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FROM SERVICE SYSTEMS ENGINEERING TO SERVICE IN-NOVATION – A MODELING APPROACH

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Research Paper

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Abstract

Due to the advent of digitization, service innovation has become even more important for both business and service research alike. Current service systems engineering approaches have employed a recombinant perspective that follows innovation mechanisms to leverage existing company resources for new service innovations. Employing these innovation mechanisms is still challenging, since there is little support on how to structure and identify these mechanisms. We propose a model-based service system engineering approach to structure existing resources into one formal model, enabling the formalization of service innovation mechanisms. The formalized service innovation mechanisms allow for a graphical illustration and enable future research to apply functions to analyze how innovation impacts entire or specific parts of service systems. Furthermore, the mathematical model enables an object-oriented value-driven perspective on service systems and is basis for graphical software tools. We contribute to literature by formalizing service innovations and its mechanisms in the context of service systems and by combining concepts of service innovation and service systems engineering. We do so by a) formalizing service innovation mechanisms and b) demonstrating the application of formal service innovations along one specific software implementation case. For practice, the service system model can with simulating the effects of service innovations.

Keywords: service systems modelling; service systems; service innovation; service science; operational service systems; service system model

1 Introduction

Service innovation has become increasingly important for both service research and practice alike, especially in complex environments (Bitner et al. 2015; Patrício et al. 2018). The systemic approach to understanding innovation has recently gained special interest (Beverungen et al. 2018; Chandler et al. 2018b; Lusch and Nambisan 2015; Ostrom A. L. et al. 2015; Wilden et al. 2017). Previous service systems research has primarily been focusing on a processual perspective on how to innovate (Beverungen et al. 2018; Hoeckmayr and Roth 2017) or on describing service systems using conceptual models (Adner and Kapoor 2010; Gawer and Cusumano 2014; van Eck et al. 2009; Zahra and Nambisan 2012). Recent operations management and information systems research on service science has introduced a novel approach to modelling service systems using a formal service system model (SSM) (Li et al. 2018; Li and Peters 2018). However, there has been little research on how to identify service innovations based on the service system model. We propose to apply a model to discover service innovations and provide the necessary information for its exploitation. RQ: *How can service innovation mechanisms be formalized to support its discovery and exploitation?*

To start understanding this question, this article begins with a short introduction of the related theoretical foundation of service innovation (Beverungen et al. 2018; Lusch and Nambisan 2015) and service systems engineering approaches. Next, it describes its conceptual underpinning of service systems as an extension of the service science literature (Maglio et al. 2010). It heavily relies on the work of SSMs, which apply and extend hypergraph theory to model service systems by configuring resources and actors into service objects and then connects service objects with other service objects (Li et al. 2018; Li and Peters 2018). SSM has the advantage that it is multidimensional and thus complex element relationships allow the intuitive modelling of the systems of systems characteristic (Bertalanffy 1968), which coincides with the notion that service systems, such as ecosystems, can consist of subsystems (e.g., independent businesses) to form a value net (Chandler et al. 2018a; Chandler and Lusch 2015). This perspective gives an explanation on innovation as a process (Toivonen and Tuominen 2009), as well as complementing innovation as outcome research (Gadrey et al. 1995), by relying on the SSM's underlying duality of both process (how) and component structure (what) (Li et al. 2018). SSM uncovers how previous service system configurations are provisioned (how) and what resources are required by what actors (who) to realize said system's proposed value. Our research therefore leverages the added knowledge of structuring existing services from a systems perspective into its base components to identify new possibilities of service innovation by means of recombination.

During the conceptual foundation chapter on SSM, we will cite its base definitions and propositions not only to provide a fundamental recap of its underpinning inner working to the reader, but also to lay the foundation for our general proofs on how SSM can model the service innovation mechanisms. The subsequent subchapter describes how service innovation is a form of resource recombination. By applying the recombinant service innovation view, we take on a service systems perspective on innovation. From a service systems perspective, any service innovation is a previously untapped service system reconfiguration (Li and Peters 2018). In other words, the value is realized through services, which is always implemented in a specific service system configuration (Maglio et al. 2010). Hence, finding a new possible service system configuration is a synonym to innovation through resource recombination. This paper will thus use reconfiguration when speaking of service systems and recombination if addressing resources specifically. This chapter lays the groundwork for the following exemplary service systems analysis by introducing five basic mechanisms of recombinant innovation (Beverungen et al. 2018).

First, a short method section gives a more detailed description of how a service systems engineer can employ SSM to identify possible service innovations. Next, this paper gives an example analysis of a simplified software implementation project, starting with a short case description and a step-by-step description of how the SSM helps with identifying resource exploration and analyses for recombination (Beverungen et al. 2018; Srivastava and Shainesh 2015). After presenting a detailed example, the next chapter includes several proofs to show the generalizability of SSM as a means to model service innovation mechanisms. We conclude with a discussion, in which we address our theoretical contribution: formalizing innovation mechanisms and proving SSM's suitability for service innovation.

2 Foundation for Service Innovation

2.1 Service Systems Engineering

Recombinant service systems engineering is a service systems engineering approach that focuses on service innovation. Due to the advent of increasingly complex service systems, (for example, service systems for smart services), many new services are not designed by using top-down approaches (Kleinschmidt et al. 2016). Several new service innovations utilize already existing resources and solutions by third party suppliers, thus innovating by recombination of resources (Beverungen et al. 2018). In this regard, Beverungen et al. (2018) introduced a recombinant service systems engineering approach. The service systems perspective differs from the traditional service perspective. Service systems engineering approaches still rely on a wide variety of existing (semi-) formal modelling techniques (Beverungen et al. 2018; Hoeckmayr and Roth 2017; Peters et al. 2015), such as the diverse set found in UML (Eriksson and Penker 2000), BPMN (OMG 2011), Sakao (Sakao and Shimomura 2007), Petri-nets (Reisig 2018; Salimifard and Wright 2001) and service blueprints (Patrício et al. 2018), to name a few. They all do not explicitly address how to identify and develop service innovation, explicitly meaning the process of dissociation or liquification of resources.

