Exploring the Potential of Smart Service Systems: A Multi-Actor View on Affordances and Their Actualization

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Abstract

Smart physical products increasingly shape a connected world and serve as boundary objects for the formation of ‘smart service systems. While these systems bear the potential to co-create value between partners in various industries, IS research still struggles to fully capture the phenomenon to support successful digital innovation in IoT settings.

In our work, we analyze the phenomenon of smart service systems taking an affordance-actualization perspective. Based on a qualitative content analysis of a multi-case study, we identify elements and propositions to build mid-range theoretical knowledge for smart service systems. These conceptual findings are further illustrated with a real-world case study. We suggest that providers and users of smart products not only realize their own affordances via their actions but can affect the immediate concrete outcomes of partners. The developed theoretical framework and six distinct propositions should build the theoretical base for further research into the phenomenon in related disciplines.

Keywords:

smart service systems, Internet-of-Things, affordances, actualization processes, digital innovation, case study research.

1 Introduction

As everyday physical objects surrounding us become increasingly data-driven, connected, and communicative (i.e., 'smart') (Porter and Heppelmann 2014; Wünderlich et al. 2015), it becomes more and more evident how technological advancements in the context of the 'Internet-of-Things' (IoT) might have a transformational impact on our work, our daily lives, and our participation in society (Allmendinger and Lombreglia 2005; Porter and Heppelmann 2014). An example of the impact of increasingly smart products is the rapidly ongoing transformation of manufacturing industries ('Industry 4.0') (Hermann et al. 2016): Digital technologies allow the integration of processes across the value chain and enable to servitize previously product-focused business models . These novel offerings blend the physical and virtual world by analyzing data collected via sensor-equipped connected physical objects and create value-in-use through contextual and preemptive services (Peters et al. 2016; Wünderlich et al. 2015).

As it is crucial to understand both social and technological influence factors on this phenomenon, Information Systems (IS) research as an interdisciplinary field is predestined to unify the primarily technically focused research in computer science and engineering disciplines with the rather benefit- and value-oriented studies in fields of economics (Beverungen, Breidbach, et al. 2019). Thus, Beverungen et al. (2019) pinpoint how digital technologies manifested in smart products are transforming service systems into smart service systems. They provide a widely recognized conceptualization of this new phenomenon and have already sparked a vivid discussion among scholars (e.g., Anke et al. 2020; Beverungen et al. 2020; Huber et al. 2019; Martin et al. 2019). In our study, we follow their understanding of smart service systems, where "smart products take the role of boundary objects that digitally mediate the interactions of service providers and service consumers and enable the co-creation of individualized value propositions" (Beverungen, Müller, et al. 2019, p. 8).

Despite the concept's rising popularity in practice and related disciplines, smart service systems yet lack a thorough theoretical grounding and linkage to common constructs and concepts. By emphasizing a systems perspective (cf. general systems theory (Garrity 2001; Maglio et al. 2009)) or by examining the dual nature of smart products either managing or increasing the system's complexity, IS research has great potential to enhance our scientific understanding of smart service systems (Beverungen, Breidbach, et al. 2019; Beverungen et al. 2020; Martin et al. 2021). In particular, investigations into the dynamics and mechanisms underlying smart service systems allow building mid-range theoretical knowledge explaining how and why the advent of 'smartness' challenges existing assumptions (Gregor 2006; Hassan and Lowry 2015). Studying the impact of smart technologies on service systems is also relevant as it potentially provides implications on the digitalization of innovation processes and outcomes, thus contributing to the study of digital innovation management. As one of four new theorizing logics for this endeavor, Nambisan et al. (2017) suggest technology affordances (and constraints) (Gibson 1977; Leonardi 2011; Majchrzak and Markus 2012; Markus and Silver 2008) as a promising lens to build new theory–as the use of digital technology offers new sets of affordances for innovating actors. Consequently, we ask: *How do smart products give rise to affordances for actors in smart service systems, and how can this potential be realized?*

As we outline in this article, the theory of affordances provides means to better grasp and operationalize the complex reciprocal relationship between technology and organizational actors in smart service systems from a critical realist perspective (Volkoff and Strong 2013). In particular, we apply Strong et al. (2014)'s affordance-actualization lens to revisit the concept of smart service systems and to extend existing theoretical knowledge. We build on insights from a multi-case study and claim that the purposeful design or 'engineering' of smart service gives rise to affordances. In simple terms, an affordance is a 'potential for goal-oriented behavior in interaction with an artifact' (Markus and Silver 2008; Strong et al. 2014; Zammuto et al. 2007) whereby in this context a smart product is the 'artifact'. Further, we differentiate between an affordance and its realization through actualization, i.e., "the actions taken by actors as they take advantage of affordances through their use of the technology" (Strong et al. 2014, p. 70). Our conceptual findings are further illustrated in a real-world case study of a smart battery solution. Our results contribute to the body of knowledge on smart service systems by presenting a conceptual framework and propositions towards a mid-range theory from an affordance-actualization perspective. Also, our work holds value for practitioners by allowing them to analyze the potentials of smart technology and by providing a vocabulary to consciously articulate the expected outcomes of participating in smart service systems.

We present our study as follows: The next section elaborates on the theoretical foundations of smart service systems and affordance theory, followed by the description of our methodology. Then, we present our conceptual results applying an affordance-actualization lens on smart service systems. Section five illustrates our findings with a real-world case study of a smart battery solution. In section six, we present the theoretical implications of our results and a research agenda. Further, we discuss the managerial implications as well as limitations of our study before concluding our research in the final section.

2 Theoretical Foundations

2.1 Smart Products, Smart Service, and Smart Service Systems

The idea of 'smartness' emerged along with technological advancements in sensing, monitoring, analyzing, and controlling physical objects (Beverungen et al. 2017), which enabled building intelligence–i.e., awareness and connectivity–into products (Allmendinger and Lombreglia 2005). These smart products offer the potential for innovating business models (Porter and Heppelmann 2014, 2015) and play an increasing role in service delivery as their abilities allow them to take an active role in service systems (Beverungen et al. 2017; Wünderlich et al. 2015). We understand service systems as "a configuration of people, technologies, and other resources that interact with other service systems to create mutual value" (Maglio et al. 2009, p. 395). Smart products offer transformative potential on how value is co-created and captured in service systems. This gives rise to the phenomenon of smart service systems (Beverungen, Müller, et al. 2019), defined as "service systems in which smart products are boundary objects that integrate resources and activities of the involved actors for mutual benefit" (Beverungen, Müller, et al. 2019, p. 12).

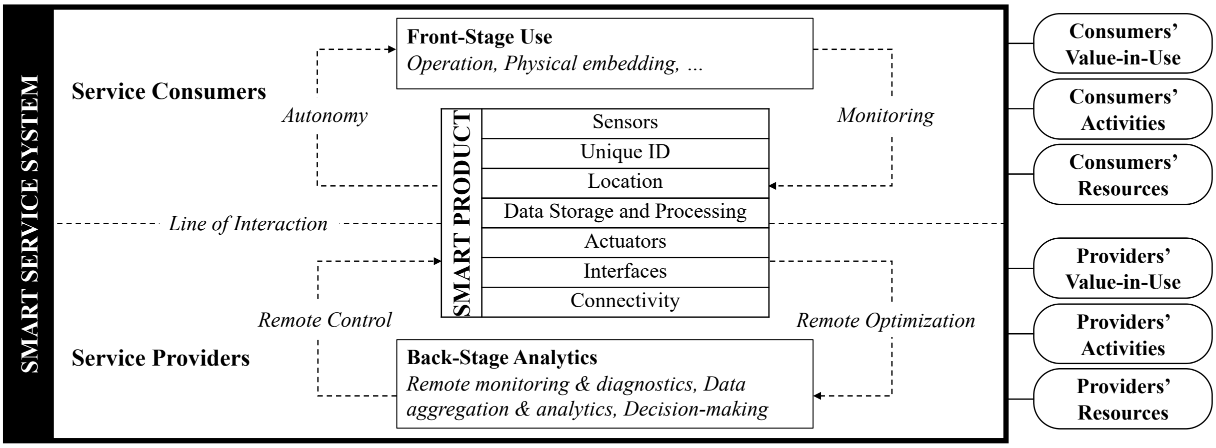

Fig. 1: Conceptualization of smart service systems, based on Beverungen et al. (2019).

