencies and resources from different organizations.

To illustrate the assignments of roles to actors, we distinguished between three types of actors: customers (C), provider organizations (P), and external organizations (E). Table 7.5 shows which roles were assigned to which actor in each project. Each column describes the assignment of actors to roles in the project indicated by the project number in the top row. An asterisk (*) indicates the co-existence of multiple, similar actors, which were not further differentiated by the experts. For example, in project 7, several actors provided applications for ticketing, billing, and travel information to be integrated. A minus sign (-) indicates that no actor was actively holding that specific role in the respective project. The last row displays the total number of identified actors in each project. The actors in bold indicate the firms where our experts that we interviewed were employed at. About half of the interviewed experts belonged to actors that we considered as external organizations (i.e., in projects 1, 4, 5, 7-9, 13-14).

Role	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PS	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
DI	P1, **E1**	**P2**, E6	P3	P4	P5, **E12**	**P6**, C4	P7, **E21**	P8	P9, **E26**	P10	C7, **P11**	P12	P13, **E35**	P14, **E37**
SI	E1	P2	E8	**E12**, E13	E12	P6	E21	E23	E26	E30	E33	E34	E35	E37
SO	E1	P2	P3	**E12**, P4	E12	P6	E21	P8	E26	-	-	E34	E35	-
CR	P1, C1*	-	**P3**, C2*	P4	C3*	C4*	C5*	P8	P9, C6	-	C7	-	C8	C9
MRP	-	E7	-	-	E18	-	-	-	-	-	-	-	-	-
UIS	E1	P2	-	E14	-	P6	E21	-	-	-	-	-	E35	-
DAS	-	-	-	-	-	-	-	E24	-	-	-	-	E35	-
LEG	-	-	-	-	-	E22	-	-	-	-	-	-	-	-
REG	E2	-	-	-	-	-	-	-	-	-	-	-	-	-
OEM	E3	-	E9	P4	-	-	-	P8	P9	E31	P11	P12	P13	-
HWS	-	-	-	E15	E19	-	-	-	E27	-	-	-	-	-
COP	-	-	-	-	E20	-	-	E25	E28	-	-	E35	-	-
CPP	E1	P2	-	-	E12	E23	-	-	E29	-	-	-	E36	E38
DCO	E4	P2	E10	**P4**, E12	-	-	-	-	-	-	-	E34	-	-
ASP	-	E6	E11	E16	E21*	P6	E22*	-	-	E32*	-	-	-	E37
ISP	E5	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	7	3	6	6	>7	4	>4	4	6	>4	3	3	4	4

Table 7.5: Assignment of Roles to Actor per Project (Grey: Primary Roles; Bold: Interviewees)

It is visible that most provider organizations had to rely on external organizations for taking on roles that can be broadly summarized under software development and system integration (projects 1, 3-5, 7-12). The UI/UX Design Specialist role was enacted in six projects, which indicates an awareness of the importance of smart service systems usability. The required skills were either found at the provider organization (projects 2, 6, 13) or acquired from external actors (projects 1, 4, 13). The Digital Innovator role is often (projects 1, 2, 5-7, 9, 13, 14) shared between the provider organization and external organizations. Interestingly, there is not a single project where the Digital Innovator role was held by an actor with no other roles. Instead, it was an additional role of actors who also assume the Project Sponsor, the System Integrator, the Application Software Provider, or even the Customer Representative role. In project 13, for instance, INTERNALIT and further consortium partners held the role of the Digital Innovator together and organized focus group discussions with customers.

External actors with the role of the Market Research Provider were involved when value propositions were targeted at large anonymous customer groups to get insights about demands and feedback on prototypes (projects 2, 5). For example, a "prediction market" was used to collect opinions on features and pricing from potential users of the smart parking service (project 5). Customers were involved by taking the role of the Customer Representative in all projects except 10 and 12. In project 11, the customer actor even assumed the role of the Digital Innovator as it provided the idea for the virtual reality training service to the provider organization PHARMACHINES. Our findings further illustrate that not only the customer but also the provider organization can take over the Customer Representative role in an SSSE project (projects 3, 4, 8, 9). This occurred when a service was intended to be used by the provider organization itself.

The Secondary Roles were frequently assumed by actors that were external to the actor with the Project Sponsor role. Hence, these roles represent competencies and resources that were often not available at the provider organization. Actors with Secondary Roles were integrated closely into the collaborative project work particularly if their work contributions had to be individualized for the respective project. However, these roles were often also taken by actors that had a Primary Role if they possessed the required competencies and resources. Other Secondary Roles refer to the provision of technical components of a smart service system. These contributions often comprise mature, well-defined products and services, for which effortful adaptations are neither possible nor required. Therefore, actors assuming these roles do not require active participation in the project work. Usually, the integration of these work contributions takes place by buying the products or services through standard market-based transactions.

7.4.5 Smart Service Innovation Patterns

From our analysis of the actor-role assignments and a reflection of the underlying dynamics during the service innovation processes, we identified four typical constellations, which we call *smart service innovation patterns*. These patterns indicate a certain strategic setup of an SSSE project. To distinguish these patterns, we looked at the assignments of roles to actors, which indicate their contributions of resources and competencies to the service ecosystem. We describe the patterns using our proposed set of roles and the defined actor types customer organization, provider organization, and external organizations. As IT-related competencies are split up into several roles, we simply use the term *IT provider organization* to denote actors with one or more of the following roles: System Integrator, Cloud Platform Provider, and Application Service Provider. Additionally, we provide a graphical model of an example service ecosystem for each pattern. These models show the involved actors as boxes, which are identified by their identifier as used in Table 7.5. Each actor has one or more roles assigned to it. They are represented using the short names of roles in small circles overlapping the actors. Any role that is not used in an ecosystem is displayed as *inactive* (in white with a dotted border). This indicates that the respective competency was not identified in this ecosystem, and hence, no actor was enacting this role.

The four patterns comprise Provider-driven Development, Joint Development, White Label Solution, and Forward Integration. In the ***Provider-driven Development*** pattern, a provider organization holds the Digital Innovator role. This actor initiates the creation of new value propositions. Another actor with the Customer Representative role may additionally assume the Digital Innovator role and contribute to the innovation process, e.g., through industry insights, requirements definition, and feedback. In this pattern, the IT provider organizations are only responsible for the technical implementation of the new service concept. Further external actors might be contracted to build and operate technical parts of the smart service system. Examples for this pattern include the electric vehicle charging service (project 3) and the fleet management for commercial vans (project 4; depicted in Figure 7.3). In the constellation described by this pattern, the provider organization as the driving actor needs to have strong innovation and project management competencies to create both the service concept and manage the actors required for the implementation and/or operation of the smart service system.

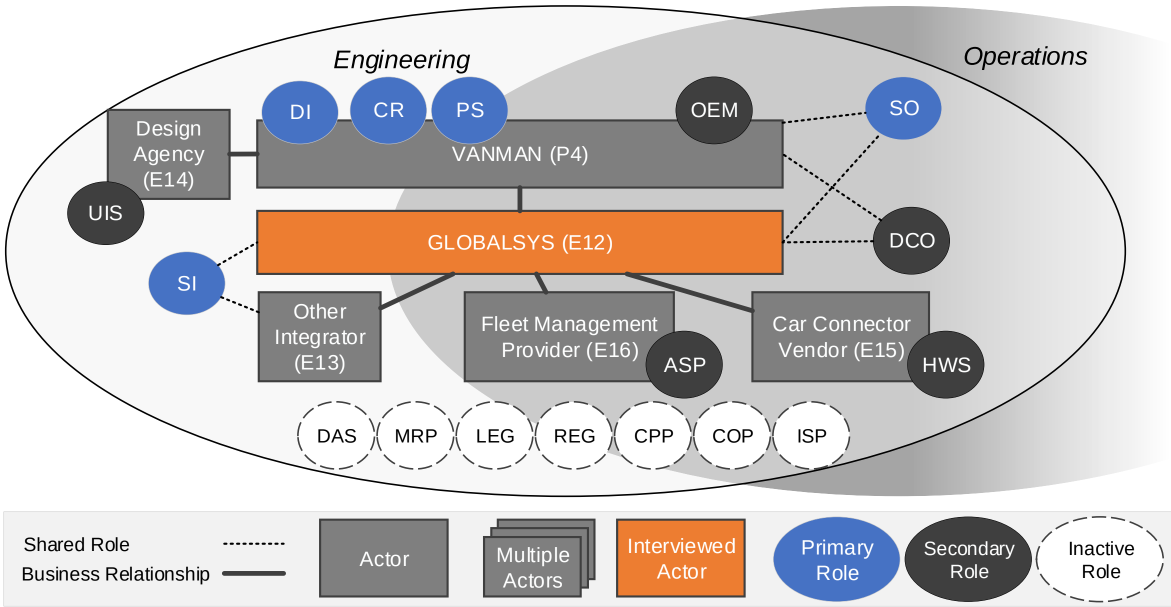

Figure 7.3: Example of the Provider-driven Development Pattern (Project 4)

In the ***Joint Development*** pattern, a provider organization works together with an external IT provider organization that usually holds the System Integrator role. Both actors share the Digital Innovator role. Hence, this setup requires digital innovation competencies at both actors. One example of this innovation pattern is project 7, which dealt with an integrated service for public transport information, ticketing, and subscriptions. Another example is project 13 in which an IT-subsidiary of a machinery manufacturer developed a predictive maintenance service. Finally, in project 9, a manufacturer of industrial doors developed a remote support service for its service department together with a digital business solution provider (Figure 7.4).

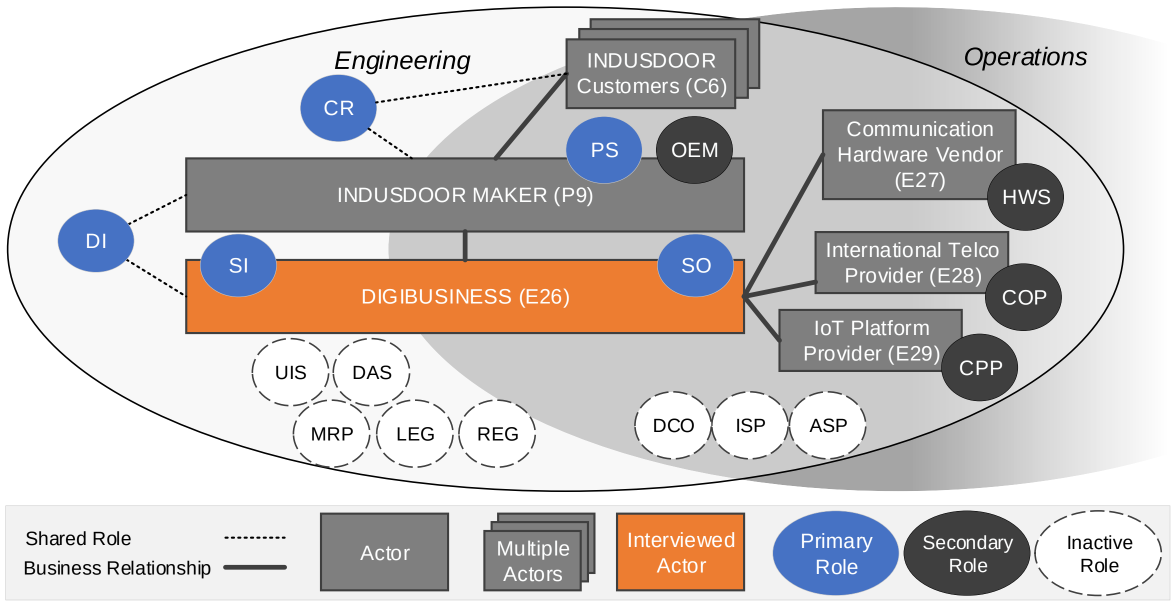

Figure 7.4: Example of the Joint Development Pattern (Project 9)

The ***White Label Solution*** pattern reflects an approach where IT provider organizations build innovative solutions on their own initiative to address a market potential that they identified. However, they do offer this service directly to the target customer, i.e., they are not the provider organization. Instead, they offer their solution to other actors, who are already active in the target markets. These provider organizations first assume the role of Project Sponsors to become Service Providers later. The provider organization and the IT provider organization share the role of the Digital Innovator, as they configure and customize the white label solution together. Examples include the energy distribution control service in project 1 (Figure 7.5), the diabetes prevention app in project 2, and the smart parking service in project 5.

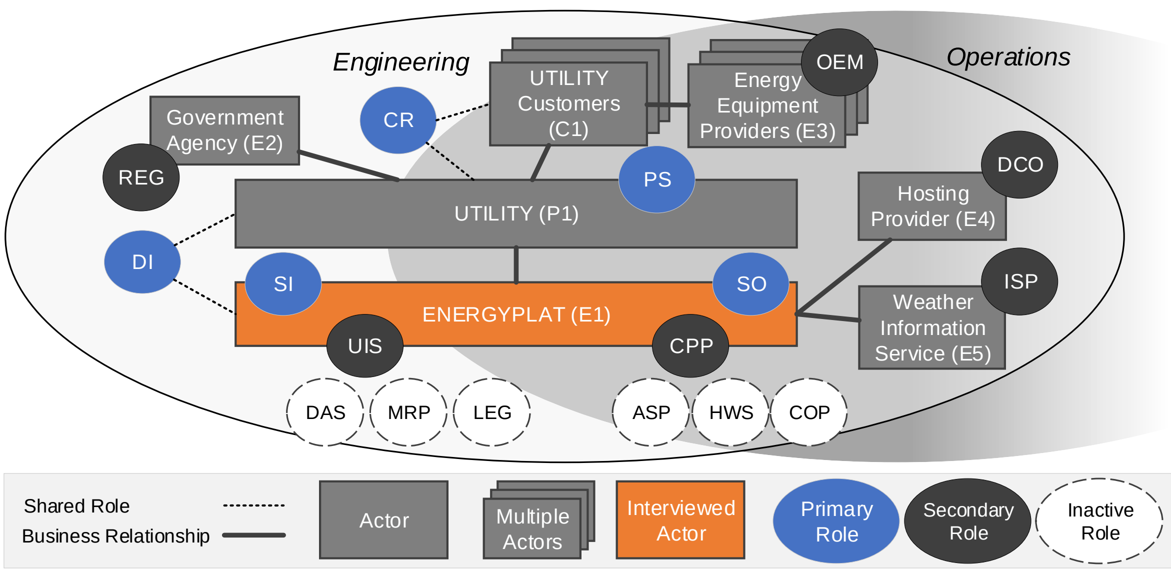

Figure 7.5: Example of the White Label Solution Pattern (Project 1)

The fourth pattern called ***Forward Integration*** goes even further, as the actor with strong IT resources and competencies does not only develop the smart service system on its own but also markets it to the target customers. The energy trading service (project 6) represents such a constellation. As Figure 7.6 shows, the ENERGYTRADE organization has the competencies to take on almost any role. The only exception is the provision of a cloud platform, which is sourced from an external actor. Another interesting aspect is that the Digital Innovator role is shared between ENERGYTRADE and its customers. In this case, one potential customer became a strategic development partner to ensure good access to knowledge about the energy trading domain.

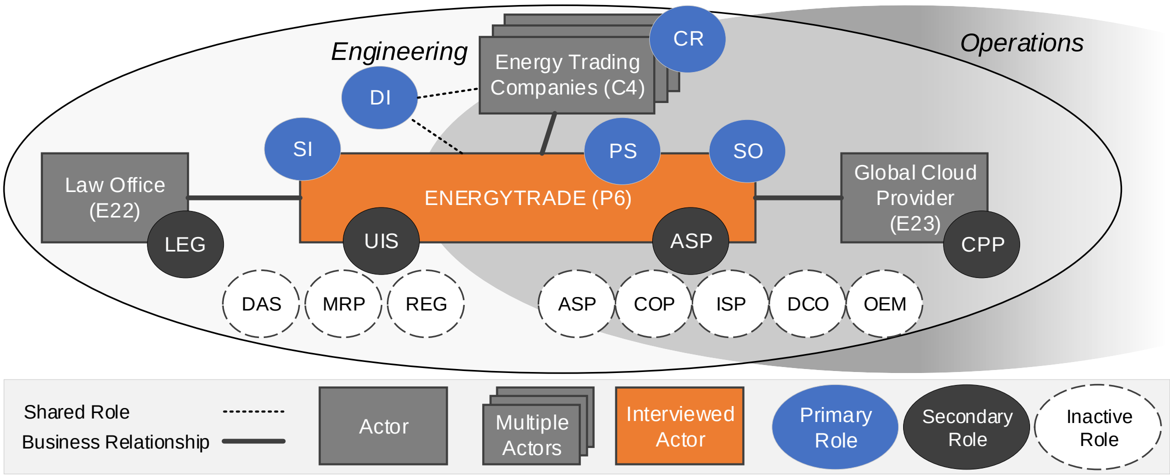

Figure 7.6: Example of the Forward Integration Pattern (Project 6)

Table 7.6 summarizes the patterns and their characteristics. As shown in the column *Projects*, we characterized most of the SSSE projects as *Provider-driven Development*. This pattern reflects a division of work between the involved actors where they largely stick to their original competencies. The provider organization knows its customers and the market and is, therefore, able to come up with new service ideas. In the *White Label Solution* pattern, firms with strong IT competencies offer a complete or customizable solution to empower other organizations to become providers of smart services. This might be their original business model if they are a startup (project 1) or an application software provider (project 2). However, if the focal actor usually holds the role of the System Integrator, this pattern makes them leave or extend their project-based integration business with time and material pricing. In either case, the provider of a White Label Solution needs to understand the target market very well and takes a higher risk compared to the Provider-driven Development pattern.

Our sample includes projects where provider organizations changed their business models in the course of smart service innovations. Specifically, projects 5 and 6 are examples of IT providers who shifted from traditional IT offerings to comprehensive value propositions for smart parking and energy trading. While both entered new markets, we considered project 6 as even more advanced as the IT provider organization decided to offer the service themselves and, hence, to take on the role of the Service Provider during Operations, whereas in project 5, the service was offered as a white label solution to enable another actor to have the role of the Service Provider.

7.5 Discussion

7.5.1 Contributions to Research

With this study, we contribute a set of 17 roles that actors of a service ecosystem can assume in smart service innovation. We further provide a systematization of roles into groups along two dimensions: (1) their relevance for SSSE (Primary and Secondary Roles) and (2) their involvement in either only the Engineering subsystem or both the Engineering and Operations subsystems. Regarding these subsystems, we illustrate the dynamics of role assignments to actors in SSSE projects and give an overview of the various constellations of roles and actors that we found in our sample of 14 SSSE projects. Based on the different constellations, we suggest four smart service innovation patterns that help us understand how very different actors of service ecosystems can use their agency, creativity, and strategic intent to innovate with smart service systems. We developed this set of contributions inductively based on the empirical data gathered through expert interviews.

Name	Characteristics	Projects
Provider-driven Development	▪ Service innovation takes mainly place at the provider organization with the designated Service Provider role, possibly in collaboration with (future) customers ▪ IT-related competencies are typically not available internally, corresponding roles are not taken on by the provider organization ▪ Strong innovation and project management capabilities are required at the provider organization ▪ High dependency on external know-how, especially from IT provider organizations with the System Integrator role, who are only responsible for the technical implementation ▪ Entrepreneurial risk at the provider organization	3, 4, 8, 10-12
Joint Development	▪ Service innovation is driven by the provider organization together with an external actor with the System Integrator role ▪ Both actors assume the Digital Innovator role together ▪ Lower requirements for innovation and project management capabilities at the provider organization due to external support ▪ Entrepreneurial risk at the provider organization	7, 9, 13
White Label Solution	▪ An actor with strong IT capabilities (i.e., an IT provider organization) develops, builds, and runs an innovative value proposition on its own ▪ The IT provider organization offers a white label solution for a common problem to (multiple) provider organizations ▪ The provider organizations, in turn, market the value proposition to their customers (i.e., they take on the Service Provider role) ▪ The provider organizations with the Service Provider role can offer innovative services with minimal effort for new service development ▪ The IT provider organization often follows a platform approach to provide customizable solutions for different provider organizations using reusable building blocks ▪ Entrepreneurial risk shared between the IT provider organization and the provider organization (with the Service Provider role)	1, 2, 5, 14
Forward Integration	▪ IT provider organization develops, builds, runs, and offers the innovative smart service system by itself ▪ This actor covers most of the relevant roles through internal resources and competencies ▪ The actor may target markets of former customers ▪ Entrepreneurial risk is at the IT provider organization	6

Table 7.6: Smart Service Innovation Patterns

This study yields important merits to research on smart service systems. It has been criticized that they “have mainly been envisaged from a practical and descriptive angle” and that there is “a clear priority for theoretical and empirical future research” on smart service systems (Djellal and Gallouj 2018, 17). Moreover, our study takes up the research priority of “leveraging technology to advance service” as put forward by Ostrom et al. (2015, 143) who suggest, amongst others, to examine “how the Internet of Things and smart services can enhance the customer experience and influence relationships between customers and service providers” (Ostrom et al. 2015, 143). However, while Ostrom et al. (2015, 143) mostly emphasize the impact of technology on "customer-company relationships", we ground our work in S-D logic and take the perspective of A2A networks that refrains from assigning narrow and predesignated roles to actors. Based on empirical insights from SSSE projects in our study, we contend that such a perspective is more appropriate to understand technology as a "game changer" that leads to "profound changes in customer experience and value cocreation; front-stage and back-stage service provision; and service organizations, networks, and service ecosystems." (Ostrom et al. 2015, 145)

As regards S-D logic, in particular, our conceptualization of roles offers a finer level of granularity of understanding roles in service ecosystems when focusing on smart service innovation. While the original S-D logic can be (mis)interpreted as being agnostic of distinct actor roles when all actors are uniformly conceptualized as resource integrators and co-creators of value (Vargo and Lusch 2016), Ekman et al. (2016) already made a distinction between inactive, passive and active as well as between provider and beneficiary roles that service ecosystem actors can assume "fluidly" (Ekman et al. 2016, 1), i.e., flexibly and simultaneously. By conceptualizing the contributions of actors into 17 distinct roles that we found relevant to smart service innovation, we went one step further and decreased the level of abstraction, which has been argued to be necessary to transfer theoretical perspectives on service ecosystems into actionable insights (Senn and Bruhn 2019). By decreasing the level of abstraction, we particularly intended to provide better descriptions and explanations of the specific states of service ecosystem structures and changes to institutional arrangements when digital technologies become "the fundamental source of strategic benefit" (Vargo and Lusch 2016, 8) as the fundamental premise 4 of S-D logic would put it. While our set of roles certainly is not "truly" generic (Ekman et al. 2016, 2) anymore, the roles are still grounded in S-D logic as we derived them based on the resources and competencies that actors bring into the exchange relationships of service ecosystems. Moreover, our results indicate that it takes multiple actors (more than only one or two) and hence a macro-context perspective (Chandler and Vargo 2011) with diverse roles to "actualize the potentiality of technology" (Vargo and Lusch 2016, 19) that smart service systems entail. A key reason for this can be seen in the „higher level of complexity in the process of endogenization or incorporation of technology in services" as smart service systems exhibit the "highest degree of [technology] infusion." (Djellal and Gallouj 2018, 16) Our empirical insights and the derived set of roles reflect this complexity of technology infusion in service ecosystems very well and, at the same time, point to the limits of too abstract role concepts that were suggested in previous studies. We thus contend that our more fine grained level of role conceptualizations helps in better understanding and explaining how actors "evolve from focusing on dyadic management of their relationships with customers to understanding and managing their role and contributions in many-to-many contexts involving value networks and service eco-systems, in which service provider-customer boundaries are blurring and multiple forms of service provision, by multiple network players, are possible." (Ostrom et al. 2015, 145)

When making sense of our empirical data, we adopted the latest contributions that conceptualize service innovation with a foundation in S-D logic. In particular, we referred to the structuration of the service innovation framework by Edvardsson et al. (2018) and added to the empirical validity of it. In particular, we did this in a context that is closely linked to the IoT, which was explicitly mentioned by Edvardsson et al. (2018) as one field of service innovation where it could serve as a conceptual foundation. The structuration of the service innovation framework integrates agency-driven and structure-driven concepts with states of the service innovation process. While the agency-driven concepts helped us in conceptualizing our set of roles, we applied the states of the service innovation process (initiating, realizing, and outcoming) and structure-driven concepts to illustrate the dynamics and patterns of role assignments. In particular, our findings support that "service innovation often takes place in cooperation between several actors contributing a wide range of resources." (Edvardsson et al. 2018, 100) The smart service innovation patterns that we derived further support the assumption that the "actors have different reasons to engage in innovative value co-creation" (Edvardsson et al. 2018, 100).

Other rather fine-grained models of roles in ecosystems have recently been suggested in technology-focused research fields, which can be considered adjacent to smart service systems. However, these do not focus on service innovation processes and the involvement of multiple actors in SSSE projects. They also provide rather static perspectives on ecosystems, while we were able to also illustrate the dynamics of roles during the service innovation process. For instance, the Passau Cloud Computing Ecosystem Model (PaCE) proposed by Floerecke et al. (2020) addresses the realm of cloud computing on a market level. Although our model addresses innovation processes, and not markets, some of the roles are similar, as smart service systems are often operated in cloud environments. For example, our Cloud Platform Provider role is similar to the Platform Provider in PaCE. Other similarities exist between Application Service Provider and Application Provider, and Data Center Operator and Infrastructure Provider. PaCE also proposes the roles of Hardware Developer and Network Operator, which are related to our Hardware Supplier and Connectivity Provider roles, however with relation to different types of hardware and connectivity. Finally, our Service Operator is roughly equivalent to PaCE's Managed Service Provider. In summary, PaCE is more differentiated in cloud-related roles than our model, while our set includes roles with a focus on smart service innovation.

While PaCE is a domain-independent model with a specific focus on cloud computing technology, two others are domain-specific. First, the model by Papert and Pflaum (2017) proposes ecosystem roles for IoT-based services in supply chain management. Project 8 of our sample would fit well in this domain, but it is only one SSSE project in the wider set of smart service innovation processes that we analyzed. Their model contains some domain-specific roles such as the Logistics Service Provider which point to the industry scope of their study, while we tried to conceptualize a set of roles that is generic across various industries. Still, a larger number of their roles also shows similarities to our set of roles. Examples include the IoT Platform Operator, Solution Integrator, and Telecommunication Infrastructure Provider. Comparing to our set of roles, the roles given by Papert and Pflaum (2017) tend to be more specific with regards to different technologies that are relevant to the IoT (e.g., IoT Platform Operator, Human-IoT-Interface Provider, and Middleware Provider). They also identify some roles that we did not derive from our interview data, e.g., Financial Intermediary or Research Institution. However, some of those roles seem to rather reflect specific actor types (e.g., Research Institution and Consultancy) than actual roles in our understanding. Our set of roles further comprises roles that we miss in their work, especially the Customer Representative. Second, Riasanow et al. (2020) also present a domain-specific conceptualization of roles from their investigation of the industrial IoT ecosystem (as one of five ecosystems they researched). This domain can also be related to smart service, especially as regards smart service systems in B2B contexts (like e.g., our projects 9, 10, 11, 12, and 13). We can again identify roles in their work that are similar to ours. Examples include Cloud Platform Provider, Manufacturer/OEM, Sensor- & Connectivity Provider, and IIoT Solution Provider. They also include the Customer in their generic IIoT ecosystem (Riasanow et al. 2020). Comparing with the two domain-specific works by Papert and Pflaum (2017) and Riasanow et al. (2020), our set of roles offers a contribution that is less specific to logistics or industrial settings. The similarities mainly illustrate the relevance of specific technologies from their domains for smart service innovation. At the same time, our set of roles extends the view into the social structures of service innovation as we were less focused on specific technologies or domains and, hence, approached smart service innovation from a broad, sociotechnical perspective. Nevertheless, we infer that our proposed set of roles is compatible with existing research in the areas of business and innovation ecosystems as it has intersections with existing models for cloud computing, smart logistics, and Industrial IoT. We consider these different perspectives on roles and ecosystems as complementary. Considering and integrating ecosystem models from different domains can be beneficial for academics and practitioners alike as it enables the planning, description, and analysis of complex structures that go across traditional industry boundaries. However, it is necessary to compare the role definitions in detail to identify potential differences even of roles with identical labels.

The identified *smart service **innovation patterns*** are actor-role constellations that describe certain strategic approaches to service innovation. Previous research has identified service innovation patterns that distinguish between Supplier-dominated Innovation, Innovation in Services, Client-Led Innovation, Innovation through Services, and Paradigmatic Innovation (den Hertog 2000). The first three patterns refer to the contributions of three types of actors: suppliers, the service firm, and the client firm, which are similar to the actor types that we defined in our study. The other two follow a different and superordinate rationale. We offer a conceptualization that is consequently derived from analyzing different roles of actors (and not only actors), i.e., actor-role constellations that reflect the required resources and competencies for smart service innovation. Furthermore, we provide a fresh perspective on service innovation patterns through the consideration of digital technologies as key sources of innovation.

Our empirical insights into real-world SSSE projects further inform ongoing discussions on approaches and methods for service systems engineering (Böhmann et al. 2014; Beverungen et al. 2018). In particular, we were able to identify characteristics of ***recombinant service system engineering*** (Beverungen et al. 2018) in our sample of SSSE projects, as the actors reused and recombined existing resources, and digital components in particular, for the realization of new value propositions. Examples are manifold and include the reuse of a ticketing app, which was adapted to additionally sell "charging tickets" for electrical vehicles (project 3), the reuse of an existing app for diabetes prevention as part of a health insurance service portfolio (project 2), the integration of various applications for ticketing, travel information, and subscription processing in public transport (project 7). Two of our service innovation patterns, that is, White Label Solution and Forward Integration, further illustrate that reusable digital resources are deliberately build up by actors in order to enable other actors or the actors themselves for recombinant service system engineering. In project 5, for instance, GLOBALSYS designed the smart parking service platform in a way that it can be reused for other cities. These patterns also emphasize the relevance of *digital platforms* for smart service systems, which is underlined by our conceptualization of the Cloud Platform Provider role. Platforms can be interpreted as a key driver for reducing time-to-market and technical complexity through the reuse of functionality and recombination of existing service components. However, platforms can also create strategic dependencies and reduce competitive advantages through standardization (Hevner and Malgonde 2019), at least for some actors in the service ecosystem like actors that traditionally assumed the

Service Provider role. While some actors used platforms as part of their technical design to reduce development costs and simplify operations (projects 6 and 9), ENERGYPLAT followed this approach consequently by becoming a platform provider itself (project 1).

7.5.2 Limitations

Due to the qualitative-empirical and exploratory character of our study, the following *limitations* must be considered. First, our conceptualization of roles in SSSE projects is grounded in data from only 14 expert interviews. While we achieved to interview experts from a broad range of different SSSE projects in diverse settings, these can neither be considered comprehensive nor representative for smart service innovation in general. Investigating further examples of smart service innovation processes and going beyond the realizing state of such processes, might lead to the identification of additional roles. In particular, the outcoming state of service innovation and, hence, the Operations subsystem was not in our scope. Future research will likely identify further roles that are specifically relevant to ongoing operations of smart service systems as well as the market diffusion and scaling up of value propositions. Second, most of the experts represented IT companies, which were contracted by other actors holding the Project Sponsor role (and aiming at the Service Provider role in the Operations subsystem). Thereby, we were able to ensure a high likelihood that our sample of experts can truly report on collaborative multi-actor project settings. At the same time, this might have introduced a bias towards such settings, where service provider organizations rely on external partners. Third, we only interviewed one expert per project, which limits the available information to her/his single, personal perspective. Therefore, it is likely that especially in large and complex ecosystems, only partial structures could be revealed. Fourth, the proposed roles resulted from our subjective interpretation of the interview data. Although we discussed the definition of roles intensively with all three researchers involved, other researchers might have come to a different conceptualization of roles. Fifth, we were not able to assess the influence of certain actor-role constellations on the overall (perceived) success of the project or even the operating smart service system later on. Most SSSE projects in our sample were in the late stages of the Engineering subsystem or the early stages of market tests. Therefore, we recommend investigating them again at a later point in time to gain insights into the influence of the project setup on project success. These limitations imply that our results should not be conceived as a normative set of roles in the sense of common, good, or best practices.

7.5.3 Practical Implications

The *practical implications* of our findings relate to innovation management, project management, and strategic issues. First, our results show that smart service innovation takes place through the collaboration of multiple actors, who form networks or become part of service ecosystems. We conclude that establishing, analyzing, and managing such networks is of high importance, especially for the service provider organization as the focal actor. Correspondingly, *innovation management* at a service firm is not only about developing and realizing new value propositions (with an output perspective) anymore, but increasingly involves network management activities. To better accomplish these activities, our proposed set of roles helps to describe current and future network constellations required for the realization of smart service systems. The set of roles also allows us to describe increasingly complex and dynamic networks, e.g., when there are multiple target customer groups, even including the provider itself.

Regarding *project management*, our proposed set of roles can be used as a reference to identify the roles and contributions that might be needed for an SSSE project and whether these can be sourced internally or hired externally. Furthermore, the complexity of project setups in our sample shows that efficient measures for managing the collaboration are needed. *Strategically*, the organization with the Service Provider role must decide upon which of the required skills, knowledge, and services it wants to build up internally and which ones are to be sourced externally. In this regard, intellectual property rights also must be considered, e.g., agreements on the non-disclosure of business ideas, technical concepts, and other potential sources of competitive advantage. As a starting point, the proposed smart service innovation patterns might help to assess the position of an actor in the ecosystem and identify potential strategic dependencies as well as options on how to organize innovation with a given set of organizational resources and competencies. Additionally, the set of roles can help to identify different and conflicting strategic directions of partners that might have to be aligned, e.g., when actors with the Cloud Platform Provider role rely on usage fees and aim to standardize and scale up their offering across multiple A2A networks while the actor with the Service Provider role intends to provide a customer-individual service.

7.6 Conclusions and Outlook

The purpose of this article was to investigate actor-role constellations in service innovation processes that aim at developing new value propositions through smart service systems. We did this through a qualitative-empirical interview study with a theoretical grounding in S-D logic. This article suggests that the development of smart service systems is a collaborative effort of multiple actors with complementary resources and competencies. We further assumed that actors could hold different roles during service innovation processes and especially in SSSE projects. In particular, we were interested in the roles that are assumed by the multiple actors who are involved in SSSE projects. We further tried to identify patterns of smart service innovation by comparing the different actor-role constellations of SSSE projects.

Our empirical data confirmed that all investigated projects required the collaboration of multiple actors, that is, an inter-organizational collaboration that goes way beyond common dyadic perspectives of a service provider and a customer. We developed a set of 17 roles that reflect the required resources and competencies of actors who engage in the development of smart service systems. Our proposed set of roles extends existing theoretical and empirical knowledge about smart service systems through an abstraction of resources and competencies that are relevant in SSSE projects. These roles can be applied to describe and explain why and how larger sets of actors in service ecosystems integrate and reconfigure complementary resources and competencies during smart service innovation processes. We found that actors can assume different roles and that roles can be assumed by and be spread across various actors. Through the analysis of such different actor-role constellations that we found in our interview data, we also identified four patterns of smart service innovation. These reflect different institutional arrangements within service ecosystems and help to illustrate the variety of strategies that can be followed by actors.

With our contributions, we aim to advance the understanding of smart service systems and stimulate future research, especially as regards the collaborative engineering through multiple actors in service ecosystems. Practitioners already benefit from a lexicon of roles that can help to express the different needs of resources and competencies for their projects. Furthermore, the identified smart service innovation patterns help to better understand the strategic dependencies between actors and can support decision-making as regards the future development of core competencies that can be of superior value to the actor itself and other beneficiaries. Researchers might use our results as an inspiration and starting point to further investigate the dynamics and service-for-service exchanges of A2A networks where digital technologies invoke changes to institutional arrangements. In particular, we see the need for more detailed analyses of the identified roles to understand their work contributions to SSSE projects, their strategic intents, and their positions in service ecosystems even better. At the same time, it is not only about contributions, but also benefits from being part of SSSE projects. Hence, the typology of roles by Ekman et al. (2016) could be adapted to provide an additional perspective on the actor-role constellations in SSSE projects. This implies that the different exchange relationships between actors need to be analyzed more thoroughly. Here, role-linkage models in business networks according to Kambil and Short (1994) or value co-creation mechanisms as proposed by Autio and Thomas (2018) could provide appropriate lenses for such analyses. Further research is also necessary to advance method support for service systems engineering (Böhmann et al. 2014; Beverungen et al. 2018) in a way that it sufficiently considers the multi-actor characteristics of SSSE projects. One way of achieving this could be to advance and extend modeling methods for business networks like e3value or REA (Schuster and Motal 2009). At the same time, current service engineering methods hardly consider inter-organizational collaboration, further research is also needed to advance them accordingly (Beverungen et al. 2018; Hagen et al. 2018; Dreyer et al. 2019).

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8 Iterative Uncertainty Reduction in Multi-Actor Smart Service Innovation

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Abstract: Smart service innovation is the process of reconfiguring resources, structures, and value co-creation processes in service systems that result in novel data-driven service offerings. The nature of such offerings requires the involvement of multiple actors, which has been investigated by a few studies only. In particular, little is known about the multiple actors' efforts to manage uncertainty in the process of establishing smart service systems. Empirically grounded in data from 25 interviews with industry experts, we explore how organizations act and interact in smart service innovation processes. For our data analysis, we adopt a microfoundational view to derive a theoretical model that conceptualizes actor engagement as a microfoundation for iterative uncertainty reduction in the actor-to-actor network of the smart service system. Our study contributes to information systems research on service systems engineering and digital transformation by explaining smart service innovation from both a multi-actor and a multi-level perspective, drawing on service-dominant (S-D) logic and microfoundations as well-established theoretical lenses.

8.1 Introduction

Smart service innovation can be a part of digital innovation and transformation initiatives that organizations pursue to strengthen their competitive positions (Klos et al., 2021; Vial, 2019; Wessel et al., 2020; Wiesböck & Hess, 2020). They appropriate digital technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and cloud computing as enablers for changing service systems into smart service systems (Beverungen, Müller, et al., 2019; Parida et al., 2019; Sjödin, Parida, Jovanovic, et al., 2020; Vial, 2019). Smart service systems connect things and people, collect and process data, are capable of independent learning, adaptation and decision making, and thereby automate and facilitate value co-creation in actor-to-actor networks (Beverungen, Breidbach, et al., 2019; Maglio & Lim, 2018; National Science Foundation, 2014). Smart service innovation denotes the process of changing the resource configurations, structures, and value co-creation processes of smart service systems (Anke, Poeppelbuss, et al., 2020b; Breidbach & Maglio, 2015; Edvardsson & Tronvoll, 2013; Vargo et al., 2010).

We can observe examples of smart service innovation in various contexts. In consumer markets, car manufacturers connect vehicles with digital platforms to analyze driving behavior based on sensor data, schedule workshop appointments, provide usage-based insurance, or give feedback on driving behavior

(Beverungen, Breidbach, et al., 2019; Husnjak et al., 2015). In industrial contexts, manufacturing firms innovate by combining digitally connected machines and equipment with value propositions like condition monitoring, predictive maintenance, remote service and control, and fleet management (Herterich et al., 2015). In both consumer and industrial contexts, a change in value propositions can go hand in hand with a change in value capture when revenue models divert from transactional product and service sales towards more relational and long-term approaches such as subscriptions, pay-per-use, and performance-based contracting (Coreynen et al., 2017; Paiola & Gebauer, 2020; Weking et al., 2020). Statistical data underpins the economic relevance of smart service innovation. Germany, for instance, envisions a productivity increase of more than 30 percent by 2025 compared to 2015 by connecting machines, systems, and factories to the Internet and thereby forming a so-called "Smart Service World" (acatech, 2015). The market volume for vehicle-based connected services in the USA and Europe is expected to rise from USD 4.7 billion and USD 2.5 billion in 2020 to around USD 22 billion and USD 14 billion respectively by 2030 (PwC, 2019).

Smart service innovation has become a central theme of information systems research over the last years (Beverungen, Breidbach, et al., 2019; Yang et al., 2021) with links to many other disciplines including services marketing (Paluch & Tuzovic, 2019; Wünderlich et al., 2013, 2015), industrial marketing management (Sjödin, Parida, Kohtamäki, et al., 2020; Sklyar et al., 2019), innovation management (Maglio & Lim, 2016), and industrial engineering (Rabe et al., 2018), amongst others. The information systems discipline is considered to be particularly suitable to study the systematic development of smart service systems due to its interdisciplinary nature (Böhmann et al., 2014). In this context, the term service systems engineering (SSE) is used to emphasize “a departure from traditional service engineering research” (Böhmann et al., 2014, p. 74) “towards systemic, interactive and collaborative service innovation based on advances in IT” (Böhmann et al., 2014, p. 74) that adopts the ideas of service systems (Beverungen et al., 2018; Maglio et al., 2009) and service ecosystems (Vargo & Lusch, 2016, 2017; Vink et al., 2021). Following this line of thought, Höckmayr and Roth (2017) formulate requirements for SSE methods that include, amongst others, the imperative to “address larger constellations within which multiple actors become joined over time and space” and to “acknowledge the role of knowledge and skills applied by various actors” in service innovation (Höckmayr & Roth, 2017, p. 5). Referring to digital transformation more broadly, Alt (2019) similarly calls for methodologies that cover an ecosystem-wide perspective that integrate aspects of business and technological change.

Applying an ecosystem's perspective is meaningful as smart service innovation requires the involvement of multiple actors (Anke, Poeppelbuss, et al., 2020b; Ekman et al., 2016; Schymanietz & Jonas, 2020; Vink et al., 2021). Organizations need to collaborate across their boundaries as the components of a smart service system are usually designed to “operate and interact with the solutions offered by many other manufacturers, used by customers, delivered by distributors, maintained by different service partners, and operated by third parties" (Kohtamäki et al., 2019, p. 381). Collaborative smart service innovation can affect the engagement of an organization with its customers fundamentally (Abrell et al., 2016; Chowdhury et al., 2018; Jussen et al., 2019; Storbacka et al., 2016), e.g., by involving them as co-designers (Jonas et al., 2018; Martinez et al., 2010). The infusion of advanced and complex digital technologies in smart service systems is likely to require partner organizations who are specialists in systems integration, user experience design, cloud computing, data analytics, or platform business, all of which are usually not available within the same organization (Anke, Poeppelbuss, et al., 2020b; Djellal

& Gallouj, 2018; Sklyar et al., 2019). Finally, external facilitators can help to guide actors through smart service innovation processes, e.g., by establishing innovation processes, organizing workshops, and managing innovation projects (Anke, Poeppelbuss, et al., 2020b; Schymanietz & Jonas, 2020). Academia has just begun to investigate smart service innovation from such a multi-actor perspective that goes beyond the single focal organization or the dyadic perspective of a provider and a customer actor, e.g., by identifying the roles of diverse actors in smart service innovation processes (Anke, Poeppelbuss, et al., 2020b; Ekman et al., 2016; Ostrom et al., 2015; Schymanietz & Jonas, 2020; Vink et al., 2021).

Multi-actor smart service innovation is beset with uncertainty as it happens in "fast-changing real-world environments" (Grotherr et al., 2018, p. 3). Uncertainty means that the multiple actors involved may not have the necessary understanding to make decisions as future states of the smart service system may be highly variable or unpredictable (Ramirez Hernandez & Kreye, 2020). The innovation process can be affected by different types of uncertainty (Ramirez Hernandez & Kreye, 2020). For instance, environmental uncertainty can lead organizations into both service and digitalization paradoxes, when substantial investments in extending the digital service business fail to deliver greater profits because of spiraling cost increases and a lack of customer understanding or willingness to pay (Gebauer et al., 2005; Sjödin, Parida, Kohtamäki, et al., 2020; Wolf et al., 2020). Relational uncertainty can result in ambiguity, opportunism, or conformity issues due to the unpredictable behavior of collaborating actors (Ramirez Hernandez & Kreye, 2020). In their recent study, Sjödin et al. (2020) find that organizations employ iterative and agile ways of working to deal with complexity and reduce uncertainty. They explicitly call for future research that takes a multi-actor perspective as broader sets of ecosystem actors shape value creation in times of digital transformation (Sjödin, Parida, Kohtamäki, et al., 2020).