Although service systems engineering (SSE) has become increasingly accepted, the methods utilized by existing modeling techniques only partially address the holistic systems perspective required for service innovations (Beverungen et al. 2018; Böhmann et al. 2014; Leimeister 2015). SSE addresses the service architecture (structure and relationship of SSM elements), the mobilization of resources (focus of this paper) and service interactions (activities of SSM). Common modeling techniques are currently dominated by a process perspective of activities, whereas a structural perspective has not been sufficiently explored. Service systems provide value by reconfiguration of resources and actors holistically (Alter 2017; Böhmann et al. 2014). The process perspective addresses "how" they are (re)configured, while a structural perspective would address "what" elements are (re)configured. Both should be considered to understand and leverage the nature of innovation mechanisms. We follow a different approach because, in practice, processes always change some form of structural representation, usually data. We argue that by embracing the process and structural duality, new possibilities arise, uncovering a more detailed service innovation approach and giving insight into the liquification of resources (Lusch and Nambisan 2015). We therefore differ from modelling techniques by taking a systems perspective and combining both process and structural aspects into one modelling approach.

In summary, the recombinant service innovation perspective already takes on a service systems perspective. It further clarifies how the inner workings of service systems look like by giving it a structure. Yet, current modelling techniques do not suffice to systematically model service innovation mechanisms, since the mechanisms combine structural and processual perspective, thus making it hard to dissociate service systems into its base elements (Beverungen et al. 2018). These mechanisms give a little indication of the inner workings on what is required to operationalize. Therefore, we introduce a service systems perspective. This systemic view requires a novel modelling approach that draws upon a new service system conceptualization, which we address with SSM (Li et al. 2018).

This chapter presented the nature of innovation from a recombinant perspective and presented the service system model (SSM) perspective (Li et al. 2018). Next, we describe how SSM is an underlying approach for a holistic SSE approach towards service innovation.

2.2 Recombinant Service Innovation Mechanisms

To develop a service system modelling concept, it is essential to first understand the basic mechanisms of service innovation. One of the purposes of modeling a service system lies in being able to analyze and innovate, for which the recombinant service innovation perspective is introduced (Beverungen et al. 2018; Fleming 2001). From a systems perspective, this also coincides with service innovation being a reconfiguration of resources (Breidbach and Maglio 2015).

Service innovation is complex (Gremyr et al. 2014). Yet, innovation is seldom based on something entirely new. More frequently, it is based on existing ideas or resources (Wirth et al. 2015). Hence, service innovation relies on already existing elements that need to be combined into recombinant innovation (Cooke 2016). Four basic mechanisms of recombinant innovation have been conceptualized, as illustrated in Figure 1 (Beverungen et al. 2018; Fleming 2001): Dissociation, association, addition and resource recombination. *Dissociation* describes how an existing service is split into related parts to design a new value proposition. These parts, which can be any isolated object of service, is then turned into new value propositions (Gadrey et al. 1995). *Association* describes the design of new value propositions by means of combining any existing resources (Fleming 2001). This also includes resources that have been split up by means of dissociation (Cecere and Ozman 2014). Association also includes employing existing resources to a new context (Toivonen and Tuominen 2009). *Addition* describes how value propositions can be added to each other. This includes adding existing value propositions together or combining them with new value propositions. By taking on the SD-logic perspective (Vargo and Lusch 2008, 2017), the addition of value propositions can also include a specific sequence of value propositions, which is more predominant in value chains typical to traditionally product-dominant sectors such as the production of components. For example, by adding new functionalities or information to a previously produced component, new value propositions can be offered to the customer. The sequence would be first producing the component and then adding additional services to provide a new value proposition entirely. *Resource recombination* explicitly states that resources can come from both internal and external sources (Gallouj and Weinstein 1997). Internal sources include all organization's internal operand and operant resources, such as knowledge and components across business units. However, external resources include all resources from suppliers, customers or any external partners in general. This enables organizations to include resources that are typically not as accessible to the organization, since they are not generated internally. By employing synergies across organizational and individual actors, concepts such as shared resources by means of shared access to resources emerge (Breidbach and Maglio 2015). *Subsystem* stems from the service system characteristic of systems of systems (Bertalanffy 1968). From a holistic systems perspective, and thus taking *dissociation*, *association* and *addition* of all resources and actors into account. Innovation is accompanied by a high complexity and can happen on different levels of *associated* services.

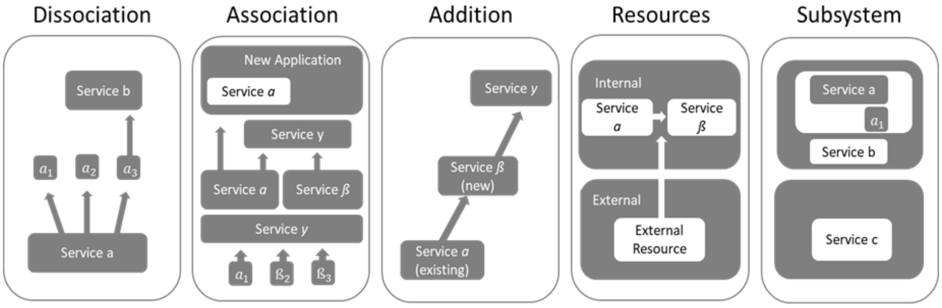

Figure 1. *Question remains how to apply the innovation mechanisms (based on: Beverungen et al. 2017, 2018; Bertalanffy 1972; Breidbach & Maglio 2015)*

These innovation mechanisms are closely related to recent theoretical findings on service innovation (Srivastava and Shainesh 2015). The three service-centric value creation mechanisms are resource exploration, resource combination and value reinforcement. The latter two are inherent in the service system innovation mechanisms, with resource combination being evident and value reinforcement mainly covered by association (Beverungen et al. 2017; Fleming 2001). Resource exploration, however, is sufficiently difficult (Srivastava and Shainesh 2015). This concept is closely related to the value-driven innovation perspective of *resource density creation* using liquification, unbundling and rebounding of resources (Hoeckmayr and Roth 2017; Lusch and Nambisan 2015; Normann 2007), and we propose that this can be achieved by a rigorous analysis of the already existing or alternative service system configurations using SSM.