As boundary objects, smart products act as a reference point for service interactions maintaining a single shared identity across all interacting communities. However, they also provide the required flexibility to be interpreted differently by the involved actors to extract different utilities from it (Beverungen, Müller, et al. 2019; Star and Griesemer 1989). In their conceptualization of smart service systems, depicted in ***Fehler! Verweisquelle konnte nicht gefunden werden.***, Beverungen et al. (2019) explain how smart products reside at the interface ('line of interaction') between the basic roles of a service consumer and service provider recognizing their built-in features 'sensors, unique ID, location, data storage and processing, actuators, interfaces, and connectivity'. Further, they assign widely recognized capabilities (Porter and Heppelmann 2014; Zheng et al. 2019) of smart (connected) products partly to the 'frontstage' (monitoring, autonomy) and partly to the 'backstage' of a smart service system (remote control and optimization). In the 'frontstage', the smart product is used to create and capture value-in-use (Vargo and Lusch 2008) for the user of the product. However, in the 'backstage' (i.e., outside its immediate physical context), the product can provide data to monitor, diagnose, or optimize the product's usage (Beverungen, Müller, et al. 2019; Hunke et al. 2021; Wünderlich et al. 2013). Further, retrieving data from a smart product can also be used to provide additional value via services to an ecosystem of third parties (Papert and Pflaum 2017) or even to the product's provider itself.

All in all, the properties of smart products give rise to various types of smart service, which we define as "the application of specialized competencies, through deeds, processes, and performances that are enabled by smart products" (Beverungen, Müller, et al. 2019, p. 12).

2.2 Affordance Theory and Affordance-Actualization Framework

The theory of affordances originates from the seminal work of the ecological psychologist Gibson (1977, 1979). Following his view, goal-directed actors do not perceive objects as a set of characteristics or material features. Instead, they rather recognize how the objects can be used (i.e., what it 'affords' the actors in terms of action possibilities for goal-oriented behavior) without requiring a cognitive analysis of the object (Gibson 1977; Volkoff and Strong 2017). For example, a reasonably sized chair affords a person the possibility to either sit down or reach something on a high shelf (according to her goals) without depending on the conscious analysis of the chair's material features (e.g., height or stability) (Volkoff and Strong 2017).

The concept of 'affordances' holds great potential as a lens for looking at a variety of IS topics (Majchrzak and Markus 2012; Ostern and Rosemann 2021). However, some important themes should be recognized when applying affordance theory to explore how technology is perceived and used by an individual or organizational actors: first, affordances only arise from the relationship of technology and its user–and not from the technology itself (Chemero and Turvey 2007; Volkoff and Strong 2017). Thus, a technological artifact has not any affordances except concerning a specific or archetypal actor with a set of tasks related to the actor's goals (Strong et al. 2014; Volkoff and Strong 2017). Second, affordances should be used to describe action possibilities for goal-directed actors–not actual actions, objects, or states (Strong et al. 2014; Volkoff and Strong 2017). In contrast, the actualization as the action itself relates to the structure, i.e., the actual configuration of behaviors making up the action (Strong et al. 2014; Volkoff and Strong 2017). These actions then lead to a state reached after realizing an affordance, which we call 'immediate concrete outcome' as opposed to affordances as the potential action (Strong et al. 2014).

When applying the theory of affordances in an IS context, several frameworks have been used (e.g., functional affordances (Knote et al. 2021; Markus and Silver 2008; Seidel et al. 2013) or technology affordances and constraints (Effah et al. 2021; Leonardi 2011; Majchrzak and Markus 2012)). This is also reflected in an ongoing debate on a few conceptions of applying the theory (Fromm et al. 2020; Ostern and Rosemann 2021; Pentland et al. 2021; Volkoff and Strong 2017). However, regarding our research question, an affordance-actualization perspective as introduced by Strong et al. (2014) (*Fig. 2*) seems particularly promising. In addition, our study considers the principles for examining affordances in IS research presented by Volkoff & Strong (2017). In Strong et al.'s (2014) study on the implementation of electronic health records (EHR), the authors describe how the EHR features, the characteristics of individual actors and the organization's goals give rise to multiple affordances. Further, they identify necessary goal-directed actions to actualize the affordances, e.g., creating and using EHR templates and following standard procedures (action) to realize the potential of standardizing data, processes, and roles (affordance). They deduce how individual-level immediate concrete outcomes aggregate to an organizational level and how affordances are interrelated and interact. These relationships can be described in two ways: 1) as a temporal relationship (e.g., realizing the affordance of capturing and archiving digital data gives rise to the affordance of accessing information remotely) or 2) as a feedback loop (cf. *Fig. 2*) so that immediate concrete outcomes affect actors, their organizational context or artifact features to give rise to further affordances that can be actualized (Leonardi 2011; Strong et al. 2014).

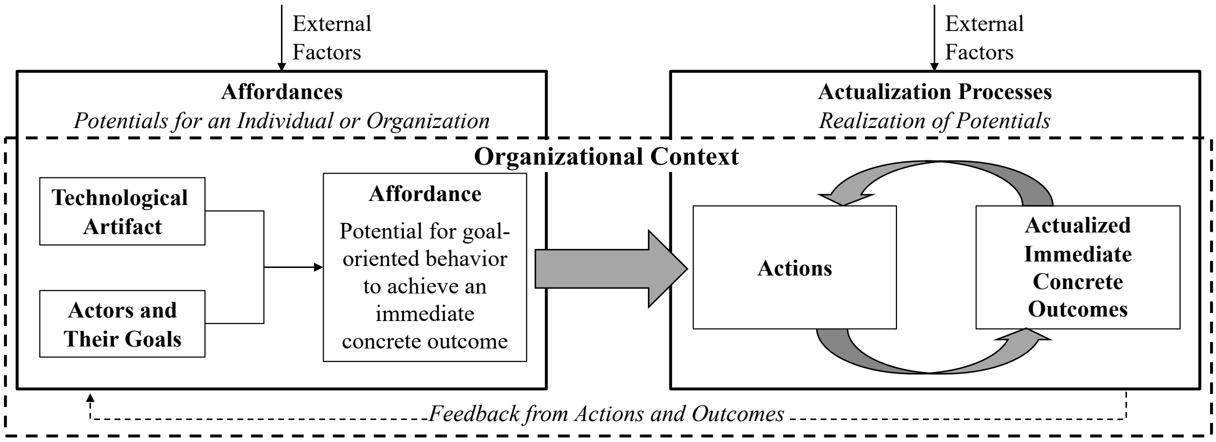

Fig. 2: Affordance-actualization framework, based on Strong et al. (2014).