This qualitative-empirical interview study intends to uncover and explain how the activities of the broader set of actors engaged in smart service innovation relate to uncertainty reduction in the overall smart service system. We approach this relationship through the theoretical lens of microfoundations (Foss, 2016; Haack et al., 2019; Storbacka et al., 2016), which helps us to explain how meso-level outcomes (i.e., the smart service system and related uncertainty) are linked to the activities of actors (i.e., organizations) at the micro-level. Accordingly, we pose the following research question: ***What are the microfoundations of uncertainty reduction in multi-actor smart service innovation?***

To answer this research question, we conducted an interview study with 25 interviews. Through a grounded-theory-based interpretive data analysis (Gioia et al., 2013), we derived a multi-level theoretical model of multi-actor smart service innovation that identifies smart service innovation uncertainty as a property of actor-to-actor relationships on the meso-level, and observable activities of actors on the micro-level. We conceptualize these micro-level activities into the four aggregate dimensions of (1) ***managing multi-actor complexity***, (2) ***crafting a smart service offering***, (3) ***developing a technical solution***, and (4) ***ensuring economic viability***. We found that these activities are carried out by the involved actors under conditions of uncertainty resulting in iterative uncertainty reduction, affecting the smart service system as the innovation outcome.

Our study yields the following contributions: First, we answer recent calls for research by investigating smart service innovation from a perspective that goes beyond a single organization or provider-customer dyads and instead considers systems of actors (Ostrom et al., 2015; Sjödin, Parida, Kohtamäki, et al., 2020). Second, we add another level of detail to our understanding of smart service innovation by adopting the framework of Storbacka et al. (2016) to investigate actor engagement at the micro-level of smart service innovation. That is, we go beyond existing studies that remain on macro- and meso-level perspectives when they empirically analyze generic roles (Ekman et al., 2016) and actor-role constellations in smart service innovation (Anke, Poeppelbuss, et al., 2020b). Third, by empirically investigating smart service innovation processes on a micro-level, we contribute to providing evidence-based design knowledge that can help advance SSE and digital transformation methodologies (Alt, 2019; Böhmann et al., 2014; Höckmayr & Roth, 2017). Finally, we identify smart service innovation uncertainty as a meso-level property and iterative uncertainty reduction as a core category from our interview data. Thereby, our findings link the previously separate research streams of innovation uncertainty (Jalonen, 2012; O'Connor & Rice, 2013) and smart service innovation (Anke, Poeppelbuss, et al., 2020b; Beverungen et al., 2018). The practical implications of our study consider the staffing and collaboration management of innovation projects in multi-actor settings, the use of agile methods, as well as ensuring customer-centricity and economic viability as central objectives of managing smart service innovation uncertainty.

The remainder of this article is organized as follows. In the "research background" section, we introduce key concepts related to multi-actor smart service innovation, innovation uncertainty, and the multi-level perspective inherent to microfoundations. Then, we explain our "research approach". The "findings" section presents our insights from the interviews along the four aggregate dimensions and the core category that leads to an integrated theoretical model in the end. Next, we provide a discussion of our theoretical contributions, study limitations, and practical implications ("Discussion" section). The article closes with conclusions and an outlook towards promising avenues for future research (Conclusions and Outlook section).

8.2 Research Background

8.2.1 Multi-Actor Smart Service Innovation

Smart service innovation is a particular kind of service innovation with smart service systems as its context. Service innovation, in general, is the process of changing the resource integration patterns of a service system in a way that is valuable to the actors involved (Edvardsson & Tronvoll, 2013; Storbacka et al., 2016; Vargo et al., 2010) and perceived as new and as an improvement considering the actors' context (Jalonen, 2012). The outcome of service innovation processes can touch upon multiple dimensions (Plattfaut et al., 2015), including the general service concept or value proposition, client interfaces or touchpoints, delivery system and use of technology (de Jong & Vermeulen, 2003), business partners and revenue models (den Hertog et al., 2010), as well as institutions and institutional arrangements (Edvardsson et al., 2018; Koskela-Huotari et al., 2016; Vargo & Lusch, 2016). Smart service innovation processes put a natural focus on the use of digital technology in service systems, but they usually also affect multiple of the other dimensions when they aim to establish new and better ways of co-creating data-driven value (Beverungen, Müller, et al., 2019; Djellal & Gallouj, 2018; Edvardsson et al., 2018; Maglio & Lim, 2018). Hence, the outcome of smart service innovation can manifest in a substantial change of an actor's business model (Barrett et al., 2015; Paschou et al., 2020; Wünderlich et al., 2015) as well as in the collective shaping of service ecosystems by multiple actors (Vink et al., 2021).

Especially in the context of digital transformation, it is argued that innovation outcomes rather evolve from a network of actors (including the customer but also other actors) than from a single organization alone (Lusch & Nambisan, 2015). Thus, service innovation often involves the cooperation of multiple actors who contribute diverse resources to the service system (Edvardsson et al., 2018; Schymanietz

& Jonas, 2020) and whose interplay during the innovation process influences subsequent events (Jalonen, 2012). This complex, dynamic and multi-actor nature of value cocreation and service innovation is central to S-D logic's service ecosystems perspective (Vink et al., 2021). Following S-D logic, "innovation is not about inventing things but about developing systems for value cocreation" (Vargo & Lusch, 2017, p. 54). Taking up these lines of thought, Edvardsson et al. (2018) emphasize that service innovation has to be viewed from the perspective of multiple actors and the institutional arrangements they are embedded in.

The term *actor* refers to any market participant that is involved in actor-to-actor exchanges that create mutual value (Vargo & Lusch, 2016). Hence, it can refer to human individuals or collections of humans, such as firms or organizations (Storbacka et al., 2016; Story et al., 2011), all of which can be understood as service systems themselves (Maglio et al., 2009). Actors can be internal or external to a focal organization (Schymanietz & Jonas, 2020), with internal actors usually referring to different entities, roles, and functions within an organization, e.g., sales and service personnel, top management, or local branches (Schymanietz & Jonas, 2020). Storbacka et al. (2016) further argue that machines and technologies should also be considered as actors due to current advances in autonomous technologies that reshape actor-to-actor interactions. *Roles* can be defined as "distinct technologically separable, value-added activities undertaken by firms or individuals" (Kambil & Short, 1994, p. 10) that reflect "clusters of behaviors expected of parties in particular statuses or positions" (Knight & Harland, 2005, p. 282). Actors can have multiple different roles simultaneously and the assignment of roles to actors can change dynamically over time (Ekman et al., 2016; Storbacka, 2019). Storbacka (2019) further argues that digitalization increasingly blurs previously strict actor roles (e.g., customer vs. non-customer, producer vs. consumer, or seller vs. buyer) and that all actors, viewed from an abstract viewpoint, have comparable processes of engagement in actor-to-actor relationships, reflecting the idea of generic actors in S-D logic (Vargo & Lusch, 2011). This idea, however, does not imply that all actors are identical. Rather, S-D logic refrains from assigning predefined or static roles to actors (Vargo & Lusch, 2016).

Recent research has already shed some light on the roles of actors in smart service innovation and related fields and how they can change dynamically (Anke, Poeppelbuss, et al., 2020b; Ekman et al., 2016; Floerecke et al., 2020; Papert & Pflaum, 2017; Riasanow et al., 2020; Schymanietz & Jonas, 2020). Anke et al. (2020b) specifically look at the roles that different organizations can hold in a service ecosystem for smart service innovation. They distinguish between three types of actors: customers (both individuals and organizations), provider organizations (those organizations that intend to provide a novel smart service offering to customers), and external organizations (which mainly refer to IT service providers and IT consultants in their study). They identify 17 roles in total that these actors can assume. These are grouped into primary (e.g., Project Sponsor, Digital Innovator) and secondary roles (e.g., Customer Representative, Data Analytics Specialist, Cloud Platform Provider). Other studies identify roles with a stronger focus on digital technologies, including the Internet of Things (IoT) services in supply chain management (Papert & Pflaum, 2017), the cloud computing ecosystems (Floerecke et al., 2020), and role clusters in platform ecosystems (Riasanow et al., 2020).

8.2.2 Innovation Uncertainty

The evolution of service ecosystems is considered to be non-linear and dynamic, and "filled with risk and uncertainty" (Vargo & Lusch, 2017, p. 61) Uncertainty is inherent to any innovation process (Jalonen, 2012) and, hence, also to smart service innovation. Despite the positive connotations associated with the concept of innovation, it has been described as a process of muddling through where the involved actors step into the unknown (Hurst, 1982; Jalonen, 2012; Rehn & Lindahl, 2012). Uncertainty, in general, can be considered as a potential deficiency in any phase or activity of a process that is not definite, not known, or not reliable (Kreye et al., 2012). It is usually distinguished from the notion of risk in that no probability can be assigned to uncertainty, while risk is defined as a measurable unknown (Jalonen, 2012).

For the smart service innovation process, uncertainty means that the multiple actors, who engage with each other, may lack the necessary understanding to make decisions because future states of the smart service system may be highly variable and unpredictable (Kreye et al., 2012; Ramirez Hernandez & Kreye, 2020). The speed of technological developments, rapid changes in customer requirements, and competitive developments in the market have been identified as potential sources of uncertainty in service innovation (van Riel et al., 2004). In a smart service system, uncertainty can also arise because actors are required to manage interdependencies of product logic and service business logic in parallel (Ng et al., 2012; Ramirez Hernandez & Kreye, 2020). The involvement of multiple actors further increases complexity in the supplier network as well as uncertainty regarding the appropriate strategic level of supplier collaboration (Ramirez Hernandez & Kreye, 2020). In the end, all of this renders the future realization of potential value to the various beneficiaries of a smart service system uncertain. In fact, substantial investments in extending the digital service business may not yield the required profits to be economically sustainable (Gebauer et al., 2005; Sjödin, Parida, Kohtamäki, et al., 2020).

Uncertainty is commonly understood as a multidimensional concept. Existing literature describes different factors, types, or categories of uncertainty in innovation processes (Jalonen, 2012; O'Connor & Rice, 2013; Ramirez Hernandez & Kreye, 2020). In the context of multi-actor service systems, Ramirez Hernandez and Kreye (2020) develop a conceptual framework of five uncertainty types, which are environmental, technical, organizational, resource, and relational uncertainty (Table 8.1). Generally, a categorization of sources and types of uncertainty is difficult because they are interdependent (Jalonen, 2012; O'Connor & Rice, 2013). This becomes evident from innovation processes where technological developments (e.g., in terms of a smart product) are combined with the market introduction, adoption, and dissemination of digital service offerings (Jalonen, 2012), which is common for smart service systems.

Ramirez, Hernandez, and Kreye (2020) investigate case studies of inter-organizational multi-actor settings and analyze the influence of two different supplier co-creation modes on the criticality of the various uncertainty types (Table 8.1). The main difference between these two modes is whether the majority of the service innovation process is mainly done in-house of the focal organization with some non-critical input from other actors only, or if multiple actors share responsibility and exhibit close cooperation during the innovation process (Ramirez Hernandez & Kreye, 2020). In the latter case, actors take the responsibility for subsystems (e.g., a product or service component, or software), with a need for subsequent integration into the overall service system. According to their case study findings, the mode with close involvement and shared responsibility shows higher levels of criticality for technical and relational uncertainty. However, this mode enables the focal organization to reduce resource uncertainty through a deeper engagement with other actors (Ramirez Hernandez & Kreye, 2020). Environmental and organizational uncertainty appear to be always of high criticality independent of the co-creation mode. The two modes show similarities to the distinction of Anke et al. (2020b) regarding the involvement of actors with primary and secondary roles in smart service innovation.

These modes indicate that actor engagement in a service ecosystem can differ according to different forms of resource contributions and that the management of actor engagement is a strategic priority (Storbacka, 2019).

Uncertainty Type	Description
Environmental	▪ Unpredictability and variability of the external environment including customers, competitors, suppliers, and larger macro-developments in the industry ▪ Supply and demand uncertainty ▪ Changes and disruptive effects on markets and the competitive landscape
Technical	▪ Degree of understanding required knowledge ▪ Design of a cost-efficient, reliable, and manufacturable technology platform (e.g., the smart product) ▪ Complexity due to customization of the service part ▪ Complexity of interface management
Organizational	▪ Variability of the internal organization including the development team and the wider organization ▪ Unpredictability of the strategic and operational flexibility of an organization ▪ Changes in the strategic importance of a service offering concerning the organization's goals ▪ Increased complexity in navigating the difference in the business logic between product and service-centered businesses ▪ Understanding of novel roles, functions, and processes required for a new offering
Resource	▪ Unknown availability of appropriate financial, technical, and human resources used during development ▪ Variability in resource availability and unpredictability in resource attraction ▪ Ability to source capabilities and resources
Relational	▪ Unpredictability of a collaborator's actions due to lack of understanding of the partner's attitudes, feelings, and behavior ▪ Conflicts caused by ambiguity, opportunism, or conformity issues

Table 8.1: Uncertainty Types (Ramirez Hernandez & Kreye, 2020)

Literature from different academic fields has discussed strategies to manage uncertainty (Miller, 1992; Simangunsong et al., 2012; Sniazhko, 2019). Simangunsong et al. (2012) distinguish between the two broad categories of *reducing uncertainty* and *coping with uncertainty*. While the former strategies intend to reduce uncertainty at its source (e.g., by applying pricing mechanisms to reduce customer demand fluctuation), the latter tries to find ways to adapt and minimize the impact of uncertainty (e.g., through advanced forecasting techniques to predict customer demand (Simangunsong et al., 2012). Existing studies show that information gathering is a key strategy that supports the reduction of decision-making uncertainty in service innovation processes, which, in turn, is associated with the likelihood of innovation success (van Riel et al., 2004). In the context of digital servitization, Sjödin et al. (2020) suggest incremental investments, sprint-based developments, and 'learning by doing' to manage uncertainty when developing customized and scalable digital service offerings. Apart from uncertainty management strategies, Ramirez Hernandez and Kreye (2020) introduce the concept of *uncertainty reallocation*, which reflects that the variation of supplier co-creation modes as described above can shift the criticality between specific uncertainty types. For instance, actors might engage in relationships with others in seeking to reduce uncertainty but might fuel relational uncertainty at the same time (Jalonen, 2012).

8.2.3 Multi-level Perspective on Managing Uncertainty in Smart Service Innovation

The service ecosystems perspective of S-D logic implies that networks of actors can be seen at various levels of aggregation since service systems and ecosystems can be nested and overlapping (Vargo & Lusch, 2017). Already when Spohrer et al. (2008) defined the service system as "a dynamic value co-creation configuration of resources, including people, organizations, shared information (language, laws, measures, methods), and technology, all connected internally and externally to other service systems by value propositions" (Spohrer et al., 2008, p. 318), they explained that their definition applies to entities at different levels of aggregation, ranging from the lowest level of individual humans as atomic service systems to the global economy. The service ecosystem concept further implies that more than two social actors interact with each other to co-create value (Vargo & Akaka, 2012), which implies a departure from a dyadic view on value co-creation to more complex actor-to-actor networks as explained above. Following these thoughts, we view a service ecosystem as a service system at a higher level of aggregation that is a supra-system of other service systems (e.g., actors like individuals or organizations); or put differently as "systems of systems" (Storbacka et al., 2016, p. 3009). Disentangling the levels of aggregation, Vargo and Lusch (2017) suggest distinguishing between dyadic exchanges on a micro-level (e.g., transactions and sharing) and more complex constellations of direct and indirect exchanges on a meso- (e.g., triads, networks, industries, markets) and a macro-level (e.g., society) of aggregation. They also strictly separate between levels of aggregation and levels of abstraction. The latter refers to theoretical levels, where S-D logic resides on a meta-theoretical level with ambitions to serve as a general theory of the market and value co-creation (Vargo & Lusch, 2017).

Taking a multi-level perspective on phenomena is at the heart of the microfoundations movement in strategic management and organization theory (Felin et al., 2015; Haack et al., 2019; Storbacka et al., 2016). Microfoundations locate "the proximate causes of a phenomenon (or explanations of an outcome) at a level of analysis lower than that of the phenomenon itself" (Felin et al., 2015, p. 587). That is, the actors, processes and/or structures at the micro-level may interact or operate alone to influence phenomena at the next upper (e.g., meso- or macro-) level (Felin et al., 2015). However, there are different understandings of the term microfoundations. Haack et al. (2019), for instance, identify three perspectives (cognitive, communicative, and behavioral) on and three conceptions of microfoundations (as agency, levels, or mechanisms) in the academic discussion. They argue that the least common denominator of a "microfoundational explanation comprises an analysis of multiple levels and the interaction across these levels." (Haack et al., 2019, p. 25) As micro and macro (as well as meso) are relative terms, any actor or entity can be micro in relation to something and macro in relation to something else (Haack et al., 2019). Therefore, it is important to explain one's understanding of micro- and macro-levels and why a given level is granted analytical primacy (Haack et al., 2019).

Storbacka et al. (2016) adopt the microfoundational view to conceptualize actor engagement as a microfoundation of value co-creation in service ecosystems. They define actor's engagement as both an actor's exchange-based and non-exchange-based resource contributions in an interactive process of resource integration within a service ecosystem, which is facilitated by the actor's disposition to engage (Storbacka, 2019; Storbacka et al., 2016). The framework of Storbacka et al. (2016) consists of macro-, meso-, and micro-levels (Figure 8.1), resembling the Coleman 'bathtub' (Felin et al., 2015). The macro-macro relationship of their framework defines value co-creation as an outcome of service exchange within the context provided by the institutional logic of a service ecosystem (Storbacka et al., 2016, p. 3009).

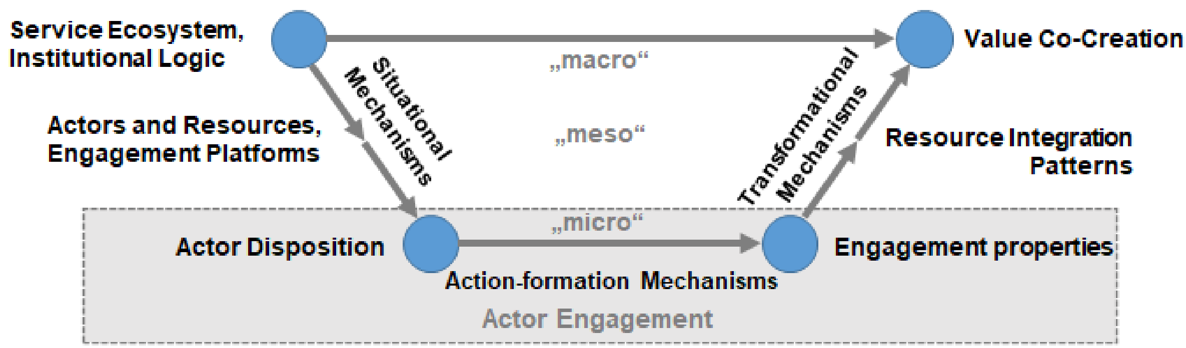

Figure 8.1: Actor Engagement as a microfoundation for value co-creation (Storbacka et al. 2016)

In their framework, Storbacka et al. (2016) understand microfoundations as mechanisms that provide explanations on why focal phenomena or effects occur on a superordinate level (Haack et al., 2019). Following the typology of social mechanisms by Hedström and Swedberg (1998) , they distinguish between situational mechanisms (macro-meso-micro) that explain how higher-level conditions or contexts affect actors, action-formation mechanisms (micro-micro) that explain how an actor turns contextual conditions into action, and transformational mechanisms (micro–meso–macro) that describe how multiple actors generate higher-level outcomes through their actions and interactions (Storbacka et al., 2016). Looking at the relationship between the levels, the institutional logic of a service ecosystem provides the macro-level context for the interaction of actors with their resources on engagement platforms at the meso-level. Engagement platforms can be understood as virtual or physical "environments containing artifacts, interfaces, processes and people" (Storbacka et al., 2016, p. 3011), which serve as intermediaries of connections between actors and thereby facilitate, but do not participate in, actor engagement at the micro-level. Resource integration patterns emerge on the meso-level as a result of actor engagement on the micro-level. Finally, these lead to value co-creation by transforming the resource configurations of the actors in the service ecosystem (Storbacka et al., 2016). The framework by Storbacka et al. (2016) has already been found useful to guide service system design (Grotherr et al., 2018) and to inform future research on how service design can effectively enable stakeholder engagement in business-to-business innovation processes (Lievens & Blažević, 2021).

For this study, we also decided to draw on the framework by Storbacka et al. (2016) as a theoretical lens to make sense of our qualitative-empirical data during data analysis. We specifically focus on the meso- and micro-level of smart service innovation. In line with our previous work, we understand actors as organizations (Anke, Poeppelbuss, et al., 2020b), where "a firm, using humans and technology, may engage with another firm's humans and technologies" (Storbacka et al., 2016, p. 3011). When multiple organizations engage in smart service innovation they form a smart service system and they usually set up a project (Anke, Poeppelbuss, et al., 2020b) that provides the engagement platform with engagement opportunities for the actors involved (Storbacka et al., 2016). Often, there is one focal actor with an *Initiator* (Ekman et al., 2016) or *Project Sponsor* role (Anke, Poeppelbuss, et al., 2020b) who initiates the project and invites further actors to create new value propositions as an outcome of the smart service innovation process (Ekman et al., 2016). Understood as the engagement platform, the project set-up provides artifacts, interfaces, and processes that facilitate resource integration and that the actors can use for their collaborative work (e.g., project management methodologies and tools) (Anke, Ebel, et al., 2020). Actor engagement on the micro-level reflects the actual collaborative project work where the actors integrate their resources to change the resource integration patterns of the smart service system in a way that is valuable to them (Edvardsson & Tronvoll, 2013; Storbacka et al., 2016; Vargo et al., 2010). Actor engagement on the micro-level is dependent on the actor's dispositions, that is, their intention and capacity to contribute resources in the specific project context (Storbacka et al., 2016). The joint project work results in changes in resource integration patterns on the meso-level. On the one hand, the actors generate smart service innovation outcomes in terms of resources like novel IT artifacts (e.g., a digital platform) and value propositions for targeted beneficiaries. On the other hand, they also shape future stages of their innovation activities by making decisions about what needs to be done in the smart service innovation project and who takes over responsibilities for work packages (e.g., by assigning tasks or subcontracting additional actors). Hence, the resource integration patterns of the project, understood as actor-generated institutions (Vargo & Lusch, 2016), change through the joint project work, too. We argue that they are changed through actor engagement on the micro-level in a way that is supposed to iteratively reduce uncertainty on the meso-level.

8.3 Research Approach

8.3.1 Data Collection

We conducted an interview study to investigate actor engagement at the micro-level and its effects on multi-actor smart service innovation at the meso-level. With this research objective, we focus on a subject matter for which empirical research is still very limited (Anke, Poeppelbuss, et al., 2020b; Ekman et al., 2016; Schymanietz & Jonas, 2020; Sklyar et al., 2019). In the context of microfoundational research, our approach of a small-sample, qualitative and exploratory study is considered as particularly promising as it can lead to new theoretical developments (Felin et al., 2015), including more midrange theory in particular, which is still needed for further advancing research on S-D logic (Vargo & Lusch, 2017). Hence, we contend that we follow a meaningful research approach that can yield novel insights and contribute to inductively building theory (Gehman et al., 2018).

Our data collection consisted of two rounds of interviews with experts as "knowledgeable agents" (Gioia et al., 2013, p. 17) who were involved in multi-actor smart service innovation. During the first round in 2018, we were interested in the roles that the different actors enacted in smart service innovation projects, reflecting the intersection of the macro- and meso-level of the framework by Storbacka et al. (2016). In the second round in 2020, we intended to capture the experts' activities and experiences in smart service innovation processes, that is, the actor engagement at the micro-level. We also took the chance to gather their reflections on further happenings concerning the projects they had reported about in 2018. Altogether, our goal was to gather information-rich data and to capture the breadth of activities of actors that can be observed in smart service innovation.

We identified appropriate experts for our interview study through a purposive approach (Eisenhardt, 1989; Yin, 2016). For the first round in 2018, we contacted those people in our personal network from whom we knew that they were involved in smart service innovation projects. We deliberately focused on practitioners and did not include fellow researchers in our study as we were interested in experiences from real-world smart service innovation processes. We deliberately approached potential experts from various industries and with different positions. This allowed us to cover the perspectives of various actors and roles. For the second round in 2020, we reached out to the same experts again and we were able to agree on a second interview with most of them. Some were not available for an interview this time or had moved to another employer and, therefore, were not part of the second round. At some other organizations, we were able to interview alternative or additional persons who could also report on the smart service innovation processes of their organizations.

In both rounds, we used semi-structured interview guidelines (Table 8.2) to stimulate the experts to report on their smart service innovation activities and experiences. As said, the first round of interviews focused on specific projects to be selected by the experts. The second round of interviews focused on the activities and interactions of multiple actors when collaborating in smart service innovation processes; we asked questions independently from specific projects to capture the experts' experiences across multiple projects in which they were involved.

Interview guideline in 2018	Interview guideline in 2020
1. Introduction of interviewer and expert, description of the expert's organization, expert's background, and his/her role in the organization. 2. Identification of smart service innovation projects, in which the expert was involved and selection of one project for closer analysis in the following sections of the interview. 3. Project initiation, including a general description of the project and the trigger for starting the project. 4. Project organization, including internal and external actors involved, the project management approach, employed methods, and specifications made. 5. Project outcome, including the value proposition, operational process design, and resource configuration of the smart service system.	1. Follow-up on the previous interview including a brief retrospective on the specific project from the initial interview. 2. Actors and roles that can be present in smart service innovation projects. 3. Multi-actor project management including methodologies, collaborative tools, and distribution/coordination of work across actors/roles. 4. Methods, techniques, and practices that are commonly used in smart service innovation projects.

Table 8.2: Interview Guidelines

In total, we conducted 25 interviews (Interview IDs in brackets in Table 8.3) with experts from 13 organizations. The first round comprises 14 interviews via phone from October 2018 to January 2019. The second round comprises eleven interviews that took place in July and August 2020 using phone and video meetings. We usually interviewed one expert per interview; except for interview 23, in which we talked to INTERNALIT's Project Manager and Data Scientist at the same time. The duration ranges from 40 to 103 minutes per interview, with a total of 29 hours of audio recordings. All interviews were transcribed for our detailed analysis. Throughout this paper, we only provide organization pseudonyms and the expert's position as we guaranteed anonymity to them (Table 8.3). As an indication of the company size, we provide their number of employees in the following five categories: A: <50; B: 51-250; C: 251 to 1000; D: 1001 to 10000; E: >10000.

8.3.2 Data Analysis

We conducted a first thorough analysis after the first round of data collection, which resulted in the identification of 17 roles that actors can assume in smart service innovation. These results have already been published (Anke, Poeppelbuss, et al., 2020a, 2020b). For this follow-up study, we applied the Gioia methodology as a widely accepted approach to grounded-theory-based interpretive research (Gehman et al., 2018; Gioia, 2021; Gioia et al., 2013). We extended our data sample with eleven additional interviews from the second round. We employed MaxQDA as software support for coding the transcripts.

Organization pseudonym	Organization description (size category)	Expert position in organization	Interview duration in 2018 (interview ID)	Interview duration in 2020 (interview ID)
ENERGYPLAT	Digital platform provider for energy management (B)	Head of Product Management	1:30 h (01)	1:05 (15)
INSURANCE	Insurance company (E)	Project Manager	1:04 h (02)	1:35 h (16)
CITYMOBIL	Utilities and public transport (C)	Project Manager	1:29 h (03)	-/-
GLOBALSYS	Global IT solution provider (E)	IT Architect and Consultant	1:17 h (04)	1:43 h (17)
		Program Manager	1:27 h (05)	-/-
ENERGY-TRADE	Digital platform provider for energy trading (C)	Project Manager	1:11 h (06)	1:41 h (18)
ITSOLUTION	IT solution provider, consulting, software development (B)	Lead Architect	1:13 h (07)	-/-
ITCONSULT	IT consulting (D)	Program Manager	0:41 h (08)	1:24 h (19)
DIGIBUSINESS	IT and digital business solution provider (D)	Member of the Project Steering Board	1:06 h (09)	-/-
UTILCONSULT	Management consulting for utilities (B)	Team Lead for Digitalization and IT	1:14 h (10)	-/-
PHAR-MACHINES	Machinery construction for the pharmaceutical industry (C)	Product Manager for Service/Support	0:48 h (11)	-/-
		Chief Innovation Architect	-/-	1:03 h (20)
		Head of Digital Solutions	-/-	0:40 h (21)
PACK-MACHINES	Plant construction for packing food/ non-food items (B)	Head of After Sales Service	0:41 h (12)	1:03 h (22)
INTERNALIT	Internal IT providers (two different entities) of a large machinery manufacturer (D)	IT Solution Consultant	1:00 h (13)	-/-
		Project Manager	-/-	1:13 h (23)
		Data Scientist		
		UX Designer	-/-	0:49 h (24)
FIELDSERVICE	Provider of field service management software (A)	CEO	1:04 h (14)	1:00 h (25)

Table 8.3: Overview of expert interviews

During our 1st-order analysis (Gioia et al., 2013), all three researchers went through the transcripts individually. We inductively assigned descriptive open and in-vivo codes to passages that provide information about the activities and collaboration of multiple actors in smart service innovation. When coding, we tried to closely adhere to the terms of our informants (Gioia et al., 2013), e.g., using code labels like "proxy product owner", "silo thinking" or "It is exciting to see how little the different departments actually talk to each other." We also revisited the interviews from the first round and assigned codes to those transcripts in the same way. In the second step of our 1st-order analysis, we jointly tried to make sense of the large number of codes, seeking similarities and differences, and aimed at a consensual understanding. Thereby, we reduced our vast amount of codes into a manageable number of 54 1st-order concepts (Gioia et al., 2013), which reflect the observable activities of actors that our experts reported on, e.g., "identifying key stakeholders" and "taking a mediating role and solving conflicts", and, hence the actor engagement on a micro-level (Storbacka et al., 2016).

In our 2nd-order analysis, we further condensed the 1st-order concepts into 21 2nd-order themes by constantly comparing the 1st-order concepts and their underlying codes across the different interviews

(Gioia et al., 2013; Hallberg, 2006). In this phase, we inductively searched for categories that help us describe the activities of actors. In addition, we also tried to identify to which roles these activities can be assigned to link the micro-level perspective of this study with the meso-level perspective reflected by the roles that Anke et al. (2020b) identified. Here, we deductively assigned the roles to our set of activities based on the descriptions as provided by our informants. We mainly identified the primary roles of the Project Sponsor (PS), the Digital Innovator (DI), and the System Integrator (SI). Furthermore, the Customer Representative (CR) also appeared to engage in smart service innovation, which reflects customer involvement as a key characteristic of agile project management approaches applied by some of our experts. Table 8.4 presents the definitions of the four roles (Anke, Poeppelbuss, et al., 2020b) that were particularly relevant during our data analysis.

Role	Key	Activities in the Service Ecosystem
Project Sponsor	PS	▪ Initiates, sponsors, and often manages the overall project ▪ Operates and offers the service towards the service beneficiary after completion of the smart service innovation project
Digital Innovator	DI	▪ Provides methodological support for the innovation process ▪ Facilitates the creation of service ideas ▪ Designs business model
System Integrator	SI	▪ Develops technical concept, e.g., system architecture ▪ Develops front-end, e.g., apps, and backend services, e.g., cloud analytics and other software components ▪ Integrates existing systems, services, and devices
Customer Representative	CR	▪ Informs the project as a target customer of the value proposition ▪ May be involved at various stages of the project, e.g., to provide feedback during development

Table 8.4: Roles Relevant to our Study (Anke et al., 2020)

In the further course of our 2nd-order analysis, we distilled the 2nd-order themes into four aggregate dimensions (Gioia et al., 2013) that group the micro-level activities of actors into categories on a higher level of abstraction (e.g., “managing multi-actor complexity”; see Figure 8.2). Finally, we decided on selecting “iterative uncertainty reduction” as our overarching core category because the 2nd-order themes resembled some associations with the types of innovation uncertainty that have been put forward in existing literature (O’Connor & Rice, 2013; Ramirez Hernandez & Kreye, 2020). When making sense of this core category we also found that it was mainly a property that refers to the actor-to-actor network with its resources and resource integration patterns, reflecting the meso-level of the framework by Storbacka et al. (2016), while the activities that we coded referred to the actor engagement on the micro-level. Hence, we decided to adopt their multi-level view to explain how activities of actors and uncertainty reduction relate to each other in smart service innovation. That is, the core category explains the underlying rationale of actors why and how they engage with other actors (reflecting the actors’ dispositions and their engagement). At the same time, the core category is the intended outcome of actor engagement, leading to changes in the actor-to-actor network and resource integration patterns on the meso-level. Hence, the core category “determines and delimits the theoretical framework” (Hallberg, 2006, p. 144) of smart service innovation that we suggest.

8.4 Findings

8.4.1 Overview

The interviewees shared their experiences from a wide range of smart service innovation processes. The smart service offerings that they implemented include mobility and vehicle charging services for citizens, remote support services for industrial equipment, as well as digital platforms for vehicle delivery tracking or energy trading, to mention just a few. The starting points and target states of the smart service innovation processes varied. Some were able to build on an already existing advanced digital infrastructure, making it comparatively easy to exploit technological options for adding further digital service offerings. Others rather followed an explorative approach, which also involved getting an understanding of technological options and meaningful customer problems in the first place.

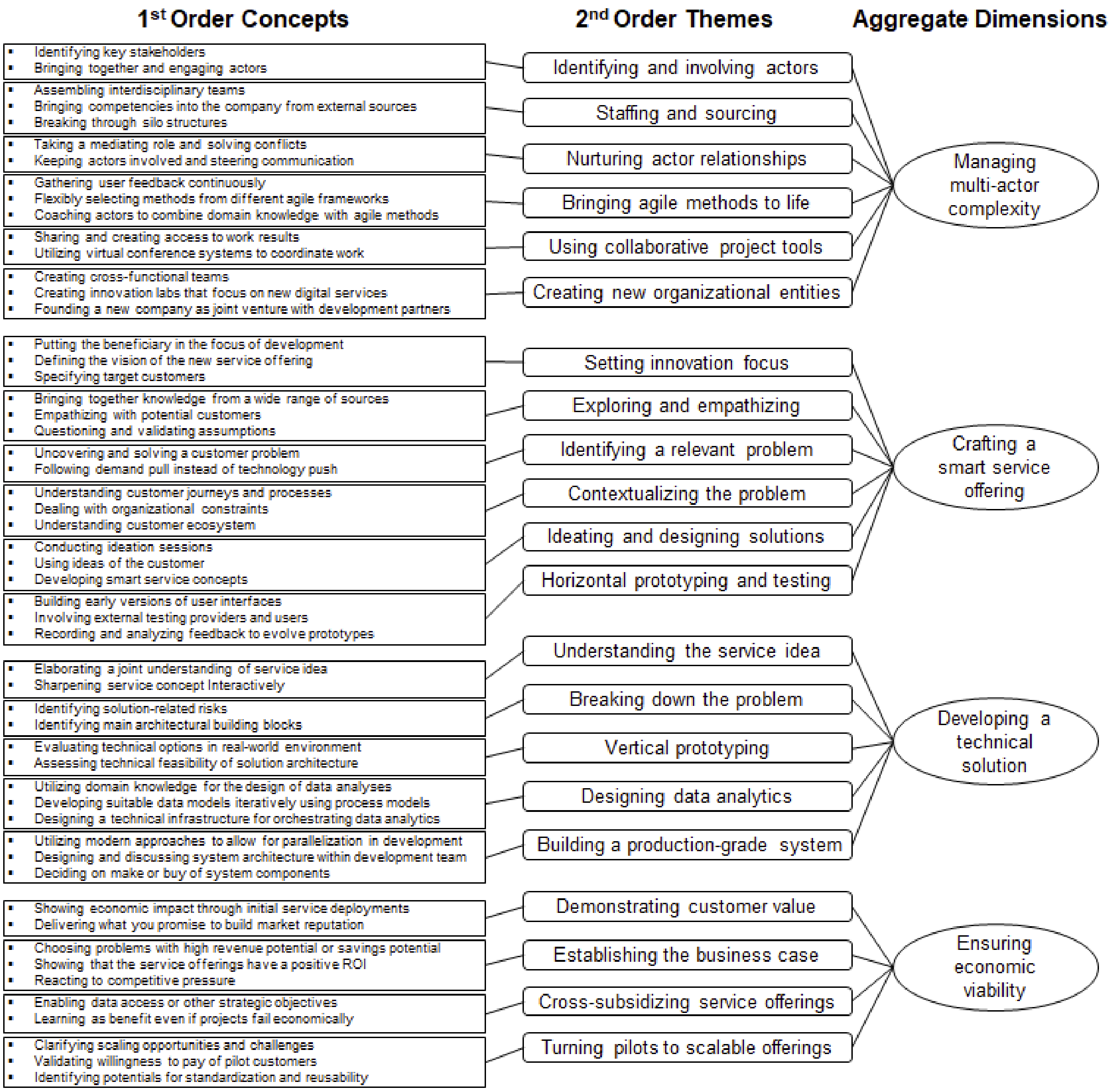

Figure 8.2: Data Structure

Independent of such differences, our interviewees consistently reported on the involvement of multiple actors in their smart service innovation projects. As also reflected by our sample of interviewees, the key actors comprise provider organizations that intend to create new value propositions for their customers as well as IT service providers and IT consultancies (simply called IT firms in the following) that support them in realizing digitally-enabled service offerings. Further relevant actors are customers that represent the target market as well as other firms and freelancers, whose expertise and capacities are required to successfully implement the smart service system. The different actors take on different roles in smart service innovation processes. For instance, it is common that the provider organization assumes the roles of the Project Sponsor and contracts an IT firm to take on the roles of Digital Innovator and System Integrator. Some other provider organizations keep more of these roles in-house. Similarly, IT firms may source expert knowledge and further resources from third parties that thereby also take over specific roles and engage in smart service innovation, too.

In the following, we report on the activities that multiple actors with different roles enact to engage with each other in smart service innovation. We structure the overall set of concepts and themes along the four aggregate dimensions of (1) ***managing multi-actor complexity***, (2) ***crafting a smart service offering***, (3) ***developing a technical solution***, and (4) ***ensuring economic viability*** (Figure 8.2). Finally, we illustrate how this actor engagement on a micro-level supports iterative uncertainty reduction in the actor-to-actor network of smart service innovation projects on the meso-level, by presenting an integrated theoretical model.

8.4.2 Managing Multi-Actor Complexity

The multi-actor setting in smart service innovation can be considered complex because a diverse set of actors (e.g., as regards expertise, resources, and organizational culture) works together to put the smart service system in place. Their different activities have to integrate smoothly to meet the time and budget constraints that are usually defined for smart service innovation projects.

First of all, our interviewees emphasize that it is important to **identify and involve actors**. Key stakeholders need to be identified and actors are invited to engage. A meaningful approach is to bring everyone to one table in a kick-off workshop.

> *"You really take a day and get all the actors who could foreseeably be involved in the project together at one table." (ENERGYTRADE, Project Manager, 2020)*

Particular dedication is put on the different departments that are usually involved at the provider organization that holds the Project Sponsor role, which can be numerous.

> *"Yes, as I said, there are several departments from the customer involved, all of which have different requirements." (ITCONSULT, Program Manager, 2018)*

Project Sponsors themselves even admit that communication across departments is an issue in smart service innovation projects. IT firms with the System Integrator role further emphasize that they have to involve the Project Sponsor's IT department early on to get consent for the planned technical implementations. Gaining their consent, however, can be a challenge.

> *"Their own IT department. This is the big brakeman in the whole game because they are drowning in work, have security concerns, and do not have resources." (FIELDSERVICE, CEO, 2020)*

Although our interviews showed that it is not uncommon that smart service innovation projects are carried out without involving actors with the Customer Representative role, end-user involvement is generally perceived as a plus. Again, this does not always come for granted:

"Ideally, you will also have pilot customers who will join the project. But of course it's not quite that simple. Because they have to find some time." (FIELDSERVICE, CEO, 2020)

Staffing and sourcing is another theme that is required to manage the collaboration with multiple actors. On the one hand, decisions have to be made at each actor about the internal staffing for the project. Here, the interviewees mostly rely on interdisciplinary teams and try to dissolve existing silo structures. Additionally, external sourcing is needed in many cases because of limited internal competencies or capacities. We already find such a sourcing decision in the case where an actor with the Project Sponsor role contracts an external IT firm to take over the System Integrator role. In some cases, external specialists are needed that can cope with certain implementation challenges. But also the IT firm's available resources can be limited, leading to the assignment of freelancers and other firms to help out.

"When it comes to cloud connectivity now, implementing China is a complicated story. And this is usually only possible in cooperation with the relevant experts from the cloud platform providers. [..] Other constellations are simply a scaling, that one says, one strengthens oneself with personnel, if one is short in the area." (ITCONSULT, Program Manager, 2020)

A further theme is to **nurture actor relationships**. A key person in this regard can be the project manager who tries to keep all strings together, although the traditional role of a project manager might not be present anymore in modern agile methodologies. The interviewees try to solve conflicts, motivate, and keep all actors involved in the project, e.g., by steering communication.

"In this context one thing is important. And that is bringing together external partners and internal employees and the customer. I have a central role, so to speak, and have to bring everything together to the right and left. And if everything works out smoothly, if no one is disappointed and we have found good compromises for everyone, if everyone is ultimately satisfied after a project like this, i.e., if not only the customer needs have been matched, but also the internal processes are in a way that the product also works very well for our internal employees and the partners were also on schedule, then I believe it is a good project in the end." (PHARMACHINES, Chief Innovation Architect, 2020)

The interviewees reported on different project management methodologies that they use in smart service innovation processes, basically including three variants: sequential (waterfall), agile and hybrid approaches, with the latter combining elements of the former two approaches. We observed that the interviewees reported on the growing popularity of agile approaches, especially when we compared the interviews from 2018 with those from 2020. At the IT firms, agile methods are nowadays perceived as the standard approach to developing solutions.

"It must be said that in projects that can be called successful projects, [..] a real agile model was driven quite strictly and successfully. And that has been one of the success factors." (ENERGYPLAT, Head of Product Management, 2020)

However, in the multi-actor settings as reported in our interviews, we saw that not all actors are equally knowledgeable about these methods, especially considering traditional manufacturing organizations that hold the Project Sponsor role. Consequently, we identified the theme of **bringing agile methods to life**. Many agile methods and frameworks including Design Thinking, Scrum, Lean Startup, or Design Sprints were mentioned. Often, just elements from the approaches were selected and integrated. One aim was to get continuous feedback to avoid developing in the wrong direction. The actors with the Digital Innovator and System Integrator roles also had to clarify the implications of agile methods for all other actors involved in the project. The interviewees mentioned, e.g., experienced domain experts who carry important knowledge for smart service innovation but often have to be introduced to agile methods and trained to use them. As there usually are different levels of experience and expertise with agile methods, the recommendation was to adjust methodologies flexibly to ensure that all actors still feel comfortable.

> *"Our goal is to work agile. [..] And it is not set in stone how we work, but we look at how we use the tools, which agile methods, whether we work according to Scrum, whether we work according to Kanban or other. We look at that and then choose what makes the most sense for the team." (INSURANCE, Project Manager, 2020)*

Sometimes, inter-organizational settings also require deviating from the role definitions that agile methods propose. The IT firms try to assign the product owner role to their customers as devised in Scrum, but sometimes have to establish a so-called *"proxy product owner"* (GLOBALSYS, IT Architect and Consultant, 2020) at their organization in cases where the customer (or the actor with the Project Sponsor role) is neither able nor willing to act as the product owner. Generally, the introduction of agile methods into a multi-actor setting was sometimes considered a particular challenge.

> *"And, of course, this also makes us a bit of a two-speed company. We have our classic rhythms of innovation in mechanical engineering, and my department is simply in much shorter loops, so we have basically found two points in the default process for us, where we can always incorporate this in an agile manner." (PHARMACHINES, Head of Digital Solutions, 2020)*

The interviewees from IT service provider organizations consistently reported on the **use of collaborative project tools**, which serve as central platforms for all actors involved, including externally sourced freelancers and firms. This activity is based on the necessity to share work results with all actors involved and to communicate with multiple actors. Here, online conferencing and project management software tools are implemented.

> *"We try to include all service providers in Jira [..] And they can be from different organizations. [They] can also be freelancers and so on. But the goal is that we have a common view on the whole topic. And ideally, as in agile by the book, we also share this with the client." (GLOBALSYS, IT Architect and Consultant, 2020)*

In addition to Jira, it is also Confluence which was commonly mentioned as one of the collaborative project tools. Confluence is perceived as a tool that is easy to use even for non-developers. Such tools can also be used by the Project Sponsor role to provide input (e.g., by filling the product backlog). Some other Project Sponsors even predefine the complete development environment and project tools that the System Integrators are obliged to use.

Finally, we also identified **creating new organizational entities** as a theme from our interview data. One approach was the establishment of an interdisciplinary team with about ten employees from different departments at PHARMACHINES that try to identify customer problems and then develop initial prototypes in design sprints. ENERGYTRADE even founded a new company with partners to have an adequate organizational shell for their smart service offering. A third possibility was presented by INTERNALIT who built up a dedicated innovation lab that focuses on digital services. Table 8.5 summarizes the themes with the involved roles and related concepts.