3 Service System Model as the Underlying Model for Innovation

3.1 Service System Model

Service is not the output of a process but rather the transformation of all input factors into the output factors (Fromm and Cardoso 2015), also known as value proposition (Chandler and Lusch 2015). Service is therefore a transformation process.

All input factors are called resources. Resources can be both human resources as well as things, which are further categorized into assets and materials. In traditional goods-dominant logic, a typical manufacturing process consists of resources that are transformed, such as raw materials, plus factors, which are needed for the transformation but are not transformed by themselves, such as tools and workers (Fromm and Cardoso 2015).We assume that the types of resources depend on the value propositions agreed upon. However, even operant resources are input factors for a transformation process that creates the desired result. We therefore acknowledge the operand and operant resource perspective and integrate both types of resources into our understanding of service. Furthermore, we define the input resources as a set of resources that can have a finite amount of each resource type, such as assets, materials or people etc. Value of service is only realized during its use, also referred to as value-in-use (Vargo and Lusch 2008). By integrating operand and operant resources, actors transform all required resources to realize the value proposition promised before. Since different actors are part of the service transformation and the value proposition is agreed upon by at least two actors, the realization of value is sometimes referred to as co-creation of value. Complimentary to our service as a transformation process perspective, research on service science regards the service system as its basic unit of analysis (Böhmann et al. 2014; Leimeister 2012; Maglio and Spohrer 2008).

Constituent factors of service systems are actors utilizing operand and operant resources (Maglio and Spohrer 2008), whose activities describe the "transformation process". An actor can be individuals, teams, organizations, cross-organizational business units or even software systems, if they mobilize the required resources. This mobilization includes conceptual actors that describe any additional restriction on the resource configuration. Recent research also revisits the importance of value propositions and engagement of service systems (Chandler & Lusch 2015), in which organizations seek to find the right constellation of actors ("who"), which enables actors to find the correct resources ("who" and "with what") for a specific context ("when") to co-create value (Chandler & Lusch 2015, p.1).

Complementary to the systems perspective are the recombinant service innovation mechanisms. They further describe how elements of a service system can be split and reused for service innovations.

3.2 Service System Definitions

Since service systems use resources as input factors, we define a set R with $r \in R$ as all required forms of resources. However, service systems also require actors (Breidbach and Maglio 2016). We define actors as a set A with $a \in A$ representing an actor required for the transformation process. A service system for a specific value proposition requires both actors and related resources. We called a pair of actors and required resources service objects and define all service objects as a set O with $o \in O$ being a single service object. Formalized, a service object is a tuple of the required resources and the required actors specific to a value proposition.

Therefore, service objects are the subject matters of service systems, which are defined in a specific context as input sets of respective outputs. Let $O \neq \emptyset$ be the set of required service objects of any service-driven organization, with $o \in O$ defined as a service object. Thus, a service object is a tuple consisting of resources and actors. Formalized, service objects are defined as follows: We apply the hypergraph theory-based service system model perspective to define our service (Li et al. 2018; Li and Peters 2018)

Definition 1 – Service Object: A finite non-empty set O with tuple of (R, A) is called service object where R is a finite set of resources with $R=\{r_1, r_2 \dots r_n\}$ and A is a family of subset actors of R with $A=(a_i)$ in which $a_i \subset R$ and $R=\bigcup_{i=1}^{n} a_i$ for $i \in \{1,2, \dots ,n\}$.

Definition 1 shows that service object O is a hypergraph (Berge 1989). Therefore, service objects O with tuple (R, A) are hypergraphs of service objects, which represent all inherently possible value propositions of service systems. In other words, the potential of a service system can be realized by reconfiguring its resources and pairing it with a suitable actor. Additionally, Hypergraph theory has extensively focused on its sets of vertices (Bretto 2013), whereas we put equal importance to its hyperedges. Due to the roles of actors in service science, we inscribe the semantic meaning of actors into hyperedges. A service object includes both actors and resources, both paramount for the realization of the service.

The service object constitutes the necessary input resources R, which actors A require, before an actor can provide value to a service consumer. In other words, it represents the potential value an actor can provide to a potential consumer. For our service systems perspective, the subject matters are different types of resources: operand resources, operant resources and actors. The vertices of a hypergraph O_i represent resources. Hyperedges of O_i represent actors, whereas we define the combination of required actors and resources as service objects. In traditional hypergraphs, they can have a relationship by intersections of their hyperedges. Definition 2 will cover how we create relationships between hyperedges. However, it is not possible to map entire hypergraphs towards other hypergraphs or toward elements of other hypergraphs. This is a problem, since there are use-cases in complex service systems that need this information (see application and demonstration). To accommodate the relationships of nested service systems while retaining the information of the relationships of these "super" service system with other "super" service systems and to define the transformation process, we need to expand upon the existing definitions of hypergraphs. We do so by introducing an approach to mapping a service object to other service objects with ψ. In the following section, we will define how to map hypergraphs to other hypergraphs. This enables us to model service systems with hypergraphs.

Definition 2 - Service Activity: *O* is a finite non-empty set of service object and *O* is a hypergraph of service objects. A mapping $\psi(\psi^-,\psi^+)$ with $\psi: O \times O \rightarrow Boolean$ where $O \times O \subset 2^O$ is called a service activity of service objects.

Service activities for service objects are represented by the binary mapping between different service objects. One service object is seen as input, whereas the other is seen as output, while the transformation process is the service activity that makes the transition from one service object to another. The mapping ψ is a tuple of (ψ^-,ψ^+), which is a directed or counter-directed mapping of hypergraphs. In this paper, ψ^+ is used for the directed mapping, accompanied by drawing an arrow line.