A few articles already apply affordance theory in the context of smart service (systems). Knote et al. (2021) take a functional affordance perspective to develop propositions on how different types of smart personal assistants (e.g., Amazon's Echo products) afford value co-creation. Effah et al. (2021) examine affordance and constraint processes in smart service systems with a focus on applying smart products in seaports. Finally, Naik et al. (2020) examine affordances in an IoT context and identify three different types of affordances, which they interpret as a "step-by-step mechanism through which the IoT creates organizational outcomes" (Naik et al. 2020, p. 240). These applications underline the growing interest in translating insights from affordance theory to smart service systems. However, existing research yet lacks a thorough analysis of how the specific characteristics of smart service systems can be reflected and how utilizing affordance theory as a lens can change how we look at the phenomenon.

3 Methodology

To explore affordances and actualization processes in smart service systems, we conduct multi-case study by interviewing senior decision-makers of 10 companies. Following a generic purposive sampling approach (Bryman 2016), we apply pre-defined criteria to identify suitable cases: the company already has deployed a smart service system at least in a mature prototype version, the interviewees are business or technical experts, and they play a significant role in shaping or running the smart service system (Patton 1990). Further, the selection is guided by the intention to consider cases of different industries, company sizes, and levels of maturity. For example, we include cases in the machinery and plant engineering industry but also providers of medical equipment and products for the chemical industry (cf. *Tab. 1*) (Eisenhardt 1989). The interviews range between 39 and 67 minutes and were conducted between May and July 2021 via video-conference software. All interviews are recorded and transcribed before being coded and analyzed using MAXQDA software. To reduce the subjectivity of interviewing only one person per case, we verified and supplemented the interview data with information available from public sources (e.g., online descriptions of smart service applications).

Throughout the conversations, we follow a semi-structured interview guideline to ensure comparability among the cases, which is particularly important as the interviewees hold different roles within their respective companies. The overarching goal of each interview is to understand the smart service system, i.e., to determine critical value-creating actions, technological features of the smart product, and relevant characteristics of the involved actors. For this purpose, we ask questions to obtain both retrospective and current perceptions from those experiencing and actively shaping smart service systems in practice (Bryman 2016). After conducting 7 interviews, we already began with analyzing the data. Despite the topic of affordances in smart service systems being far from exhaustively covered, including 3 additional cases did not substantially challenge our elaborated conceptual understanding. Therefore, we interpret the sample of 10 cases as a sufficient level of theoretical saturation for this study's purpose, which seems appropriate to balance between empirical evidence and the volume of data in the context of theory-building case study analyses (Eisenhardt 1989).

Case (mm:ss)	**Description of Smart Service System**	**Role**
CarCo (65:43)	Digital innovation unit of a global car manufacturer providing an intermodal mobility platform	CEO/CTO
ChipCo (60:18)	Provider of semiconductor software and chips and further wireless technology solutions	Vice President Technology EMEA

DriveCo (59:48)	Provider of integrated electric drive systems with IIoT-based automation services	Head of IIoT & Service
FilterCo (61:33)	Provider of filter systems and pressure vessels, equipped with IoT-technology	Managing Director
GearCo (67:05)	Provider of electromechanical drive systems for machines with IoT-based monitoring services	Business Developer Digitalization
HealthCo (47:39)	Provider of medical devices with subscription-based software packages	Managing Director DACH
IoTCo (41:07)	Subsidiary firm of a technology company focusing on AI-powered solutions for IoT ecosystems	Product Manager Track & Trace
LaserCo (43:53)	Provider of production machines and software solutions to implement IoT-based smart factories	Product Manager Digital Service
PrintCo (39:28)	Provider of printing machines integrated with cloud-based performance services	Global Head Subscriptions
ValveCo (55:12)	Provider of control valves for hydraulic systems complemented with digital service apps	Director Engineering

Tab. 1: Overview of 10 interviews with smart service system providers.

After the interviews, we apply qualitative content analysis (Hsieh and Shannon 2005; Mayring 2004) to our data to identify the actors′ goals and organizational context, smart product features, affordances, actualization actions, and immediate concrete outcomes. In a second step−similar to Strong et al. (2014)′s analysis of EHR implementation−we synthesize our findings: Aiming for an appropriate and consistent level of granularity, we arrange the coded items as affordances and corresponding actualization processes (Volkoff and Strong 2017). Interviewing only one person per case does not allow for claiming completeness of the identified affordances. However, comparing the heterogeneous set of cases allows us to abstract and theorize how smart products give rise to potentials of goal-oriented behavior (affordances) and how actors realize these potentials (actualization processes). Despite a wide variety of additional potentially interesting questions to analyze the data (e.g., interrelations of the affordances), we restrict our analysis to the general mechanisms of affordances and actualization processes in smart service systems as presented in the following section. In doing so, we propose a conceptual framework of affordance-actualization processes in smart service systems including six propositions. Adding to the described multi-case study, we complement our research and illustrate the conceptual findings with a real-world case study building on three consecutive workshop sessions. With the example of EnergyCo′s smart battery solutions, we provide a more applicable perspective on how our proposed affordance-actualization view can help to decompose multi-actor constellations in smart service systems. In section 5, we provide more details on the content of the workshops and how this evaluative episode is linked to the already presented research methodology.

4 Affordance-Actualization Processes in Smart Service Systems

In this section, we build on our multi-case study to propose a conceptual framework (*Fig. 3*) incorporating affordance-actualization theory (Strong et al. 2014) as a lens to further evolve the concept of smart service systems (Beverungen, Müller, et al. 2019). By presenting and discussing six theoretical propositions (P1-P6), we underline certain aspects of the framework and make its implications for the conceptual understanding of smart service systems more tangible. For the most part, these propositions result directly from the combination of the two established frameworks presented in section 2 (cf. *Fig. 1* and *Fig. 2*) and are further supported by evidence from our case study (cases given in parentheses). Greater adjustments based on empirical findings are mainly made regarding P5. In the subsequent section, we, first, describe affordances in smart service systems (left side), and then present findings regarding the actualization processes in smart service systems and their implications for the conceptualization of smart service (right side).