Themes	Roles	Concepts
Identifying and involving actors	PS, SI	▪ Identifying key stakeholders ▪ Bringing together and engaging actors
Staffing and sourcing	PS, SI	▪ Assembling interdisciplinary teams ▪ Bringing competencies into the company from external sources ▪ Breaking through silo structures
Nurturing actor relationships	PS	▪ Taking a mediating role and solving conflicts ▪ Keeping actors involved and steering communication
Bringing agile methods to life	SI, PS, DI	▪ Gathering user feedback continuously ▪ Flexibly selecting methods from different agile frameworks ▪ Coaching actors to combine domain knowledge with agile methods
Using collaborative project tools	SI, PS	▪ Sharing and creating access to work results ▪ Utilizing virtual conference systems to coordinate work
Creating new organizational entities	PS	▪ Creating cross-functional teams ▪ Creating innovation labs that focus on new digital services ▪ Founding a new company as a joint venture with development partners

Table 8.5: Themes, Roles, and Concepts for "Managing multi-actor complexity"

8.4.3 Crafting a Smart Service Offering

Smart service innovation involves crafting a smart service offering that attracts customers and has the potential to solve relevant customer problems. A key aspect of this area is customer involvement. Some experts emphasized that they try to follow a customer-centric approach whenever possible. Such a mindset turns out to be challenging to implement, as companies are used to existing industry logic and ways of working. However, the relevance was underpinned by the fact that projects can fail due to a lack of customer orientation.

> *"It is an unusual thought for a mechanical engineer not to think so much about what is technically possible and what would be fancy, but to think: 'What does the customer actually want?' [..] For [us], it is totally counter-intuitive, normally we hide in our chamber for six years, develop the greatest machine in the world and it has to work completely when we take it out to customers." (PHARMACHINES, Head of Digital Solutions, 2020)*

> *"The biggest mistake [we] could have made. It was developed because we liked it and not because the customer needed it. The approach was wrong from the start." (PACKMACHINES, Head of After Sales, 2020)*

In the following, we present the activities that we identified for crafting a smart service offering. In most cases, these were observable from actors with the Project Sponsor or Digital Innovator roles who also involved Customer Representatives. Especially in the early phase of innovation initiatives, defining a vision for the service offering is one key action the participants mentioned. Also, the selection of a target user group seems essential. We summarized such activities under **setting innovation focus**. User groups can be selected based on various criteria, e.g., financial or geographic aspects.

> *"And there was just a user group that we chose. Users who, if you look at it from a purely economic point of view, constantly generate costs. We also have the goal of reducing costs and one way of doing this is to take precautions to actively support the customer." (INSURANCE, Project Manager, 2020)*

Exploring and empathizing covers activities that bring together a great variety of knowledge of different sources needed for innovation. A huge part is about understanding potential customers. Project Sponsors and Digital Innovators draw on the expertise of UX designers or have the required expertise themselves. The interviewees reported that they conduct exploratory interviews or do observations in the field for an unbiased analysis of the processes and pain points of the target customer. Problems and needs of the customers are identified through listening, observation, and targeted questioning. The aim is to avoid making decisions based on assumptions or to at least substantiate or prove assumptions by gathering as much information as possible. Here, the interviewees pointed out that it is necessary to force oneself not to propose solutions or to have them in mind.

> *"A design thinking expert and one of our salespeople went there and asked a little bit of a prepared questionnaire, but a lot was about really understanding: Okay, why does this bother you? What do you do then? What is the situation exactly? Not only to take away what the customer wants but also to really say: I have understood what annoys him so that my ideas really hit the nerve afterward." (PHARMACHINES, Head of Digital Solutions, 2020)*

It is also interesting to note that these activities were considered particularly important, as they lay the foundations for further activities. Actors therefore also want to deploy more resources in these phases.

> *"In any case, I would first of all talk more intensively with the customer, potential users. I would do very extensive user experience research to understand the customer holistically. And only then would you be able to plan the project properly." (INTERNALIT, Project Manager, 2020)*

Identifying a relevant problem describes the activity of uncovering and solving significant customer problems. While some build on a very detailed exploration as described above, others make assumptions and considerations about customer needs and constantly change between solution generation and problem assessment. However, it became clear that innovation should not follow a technology push but a demand pull. Especially after very extensive exploration, the data can be overwhelming, which is why organizations try to synthesize information into a problem to solve.

> *"What I like to do before that is an NABC. An NABC says okay, what is my target group? Then I think about the target group: What is the need of the target group? In other words, what is it that drives them around, what would they be willing to pay money for, or what offers them added value? Then I would have the approach, that is, how do I serve this added value? What is actually my solution? Then I consider: What is the benefit of my solution and what is the benefit for the target group? What do they get out of it?" (GLOBALSYS, IT Architect and Consultant, 2020)*

> *"In the end, it is difficult to achieve a reasonable synthesis, because you always have this bias of two to three interviews, which stuck in your head. [..] We have a [method which] gives you a relatively quick overview of which customer said what. [..] We try to take all points of view and actually have a brainstorming session. We [..] make a problem statement. That means we frame the problem again in two sentences" (PHARMACHINES, Chief Innovation Architect, 2020)*

Different contexts and restrictions hamper smart service innovation and therefore need to be considered and understood, which we label **contextualizing the problem.** Even though it seems that most problems apply across industries, the specifics of certain industries should not be underestimated. To tackle such challenges, it is necessary to analyze customer processes, whole ecosystems, and various contextual conditions. Organizational constraints can appear due to data security issues, regulations, or process certifications, e.g., in the pharmaceutical industry where

PHARMACHINES operates. By contextualizing the problems, hurdles can be identified and addressed already at an early stage.

> *"That's why I like to do these interviews in context. So, I really run for a day, or a few hours, depending on how much time they can give me. They can work all the time. Sure, I ask things from time to time, but otherwise? I just observe a lot. I just observe the whole day." (INTERNALIT, UX Designer, 2020)*

Ideating and designing solutions subsume activities that refer to the use of creativity methods and brainstorming sessions but also include activities to conceptualize offerings regarding its value proposition or business model. Although organizations try to focus on the desirability for the target customer, ideas have to be developed considering technological possibilities, because, in the end, it is also about being able to offer working solutions. Instead of developing new ideas internally, they can also be picked up from the customer. All in all, it is a matter of developing a suitable solution, which can also rely on third-party providers and existing solution elements.

> *"We will build on the user experience research results and see which smart services we can help the customer with, but this still goes hand in hand with the technical planning. In other words, this is what I want, this is what the customer wants. But how could we even map this with the database that is available to us?" (INTERNALIT, Project Manager, 2020)*

> *"This does not necessarily have to be a new development, [..] you just have to provide it." (ENERGYPLAT, Head of Product Management, 2020)*

Finally, **horizontal prototyping and testing** is the building and testing of early versions of user interfaces. Prototyping techniques like wireframes or click dummies can help to implement ideas and solutions quickly. A lot of insight and feedback should be generated with as little effort as possible. Too detailed and fully developed prototypes are even described as an obstacle to feedback.

> *"I just do everything on paper first. Actually, because then I can throw it away the easiest and fastest way." (INTERNALIT, UX Designer, 2020)*

Prototypes are handed over to the Customer Representative for testing and gathering feedback for improvement. Also, external testing providers and users can be involved to gain feedback.

> *"There are providers who enable test scenarios, that means you give them, for example, an app and the app is then released to numerous users and they can give feedback over a platform" (INSURANCE, Project Manager, 2018)*

Such feedback is recorded and analyzed to further evolve prototypes. Such an iterative approach is considered important in order not to develop in the wrong direction or to be able to counteract.

> *"Feedback is then incorporated and the prototype is given another depth, another sharpness. This goes from low-fidelity to high-fidelity and then we test it again." (PHARMACHINES, Chief Innovation Architect, 2020)*

Table 8.6 summarizes the activities with the involved roles and related concepts.

Themes	Roles	Concepts
Setting innovation focus	PS, DI	▪ Putting the beneficiary in the focus of development ▪ Defining the vision of the new service offering ▪ Specifying target customers
Exploring and empathizing	PS, DI, CR	▪ Bringing together knowledge from a wide range of sources ▪ Empathizing with potential customers ▪ Questioning and validating assumptions
Identifying a relevant problem	PS, DI, CR	▪ Uncovering and solving a customer problem ▪ Following demand pull instead of technology push
Contextualizing the problem	PS, DI, CR	▪ Understanding customer journeys and processes ▪ Dealing with organizational constraints ▪ Understanding customer ecosystem
Ideating and designing solutions	PS, DI, SI	▪ Conducting ideation sessions ▪ Using ideas of the customer ▪ Developing smart service concepts
Horizontal prototyping and testing	PS, DI, CR	▪ Building early versions of user interfaces ▪ Involving external testing providers and users ▪ Recording and analyzing feedback to evolve prototypes

Table 8.6: Themes, Roles, and Concepts for "Crafting a smart service offering"

8.4.4 Developing a Technical Solution

As smart service systems are socio-technical systems, the technical resources of such systems need to be designed and implemented, too. The activities to develop a suitable technical solution for the planned service includes, for example, the selection of technologies and frameworks, assessing the feasibility of a technical approach and the satisfiability of non-functional requirements, and managing the required efforts. From the analysis of our interviews, we identified the following themes, which usually refer to activities performed by the actor (typically an IT provider organization) with the System Integrator role. However, in some cases, the actor with the Project Sponsor role had the resources to also assume this role and perform these activities itself.

In case that an external IT provider organization assumes the System Integrator role, this actor is often confronted with existing service ideas that were developed by other actors with Project Sponsor or Digital Innovator roles. Therefore, one activity of Systems Integrators is **understanding the service idea**. To build a technical solution, a joint understanding between Project Sponsor and System Integrator has to be elaborated. Such understanding is to be sharpened by an iterative concept building. Typically, this takes place in an initial workshop.

> *"The customer usually has an idea, a rough direction where he wants to go. What we do there is, first of all, a workshop with the customer to better understand the idea, to sharpen it and ideally to split it up, in an agile sense into epics, to say okay, if that is your vision, into which basic components can you break it down?" (GLOBALSYS, IT Architect and Consultant, 2020).*

Once the basic idea and the scope of the task are understood, System Integrators try to **break down the problem** into smaller parts. This might involve the identification of major system components such as apps, backend, external systems, cloud services, and devices. Additionally, agile techniques such as epics and customer tasks are applied to describe the main building blocks of functionality. This helps to draft an initial project plan and identify both risks and required resources. Risks at this stage result from external dependencies, such as providers of external systems and hardware, which need to be integrated.

"When you integrate hardware and integrate other systems, it is important to start integrating these other systems or hardware at a very early stage, because that's where the risks lie, including certificate management and all the other issues: protection, security." (GLOBALSYS, IT Architect and Consultant, 2020).

Another theme that we identified for the System Integrator role is **vertical prototyping**. Unlike horizontal prototypes used by Digital Innovators in crafting the service offering, System Integrators build vertical prototypes. These are minimal versions of the technical system which involve multiple layers or system components. This approach aims to gather feedback from a rough version of the system to evaluate technical design options and reduce risks that might be associated with technology choices. Such vertical prototypes help to evaluate technical options in real-world environments.

"I think we have tested six different [smart] glasses with customers and found out that: Phew, some of them are operated by voice, but it's too loud in the production environment, that didn't work, they're often made of glass, which can shatter, so broken glass in our production is a no-go. Then, some don't have any battery power that lasts for several hours [..], that is technically not possible." (PHARMACHINES, Head of Digital Solutions, 2020).

Since access to the field is not always available, organizations with the Project Sponsor role also work with their test scenarios to investigate the technical constraints for a potential solution at the target customer's site. Systems at this stage are aimed at an improved understanding of potential solutions and their parameters, but not for productive use.

"And now we have a machine in the laboratory where we can learn by ourselves. [..] We always do the whole thing under laboratory conditions. We don't have anything productive. I think that as soon as you transfer this to a productive operation, you might work a little differently. You have data engineers who develop everything in compliance with security requirements. Everything is still vulnerable to certain errors and attacks. It does not have the maturity level yet." (INTERNALIT, Project Manager, 2020)

As one of the key characteristics of smart service is data-driven value creation, it is not surprising that Systems Integrators also **design data analytics**. This theme includes the work of data scientists, who investigate the functional aspect, i.e., which data is needed to gain the desired result or which insights can be generated from available data. Here, we see a connection between the crafting of the smart service offering and the technical solution, as the potential value creation of a smart service is constrained by the available data. Consequently, Customer Representatives can be involved in the process.

"The customer is an important partner in the development of such projects because the customer carries the expert knowledge also for the analysis of the data. After all, this expert knowledge must ultimately also be incorporated into the data analyses." (INTERNALIT, Project Manager, 2020).

Data scientists work on the mathematical and statistical level of the problem and develop suitable data models and select appropriate methods for data analysis. Standards like CRISP-DM are applied to guide the iterative development of data mining models.

"This is an industry standard, which is called cross-industry standard for Data Mining. This is applied by first understanding the companies, understanding the issues, then looking at what information we get.

Afterward, pre-processing up to the development of the model and evaluating the whole thing. [..] If it is not good, then the loop starts all over again." (INTERNALIT, Data Scientist, 2020).

Moreover, data engineers are contributing to this by planning and setting up the infrastructure that collects, stores, and analyzes data according to the functional concept of the service system. This task is supported by state-of-the-art tools, which allow graphical modeling of data analysis processes.

"Implementation then via orchestration frameworks, for example, Apache Nifi or Apache AirFlow. In the end, frameworks with which you orchestrate the whole process. So which data sources do I have? How do I import them? Where do I pass them on to? Where does the ETL take place? Do I pass it on to a third party?" (GLOBALSYS, IT Architect and Consultant, 2020).

Finally, we also consider **building a production-grade system** as a relevant theme. It involves steps like defining system components and their interfaces as well as the actual coding and testing. For that, established techniques like the Unified Modelling Language (UML) are used to develop, discuss, and communicate design decisions within the team. In addition, problems must be considered more holistically than in the prototyping phase to minimize technical uncertainty. This also raises the question of whether solutions should be purchased or developed in-house. Furthermore, we found that modern approaches like API management are used to define interfaces early and parallelize work even between different teams:

"Because the developers can store this API, that is, this Swagger API, in advance and can also tell which default values are returned. [..] This means that you can also code against this [interface] within an app, while the backend developers can develop the complex logic in the backend in parallel. That means you can decouple these two systems, even though they can pretend to talk to each other." (GLOBALSYS, IT Architect and Consultant, 2020).

"Of course, there is already a gap between the production department, which wants to have a problem solved quickly, and the IT department, which says that for me security is the highest priority. If production is not running, then production should first show me how high the loss is, because if we have a hacker attack, then I assume a loss of a few billion. They first have to make up for that with their production downtime." (PHARMACHINES, Product Manager for Service/Support, 2018).

Table 8.7 provides the themes, roles, and concepts for this aggregate dimension.

Themes	Roles	Concepts
Understanding the service idea	SI, PS	▪ Elaborating a joint understanding of service idea ▪ Sharpening service concept Interactively
Breaking down the problem	SI	▪ Identifying solution-related risks ▪ Identifying main architectural building blocks
Vertical prototyping	SI, PS, CR	▪ Evaluating technical options in a real-world environment ▪ Assessing technical feasibility of solution architecture
Designing data analytics	SI, PS, CR	▪ Utilizing domain knowledge for the design of data analyses ▪ Developing suitable data models iteratively using process models ▪ Designing a technical infrastructure for orchestrating data analytics
Building a production-grade system	SI	▪ Utilizing modern approaches to allow for parallelization in development ▪ Designing and discussing system architecture within the development team ▪ Deciding on make-or-buy of system components

Table 8.7: Themes, Roles, and Concepts for "Developing a technical solution"

8.4.5 Ensuring Economic Viability

Developing value propositions that are attractive to target customers is a prerequisite for being successful in the marketplace. However, Project Sponsors also need to consider the capturing of value for themselves. The uncertainty related to this aspect is driven by difficult cost estimations for the smart service innovation project and operational costs during service provision, the unknown size of the target market, and the customers' readiness and willingness to pay for the new service offering.

Demonstrating customer value describes the theme which refers to activities aiming at market acceptance. Interviewees mentioned that such acceptance needs to be achieved by demonstrating the economic impact of pilot service deployments. Solving the customer's problem as promised leads to market acceptance and, thus, a customer's willingness to pay. But the same applies in the opposite direction.

> *"If you promise a lower downtime or a lower standstill, you have to see if you really do what you promised in the end. If so, a corresponding willingness to pay arises, and you have to demonstrate the whole thing several times, prove that you can do it before you can scale the big one. Otherwise, you make empty promises and lose trust in the market. (INTERNALIT, Project Manager, 2020)*

Our second round of interviews showed that the interviewees increasingly have to justify certain projects more thoroughly from a financial perspective to internal stakeholders. Hence, the theme **establishing the business case** subsumes such activities that justify smart service innovation projects. The interviewees try to select financially attractive customers right from the start. Whereas previously a lot of attention and effort was put into pilot projects and feasibility studies, as well as reactive measures to competitive pressures there is now an increasing demand for economic project justification.

> *"Of course, we are currently entering a phase in which this business case view is becoming increasingly important, partly due to the organizational changes. And in this respect, I have already had to make classic business case calculations for projects." (INSURANCE, Project Manager, 2020)*

> *"And that's why you generally have discussions right now about how to proceed with the projects at all (...) and then to clarify whether this is still worthwhile in terms of a return on investment." (GLOBALSYS, IT Architect and Consultant, 2020)*

Even though financial considerations are becoming increasingly relevant, it is still common that organizations **cross-subsidize service offerings** through other sources of income. Project Sponsors justify smart service innovation through the generation of data that are valuable for their operational processes. In addition, organizations do not want to lose ground to competition and, even if projects fail economically, the interviewees described the learnings as beneficial for future endeavors.

> *"In the end, the company generates the added value. We have two problems. Their competitors have such a service in the market, and they want to keep up. And secondly, they profit when customers give them the data so that they can generate orders and do business again. And that is why they want to keep the hurdle so low." (GLOBALSYS, IT Architect and Consultant, 2018)*

> *"At the car manufacturer, they know how important data is because they need to measure up to Tesla. Because Tesla has data, and that is the business model. They know that they have to get to market quickly. They have to exploit the data…" (ENERGYTRADE, Program Manager, 2020)*

Turning pilots into scalable offerings is the last theme that was often discussed in our interviews. Standardization, as well as the creation of platforms, were named as examples. Standardization describes the approach of reusing existing solutions and resources to minimize efforts and financial expenses. Another described action is the continuous validation of the customer's willingness to pay.

> *"For the MVP we also try to find three to five paying customers. If they don't pay, then we haven't solved the problem. The first customers, they might get it a bit cheaper, but then we work with these five customers (...) and when that's stable, then we add a few more customers and at some point, you're in a mode where you say: Okay, now it works with 20 customers, now it will work with 200 customers and then we pass it on." (PHARMACHINES, Head of Digital Solutions, 2020)*

The development of platforms or larger portfolios of smart service offerings is considered to lead to improved utilization of infrastructure investments.

> *"I don't think that any single service justifies all these implementation costs. [..] And if it only remains with one service, this project cannot be economical." (ITCONSULT, Program Manager, 2020)*

However, many organizations still seem to be awaiting the scaling phase.

> *"How do you scale smart service? The challenge is that currently smart services are developed very, very individually (...) For a long time to come, it will remain purely a project business. That in the end, a product will emerge that can be scaled in a standardized way. That's still a dream of the future, it's very, very difficult because each data model must be developed individually for each machine." (INTERNALIT, Project Manager, 2020)*

Table 8.8 provides the themes, roles, and concepts for this aggregate dimension.

Activities	Roles	Concepts
Demonstrating economic value	PS, DI, CR	▪ Showing economic impact through initial service deployments ▪ Delivering what you promise to build market reputation
Establishing the business case	PS, DI	▪ Choosing problems with high revenue potential or savings potential ▪ Showing that the service offerings have a positive return-on-investment ▪ Reacting to competitive pressure
Cross-Subsidizing	PS	▪ Enabling data access or other strategic objectives ▪ Learning as a benefit even if projects fail economically
Turning pilots into scalable offerings	PS, SI	▪ Clarifying scaling opportunities and challenges ▪ Validating willingness to pay of pilot customers ▪ Identifying potentials for standardization and reusability

Table 8.8: Themes, Roles, and Concepts for "Ensuring economic viability"

8.4.6 Iterative Uncertainty Reduction in Multi-Actor Smart Service Innovation

The themes and dimensions that we derived from our interview data together with the assignment of roles illustrate that multiple actors have to accomplish many things and contribute various resources to establish a smart service system. To give some instances of how the actors engage with each other, we see that the Project Sponsor is involved in most activities and frequently collaborates with the Customer Representative and the Digital Innovator (Figure 8.3). Actors with the System Integrator role tend to be responsible for most technical tasks, but also participate in various project management activities in multi-actor settings. The Digital Innovator role is usually involved in those activities that require interactions with Customer Representatives. All these activities can generally be shared between multiple roles. That is, actors can assume multiple roles, and a role can be assigned to several actors at the same time. This is particularly visible from *bringing agile methods to life* and *ideating and designing solutions*, where we assigned three roles. *Ensuring economic viability* also requires the Project

Sponsor to collaborate with all other actors. In contrast, *developing a technical solution* is a theme that is rather exclusive to the System Integrator role. Therefore, the complexity of the multi-actor setup depends on the distribution of roles among concrete actors in the specific smart service innovation project and provides conditions for actor engagement during the actual project work.

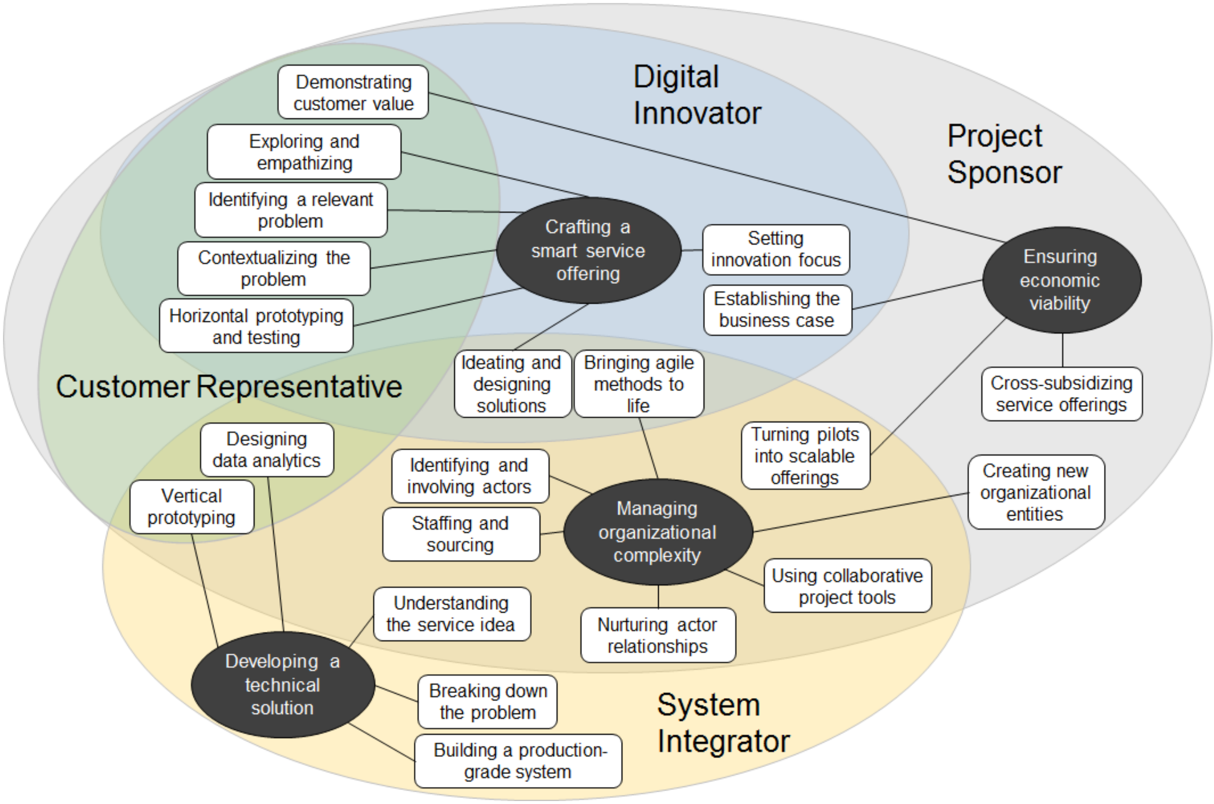

Figure 8.3: Themes of Smart Service Innovation Assigned to Roles

The themes and dimensions further substantiate that uncertainty affects smart service innovation. For example, the crafting of a smart service offering is an innovation activity that is inherently affected by environmental uncertainty. The utilization of recent technology leads to technical uncertainty. Similarly, finding the right people with the right resources for the project on time, as well as coordinating their work was also perceived as a source of resource and relational uncertainty. Finally, the economic viability depends on decisions in all the previous areas as well as specific activities related to financial management. Moreover, strategic management decisions related to smart service innovation are likely to cause organizational uncertainty. Hence, smart service innovation is beset with uncertainty that stems from multiple sources. To manage uncertainty, a lot of the experts' attention was given to the agile ways of working together, which is characterized by an iterative and incremental approach to developing the different components of a smart service system.

Correspondingly, we interpret that it is *iterative uncertainty reduction* that drives the various actors to perform the activities in the way we learned from the interviews and, hence, we conceptualize it as our overarching core category. We refer to 'uncertainty reduction' and not to 'coping with uncertainty' since our impression was that the multiple actors intend to reduce the different types of uncertainty of smart service innovation at their sources instead of just adapting to them (Simangunsong et al., 2012). We deliberately add the term 'iterative' to 'uncertainty reduction' because the activities across all dimensions indicate that the interviewees choose or recommend iterative approaches in response to uncertainty. When following an iterative approach to uncertainty reduction, innovation activities are carried out, their outcome is put to the test, and adjustments can be made quickly. An iterative approach was perceived to support customer involvement and gather regular feedback on the emerging solutions.

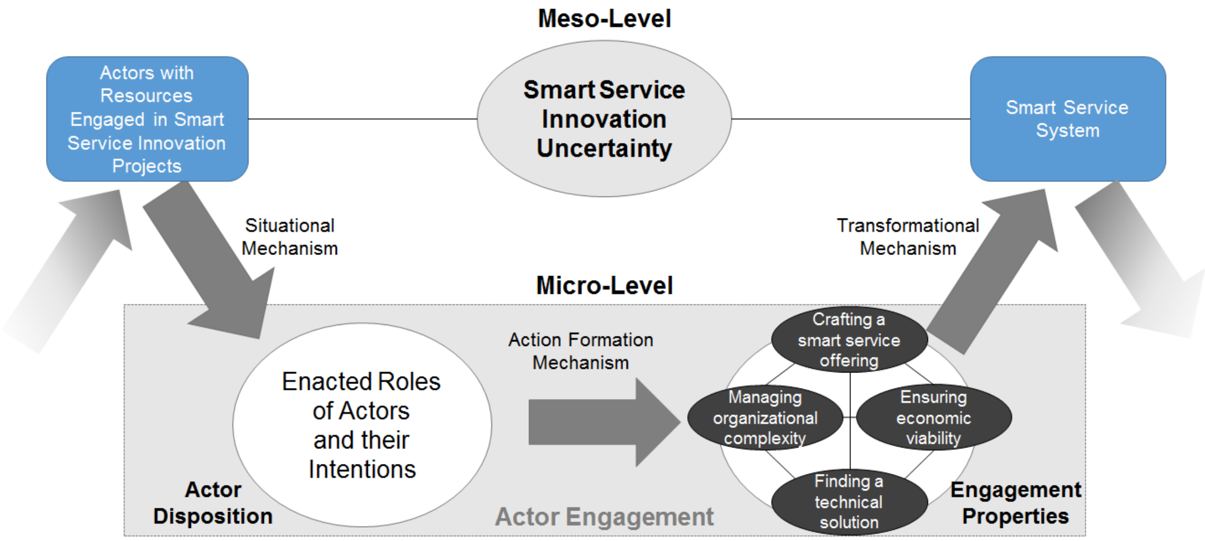

Figure 8.4: Theoretical Model of Iterative Uncertainty Reduction in Smart Service Innovation

When making sense of iterative uncertainty reduction as our core category, we further realized that uncertainty is a property on a higher level of aggregation compared to the actors' activities as it refers to the collection of multiple actors that engage with each other during smart service innovation. The aforementioned uncertainty types mainly relate to the multi-actor nature of smart service innovation (pointing towards, e.g., resource and relational uncertainty) where the outcome in terms of changes to the smart service system (pointing towards, e.g., technical, organizational, and environmental uncertainty) is difficult to predict. Following the framework by Storbacka et al. (2016), we therefore conceptualize smart service innovation uncertainty as a property of the meso-level (Figure 8.4), which refers to both the actor-to-actor network with a joint smart service innovation project as the engagement platform and the smart service system with its changed resource integration patterns as the outcome of smart service innovation. In light of the existing conditions of uncertainty relevant to a project, the involved actors perform activities generating a new configuration of resources which is usually supposed to reduce uncertainty. Adding a microfoundational view to this meso-level relationship, the project set-up provides the conditions for actor engagement on the micro-level during project work (situational mechanism). We understand the intentions and the roles that the actors enact during project work as actor dispositions that are turned into action in the specific project context (action-formation mechanism). The concepts, themes, and dimensions of activities, which we presented above, reflect the engagement properties, which are the observable engagement activities on the micro-level (Storbacka et al., 2016). The collective action of all actors leads to the emergence of a new smart service system or changes to an existing smart service system (transformational mechanism), which can, in turn, be the outset of future innovation processes (as reflected by the fading arrows in Figure 8.4).

The theoretical model resembles that the engagement properties that we derived from our data analysis are interdependent (Figure 8.4). For example, involving users as part of *exploring and empathizing* causes additional *multi-actor complexity* that needs to be managed. Similarly, the design of a certain *technical solution* requires specialists that must be involved in the project but also influences the *economic viability* of the overall service system. Furthermore, the technical solutions are dependent on the service offering to be delivered. The interdependencies are not limited to the micro-level, but also constantly affect the actor-to-actor network on the meso-level and, hence, the smart service innovation uncertainty as a property of that level.

8.5 Discussion

8.5.1 Theoretical Contributions

With our grounded-theory-based interpretative study, we make contributions to the empirical inquiry of smart service innovation in multi-actor settings. We developed a theoretical model that is grounded in the data of 25 interviews with experts, who were involved in multi-actor smart service innovation. Our model draws on the framework by Storbacka et al. (2016) and thereby provides a multi-level perspective on iterative uncertainty reduction in smart service innovation. We specifically focus on the micro- and meso-level of the framework and describe how actor engagement in collaborative innovation activities on the micro-level relate to the smart service system on the meso-level. We identified four aggregate dimensions of activities including (1) *managing multi-actor complexity*, (2) *crafting a smart service offering*, (3) *developing a technical solution*, and (4) *ensuring economic viability*. We found that these activities are carried out by the involved actors under conditions of uncertainty resulting in *iterative uncertainty reduction*, affecting the smart service system as the innovation outcome. This study yields multiple contributions to the academic discourse on smart service innovation as described in the following.

First, we answer recent calls for more theoretical and empirical research on smart service systems (Djellal & Gallouj, 2018), especially considering broader sets of ecosystem actors that shape value creation in times of digital transformation (Sjödin, Parida, Kohtamäki, et al., 2020; Vink et al., 2021). Our findings emphasize that smart service innovation requires the collaboration of several actors who contribute a wide range of resources (Beverungen et al., 2018; Edvardsson et al., 2018; Lusch & Nambisan, 2015). With our study, we also address the need for evidence-based research on S-D logic that is "more midrange and microlevel theoretical in nature [...]." as put forward by Vargo and Lusch (2017, p. 50). In particular, our empirical insights shed light on the research frontier that they see concerning the co-creation of strategic planning and implementation by multiple stakeholders and how this co-creation affects firms and their stakeholders (Vargo & Lusch, 2017). In this regard, our findings indicate that smart service innovation projects can be considered as engagement platforms that provide shared institutional arrangements and facilitate the co-creation of strategic innovation initiatives. We identified iterative uncertainty reduction as our core category that reflects how co-creation in smart service innovation affects the actors involved. Moreover, we utilized the framework by Storbacka et al. (2016) to develop our multi-level theoretical model of iterative uncertainty reduction in smart service innovation, which is grounded in empirically observed activities (as reflected by the concepts, themes, and dimensions). Thus, we support ambitions leading to additional midrange and micro-level theory development that can help bridge the gap between S-D logic as meta-theory and real-life practice (Vargo & Lusch, 2017).

Taking a broader view, we also contribute to a better understanding of microfoundations in the context of digital transformation, which has been identified as an open research issue (Vial, 2019), too. Our grounding in S-D logic could provide a fresh perspective on how digital transformation can lead to changes in resource integration patterns and value creation. Parts of our theoretical model could be applicable to other settings of digital transformation beyond smart service innovation, which needs to be investigated further in future empirical studies. With regard to research on microfoundations in related fields, other works have previously conceptualized microfoundations of service innovation (Kindström et al., 2013) and digital transformation (Warner & Wäger, 2019) capabilities. These works, however, basically follow an understanding of microfoundations as sub-capabilities (Warner & Wäger, 2019) of organizational dynamic capabilities in line with Teece (2007). Hence, these works look at different levels of abstraction of capabilities (of a single organization), but do not consider different levels of aggregation (e.g., actors, service systems, and service ecosystems) as we do in this study based on the framework provided by Storbacka et al. (2016), which helped us to conceptualize the multi-actor nature of smart service innovation with its relevant facets.

Second, our study adds another level of detail to our understanding of smart service innovation by investigating activities at the micro-level of actor engagement (Storbacka et al., 2016). Thus, we go beyond existing studies that remain on macro- and meso-levels (e.g., Anke, Poeppelbuss, et al., 2020b; Ekman et al., 2016). Precisely, our findings illustrate what different actors actually do when they innovate collaboratively and how these activities provide microfoundations for managing uncertainty in smart service innovation. Our data structure with 54 concepts, 21 themes, and four aggregate dimensions gives a detailed and empirically grounded account of smart service innovation that was not available in previous studies. Furthermore, we provide linkages between the micro-level and the meso-level through our mapping of activities and actors' roles (Anke, Poeppelbuss, et al., 2020b). Adopting the concepts that Grotherr et al. (2018) use, we can say that our previous study (Anke, Poeppelbuss, et al., 2020b) has focused on the institutional design cycle that connects the macro- and the meso-level, whereas this study provides additional empirical insights into the engagement design cycle that links the meso- and the micro-level. Thereby, our previous (Anke, Poeppelbuss, et al., 2020b) and this study viewed together can provide a holistic understanding of smart service innovation across all levels that the framework of Storbacka et al. (2016) defines, from the macro-perspective of service ecosystems to actor engagement during operational project work.

Third, our results contribute to a better understanding of what makes methodologies suitable for collaborative projects that intend to develop socio-technical systems. Our interviewees mostly recommended the use of agile methodologies from software engineering like Scrum. These methodologies put a focus on short development cycles and continuous involvement of customers to enable the joint exploration of the customer problem and the iterative development of a suitable solution. Basic ideas of such agile approaches have also been integrated into SSE methodologies (Beverungen et al., 2018; DIN, 2019; Jussen et al., 2019; Usländer & Batz, 2018), too. However, they do not consider the involvement of multiple actors (beyond the customer) yet, and therefore do not guide how a network of actors can collaborate effectively during smart service innovation projects. To address this blind spot of existing SSE methodologies, it is conceivable to consider other, but more complex process models from software engineering like the Rational Unified Process (Kruchten, 2004) and the German 'V-Modell XT' (Angermeier et al., 2019) because these have been specifically developed to address multi-actor collaboration in large software development projects. However, the interviewees also emphasized that a flexible choice of easy-to-use methods for tasks at hand is required to cater for the explorative characteristic of smart service innovation, which would contradict the use of too formal and complex methodologies.

Fourth, by identifying iterative uncertainty reduction as the core category underlying our theoretical framework, our study links the two separate research streams of innovation uncertainty (e.g., Jalonen, 2012; O'Connor & Rice, 2013), and smart service innovation (Anke, Poeppelbuss, et al., 2020b; Beverungen et al., 2018). On the one hand, literature on the development of smart service systems, although recognizing them as "complex, open, and dynamic sociotechnical systems" (Beverungen, Breidbach, et al., 2019, p. 1202), has rarely touched upon the phenomenon of uncertainty. SSE methodologies and procedure models for smart service innovation (Beverungen et al., 2018; Jussen et al., 2019) consider uncertainty only implicitly when they recommend agile approaches, which are generally expected to help actors in accommodating and adapting to unforeseen changes in dynamic environments (Sjödin, Parida, Kohtamäki, et al., 2020). Our empirical findings provide a better understanding of why agile process models are particularly suitable for smart service innovation. The attribute *iterative* of our core category supports this basic idea of dealing with uncertainty.

In contrast, uncertainty has been discussed in innovation research intensively (Beynon et al., 2020; Jalonen, 2012; O'Connor & Rice, 2013), and a few times even in specific relation to (1) service innovation, (2) multi-actor settings, (3) digital transformation or combinations thereof (Ndubisi et al., 2020; Ortiz de Guinea & Raymond, 2019; Ramirez Hernandez & Kreye, 2020). Our empirical findings indicate that all of these three characteristics of multi-actor smart service innovation require activities directed towards reducing uncertainty. Ad (1), service innovation is usually linked to environmental uncertainty as customers' needs, preferences, and demands may not be well understood or can change unpredictably (Ndubisi et al., 2020). For product-oriented firms, service innovation is also likely to cause organizational uncertainty on their servitization journey, e.g., in relation to pricing and reorganization decisions or due to a lack of service culture (Ramirez Hernandez & Kreye, 2020; Sklyar et al., 2019). Ad (2), multi-actor settings fuel relational uncertainty, while, at the same time, they can reduce resource uncertainty by making specialized knowledge and technical resources of other actors available (Ramirez-Hernandez Kreye 2020). Ad (3), the context of digital transformation can lead to technical uncertainty in manifold ways because of the fast development of digital technologies, the increasing number of interfaces between smart products, digital devices, and legacy systems (Ramirez-Hernandez Kreye 2020), as well as the increasing influence of consumers on trends related to the use of digital technologies (Vial, 2019).

Our empirical findings mirror all these uncertainty types and emphasize that they need to be addressed holistically in smart service innovation. Through our data analysis, we were able to uncover the activities that the actors enact simultaneously to reduce these various influences of uncertainty in their smart service innovation processes. For instance, *exploring and emphasizing* as well as *horizontal prototyping and testing* support the reduction of environmental uncertainty, whereas *vertical prototyping* helps manage technical uncertainty. Mapping the aggregate dimensions of our theoretical model with the uncertainty types, we see that *managing multi-actor complexity* mainly addresses resource, organizational and relational uncertainty; *crafting a service offering* mainly considers environmental uncertainty, especially in terms of customer understanding; *developing a technical solution* covers the management of technical uncertainty; and *ensuring economic viability* is directed towards organizational and environmental uncertainty with regards to the wider business context of competitors, suppliers and larger macro-developments in the industry (Ramirez-Hernandez Kreye 2020). Furthermore, the four aggregate dimensions are not independent. The multi-actor setting of smart service innovation inherently causes *uncertainty reallocation* as described by Ramirez-Hernandez and Kreye (2020). On the one hand, the interdependent actors provide access to and recombine each other's resources (Beverungen, Müller, et al., 2019), thus reducing resource uncertainty. On the other hand, this leads to increased relational uncertainty, which requires the *management of multi-actor complexity*.

Our insights from the two rounds of interviews also indicate that the strategies of managing uncertainty, and, hence the relative importance of aggregate dimensions to different actors, might change over time, both during a single project and in the long term. In particular, ensuring a smart service system's economic viability has become a pressing challenge. Our experts reported that there was an increasing expectation to establish business cases for smart service innovation, while they had often been considered strategic investments or exploration projects without such a financial assessment only a few years ago. This might indicate a move from just coping or even accepting environmental uncertainty towards uncertainty reduction in its actual sense.

8.5.2 Limitations

As with all exploratory research, this study is not without limitations. Our data structure and theoretical model are grounded in the qualitative-empirical data of 25 interviews with informants from 13 organizations only. Although we felt to have achieved theoretical saturation with this set of interviews, investigating additional examples of smart service innovation processes as well as interviewing informants from other types of actors (e.g., customer organizations) could have led us to different conceptualizations. Another limitation concerns the limited perspective that we gathered on the activities of organizational actors because we interviewed only one expert per organization in most cases. The two deviant cases are PHARMACHINES and INTERNALIT, where the initial respondents from 2018 had left the organization by our second round of interviews in 2020. On the one hand, this inhibited a consistent perspective across the two rounds of interviews and forced us to search for alternative informants. This, however, even led to multiple respondents in 2020, and, hence, to a more comprehensive view on their smart service innovation processes, which we did not achieve for the other organizations. Furthermore, our codings and conceptualizations resulted from subjective interpretations of the interview data. We did not strive for any reliability of our codings. Instead, all three researchers engaged in a joint sensemaking process that aimed at a consensual understanding that offers meaningful descriptions and explanations for the phenomenon under study. All the aforementioned limitations might also restrict the transferability of our theoretical model into a wider research context, e.g., digital transformation or radical innovation projects more generally. Finally, the aggregate dimensions and concepts from our data structure should not be considered as normative advice on what good or best practices are. Based on the interview data, it is difficult to make a statement about the success of those activities because we were not able to assess innovation performance.

8.5.3 Practical Implications

For practitioners, our results are relevant regarding (1) the staffing and management of projects in multi-actor settings, (2) agile methods as key enablers for service innovation, and (3) developing economically viable service offerings.

First, our dimensions, themes, and concepts describe what the different actors typically do when they engage in collaborative smart service innovation. In this sense, they can provide a basic idea about the necessary resources, skills, and processes for smart service innovation. This does not only provide guidance for setting up and conducting such initiatives but also highlights potential dependencies on other actors. As smart service innovation takes place in multi-actor settings, it is key to identify and maintain relationships with relevant partners that complement the resources of one's organization. From a more strategic perspective, the different actors (e.g., the service provider) need to decide which of the required resources they want to build up internally and which ones are to be sourced externally. Our findings show which activities are usually taken over by which role and can thereby serve as a guideline for sourcing decisions. During data analysis, we assigned the activities to multiple roles. This indicates the necessity to collaborate with others unless a single actor assumes all relevant roles itself, which reduces complexity due to less cross-organizational coordination.

Second, the identified core category of iterative uncertainty reduction emphasizes the importance of an iterative process for smart service innovation. While it has to be acknowledged that uncertainty is an inherent part of any innovation, the awareness of the various sources of uncertainty as well as possible approaches to handling them may improve the innovation process (Jalonen 2012). The experts consistently recommend the use of agile methodologies to gradually reduce uncertainty. They also expect that following agile methodologies increases the likelihood that new smart service offerings are designed in a way that they meet actual customer demands. Nevertheless, agile methodologies also come with certain obligations for customers, e.g., the active participation in the role of a product owner during the project.

Third, as it cannot be overstated that smart service offerings need to solve a relevant problem of a customer, it makes sense to follow customer-centric approaches. Practice-oriented literature on business model innovation describes a continuous testing and experimentation process that distinguishes between desirability, feasibility, and viability in the progress of scaling business ideas (Bland & Osterwalder, 2019; Osterwalder et al., 2020). As progress is made, the focus shifts more towards assessing and ensuring viability. Hence, it is important to keep a balance of customer needs, technical feasibility, and provider value when crafting a service offering as reflected by our set of aggregate dimensions. That is, looking at *crafting a smart service offering* in isolation only addresses the issue of 'desirability'. This theme needs to be combined with assessing feasibility, to avoid putting a lot of effort into service ideas that cannot be realized in the end. If services are built from a technical perspective (*developing a technical solution*) without involving the customer, the Project Sponsor risks creating a service offering that fails to address customer needs. In the end, *ensuring economic viability* is needed to ensure that costs for building and operating the smart service systems are exceeded by benefits at the provider, which can take the form of revenue, savings, or strategic benefit (Zolnowski et al., 2017). Likely, the basic digital infrastructure that needs to be built up before any smart service can be offered is very costly due to its technical complexity. Therefore, practitioners should think ahead in how far their investments can lead to platforms, standardized components, or even white-label solutions that can be reused at a larger scale. Alternatively, it might make sense to incrementally build up micro-services as Sjödin et al. (2020) suggest.