Definition 3 – Service System Graph: We define a finite non-empty set R of resources, a finite non-empty set A of actors and set O defined as tuple (R, A) as hypergraph of a service object, Ψ set of value creation functions as service activity, then the tuple SSG(R, A, Ψ) is called the service system graph, representing the service system; the value creation function is defined as follows:

(i) Ψ: $\Psi(O) \rightarrow O$ with $\bigcup_{i=1}^{n} \psi_i(o)=O_{output}$, where $o \in O_{input} \subset O$ and $O_{output} \subset O$ and $\exists\ o \in O\ |\psi^-(o) \cap \psi^+(o)= \emptyset$ and Ψ^* be called associated function with:

(ii) $\Psi^*=\Psi^K \circ \Psi^L$ where $\Psi^*, \Psi^K, \Psi^L \subset \Psi$. The element function $\psi \in \Psi$ coupled with a service object is called value proposition with:

(iii) $\psi(o)=o'$, where $o \in O_{input}$ and $O_{input} \subset O$, $o' \in O_{output}$ and $O_{output} \subset O$, $\psi \in \Psi$.

Function $\Psi^-(O)$ defines which service objects are required as input factors, and function $\Psi^+(O)$ defines the output service objects. ψ^* defines the association between two activities. The service system is a family of subset service objects (Berge 1989; Li and Peters 2018). Thus, to be precise, a single service object itself is also a service system. Additionally, we briefly list three propositions that are required for formalizing and modeling the service innovation mechanisms. The detailed propositions are subject to a different research paper (Li and Peters 2018).

Proposition 1: Service objects can be shared for different value propositions. **Proposition 2:** Service objects can be provisioned by different service objects. **Proposition 3:** Service objects can be provisioned by service objects and simultaneously be a service object, which provisions another service object.

3.3 Application in Service innovation

Service innovation and service systems are closely interrelated (Beverungen et al. 2018; Hoeckmayr and Roth 2017). Especially recombinant service innovation takes on a strong service systems perspective, in which its service innovation mechanisms describe how innovations are formed within a service system (Beverungen et al. 2017). Yet, this paper conceptualizes service systems from a service system model perspective. Thus, we employ the service system models upon conceptual knowledge of service systems engineering (Li and Peters 2018). This view differs slightly from conventional approaches, since it only refers to its constituent elements, as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**. Hence, SSM defines the system borders of the service system, and by first modelling the existing service system, the model captures both the service architecture (holistic service system model) as well as its service interactions (activities) (Böhmann et al. 2014, 2018). Furthermore, using SSM, service innovation mechanisms can be used as a means of analysis rather than for descriptive and explanatory purposes (Fleming 2001). By modelling a service system using SSM and then subsequently utilizing its mechanisms, new service innovations can be identified and modelled within SSM.

Additionally, SSE addresses resource mobilization (Böhmann et al. 2014), which is comparable to the innovation mechanisms (Beverungen et al. 2018; Fleming 2001) and the resource density perspective of resource unbundling and liquification (Lusch and Nambisan 2015; Normann 2007). By applying SSM, we are not only able to dissociate resources as such but do it while in its contextual configuration, which exists in the service system model.

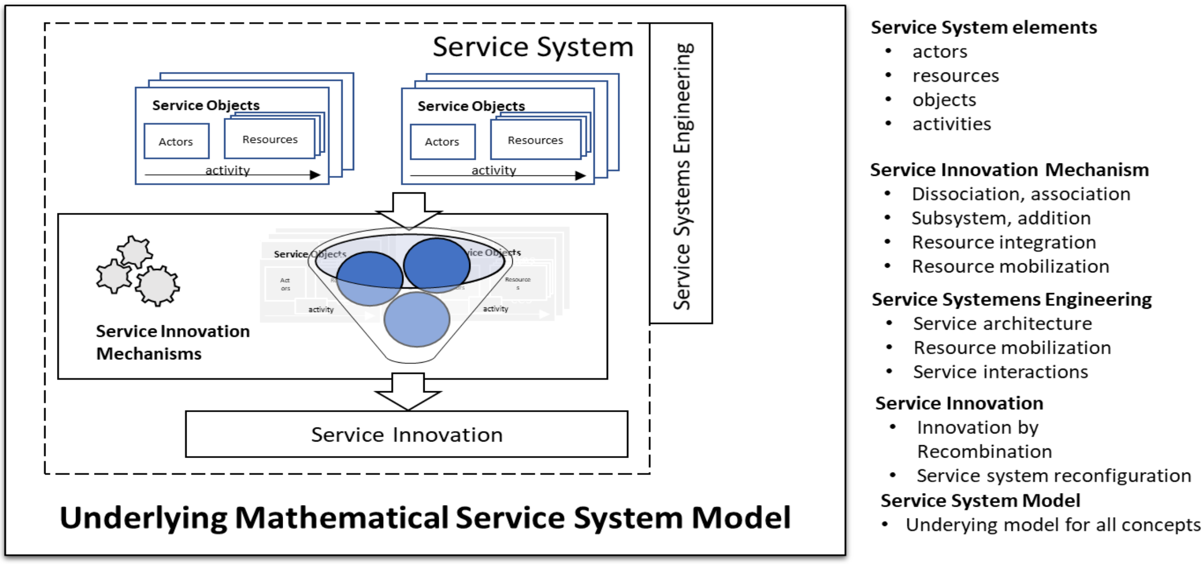

Figure 2. Service System Model: Underlying mathematical model for Service Systems

SSM is a modelling tool based on mathematical models. Its user interfaces are represented by graphs, explicitly mathematical meaning of graphs. We can use the rules of graph theory to calculate, decompose and simplify the graph. For example, the operation of induced paths to find the most suitable path. The relationship between the two sets of resource combinations is represented in SSM by graphical edges. This edge is not only a description of the input and output relationship between them but it is also endowed with the meaning of the function relationship. This is also a reflection of what differs from other model tools. The function can be used to dynamically assign the value for resources involved in combination with activity to provide a quantitative decision basis for the selection of resource combination and the construction of sub-structure. SSM allows a combination of resources to be defined as a new resource, further applied on a model basis that allows sub-diagrams of substructure and mathematics to be defined as a resource. This reflects a modular concept implemented within SSM. This knowledge can be leveraged to go a step further and apply all other innovation mechanisms to find and create new innovations in the form of service system reconfigurations (Breidbach and Maglio 2015).