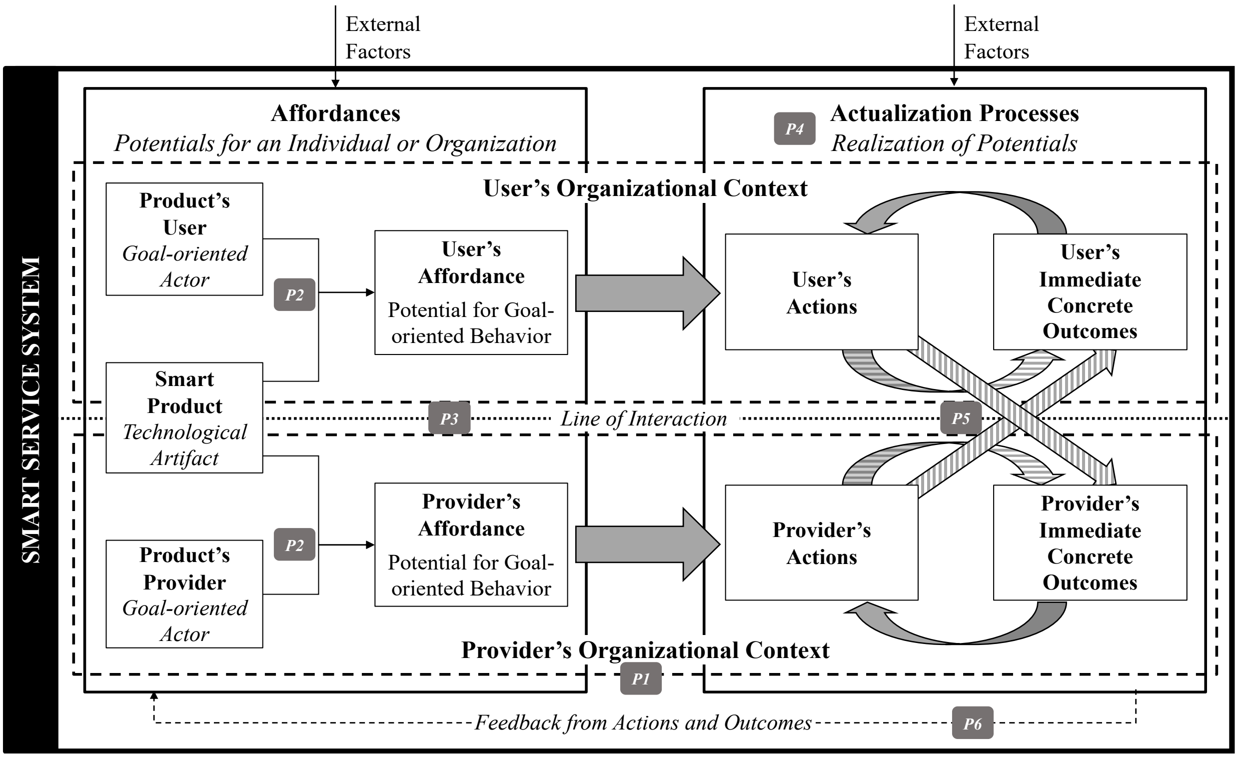

Fig. 3: Affordance-actualization framework and propositions for smart service systems.

Past studies on affordances typically only consider the direct user of an artifact. However, "smart products can be interpreted differently by service consumers and service providers, subject to the value proposition that they offer" (Beverungen, Müller, et al. 2019, p. 12). The interview data arranged as affordances and actualization processes support this as we found that smart product providers increasingly seek to interact with the product during its usage. For example, PrintCo connected most of its customers' machines with a customer spanning IoT-cloud network. Having access to usage data made them "recognize that many customers remain below their potential machine productivity" (PrintCo). They understand this as an affordance to support their customers in using their products, primarily realized through analytics-based service offerings. Hence, we propose that in smart service systems, multiple dimensions of organizational contexts and the contained affordances and actualization processes should be reflected. To illustrate this approach, we consider a product's provider and its user as a basic service system, akin to the conceptualization of smart service systems (*Fig. 1*)–acknowledging that smart products can give rise to affordances for 'third parties' as well.

P1: *Multiple organizational actors interact with smart products as they allow for remote access and reconfiguration giving rise to multidimensional affordances (CarCo, FilterCo, GearCo, HealthCo, IoTCo, PrintCo, ValveCo).*

4.1 Actors and Their Affordances in Smart Service Systems

As discussed in section 2, affordances generally arise from the technology-user relationship and are not mere reflections of the technology itself. This ontological theme offers a useful perspective on smart service systems: As the product manager of IoTCo's track and trace solutions points out, making a 'thing' smarter, i.e., increasing its technological capabilities, is not an end in itself. It is rather the combination of these features with an actor's goals and organizational context that might give rise to goal-oriented behavior. During the journey of learning about the user's goals and context, his team came to realize that the offered artifact fits better for tracking load carriers than the asset itself, as this provides more potential for decreasing costs and increasing transparency in the business context of the product's users. Multiple interviewees referred to the importance of turning this view into action by deliberately approaching well-trusted customers with suitable goals and organizational context to pilot smarter versions of their product to understand which affordances are perceived. This early-stage feedback process helped the companies to purposively promote the potential of these identified affordances–regardless of whether they were anticipated or not.

P2: *Desirable potential actions enabled by smart technology arise from the technology-user relationship, not only the smart product's features itself. (CarCo, ChipCo, DriveCo, FilterCo, GearCo, HealthCo, IoTCo, PrintCo)*

Next, we examine whether the formation and perception of affordances take place at the intersection of multiple organizational contexts. As our conceptual framework serves as a rather static portrait of a smart service system's mechanisms of perception and action, we argue that affordance as a potential for action is separated by the line of interaction spanned by the smart product as a boundary object. However, the actions in actualization processes, then, can and often do cross the line of interaction. Few of the examined cases emphasize dividing even the overall affordance-actualization process along the distinct organizational contexts, thus using the smart product as a true boundary object. This allows the product's provider to "standardize their offerings allowing for a better scalability of the smart product business model" (IoTCo). In our interview sample, we see tendencies for the more mature a solution is, the more independently different actors interact with the smart product (e.g., PrintCo, HealthCo and IoTCo). In contrast, companies who still extensively explore technological possibilities typically closely collaborate with their smart products' users (e.g., FilterCo, DriveCo, ValveCo).

P3*: Actors interacting with the smart product perceive affordances largely independently as smart products serve as a boundary object at the line of interaction. (GearCo, HealthCo, IoTCo, PrintCo)*

4.2 Smart Service as an Actualization Process

We now turn towards the actualization processes as mechanisms to realize the discussed affordances. First, the multi-case study substantiates our assumption that a distinction between affordances and their actualization seems appropriate. The interviewees in our sample name multiple actualization actions such as identifying a suitable combination of hardware and software packages for the individual customer (HealthCo), installing the smart product at the user's site (IoTCo), handling and processing the accessible data (LaserCo, CarCo) or making value-adding suggestions for improvement of the user's processes based on analytical insights (PrintCo). This extension of the conceptualization of smart service systems provides a clearer description for theory and practice, as it further clarifies distinctions between potentials, actions, and outcomes.

P4: *Due to the artifact's complexity, affordances enabled by smart products require coordinated actions, i.e., actualization processes, to realize their potential. (CarCo, DriveCo, FilterCo, HealthCo, IoTCo, LaserCo, PrintCo)*

We identify cyclic processes of actions and immediate concrete outcomes in smart service systems: In the case of CarCo, increasingly connected cars drive the transition in the industry's development practices from multi-year lifecycles towards a continuous improvement via software updates. One of our most promising findings builds on this insight: separating the action potential from its realization operationalizes the conceptual understanding of 'smart service'. Comparing different cases, we found that some affordances can be realized within an actor's organizational context ('self-service') whereas others require crossing the line of interaction ('interactive service'). Further, by looking at the outcomes we observed that not only the smart product's user but also its provider can obtain 'value-in-use'–and not only value-in-exchange (Grönroos and Voima 2013). This notion challenges existing categorizations in 'service providers' and 'service consumers' (cf. *Fig. 1*, Beverungen et al. (2019)). Hence, in this study, we instead distinguish between the smart product's provider and the user. In the examined cases, we find examples of all potential combinations resulting in four constellations of smart service in dyadic smart service systems, as illustrated by the hatched arrows in Fig. 3 and the matrix in *Fig. 4*.