8.6 Conclusions and Outlook

In this qualitative-empirical interview study, we examined how multiple actors collaborate in smart service innovation. Drawing on the theoretical lens of microfoundations (Felin et al., 2015; Haack et al., 2019) and the framework by Storbacka et al. (2016), we went beyond existing studies that remain on macro- and meso-level perspectives (Anke, Poeppelbuss, et al., 2020b; Ekman et al., 2016; Grotherr et al., 2018; Storbacka et al., 2016) and looked at the actor engagement on the micro-level in particular. Grounded in our interview data, we conceptualized four aggregate dimensions of actor activities, which are (1) *managing multi-actor complexity*, (2) *crafting a smart service offering*, (3) *finding a technical solution*, and (4) *ensuring economic viability*. We mapped the activities to the roles as conceptualized by Anke et al. (2020b), thereby providing a connection to the actor-to-actor network on the meso-level. We further conceptualized *iterative uncertainty reduction* as the core category underlying our theoretical model. Our findings explain how the activities of actors on the micro-level influence the environmental, technical, organizational, resource, and relational uncertainty (Ramirez Hernandez & Kreye, 2020) as a meso-level property of multi-actor smart service innovation.

Future research should try to understand the specific sources of uncertainty in smart service innovation processes better. From our interview data, we were able to derive that the actors were inherently confronted with manifold types of uncertainty, but they hardly named them explicitly. Future qualitative interview studies should dig deeper here, putting the interviewees' perceptions of uncertainty center stage and relate them to further aspects that might relevant to smart service innovation success, like developing a service culture, a customer-centric culture, or a digital mindset within organizations (Kindström et al., 2013; Ramirez Hernandez & Kreye, 2020; Warner & Wäger, 2019). In this regard, it could also make sense to explicitly study innovation failures. Such perspectives would probably also shed additional light on the various paradoxes that organizations have to cope with in today's dynamic environments (Gebauer et al., 2005; Kohtamäki et al., 2020; Sjödin, Parida, Kohtamäki, et al., 2020), like, e.g., the implementation of a customer orientation while maintaining an engineering mindset. Apart from these suggestions for further small-sample and qualitative studies, large-N survey studies could provide a further promising avenue for advancing microfoundational research (Foss, 2016). Here, the diverse existing conceptualizations of microfoundations and capabilities for service innovation and digital transformation (e.g., den Hertog et al., 2010; Kindström et al., 2013; Plattfaut et al., 2015; Warner & Wäger, 2019) could be put to the test in how far they can explain dependent variables like innovation performance or corporate success.

Future research should also try to investigate the engagement properties of the activities that can be observed in smart service innovation more thoroughly (Storbacka et al. 2016). Our findings already indicate that most, but perhaps not all, of the activities (as reflected by the concepts, themes, and dimensions of our data structure) require the mutual contribution of resources by multiple actors and hence can be classified as 'co-production activities' rather than 'value-in-use activities', which would be independent from the providing actor's presence (Storbacka et al., 2016, p. 6). Further issues relate to the information, relational, and temporal engagement properties of actor engagement (Storbacka et al., 2016). Regarding temporal properties, for instance, we can conclude from our previous research that actors may join or leave the smart service innovation project as the required resources also change over time (Anke, Poeppelbuss, et al., 2020b).

Finally, our findings might also spark design science research projects that advance the development of methodologies for smart service innovation and digital transformation (Alt, 2019; Anke, Ebel, et al., 2020). In particular, the two aspects of multi-actor settings and uncertainty reduction could be considered as blind spots of existing methodologies. Our findings support that the agile and iterative outlines of recent process models for smart service innovation (Beverungen et al., 2018; DIN, 2019; Jussen et al., 2019), which appear to be borrowed from software engineering, are meaningful and appear to be compatible with common practices of our interviewees, at least on an abstract level. However, it also became apparent from the interviews that the experts from practice usually do not know smart service-specific process models and methods that have been suggested in academia. Involving practitioners in such developments might also simplify the transfer of these methodologies into practice. One further approach may also be the adaptation of rather complex agile frameworks from software engineering like the Scaled Agile Framework (Scaled Agile Inc., 2020) or Disciplined Agile (PMI, 2020) to smart service innovation. Here it could make sense to map our dimensions, themes, and roles to the practices and roles as described in these agile frameworks.

Another important aspect with regard to methodologies is to find a suitable level of flexibility for the choice of methods and techniques. Due to the variety of aspects to be considered in the development of smart service systems, methods from different disciplines can generally be employed. As recent research has shown, different types of methods can be flexibly combined to effectively guide practitioners within an innovation process for digital services (Anke, Ebel, et al., 2020; Richter & Anke, 2021). Future studies should work towards an inventory of existing methods, which are suitable for smart service innovation, ideally based on empirical evaluation. A step towards such an inventory can be seen in the method compendium proposed by Holler et al. (2018), which contains methods for user-centric innovation, prototyping, system modeling, feedback, and service-/process modeling. Moving further towards this direction would help academics to develop methods and tools that address practical design problems in multi-actor smart service innovation.

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

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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.

9.1 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 qualify 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.

9.2 Research Background

9.2.1 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.

9.2.2 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'.

9.2.3 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).

9.3 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 9.1: Overview of expert interviews

We collected our qualitative interview data via phone between October 2018 to January 2019 (Table 9.1). 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.

9.4 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 9.2). 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 9.3). Furthermore, we grouped the project management challenges into the categories of planning, collaboration, and go-live (Table 9.4). 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.

Projec	Smart	Project Description
1	Energy distri-bution network	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	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 market-place, shows current tenders and market pricing.
7	Customer service for public	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	Development of a remote support service for industrial doors by DIGIBUSINESS for the door manufacturer.
10	Intermodal public transport	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	Development of a virtual reality training service using maintenance simulations of PHARMACHINES' products, which one of its customers triggered.
12	Remote support via	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 9.2: 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 9.3: 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	1, 5, 7, 9
	Getting access to and aligning work with stakeholders, e.g., partners, internal	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,	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 9.4: 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 9.5). 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 9.5: 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 Proposition	*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 9.6: 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 9.6). 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 9.7). 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,
		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 9.7: 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 9.8: Challenges in the process dimension

In total, only two experts mentioned challenges that refer to the process dimension (Table 9.8). 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 to 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 9.9: 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 9.9). 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.

Cate-gory	**Sub-category**	**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
	Organizatio n	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 9.10: Challenges in the resource dimension

Challenges regarding the resource dimension (Table 9.10) 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.

9.5 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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10 Combining Methods for the Design of Digital Services in Practice: Experiences from a Predictive Costing Service

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Abstract. Exploiting digital technologies for innovative service offerings as part of the digital transformation has been under discussion for several years. As recent research has shown, practitioners struggle with the systematic design of digital services. Along with the progress in the understanding of digital service systems, academia has proposed various processes and methods which are contributing to a methodology for Service Systems Engineering. However, such methods are rarely applied in practice. In our study, we utilize Action Design Research to evaluate how existing methods can be applied in a project that aims to design a service for predictive costing. Our findings are formalized as a combination of methods and their links. It shows how these methods can be employed to guide the innovation process. Although the generalizability of the results is limited through the single case study approach, the proposed combination of methods provides evidence-based knowledge on Service Systems Engineering, which is relevant for practitioners and researchers alike.

Keywords: Digital Services, Service Systems Engineering, Action Design Research, Methodology, Service Innovation

10.1 Introduction

Applying digital technologies for services enable new value propositions and innovative business models. Such digital or smart services thus represent an interesting source of competitive advantage for many companies. However, companies struggle to design economically sustainable digital service offers [1]. Due to the complexity of such systems and the uncertainty in the innovation process, experts from various disciplines have to be involved [2]. Systematic design and development of digital services are addressed by Service Systems Engineering (SSE). Agile engineering processes for such services have been proposed, e.g. the DIN SPEC 33453 [3] or Recombinant Service Systems Engineering [4]. These process models organize the dynamic aspects, e.g., project phases. Concrete methods can be applied to guide the steps required to create intermediate work products, such as business models, service concepts, or system architectures. A variety of methods that address the specifics of digital service systems has become available as a result of recent research.

While the body of knowledge on SSE for digital services is growing, there is little empirical evidence on their suitability and practical application. To inform future research on this topic, we concur with Böhmann et al., who call for evidence-based design knowledge for SSE [5]. As a recent analysis of 14 smart service projects has shown, there is a wide variety of methods employed but in none of the investigated projects, any method specifically design for digital services or smart services was used [2]. At the same time, several established methods are applied for the engineering of Smart Service Systems in practice and appear to be suitable for this task [2]. Against this background, we pose the following research question: *How can existing methods for designing digital service be combined in a real-world scenario?*

We consider this research question as timely and relevant, as it is not required to "re-invent the wheel" but identify existing suitable methods and combine them with new methods specific to digital services. Our research aims to provide insights on both the suitability of different methods for the task but also their combination.

To address the research question, we apply Action Design Research (ADR) as the leading paradigm. It describes the systematic learning from the collaboration between practitioners and researchers in real-world settings to design an artifact. ADR is organized in four stages (1) problem formulation, (2) building, intervention, and evaluation, (3) reflection and learning, and (4) formalization of learning [6]. As previous research has shown, ADR is suitable for transferring knowledge for innovation in the practice [7, 8]. We consider ADR suitable for our research, as it allows us to apply and evaluate methods in a real-world scenario. The intended outcome is organizational knowledge of how digital service innovation can be supported by a set of existing methods. This combination of methods can be considered as the artifact to be designed.

The remainder of this paper is structured as follows: After this introduction, we provide the conceptual foundation, followed by the research approach. The fourth section covers the case study and project organization. This is followed by a discussion of the results. The paper closes with a conclusion and an outlook.

10.2 Conceptual Foundation

Service Systems are a configuration of people, processes, and technology to co-create value. **Digital Service Systems** utilize digital technologies such as cloud computing, big data, and artificial intelligence as fundamental system elements for the provision of resources, competencies, or value creation. Therefore, value co-creation is mainly based on data [9]. Furthermore, it should be noted that there is a difference between digital and smart services [10]. Smart services are therefore considered as a subset of digital services, as they additionally include the integration of connected objects (smart products). It should be noted that digital services and smart services are often used interchangeably, as the stricter distinction has been proposed only recently.

Service Systems Engineering (SSE) [5] refers to the systematic design of Service Systems and incorporates processes, models, and techniques. Processes for SSE include the DIN SPEC 33453 [3], Recombinant Service Systems Engineering [4], and Smart Service Engineering [11]. They mainly provide a set of phases and activities, which help to structure the overall engineering endeavor. Another set of contributions for SSE consists of concrete methods that guide individual activities through models, e.g. Design Thinking for Industrial Services (DETHIS) [12] or the Smart Service Canvas [13]. To distinguish the four sets of methods, we introduce the categories "digital service specific methods" (DSM), existing "service engineering methods" (SEM), methods regarding "user-centered design" (UCD), and "general-purpose methods" (GPM). These categories represented existing methods and practices, which are applied for different purposes. Methods of the GPM category are the most general ones, e.g., from social research or general management. UCD methods are used within agile projects with innovative character to ensure that the resulting products are accepted by the user. While UCD can be applied to any kind of technical or digital product, service, or process, SE methods are targeted at the engineering of services. Finally, DSM consider the specifics of digital services, such as data, devices, and analytics.

Based on the insight that a single process model will not be suitable for a large variety of project settings, the concept of **Situational Method Engineering** (SME) [14] was proposed. It aims to flexibly combine various methods to adapt to the development process depending on the individual situation at the beginning of the project. However, it requires formal modeling of methods (fragments) and their storage in a method base to flexible combine them at the beginning of a project. A study by Clarke and O'Connor has identified eight groups, 44 factors, and 170 sub-factors that influence the selection of methods [15]. For smart services, there are typically agile approaches employed. They are less formalized, and the choice of methods is not fixed at the beginning of the project. Rather, the agile project team continuously review and adapt their way of working, e.g. during "retrospectives".

10.3 Preparing the Action Design Research Project

10.3.1 Problem Formulation

The first step of the ADR approach is problem formulation. Based on the state of the art, we can identify two problems: (1) DSM are unknown in practice, and (2) existing process frameworks for SSE may propose a set of methods but do not provide guidance for their combination. The ADR process can help to solve both aspects of the problem. DSM can be transferred to the project setting through the researcher, which also fulfills ADR principle 2: "Theory-ingrained artifact". For that, a list consisting of 30 methods was created, which serves as the basis for method selection in each iteration (Table 10.1).

As indicated in Table 10.1, the method list is largely based on the methods mentioned in the appendix of DIN SPEC 33453. Although the DIN SPEC 33453 is aimed at digital service systems engineering, there were no DSM mentioned. Therefore, we added DSMs that were cited in the 2020 edition of a textbook on data-driven service engineering and management [16] or recently published at information systems conferences. Due to the large number of methods proposed by academia, the list cannot be considered exhaustive. However, as the compiled list contains methods for various purposes in service innovation, we are confident that it is sufficient in a real-world project.

10.3.2 Introduction of Case

We collaborated with a medium-sized German software company, which we refer to as ALPHA in this paper. It develops solutions for product cost calculation based on a common platform. The products are targeted mainly at car manufacturers and their suppliers. To be competitive in the market, the company aims to expand its product range with a new smart service, known as predictive costing, which supports cost estimation. If a car manufacturer submits a request for an offer to a supplier, they usually have little time to deliver a valid offer in terms of costs to the car manufacturer. The planned service is intended to have a supportive effect on this process. As the innovation project for the predictive costing service is an instance for this class of problems, it fulfills the ADR principle 1 "practice-inspired research". To jointly solve this service innovation problem in a structured way, i.e., use appropriate methods, is the goal of the project.

Type	Methods	
GPM	5 Why's [3] 9-P Marketing Mix [3] ABC-Analysis [3] Brainstorming [3] Conjoint-Analysis [3] Environment Analysis [3] Expert Interview [17] How Might We-Questions [3]	Idea-Contest [3] Interview for Empathy [3] MoSCoW- Prioritization [3] Nightmare Competitor [3] Shadowing [3] Stakeholder Analysis [3] Stakeholder Map [3] SWOT-Analysis [3]
UCD	Customer Journey [18] Digital Mock-Up [3] Low-Resolution Prototyping [3] Pains & Gains [3]	Persona [3] Prototyping [3] User Story Mapping [19] Value Proposition Canvas [3]
SEM	Customer Journey Mapping [20] Job Mapping [3]	Minimum Viable Service [3] Service Blueprinting [3]
DSM	Information Service Blueprint [21]	Smart Service Canvas [13]

Table 10.1: Overview of considered methods

Long-term support is provided as the partner company is willing to develop a new smart service. One researcher assumes the role of the action researcher, while employees of the company are the practitioners. The development process is led by the action researcher in consultation with the partner company. The selection, application, and evaluation of these methods were discussed with the second researcher to ensure state-of-the-art guidance for the project as well as effective learning and reflection. In conjunction with the knowledge of the practitioners regarding the currently used technologies and their potentials, the ADR principle 4 “Mutually influential roles” is addressed. Additionally, this setup represents an inter-organizational collaboration often found in SSE [22]. Using the set of roles proposed by Anke et al., the company can be characterized by the “Project Sponsor” role, while the university took over the “Digital Innovator” role [22].

10.3.3 Project Setup and Process Model

As an overall project structure, the basic process of DIN SPEC 33453 was chosen, which describes an agile process with the phases analysis, design, and implementation [3]. These phases are connected by a decision point and can be conducted in any sequence [3]. While other process models for designing Digital Service Systems might be equally suitable, we chose it as we expect it to become more widely known in the future due to its governance by an established standardization body.

The overall project was conducted from April to June 2020. In line with the agile approach of DIN SPEC 33453, it was subdivided into iterations to facilitate feedback and reduce risk. Each iteration begins with the decision on a method that appears appropriate. For its selection, the iteration objective, and the situational factors (conditions) are considered. For example, the "idea generation" activity of the analysis phase is characterized by creativity and cooperative knowledge exchange [3]. Workshops are an organizational format that is suitable for these specific requirements [23] but limits the set of applicable methods, as not every method for generating ideas can be applied in a workshop. For generally applicable methods, it needs to be decided on whether they are suitable for the given context. A qualitative approach is being taken to answer this question. A method is to be considered "suitable" if it creates results that can be used in a subsequent iteration. In the next section, the planning, execution, and results of each iteration will be presented in more detail.

A total of five iterations were conducted to design the predictive costing service. Iterations I and II are part of the analysis phase of the DIN SPEC process model. After that, a decision had to be made on whether the service idea will be further pursued. Following the positive decision, iteration III focused on a more detailed elaboration of customer demands. The decision after that iteration was to pursue activities of the design phase. Iterations IV and V are therefore in the design phase, as the established understanding was used for the development of a service concept. Table 10.2 provides an overview of the methods and settings for each iteration.

Iteration Objective	Applied Methods (Type)	Setting
I. Identify Innovation Potentials	- Customer Journey Mapping (SEM)	Workshop (digital)
II. Idea Assessment	- Expert interviews (GPM)	Meetings (digital)
III. Elaborate Customer Assumptions	- Smart Service Canvas (DSM)	Workshop (digital)
IV. Complete the Value Proposition	- Smart Service Canvas (DSM) - How Might We (GPM)	Individual work
V. Design the Service Concept	- Information Service Blueprint (DSM) - Smart Service Canvas (DSM)	Workshop (digital & face-to-face)

Table 10.2: Overview of iterations and applied methods

Subsequently, details of each iteration are provided based on the following structure. It relates to the "building, intervention, and evaluation" phase of the ADR process:

- What was the initial situation and objective of the iteration?
- Which methods were considered and how were they selected?
- How were they applied and which results did they yield?

Unlike other ADR projects, we did not develop an IT artifact, as a selection and combination of innovation methods is an organizational artifact. Therefore, ADR principle 3 (Reciprocal Shaping) did not apply in our study. To address the ADR the principle 5 "Authentic and concurrent evaluation", we gathered feedback after each workshop. Participants were asked (1) if the applied method or parts of it was known in advance, (2) if the objective were achieved, (3) if the method yielded a meaningful result that could be used further. Additional feedback was collected on potential improvements and positive aspects of the method. This fulfills the ADR principle 6 (guided emergence), as it helps to iteratively design the desired artifact. It also helped us to understand if the introduction of these new methods was rather difficult. After each iteration, the researcher reflects upon the effects of the applied method, which addresses the ADR phase "Reflection and Learning".

10.4 Application and Evaluation of Methods

10.4.1 Iteration I: Identify Innovation Potentials

Initial Situation and Objective: The starting point of service development is a rather unclear idea of a predictive costing smart service. The targeted customer segment as well as the outgoing customer process are not sufficiently clear to the practitioners at the beginning of the development. The physical presence of all participants cannot be assumed, which is why methods and technologies must be used that allow execution over the Internet. New service ideas are based on known or assumed customer needs. Within the analysis phase, they can be identified and prioritized [3]. Subsequently, the service concept can be developed from an understanding of customer problems. Possible methods to tackle this objective are e.g., Interview for Empathy, Expert Interview, Job Mapping, Customer Journey Mapping, Shadowing, or the Smart Service Canvas. To speed up the development process, assumptions regarding the customer are made in the first iteration. Subsequently, the service concept is developed incrementally. Its realization as a prototype allows the verification of the assumptions of the customer.

Applied Method and Rationale for its Selection: A suitable method is *Customer Journey Mapping* (CJM). It helps to describe the service process from a customer point of view and improve the understanding of customer experience during the use of the service. Unlike *service blueprinting* or *multilevel service design*, or *customer experience modeling,* the customer process, ("journey"), is considered holistically in customer *journey mapping.* Instead of using a General Purpose Modeling Language and focusing on a service system or a single service provider, a holistic approach is used here [24]. The chosen organizational setting is a workshop, which has been identified as suitable for the collection and sharing of ideas [23], including CJM [24].

Application of Method and Results: A total of five persons, aged 35 – 45, from the departments Research & Development (R&D), product management, sales and consulting participated in the workshop. All results were documented by the moderator in "Draw.io" using a shared screen. In the beginning, the participants were instructed on the method and its application. After that, a persona was modeled to represent a typical user of the service. Based on this, the customer journey for the current service process (AS-IS) is modeled. Using a voting scheme, all workshop participants could identify customer touchpoints, which were considered particularly positive or negative on the overall experience, the so-called "moments of truth". Negative touchpoints represent potential sources for innovative ideas that improve the customer experience. In the last step of the workshop, these innovation potentials were jointly identified. After the workshop, identified innovation potentials were evaluated through a first technical analysis and a rough estimation of development cost. The workshop resulted in a definition of a persona with 24 attributes as well as a customer journey with eleven touchpoints and six moments of truth. All the six moments of truth were identified as negative influences on customer experience. Based on that, a potential innovation idea for predictive costing service was identified and documented in the form of a mind map.

Evaluation: The gathered feedback on the iteration was positive, as all participants stated the workshop achieved its objective, and only one participant said that no meaningfully usable result was created. 2 of 5 participants stated they had not known the method used beforehand. Positive feedback was received for structuring the method introduction using an example before each process step. Improvement potential was identified regarding time planning. Especially for the task "Model Customer Journey" participants wanted more time, which was interestingly the part that already took more time than originally allocated for it.

Reflection and Learning: The noted insufficient time for designing the customer journey is most likely attributable to the relatively high level of detail of the produced method artifact. To account for this, it seems reasonable to start with a more general method, e.g., the customer perspective of the Smart Service Canvas.

10.4.2 Iteration II: Idea Assessment and Follow-Up Decision

Initial Situation and Objective: The second iteration aims to examine whether identified innovation potentials are promising enough to be pursued further or whether new ideas must be searched for.

To this end, insights into the related problem “carry-over part analysis”, especially the frequency, are to be required. Carry-over parts are elements, which can be used in multiple products without modification. As other vendors in the market are already offering solutions for carry-over part analysis, it is important to understand its relation to the potential new predictive costing service. Generally, suitable methods are e.g., Interview for Empathy or the Expert Interview, “to be” Customer Journey, and Idea Contest.

Applied Method and Rationale for its Selection: The *expert interview* is a method that is suitable for data collection when the knowledge of the expert to be interviewed appears useful in the design, implementation, or control of problem-solving. The interview attempts to reconstruct (explicit) expert knowledge and to gain useful insight from this. Characteristics of expert interviews are the thematic focus, the use of technical terminology, and the communication of all participants at eye level [17].

Application of Method and Results: In total, three interviews were conducted. Selected experts were two product managers as well as a customer, who is the Head of Cost Engineering and Order Design of an automotive supplier. The duration of the interviews was one hour for each product manager and 30 minutes for the customer.

The execution is divided into three phases: preparation, interview, and follow-up. The preparation aims to make the actual interview as efficient as possible. Specifically, the interviewer familiarized himself with the topic and elaborated a guideline with relevant questions. Within the preparatory phase, the questions are forwarded to the interviewee, so that they can prepare themselves for the interview, too. The interviews are conducted digitally through the collaboration tool Microsoft Teams. After a short introduction at the beginning of each interview, the questions sent in advance are answered by the expert and recorded in writing by the interviewer. After successfully conducting all three expert interviews, the results are processed and consolidated. Similarities and differences within the answers are identified. This serves as a basis for discussion as to how the developed innovation potential "equal part analysis" should be pursued.

Evaluation and Learnings: The results and the subsequent discussion helped to make an informed decision on the follow-up of the innovation potential. In addition to the decision-making discussion, the expert knowledge collected is useful and valuable for further service development. Due to the intensive preparation of the appointments, it was possible to hold technical and efficient discussions. Expert interviews are suitable for situations in which in-depth knowledge is required and where a common knowledge base and technical language already exist between the participants.

10.4.3 Iteration III: Elaborate Customer Assumptions

Initial Situation and Objective: According to DIN SPEC 33453, the identification of innovation potentials is followed by the structured elaboration of customer assumptions regarding the innovation potential. In this step, it is important to understand what the customer is doing, what goals he pursues, and which circumstances are inhibiting or promoting, e.g., with Shadowing or the Smart Service Canvas. Ideally, this is done in collaboration with potential customers. Due to external influences, this was not possible for this iteration. The availability of the company's employees, as well as the willingness of customers to spend time on this task, was low due to other priorities (mainly caused by the COVID-19 pandemic). To create high-quality results, this iteration is based on the employees with high customer contact, as they are available for a sufficiently long period. Meetings and workshops could still only be held online.

Applied Method and Rationale for its Selection: The first workshop shows that a less straightforward and more interactive method should be chosen. A structured yet flexible approach for the analysis, development, and description of smart services is the *Smart Service Canvas* (SSC) [13]. It builds on the Value Proposition Canvas (VPC) [19] and extends it with smart service specific aspects, which classifies it as DSM. The SSC is organized into the value perspective, the customer perspective, the ecosystem perspective, and the fit between these perspectives (see Figure 10.1). As one of these perspectives focuses on the customer, this section of the SSC should serve as the basis for the workshop. The customer view is based on the customer profile of the VPC and includes the fields *Customer Routines and Jobs*, *Customer Pains,* and *Customer Gains*. These are supplemented by the fields *Context of Customer Tasks* and *Contextual Things and Data*. A customer view is recommended for each customer segment to be considered [13]. We expect the SSC to support gaining a structured understanding of the customer and elaborate on the service using the other perspectives at a later stage.

Application of Method and Results: To prevent the timing problems that occurred in the first workshop (Iteration 1), the time-boxing technique was applied in this iteration. Time-boxing was originally applied in agile software development to restrict the available amount of time for a task. This should lead to a selection of the most important tasks, which fit in the defined time box and thus lead to an improvement in software quality [25]. In our case, two workshops were planned with three slots of 40 minutes each to address the modeling of aspects persona, Customer Gains, Customer Routines and Jobs, Customer Pains, Context of Routines and Jobs, Contextual Things and Data. The workshop was conducted using Microsoft Teams and all results were continuously documented in a shared "Draw.io" document. The four participants were aged 35 – 45 and worked in the departments R&D, product management and sales. The result of the workshop is another persona with 22 attributes. The SSC customer perspective could be filled with 13 entries for Customer Gains, 11 for Customer Jobs, 19 for Customer Pains, 12 for Context of Customer Jobs, and 10 for Contextual Things and Data.

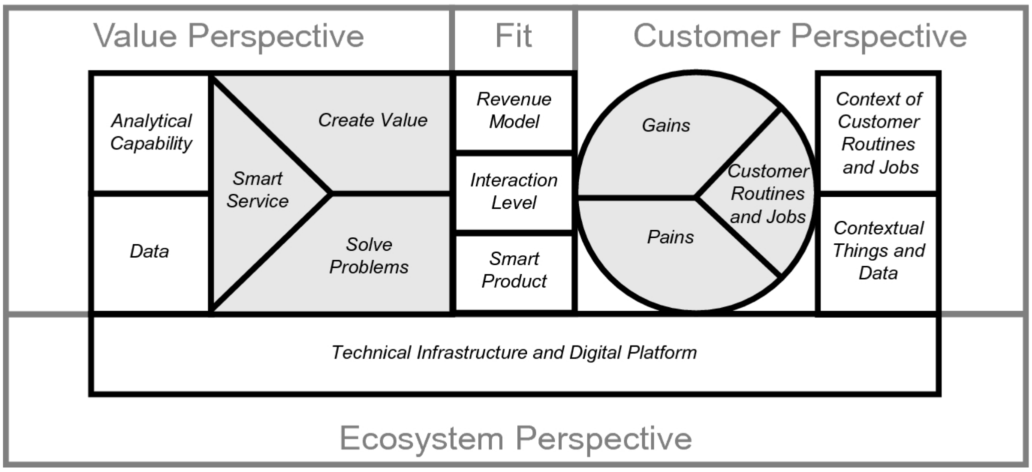

Figure 10.1: Smart Service Canvas [13]

Evaluation and Learnings: The creation of the persona was significantly faster than in the first workshop. According to the principle of time-boxing, the gained time was transferred to the task modeling of Customer Gains. Due to the economic situation of the company, fewer people took part in the second workshop day. This resulted in a lower communication effort, which saved time that was added to the discussion on Contextual Things and Data. The classification of Customer Gains and Jobs/Routines resulting from the literature proved to be difficult and not clear-cut. For this reason, this differentiation was dropped in the second workshop. It was also found that many Customer Gains are mutually dependent. The Contextual Things and Data field received special attention within the workshop, with a focus on the area of data.

The feedback of the workshop participants shows that the method performed was either not known among the participants or was not known in the smart service-specific form. The objective of the workshop has been achieved and the result has been evaluated as reusable. On the positive side, an increase in the participants' understanding was recognized. The structure of the workshop and the time organization was also positively noted. For even more efficient meetings of this kind, a stronger usage of an example scenario was asked for. The customer's perspective of the SSC can be used when an identified customer segment must be investigated. It is important to limit customer activities, which are to be considered within the SSC. Therefore, the method is not suitable for an exploratory approach. However, in the initial phase of service engineering, the open design of the SSC reveals strengths through its flexibility.

10.4.4 Iteration IV: Complete the Value Proposition

Initial Situation and Objective: The results of the first two workshops in Iteration I and Iteration III were able to provide a comprehensive understanding of the customer. Based on these findings, the first thoughts on the actual service offer are now being made. The goal of this iteration is to formulate the service's value proposition. This value proposition should be the basis for the initial design of the service concept. The service concept in turn should be sufficient as a basis for an initial prototype.

Applied Method and Rationale for its Selection: In this iteration, we focused on the value perspective and the ecosystem perspective of the SSC. For that, a basic idea of the service is required first. Due to holidays, short-time work, and pandemic-related restrictions, a workshop-format implementation was infeasible for the targeted time frame of this iteration. Therefore, we needed a flexible method that supports creativity in service development. One of them is to ask result-oriented questions, the so-called "How Might We"-questions. They aim to trigger creative solution approaches for relevant customer problems [3]. This approach is based on two assumptions: Firstly, a general common understanding has been already established so that this step can be carried out individually and does not necessarily require the organizational framework of a workshop. Secondly, the value perspective can be filled with the help of result-oriented questions. The relevant fields are Smart Service, Create Value, Solve Problems, Analytical Capabilities, and Data [13]. The ecosystem view describes the digital platform and technical infrastructure that underlies the smart service. The technical infrastructure includes, for example, the necessary hardware for power supply, but also the required network connection. The digital platform encompasses the ecosystem on which the smart service is based [13].

Application of Method and Results: The basis for the creation of the "How Might We"-questions are the customer problems of the SSC's customer perspective. At first, a thematic clustering of the problems is carried out here. Subsequently, the corresponding questions are derived from it. The preparation of the questions is iterative, to ensure that they are neither too broad nor too narrow for the required level of creative freedom. The questions were sent to each participant and answered individually. An individual discussion of the answers takes place after that. The result of this iteration first thoughts on the design of the new smart service. It also provided a reason to discuss the differentiation with the competition. It was also determined that the original service positioning had to be modified: Instead of a general similar part service, the focus shifts towards target price offerings, i.e. a specific form in the preparation of quotations.

Evaluation and Learnings: The method used by the "How Might We"-questions is well suited as a creative solution-oriented introduction. The value perspective of the SSC helped to thematically structure the answers. Individual elaboration seems to be possible if a common understanding of the topic has been established in advance. The integration of an initial definition question ensured that all participants had considered the content of the same topic. This increases the response quality and enables the combination of individual solution proposals. However, the high flexibility must be paid for through high effort in the preparation of the questions, as well as in the follow-up through individual discussions and the evaluation of the answers.

10.4.5 Iteration V: Design the Service Concept

Initial Situation and Objective: The goal of this iteration is to create a service concept in a structured form. The quality of the result should be sufficient for the creation of an initial simple prototype. Initial considerations from previous iterations are to be incorporated into the concept creation. Based on the results, the value perspective of the SSC is to be refined. To tackle these objectives potential methods are e.g. Job Mapping, Digital Mock-up, Paper Prototyping, and (Information) Service Blueprinting.

Applied Method and Rationale for its Selection: Service Blueprints are structured visual descriptions of a service delivery process [26]. It allows the separation of tasks performed by the customer and backstage activities. *Information Service Blueprint* (ISB) is a variant of Service Blueprints for Information Intensive Services (IIS) [21]. The ISB is structured in a matrix of layers and phases, to which the individual actions are assigned. The default structure of the ISB comprises the seven rows Customer Action, Information, Information Delivery System (IDS), Information Production System (IPS), and Partners. The IDS and IPS rows are divided into Information and Communication Systems (ICT Systems) and Roles of Employees. This is completed by the horizontal grouping of activities into the seven phases of objective attainment in an IIS process: Define, Prepare, Execute, Monitor, Modify, and Conclude [21]. The first row of the ISB default structure lists the customer's activities, while the second row describes the information content. The rows IDS and IPS shows which roles of the employees, respectively of the ICT systems, participate in the generation and provision of the information. The bottom row represents the partners of the provider network that may be involved in the service process [21]. It is highly recommended to customize the structure of the ISB according to individual needs and the intended scope.

Application of Method and Results: The workshop is carried out on two dates with the partial physical presence of the participants. Two employees of the R&D department and one member of the company's product management department are involved. As a starting point, an overview of the *Service Blueprint* method is given, followed by the ISB. The workshop is organized in three phases according to the ISB design approach: Customization, Blueprinting, and Analysis. In phase one, a customized ISB is created, which is used to design the target service. Depending on the purpose, the default structure of the ISB can be adjusted by deleting, reworking, splitting, consolidating, or extending the rows. The initial step in phase one is to define the scope of service blueprinting. Here, the related customer segment and the participants of the design process are determined. Step two adjusts the rows of the ISB. The IIS is drafted in phase two. All components of the previously defined ISB are traversed row by row. The exact sequence of the rows to be traversed can be varied, provided that the customer-oriented perspective is valued. Finally, for this phase, the ISB is divided into the individual columns that categorize the service process. The third and final phase involves the analysis of the designed IIS. First, the Service Blueprint is thoroughly reviewed to ensure that no important points are missing. The final step is to look for ways to improve the design. If necessary, a further breakdown of customer actions or customer information may also be carried out beyond phase three [21]. The completed ISB for the predictive costing service is shown in Figure 10.2. It shows the ISB in the adapted version, as it was used in the workshop. The rows Customer Actions, Information, and ICT Systems were adopted from the default structure. For the optimal mapping of the Predictive Costing process, the rows Algorithm, Data Location, as well as Internal and External Data Provider were introduced. They emphasize the data-heavy nature of the service design developed in this workshop. After the workshop, the existing contents of the SSC value perspective were refined. The discussed findings and the developed service concept from the ISB workshop are incorporated. The result is a further elaborated value proposition of the service.

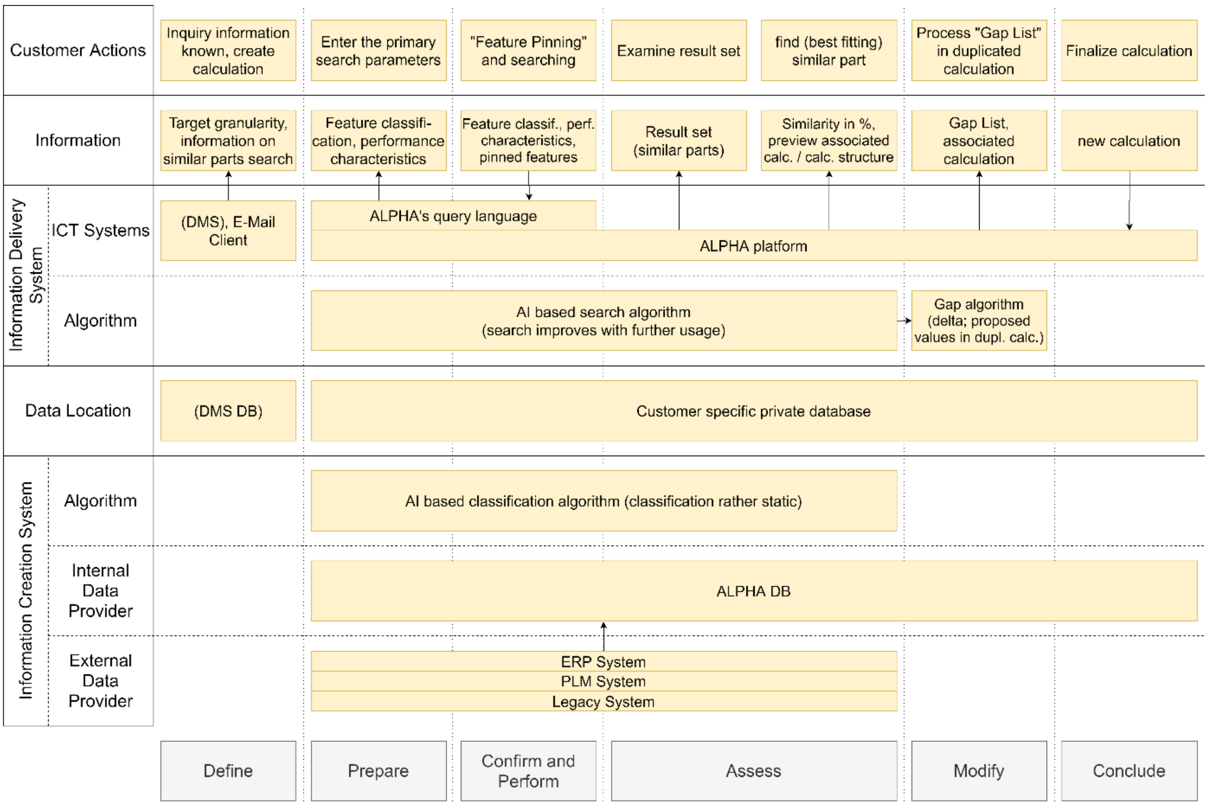

Figure 10.2: Workshop Artefact "Information Service Blueprint" (own depiction)

Evaluation: A structured, comprehensive service design was successfully developed in two workshop appointments. In the beginning, the high degree of abstraction of the method, as well as the high flexibility, was perceived as challenging. However, this was successfully addressed with an iterative approach. Like the CJM method, ISB is particularly suitable for "happy path"-representations. The results of the SSC were a useful basis for the work on this task. By dividing the service process into seven phases, we discovered new customer steps that were not considered before. The ISB helps to discuss specific details of the service, as it shows how individual steps and the various systems interact with each other. Through the discussion within the workshop, also a new customer segment for the service was identified. The first result, classified as a "convincing first draft", can be transferred to a *Paper Prototype* in a further step. It may also be useful for a discussion with customers.

Reflection and Learning: After several iterations, the SSC proves to be a viable tool to keep an overview and consecutively enhance the service while also keeping in check, that the value proposition aligns with the customer needs in the end.

10.5 Discussion and Formalization of Learning

The overall project can be considered as a success, as a useful service concept was collaboratively developed within the Action Design Research approach. Several artifacts were created, which represent a growing understanding and advancement in the development of a new service. Our research yielded the following **findings**:

1. All identified tasks could be supported with a method from our pre-compiled list, which contained DSM, SEM, UCD, and GPM types of methods.
2. All selected methods were found to be suitable as they created useful results that could be further elaborated and reused in subsequent iterations.
3. The combination of methods is not only possible but also particularly useful. It turned out that they helped to provide structure and guidance for the service innovation project, e.g. through different perspectives and levels of detail.

However, the variety of methods poses a high demand on the competence of project participants. DSM were not known to most practitioners, which underlines the findings by Wolf et al [1] and Anke et al [2]. Even more established methods like *Customer Journey Mapping* required an introduction to the participants. Being aware of a certain method and its purpose, however, is not enough. We found that many details needed to be taken care of to apply the selected methods effectively.

Besides the practically relevant result, the learning regarding the research question must be considered. In phase four of the ADR method, the learning should be formalized. For that, the ADR principle 7 "generalized outcomes" needs to be applied. The main result of our study is a selection of methods and their combination to support the systematic design of a new digital service. For that, we (1) extracted the chosen methods used in the project, (2) identified and labeled the output of each applied method, and (3) connected the methods based on their input-output-relation. A visual representation of the method combination is shown in Figure 10.3.

Starting from an initial service idea, the methods on the right-hand side are focused on advancing the understanding of the customer and its problems. These are the input for the customer perspective of the Smart Service Canvas. The link to the value proposition is achieved using the "How might we?"-method. A detailed service concept for the developed value proposition can then be elaborated using the Information Service Blueprint, as shown on the left-hand side of the figure. It has also helped to improve the value proposition, as indicated by the dotted arrow. The figure indicates the central role of the Smart Service Canvas for the innovation process, as it combines the customer view with the value proposition view.

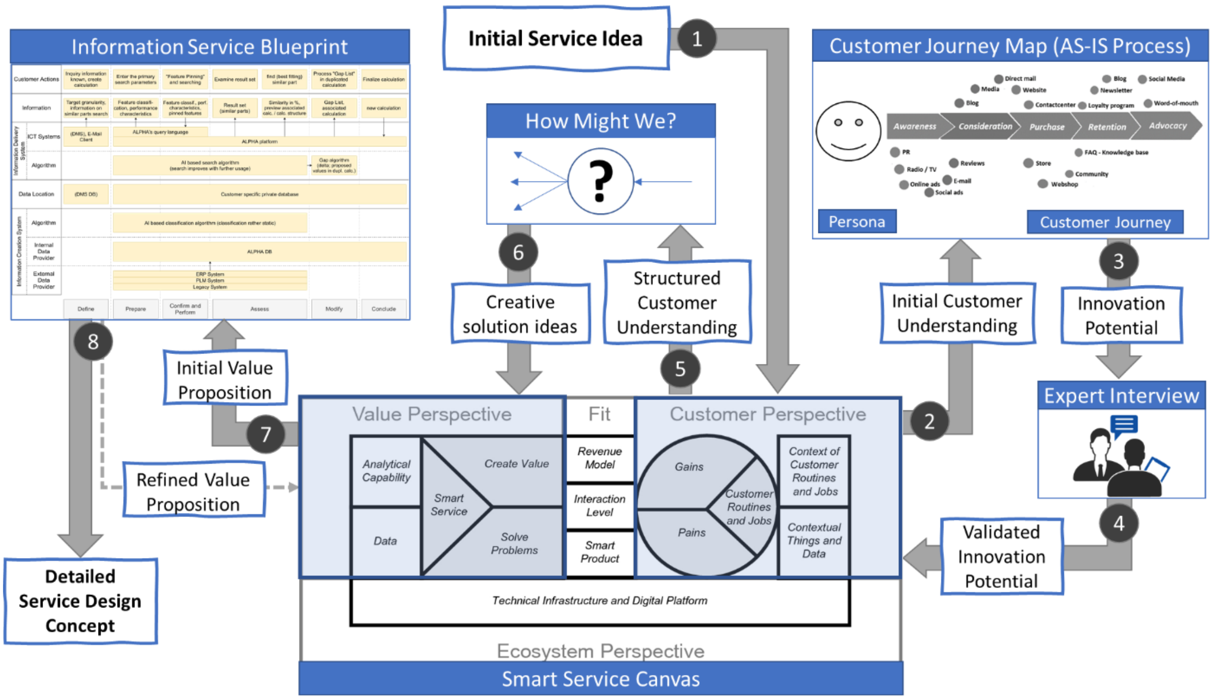

Figure 10.3: The proposed combination of methods for iterative service innovation

Concerning the underlying DIN SPEC 33453 reference process model, we found that the first three steps are related to "Analysis" phase activities, while steps 4 and 5 are part of "Design" activities. None of the methods contribute to the "Implementation" phase, as it was not within the scope of the ADR project in this study. However, we would like to highlight that the proposed combination of methods is not limited to projects using the DIN SPEC 33453 process model.

The result shows a combination of existing methods for digital service innovation, which was successfully applied in a real-world project. We assume, that this specific case is a representation of a digital service according to Heuermann, Duin, et al. [27]. It should be noted that the proposed combination is neither claimed to be the best nor the only one. However, we assume that it is applicable to similar innovation projects, as the selected methods are designed for these tasks. Furthermore, the input-output-relationships between the proposed combination of methods are not specific to the concrete case in our study. Practitioners might use it as a starting point, especially if the methodological competence in an organization is low. It might also help to stimulate discussion about method combinations for both practitioners and researchers alike.

The results of our study are subject to **limitations**. ADR, as a research paradigm, is inherently subjective, i.e. a different researcher might have selected different methods and/or applied them slightly differently. Also, the competence and knowledge of methods and their application highly depends on the individual. This is amplified by the application to only a single case. Finally, the underlying list of 30 methods in total was not exhaustive. Other researchers might have known different methods. Due to the many factors that influence the suitability of methods in a concrete situation, our results should be considered as an illustrative yet thoroughly conducted example. Finally, the project took place during the COVID-19 virus pandemic. Therefore, most settings had to be digital rather than face-to-face meetings. This imposed further restrictions on the selection of methods, as not all methods are suitable for digital settings. However, as remote work is a widely used way of collaborating, this is setting is not exceptional.