In summary, we first employ SSM to model service systems to identify and refine the status quo of a service system (Li et al. 2018; Li and Peters 2018). Then, by analyzing the service system, we dissociate possible configurations (Beverungen et al. 2018; Breidbach and Maglio 2015) while further employing the innovation mechanisms to unbundle resources (Lusch and Nambisan 2015; Normann 2007). Afterwards, the resources could be recombined, and thus mobilized (Böhmann et al. 2014). This can happen, for example, by analyzing shared resources (see case example below) to reconfigure the service system into service innovations. The process of identification, refinement, analysis and recombination also reflects the structure in how we present our case. Particularly the implementation of the steps of the above innovation mechanism is achieved in a mathematical sense, and it is based on the definition of SSM according to the rules of graph theory. Their applicability and rationality are mathematically proven. Furthermore, we propose SSM as an underlying model integrating all three research concepts of service systems, service systems engineering and service innovation.

4 Formalizing Innovation Mechanisms with SSM

In the previous chapter, we have shown how the service system model perspective can be applied for identifying existing service system configurations and thus help in identifying or even operationalizing service innovations. We now focus on the generalizability of modelling each innovation mechanism using the previously listed definitions of SSM.

4.1 Association:

Association brings different value propositions together to create new services. This can be accomplished by following SSG's definition 2 and 3, based upon which SSGs can be seen as mappings between hypergraphs. Hypergraphs can thus be seen as a "network" of sub-graphs as well. A join of subsets is therefore still part of the hypergraph. In other words, service objects can be joined together. Thus, the association between service objects and service systems are allowed.

<u>Proof</u>: According to the SSG definition, existing service Object $\exists o_i \in O$ with $\bigcup_{\exists i} \boldsymbol{o}_i \subset O$ and $\exists \psi_i \in \Psi$ with $\psi^* = \psi_j \circ \psi_{j+1} \in \Psi$ for $j \in \mathbb{N}$ and $\psi^*(o) \in O$, so $SSG_{sub}(o_i, \psi^*) \subset SSG$.

4.2 Dissociation:

Following definition 3, a service system graph can be dissociated into sub systems SSG_{sub}. Dissociation is a very commonly applied method to analyze complex systems. SSG is very flexible and accommodates this requirement. As mentioned above, SSGs can be seen as a representation of sets and the merging of sets is allowed (association). Thus, a separation of sets is still a set. Therefore, both merging and separating the subgraphs of a hypergraph still results in a graph. In tandem with the understanding association, dissociating SSGs is also valid.

<u>Proof</u>: Under definition 3, considering the association, let $Sub_1 \subset SSG$ and $Sub_2 \subset SSG$ with $Sub_1 \cup Sub_2 = SSG$, then $SSG \cap Sub_1 = Sub_2$.

4.3 Addition:

Our modelling approach allows the addition of one or multiple value propositions. Since one focus of service science is the value proposition, one of the strengths of SSG lies in the combined modelling of required activities and service objects. A value proposition in SSG describes the resulting value after an actor acts upon all required resources, thus co-creating and realizing value. Value creation thus is defined by tuples of service objects and activities. It is therefore clear that addition is a basic rule for modelling entire service systems. Proposition 3 shows how a sequence of co-creation can be required to realize a single value proposition. In other words, proposition allows the downward addition of service objects and activities, like supply chains.

<u>Proof</u>: Based on proposition 3, let a service object $o_1 \in O$, $a \in \Psi_{after}$ with $\Psi_{after} \subset \Psi$ and $b \in \Psi$ with $\Psi_{before} \subset \Psi$, then o_1 is only realized through the addition of a and b.

4.4 Recombination:

Resource recombination is the basic principle on which SSG is based upon, since it is synonymous to the concept of resource reconfiguration. Resources are fundamental elements and the foremost element we are concerned with. From set theory perspective, we view resources as sets to be arbitrarily combined, not differentiating whether resource sets belong to internal or external actors. Resources can hence be recombined as the situation requires and the modeler sees fit. Since resources are constituent elements of a service object, its recombination is essential for SSG.

<u>Proof</u>: Let the recombined resource subset R_i with $R_i \subset R$, then following definition 1, it is possible to recombine SSGs， because $\bigcup_{\forall i} R_i = R$.

4.5 Subsystem:

A service system of a service system is allowed in SSG modelling. The phenomenon of systems in systems occur in many applications. The addition is one form of how service systems consist of subsystems. This is based on how a single resource of service objects can be used for a different activity, thus making it a service object. The service object helps to structure the system of systems phenomena using both the sequential and structural characteristics.

Proof: Let o* be the sub system of SSG and o*∈O, then according to definition 1, a service system of service systems is valid.

By first validating that SSM model service innovation mechanism in general and then demonstrating how SSM can be utilized using a simplified software implementation project, we show its applicability for modelling service systems and identifying potential service innovation as recombination (Beverungen et al. 2018; Hoeckmayr and Roth 2017) in the form of novel reconfigurations.

5 Service Innovation Case

For the purposes of demonstrating how the different service innovation mechanisms can be systematically identified using the SSM approach, this section introduces a simple "CRM implementation" project as an example case. Based on our software implementation research project with the mid-sized energy provider Enervate, we assume five key services as necessary aspects for accomplishing a successful implementation: (1) someone needs to setup the CRM software system on any form of hardware; (2) users require tailored training; (3) conceptual work and configuration, including testing, is essential; (4) user support has to be available to users; (5) expert business unit members need to contribute their critical domain-knowledge. Using this simplified CRM implementation project case, we illustrate how SSM is useful for modelling innovation mechanisms and show how combining process with data structure modelling views' added dimension of information uncovers new analysis potentials. ITCon is a total solution provider for CRM systems, who is currently working for Enervate. Enervate struggled with whether they should outsource the entire project to ITCon or whether some parts can be done by other long-term key partners that might be more cost-efficient. They task a service system engineering team to assess possible options and analyze the situation by applying a service system perspective. We start with an as-is identification of key objects, refine the model in more detail, then start to analyze alternative service system configurations to possibly identify more cost-efficient or useful constellations. Next, we go from object level to resources and compare the different configurations. Based on the shared resources, they are recombined into a new system configuration, which can then be compared to the previous two offerings.