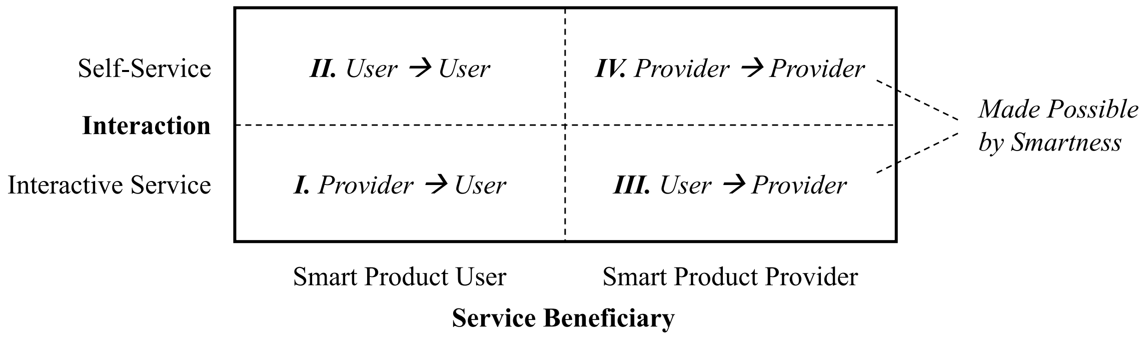

Fig. 4: Classification of smart service constellations in smart service systems.

As an illustration, one case now experiments with a "shadow mode" where the user initially gives his consent to the provider (III) to autonomously collect usage data to improve their analytical models and understand the customers' processes (IV). After some time, the provider leverages this knowledge by creating customized offerings and rewards the user by offering performance-improving service free of charge for a limited amount of time (I). Besides these individualized offerings, the user can use standardized service offerings enabled by smart technology such as monitoring the condition of the product and accessing historical sensor data without further interaction (II). While this notion is in line with the definition of 'smart service' given in section 2, we acknowledge that this simplified classification neglects important aspects such as the co-creation of value for both actors and the role that third parties might play. Thus, we suggest further research to critically examine and potentially extend this classification.

P5: *Both actors can be the beneficiary of smart service by achieving an immediate concrete outcome. Further, both can actualize affordances for their own benefit (self-service) or some other actor's benefit, thus, crossing the line of interaction (interactive service). (Combined evidence from all cases to develop the classification)*

Finally, the immediate concrete outcomes achieved through actualization do not only trigger further actions to realize already existing affordances but can also change the initial agencies and affordances via feedback loops‒at least across a larger time frame: After the initial release of their smart product, ValveCo understood that the built-in memory space severely constrained value-adding activities, which led them to replace the initial hardware with an electronic interface card, and ultimately, realize multiple new smart service potentials. This proposition might be particularly interesting for research on smart service systems when taking a dynamic perspective to better understand how consecutive actions iteratively shape the configuration of smart service systems by adjustments of the actors′ goals or the smart product′s features.

P6: *The actions and outcomes of actualization processes provide feedback affecting the actors, their organizational context, and the smart product's features, giving rise to new affordances. (CarCo, DriveCo, FilterCo, GearCo, IoTCo, PrintCo, ValveCo)*

All in all, our qualitative analysis supports the proposed conceptual framework and demonstrates how an affordance-actualization perspective may contribute to an understanding of the smart service system phenomenon. The heterogeneity of our sample allows us to highlight different aspects as discussed along the six propositions. Particularly the different levels of maturity between cases have a large impact on the richness of information regarding the discussed topics. However, this qualitative conceptual research only serves as an initial step towards theorizing affordances in smart service systems and should be complemented by additional empirical research.

5 Illustrating Multi-Actor Affordances with the Case of EnergyCo's Smart Batteries

After introducing a framework and six propositions on how multiple actors perceive and actualize affordances in smart service systems, we now turn to illustrate these conceptual findings with an in-depth case study. With the case of EnergyCo′s smart battery solutions, we provide a more applicable perspective on how our proposed affordance-actualization view can help to decompose multi-actor constellations in smart service systems. The case study was conducted after we developed the conceptual framework, which we presented and discussed in an initial version of this article (Heinz et al. 2022). Applying the conceptual results in a second qualitative research episode serves two purposes: first, we can demonstrate its conceptual implications by re-translating the generalized observations back to an empirical layer. Second, we retrieve valuable managerial feedback that allows us to evaluate our findings regarding their accuracy and to unfold further insights regarding their practical applicability.

5.1 Case Introduction and Conducted Workshops

Founded in 2011, EnergyCo soon became a regional leader in providing innovative battery swap systems and charging infrastructure elements. Their current core product is a universal battery that can be integrated into a wide variety of energy storage applications such as modular house storage solutions in the private sector but also different use cases in industrial scenarios. In the past two years, EnergyCo launched a smart service systems engineering (SSSE) project to identify opportunities where they can leverage existing IoT-related technical capabilities of their products to create additional value-in-use and become a smart service provider. In the process of this project, EnergyCo decided to focus on the application scenario of uninterruptible power supply (UPS), which they primarily offer for small and medium-sized enterprises as customers. An UPS system locally stores energy and automatically bypasses the local power network in case of a power outage, thus increasing the reliability of critical local infrastructure (e.g., server networks, etc.) and preventing issues such as data loss or hardware damage.

In the following case study, we will focus on the multi-actor setting of such IoT-enabled UPS systems, which was subject of a series of three workshops that have been empirically observed, documented, and analyzed. At the time of the workshops, EnergyCo is still in a 'proof-of-concept' stage on their journey towards becoming a smart product provider. Yet, their case is well-suited for this study's purpose, as the emerging 'as-a-Service' business model offers rich insights into a multi-actor smart service setting. In the specific constellation, EnergyCo plays a critical role as both a technology provider and orchestrator of the ecosystem, and thus lays the foundation for the successful service exchange in the arising smart service system. Further, EnergyCo already developed first technical prototypes and intensively discussed the smart service offerings with potential stakeholders fulfilling each of the introduced roles. Therefore, they were able to make precise statements about the needs, goals and context of all partners involved.

The overarching goal of the workshops was to reflect on EnergyCo's current state of smart service innovation and to identify further steps to refine the multi-actor business model and a roadmap of the required technical features. In total, we conduct three workshops ranging on average 1:53 hours. The first workshop aimed at building an understanding of the smart service provider, their products and capability. Further, relevant actors and roles within the innovation process were identified, which was facilitated by the framework of Anke et al. (2020). With the UPS application in mind, the second workshop focused on discussing goals, contextual conditions, and pain points of all relevant roles. During the third workshop, we defined the affordances of different actors and identified the key activities for value creation (i.e., the actualization actions) within the smart service systems. Despite technical features have been discussed throughout all the three workshops, we deliberately chose an 'affordance-first' approach in mapping the envisaged smart service system. The individual workshops' focal topics and outcomes are described in *Tab. 2*.

Nr.	Duration (hh:mm)	Focus
1	02:04 h	Understanding the case (smart service provider, their products as well as technical and organizational capabilities)
2	01:14 h	Definition of relevant stakeholders and their goals, context, and pain points
3	02:21 h	Identification of affordances and actualization actions within the smart service system

Tab. 2: Overview of the workshop series with EnergyCo.

In all three workshops, two researchers, two employees of EnergyCo and one employee of a closely collaborating technology provider were participating. The three workshops have been recorded and documented via meeting minutes, further the results of the applied methods were available during the case analysis. Between and after the workshops, a group of two authors discussed the empirical findings and their implications as well as depictured the respective insights in a representable format. Despite planning to conduct another series of workshops with the partner in the future, we already "reached closure", i.e., theoretical saturation, at this step of the project for the purpose of demonstrating this work′s conceptual findings (Eisenhardt 1989). Finally, after finishing the in-depth case study, we reflected on the insights gained from both empirical episodes of our research design and deduced valuable observations on how to transfer the conceptual approach into practicable formats (cf. section 5 and 6).