10.6 Conclusion

This study sheds light on the application of multiple SSE methods in a real-world project and thus helps to understand how these methods are used together to develop new digital services. It shows how methods are combined and how synergy effects are used. These are DSM, such as *Smart Service Canvas*, and SEM, such as the *Customer Journey Map*, but also GPM such as the *Expert Interview*. The special circumstances of the case study also show that medium-sized companies with scarce resources can successfully develop digital services using new methods. The exchange between science and practice was organized efficiently through the structure provided by ADR, which makes the use of this approach for future innovation projects promising [7].

The **contributions** of this study are as follows: First, we showed how existing methods for SSE can be applied in practice and evaluated their suitability for the task. We provided rationales for the selection of methods, described their application, and created results. Second, we critically reflected on the challenges and pitfalls that occurred during the usage of chosen methods. Third, we showed how the results of the applied method can be used for other methods in a later iteration. The link between inputs and outputs of methods is the basis for a combination of methods in a meaningful way. The work also helped to gain new insights into the methods used, e.g., *Customer Journey Mapping* was carried out in its entirety. Unlike the study by Senderek et al. [11], it was applied to a complex customer process. The *Smart Service Canvas* from Pöppelbuß and Durst [13] proved to be a helpful framework for structuring the development work across multiple iterations. The application of the *Information Service Blueprinting* [9] provides another example of a customized ISB, which can be used as an additional source of inspiration. Finally, our results indicate a set of methods that actors with the "Digital Innovator" role could use to facilitate the creation of new service ideas [22]. From our results in the investigated project, the following **conclusions** can be drawn:

- There was no lack of methods for the tasks at hand, but a lack of awareness for their existence and competence for their application. Hence, the focus should be on the transfer of existing methods to practice, rather than on the development of new ones. This appears to be inconsistent with a study that found that existing methods do not cover all phases and perspectives in SSE for smart services [28]. However, it is not contradictory as they evaluated the suitability of methods regarding smart service characteristics, while we focused on the innovation stage of a single case in practice.
- The combination of methods is helpful to coordinate work in digital service innovation projects, but as of now, there is little guidance on how to combine which methods. Therefore, future research should focus on the potential links between existing methods, e.g. through input/output-relationships.
- High flexibility in selection and combination of methods is needed to cater to different types of tasks, settings, and competencies. Thus, better means for descriptions of such settings are needed, e.g. through taxonomies of services, innovation patterns, and skillsets. Furthermore, there are no criteria to evaluate these combinations, e.g. regarding their suitability to a concrete setting. Some of the concepts from SME might be useful but should probably be less formal.

Overall, the results of this research provide an example for further advancing empirically grounded knowledge on SSE. Due to the high relevance for practice, this topic offers opportunities for collaboration between academics and practitioners.

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11 Modelling of a Smart Service for Consumables Replenishment: A Life Cycle Perspective

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Abstract. Smart services are an approach for the IT-supported provision of services based on networked products. They enable new relationships between manufacturers and end users, as well as the establishment of new value-creation networks. To gain benefits from these potentials, service providers face the challenges of designing and managing smart services. This is mainly due to the complexity of the underlying cyber-physical system (CPS) as well as the individual life cycles of components and third-party services it consists of. Additionally, a number of actors and their tasks, various tangible and intangible benefits, as well as flows of material, information and money need to be considered during the planning and provisioning of the service. In this paper, we investigate the potential of modelling smart services with the Lifecycle Modeling Language (LML). To this end, we analyse the fulfilment of information need of different stakeholders based on a consumable material replenishment service for 3D printers.

Keywords. Life Cycle Modelling, Smart Services, Internet of Things, LML, Supply Chain Management

11.1 Introduction

11.1.1 Motivation

As part of the ongoing development of the 'Internet of Things' (IoT), physical products get enhanced with embedded systems and communication capabilities to turn them into intelligent and networked products. Such products provide globally usable digital functions in addition to their local physical functions (Fleisch et al. 2015). Services provided based on the data from connected products are called 'Smart Services' in this paper. For example, networked bicycles provide smart services to track training data, warn at chain wear-out and to request assistance when sensors indicate a crash (Shaw 2014). Industrial products such as compressors, ventilators and elevators get upgraded with smart services for remote control, monitoring, usage based billing and other services (Herterich et al. 2015).

The transformation of product-based value offerings towards service-based ones is called 'Servitization' (Neely 2008). It enables entirely new relationships and interactions between manufacturers, operators and users of physical goods and thus provides the basis for new data-driven business models (Velamuri et al. 2013; Zolnowski et al. 2016). Especially manufacturers of technical products and devices can

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reshape the nature and quality of their customer relationship by offering innovative services and thus differentiate from the competition (Fischer et al. 2012; Herterich et al. 2016). Additionally, such services can be provided by third parties, which become part of new value-creation structures as service providers and intermediaries in platform ecosystems (Mikusz 2015).

To design smart services, providers have to combine the suitable functionality to create value for the respective customer groups and plan the steps for service provisioning, which may involve partners and third-party services. At the same time, the financial impact of the new service has to be estimated based on the necessary resources and the expected sales volume. Particularly during the transfer of demonstrators and prototypes into marketable offers, a number of steps have to be taken to provide a quality level demanded by customers. For that, the entire life cycle of development, manufacturing, usage, maintenance, and disposal must be considered and flows of information, material and money taken into account.

The resulting complexity is on one hand due to the interdisciplinary design process, in which different departments of the company have to collaborate. On the other hand, smart services are complex systems, which consist of many technical and organisational subsystems that need to work together in order to provide the service. Each of the subsystems and the smart service as a whole have different life cycles (Aurich et al. 2007). As the design of complex systems can be supported with appropriate models (Becker et al. 2010), we address the following research question in this paper: *Which benefits can stakeholders gain in the development of smart services through a modelling of the life cycle with LML?*

Our main thesis is, that modelling life cycles of smart services with LML increases transparency about the processes of service delivery as well as the dependencies of components with each other. Therefore, an LML model of smart services can facilitate both the provision of information needs for various stakeholders and the early identification of risks.

11.1.2 Methodology

Research Goal. The goal of this article is to demonstrate and discuss the benefits of making smart services transparent by modelling their life cycles. This enables developers of smart services to better understand the effects associated with the planned service. The underlying assumption is that a better comprehension of relationships between various product-, software-, and process elements in a smart service improves the handling of complexity, e. g. identification of risks.

As result of our research, we expect insights regarding the potential benefits that a smart service life cycle model can provide for different stakeholders. Identified shortcomings may at the same time provide a basis for an extension of the modelling language.

This work focusses exclusively on the evaluation of a model of processes and structures for the provision of smart services for networked products. The modelling procedure as such is explicitly not considered and therefore out of scope.

Research Approach. We address the research question based on a case study in five steps:

- At first, smart services for networked products are characterised as product service systems provided by a cyber-physical system. For that, we identify the main system elements and the relevance of their life cycles.
- From these two aspects we derive information needs for different stakeholders that participate in the design and operation of smart services.

- Afterwards, we introduce a scenario for a smart service, which provides automated replenishment of consumables for 3D printers. This scenario is modelled using LML.
- Finally, the model is evaluated based on the objectives which were elaborated in the second step. Furthermore, we evaluate benefits of the model based on the fulfilment of information needs of different stakeholders.
- From these results we draw conclusions about the suitability of life cycle models in the design process for our chosen case study and further research needs.

This paper is structured according to this approach.

11.2 Life Cycles of Smart Services

11.2.1 Characteristics of Smart Services

'Smart Services' denote the needs-based provision of a combination of Internet-based and physical services (Kagermann et al. 2015). Smart services can also be considered as *product service systems* (PSS) as they are 'an integrated offering of tangible products, intangible services and enabling infrastructure' (Tietze et al. 2013). PSS are means for transforming product-oriented offerings to service- and results-oriented offerings, especially for technical products (Adrodegari et al. 2015).

Networked products are also referred to as 'intelligent products' (Meyer et al. 2009) or 'smart objects' (Vasseur and Dunkels 2010). The terms may vary in detail, but they all share the idea that physical products are equipped with digital communication capabilities as well as IT-based functionality to acquire or even influence the state of a product and its environment. This allows products to get integrated more efficiently in the usage-context of the customer (Kees et al. 2015). The networking of the products also enables the easy integration of the product as an external factor and thus creates the basis for data-driven service offerings (Porter and Heppelmann 2014).

The provision of smart services is typically based on the following principle: A networked product records its state using sensors and supplies the data using machine-to-machine communication (M2M) over the Internet. Some devices also provide actuators and respective control operations. The communication between product and central server or cloud service is conducted via the Internet (Wortmann and Flüchter 2015). In the cloud, the product state data serves as basis for operational and analytical functions. A smart service combines different functions on the cloud, augmented with data and functionality from other Internet services. Customers can consume the service via mobile apps or Web applications.

Smart services are thus socio-technical systems, consisting of sensors, actuators, embedded systems, digital networks, Internet services as well as coordination and management processes. Systems with this set of elements are *called cyber-physical systems* (CPS) (Broy et al. 2012). Existing work on CPS deals mainly with technical aspects. However, there is also the view of CPS as a basis for service provision. This view focusses on a combination of products and services as well as their coordination via of software to create value for customers (Mikusz 2014).

In this paper, we define *smart services* as PSS, which provide services using data from technical products based on a CPS (cf. Mikusz 2015). A prerequisite for the analysis and modelling of life cycles in smart services is the understanding of its system components. To this end, we have concretised the general CPS elements for the case of a CPS facilitating the provision of smart services (see Table 11.1). These CPS elements will get mapped to LML elements later on.

11.2.2 Fundamentals of Life Cycles

Terms and Concepts. A life cycle denotes different, successive periods of time that mark the way of a product or a service. From this flow-based perspective (Umeda et al. 2012), the life cycle can be divided into phases. Kiritsis suggests the separation into beginning-of-life (BOL), middle-of-life (MOL) and end-of-life (EOL) phases (Kiritsis 2011). The three phases can be further subdivided into processes. For example, material-, energy-, and information flows throughout the life cycle can be mapped to the life cycle phases (Umeda et al. 2012). An example of a product life cycle model is shown in Figure 11.1.

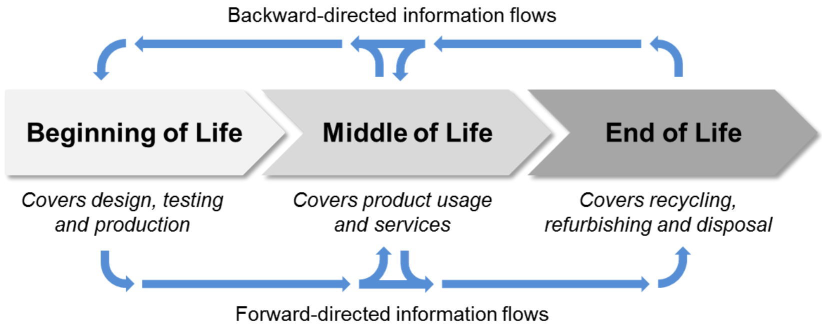

Figure 11.1: Example of a product life cycle model (Wellsandt et al. 2015)

An even more specific perspective on the life cycle is the consideration of individual products (Hans et al. 2010) rather than classes of products. This so-called 'item-level PLM' focusses on product information, which belong to a single, identifiable product or product component. This information, for example, is relevant for the individualisation and servicing of products (Corcelle et al. 2007).

General CPS item	Manifestation of the CPS element for a smart service
Physical process	Local, physical function of the product
Sensors and actuators for capturing and controlling physical processes	Various forms depending on the specific product, such as sensors for fill level, temperature, pressure, and actuators for switching and control
Embedded systems	Embedded system for monitoring and control of the physical product with embedded software and communication module for data transmission
Digital networks	Various technologies for the connection of embedded system and operator cloud platform, e. g. mobile communications, Wi-Fi, or corporate networks
Utilization of globally available data and services	(cloud-based) operator software platform and any additional Internet services, e. g. electronic marketplaces
Multi-modal human ma-chine interfaces	Various forms of user interaction on the product itself, via mobile apps or Web applications
Management processes	Management of the service (booking, configuration, billing)
Coordination processes	Provision of the service, control of service provision
Logistics processes	Delivery of physical (e. g. spare parts, consumables) or digital components (e. g. software updates)

Table 11.1: Manifestation of the CPS elements for a smart service

Life cycles and smart services. The provider of a smart service is typically responsible for the entire life cycle of the underlying service system. The challenge in designing such a system is that individual components of the system are developed separately but have to work together in order to provide value to the customer. Each service system element can have an individual life cycle. For example, different versions of a component can exist over time (e. g. software platform). Changes in the life cycle of individual components may arise through new customer requirements, legal changes or availability of new technologies (Wolfenstetter et al. 2015).

In contrast to the product life cycle shown in Figure 11.1, several life cycles need to be considered simultaneously. These life cycles run in parallel or side by side with a temporal offset. Furthermore, there are relations between the stages of life cycles. The following list shows examples of effects arising from changes in the life cycle of a smart service system element:

- *Customer or product reports problem:* Identification of the associated elements, classification into potential physical or digital problem fixes. Remote control, configuration or update procedures or dispatching of technicians have to be performed for affected components.
- *Defect of the product:* Replacement of the physical product requires logistics for the delivery, return of the defective product, as well as updating the service configuration to make it work on the new product.
- *Defect of embedded system:* Replacement of the affected hardware, update of the embedded software, transfer of service configuration, e. g. to preserve the product's digital identity.
- *Changes in the service management processes:* Enhancement of the operator cloud-platform and service configuration for customers, update of the embedded software, e. g. to facilitate additional pricing models, such as prepaid or subscriptions.

These examples show that modifying one element can affect others, which may lead to disruptions in the service provisioning. Being aware of these dependencies is of great importance for ensuring a high availability of the system. As we will show in the analysis of information needs for different roles, this holds true for activities in all life cycle phases. It also helps to prevent unwanted side-effects and supports collaboration in the ongoing operation and optimisation of the service system.

The types of relationships between life cycles or parts of a life cycle are currently being discussed. Westphal et al. (2015) and Wiesner et al. (2015) explain the importance of interactions between product and service life cycle management for manufacturing companies. Kwak and Kim (2013) present an approach for life cycle costing and life cycle assessment to analyse the economic and ecological impact of PSS. Lindström et al. (2014) show interactions of life cycles in 'Functional Products'. This type of PSS consists of hardware, software, management operations and a service support system. Further challenges in dealing with multiple life cycles in the product and service development are investigated in current research projects, e. g. the Manutelligence Consortium (2016), the Falcon Consortium (2016) and the Psymbiosys Consortium (2016). *Classes and instances of service elements.* While the aforementioned life cycle considerations refer to the management of smart service component types, the advances in information technology provide increasing possibilities to trace individual components. These components will be referred to as "instances" in this paper – the same notion is already used for physical objects (Hans et al. 2010). Each instance of a smart service component has information about its own life cycle, e. g. how and where it was produced, used and disposed. Taking an instance-level perspective on smart services increases the complexity of the system under investigation. Herein, complexity refers to the number and diversity of components, as well as their relations among each other (cf. Funke 2012, p. 683). Instead of managing types of products, software and services, a plethora of instances with own life cycle information must be handled by the smart service provider. This increase in complexity challenges the existing life cycle management approaches. On the other hand, access to instance-level information can be a valuable basis for additional smart services, e. g. predictive maintenance. Further, it enables smart service designers to improve the service system (Lützenberger et al. 2016).

11.2.3 Modelling of Life Cycles

From the previous sections, it can be seen that a smart service as CPS-based PSS is characterised by high complexity due to two properties:

- *Diversity* of system elements (e. g. mechanical and electronic components, software, processes for service provisioning and management) as well as the number of relevant stakeholders.
- *Interdependencies* caused by relationships among system elements as well as the necessary consideration of information flows, material flows, and money flows between them (cf. Sect. 11.2.2).

These two aspects should be addressed by life cycle modelling, to make the model useful for smart services design. This is substantiated by following objectives:

- *Illustrate the complexity and thus improve its manageability.* Complexity is characterised by the number and by the variety of system elements and by the number of relationships between them. The model should be able to represent the required elements and relationships.
- *Enable identification of risks through dependencies between system elements.* Effects caused by modifying one component on other system elements must be identifiable, e. g. the exchange or upgrade of hardware or software.

A comparison of modelling approaches for services from various disciplines showed that especially the modelling of PSS, as well as the representation of life cycles were only weakly supported (Hoffmann et al. 2009). Some basic model types that can be used in the context of service modelling, are described by Scheer et al. (2004). More specific approaches used to describe processes are for example proposed by Gronau et al. (2010), Klingner and Becker (2012) and Meis et al. (2010).

Widely acknowledged modelling languages are Business Process Model and Notation (BPMN), Unified Modeling Language (UML) and Systems Modelling Language (SysML). A comparably novel language is the Lifecycle Modelling Language (LML). A committee of systems engineering practitioners and academics introduced it in 2015. LML bases on SysML and the Department of Defense Architecture Framework, and it focuses on life cycle modelling in particular.

Characteristic	BPMN 2.0	UML 2.5	SysML 1.4	LML 1.1
Focus	Business processes	Software-based systems & business processes	Systems engineering problems	Systems engineering problems along entire life cycle
Type	Process modelling	General-purpose modelling		
Spec page count	538 pages	794 pages	346 pages	70 pages
Reference	OMG (2011)	OMG (2015b)	OMG (2015a)	LML Steering Committee (2015)
Ease of use	Low	Low	Medium	High

Table 11.2: Application difficulty of systems modelling languages in life cycle modelling

Very few academic papers mentioned LML since its release in 2015 (e. g. Hefnawy et al. 2016). Therefore, we had little complementary literature to evaluate it. All four modelling languages are potential tools to support life cycle modelling. An important characteristic of a smart service is the component diversity. Actors with different backgrounds are involved to plan these components and their orchestration. Examples are marketing experts, mechanical and electrical engineers, programmers, sales people, lawyers and customers. For this reason, the ease of use is an important criterion to evaluate the suitability of modelling languages. It means that a language is, for instance, comprehensible and easy to learn. Table 11.2 provides an overview about the focus, type, page count, and the ease of use of the identified languages. We derived the focus and type values from the languages' specification documents (see references). The page count refers to the pages of the specification document in PDF format – we do not differentiate preface, content and annex. We consider it as a rough indicator for the time an actor needs to learn a language. Our estimation of the ease-of-use grounds on the page count and the scope of a language. In this context, more pages lead to a lower ease of use.

BPMN's focus on business processes and the extensive documentation indicates the high complexity of the language. UML follows a general-purpose modelling approach and its specification is even more extensive compared to BPMN. Therefore, we consider it as difficult to use as well. SysML is an extension of UML and a general-purpose modelling language. We identified it as easier to use compared to the other two languages. The reason is that SysML aims to support the collaboration between systems engineers and software engineers. This objective reflects the involvement of heterogeneous actors in a development task. LML is a general-purpose modelling language meant for systems engineering with a dedicated focus on the product life cycle. The specification has 70 pages, which indicates a high ease of use. The preceding assessment identifies LML as the most promising candidate for a language in life cycle modelling.

One of the distinct features of LML is an ontology that stores the specified entities and their relationships. The ontology includes twelve basic entity types. Each of these entities is related to all other entities in specific ways. LML supports inheritance, for instance, the entity type "resource" is derived from the superordinate type "asset". The LML ontology is supported by different visualization methods to represent the behaviour as well as the structure of systems. Examples include activity diagrams (how the system behaves) and hierarchy diagrams (how system elements relate to each other). Figure 11.2 illustrates an excerpt of the entities and their relationships.

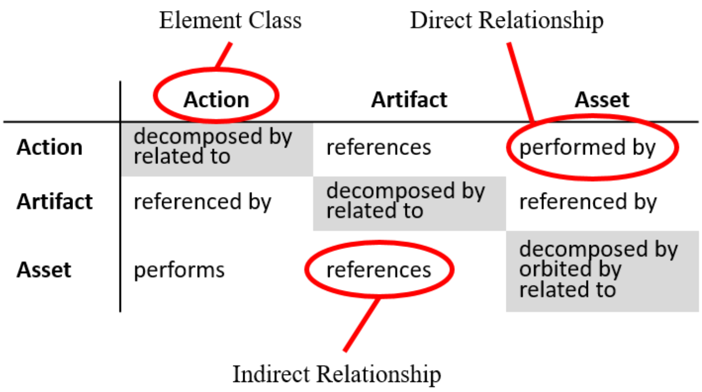

Figure 11.2: Selected element classes and relationships

The applicability of LML in the context of smart service life cycle modelling is illustrated in Table 11.3. On the left column of the table the aforementioned elements of a smart service are listed. The middle column contains examples of LML entities that can be used to represent the elements. For each entity, there are examples provided in the right column.

General CPS Items	LML Entities	Examples
Physical process	Activity Input/Output Asset	Represents the actual process. A consumable that is used up. Hardware performing the process.
Sensors and actuators for capturing and interacting physical processes	Activity Input/Output Asset	Measurement or actuation. Sensor data. Sensors and actuators are product parts.
Embedded systems	Asset	The hardware and software.
Digital networks	Conduit Input/Output Asset	Internet, Wi-Fi, 5G network. Data shared via network. Software systems sharing data.
Use of globally available data and services	Activity Input/Output Asset	Service integration. Data. Services, service market.
Multi-modal human machine interfaces	Conduit Input/Output	Human-machine interface. Data shared via the interface.
Management processes	Activity Input/Output Asset	Represents the actual process. Shared data/information. Business unit, role, IT-system.
Coordination processes	Activity Input/Output Asset	Represents the actual process. Shared data/information. Business unit, role.
Logistics processes	Activity Input/Output Asset	Represents the actual process. Parcel that is transported. Truck, logistics provider, customer.

Table 11.3: Mapping of CPS elements to LML expressions.

11.3 Case Study

11.3.1 Replenishment for 3D Printers

In this section, we present an example for a consumable replenishment service. Consumable replenishment is a commonly offered smart service. Table 11.4 summarises several examples of these services, which are currently offered.

Case	Scenario	Consumable	Source
Winterhalter	Pay-per-wash offering for industrial dishwashers	Detergents	(Winterhalter 2016)
Canon	Pay-per-page offering for industrial printers	Ink, Paper	(Canon Europe 2017)
HP	Pay-per-page offering for consumer ink cartridges	Ink	(HP Inc. 2016)

Table 11.4: Existing Cases of Smart Services for Consumables Replenishment

One goal of a consumable replenishment service is to ensure that customers have access to a previously agreed service level. The service operator charges the customer based on this service level agreement. An example for a service level is the amount of printable pages in an office printer. In the case of intelligent products, embedded measurement devices monitor the service level. An office printer, for instance, monitors the remaining amount of ink/toner to calculate the amount of printable pages. Once the ink/toner supply reaches a threshold value, the printer orders additional consumables.

In this paper, we focus on a consumable replenishment service for 3D printers. We created the concept and the life cycle model for this service during the EU-funded research project Manutelligence. A producer of additive manufacturing machines collaborated with us in this process. For them, the service concept was an opportunity to estimate the complexity of a consumable replenishment service. With this information, we supported them in their decision regarding the realization of the service. Thus, the life cycle model represents a real case for a consumable replenishment service. The following descriptions and models refer to main components of the envisioned smart service for 3D printers, which serves as a representative for similar cases.

3D Printers. Additive manufacturing processes have been in use for many years for building prototypes. In consumer 3D printing, the 'fused filament fabrication' (FFF) technology is mainly applied, for example in the open-source 3D printer 'RepRap' (RepRap Project 2014). The basis of FFF is a heated printing head that melts solid materials, like thermoplastics. The print head can be moved in all three spatial directions with the help of a moving frame structure. Once applied, the liquid material hardens and forms the body to be manufactured layer by layer. In the following, we use the term '3D printer' as a synonym for FFF-based printers.

Consumables Replenishment. Similar to conventional paper printers, a 3D printer requires a steady supply of printing material. It is typically provided in the form of a plastic wire coiled on a spool. Depending on the printer type, one or more spools with filament can be stored in the printer, e. g. different colours or water-soluble material for support structures. A service which is relevant to owners of personal 3D printers as well as for professional service providers, is the automated deployment of filament. The provision of the service does not only involve the customer and the service provider (operator) but also other companies, e. g. the logistics provider and disposer of empty spools. The service falls in the category of condition monitoring services, which require existence of distinct product instances, relevant product state properties and target levels for these properties (Knoke and Thoben 2014). The basis for the performance of the service is a contract between the customer and provider, which defines the technical requirements, performance levels, terms and conditions. As first step, the 3D printer has to be connected to the ordering system of the operator and registered as a new instance of the product. Afterwards, the state 'remaining printing material' from the printer can be queried and delivered for further monitoring to the operator's platform.

The actual service provision is conducted according to the proposal of Knoke and Thoben: At the customer site, a purchase order is automatically triggered by the 3D printer when the state of 'remaining printing material' falls below a threshold value of e. g. 10%. Depending on the configuration, an approval of the order is required by the customer. At order receipt, the operator has to fulfil it by supplying the consumables to the customer. The provider can delegate this task to a wholesaler for plastics or to a plastic manufacturer. The purchased materials have to be delivered to the customer via a logistics service provider. The provision of consumables can additionally be bound to the obligation to take back the emptied material spools to facilitate recycling. Depending on the contractual agreement, collection points or a return shipping via a logistics service provider can be arranged for this. The billing in turn depends on the pricing model. In the example described, both individual order and subscriptions are possible. Both variants are offered with comparable services such as 'Total Service Care' (Canon Europe 2017) and 'Instant Ink' (HP Inc. 2016).

11.3.2 Information Needs of Stakeholders

Designing smart services is a interdisciplinary project. The service provider must involve different departments in order to get a comprehensive understanding of the requirements for a new service (cf. Laurischkat 2013). With regard to our research question, we need to evaluate the benefits of a smart service life cycle model for the involved stakeholders. In the following, we denote the different stakeholders as roles. To derive the information needs of each role, we first identify some of their main tasks and goals (cf. Junginger et al. 2006):

1. ***Marketing:*** Increase customer loyalty, sell service contracts, understand customer needs
2. ***Development:*** Design and implement smart service system technically
3. ***Finance:*** Minimise required investment budget, ensure profitability of the service
4. ***Procurement:*** Procurement of consumables and spare parts
5. ***Logistics:*** Picking, packing and transporting of consumables and spare parts
6. ***Customer Support:*** Solving customers' problems, improving service availability

From the tasks and goals, we have identified information needs in the different life cycle phases, which are summarised in Table 11.5. For a model to fulfil these information needs, we have derived a more general set of objectives as follows:

- *O1: Support the conception of product-related services.* Modelling should support planning of smart services, as well as the preparation of further analyses, e. g. life cycle assessment, or life cycle costing.
- *O2: Allow an assessment of the service concept.* The model must be easy to comprehend, e. g. through clarity and unique labels for elements and relationships.
- *O3: Support the planning of required capacity for resources.* Required resources and capacities such as person hours can be depicted in the model.

11.3.3 LML Model of the Smart Service

Modelling Approach. The aim of this model is to describe the elements and their relations with respect to the features of the chosen smart service example. The formally correct modelling is not the primary goal. Instead, we focus on the assessment of the life cycle modelling based on the objectives and information needs listed in Sect. 3.2. The modelling of the example service is done by the derivation of specific items from the LML ontology element classes. The corresponding relationships are automatically created according to the LML specification by the modelling tool Innoslate (SPEC Innovations 2016), which we have used for our research. Activity diagrams and graphs are used to visualise the elements. The term 'Graph' is used instead of 'Spider Diagram' specified in LML. Spider diagrams typically have a different structure and meaning than the chart type in the LML specification.

Role	BOL needs	MOL needs	EOL needs
Marketing	customer needs, prices	customer satisfaction, customer number	next generation products, recycling demands
Development	system requirements, solution approaches	Identified problems and bugs	technical migration paths to next version
Finance	planned revenues and development cost	operating cost and actual revenues	cost for warranties and recycling
Procurement	type of items for procurement, planned lead times, potential suppliers	quantities and times for the provision of intermediate consumption	(no information need identified)
Logistics	required stock space, lead time, package sizes, quantities	Items to be delivered quantities and dates	removal of old equipment from customer sites and / or recycling
Customer Support	contact channels, availability, languages, response times	current incidents / tickets	(no information need identified)

Table 11.5: Examples of information needs of different roles by life cycle phase

Step 1 - Determine Stakeholders and their Relationships. As the first step, relevant stakeholders have been identified (similar to the perspectives in a service blueprint). This way, the model is given an initial frame, which can be detailed further. The number of stakeholders to be included depends on the required level of detail in the modelling. It is not our intention to show how a service can be described as comprehensively as possible. Therefore, we have only taken a small number of stakeholders taken into account. A selection of stakeholders allows a first consideration of the life cycle, i. e. stakeholder from different phases of the life cycle should be considered (but ultimately not all have to be modelled). In addition to stakeholders, first relationships were also taken into account. Relationships denote information and material exchange between stakeholders. An overview of the stakeholder and their relationships of the example service is given in Figure 11.3.

Besides the customer, who is at the centre of the service, three companies are identified as external partners. The service provider communicates directly with the customer and determines current needs for consumables. The provider passes the request on to a wholesaler for plastics, which in turn informs a logistics provider. The logistics provider receives the required material from the wholesaler and delivers it to the customer. Emptied spools are returned by the customer to the logistics service provider, who transports it to the wholesaler or disposer. Returning emptied spools is not part of the model.

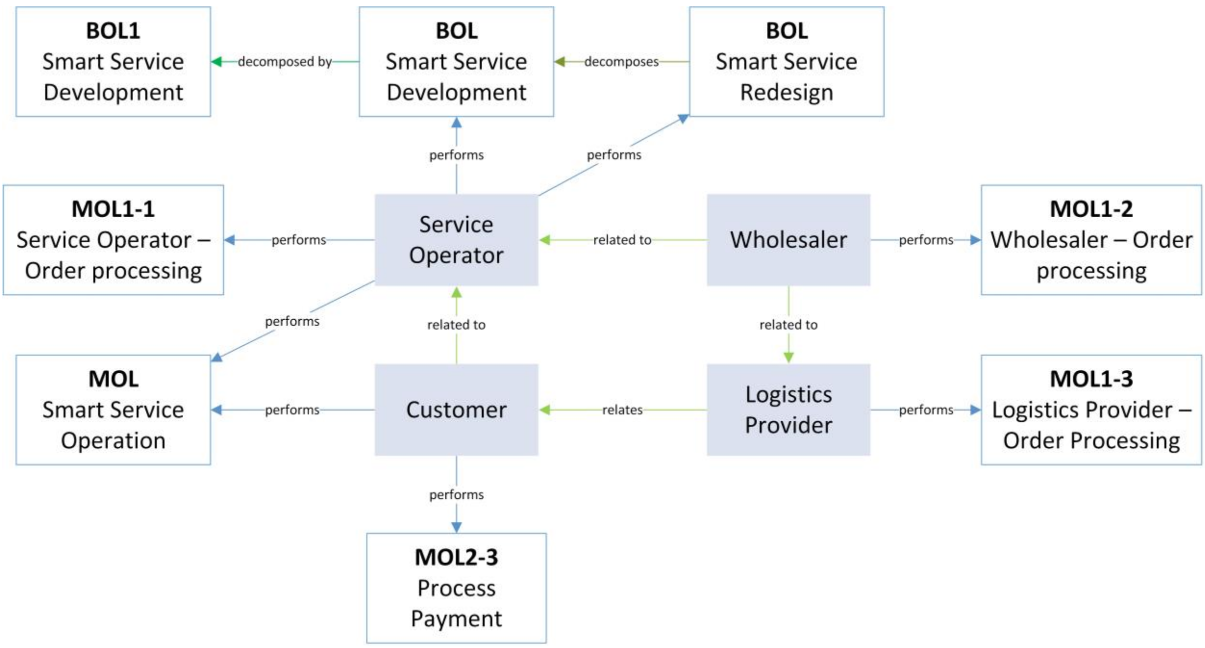

Figure 11.3: Overview of stakeholders and important relationships

Step 2 - Modelling Structure and Processes. Starting from the stakeholder network shown in Figure 11.3, some parts of the service were modelled in more detail. Here, we differentiate static and dynamic elements:

Static elements comprise physical, software-based and abstract elements, which describe the static structure of a smart service system. In addition to physical and software-based components, also abstract elements are defined. They are used to realise different levels of detail in the form of model layers. An overview of the essential elements of the modelled smart service is provided in Table 11.6.

Dynamic elements relate to life cycle stages, processes and activities. The life cycle represents the top level of the smart service. It consists of the three phases of BOL, MOL, and EOL, as depicted in Figure

11.4. The development phase of the smart service generates a 3D printer which can determine and communicate information on the material consumption. Furthermore, a service platform is developed, to facilitate parts of the service provisioning, e. g. billing. Service data is returned from the operating phase into the development phase, where it is used for further improvement of the service.

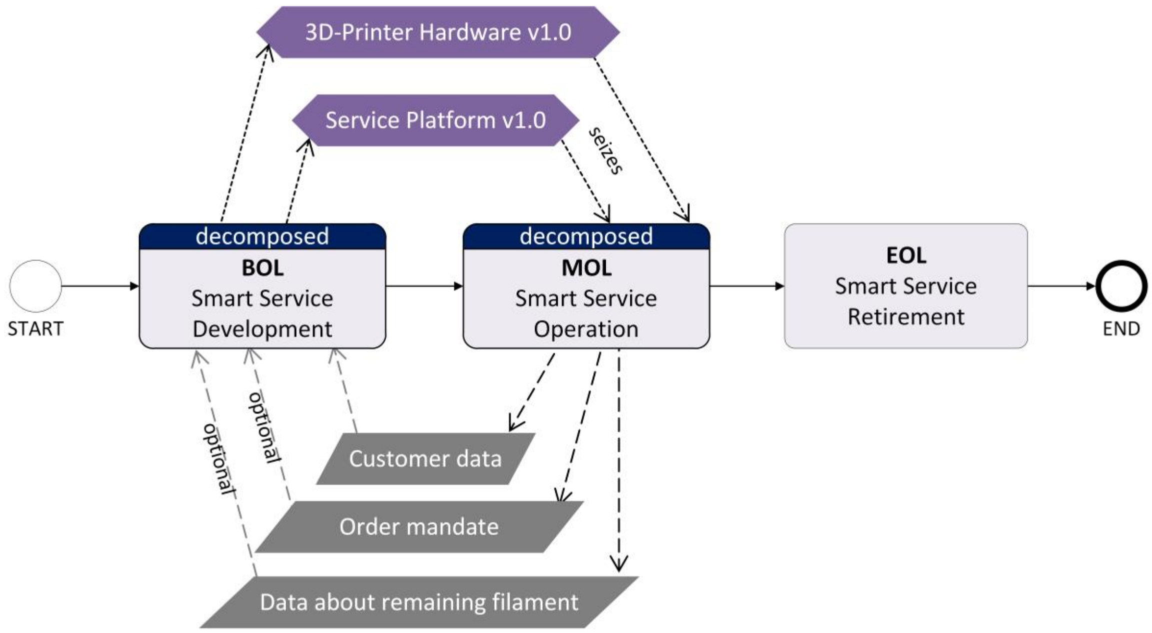

Figure 11.4: Representation of the life cycle as a top-level model

The BOL and MOL phases of the top-level model are further detailed into processes and inputs/outputs, as indicated by 'decomposed'. Two model layers with details of the MOL phase are shown in Figure 11.5. The naming of child activities includes the life cycle name and a sequential number (top left of each box).

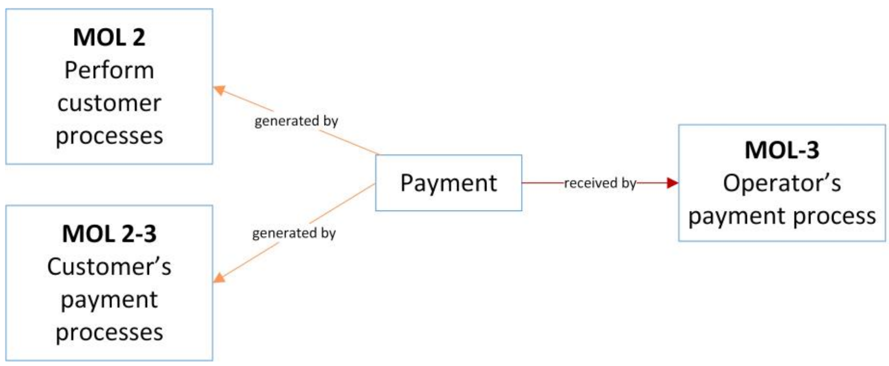

Figure 11.5: Example of a graph for the input/output 'Payment'

Graphs in LML represent the relationships between the modelled elements. The relationships are specified by the LML ontology. If, for example, an element of the 'Action' class is connected to an element of the 'Input/Output' class, the relationship is 'generated' or its inverse 'generated by'. An example of a simple graph is shown in Figure 11.6. A disadvantage of the visualization via graphs is the growing complexity if more than just the immediate neighbours of an item have to be displayed. Figure 11.7 shows the same example for the input/output 'Payment' with neighbouring elements of the second degree. The complete graph on the model represents all modelling levels. To make work with LML graphs meaningful, relevant parts must be filtered out.

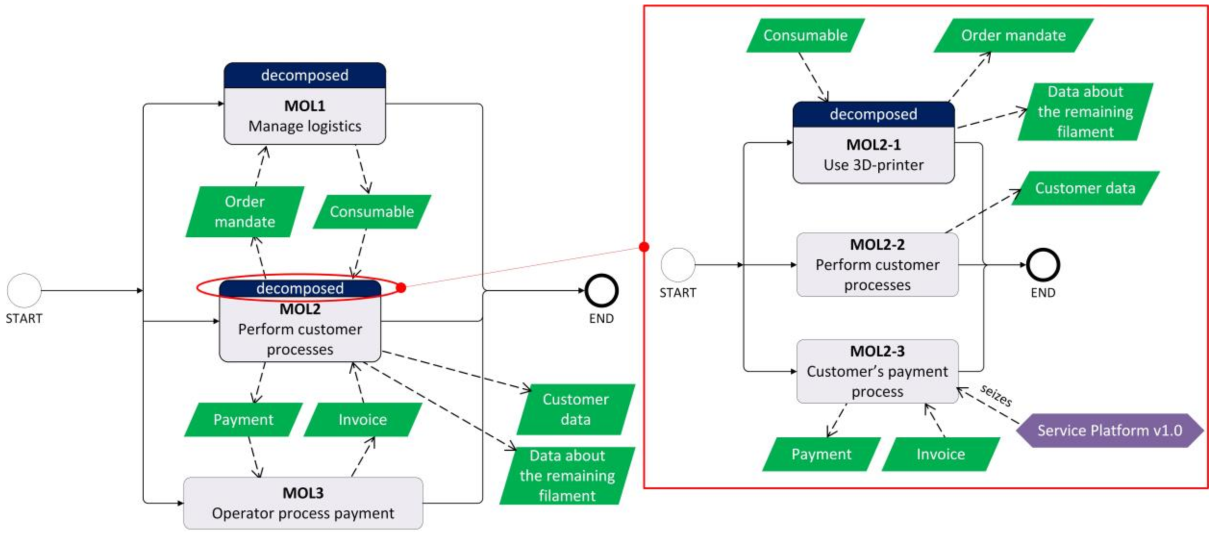

Figure 11.6: Examples of MOL activities on different layers of the model

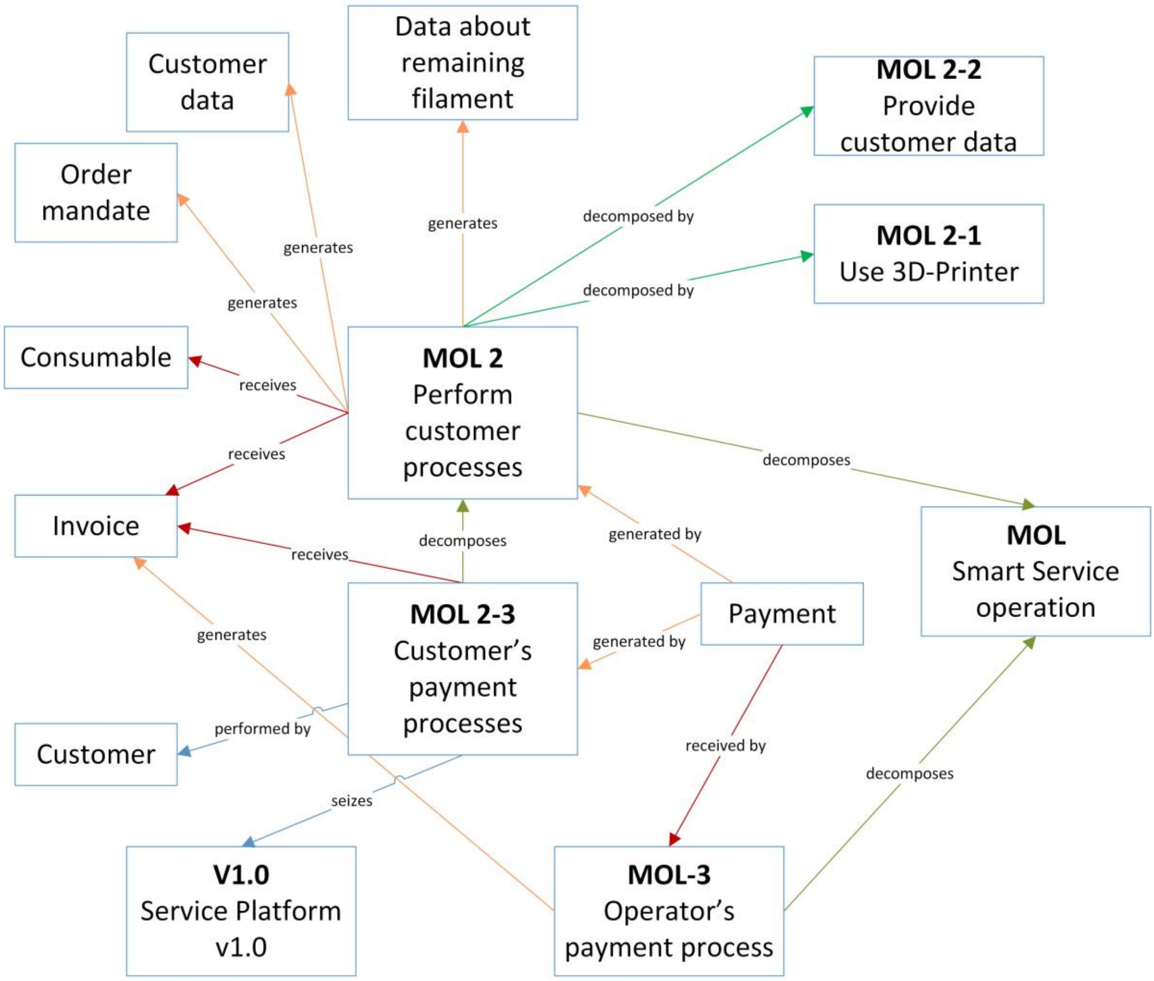

Figure 11.7: Extended example of the graph for the input/output 'Payment'

Relationships across life cycle phases are depicted only for a case in our model: the material fill level of the printer is created in the operation phase of the service and sent back in the development phase, together with the customer data, and performed orders for consumables. With the obtained information the service can be improved in general or specifically for a certain customer.

Description	Form	Note
3D printer	Abstract	Combines hardware and software
Hardware	Physical	Structure, mechanics and electronics
Software	Software	Data processing
Printing material	Abstract	Combines spool and plastic wire
Coil	Physical	The plastic wire carrier
Plastic wire	Physical	Consumables
Operator platform	Software	Software of the service operator

Table 11.6: Core components of the smart service model

An example of a possible data-based improvement is the use of the material fill level to optimise the filament stock capacity in the printer. This could be done, for example, on the basis of a parametrised CAD model of the printer. A design approach for this purpose is provided by (Klein et al. 2015). Another example is the adaptation of the smart service with regard to logistics: Additional material providers can be chosen based on customer data and order quantities. Therewith, delivery times of consumables can be reduced accordingly.

The way this improvement is depicted in the model provides the benefit that the role of the logistics provider (and optimization of related processes) is already considered in the design of the smart service. Therefore, a meaning and a value can be assigned to data from the printer in the development phase. Fig. 11.8 shows how the use of data for service improvements was modelled.