Identification: The analysis starts with a high-level initial assessment of the main service that is considered essential by the customer - in this case the project leads - and that are required for a successful post-implementation phase. We call the final service turn-key service, metaphorically giving the keys to a CRM solution to the board. However, the company can decide how it wants the project to be configured. The focus was put on the previously mentioned five factors (1) – (5) by applying SSM to ensure that the system was technically setup and integrated, enough testing and change management was done, sufficient training to users and IT support services are provided and that the users exchange their knowledge sufficiently. The high-level service system is shown in Figure 3 with each corresponding responsible actor omitted due to brevity. The figure shows the graphical representation of each service system and includes a short legend with corresponding constituent element descriptions.

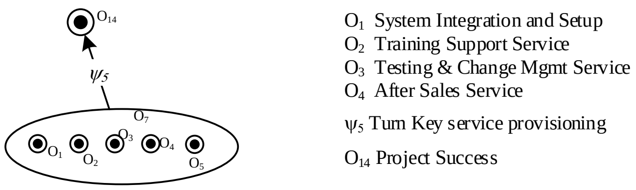

Figure 3. Initial Service System model G_0

Refinement: There is not much insight provided by the simple service system model. However, by applying the *subsystem mechanism* and knowing that service objects can be the results of *addition*, each service object's dependencies are identified by asking the question who else than the core team providing the services needs to bring in their knowledge or skills. A quick assessment shows three more parties: 1. ITCon and their IT consultancy department (O_{13}). After further inquiry, ITCon has two services it markets: O_{13}, a total solution, which is comprised of setting the system up, training the staff, managing testing and changing initiatives and all additional service support. In a skimmed down version, ITCon can also just provide the initial technical system setup and the staff training (O_6). Additionally, Enervate has a long-term relationship with another IT-consultancy, which is led by a former Enervate IT department employee.

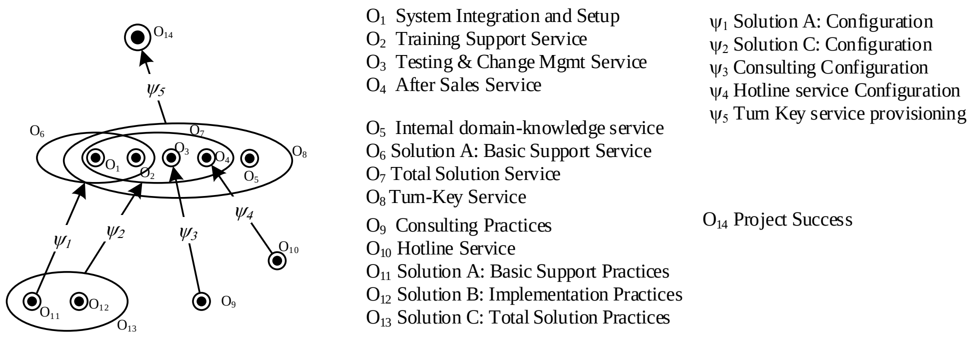

Figure 4. Finding Dependencies to model SSM G_1 (actors omitted)

They have extensive knowledge and good practices that they could leverage in order to take over the implementation and testing services, which also include the challenging organizational change issues of Enervate O_9. Lastly, Enervate has a long-term IT-support contract with an external partner, which also promises to provide telephone after-sales support for this specific CRM system O_{10}. Corresponding activities are named configuration, since they need to configure their own operant resources according to the specific organizational context. The resulting SSM is illustrated in Figure 4.

Analysis: Once the initial service system model has been established, the analysis begins. In this example case, we try to explore possible service innovation mechanisms. This is achieved step by step by first applying the *dissociation* and *subsystem* mechanism on the entire service system to identify two possible service system configurations. Both configuration (A) and (B) achieve the same goal, yet, in our case, are mutually exclusive. In (A), Enervate completely relies on ITCon as a total solution provider to take the lead on the implementation project as a value proposition (O_{13}; Ψ_2), while also having to involve the CRM users (O_5). (B) relies on ITCon's basic support practices (O_{11}). The rest is provided by other existing partners.

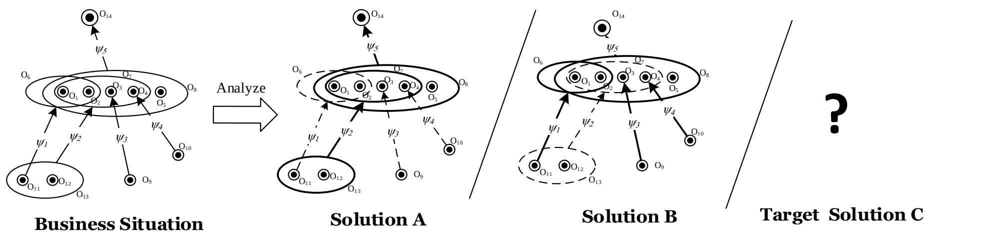

Figure 5. Step 1: Dissociating a service system G1 into subsystems (A) & (B)

As Figure 5 shows, each configuration (also called solution) is a subsystem of the initial SSM and can be dissociated from it if required. However, due to Enervates constant flux of implementing new software systems and its strategic reliance on external providers, it is considering incorporating some capabilities inhouse. Therefore, it wants to see if there is a possibility to use the CRM project as an opportunity to build new capabilities within their own organization and move away from the traditional carveout and external solution providers and start building up its digital capabilities. The question therefore arises whether there is a fitting third target configuration.