5.2 The Ecosystem Forming around EnergyCo's Smart Products

Throughout the workshops, a first important result was to capture and differentiate participating actors in the smart service system focusing on the envisioned ′operations′ phase after implementing and instantiating the respective smart service features. For this purpose, we take a role-centric approach and postpone decisions which actors ultimately fulfill these roles. As the workshops suggest, in different stages of rolling out the offering it might be either beneficial or obstructive to unify roles, e.g., EnergyCo being the technology provider and service operator. However, to derive and assess the technological features of the smart product by discussing its multi-actor affordances, these strategic decisions can be neglected.

In total, we identify four primary roles interacting with the smart product during its usage as a UPS: first, EnergyCo itself acts as the ′technology provider′ that is constantly evolving the implemented software features, and further, aims to gain a better understanding of how their physical products are used in the field. Second, another company (e.g., an electrical service provider) serves as the ′service operator′ throughout the UPS life cycle who applies the technology provided by EnergyCo to operate and maintain the system, whereby as much interaction with the product as possible takes place via a remote connection. Third, the actual customer of the UPS can apply certain IoT features to monitor the reliability of its emergency system (″peace of mind″) and access all required information in case of an outage event where the UPS is activated (e.g., receive the expected run time before the battery is discharged). Finally, EnergyCo plans to realize the smart service via an ′as-a-Service′ business model, where the customer leases the whole UPS system combining the smart product and additional service offerings instead of purchasing the product and paying a monthly service fee. However, it is neither the core competency of the technology provider, nor the service operator to offer such financial services and take the associated risk. Thus, a fourth role can be described as an external ′financial service provider′ buying the product, and then, lending it to the UPS customer while forwarding a service fee to the service operator. The overall network of participating roles in the smart service system as well as their interaction with each other and the smart product are depicted in *Fig. 4*. Further, the illustration depicts the modular structure of the smart product′s IoT components, which will be discussed in the following subsection.

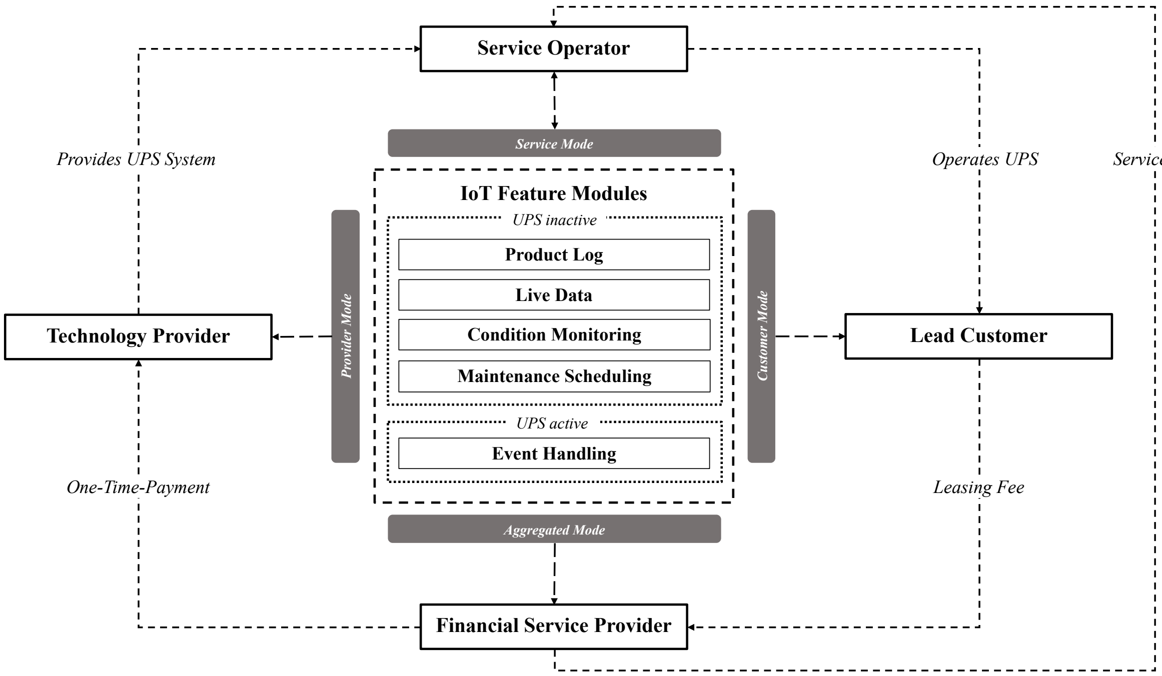

Fig. 5: Generalized structure of EnergyCo's envisioned smart service system.

5.3 How EnergyCo's Smart Products Enable Multi-Actor Affordances

Another observation derived from the workshops was the demarcation and description of five modular IoT feature modules (cf. *Fig. 4*): 1) a *product log* allowing to access historical data of the product, 2) a module allowing to easily access pre-processed *live*[1] *data* of the respective battery, 3) an aggregated condition monitoring view[2], 4) a data-driven *maintenance scheduling*[3] tool, and 5) an application to support *event handling*, i.e., providing relevant information during power outage incidents. Referring to the conceptual framework, these hardware and software components manifest a set of technological artifacts that transform the core battery system into a *smart* product.

These functional blocks can be flexibly combined into individualized touchpoints for the respective interacting roles and form the technical basis for providing smart service to the relevant stakeholders. By discussing the affordances of these feature modules referring to the goals and context of the different stakeholder groups, the participants also defined which of the modules should be included in the touchpoints for the different stakeholder groups. In *Tab. 3*, we provide the current set of accessible feature modules for each of the involved stakeholders. For example, while the service operator should be able to access all the modules as he is involved in the overall usage process, the financial service provider is only interested in monitoring the historical and current health condition of the financed UPS systems.

	Product Log	Live Data	Condition Monitoring	Maintenance Scheduling	Event Handling
Technology Provider	X		X		

[1] In this application context, real-time availability means a small single-digit minute time window.
[2] e.g., minimum available power, state of health (SoH) of the battery system.
[3] Including prediction, planning, and documentation of the maintenance tasks.

Service Operator	X	X	X	X	X
Lead Customer			X		X
Financial Service Provider			X		

Tab. 3: Mapping of stakeholders and accessible IoT feature modules.

As a third step, we apply our proposed affordance-actualization perspective to analyze, how and why the respective IoT feature modules allow the provision of smart service, i.e., the creation of value-in-use enabled by the smart product. For this purpose, we discussed the respective smart product-enabled value propositions towards each of the four roles, which we link with the 'affordances' construct in our framework. We then mapped each affordance with the required IoT feature modules and described the stakeholder's overarching goals for participating in the smart service system. Finally, we considered a minimal set of required value-creating activities ('actualization actions') and the immediate outcomes of realizing each of the identified affordances ('outcomes'). The results of this workshop episode are presented in *Tab. 4*. The case study demonstrates that smart products such as EnergyCo's UPS systems can simultaneously afford multiple actors to realize value, as their certain technical features provides relevant information for them to take goal-oriented actions. Further, the case study revealed that introducing these novel technologies allows actors to "co-create" mutual value– for example, by allowing a service operator to remotely operate and maintain the system and thus save expenses, or by facilitating novel financial models. The workshop participants also reflect on the shared interest among all stakeholders to collaborate towards a more durable, and thus sustainable UPS usage scenario. However, the workshops also unfolded certain challenges to evolve the smart service concept into a marketable stage such as deciding on reasonable pricing mechanisms to distribute the added value between the involved stakeholders.