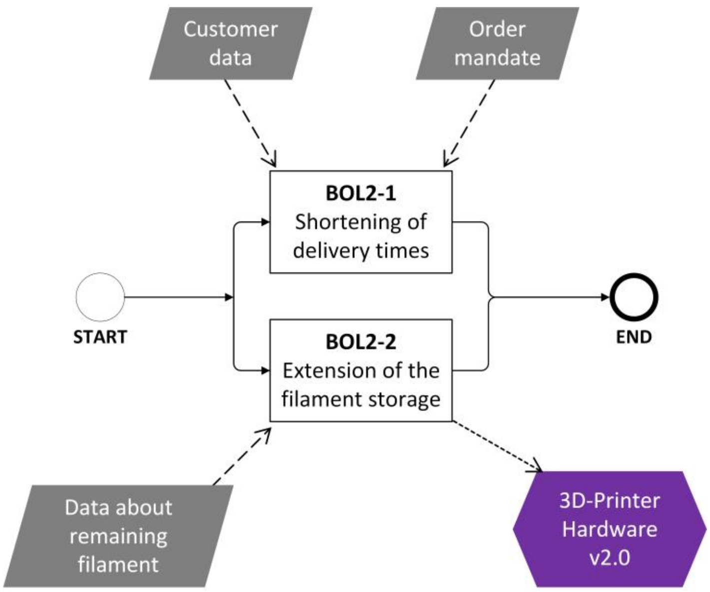

Figure 11.8: Use usage information for the further development

The complexity of the model and other characteristics are summarised in Table 11.7.

Characteristic	Manifestation in example LML model
Number of model elements	57 total: 31 actions, 7 assets, 19 inputs/outputs
Number of abstraction levels	Maximum of 5 levels, e. g. smart service operation > customer processes > printer > hardware-related functions > print object)
Design of activity diagrams	A maximum of 3 processes were used in activity diagrams, otherwise a new abstraction layer was created.
Used types of flows between processes	electronic and analogue information (e. g., sensor data, delivery note), material (e. g. consumables, empty spools), money (payment)

Table 11.7: Complexity of the LML model for consumables replenishment

11.4 Discussion of the Modelling Approach

11.4.1 Review of Information Needs

In this section, the proposed modelling approach for the life cycles of smart services is discussed and evaluated. The hypothesis stated in the introduction will be verified. Its main assumption is that life cycle modelling makes relations among service elements transparent and thus improves the identification of risks and fulfils various information needs. For the evaluation, the information needs of different roles (see Tab. 11.5) are compared with the capabilities of the life cycle modelling approach.

- *Marketing.* In the BOL phase a key concern is the identification and documentation of customer needs. From the marketing perspective, the activity diagram is not supporting this process significantly, as requirements cannot be modelled with it. However, the graph diagram may contain "requirements" entities that are connected with other service components (e. g. activities). This way a traceability can be realised to support the identification of problems introduced by changing requirements or functions. Specific risks, such as missing or erroneous requirements, may not be identified through the graph. During the MOL phase, the feedback about customer satisfaction is a key indicator to measure success of the smart service. For this purpose, the modelling approach must consider dynamic data coming from the market (e. g. a survey). Currently, the modelling approach is not capable of satisfying this information need. In the EOL phase information is needed, for instance, to understand the recycling demands of physical components. The modelling approach supports the description of activities and input/outputs related to the EOL. Their relation with other activities (e. g. redesign and legal activities) may indicate risks, such as missing activities to manage legally mandatory take-back of electronics.
- *Development.* During the BOL, the smart service hard- and software is designed. Activity diagrams can help to visualise the functionality and related technical requirements. In addition, data, material, energy and monetary flows can be made transparent by establishing them as inputs/outputs between activities. 'Design for X' approaches, where "X" concerns, for instance logistics, maintenance, recycling and reliability, can be supported by incorporating specific activities, assets or characteristics into the life cycle model. The MOL phase is interesting for designers, since the smart service components may be subject to failures and insufficiencies. Since the life cycle modelling approach is not supporting dynamic data (e. g. field data), feedback from the MOL phase is not represented in the life cycle model. For the EOL phase, migration paths are an information need. The developers need to plan, for instance, how non-supported service components (e. g. hardware and software) are exchanged. Possible migration paths can be described with activities and by defining related requirement entities.
- *Finance.* During the BOL phase, the estimation of financial revenues and development cost can be supported by describing value streams in activity diagrams with input/output entities. The activities can be related to assets representing different value chain partners (e. g. suppliers). In addition, cost entities can be assigned to almost any other entity to clarify, for instance, the amount, currency and frequency of payments. The MOL phase and the EOL phase cannot be sufficiently supported with the current modelling approach, since dynamic data from business transactions (value streams) are not supported.
- *Procurement.* In the BOL phase, LML may support the planning of the required types of items from different suppliers. The decomposition of assets allows to model the service components

and assign them with a "purchase" activity that can be performed by different suppliers (assets). Depending on the complexity of the supply chain, the model might become quite extensive and thus difficult to manage (e. g. update in case a supplier changes). The MOL phase is not supported well, due to the lack of real time data integration.

- *Logistics.* During the BOL phase, specific values for the types and sizes of consumables must be identified. The different types of consumables, as well as their packages, can be defined as separate assets that are related to wholesalers. The size of the package or the products can be added with measure entities for length, width and height. In addition, the supply chain stakeholders and their activities can be modelled. The MOL and EOL phases, once more require dynamic data which is not well supported in LML.
- *Customer Service.* Important BOL-specific information, such as contact channels, languages and the definition of response time, can be described in a life cycle model with different entities. While channels can be modelled as resources, the language and response time can be defined with characteristic or measure entities. Dynamic MOL data, such as current incidents, are not well supported by LML.

The summary of evaluation results regarding information needs is shown in Table 11.8.

11.4.2 Review of General Objectives

The modelling approach is further evaluated according to the objectives defined in Sect. 3.2.

- *O1: Support the conception of product-related services.* The uniform description and expressions of LML, as well as the similarities with the widely-used SysML standard, provide stakeholders involved in the design an easy access to the creation and adaptation of the model. Further analyses during the conception phase may benefit from the uniformly described model elements. An example is the performance of a life cycle cost calculation grounded on the information stored in the life cycle model (this possibility is currently researched in the Manutelligence project). The specification of LML (version 1.1) provides 12 entities and their relationships among each other. In case that these original entities are not sufficient to describe the concept of an application case, new entities can be created by inheritance (i. e. the new entity inherits characteristics of its superordinate entity). In a similar way, new relationships can be created between entities. [fulfilled]

Role	BOL needs	MOL needs	EOL needs
Marketing	No	No	Yes
Development	Yes	No	Yes
Finance	Yes	No	No
Procurement	Yes	No	No
Logistics	Yes	No	-
Customer Support	Yes	No	-

Table 11.8: Fulfilment of information needs of different roles by life cycle phase

- *O2: Allow an assessment of the service concept.* The assessment of a service concept can be carried out from different perspectives (e. g. financially, technically, logistically and environmentally). Depending on the perspective, different entity types must be added to the model, for instance, cost entities in case of the financial department's perspective. A key issue of the modelling approach is that dynamic characteristics of service elements are not well supported. Each life cycle model is static, i.e. it represents the system at a specific moment. Through the integration of additional software tools, the model may be updated with real time information (a research question investigated in Manutelligence). An example is the regular update of the market price of printing filament – this could be realized by updating the associated value of a cost entity. This way, the life cycle model supports the assessment of the current system status which is an information need emerging from the MOL and EOL phases. The assessment of risks, in particular, can be realised through risk entities. Whether all risks can be modelled this way was not investigated in this paper. Some risks may be relevant at certain phases of the life cycle. In the case of a complex smart service, risks may be caused by the relationship between service elements. For instance, if a service component that acts as an information source for other components is removed, the whole service may be affected in a negative way unless the risk is addressed by appropriate measures. The time-dependency of this example is related to the fact that one component is in its EOL, while the others are still in their MOL phase. [partly fulfilled]

- *O3: Support the planning of capacity for resources.* Resource planning and the identification of resource bottlenecks can be realised with resource entities. Modelling resources with LML is difficult, since they are either created, seized or consumed. In the case of 3D-printing, the consumable could be represented by a resource entity that is created by the wholesaler and consumed by the printing process. However, the logistics process neither consumes nor seizes the consumable. For this reason, the consumable was represented by an input/output entity that moves between processes. The representation resources is not intuitive using LML. [not fulfilled]

The assessment of the objectives, given the modelled example case and the modelling environment (Innoslate), is summarised in Table 11.9. For the interpretation it must be noted that only one example was modelled without a specific organizational context. It is further worth of notice that software support for LML is still rather poor (modelling environment).

Objective	Review
O1: Support the conception of product-related services	Fulfilled
O2: Allow an assessment of the service concept	Partly fulfilled
O3: Support the planning of capacity for resources	Not fulfilled

Table 11.9: Assessment of general objectives

11.5 Conclusion and Outlook

The evaluation of the life cycle modelling of smart services did not lead to a definite result. The initially stated hypothesis, information needs and general objectives were assessed very differently from our perspective. The following paragraphs contain conclusions on aspects of the modelling approach. At the end of each paragraph, potential research questions and, in some cases, suggestions for literature are provided.

The collaborative design of life cycle models is well supported by the applied modelling approach. LML's ontology provides different entity types and relations that reflect stakeholder perspectives. The relations are "speaking", i.e. named to be easily understood by stakeholders – they support the modelling process even though stakeholders might not have expert knowledge in modelling. Conflicts arising from discussions among different stakeholders were not covered in this paper. Research questions concern how a collaborative design of the life cycle model happens in practical cases, which conflicts or problems occur and how these issues could be mitigated. Previous work, for instance in Computer-aided Service Design (Laurischkat 2013), is a starting point for this research.

The static nature of the model has been identified as a weakness of the modelling approach. However, it is an open question whether a life cycle model should be designed more static or more dynamic. The integration of dynamic data, such as product states, could satisfy several information needs of the MOL and EOL phase. An open research questions is how dynamic data could be integrated into a life cycle model on the conceptual level and on the practical level (software).

The required level of detail of the life cycle model appears difficult to estimate in advance. We assume that the model itself evolves concurrently along the life cycle, i.e. it starts simple in the conceptualization phase and becomes more complex as new perspectives need to be considered. With an increasing complexity of the model, the visualization methods proposed in the LML standard become difficult to read, especially the net diagram. An option is to reduce the scope of the net visualization; however, the reduction may limit the chances to identify potential risks and opportunities because a part of the system is no longer visible to stakeholders. Research questions concern how risks and opportunities in smart services emerge and how their identification could be supported. During the research, a classification of challenges of PSS could be useful as proposed by Kurak et al. (Di Francisco Kurak et al. 2013) as well as previous work on understanding service uncertainties of PSS cost estimation (Erkoyuncu et al. 2011).

The lack of an item-level representation of service components and the limited functions to consider dynamic system characteristics (e. g. data streams) are arguments against the use of the life cycle model for the operational management of a smart service. A research question is to determine the benefits of using a common life cycle model in the operation phase of a smart service. The question is related to the existing research on Product Lifecycle Management, i. e. the management of product-related information (e. g. Demoly et al. 2013; Kiritsis 2011).

To gain more insight into life cycle modelling, additional real-world cases should be modelled and evaluated. Action-based research appear to be a suitable methodology to determine how stakeholders develop and use the model. On this basis, best practices for modelling could be elaborated to provide orientation to new users of LML regarding structuring models and useful level of model details. Finally, different modelling languages (e. g. BPMN) should be evaluated against the requirements of different roles involved in the process of life cycle modelling. A starting point can be the information requirements identified in this paper. The result of such a comparison could clarify whether one language is sufficient to describe the life cycles of smart services or not. In the latter case, the results might indicate that different modelling languages should be used in the process.

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12 Design-integrated Financial Assessment of Smart Services

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Abstract: The emergence of data-driven services in the Internet of Things provides manufacturers of technical products the opportunity to become providers of services, which use data as primary input. The development of such smart services, however, is characterized by high complexity and uncertainty. To identify service ideas which are worth to pursue further, the potential financial impact is an important criterion. While the importance of a business case is acknowledged in service engineering, there is currently no concrete method that is integrated with the early design phases of smart services. Therefore, we propose a tool-based method for the design-integrated financial assessment of smart services. We use a design science research approach to develop a meta-model, which is implemented in a web-based tool. The experimental evaluation shows that the proposed tool provides benefits, especially in structuring the task for project teams. Therefore, it appears to be beneficial to provide interdisciplinary teams a tool-based support for the design and evaluation of smart services.

Keywords: Smart Services, Intelligent Products, Service Engineering, Product-Service Systems, Cyber-Physical Systems, Profitability Analysis

12.1 Introduction

12.1.1 Motivation

The ongoing proliferation of connected devices and assets drives the emergence of the Internet of Things (IoT), which is the enabler for a variety of innovative applications. Recent forecasts estimate the market size of IoT solutions to grow to 267 billion USD in 2020, of which 50% is to be created for applications in industries like discrete manufacturing, transportation and logistics, and utilities (Columbus 2017). Autonomous data acquisition through sensors as well as the remote control of devices through actuators using the Internet is the basis of so-called smart services (Allmendinger and Lombreglia 2005; Georgakopoulos and Jayaraman 2016). The concept refers to physical products, which are augmented with globally usable digital functions, in addition to their local physical functions (Fleisch et al. 2015). The provision of such services is based on the recording of sensors and operational data, its transmission via digital networks, as well as its evaluation and the delivery of the analysis results, e.g. via smartphone apps. For example, networked bicycles warn of chain wear and call assistance in case of accidents (Shaw 2014). Industrial products such as compressors, ventilation systems, and elevators are also being upgraded with digital services for remote control, monitoring, usage-based billing and other services (Herterich et al. 2015). As the type of value exchange is shifted from selling products to providing services, smart services allow for a completely new relationship between manufacturers, operators, and users of physical goods and thus enable new business models (Velamuri et al. 2013; Zolnowski and Böhmann 2013).

How to turn these opportunities into useful applications and economic benefit has become an important topic in various research streams in the recent years (Wuenderlich et al. 2015). One research stream is business models in the Internet of Things (Velamuri et al. 2013; Fleisch et al. 2015), another is the creation of IoT-based product-service systems. As Herterich et al. (2016) show, digitized products can enable service innovation for industrial products. The process of "creating value by adding services to products" (Baines et al. 2009) is called "servitization". It provides opportunities for manufacturers to establish new customer relationships, increase loyalty, differentiate from competitors (Neely 2008; Fischer et al. 2012) and create new data-driven business models (Wiesner et al. 2013; Zolnowski et al. 2016). From a marketing perspective, a smart service contains both service elements and physical products. They can be therefore considered as product-service systems (PSS). PSS are well suited as a unit of analysis as they are "special case of servitization" (Baines et al. 2007) and even enable result-oriented services as a business model (Tukker 2004; Adrodegari et al. 2015). In its most advanced form, products are offered as outcome-based contracts, i.e. the customer pays for the actual performance of a product rather than the product itself (Wuenderlich et al. 2015; Visnjic et al. 2016). All these efforts contribute to the overall goal of higher customer-orientation, which improves the competitiveness of service providers (Brady and Cronin 2001).

While the potential of digital services in the IoT appears to be obvious, there is only fragmented knowledge on how to systematically develop them (Böhmann et al. 2014; Wuenderlich et al. 2015). Designing service systems for connected products is challenging as it requires the right configuration of people, technology, organization and information to create value for both the provider as well as the consumer of a service (Maglio and Spohrer 2013). Due to the complexity of PSS, it is reasonable to support this process with IT-tools for collaboration and modeling, which is however still in its nascent stage (Pezzotta et al. 2015). One approach, called Computer Aided Service Design (CASD) is proposed by Laurischkat (2013). The CASD method supports the design of both manual as well as automated service elements in PSS. It focuses particularly on the knowledge management and service information reuse in early conception phases. A comprehensive approach for the engineering of "informatics-based services" is proposed by Lim et al. (2015). Essentially, they support the design of services for vehicles, heavy equipment, and machinery by identifying needs through analysis of data, which comes from the respective products as well as other data sources. Additionally, they present a conceptual model of the informatics-based service value creation process (Lim et al. 2015). Marilungo et al. (2016) propose an integrated toolset for the ideation and design phase of PSS to support open-innovation processes. These allow integrating the customer, who is a key stakeholder in the design process (Isaksson et al. 2011).

This paper aims to contribute to the body of knowledge in service system engineering by focusing on the tool-based financial evaluation of smart services in the early stages of conception. The development of these services is an interdisciplinary task, which sets the context of an application for the envisaged tool.

12.1.2 Research Goal

The development of smart services, like every service development, is a creative process that is often carried out in interdisciplinary teams and is characterized by high complexity (Barrett et al. 2015). Particularly in the early stages of such processes, often many ideas are created. However, only a limited number of them can be pursued further to allocate resources effectively. This is also highlighted within the "IoT Business Model Builder", a toolset jointly developed by University St. Gallen and Bosch:

"Besides developing a qualitative business model, it is essential to predict quantitative forecasts (i.e., a business case) to back investment decisions" (Bilgeri et al. 2015). Thus the financial case has to be a possible break-off criterion of the development process (Alam and Perry 2002). The evaluation of product-service systems (PSS) is called for in many PSS engineering methods but lacks concrete methods that are integrated with the design of the services (Lin and Hsieh 2011).

In today's businesses, a large number of business decisions including financial evaluations are performed using spreadsheets like Microsoft Excel (Grossman et al. 2007). For example, a study shows that in agile projects, spreadsheets were the second-most used tool behind wall and paper (Azizyan et al. 2011). Spreadsheets are also used in the design of sustainable PSS (Omann 2003), for assessing IoT business models (Bilgeri et al. 2015), and the early stage evaluation of medical innovations (Craven et al. 2013). However, spreadsheets have been found to contain various types of errors, which impede their usage for business decisions (Caulkins et al. 2007; Panko and Aurigemma 2010; Reschenhofer and Matthes 2015).

Spreadsheets work well if the drivers of revenue and cost are known and well-structured for the investment object at hand. However, in early design phases of smart services, the structure of a service system is elaborated and restructured frequently, e.g. in interdisciplinary workshops (Dewit et al. 2014). To provide the financial impact of design decisions in the early stages of service conception, the structure of a spreadsheet would have to be adapted whenever elements are added, modified and removed or new information on prices, offers, cost, and quantities become available. This type of evolution of spreadsheets is an erroneous task, as the manageability of spreadsheets has found to be limited (Reschenhofer and Matthes 2015). Consequently, if spreadsheets are used, the financial evaluation will not take place before the service concept is relatively stable. Furthermore, the users must develop a spreadsheet model that contains all financially relevant information and formulae on their own. Afterwards, all information must be manually transferred from the service concept into a spreadsheet. To mitigate these problems, our research goal is to explore the potential of tool-based support for the design-integrated and continuous financial evaluation in the early phase of smart services for connected products. More specifically, we aim to:

- Develop a flexible data structure that captures the main drivers for profitability in a smart service
- Provide a tool, which enables fast and iterative modeling of smart services elements and their attributes
- Enable immediate update of profitability on every model change to illustrate financial impact and support decision making in the conception phase

From these goals, we have derived two research questions to design and evaluate such a tool:

- RQ1: How can the profitability of a smart service be assessed at an early stage of service design?
- RQ2: What is the benefit of employing a tool for profitability assessment in the engineering process?

To provide such a tool, the structure of service, which emerges in the conception phase, must be linked with a financial case structure. In this paper, we argue that meta-models for the service and the financial case can be developed and instantiated in a web-based tool prototype, to fulfill the research goals stated above.

12.1.3 Research Methodology

We use the Design Science Research Process as proposed by Peffers et al. (2007) based on the design science approach by Hevner et al. (2004). In the first step, we analyze the problem domain based on a literature review, which includes identification of key concepts and terms. The structure of smart services, as well as the design process, are extracted from literature and analyzed to identify the causes of the difficulties in the assessment of smart services. These are used to derive requirements for a tool-based approach that addresses these challenges. The second step comprises the artifact design, which focuses on the development of meta-models for both the service and the financial case. In a first evaluation step, the meta-models are instantiated using real-world cases. Furthermore, a web-based tool prototype is developed to make them accessible for interactive manipulation. The third step is a lab experiment, which aims to reconstruct a service conception and evaluation context. It is evaluated through a survey.

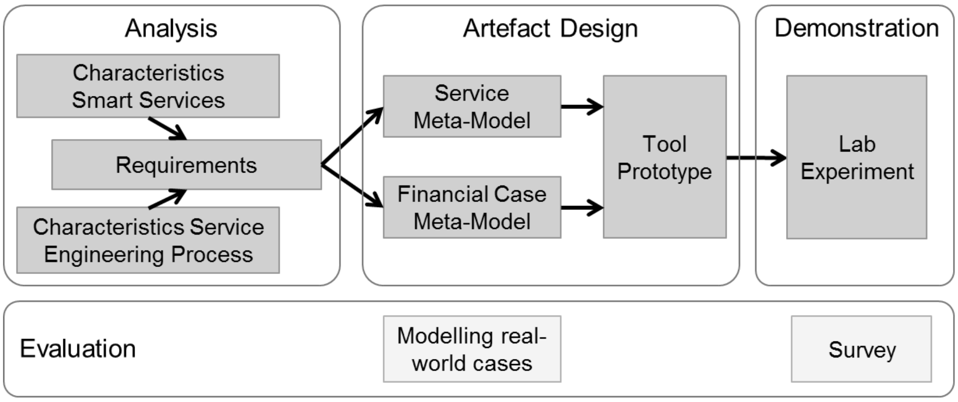

Figure 12.1: Design science-oriented research approach

The remainder of this paper is structured according to the outlined method, which is depicted in Figure 12.1, followed by a discussion and conclusion.

12.2 Problem Analysis

12.2.1 Smart Services

To understand smart services as the artifact to be designed, we reviewed the literature to identify main characteristics of smart services as an input for the requirements analysis. Allmendinger and Lombreglia (2005) characterize *smart services* as being pre-emptive in their behavior, creating the "value of removing unpleasant surprises", and relying on machine intelligence provided by information technology. As outlined by Porter and Heppelmann (2014), such services require computing, sensors, and communication capabilities embedded into products. With these in place, data can be exchanged with the manufacturer to integrate the product as an external factor and create services for its customer (Kees et al. 2015). Smart services are therefore service systems, which enable value co-creation between service provider and beneficiary through the joint performance of service activities (Edvardsson et al. 2011).

Products with these capabilities are termed ***smart things*** (Püschel et al. 2016), ***smart objects*** (Kortuem et al. 2010) or ***intelligent products*** (Leitão et al. 2015). As intelligent products require communication to a central server, as well as various processes and potentially further external internet services, they can become part of a cyber-physical system (CPS) (Barbosa et al. 2016). From a technological point of view, smart services qualify therefore as CPS, which "involve a multitude of parallel and interlinked sensors, computers, and machines, which collect and interpret data to decide on this basis and control real-world physical processes" (Marilungo et al. 2017). With the ongoing proliferation of IT components in physical products, the potential of cyber-physical systems and smart things as an enabler of PSS has been recognized and conceptually substantiated (Mikusz 2014; Herterich et al. 2015; Medina-Borja 2015; Marilungo et al. 2017). The emergence of digital service systems in the IoT is accompanied by the analysis of their impact on business models (Fleisch et al. 2015; Laudien and Daxböck 2016) and innovation (Herterich et al. 2016). Finally, the concept of smart service systems emerged within service science, which highlights the adaptability of systems, e.g. with the help of big data (Maglio and Lim 2016).

Other concepts similar to smart services for connected products are Product Extension Services and Cyber-Physical Features (Scholze et al. 2016) or Extended Products (Thoben et al. 2003). As these terms are less established, we use "smart services" for our research and define them as data-driven services for technical products, which are provided as product-services systems based on cyber-physical systems. More specifically, a smart service is typically provided using the following approach: A networked device provides information about its state, which is detected, for example, by means of sensors. On some devices, also actuators (control operations) must be considered (Porter and Heppelmann 2014). Communication between the device and the central server or cloud service is done over the Internet using machine-to-machine communication (Wortmann and Flüchter 2015). Users interact with smart services through various clients such as mobile apps or web applications.

From these aspects found in literature, the following five characteristics (SC1..SC5) of smart services were identified:

- *Data transmission [SC1]:* To transfer data from products to a central server, e.g. in the cloud, connectivity is needed (Weinberger et al. 2016). Depending on the transmission technology, usage-based cost is incurred for data transmission between product and manufacturer, e.g. for mobile network usage (Luong et al. 2016).
- *External Services [SC2]:* Data is used for operational and analytical functions in the cloud, such as "determine current position" or "list of most frequent operating conditions". Functions may also require external Internet services, such as weather information, which are provided with different pricing models (Laatikainen et al. 2013).
- *Services as a combination of functions [SC3]:* Smart services are a combination of functions provided as an offer for a specific target group (Kim et al. 2015). The functionality of the services and their prices must be aligned with the needs of the target group (Peruzzini et al. 2015).
- *Value Co-Creation [SC4]:* Customers have to integrate their resources in the service system, to have it perform its function for the creation of the desired outcome (Edvardsson et al. 2011).
- *Various types of costs and pricing models [SC5]:* To operate a smart service system, costs with different payment intervals must be considered, which are settled in different ways. For cloud services, for example, there are one-time and running costs, which can additionally be dependent on the number of users or devices (Laatikainen et al. 2013).

The complexity of smart services drives the challenges associated with their conception in the design phase, as discussed in the next section.

12.2.2 Engineering of Smart Services and Digital Business Models

Engineering methods for services are an important topic within service science. Currently, the engineering of service systems still lacks suitable models, methods and design knowledge to exploit the opportunities provided by such systems (Böhmann et al. 2014). Within the realm of PSS, a number of design methodologies have been developed (see Cavalieri and Pezzotta 2012; Vasantha et al. 2012 for an overview). Scherer et al. (2016) propose a stage-gate-based process for complex systems and a "PSS Canvas" for simpler cases. Other variants of PSS engineering methods include the focus on PSS for consumer products with integrated intelligent data units and other IoT-technology (Yang et al. 2009; Carpanen et al. 2016), applying the design science methodology for PSS development (Niemöller et al. 2014), or improve the development of PSS by adopting ideas from the design of functional products, which put higher emphasis on IT-components (Sas and Lindström 2014).

As PSS are understood as integrated offers, their design is also intended to be integrated (cf. Marques et al. 2013). However, in this research, we focus on existing products and their servitization through additional services rather than the integrated development of product and services. To support this transformation, Pieroni et al. (2016) propose a methodology called "PSS Transition Framework", which is depicted in Figure 12.2. As the business dimensions in the lower part of the figure show, financial criteria (cost and revenue) are to be defined in the first part of the overall process, called Front End of Innovation (FEI). Hence, the economic viability is to be decided at the end of the FEI stage and could be used to determine, whether the project should proceed into the Development phase or not.

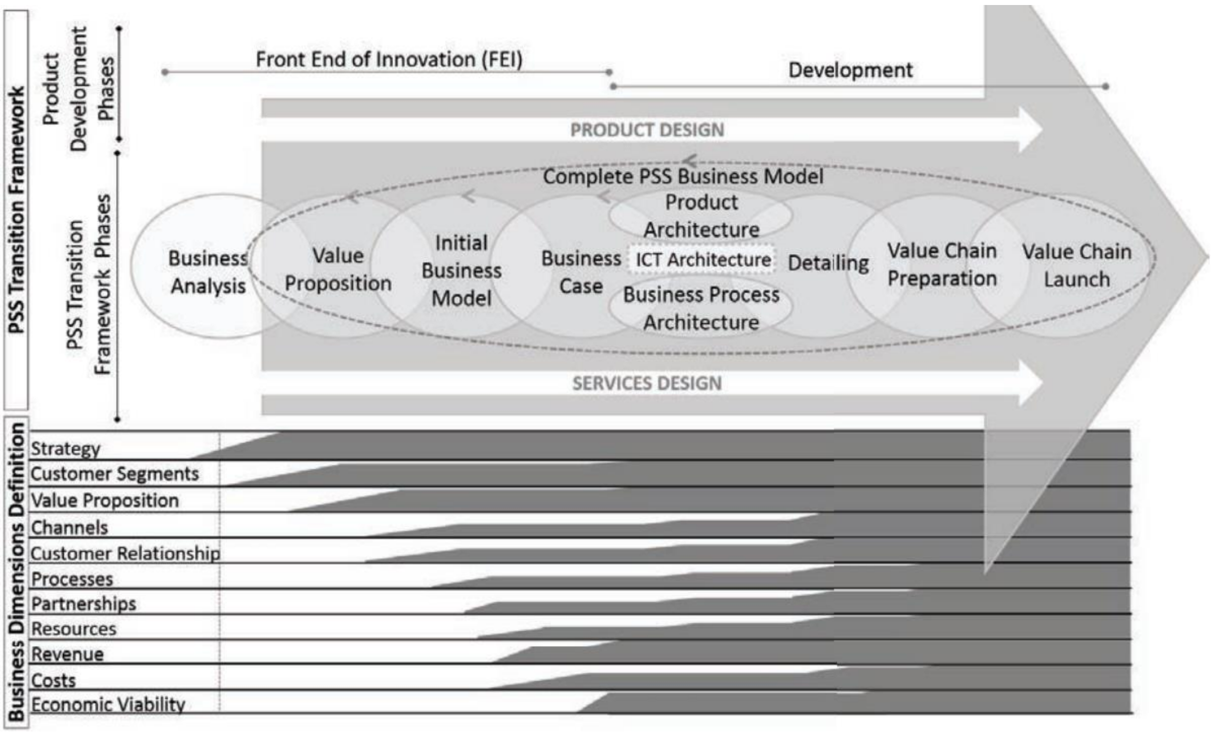

Figure 12.2: PSS Transition Framework (Pieroni et al. 2016)

In summary, the following four characteristics (PC1..PC4) of the design process for smart services were identified from literature:

- *Interdisciplinarity and information asymmetries [PC1].* To design successful smart services, the customer requirements, technical possibilities, and financial requirements have to be aligned (Maglio and Spohrer 2013). Manufacturers face a variety of decisions, which are related to technology and influence the value of the service for both the customer and the provider at the same time. Contributions and requirements from various stakeholders such as marketing, development, IT, sales, purchasing, controlling and the customer are relevant for this (Wallin 2013). As Kim and Bae (2012) point out, there are different stakeholders with conflicting goals involved in the process of PSS design. Therefore, an asymmetry of information between the parties exists, which leads to high coordination costs.

- *Creativity and interaction [PC2]*. In the early stages of the concept, the service ideas are developed iteratively with different participants. There is a high degree of creativity and interaction, whereby findings do not arise in a predictable order (Dewit et al. 2014). Ideas and interim results should be recorded promptly, and their impact be assessed.
- *Complexity and interdependencies [PC3]*. Smart services are complex systems, as they consist of many elements, which influence each other (Wiesner and Thoben 2017). For example, a more detailed data analysis may require more frequent data queries from the devices. This, in turn, leads to higher data volumes, higher transmission costs and higher energy consumption in the communication module. If the necessary data rate is higher than the planned capacity, it may even be necessary to switch to a more powerful transmission technology, which results in more expensive communication modules with different physical dimensions. These interdependencies are not always obvious to all parties involved, which might lead to misjudgments and increased planning efforts.
- *Uncertainty in the estimation of key parameters [PC4]*. Design decisions for services are often based on uncertain information (Klein et al. 2004), e.g. customer requirements, market development and willingness to pay. For the business model, quantitative parameters such as prices, price models, and customer numbers must also be defined. While there is preparatory work on the selection of pricing models for internet services (Stiller et al. 2003), the concrete price must be determined considering own costs, customer needs, competitive environment and profitability targets. Especially regarding the pricing for new services, however, providers often have little experience (Baines et al. 2007). In addition, there is uncertainty about the customer growth rate, their usage behavior, and the behavior of the networked devices in use.

12.2.3 Early-Stage Evaluation of Services

The financial evaluation is typically performed at a stage, where existing service ideas are elaborated into service concepts. For example, in the "Feasibility Analysis" phase of the technical service design process proposed by Aurich et al. (2006) the assessment of cost and benefits is performed. In the strategy-based service engineering approach proposed by Ehrenhofer and Kreuzer (2012), a "financial reflection" activity is part of the "Service Design I" phase. While many PSS engineering methods call for a "business analysis" to determine the financial impact, there is a lack of concrete methods how this can be achieved (Lin and Hsieh 2011). As a comparison by Marques et al. (2016) show, there are only a few concrete activities related to financial analysis in PSS engineering methods.

However, some evaluation approaches were developed for specific situations and purposes. Established methods like cost-benefit analysis, total cost of ownership (TCO) or lifecycle costing (LCC) have only recently been linked to PSS engineering (Kambanou and Lindahl 2016). Becker et al. (2009) proposed a method for the calculation of economic effects for customer-specific configurations (value bundles) of PSS. Other evaluation approaches of PSS focus on the customer value, rather than the financial impact (Sakao and Lindahl 2012). An approach for using of KPIs to evaluate PSS designs in a feedback loop during the design process was proposed by Mourtzis et al. (2015). However, they do not cover financial criteria as part of their evaluation. A comprehensive list of 94 evaluation criteria for PSS from existing literature and their categorization is provided by Kim et al. (2016).

In summary, it can be observed that there is considerable previous work on concepts, engineering and evaluation methods for PSS, of which smart services are a special form. While the importance of a financial case is stated by several authors, no concrete approach for the integrated financial assessment of smart service concepts could be found in the extant literature. Furthermore, with the exception of the approach proposed by Mourtzis et al. (2015), no contribution could be found, which explicitly integrates evaluation results into the design process through a feedback loop.

12.2.4 Requirements

Through argumentation and reasoning, the requirements for a design-integrated evaluation tool were derived from the characteristics of smart services, the design process, and the research goals (Johannesson and Perjons 2014). The list of requirements is summarized in Table 12.1.

Characteristics	Requirement
SC1, PC3, SC5	R1. Data volumes for data transmission, e.g. for cell networks, must be calculated.
SC3, PC2	R2. Model elements need to be flexibly assigned, e.g. functions to services.
SC1, SC2, SC3	R3. Demands, quantities and usage intensity must be expressible in a simple manner.
SC1, SC2, SC3, SC5	R4. Various types of costs as well as pricing and billing models must be supported.
PC1, PC3, PC4, SC4	R5. Early assessment of the service must be possible, even with incomplete information.
PC2	R6. The addition and modification of elements, properties, relationships, quantities, prices, and costs must be possible in any order.
PC1, SC4	R7. Models must be comprehensible for experts from different disciplines.

Table 12.1: List of derived requirements

The references to the above-mentioned characteristics SC1 to SC5 and PC1 to PC4 indicate which of them were used to derive the requirements R1 to R7, for which the reasoning is as follows:

- R1: As identified in SC1, data transmission is required for IoT devices. It must therefore be considered as part of the model. The cost for transmission is typically incurred in a usage-dependent manner and might also contain monthly subscription fees (SC5). The demand for data transmission is caused by the invocation of functions to provide the desired service, which is an example of interdependencies (PC3).
- R2: The bundling of functions to provide services enable modular system architectures as well as reuse of functionality into different target-group specific offers (SC3). Identifying these relations is a creative process in the early conceptual phase (PC2).
- R3: Both external services (SC2) and data transmission (SC1) incur costs for providing the required functionality, while revenue is driven by customer demand for offers (SC3). These demands need to be provided in a simple and easily modifiable way.
- R4: Pricing models for external services (SC3), data transmission (SC1) and offered services (SC2) may contain multiple components (SC5), which need to be part of the modeling approach.
- R5: Early stage evaluation is challenging due to incomplete information about the metrics and values required (PC1). While these are added and refined iteratively, the evaluation result

should continuously be updated to reflect the current level of detail provided (PC4). This helps to see interdependencies between the parameters (PC3) and allows deciding on which cost might be borne by customers (SC4).

- R6: As early stage elaboration of service ideas into service concepts is an interactive process (PC2), the creativity, agility and iterative design need to be supported by the tool.
- R7: The issue of diversity of backgrounds among the members of the design team (PC1), possibly also including the customer (SC4), needs to be addressed by models that are easily comprehensible.

12.3 Meta-Model Design

The core of the proposed approach is the creation and iterative refinement of a service model, which is annotated with parameters to instantly calculate the financial impact on every model update. This requires a meta-model which links the main elements of the service with its financial impact. For the development of the meta-model, the top-down analysis method was used (Grässle et al. 2005). It contains the steps 1 to 3. Step 4 is performed to verify whether the created meta-model can represent typical smart service cases.

1. Identify and model classes for key concepts, e.g. customers, devices, offers, functions, revenue, cost as UML classes
2. Identify and model associations and cardinalities between classes to describe the relations between them
3. Identify and model attributes, e.g. prices, quantities, and cost in the respective UML classes
4. Test of the model using real-world cases of smart services for connected products
5. Repeat steps 1-4 until no further changes were required

As a meta-model provides the language with which a modeler can afterwards express a concrete case in a model instance, it needs to fulfill all characteristics defined by Stachowiak (1973): a model is a mapping, a reduction, and is pragmatic, i.e. serves a dedicated purpose. Therefore, a key challenge for a meta-model design are the same as with every other model: granularity vs. comprehensibility. A fine-grained model can express many aspects of a service and thus cover a wide range of possible scenarios. Given the fact, that our model is to be used for rough assessment in very early stages of conception, a high level of detail might neither be available nor needed. Therefore, we deliberately kept the meta-model simple and the number of modeling elements at a minimum. This also serves the purpose of better comprehension for diverse groups of people that take part in a service design project.

12.3.1 Smart Service Meta-Model

Modeling digital services has been proposed in different forms, e.g. by Yoo et al. (2010), Weinberger et al. (2016) and Porter and Heppelmann (2014). They all share the concept of dividing the service into different layers, with (digital) services as the top layer, connectivity, and data processing as the middle layer, and physical products with sensors, actuators etc. as the bottom layer - see Püschel et al. (2016) for a comparison. The service model proposed in the present paper uses the integrated consideration of business, functional and technical aspects as well as the layers as guiding ideas.

The service model (Figure 12.3) describes the available model elements and their relationships. The basic elements (white) relate to each other using links (light gray) that provide attributes for quantification of the relationship. The desired easy understandability (requirement R7) is to be achieved by a minimum number of elements and relationships. Since our research is exploratory, only the elements necessary for financial assessment (requirements R3 and R4) are included.

- ***Offers*** are targeted at groups of customers *(Customer Segment)* and have a ***price***, which is defined using the ***PriceModel***. The link between them is described using a set of *bookings,* which includes the attributes *year* and the number *(count).*
- The provision of an *Offer* requires *Functions* that represent software components with processing logic. Each function can be used by multiple offers. This results in an M:N relationship between services and functions (requirement R2), which is realized through a use of a function usage link *(F_Usage)*. The attribute *invocationsPerMonth* expresses the frequency of function calls per month by a service (requirement R3).
- Functions may be using data and operations provided by *devices* or *external services,* such as weather information, traffic information or SMS delivery. This dependency is modeled in the relationship *ES_Usage*, where the percentage of function invocations leading to an external service call can be specified in the attribute *usageRatio.* The idea behind this is that not each call to a function requires external services, e. g. in 5% of the cases, an alarm message is sent out using SMS. To capture the cost of external services (requirement R4) information on the ***price*** can be stated; using the ***PriceModel*** explained below.
- Data and operations provided by a *device* are modeled as *data points,* which have a *requestSize* and *responseSize* to describe the transferred data in bytes during retrieval. Functions and data points are connected via *D_Usage*, which contains the proportion of calls *(usageRatio)* that cause request/response communication. Additionally, push communication is expressed using the *updatesPerDay* attribute of a *data point* (requirement R1).

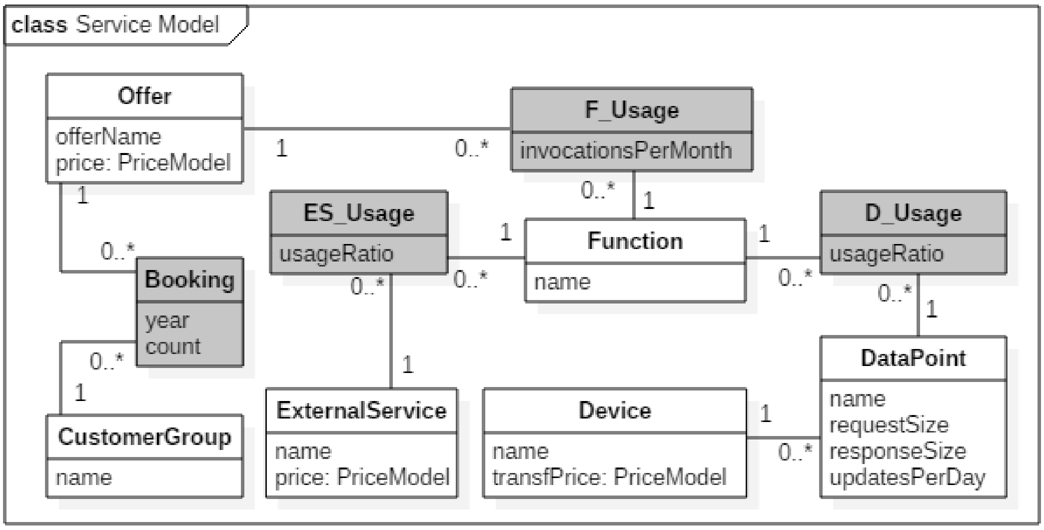

Figure 12.3: Class diagram of the meta-model for the description of smart services

To represent various pricing schemes for services to offer and to consume (requirement R4), we propose the meta-model for pricing models depicted in Figure 12.4a. It allows specifying an optional base fee, which is independent of the actual usage of the service, e.g. a subscription fee. The payment interval is expressed through the ***Interval*** enumeration. Additionally, one or more price levels can be defined by creating the required number of ***UnitPrice*** objects. The applicability of the price can be specified using the optional ***minQty*** and ***maxQty*** attributes, e.g. a price for a certain amount of transactions, bookings or data transmission volume. An example instantiation is a weather service with a monthly fee of 9.95 €, where the price per transaction drops from 0.10 € for 1 to 20 calls per month to 0.05 € if the service is invoked more than 100 times per month (Figure 12.4b).

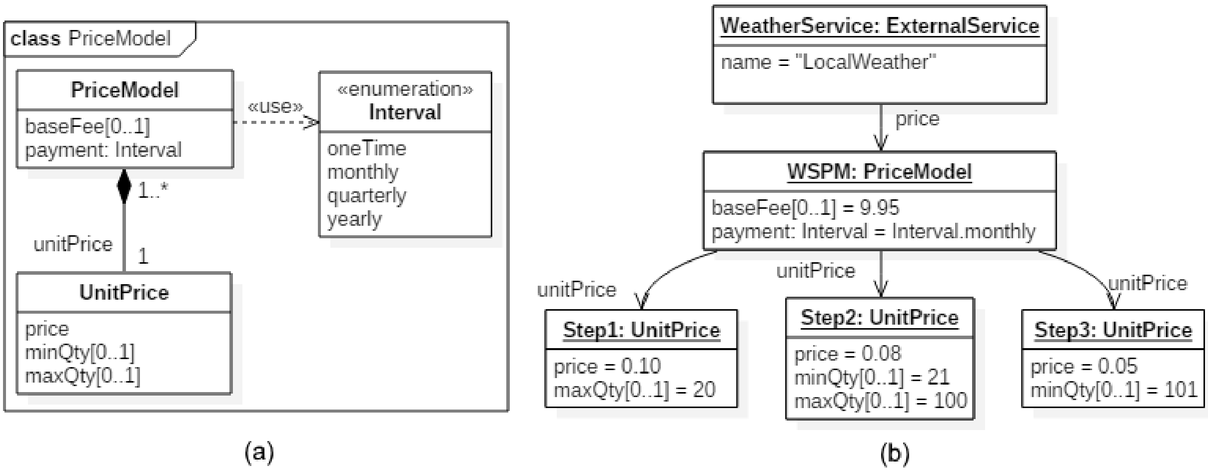

Figure 12.4: (a) Class diagram for Price Model and (b) Example of instantiation

12.3.2 Financial Case Meta-Model

A financial case is an instrument to investigate the profitability by providing decision makers a structured view on the returns for an investment. Common decision criteria and methods are net present value (NPV), return on investment (ROI) or internal rate of return (IRR). Each of them requires a payment series, which consists of the difference between incoming and outgoing payments for a certain period, e.g. a year. The challenge we address in our research is to integrate the creation of this payment series in the design process of a smart service. For that, the cost of building and operating the service system as well as the revenue created through offering services to customers must be considered.