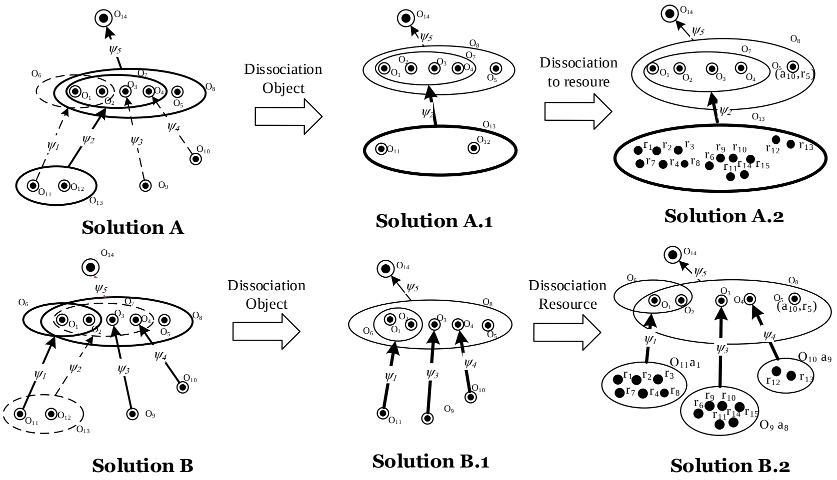

Figure 6. Step 2: Analysis of Resources using Dissociation

As mentioned, service system model G_1 incorporates two alternative service system configurations, forming two distinct "paths" to the project success. Therefore, we *dissociate* configuration (A) and (B) each into a subsystem (A.1 and B.1). Then, we further *dissociate* service objects into their *resources* (see Figure 6).

The SSM thus zooms from an object-level view into a resource-based view to uncover potential similarities between service objects that were not evident from an object-level view. By comparing A.2 and B.2, one can assume that they have great commonalities due to their shared operand and operant resources. This is the reasoning for dissociating the G_1 into C.1 and then it gets obvious in Figure 7, based on the resources, that the single objects O_9 and O_{10} can be integrated into subsystem O_{13} because of $O_{12}(R)= O_9(R) \cup O_{10}(R)$.

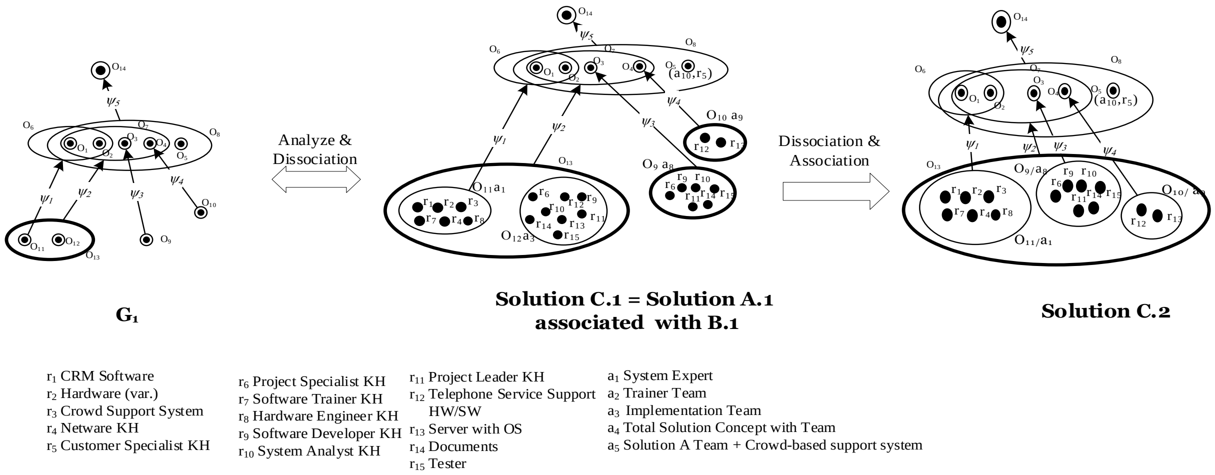

Figure 7. Step 3: Resource Recombination after Dissociation

Recombination: Lastly, we associate C.2 into C.3 and the final reconfiguration is the resulting innovation, as shown in Figure 8. The main difference is that the O_{new1} is a new service object, since the actor changed – in our case, an inhouse team. This leads to a new relation Ψ_{new} to the other two required service objects O_3 and O_4. In other words, this new service system configuration must now undergo the operational analyses (e.g., cost analysis). Each of the three service system configurations can thus be compared to each other.

Although not in the scope of the paper, subsequent analyses can also be done using the identified SSM configuration. For simulation-based analysis, different functions can be attached to Ψ. For example: to assess simple costs of solution A and B, one can add total costs of all activities for solution A and compare it to the total of B. The individual cost structure relies on each activity. The activity uses a function that depends on both the actor and the required resources. The actor is essential, since, depending on the actor, they might require fewer resources.