Stakeholder	Perception		Actualization		
	Goal	**IoT Feature Modules**	**Affordances**	**Actions *[Stakeholder]***	**Outcomes**
Technology Provider	Increasing product lifespan and reliability	Product Log + Condition Monitoring	Understanding better the battery's lifecycle at the customer site	Collect and analyze usage data *[Technology Provider + Service Operator]*, adapt the battery system *[Technology Provider]*	Possibility to improve battery development and UPS configuration
		Condition Monitoring	Improving the existing IoT hardware and software	Collect and analyze usage data and feedback *[Technology Provider + Service Operator]*, rework the IoT applications *[Technology Provider]*	Continuous evidence-based improvement process
		Condition Monitoring	Identifying unfulfilled needs (e.g., information gaps) to develop novel IoT applications	Collect and analyze usage data and feedback *[Technology Provider, Service Operator]*, develop and deploy novel IoT applications *[Technology Provider]*	Deeper understanding and inspiration for possible new IoT applications
Service Operator	Efficiently guarantee reliability of the battery	Condition Monitoring + Live Data	Remotely detecting operational problems	Establish a continuous remote connection, automatically track usage	UPS sends an alarm and IoT system provides further

				data [Service Operator]	information if battery/UPS behaves unexpectedly
		Condition Monitoring + Event Handling	Remotely solving operational problems	Establish remote connection and modify configurations [Service Operator]	Ability to solve problems in a fast and efficient way
		Condition Monitoring + Product Log	Estimating the state of health of the battery	Establish remote connection, collect, and analyze usage data [Service Operator]	Service Operator can decide to replace the battery when needed
		Condition Monitoring + Maintenance Scheduling + Event Handling	Planning (physical) maintenance in accordance with customer needs	Coordinate maintenance date with customer and ensure full functionality via remote maintenance [Service Operator + Lead Customer]	Ability to offer personalized maintenance
		Condition Monitoring	Understanding and optimizing the UPS's charging cycles when UPS is inactive	Collect and analyze usage data, reconfigure UPS [Technology Provider + Service Operator]	Improved operating efficiency
Lead Customer	Reliable power supply to allow safe reaction to outages	Condition Monitoring	Checking battery condition and monitoring available UPS capacity	Collect, analyze, and visualize usage data [Technology Provider + Service Operator]	Reassurance of reliable power supply
		Condition Monitoring + Event Handling	Accessing further information that allows to	Establish (remote) connection, track usage data and provide required information in real-time	Ability to consciously respond to power outages

			make conscious decisions during power outages	[Service Operator + Lead Customer]	
Financial Service Provider	Calculatable risk and profitable ROI	Condition Monitoring	Assessing current state of investment and refining asset prediction models	Collect and analyze usage data, provide target-actual comparison [Technology Provider + Service Operator]	Ability to continuously evaluate state of investment
		Condition Monitoring	Making evidence-based investment decisions	Collect and analyze usage data, provide benchmarking insights [Technology Provider + Service Operator]	More calculatable risk, enhanced trust in the asset and increased predictability of investment decisions

Tab. 4: Affordance actualization overview of EnergyCo's smart service system.

6 Discussion

In this section, we first review the theoretical implications of our study and pinpoint avenues for future research in form of a research agenda. Afterward, we discuss the managerial implications of our findings, point out the limitations of our study and provide an outlook on how we plan to extend our research.

6.1 Theoretical Implications and Research Agenda

Our study offers theoretical implications to the ongoing debate on co-creating and realizing value through digital innovation by underpinning and extending Beverungen et al. (2019)'s conceptualization of smart service systems. By taking an affordance-actualization perspective, we explain how smart products give rise to affordances for multiple actors in the system and how these potentials can be realized. We hope to inspire further conceptual research on this relevant phenomenon with this mid-range theoretical perspective. To make this potential more concrete, we refer to three ongoing academic discussions ('research streams'), on which future research can build upon to establish a more rigorous theory of affordances in smart service systems: 1) business model innovation in smart service systems, 2) value co-creation in multi-actor service ecosystems, and 3) IT-enabled affordances beyond a single-organizational level. In the following, we discuss linkages to the perspective established in this article and exemplary research avenues (RAs) as potential starting points for future studies in IS research (and beyond). The resulting research agenda is summarized in *Tab. 5*.

Research Stream	Exemplary Research Avenues (RAs)
Business model innovation in smart service systems	**RA1:** Apply the proposed theoretical perspective to design applicable artifacts assisting business model innovation processes in smart service systems. **RA2:** Analyze how and why the different actors in smart service systems perceive smart service outcomes as 'valuable'. **RA3:** Study how actors can equilibrate the perceived benefits and sacrifices via suitable smart service revenue models as monetary compensation.
Value co-creation in multi-actor service ecosystems	**RA4:** Emphasize the multi-actor nature of smart service systems by identifying and formalizing 'smart service ecosystems' as a unit of analysis. **RA5:** Reflect on how smartness-enabling technologies potentially change prevailing theoretical constructs in service science. **RA6:** Discuss how aligning different constructs in the multi-actor affordance-actualization process manifests institutional arrangements for value co-creation and service exchange.
IT-enabled affordances beyond a single-organizational level	**RA7:** Investigate aggregated affordances on an (eco-)system-level, which are shared by multiple economically independent actors.

	RA8: Study dynamic path-dependencies, i.e., interrelations and interactions of affordances, to understand the 'imbrication' processes in inter-organizational settings.

Tab. 5: Research agenda to build on this work's theoretical implications.

Business Model Innovation in Smart Service Systems

Our work underlines the scientific potential of examining smart service systems, as related technologies rapidly advance, and more mature cases can be subject to empirical research. Hence, we see great potential for future studies in the field of business model innovation in smart service systems. Our results can serve as a conceptual basis for further empirical or design-oriented studies assisting practitioners in their process of implementing these emerging technologies in viable smart service business models.

As a first exemplary research avenue, future research can apply our findings to design applicable artifacts (e.g., processes, methods, tools) and thus, extend existing research of smart service innovation (Pöppelbuß et al. 2021) and smart service systems engineering (Halstenberg et al. 2019; Wolf et al. 2020). Potential affordance-driven design choices could include separating a smart product's bare technical features from the resulting potentials for goal-oriented behavior (i.e., affordances) in a certain application context, emphasizing required engagement through actualization actions that must be taken to realize potentials and achieve valuable outcomes, or distinguishing between potential interactive service or self-service constellations. Further, deliberate consideration of feedback processes in the smart service system can assist in creating a road map for technical or business-related features.

RA1: Apply the proposed theoretical perspective to design applicable artifacts assisting business model innovation processes in smart service systems.

Second, a highly relevant discussion in smart service innovation is to translate the objective achievable outcomes in smart service systems (e.g., the availability of certain information) into the subjective value perceptions of the concerned actors as the balance between the 'benefits' and the 'sacrifices' made to obtain it. Providing reference cases or methodological support can then be applied by decision-makers to prioritize their innovation efforts on 'win-win' constellations for the involved actors and establish an equilibrium through adequate monetary compensation. Our extension of existing smart service conceptions is particularly relevant in this context as traditional service provider versus service consumer roles do not necessarily hold in smart service settings. Instead, smart products' remote capabilities and layered architecture turn them into boundary objects that allow the parallel realization of complex patterns of value-creating activities beneficial for multiple actors (see *Fig. 4* and *Tab. 4*). We suggest further research to study smart service outcomes in more detail from a value-oriented perspective to derive further insights for business model innovation (e.g., robust actor alignments or common revenue models).