To assess the profitability, we propose a model which depicts the structure of payments for each planning year. It contains the ***ServiceVariableCost***, which can be derived automatically from the service model and will be stored in the attributes ***extServCost*** and ***dataTransCost*** respectively (Figure 12.5). Furthermore, it allows to specify additional costs manually, e.g. for the development and operation of the service system (***ManualCostItem***). They are specified through a ***price***, which is expressed through the ***PriceModel*** structure introduced above (requirement A4).

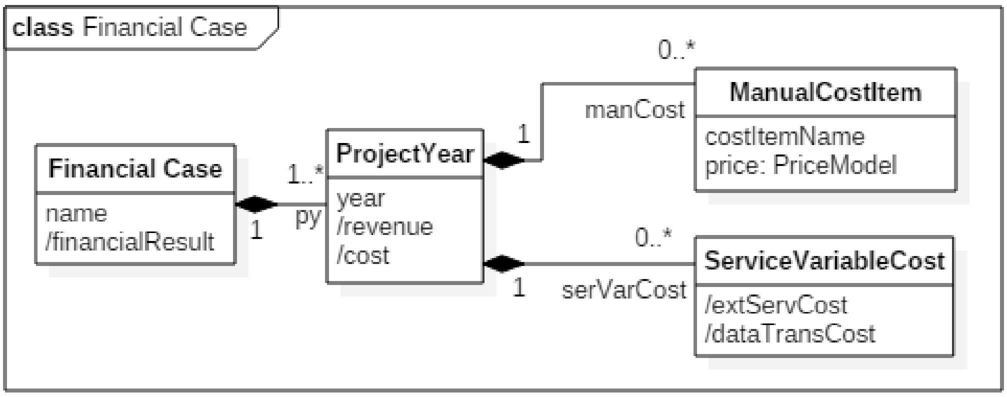

Figure 12.5: Class diagram for the financial case model

12.3.3 Calculation of Financial Case

To derive the financial case from the annotated service model, a service model and a financial case model must be instantiated. Therefore, a set of related objects of the classes defined in the meta-models for the project at hand is created. For the calculation, the following functions are defined for accessing the instantiated objects:

- *fUse(x, y).. F_Usage for Function x and Offer y*
- *eUse(x, y).. ES_Usage for Function x and External Service y*
- *dUse(x, y).. D_Usage for Function x and DataPoint y*
- *DP(x, y).. DataPoint x for Device y*
- *ES(x).. External Service x in list of all external services*
- *DE(x).. Device x in list of all devices*
- *BK(x,y,z).. Booking for CustomerGroup y and Offer z in year x*

Additionally, a helper function ***getPrice(qty)*** is defined for ***Offer***, ***ManualCostItem***, ***ExternalService,*** and ***Device***. It determines the price for a given quantity ***qty*** at the reference object as defined by the ***PriceModel***.

The external service cost consists of transactional cost and recurring cost for all required external services. As transactional cost are dependent on the actual usage of services, the number of invocations per external service is stored in the ***invocs()*** list. It is determined by iterating over all functions ***f*** and the number of invocations caused by the services stored in the ***invocationPerMonth*** attribute of each ***F_Usage*** instance. For each invocation, a certain percentage specified by *usageRatio* leads to an external service call, which is charged with a transaction fee determined through the ***getPrice()*** function. Finally, the recurring cost of all required external services e are added. The factor ***intvl*** is used to convert payments during the year to yearly value; e.g ***intvl*** will be 12 for monthly payments and 4 for quarterly payments.

$$invocs\big(ES(k)\big) = \sum_{i=1}^{f} eUse(i,k).usageRatio * \sum_{j=1}^{o} fUse(i,j).invocationsPerMonth * 12$$

$$extServCost = \sum_{k=0}^{e} invocs(ES(k)) * ES(k).getPrice\big(invocs(k)\big) + ES(k).price.baseFee * intvl$$

For the calculation of data transmission cost, push and pull communication mechanisms are considered separately. For the calculation of data volume in pull mode, the *requestSize* and *responseSize* (in byte) must be considered for every data point that is requested by a function using ***F_Usage*** and ***D_Usage***. The data volume is then converted into megabyte and stored in the ***pullVol()*** list, which keeps the required data volume for every device. For push communication, the *updatesPerDay* attribute of all data points *p* is evaluated and multiplied with the ***responseSize*** of each data point. The result is stored in the *pushVol()* list for each device. As described above, the push communication is independent of individual requests and takes place separately from pull communication, if a value for the *updatesPerDay* attribute is provided. To determine the total transmission cost ***dC***, the combined volume of push and pull communication is multiplied with the price for the transmission of each device specified in a price model, which is retrieved using ***getPrice().***

$$pushVol(DE(j)) = 365 * \sum_{i=1}^{p} (DP(i,j).updatesPerDay * DP(i,j).responseSize) \;/\; 1048576$$

$$pullVol(DE(j)) = \sum_{i=1}^{p} \big((DP(i,j).requestSize + DP(i,j).responseSize)\big) \;/\; 1048576 * \sum_{k=1}^{f} dUse\big(k, DP(i,j)\big).usageRatio * \sum_{m=1}^{o} fUse(k,m).invocationsPerMonth * 12$$

$$dC = \sum_{i=1}^{d} (pushVol\big(DE(i)\big) + pullVol(DE(i)) * DE(i).getPrice(pushVol(DE(i)) + pullVol(DE(i)))$$

All other cost calculations are related to manual cost items. They are simply calculated by multiplying *quantity* and the ***price*** defined for this quantity with consideration of the payment interval through the appropriate ***intvl*** factor to convert into yearly cost, e. g factor 4 for quarterly occurring cost. While cost is modeled without relation to a specific planning year, revenues can vary through the count attribute of the *Booking* class. Therefore, for the calculation of revenues, all bookings for all customer groups **g**, their assigned offers ***o*** in planning year ***i*** need to be considered and multiplied by the *price* for the respective offer.

$$rev(i) = \sum_{j=0}^{g} \sum_{k=0}^{o} BK(i,j,k).count * intvl * \; Offer(j).getPrice(BK(i,j,k).count * intvl)$$

The results of these calculations are stored in the attributes *revenue* and *cost* of a *PlanningYear* object. A set of *PlanningYear* objects within a *Project* is the payment series. For the sake of simplification, it is assumed that all revenues and cost are cash-effective in the respective period. Afterwards, established methods for capital budgeting like NPV or IRR can be applied to the payment series to determine the economic viability of the current service model (Pieroni et al. 2016).

12.4 Application of the Meta-Model in a Tool Prototype

To facilitate easy collaboration within an interdisciplinary team as well as to allow storing results between multiple workshops, the implementation of the tool as a web-based application was devised. For the frontend, the JavaScript framework AngularJS was used, which communicates via REST APIs with backend services developed in C#. These, in turn, use a Microsoft SQL Server database to store the models as described in the previous sections. Based on the models created through user interaction in the Editor View, a calculation component creates the financial case model and displays the result ("FC Result") instantly in the Editor View after every modification.

The tool allows the creation of projects and the configuration of their planning period. For each project, there is an overview page, from which the user can navigate to model editing, project configuration, and reporting. On the right-hand side, the model editing view provides navigation icons for customer groups, offers, functions, external services, and devices (requirement R6). Elements of the respective type can be added or deleted. On the right-hand side, there are input options for attributes of elements and manipulation of links (Figure 12.7).

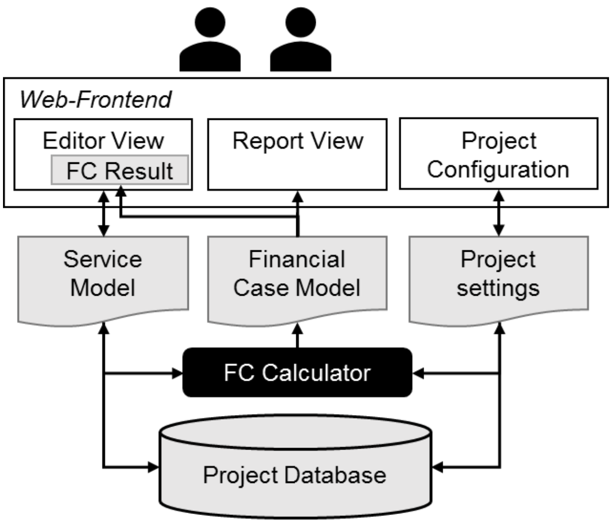

Figure 12.6: Architecture of the prototype

The application of the tool in a practical setting is depicted in Figure 12.8. It allows the service structure to be built up in parallel with quantities, prices and usage behavior. The model can be iteratively manipulated and expanded as often as required. Each change leads to a recalculation of the financial case, which can be incorporated into the design process (Figure 12.8). At the same time, it serves as a documentation of the development status over various workshop sessions and thus avoids the loss of important contributions. The tool prototype can also be used within a co-innovation process to include customers as important stakeholders as proposed by Marilungo et al. (2016). The revision is continued until the project team can decide on the continuation or rejection of the service idea.

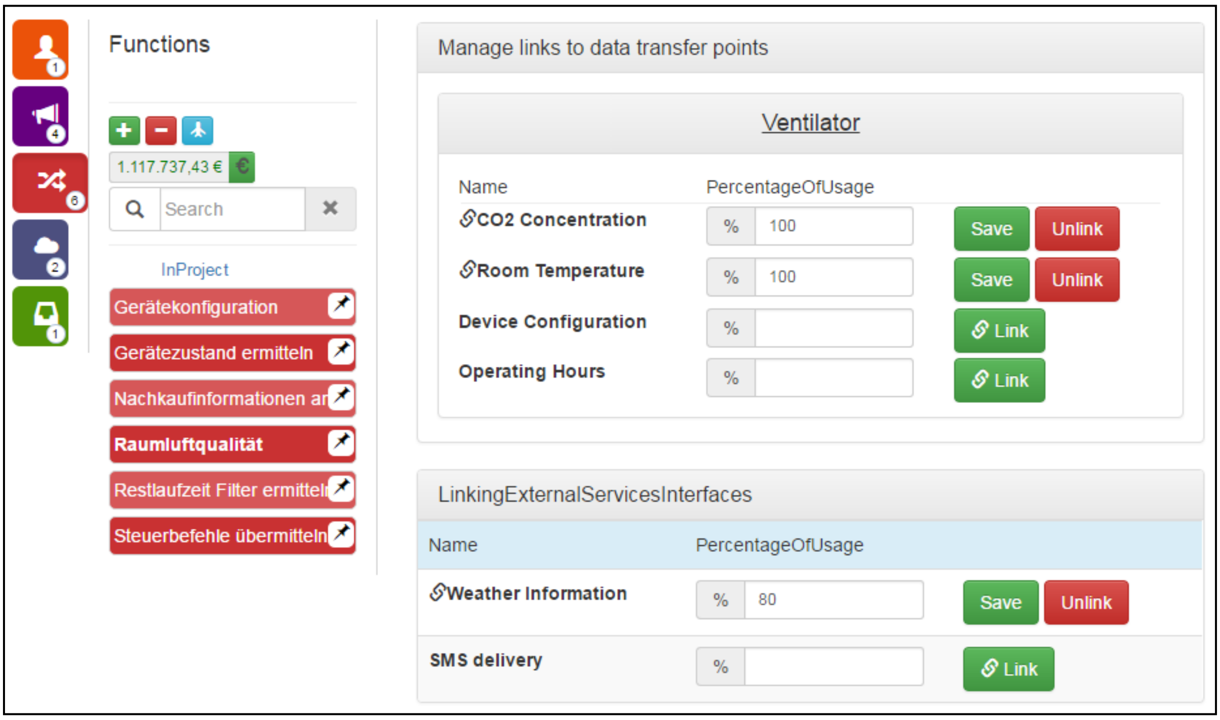

Figure 12.7: User Interface of the web-based tool prototype

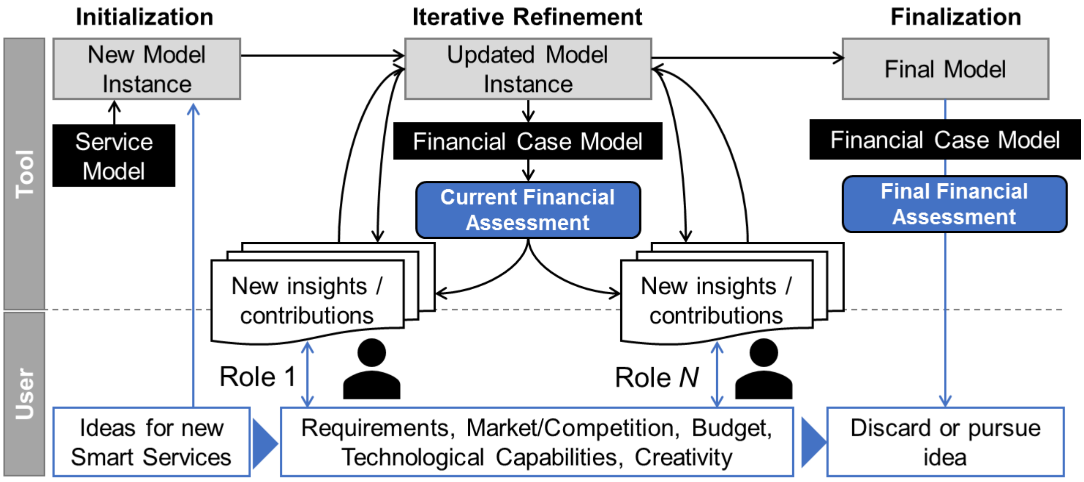

Figure 12.8: Application of the proposed tool in the design process

12.5 Evaluation

12.5.1 Model Evaluation

To evaluate models in general, the criteria ***completeness***, ***fidelity with real-world phenomena***, ***internal consistency***, ***level of detail***, and ***robustness*** are proposed by March and Smith (1995). *Fidelity with the real-world phenomena* refers to the external consistency, which was evaluated through the test of the model with real-world cases in the design phase. The ***level of detail*** and ***completeness*** are more difficult to evaluate as both the spectrum of potential cases as well as the information demand for the individual model users can be very different. An indirect evaluation of these two criteria is performed through the application of the model in the tool prototype as described below. ***Internal consistency*** and ***robustness*** of the meta-model were not evaluated. As this research aims to explore the overall approach of integrating financial evaluation in the design process, we argue that internal consistency and robustness should be considered for future research when the approach is more mature.

The specific evaluation of the meta-model is performed regarding the requirements in Table 12.1. Here, it can be stated that the requirements R1, R2, R3, and R4 are fulfilled to a large extent, as they relate to the structure of the model and were addressed in the design process. In terms of transferability, there will always be a debate on whether such meta-models provide too much or too little detail. Further evaluations steps are required to get a better understanding of the potential improvement on scope, expressiveness, and comprehensibility of the meta-models, especially for interdisciplinary teams.

12.5.2 Design of an Experiment for the Tool Evaluation

The tool prototype is an instantiation of the meta-model, for which potential evaluation criteria are ***effectiveness***, ***efficiency***, and ***impact on the environment and the artifact's users*** (Sonnenberg and Vom Brocke 2012). We follow the notion of Prat et al. (2014), according to which models are considered as abstract artifacts that can be indirectly evaluated through their instantiations. Therefore, we indirectly evaluate the proposed meta-model through the evaluation of the tool prototype based on it.

An experiment is used out to evaluate the tool, in which multiple teams carry out the design and evaluation of smart services. The aim of the experiment is to identify effects of the tool by comparing teams with and without the support of the tool prototype in a setting, where service ideas need to collaboratively be evolved into service concepts.

The participants were 30 information systems students of a German Cooperative State University in their final year of study. Due to their dual study model, which integrates academic studies with on-the-job training, they have a much higher level of practical experience compared to “typical” students. As preparation, all of them received a two-hour introduction to the topic "Internet of Things and Smart Services". The basic structure of smart services and the basics of financial evaluation were explained without presenting the tool in detail.

This was followed by a brainstorming of 30 minutes to generate ideas for smart services, from which a total of four ideas were selected for the experiment. We deliberately chose not to use predefined service ideas or scenarios for two reasons: First, in a creative workshop setting, it is common that many ideas are generated from which only a small fraction is chosen for further elaboration. Second, the brainstorming utilizes existing knowledge of the participants, which directs the generation of ideas to domains, they are more familiar with than with externally prepared service ideas.

Afterwards, they were randomly divided into eight teams with three to four members. Due to the randomization of the assignment between experimental and control group, a pretest is dispensable (Wilde 2008). Therefore, the "Posttest-only control group design" (Recker 2013) was chosen. Each service idea was assigned to a team of the experimental group (EG) with access to the tool prototype and a team of the control group (CG) without access to the tool prototype. Participants of the CG were however allowed to use other software. All teams in the control group decided to use spreadsheet software, in most cases MS Excel. It should be noted that there was no spreadsheet model provided. This was decided for two reasons: First, to evaluate the benefit of the proposed meta-model. Second, in a real-world situation, the spreadsheet model for financial evaluation would not be available upfront but would have to be developed by the team.

The design task given to the participants was: "(a) Elaborate and describe the assigned scenario in detail with its target customer groups, offers, functions, and data. (b) Assess the profitability based on cost and revenue with a planning horizon of three years." Part (a) of the task specifically refers to the structure of smart services. Part (b) of the task is a general profitability question, which can be placed in a similar way for every project proposal or investment object. However, as the profitability is asked for at an early stage of service development, i.e. conceptual elaboration, it creates a setting which is specific to our research question.

Each team had up to 75 minutes to complete the task. Immediately afterwards, the participants were asked to complete a survey to assess their experience with the task and the utility of the tool support. The overall design of the experiment is shown in Figure 12.9.

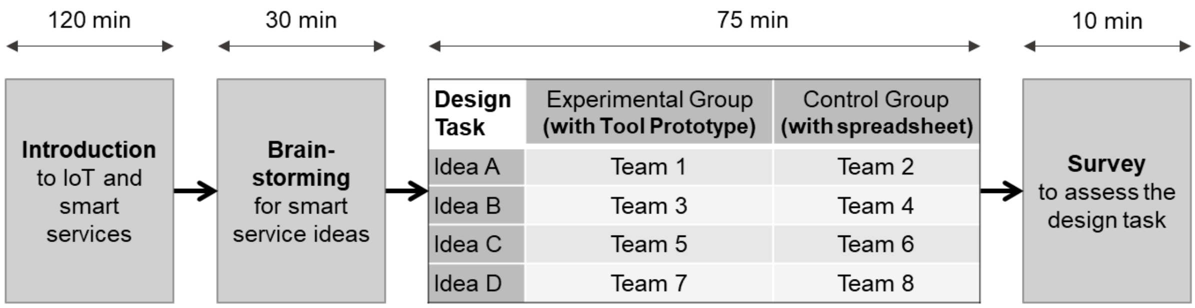

Figure 12.9: Design of the experiment to evaluate the prototype

For the assessment, a set of criteria was established in a questionnaire, which relates back to the research goals as well as the requirements stated above. It allowed participants to rate their experience with the design task. Table 12.2 shows how the statements in the questionnaire relate to the evaluation criteria of instantiations.

Statement	**Variable**	**Effectiveness**	**Efficiency**	**Impact on Environment and Artifact' s Users**
It was easy for me to find a structure for the design task.	STRUCTURE		X	
It was easy to make decisions about the service design.	DECISION		X	
The impact of our decisions on the profit of the service was easy to estimate.	IMPACT		X	
I felt that everyone in the team had the same view on the current state of work.	PROGRESS	X		X
I am satisfied with the result of our work.	RESULT	X		X
Using the tool has helped me with the design task.	TOOL_USEFUL		X	X

Table 12.2: Questionnaire statements and their relation to evaluation criteria

All statements could be rated on a Likert scale from 5 (strongly agree), 4 (agree), 3 (neutral), 2 (disagree) to 1 (strongly disagree). As participants in the CG were unable to rate the criterion TOOL_USEFUL, an additional option 0 („I did not use the tool") was added to this particular statement.

12.5.3 Results of the Tool Evaluation

All 30 participants completed the survey. *For all variables, the median was determined for the EG and CG. Since the Likert scale can also be interpreted as interval-scale, the arithmetic mean and the standard deviation is also given for better differentiation of the results* (Table 12.3).

	EG (with Tool Prototype)			**CG (with spreadsheet)**		
Variable	Median	Mean	Std. dev.	Median	Mean	Std. dev.
STRUCTURE	**4.0**	3.88	0.885	3.0	3.21	1.051
DECISION	3.5	3.50	0.894	3.5	3.57	1.016
IMPACT	3.0	2.69	1.014	3.0	2.79	1.051
PROGRESS	4.0	3.79	0.998	4.0	3.94	0.975
RESULT	3.0	3.38	1.204	3.0	3.21	1.251
TOOL_USEFUL	**4.0**	4.21	0.696	-		

Table 12.3: Results of the Evaluation (N=30)

12.6 Discussion

First, it should be noted that EG participants have considered the use of the tool to be very helpful. Furthermore, support for structuring the task was positively assessed. This can be interpreted as an indication for the basic comprehensibility (requirement R7) of the developed service model, at least for participants with an information systems background.

All other variables have nearly identical ratings in both groups. The reason for this could be that the utility of the tool increases with larger groups, longer processing time or when using it in a series of multiple workshops. Furthermore, it would have to be examined in future runs of the experiment whether an improvement in the results is achieved with a more precise introduction into the functioning of the tool. We deliberately kept the introduction of using the tool rather short, as we assumed that in practice people would not spend much time on training. Related to this is the usability of the tool prototype. The prototype is only a mean to make the meta-model usable in practice. While we tried to comply with established standards of web-based applications regarding layout, navigation and interaction, we did not have usability as an explicit design goal. It, therefore, can be assumed that improving the usability would increase the tool's utility without changing the meta-model in any way.

Regarding the tool-support of the design process, we can state that R6 was also fulfilled as the sequence for manipulation of model elements is not restricted in any way. As the complexity of the meta-model was kept deliberately low and the evaluation indicated a benefit for structuring the task, we can assume the R7 to be fulfilled as well.

The measurement of the variable IMPACT is particularly relevant regarding the fulfillment of requirement R5. As the evaluation showed no difference between EG and CG, further research is needed to investigate whether this requirement can be fulfilled. One strategy could be to observe the individual modeling steps in both EG and CG and compare at which points in time intermediate results were achieved.

While our results indicate that the general approach of integrating evaluation in the design processes is helpful to better manage complexity, we acknowledge the limitations or our research: First, the experiment is conducted with students. While they have a very good state of knowledge and some practical experience due to the dual study model, it is likely that results will be different for professionals with more experience in designing complex IT-based services. Second, the length of the conceptual work in the experiment was relatively short and conducted in a single session. Real-world service engineering projects are very likely to be conducted in multiple sessions over a longer period, even with changes in the team structure. Third, the training with the tool might have been too little. More complex cases or repeated usage in the real-world would justify a more intensive training to familiarize users with the concept and functionality in more detail.

Finally, we have not evaluated the internal consistency and robustness of the meta-model. As stated above, we see these evaluations as part of future research, once the overall approach of design integrated financial evaluation is more mature and the meta-models are stable.

12.7 Conclusions

In this article, we have presented an approach for tool-based support of the financial analysis of smart services, which is integrated into the design process. As we have discussed, most PSS engineering methods are particularly concerned with the design process and lack of explicit support for IT artifacts as part of the PSS. Furthermore, while there are design-integrated methods for evaluation of PSS (Mourtzis et al. 2015), they do not cover financial impact. Existing approaches for tools are typically too complex for an early stage evaluation of service ideas (Becker et al. 2009; Laurischkat 2013).

We addressed these deficits by providing a meta-model as the basis for a tool to allow immediate calculation of evaluation results based on the proposed meta-model. The objectives were to enable financial evaluation in early design stages and to help interdisciplinary project teams to collaborate in the design and evaluation process. Our solution is suitable for interactive use in workshops as it allows instant feedback in an iterative design process. Based on the characteristics of smart services as complex systems and their engineering process, we derived seven requirements. After designing meta-models for both the service and the financial case, we implemented a tool prototype based on these models. From our experimental evaluation, we can derive the following findings:

1. *Using the tool prototype is not obstructive:* None of the participants in the experimental group showed a lower ranking of utility criteria than the control group. This indicates that using the tool was not hindering the design process within the experiment.
2. *Tool-support is perceived as helpful:* Participants of the experimental group showed a strong option towards the general benefit of using the tool (median of 4 on a 1 to 5 scale). This implies that the participants explicitly saw not only a benefit of having a tool in general but perceived this particular tool prototype as helpful for the task at hand. This indicates that the general approach of tool-based design was accepted and appreciated within the group of participants.
3. *Structuring of the task is a major benefit:* The results of the experiment indicate that a tool with the underlying meta-model is helpful to describe a smart service. This indirectly provides an evaluation of the suitability of the model for the given task.

The theoretical contributions of this paper to the body of knowledge in model-based service engineering are as follows: First, we introduced the concept of design-integrated financial evaluation for smart services, which addresses the identified research gap of missing concrete methods for financial evaluation in PSS engineering. Secondly, we developed a data structure (meta-model), which enables the early stage modeling of smart services, and its link to a financial case model. This link is established through a calculation model provided as a set of formulae. The meta-model can only be understood as a first proposal on how to integrate design and financial evaluation. Especially the flexibility of the meta-model regarding different business models is currently rather low. A more comprehensive test with smart services in different industries and with varying level of complexity will offer insights into shortcomings of the current meta-model.

Regarding practical contributions, there is an indication that our approach can help to improve the design process of smart services through tools. For that, empirical evidence on the utility of the design-integrated evaluation of smart services was collected, which indicates that the proposed approach is beneficial. Additionally, we showed the technical feasibility of implementing a working tool from our concept. Both the meta-model and the presented architecture can serve as a foundation for the development of similar tools for similar purposes. While tool-support for complex tasks such as smart service design and evaluation appears to be rather obvious, creating actual benefits from it depends on many factors such as qualification of users, complexity of the problem, and usability of the tool. Most of them were not explicitly investigated in this study but will be relevant in practice.

Empirically, we could find comparatively small improvements caused by the tool in the design process. Future research should focus on the elaboration of conditions under which such a tool use becomes more effective. This refers to the "Eval4 activity", as proposed by Sonnenberg and Vom Brocke (2012), which aims to evaluate applicability and usefulness of artifacts in practice, e.g. through field experiments, case studies, and expert interviews.

Future research topics are usability improvements and a graphical notation for the model. Extension to the modeling capabilities of the meta-model should also be considered. For example, the meta-model does not provide any means to express the sequencing of function to model processes. It should be investigated, whether this is an important addition to get a more detailed analysis of cost or whether the added complexity counters intuitive use.

In general, the technical and organizational integration of a smart service modeling and evaluation tool as part of the overall service engineering process is still an open question. For that, further research needs to be conducted to better understand the acceptance of tool-based business modeling and evaluation schemes. Furthermore, the reuse of created service models in other tools for more advanced design stages of digital product-service systems (McKay and Kundu 2014) needs to be address to enable integrated tool-chains. Research regarding these topics will be highly beneficial to both research and practice, as the economic relevance of smart services will continue to increase.

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13 Towards a Cost-Benefit-Analysis of Data-Driven Business Models

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Abstract. The emergence of data-driven business models calls for their systematic design and evaluation. In this paper, we focus on a first step towards a Cost-Benefit-Analysis of data-driven business models. Within data-driven business models, data act as enabler for the development of innovative services. However, to justify internal funding of new services, an assessment of the financial impact for the service at hand is often required. We approach this by identifying drivers of cost and benefit based on the Service Business Model Canvases of twenty cases. Based on the results, all drivers and their associated models for quantification were consolidated into a single meta-model. With this, we provide a basis for the economic assessment of service ideas and their refinement during the design process.

Keywords: Data-driven Business Models, Profitability, Service Engineering, Cost-Benefit-Analysis, Smart Services

13.1 Introduction

Many services have been proposed to transform product-oriented into service-oriented businesses [1, 2]. To systematically design and communicate ideas for new service business models, the Service Business Model Canvas (SBMC) has been proposed by Zolnowski [3]. With the ongoing digitization of service delivery processes, a new class of data-driven services has emerged [4]. While the SBMC is not restricted to data-driven services, it obviously can be used for this purpose as well.

One of the key characteristics of component-based business model representations [5], like the Business Model Canvas (BMC) [6] or the SBMC [3], is their qualitative nature, which is very suitable for developing and refining the business logic of an idea [3, 7]. However, to justify internal funding of service engineering initiatives, an assessment of the financial impact for the planned service is required. To this end, various cost items for service provision have to be considered as well as savings through process improvements and revenues through additional offers to customers. Assessing these factors in early stages is challenging but helpful for decision making.

In this paper, we develop a concept for the quantification of data-driven business models (DDBMs). For this, we provide a basis for the economic assessment of service ideas and their refinement during the design process. Hence, we answer the question "What factors need to be considered in a Cost-Benefit-Analysis of a data-driven business model?" To answer this question, we analyze twenty case studies to identify factors that are relevant to describe and evaluate business models. Based on the results, all factors and their associated models for quantification were consolidated into a single meta-model. With this, we strive to improve the overall service design process in practice.

Within this contribution, we focus on a refinement and assessment of business model ideas but do not address the issues of finding a good value proposition, price model or partners. However, with our integrated model, we can support showing the (financial) impact of the design decisions made in the SBMC.

Furthermore, we acknowledge the relevance and importance of non-financial benefits [8-10], especially for innovative offers such as data-driven services. However, in this paper we focus explicitly on the financial dependencies in a DDBM.

The paper is structured as follows. Firstly, we introduce our conceptual foundations with regard to a DDBM. Then we explain the research methodology and introduce the applied case studies. This is followed by the results of the analysis of the cases. Thereupon, a cost-benefit analysis model for a DDBM is proposed and discussed. The paper ends with a conclusion and an outlook.

13.2 Conceptual Foundation

13.2.1 Service Business Models

Considering business models, there is a variety of different understandings and definitions [3, 7, 11]. Due to the lack of definitional clarity, alternative conceptualizations of business models exist (e.g. [12-14]) that result in conceptual diversity like a variety of ontologies and representations. Common ontologies for business models are e3-value Ontology [15] and the Business Model Ontology [16]. Representations can be distinguished in two research streams. The first research stream comprises a more flow-oriented perspective on business models. A prominent example for this stream is the e3-Value method [15]. The second research stream comprises a system-level holistic view on the business logic of an economic entity or offering [7]. The most prominent example for this stream is the (BMC) [6].

Fostered by a service-based change in value creation [17, 18], business models are also discussed in service research [3, 19, 20]. Service business models are different from product-based business models because of the specific characteristics of service. In general, service is a process between interacting parties for the benefit of another party. Especially, the interaction is of high relevance. Known as value co-creation, it is one key aspect of service [18, 21]. Additionally, service value has a unique and phenomenological character [18, 22]. Furthermore, the interaction of service results in a mutual integration of resources and activities. Possible resources that have to be integrated are e.g. skills, knowledge, physical resources and decisions [23, 24].

Because of their specific characteristics, representations for service business models differ from representations for traditional business models [3, 25]. One service specific business model representation is the SBMC. The SBMC highlights the integration of different actors within a service business model and thus, allows focusing on the strategic relevant co-creation in the business logic of service-based business models. As overall logic, the SMBC focuses on the contribution to and benefit of each actor. This logic is applied in the seven dimensions value proposition, relationship, channels, revenue stream, key resources, key activities, and cost structure. In the dimensions customer and key partners, the different actors are defined [3]. The SBMC is displayed in Figure 13.1.

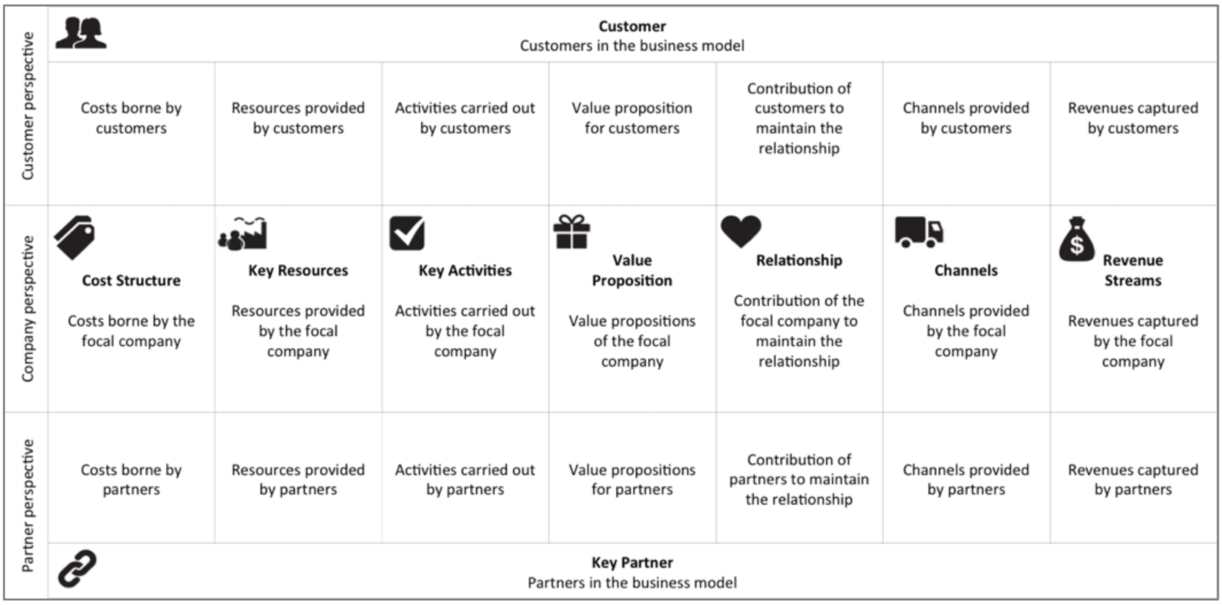

Figure 13.1: Service Business Model Canvas [3]

13.2.2 Data-driven Services

Based on the service-oriented paradigm new services like data-as-a-service or analytics-as-a-service emerge [26, 27]. Within DDBM, data act as enabler of such innovative services. With enabling technologies, like sensor technology and cloud computing, companies can exploit data from and about their customers. In their own environment companies get enabled to generate new profitable know-how based services [28, 29].

Requiring such new technologies Veit et al. [30] state that “a business model is digital if changes in digital technologies trigger fundamental changes in the way business is carried out and revenues are generated.” The BITKOM [31] quotes in their report a similar definition whereupon business models are digital if changes of digital technologies do have fundamental consequences for the business processes and the revenues of the company.

According to Hartmann et al., DDBM is defined as “a business model that relies on data as a key resource” [26]. Brownlow et al. [32] similarly state that “data is obviously fundamental to a DDBM” and Bulger et al. [33] agree, that “data should be central to the business.” These definitions are rather simple and differentiate business models on their use of data or not. A more complex perspective on DDBM is proposed by Schüritz and Satzger [4]. According to this, there is no DDBM per se; rather, there is a continuum of options how to provide data-driven service. Hence, there is a smooth transition between business models that use little data and those that enrich all areas of its business model with data analysis [4]. Thereby existing data or new data can be used to either create new business models or enhance existing ones [31]. In the latter case either the value creation, the value proposition or the value capturing or combinations of these can be enhanced by data [4]. For the purpose of our research, a complex differentiation of DDBM is not necessary. Thus, we chose to define DDBM according to Hartmann et al. [26].

The most relevant aspect during the design of a DDBM is the value that should be attained by the data analysis. Hence, the why and how [33] need to be examined. This includes defining the used data. For this purpose, Mathis und Köbler [34] developed a data canvas. The canvas distinguishes between batch and stream as well as internal and external data. Internal stream data do provide the most value since they allow a constant monetization and the data are accessible at any time without any restrictions“ [34]. However, to be able to exploit the analysis potential data needs to be well integrated into the business model [33].

13.2.3 Cost-Benefit Analysis

To make the decision if to invest in a project, a Cost-Benefit-Analysis (CBA) can be performed [35, 36]. A CBA is an established tool for assessing the economic benefit of an investment. As such, it can support decision making on whether a service provider should proceed with the engineering and implementation of a new data-driven business model or not [35, 36]. Due to the complexity of service [37], a systematic capture and analysis of CBA-related factors is a desirable goal. To facilitate end-to-end engineering of smart services, we propose to enrich the qualitative perspective of component-based business model representations, in particular the SBMC, with quantitative information. Existing work dealing with business models do not provide means for quantification. Moreover, currently profitability modelling does not include the customer perspective in detail.

One example of a method for assessing data-driven services for connected products was proposed by Anke and Krenge [38]. They propose a meta-model for "Smart Services" from which a business case is derived during the modelling process. In their work "Smart Services" are understood as digitally provided services for connected products. Therefore, "Smart Services" are data-driven services that rely on data which is at least partly provided from connected products, i.e. the Internet of Things. While the meta-model of Anke and Krenge is not directly related to a business model, it provides a connection between service design and its financial evaluation. We therefore will use it as foundation for the concept presented in this paper, as we consider the data-driven business model that might consume data from sensors and the Internet of Things as well.

13.3 Methodology

In order to design a framework for early-stage profitability assessment, this research applies the following method: first, we identify quantifiable influence factors from a consolidated list of influence factors of digital services on service business models. This list was gained through a multiple case study [39], conducted by Zolnowski et al. [40]. The focus was placed on international companies that successfully developed and implemented successfully data-driven innovations.

The identified cases cover (1) the improvement of the customer orientation, (2) process optimization, (3) optimization of resource consumption, and (4) the collection of information to complement and accelerate decisions. In sum, twenty cases from seven industries were selected and analyzed. Thirteen cases were identified from data of a consulting company and seven cases were derived from literature and public information. The chosen cases cover data-driven innovation projects in different industries (see Table 13.1).

The results of this work are shown in Figure 13.2. This figure shows the identified influence of data-driven innovation projects on the business models of the analyzed companies. The effects are symbolically illustrated by gray boxes and grouped if being similar with bold titles describing aggregated types of effects. Because of the networked character of a DDBM, all influences are differentiated according to their impact on customer, company, or partner. Thus, elements that have a direct influence on the customer, are classified to the customer perspective.

Companies	Company description & Examples for implemented data-driven innovation projects
Three automotive companies	**Two** German automotive manufacturers >70,000 employees (2014) **One** from the automotive parts industry >30,000 employees (2014)
	Project: Predictive Maintenance by expansion of sensors on assets; Optimization of processes by data integration
Seven manufacturing companies	**Three** German companies >6,000 employees **Two** German companies >63,000 employees **Two** American companies >80,000 employees
	Project: Predictive Maintenance by expansion of sensors on assets; Service innovation and use of Internet of Things; Optimization of processes by data-driven forecasting
Five logistics and transportation companies	**One** joint venture, 51-200 employees (2014) **Four** companies, 1800-5.000 employees (2014)
	Project: Coordination of infrastructure by real time data of players; Tracking of assets by expansion of sensors
Two retail companies	**One** German retail company >17,000 employees (2014) **One** Swiss food company >300,000 employees (2013)
	Project: Optimization of disposition by analysis of market data
One insurance Company	**One** American start-up, 201-500 employees
	Project: Product innovation in car insurance by use of Internet of Things
One energy company	**One** German electric utility company > 50,000 employees (2014)
	Project: Predictive Maintenance by expansion of sensors on assets
One telecommunication Company	**One** Swiss telecommunication provider >20,000 employees
	Project: Coordination of infrastructure by data of passenger traffic

Table 13.1: Description of the analyzed cases

In the next step, we analyzed the identified influence factors according to their quantitative or qualitative nature. This was necessary to identify those factors that have a quantitative influence on the costs and benefit of the DDBM. Based on this information, we were able to determine the influence factors for a CBA of a DDBM on an empirical basis. To summarize, the proposed CBA model adapted for the DDBM is developed in the following steps:

1. Categorization of quantitative influence factors from twenty case studies into cost, revenue and savings.
2. Development of a parameter set to simplify the capture of relevant inputs and derive the financial values for identified influence factors.
3. Integration of the parameter sets into an integrated meta-model, based on the meta-model proposed by Anke and Krenge [38].

The remainder of this paper is structured as follows: In section 4, we conduct step 1 and 2, while section 5 covers step 3 followed by a discussion of the results. The paper concludes with an outlook on further research questions.

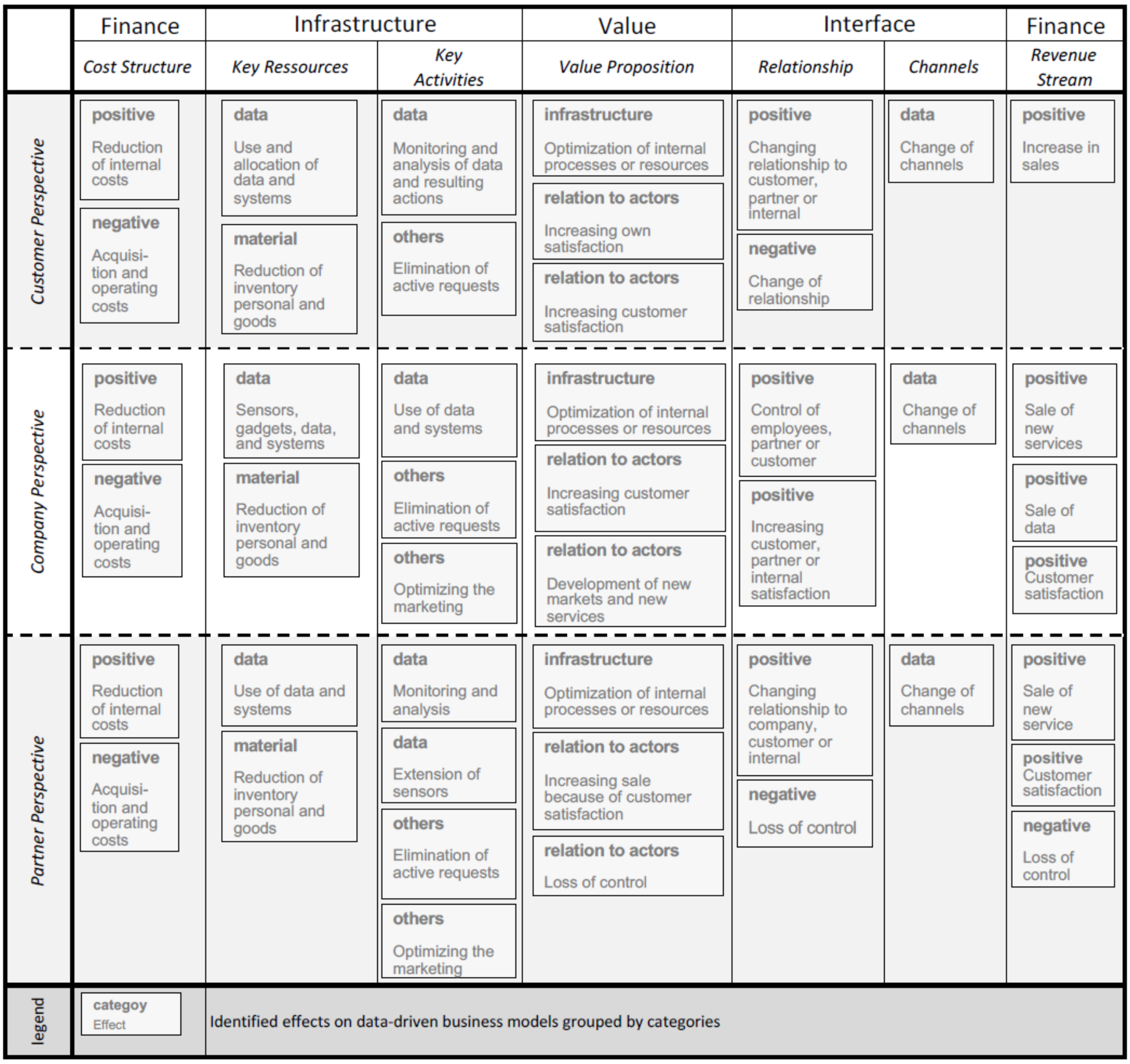

Figure 13.2: Identified effects of data-driven innovation projects [40]

13.4 Case Analysis

13.4.1 Identification and classification of CBA-related parameters

In our multiple case analysis, we were able to differentiate between qualitative and quantitative influence factors on the business models. Qualitative factors comprise effects like increasing customer satisfaction or change of relationship that cannot be translated directly to a countable metric. However, influence factors with a quantitative nature enable a direct analysis of countable and monetary consequences. These factors comprise effects like reduction of internal costs or sensors, gadgets, data, and systems. As already stated, we acknowledge the relevance and importance of non-financial benefits [8-10]. Nevertheless, in this paper we focus on quantitative influence factors and exclude qualitative influence factors intentionally. Within these factors we are able to distinguish between three classes of effects. In the following, we present the results of our multiple case analysis according to the identified classes (1) costs, (2) revenues, and (3) savings.