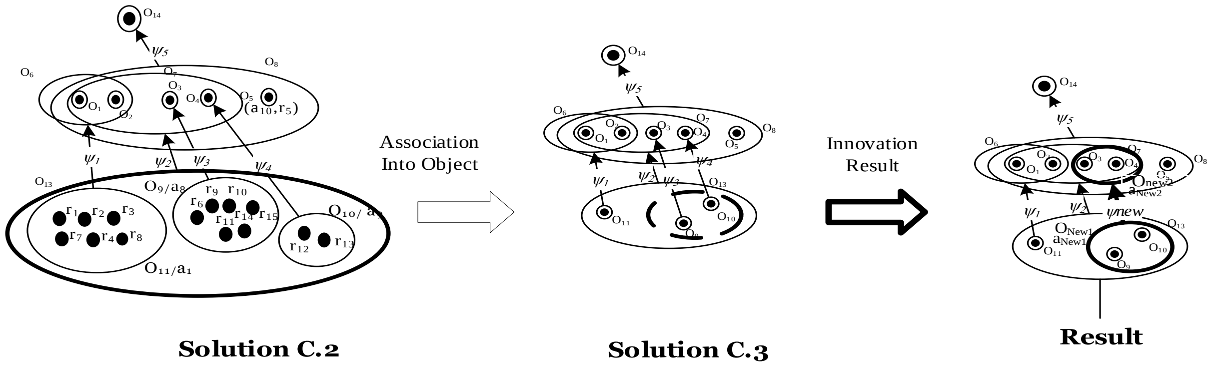

Figure 8. Step 4: Innovation through Recombination

In conclusion, by relying on the detailed service system model, the model can provide a high detail of information relevant to identifying further possible system reconfigurations, also called service innovations. Typical conceptual models focus on either a static perspective (e.g., Bill of material or data model) or a dynamic perspective, such as with semi-formal business process modeling techniques. However, leveraging the advantages of SSM, the model can capture the relationships between all resources and actors using service objects. Thus, a new service object O_{new1} was identified. For further exploitation of the newly discovered service innovation in the form of a service configuration, the focus needs to be put on $\Psi_{new.}$ Next, we discuss the general applicability of SSM for the service innovation mechanisms.

6 Discussion and Future Work

SSM is a model based on graph theory and describes the relationship between resources and activities. As input and output of activities, all necessary resources are explicitly modelled, resulting in integrated input/output structures. By applying SSM, we show that service innovation mechanisms can be structured and made explicit. The model is also a starting point to identify new innovation possibilities by structuring what resources and objects are currently available. Future research could include service engineering methods, such as recombinant service systems engineering to leverage existing service system models (Beverungen et al. 2018).

Currently, to address added layers of information, enterprise applications apply coloring of simple graphs (Saitou et al. 2002) or adding attributes in data models (Alter 2012) to meet the needs of system engineers. We provide a more elegant solution directly on a new service system model layer. We predict that systems, which run on service system models, will lead to different opportunities, largely regarding interoperability.

The resulting, post-innovation service system, which includes the service innovation, is a normalized SSM structure, thus enabling relatively simple data exchanges with existing data structures, due to both being based on mathematical foundations (e.g., relational databases are based on relational algebra). SSM describes the relationship of actors, resources and objects within its service system structure, which can be directly translated to relational structures commonly found in modern databases. Future research is thus able to develop graphical modelling tools with a database interface. This illustrates how resulting service innovation leverages SSM to model service logic and directly generate application-readable data models. The new, post-innovation SSM includes mappings that are essentially used for functions. Depending on the context and purpose, they enable simulations running on functional operations (Li et al. 2018). This provides service engineers with dynamic experimental data and allows different service system paths to generate data that can be employed to make prototypical service innovations more persuasive. In practice, our model can thus use pre-existing data to build the SSM and service innovations.

Current ways to model the complexity of real-world scenarios and the complex relationship of required data is hard to do, because they can only model relationships on a two-dimensional plane in a mathematical sense. Using models that run on simple graphs, the complexity of real-world service system relations is therefore often hard to capture. BPMN and UML are two commonly used expressive modelling tools, and their emergence is largely attributed to its application for requirements engineering in practice. From a mathematical view, these modeling approaches are rooted in simple graphs and can therefore only express a 1:1 relationship between nodes with (directed) edges. To add additional information, colorings and labels are employed, whereas SSM can rely on its system in system characteristics of hypergraph theory. We leverage said added expressiveness to model all service innovation mechanisms and prove its generalizability. This mathematically-grounded approach is privy to the future development of tools that enable illustrating service systems and innovations and directly transferring it into corresponding data structures. This allows manipulation from a mathematical standpoint. For example, it is possible to transform complex graphs into simple graphs. These substructures can in turn be redefined to reduce complexity according to the actual usage condition. Given that operations are correctly defined as functions, all derived models are complete and accurate, if they stay within the mathematical rules. SSM strives to use the advantages of canonical expression to provide persuasive modelling capabilities for service innovation.

Also, service systems are responsible for the service provision, which is responsible for the *density* of other service systems (Normann 2007). Density creation as a process of rebounding unbundled and liquefied resources and reconfiguring them into the service system (Lusch and Nambisan 2015) is equivalent to service innovation (Vargo and Akaka 2009). We advance its understanding using the SSM by configuring service objects. Also, contrary to other service systems engineering approaches (Hoeckmayr and Roth 2017), we propose that increasing *service object density* is more important than just resource density, since objects exist with value in mind. Service objects have a form of high-cohesive value potential and should be explored further as a means of pattern recognitions. The mathematical model thus can apply different functions to explore a wide assortment of uses, such as cost, profitability and time analyses for service innovations. Future research could also explore how SSM can be applied to a recent finding on multi-level service system design. Especially its research integration patterns could be paired with SSM's system of systems characteristics to analyze service innovation mechanisms (Grotherr et al. 2018).

We demonstrate how SSM can be an underlying model and tool for integrating concepts from SSE, service innovation and service systems and apply it for operational purposes and argue for future work to apply it to information systems for services, comparable to ERP systems for production.

7 Conclusion

This paper contributes to service literature by formalizing service innovation mechanisms using SSM, which can be used as a modelling approach for service system engineers. Potential service innovations can be modelled with a graphical representation, analyzed and embedded into pre-existing service systems to illustrate or simulate its effects. It starts by introducing recent service systems engineering approaches and recombinant service innovation concepts. Followed by a short recap of the service system model, the paper continues to present its main contribution: its formalized service innovation mechanisms. We show that SSM can be a suitable model to structure any service system to recombine resources into a service innovation, which is the basis for its discovery and exploitation. The main contribution of this article therefore lies in the formalization of service innovation mechanisms. The secondary contribution lies in providing a mathematical theoretical foundation for the development of modeling tools for service systems. Future research could both develop and benefit from modeling and analysis tools that are based on SSM because they provide a basis that ensures high interoperability on the data layer and model businesses holistically as service systems.

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