RA2: Analyze how and why the different actors in smart service systems perceive smart service outcomes as 'valuable'.

RA3: Study how actors can equilibrate the perceived benefits and sacrifices via suitable smart service revenue models as monetary compensation.

Value Co-Creation in Multi-Actor Service Ecosystems

In line with current discussions in service research (Vargo and Lusch 2016, 2017), we ask whether a dyadic juxtaposition of a 'provider'/'producer' and a 'user'/'consumer' accurately reflects prevalent actor constellations in smart service systems. Today's service research increasingly turns to rephrasing these constellations as 'actor-to-actor' networks. Therefore, we replaced Beverungen et al. (2019)'s service-focused role names with names describing the actors' relation to the smart product, as our data suggest that both actors can be the beneficiary of smart service (cf. *Fig. 4*). However, we argue that after all, the taken dyadic, micro-level perspective does not adequately reflect the complex organizational actor networks forming smart service systems. Thus, we encourage future research to extend our model by applying a multi-actor service ecosystem perspective. In this spirit, our evaluative case study considers affordances and actualization processes of multiple actors in EnergyCo's smart service system. While serving as a fruitful starting point towards evolving the concept of smart service systems into 'smart service ecosystems', this work yet lacks to pinpoint all the transferable conceptual insights from recent service research towards studying smart service systems. On the other hand, future research can also build on our work to examine how the discussed emerging technologies enabling smartness might affect prevailing knowledge on theoretical constructs in service science.

RA4: Emphasize the multi-actor nature of smart service systems by identifying and formalizing 'smart service ecosystems' as a unit of analysis.

RA5: Reflect on how smartness-enabling technologies potentially change prevailing theoretical constructs in service science.

Further, our study yet mostly neglects the potential of multiple actors aligning their actualization actions, which might be a valuable perspective to operationalize the understanding of value co-creation in smart service systems. Hence, it might be interesting to further investigate the interaction in the 'joint sphere' of smart service systems and how such interaction can be purposefully promoted–e.g., by building trust among actors or formalizing governance mechanisms (Grönroos and Voima 2013; Matzner et al. 2021; Schüritz et al. 2019). Referring to our proposed theoretical framework, this could result in shared goals among actors (e.g., reducing information asymmetries), overlapping organizational contexts, and jointly developed smart product capabilities manifesting shared institutional arrangements. Relating to existing conceptualizations in service research, these institutional arrangements can be considered as a constituent factor of successful value co-creation and service exchange in service ecosystems (Vargo and Lusch 2016). However, so far, existing research lacks to combine insights on affordances and their actualization with service research. Our conceptual study can build the basis to bridge these two research streams and, therefore, close this research gap.

RA6: Discuss how aligning different constructs in the multi-actor affordance-actualization process manifests institutional arrangements for value co-creation and service exchange.

IT-Enabled Affordances beyond a Single-Organizational Level

This study broadens the scope of affordance research by taking a multi-actor perspective, as we argue that smart products' capabilities allow multiple actors to interact with the artifact, and thus co-create value at once. In contrast, most studies on IT-enabled affordances examine affordances and their actualization on an individual user level, and few on an aggregated single-organizational level (cf. section 2.2). The domain of smart service systems appears as highly promising to evolve existing theory and study affordances beyond a single-organizational level since technology mediates between a multilateral set of actors and allows them to continuously interact. Therefore, future research could build on our findings to expand affordance theory's implications from an organizational towards an (eco-)system-level where multiple economically independent actors jointly give rise to and realize "mutual" or "shared" affordances. In this spirit, another possibility would be to investigate shared affordances of closely intertwined smart products like in smart manufacturing networks.

RA7: Investigate aggregated affordances on an (eco-)system-level, which are shared by multiple economically independent actors.

Finally, our empirical data suggests that it could be promising to examine the interrelations and interactions of affordances that are characteristic of smart products. Taking such a more dynamic perspective could provide valuable insights to analyze and understand the 'imbrication of human and material agencies' shaping smart service systems over time (Leonardi 2011). In today's connected world, such dynamic path-dependencies in the context of digital innovation usually concern multiple intertwined actors and successful innovation takes continuous collaborative efforts over time. Particularly the sudden ability to continuously integrate and deliver new features rapidly transforms innovation potentials in previously product-driven industries. Again, our results indicate that smart service systems constitute a promising application domain to also derive more general knowledge, which hold for the application context of further emerging technologies as well (Pentland et al. 2021).

RA8: Study dynamic path-dependencies, i.e., interrelations and interactions of affordances, to understand the 'imbrication' processes in inter-organizational settings.

6.2 Implications for Practice

We consider our results also as useful for practitioners. First, a differentiation between affordances and their realization can be a valuable construct for decision-makers to analyze possibilities presented by smart technology. Further, consciously articulating expected outcomes of participating in smart service systems supports more efficient management of digital innovation within and beyond the organization (Heinz et al. 2021; Nambisan et al. 2017). Particularly, our understanding of smart service can inspire practitioners to rethink traditional roles of providers and consumers, as smart products and their connective capabilities allow novel value-creating actor constellations. We provide the case study of EnergyCo's smart battery solutions as an illustration of these study's implications and a potential blueprint for practitioners applying our findings. Finally, the presented research agenda pinpoints potential starting points for further applications of the proposed affordance-actualization perspective on smart service systems. This holds great potential for researchers to create meaningful theory and artifacts to support managers in solving practical problems in the future.

6.3 Limitations and Outlook

The results presented in this article certainly are subject to limitations. First, our multi-case study lacks considering multiple perspectives within each case since we restrained our sampling approach to providers of smart products and only interviewed one person per case. Adding more interviewees to the sample would enhance a better understanding of the organizational context(s) and collective actions in each case. However, to reduce this subjectivity, we verified and supplemented the interview data with information available at public sources. Further, conducting only one interview per person–despite asking for the case's historical development–somewhat impedes understanding the dynamics within each case. Thus, having multiple sequences of interviews per case at different stages of maturity would certainly improve the findings on affordances, their actualization and feedback loops, and particularly how they influence each other over time. We partly address this limitation by conducting a more detailed case study to evaluate and demonstrate our findings in section 5. However, we are still only able to depict a static perspective on EnergyCo's smart service system.

These limitations at the same time leave the potential for future research that can contribute to answering our research question. Particularly, testing and extending the proposed findings by conducting an in-depth longitudinal case study could be a useful extension (Street and Ward 2012), which we aim to conduct in the future. By examining a chronological timeline of events in a real-world case, one could not only further illustrate the general utility of affordance theory in the context of smart service systems but could also further develop our proposed framework and contribute to the unresolved questions presented in the research agenda. Hence, we will continuously observe EnergyCo's path towards becoming a smart service provider and complement these insights with consecutive interviews with the companies within our multi-case study sample.

7 Conclusion

Smart physical products increasingly shape a connected IoT world and serve as boundary objects for the formation of smart service systems. While these systems bear the potential to co-create value between partners in various industries, IS and service research still struggles to fully capture the phenomenon to support successful digital innovation in IoT settings. In this work, we analyze the phenomenon of smart service systems taking an affordance-actualization perspective. Based on a qualitative content analysis of a multi-case study, we identify elements and propositions towards a mid-range theory for smart service systems as a basis for further research in the IS discipline. We suggest that providers and users of smart products not only realize their own affordances via their actions but also may affect the outcomes of other actors in the service system. Finally, we demonstrate and evaluate our findings with an in-depth case study and point out starting points for future research applying our proposed theoretical perspective in a research agenda.

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