13.4.2 Costs

There are a variety of costs that can be directly related to the development and management of a DDBM. This includes all necessary preparation and the use of data and systems (including the influence factors different use of data and systems; monitoring and analysis of data, actions; and extension of sensors in the key activities and use and allocation of data and systems; sensors, gadgets, data, and systems; use of data and systems in the key resources). Especially in the development phase, the improvement or implementation of infrastructure is an important cost factor. For example, in a manufacturing case, customers have to implement remote services hardware in their machines to collect data and enable the connectivity between the customer's machines and the provider's servers. A driving force for the improvement or implementation of new infrastructure is the lack of sensors, actuators, and connectivity in older machines. Highly depending on the industry, these elements can already be part of an existing infrastructure, or they need to be added. However, all three elements are enabling technologies for the DDBM. Sensors are necessary to monitor machines and collect data. Connectivity establishes a link between the systems of the customer and provider to transmit the collected data, and actuators enable the provider to remotely take control or even change things automatically based on data. If relevant infrastructure is missing, companies having no or limited experience and are often surprised about the advancement in sensor technology. Off-the-shelf products can cost a few cents per sensor. Even equipping an existing product with an additional sensor can result in marginal extra costs. However, if customized sensors are required, development costs can reach several hundred thousand Euros.

Besides the infrastructure, specialized software can be necessary for a DDBM. As our cases show, such software can be developed, purchased, or leased. Alternatively, cloud services can be applied. According to the respective decision, in many cases the costs occur on-demand, recurring, or for the development of the software. Integrated in this software, algorithms enable the processing of the data. These algorithms can be highly individualized and need to be developed, maintained, and processed by the provider or other partners. This also applies to the resulting reports of this process.

To enable the whole DDBM, the connectivity between all actors and their infrastructure and software is of high relevance. According to the type of connectivity, e.g. permanently or recurring, the actors have to calculate with different pricing models.

According to our analysis, the influence of infrastructure, software, and connectivity have an important influence, with a direct effect on the focal company, the customer, and partner. Hence, in order to introduce a DDBM, invests into all factors are needed in the entire service system.

13.4.3 Revenues

As our cases show, in a DDBM, revenues can be enabled for any actor. From a company perspective, revenues can be generated from sales of new services and possibly also from the sale of data to third parties. Despite an existing relation to a customer, an increase in revenue is not mandatory with existing customer satisfaction. In our cases we were able to identify companies that establish completely new DDBMs that were offered to the customers. For example, a manufacturer facilitates higher safety standards by offering the tracking of tools in the maintenance process of the customer. This leads to an increase of responsibility through employees and avoids occurrence of abandoned tools.

But also customers and partners are enabled to generate additional revenues. By facilitating existing or enabling new processes, they can improve their existing or establish completely new business models. Target of these operations is to increase sales or to exploit economies of scale.

13.4.4 Savings

Beside of revenues, another positive economic effect are savings. In particular, the implementation of a DDBM allows for optimization of processes or reduction of assets, which both lead to lower costs by the reduction of inventory (key resources).

From a company's, partner's, and customer's perspective, DDBMs have direct influence on the operational processes. The processes can be optimized in a different manner. In one case, the provider gathered data about his and the customer's processes. Based on his knowledge, he was able to provide consulting services to his customer and to optimize his processes. Another case illustrated the elimination of active requests. Within this case, manual requests and process executions were replaced by automatized processes. This led to a reduction of operating costs.

Additionally, a reduction of inventory, personnel, and goods is possible. In particular, we observed a reduction of resources by an optimization of resource planning and hence, adjusted resource utilization.

13.5 A Cost-Benefit-Analysis Model for DDBM

13.5.1 Parameter Categories and financial quantification

In general, a CBA considers all costs and benefits to assess the economic value of an investment project. Cost refers to the financial effort required to build and operate a DDBM system. For all effects created by the investment project at hand, monetary values have to be assigned. Benefits can be either additional revenue or cost savings, e.g. through improved process efficiency. In the context of business models, we expect a CBA to support in experimentation and finding better solutions through an additional evaluation criterion. As a foundation for the CBA model, we use a series of payments, which contains the net cash effect per planning period.

As we take the perspective of the service provider, we build our model based on the quantitative factors of the focal firm identified in the previous section. The required elements and their relationships will be expressed as a UML class-diagram meta-model, which is why we use the terms class and attributes in the description below. The complete meta-model is shown in the next section.

Cost is already expressed in monetary values. However, it is usually difficult to estimate a total value. Therefore, we propose to break down cost into various more concrete items, which can be estimated with higher confidence. As we have identified cost items that are relevant for a DDBM, this helps to create a CBA model for these scenarios. We differentiate between one-time, recurring constant, and recurring-growing cost. For simplification, growth rates are fixed per period (see Table 13.2).

SBMC Factor	*Capture Model*
Acquisition and operating costs	Operating costs are recurring, and can be both constant and growing. We use the `OperationCost` class to describe cost of various `CostTypes` and `PaymentIntervals`. For all costs related to the use of external services, such as weather info, messaging etc., we provide the `ServiceVariableCost` class. It relates to the `Functions` and their usage of `ExternalService`. `Functions` can also use `DataPoints` from connected `Devices`. As the latter are provided from connected products, these can be modeled as `Device` with attributes for `costPerMBTransfer`, `devicePrice`, `initialDeployment` and `growthPerYear`.

Sensors, gadgets, data and systems	Equipment of all kind has to be purchased (one-time cost), so type of equipment, price and quantity capture these cost. In the model, these are captured in the `InitialInvest` class.

Table 13.2: Translation of costs into the capture model

Revenue is created by providing value to customers. It is also already expressed in monetary values. As with costs, we propose to break down revenue into more concrete offers with a single price. This helps decision makers to describe the service in a more specific way and see the impact of various configurations (see Table 13.3).

SBMC Factor	*Capture Model*
Sale of new services	An `Offer` can be modelled with a `offerName` and `price`, which can be interpreted as subscription or transaction-based price. The quantity is defined using the `CustomerDemand` class, which contains attributes for `customerGroupName`, `initialYear` and optional `growthRatePerYear`.
Sale of data	

Table 13.3: Translation of revenues into the capture model

Savings refer to reduction of cost at the service provider. They can be created through process efficiencies, reduction of stock, resource consumption etc. To quantify these effects, the internal organization of the service provider has to be known in great detail. However, this would increase the complexity of the CBA model greatly. Therefore, we propose to model savings as relative improvement to a certain level, which can be expressed by three simple parameters. In the following table, we list the identified SBMC parameters by category, and show how we quantify them. Please note, that the factor "Reduction of internal costs" is not explicitly mentioned, as it is covered by the four factors listed in the table (see Table 13.4).

SBMC Factor	*Capture Model*
Reduction of inventory, personnel and goods	To quantify these effects, we use the Savings class, which can be instantiated for every relevant savings effect. It is modelled with the name of the factor, its `initialLevel` as monetary value and the `reductionInPercent` to capture the savings effect.
Elimination of active requests	
Optimizing the marketing	
Optimization of internal processes or resources	

Table 13.4: Translation of savings into the capture model

13.5.2 Integrated Meta-Model

All factors and their associated models for quantification were consolidated into a single meta-model, which is depicted as a UML class diagram. Class diagrams are an established way of representing the structure of domains semi-formally. Classes represent entities and their attributes. Relations are expressed with associations, which can also be qualified with cardinalities to show how many instances of one class can be related to a certain number of the associated class.

Our integrated meta-model is depicted in Figure 13.3 below. It adapts and extends the smart service and business case model proposed by Anke and Krenge [38]. All white classes are part of the quantification model described in the section above. The classes with grey a background are used to describe the basis for calculating the CBA. From the original model, we mainly reused the parts concerning the `DataPoints` from `Devices`, their usage in `Functions` which are subsequently bundled in `Offers`. Furthermore, the concept of `ExternalServices`, their usage as well as `Projects` were part of the original model. Our extensions are mainly related to `Savings`, the `SMBC_Factor` relation and `InitialInvest`. Also, the modelling of cost was extended to enhance flexibility.

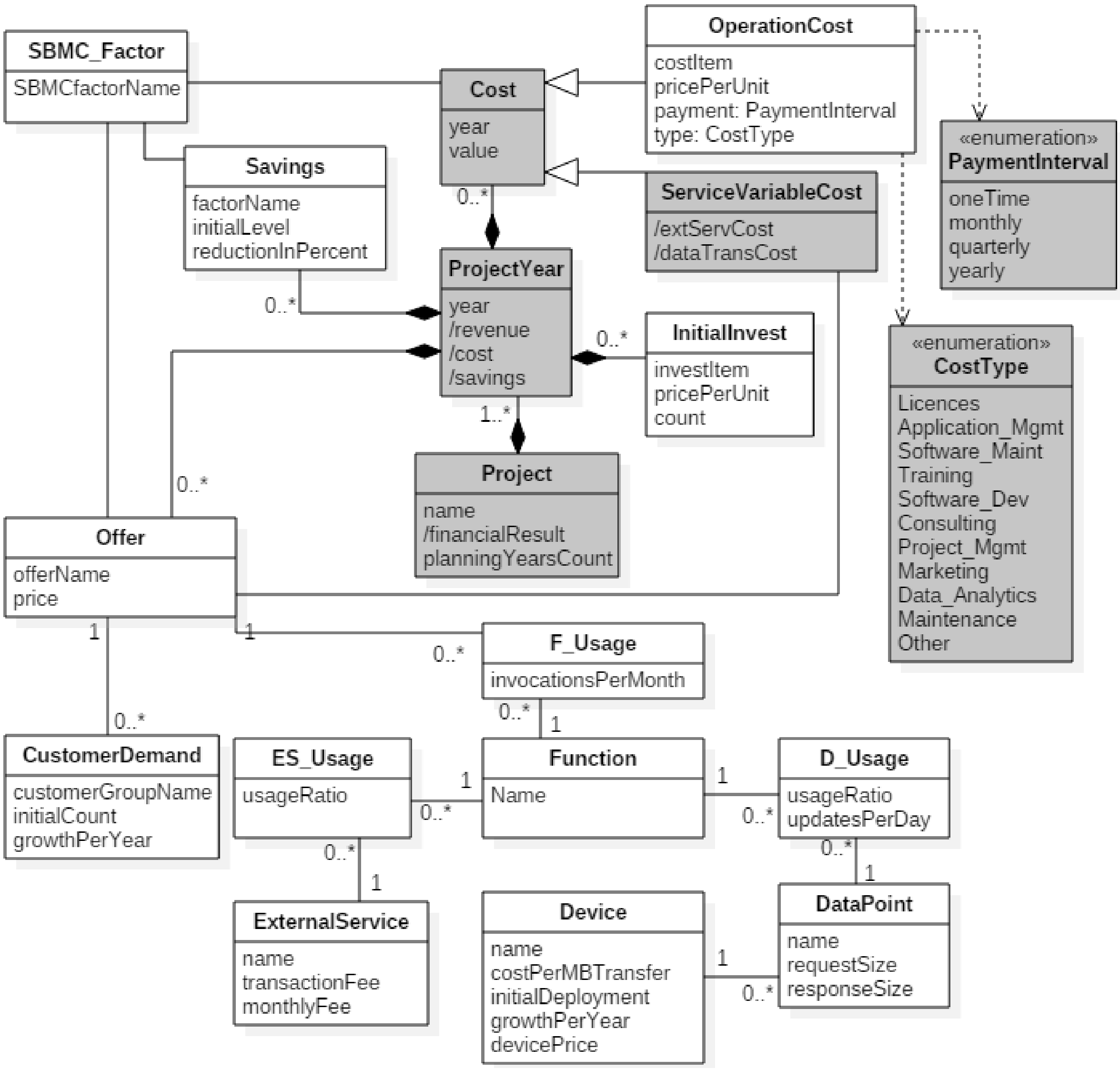

Figure 13.3: Integrated Meta-Model

The starting point is a `Project`, which contains a number of `planningYears`, a `name` and a derived attribute `financialResult`. It is calculated from a series of payments, which is represented by `ProjectYears`, which in turn contain derived attributes for `revenue`, `cost` and `savings`. Costs can either be manually specified `OperationCost` or automatically calculated using the class `ServiceVariableCost` for data transfer and external services. This only applies to services (Offers), which are modeled using `Functions`, `DataPoints`, `Devices` and `ExternalServices`.

For a concrete project, the meta-model has to be instantiated. The service designers start with a qualitative design of the DDBM in a SBMC. Each factor in the SMBC can then be represented by either an Offer, Savings or Cost item. The quantification of each item is achieved through the parameters described in section 5.1.

13.5.3 Discussion

The high complexity and qualitative nature of service make it difficult to judge the financial impact of services, like of a DDBM, in early conception stages. While methods for financial decision making, like Net Present Value or Return on Investment, are well established, they are rather generic and not linked to the specific development of business models. Our proposed meta-model establishes links between the qualitative dimensions of the SBMC and main drivers of business value in a DDBM, i.e. new offers, savings and associated cost. To support the refinement of a SBMC, the model includes parameters (e.g. prices, costs and quantities), which are sufficiently detailed to allow for a first estimation during the design process. As these factors were derived from case studies focusing on data-driven innovation projects, our meta-model is designed to facilitate the development of a DDBM. This is expressed through dedicated elements that must be considered during the development.

In summary, an integrated meta-model divided into three states was derived. To apply this meta-model, firstly, a user has to develop a business idea and fill out a SBMC. Based on this information, a refinement of the business model with Cost-Benefit-Analysis related parameters has to be conducted. To allow an assessment of a DDBM innovation project, we propose concrete influence factors (see `CostTypes` and `PaymentIntervals`) that have to be considered in its specific CBA. In addition to the costs, we were able to derive potential savings and revenues in DDBM initiatives. Finally, a business case can be derived and decision can be taken, whether to proceed with the implementation of this service or not. To improve the creation and refinement of models as well to perform calculations, a software tool can be of great benefit. We see the development of the meta-model as a starting point to develop such a tool in the future.

13.6 Conclusion and Outlook

In this paper we propose a first step towards a Cost-Benefit-Analysis of data-driven business models and therewith address an important issue of companies in the field of existing service development and service engineering initiatives [35, 36]. We analyzed twenty case studies on data-driven innovation projects and derived influence factors that have an impact on a business model. A set of parameters was developed that allow identifying relevant inputs and deriving financial values for the included factors. As an extension of the existing smart service model [38], an integrated meta-model was derived that if being applied allows for the quantitative evaluation of a DDBM. This method enables decision makers to evaluate and calculate their business case for a data-driven innovation through refinement of a business model.

Our integrated meta-model provides a theoretical contribution as it helps researchers by fostering the understanding of financial dependencies in data-driven innovation processes towards new business models. By analyzing data-driven innovation projects, we were able to determine quantitative influence factors that have a direct monetary impact on a DDBM. Based on this knowledge, it is possible to create, shape, and improve tools and methods that foster service innovation and the design of a new DDBM. Practitioners can utilize these results in order to foster the development of data-driven innovations in their servitization efforts. Moreover, they can analyze different innovation projects in regard to their financial effects and thus, better intercept business potentials.

Nevertheless, also some limitations have to be considered. Firstly, this paper focuses on quantitative influence factors in the development of a new DDBM. This decision was made purposely and need to be addressed in further research. Hence, qualitative influence factors must be considered and their impact added to the meta-model. This includes qualitative criteria, such as improved customer satisfaction, loss of control, and competitive advantage. The twenty case studies on data-driven innovation projects analyzed in this paper could be extended with new cases in further research.

Besides addressing these limitations, further research should focus on the practical application in a field experiment and/or lab experiment to evaluate the meta-model and its benefits. Equations need to be developed allowing the computation of the overall benefit. Subsequently, instructions describing how to apply the meta-model in a concrete scenario could be developed.

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14 Enabling Design-integrated Assessment of Service Business Models Through Factor Refinement

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Abstract. Business Model Innovation is a complex task, which requires creativity and is often performed in interdisciplinary workshop settings. To support this, practical techniques have been developed, e.g. the Business Model Canvas (BMC). It has been found that assessing financial and non-financial effects of the current business model (BM) design likely influences design decisions. However, such an assessment is difficult to integrate into the design process. Business model development tools (BMDT) are an emerging category of software, which supports business model innovation. While they have the potential to shorten the feedback cycles between the design and assessment of BMs, there is little design knowledge available on this integration. In this paper, we introduce the factor refinement approach, which establishes a link between models for the canvas-based BM design and information for their assessment on factor level. The concept is made actionable in a tool prototype, which has been found to be practically applicable in a demonstration. With that, we contribute to the design knowledge for BMDTs particularly regarding the design-integrated assessment of BMs. While our tool uses the service business model canvas, the factor refinement concept is transferable to extend other canvas-based BMDTs with assessment functionality as well.

Keywords: Service Business Models, Business Model Assessment, Business Model Design Tools, Prototyping.

14.1 Introduction

Smart products can sense their condition and surroundings, allow for real-time data collection, communication and feedback, and thereby enable the provision of smart services [1, 2]. Providers of such services can utilize business models to describe "the value logic of an organization in terms of creating and capturing customer value" [3]. Fostered by a service-based change in value creation [4], business models are also discussed in service research [3, 5]. Because of their characteristics, representations for service business models (SBM) differ from representations for traditional business models [5, 6]. A service-specific representation is the Service Business Model Canvas (SBMC) [5]. It is based on the well-known Business Model Canvas (BMC) [7] but highlights the integration of different actors within an SBM and thus, allows focusing on the co-creation in the business logic.

One of the key characteristics of component-based business model representations is their qualitative nature, which is suitable for developing and refining the business logic of an idea [5, 8]. However, to justify internal funding of innovation projects, an assessment of the planned service is required [9]. To this end, various cost items for service provision must be considered as well as savings through process improvements and revenues through additional offers to customers. Other aspects of a BM are qualitative, such as strategic relevance or non-financial benefits, especially for innovative offers. Assessing these factors in the early stages is valuable for deciding on which SBM idea should be pursued further [9]. Furthermore, it was found that determining cost and benefits has a high potential to influence BM design decisions and should, therefore, be part of an iterative BM design process [10]. To support this task, the software category "business model development tool" (BMDT) has emerged. Their functionality was recently systematized in a taxonomy by Szopinski et al. [11]. Out of the 30 tools covered, only four support both financial and non-financial assessment [11].

Nowadays, many business decisions including financial planning are performed with the help of spreadsheets like MS Excel [12]. Spreadsheets work well if the structure of the model is known and stable. However, in BM design, model elements are frequently added, removed or modified [11]. Thus, the content and structure of the spreadsheet, e.g. cell values, references, and formulas, would have to be adapted whenever changes occur, e.g. new decisions on prices, offers, cost, and quantities are made. Such a spreadsheet model evolution is an erroneous task, as the manageability of spreadsheets has found to be limited [13]. Consequently, if spreadsheets are used, the assessment will not take place before the business model is relatively stable. This delays important insights, which in turn could influence the BM design [10]. Furthermore, users must develop spreadsheet models on their own and manually transfer all financially relevant information from the business model into the spreadsheet.

Therefore, the goal of this research (problem statement) is to *design a solution, which allows shortening the feedback cycle between design and assessment of service business models, as well as reducing the manual effort and sources of error associated with it.* To address this problem, we envision a web-based collaborative tool, which supports BMI for smart services by interactively capturing the design and assessment of relevant information and instantly shows the impact of changes made by the users.

14.2 Related Work

There are two streams of related research: (1) approaches and tools for the assessment of BMs and (2) the mapping of BMC structures to other models. Kayaoglu [14] found that there is little previous work on the assessment of BMs. He proposes a hierarchical evaluation logic, which was implemented in a software tool. It provides recommendations on how to reach a defined business state but does not support canvas-based modeling [14]. Daas et al. [15] present a system that supports BM design decisions through market analysis, success factors, and comparison of design alternatives. However, it is based on Excel and due to its high complexity, it is unlikely to be suitable for collaborative business model design. Software tools for BM stress tests are proposed by Bouwman et al. [16]. They state that "[w]hen it comes to making informed management decisions with regard to financial aspects of alternative business models, there are hardly any tools available, specifically when multiple stakeholders and financial objectives are involved" [16, p. 19]. Turetken et al. propose a "Service-dominant business model radar" as part of a BM engineering framework [10]. Although it captures cost and benefits, it is a paper-based approach for workshops, which prevents instant calculations. Jesus and da Silva advocate the combination of financial projections with the BMC to support the design of viable BMs [17]. Their canvas-based tool provides profit and loss data as well as financial indicators such as break-even point. However, it is not disclosed how the BM and calculation schemes are linked, i.e. there is no meta-model.

The second research stream deals with the mapping of (S)BMC structures to other models. This includes budget planning [18], for which some of the BMC factors are mapped to positions of a financial budget. Another purpose is the mapping of the BMC to ArchiMate [19]. The authors argue that linking the BM with the enterprise model enables better migration from as-is to to-be architectures and a more realistic cost-benefit analysis. Also, the evaluation of business models using the business case method is proposed [20]. The authors do not provide a meta-model but suggest a process in which BMC alternatives are evaluated based on data gathered before, including financial and non-financial criteria [20]. Brussee and de Groot present an online tool which uses refined basic blocks of a BMC [21]. They do provide substructures to the BMC model, but their goal is to simplify experimentation rather than to support BM assessment. The use of attributes for financial calculation in a BMC was analyzed in [22], however without details on how these were implemented. Our own work includes a meta-model that links SBMC structures to models for the assessment of SBMs [23], which is empirically grounded in 28 cases of data-driven BMs. However, this meta-model does not support non-financial assessment and has not yet been demonstrated [23]. The approach of design-integrated assessment in the area of smart services has been proposed [24], but it is also limited to financial aspects and does not provide a representation of SBMs.

In summary, we can state that BM assessment and its tool-support has been identified as a relevant problem. Only a few of the existing tools in practice [11] provide support for financial and non-financial assessment. Some academic works deal with the mapping of the BMC to other models for various purposes. To the best of our knowledge, there is no research on how to apply a meta-model in a BMDT for design-integrated assessment of service business models.

14.3 Research Goal and Method

Our research goal is to explore the applicability of the factor refinement concept for design-integrated assessment of service business models in BMDTs. For that, we apply the design science research (DSR) process according to Peffers et al. [25], which contains the following steps: First, the requirements for the envisioned tool are derived from the problem statement and the key concepts are defined. Second, we present the input knowledge for the solution to be designed, including an existing meta-model for a cost-benefit analysis of SBMs [23]. Third, we describe the software prototype and the rationale behind its design decisions. For its demonstration, we asked test users to complete a set of tasks using the tool prototype. Afterward, they rate a set of statements in a questionnaire to assess their experience. The discussion of results is used to derive changes for the next iteration of the tool. This paper is structured along the six core dimensions of DSR [26]. Table 14.1 provides an overview of these dimensions along with their use in the study at hand and the respective paper section.

Dimension	Usage in our study	Sect.
Problem	Lack of integration between the design and assessment of BM prevents short feedback cycles in the business model innovation process	1
Input Knowledge	SBMC [5], tool-based financial projections of a BMC [17], meta-model for SBMC assessment [23], design-integrated assessment [24]	2
Research Process	Derive Requirements from problem statement; extend existing meta-model; design and build tool prototype, demonstrate the prototype	3
Key Concepts	SBMC; factor refinement; cost-benefit analysis; impact-effort matrix	4
Solution Description	A web-based tool BMDT allowing the refinement of SBMC factors with assessment information based on a meta-model	5
Output Knowledge	Applicability of factor refinement as an approach for design-integrated assessment of SBMs in BMDTs	6

Table 14.1: Structure of the DSR project according to [26]

14.4 Solution Design

Requirements. From the problem statement given in section 1, we can derive functional requirements (FR) and quality requirements (QR) for the envisioned tool (Table 14.2). To enable short feedback cycles between business model design and assessment, the tool needs to capture information on both aspects (FR1, FR2). Similarly, while the relevance of financial assessment has been stated [9], some aspects cannot be quantified in monetary terms and therefore require a strategic assessment (FR3). The target groups for the use of our tool are individuals or teams (FR4), which are given the task to develop or improve service business models. This is a highly creative task [27], which calls for easily comprehensible tools (QR1-3). Similarly to process modeling tools [28], high usability is expected to drive acceptance, especially for interdisciplinary teams.

ID	Requirement	Source
FR1	The tool must allow the capture of BM design decisions.	[10]
FR2	The tool must allow the capture of BM assessment-relevant information.	[10]
FR3	The tool must support financial and strategic assessment.	[9, 11]
FR4	The tool should support collaborative work.	[11, 27]
QR1	The capture of design information must be usable intuitively.	[28]
QR2	The capture of assessment information must be usable intuitively.	[28]
QR3	The presentation of the assessment results must be easily comprehensible.	[28]

Table 14.2: Requirements for the SBM assessment tool

Key Concepts. An SBMC is divided into three ***perspectives***, namely Customer, Company and Partner [5]. In each perspective, there are the seven ***dimensions*** (building blocks) of the BMC as defined by Osterwalder [7]: cost structure, key activities, key resources, value proposition, customer segment, channel, and revenue streams. When working with an SMBC, the users adds, removes or shifts sticky notes ("Post-Its") to design the new SBM. These items are called ***factors*** [23]. For the assessment, this structure must be augmented with additional information. We propose the name ***factor refinement*** for the concept of adding assessment information to factors.

In general, qualitative and quantitative assessment criteria for BMs can be distinguished. Based on empirical data, three different types of quantitative criteria were identified in [23]: costs, revenues, and savings. In general, cost refers to the financial effort required to build and operate a service system that enables an SBM. For all effects created by the investment project at hand, monetary values must be assigned. Benefits can be either revenue or savings, e.g. through improved process efficiency. To support decision making on whether a service provider should proceed with the engineering and implementation of a new SBM or not, a simplified ***cost-benefit analysis*** (CBA) can be performed to assess the economic value of an investment project [29].

Several effects, especially in the relationship and channels dimensions, are qualitative, i.e. they cannot be translated directly to a countable metric. However, they could still be important for the assessment of the SBMC at hand. For example, a key activity might be real-time data analytics. If it has a high impact on a new business model and the service provider requires little effort to provide it, it is apparently beneficial. A simple instrument for a non-financial assessment is the ***impact-effort matrix*** (IEM) [30]. It allows prioritizing items based on a qualitative ranking of effort and impact using a qualitative rank of low, medium and high for each factor. Afterward, a consolidated score can be calculated for each dimension to allow for an overall non-financial assessment of an SBM.

Meta-model for SBMC factor refinements. To facilitate BM assessment through factor refinement in a BMDT, we adapt a meta-model [23] that links SBMC factors to CBA and IEM. The meta-model used for the prototype is provided as a UML class diagram (Figure 14.1). Classes represent domain concepts and their attributes. Relations are expressed using associations, which can be qualified with multiplicities to show how many instances of one class can be related to another class. Compared to the original model [23], the `Non-Financial` class was added. It uses the `QualRank` enumeration to express different levels of impact and effort. Additionally, the modeling of `Cost` was slightly simplified by focusing only on manually added cost items. The overall results for the assessments are stored in attributes of a `Project`. They are calculated from a series of payments (represented by a set of `ProjectYears`), which in turn contain derived attributes for revenue, cost, and savings.

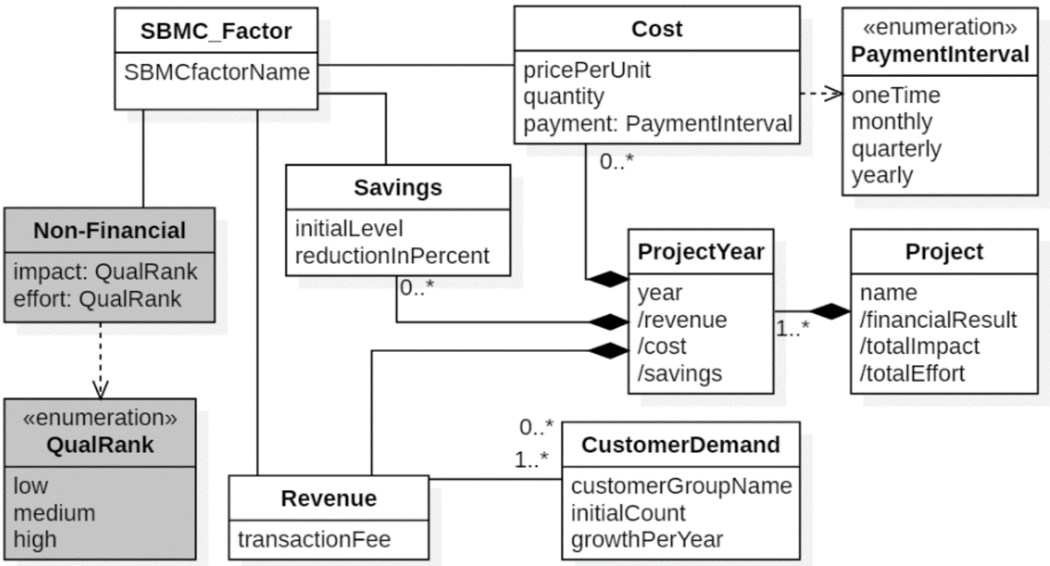

Figure 14.1: Subset of the adapted meta-model from [23] (new elements are highlighted in gray)

Development of a Prototype. To demonstrate the concept of factor refinement, a working web-based prototype[11] was implemented using Axure RP 8. Here, we present design decisions, their rationale, and reference to requirements (Table 14.2). For simplicity, the tool has only two main views: editor and report. Users can switch between them at any time using the two buttons at the bottom of the screen. The screen layout of the editor is identical to the SBMC, to make it easily comprehensible for those familiar with the SBMC (QR1). New factors can be added using "+"-sign, as it established in most web applications nowadays (FR1). Factors are displayed as boxes to resemble post-it notes as known from paper-based canvases (QR1). Clicking on a factor opens a dialog where users can refine the factor into either cost, revenue, savings or non-financial (FR2). Selecting one of the options allows entering further information to describe the refinement according to the meta-model (Figure 14.2).

All inputs are aggregated in a reporting sheet (Figure 14.3) for the focal company, i.e. the service provider. The report view contains both financial and non-financial assessment (FR2). All calculations are performed based on the data entered by the user. Financial data are shown in the categories cost, savings and revenues; and separated into one-time invest and recurring cash-flows. For each category, the total amount is shown. The factors contributing to the total amount can be shown/hidden using a

[11] Accessible at https://yc8uyf.axshare.com/sbmc_editor.html, tested with Firefox and MS Edge

plus/minus sign next to the sum (Figure 14.3). The result of the non-financial assessment is displayed in a color-coded matrix, with all contributing factors listed below. We assume that this representation is familiar to users who know both the IEM and financial cases (QR3).

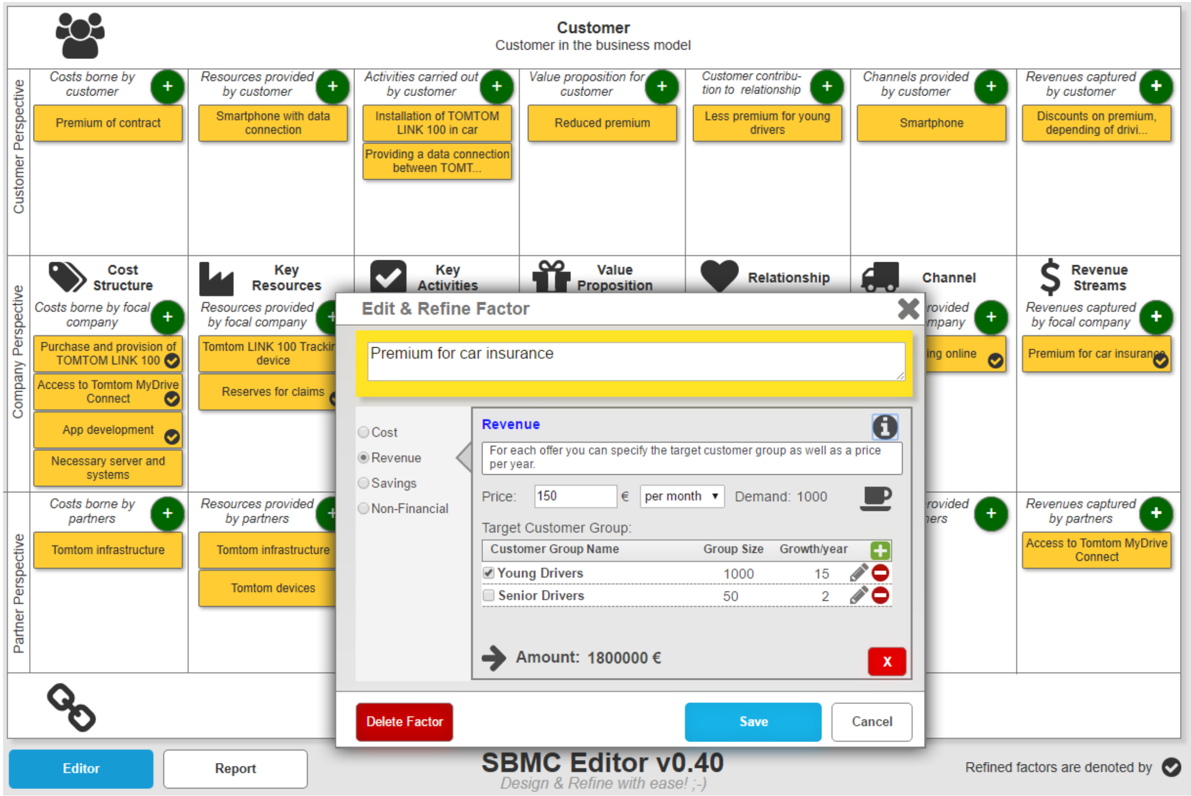

Figure 14.2: The prototype showing the usage-based insurance BM and a refinement

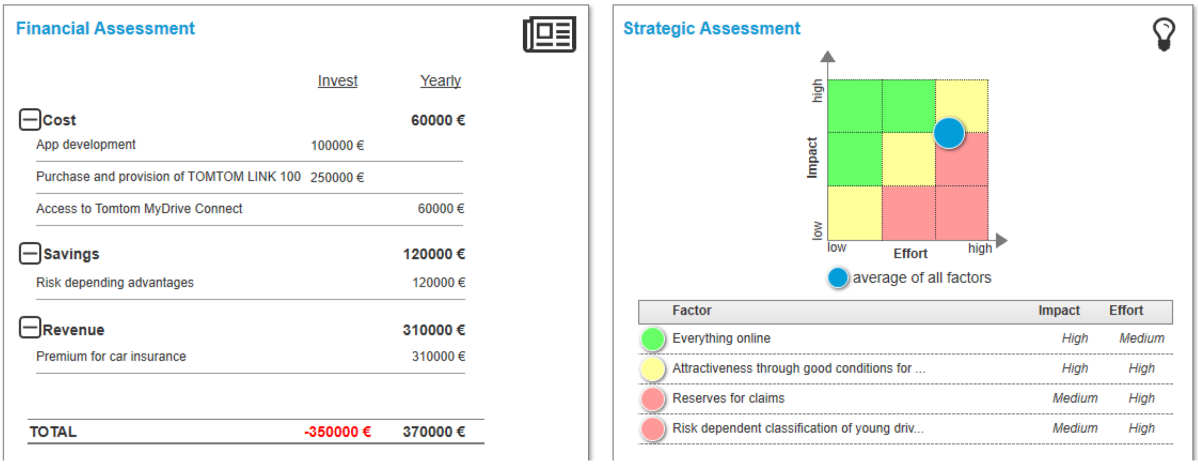

Figure 14.3: Reporting view of the prototype

Being a prototype, the tool does have limited functionality. First, it does not persist any data between sessions yet. Second, there are currently no measures for collaborative work (FR4), such as users, permissions, and workspaces [11]. Finally, the reporting does not distinguish between customer, company, and partner perspectives, as the prototype is focused on the perspective of the (focal) company, i.e. the service provider. While these features are required for real-world applicability, their absence does not impede the goal of demonstrating the concept of factor refinement. Whether the approach of collecting assessment information by refining factors is intuitively usable (QR2) was not known during the design and had to be considered in the demonstration.

14.5 Demonstration

Case. The focus of the demonstration is to assess the feasibility and efficacy of the artifact in one case and can be seen as a "weak form of evaluation" [31]. We chose a real, anonymized case, as real cases provide higher external validity [31]. The case deals with usage-based insurance (UBI), which extends the traditional car insurance business model through data-based elements. These are gathered through sensors in the car [32]. The insurer can process data about the driving behavior to assess the risk of a specific driver and to adjust the premium. If the driver is driving carefully, the insurer offers discounts up to 25% of the monthly premium. The more aggressively the insurant drives, the less discount he or she will get. Hence, from a customer perspective, this SBM provides an opportunity to reduce the premium of the car insurance. The insurer provides a vehicle tracking device that must be installed into the car. This device is connected via Bluetooth to the customer's smartphone. All necessary data are transmitted to the insurer using a dedicated application. We consider this case as suitable, as it represents an innovative SBM to which many people can relate.

Setup. To gain an understanding of how the factor refinement approach is perceived by real users, we used the "thinking aloud" test for formative feedback. This is a method for usability testing and has successfully been applied for evaluating the work with the SBMC [33]. For the test, individual users are given a list of ten tasks, which are to be completed using the tool as proposed by [31]. Nine tasks require the refinement of factors and one refers to the interpretation of the report. As preparation, we showed the participants a short video, which introduces the SBMC, the exemplary case and the basic functions of the tool. The actual test was conducted using an online application sharing platform, which allowed us to see and hear what participants did while they processed the tasks. All sessions were recorded for further analysis. After completion of the tasks, participants were asked to fill out an online questionnaire to rate their experience. It contained a list of statements (see Table 14.4), to which the participants could express their opinion on a Likert scale from 1 (strongly disagree) to 5 (strongly agree).

The demonstration was conducted with 11 participants, consisting of seasoned business modeling experts and newcomers to the field, who are equally potential users. The sample included four researchers in the area of digital transformation, two practitioners with considerable experience in IT-driven BMI, and five master's students in information systems with first work experience in the IT and telco industries.

Results. To analyze the test results, a "degree of completion" indicator was defined with five levels: (1) correct perspective found, (2) correct dimension found, (3) correct factor found, (4) correct refinement type chosen, and (5) data for refinement entered correctly. The result of this analysis is provided in Table 14.3, along with the refinement type, which is either cost, revenue (Rev), savings (Sav) or non-financial (NF).

Task	T1	T2	T3	T4	T5	T6	T7	T8	T9
Refinement Type	Cost	Cost	Rev	Rev	Cost	Cost	Sav	NF	NF
Mean	3.4	4.0	2.4	1.6	5.0	4.8	3.4	4.1	5.0
SD	1.6	1.3	2.3	2.0	0.0	0.6	1.2	1.9	0.0

Table 14.3: Average Degree of Completion for Tasks (N=11, SD: Standard Deviation)

The results of the survey are shown in Table 14.4. Although the number of participants is low, we still can derive some initial findings from it. First, there is a strong indication that the tool was not only helpful for the tasks assigned to them (S2) but they also prefer it over Excel (S3) which is typically used for such tasks. Furthermore, participants indicated almost unanimously that assessment of BMs models should be tool supported (S4). Therefore, we can conclude that the efficacy and utility of the tool are considered as positive within this sample of users. This is supported by statement S5, in which respondents expressed that they understood the concept of refinement (fulfills QR2). As for the model, the results indicate that the refinement possibilities are not considered as too complex (S6). However, the results also show that at least for some users important input possibilities for the assessment were missing. Further research is required on whether this is due to a deficit of the model or usability deficits in the tool prototype. The reporting (S8-S10) is generally understood, however, there is considerable variance in the replies, which also requires further analysis.

General statements regarding the task		Mean	SD
S1	I understand the example case of Usage-Based Insurance (UBI).	4.6	0.6
S2	The tool helped me evaluate the UBI case.	4.3	0.7
S3	I would have preferred to evaluate the business model using Excel.	1.8	0.7
S4	The assessment of business models generally requires tool support.	4.2	0.6
Suitability of the assessment approach		Mean	SD
S5	I have understood the concept of refining factors.	4.6	0.5
S6	The possibilities for refining factors are too complex.	1.7	0.4
S7	I missed important input possibilities for the assessment.	2.5	1.2
Assessment results / reporting view in the tool prototype		Mean	SD
S8	I have understood the results of the financial assessment.	3.9	0.8
S9	I have understood the results of the non-financial assessment.	4.4	1.0
S10	I find the possibility of a non-financial assessment useful.	4.5	1.2

Table 14.4: Statements and rating results (N=11, SD: Standard Deviation)

14.6 Discussion

Interpretation of results. As the results show, the highest degree of completion was achieved for tasks that referred to cost or non-financial refinements. Savings and Revenue refinements were less well understood. Some of the participants had difficulties in finding the correct factor for refinement. Misjudgments were mostly caused by insufficient knowledge on insurance terminology or problems to fully comprehend the structure of the case but also by minor bugs in the tool. Future tests should also contain tasks for the design of the SBM, not just the refinement of factors for assessment. With that, we expect users to understand the structure of the business model better than with a predefined one.

Limitations. The results of our study are limited by several factors. First, the tool was not designed with the help of UI/UX specialists. An optimized experience would probably have helped some of the users in our sample in completing their tasks. Second, the number of participants in the demonstration was relatively low, which reduces the generalizability of results. Also choosing UBI as the case for the evaluation could have influenced the results as some of the participants might be impaired by insufficient knowledge on insurance terminology.

Next iteration. In the next iteration of the tool, we plan to include the modeling of offers with devices, data points, data transmission, and external services (as provided in the original meta-model [23]) to support the specifics of smart services. Furthermore, we plan to assess each perspective separately, which makes value co-creation between customer and provider as well as provider and partner transparent.

Approach for evaluation. The initially stated objective of shorter feedback cycles will be subject to an artifact evaluation. Employing the tool aims to improve effectiveness in the BMI process and to obtain better results. An approach, similar to [24], is to measure this in an experiment, where two groups in a workshop are given the same BMI task. The experimental group is given the tool prototype, and the control group uses Excel. After a specified time, the results are compared. Potential measures include the number of iterations, a subjective rating of utility by the participants, or a comparison of the designed business models regarding their viability by external experts.

14.7 Conclusion

The high complexity and qualitative nature of SBMs make their assessment difficult during design. While instruments for financial decision making, like NPV, are well established, their link to the structures of BMs is barely discussed in the literature. Furthermore, they are typically conducted using spreadsheets. These are not suitable for design-integrated BM assessment, where the level of detail is low and design changes are frequent. The integration of BM assessment into BMDTs appears to be a much more promising strategy as recognized by a taxonomy on BMDT functionality [11].

Our proposed tool targets BMI for smart services. It builds on the SBMC and thus follows a canvas-based approach, which is popular in practice [11]. It uses a meta-model that links the qualitative dimensions of the SBMC and established methods for assessing BMs. To make this link usable for BMDTs, we introduced the concept of factor refinement. It allows adding assessment-related information to each factor placed on an SBMC. The demonstration of the tool prototype that implements this concept showed that particularly tasks regarding the refinement of factors with cost and non-financial aspects were successfully completed. The factor refinement concept has been found to be generally understood by the participants, which is the key prerequisite for ultimately achieving feedback cycle reduction between BM design and assessment.

The integrated meta-model in our approach provides a theoretical contribution as it helps researchers by promoting the understanding of assessment dependencies in SBM innovation processes. Specifically, it contributes to the body of knowledge as follows: (1) We extend the canvas-based modeling [17, 22] through an explicit meta-model of the connection between BMC elements and assessment instruments. Our approach furthermore adds non-financial assessment and support for SBMs. (2) The concept of factor refinement shows, how a meta-model can be made usable for BM assessment in BMDTs [11]. It combines canvas-based design, refinement, and instant assessment feedback and therefore transfers the idea of design-integrated assessment [24] to SBMs. (3) Our proposed solution complements the process of data collection with the business case approach for BM assessment [20]. Providing data from SBMs directly might streamline the process of comparing BM alternatives. This work provides a practical contribution for BMDT developers by demonstrating how a meta-model enables the mapping of BMs factors and assessment models can be integrated into a software tool.

Future research should focus on the interplay of meta-model and tool: First, a good balance must be found between simplicity to facilitate quick adaptions of the model and expressiveness of the result to make informed decisions on whether to pursue the service idea further. Second, the meta-model should be modularized to integrate other assessment schemes and reuse existing pricing models for external services (e.g. cloud providers) more easily. Third, it can be observed that in SBMs, factors are related to each other, e.g. the revenue of the service provider is the cost borne by the customer. By including such relations in the meta-model, designing new SBMs would be simplified. Finally, the integration and utility of an SBMC assessment tool in the overall engineering process for service business model innovation is an open question. Hence, further research is needed to understand their effectiveness for designing and managing different types of service business models [34].

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