Towards an Integrated Approach for Modelling Product-Service Systems: Status Quo and Future Challenges

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Abstract: Product-Service Systems (PSS) are a well-established approach that holds great promises for sustainable business success. However, continuous changes such as technological innovations constitute novel challenges for the development and the offering of PSS. As these challenges become more and more diverse and complex, single companies, especially SME, are often not able to handle this level of complexity and involve further multidisciplinary expertise in PSS design. While prior research mostly focuses on a tighter integration of the product and service domain, there is a lack of integrated approaches that consider even further disciplines like software, mechanical or electrical engineering. Accordingly, this study aims to explore how conceptual models such as process models can be applied as a basis for combining various domains to contribute to the development of new PSS. Therefore, we specified corresponding problems and challenges that motivate our work and report first results of our research project.

Keywords: Product-Service Systems, Conceptual Modelling, Method Engineering.

1 Introduction and Problem Awareness

Product-Service Systems (PSS) typically comprise bundles of products and services in order to fulfil individual needs from customers [BAI07] [LG08]. In doing so, PSS aim to transform businesses from a product-dominant to a service-dominant paradigm [VL08]. The customized combination of tangible and intangible components contributes, for example, to enhanced differentiations, reduced plagiarism, and increased competitive advantages [LG08]. However, constant technological improvements (e.g., Cyber-Physical Systems) and booming digitalization as well as more complex customer demands pose fundamental challenges for the development of PSS (e.g., [Ha18] [Va12]).

Exemplarily, car sharing business models have become an appropriate strategy to satisfy mobility needs in the form of a PSS [Wo15] [SBK17]. Here, it can be observed that besides products and services an increased amount of software and technology-related components (e.g., sensors to locate a vehicle) are implemented. In addition, electric vehicles are used more frequently, which has severe impact on the entire PSS (e.g., infrastructure). This example demonstrates that multiple disciplines are involved in PSS

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development [Be12]. Each discipline develops PSS components on their own [Be11], which are mutually interrelated with other components. Accordingly, all stakeholders have to synchronize their individual processes to allow creating integrated PSS. As especially process models can act as a combining and controlling unit between different perspectives and support coordination of actors, this might act as an appropriate basis.

For the development of PSS, multiple modelling methods have emerged in the involved disciplines as an integral means to conceptualize and specify each component in form of (semi-)formalized models. Modelling methods have been a valuable asset in PSS, and the demand and the development of adequate methods has been frequently explored in recent years [Mo16]. However, up to now only few studies addressed an integration of different PSS disciplines from a modelling point of view (besides product and services), although a tight synchronization of discipline-specific development processes is required for interdisciplinary PSS development. Most of the presented approaches in literature are limited to the integration of a single discipline (e.g., software engineering [Be11]), and thus do not consider methods from each discipline along the PSS development. This, of course, hampers the overall efficiency and quality of PSS development, since a distinct conceptualization of PSS components in each discipline facilitates misunderstandings and communication errors, increases the development complexity due to model translation efforts, and prevents co-creation and the seamless exchange of knowledge from all involved fields [Va12]. On the basis of the stated reasons, the primary objective of our research project is to explore how modelling methods and resulting conceptual models can act as an interface to link various disciplines across the PSS development process in order to provide a shared comprehensibility and coordination between multiple disciplines. Hence, our research is guided by the following key question: *How to design an integrated modelling approach allowing multidisciplinary design of PSS?*

To pursue this goal, we carry out a method engineering (ME) study in which we iteratively design and evaluate an integrated modelling approach with respect to the multidisciplinary development of PSS. We aim to contribute to the knowledge base by investigating requirements and modelling techniques from a wide range of domains to ensure that no design relevant information will be lost, with the long-term objective to achieve an integration of modelling methods of disciplines involved in PSS.

2 Research Background

In research and practice, a lot of work has been spent on planning, modelling and developing PSS intuitively and efficiently. Similar to other modelling techniques (e.g., information or process modelling), several approaches were published either distinctively or integrated (e.g., [Bo16] [Mo06] [Pe15]]). Often, the process dimension plays an important role in PSS development as it has the potential to integrate diverse dimensions, represents a core part of the system and can be used for measuring the productivity, e.g. the combination of BPMN and Service Blueprinting [Pe15].

Since the adaption of PSS progressed, more disciplines and therefore more components require consideration while developing PSS. For instance, Nguyen and Stark [NS17] name software as an important module. Berkovich et al. [Be11] present a requirements engineering approach for PSS by analysing also product, service and software engineering approaches and their integration. Spath and Demuß [SD06] even go further and present a development method for PSS considering service, production, software, electrical and mechanical engineering. A generic approach is presented by Welp et al. [We18] who argue that industrial PSS (IPS^2) consider any combination of product and service shares. They present a model-based approach to support an IPS^2 designer generating heterogeneous IPS^2 concept models in the early phase of development. The approach allows combining multidisciplinary solution elements on arbitrary levels of abstraction from different development perspectives. According to Vasantha et al. [Va12], several techniques have been used for PSS modelling like UML, SADT, Functional Analysis, BPMN, and SysML. However, if further models are required to represent all stakeholders needs, they also have to be integrated [Va12].

3 Research Design

Primary objective of our study is to design a modelling approach (describing conceptual structures and representations) that integrates different existing modelling techniques from relevant domains within PSS development. To this end, we particularly draw on established concepts from ME [Br96]. Due to an increased complexity and diversity in IS research and practice, the need for Situational ME, the individual, domain-specific design of methods that are tailored towards certain situation and individual preferences, continues to grow. ME is a discipline that captures approaches to design, construct and merge methods and techniques to support IS development [Br96].

As suggested by several ME approaches, the examination of a problem, the motivation of the purpose of a method and the search for existing methods are followed by three basic strategies for method design: First, reusing existing methods (i.e., choose methods and adopt them to a new context). Second, tailoring existing methods (i.e., slightly modify/recombine methods or constructs). Third, developing new methods (i.e. engineer completely new methods from scratch). In this paper, we focus on the second strategy, tailoring and recombining existing methods to create a new approach (Fig. 1). This strategy is particularly suited for the purpose of our research for two reasons: First, each discipline involved in PSS development has already established modelling methods in place that capture domain-specific knowledge. Thus, a reuse of such languages facilitates applicability of an integrated method across all disciplines. Second, a new modelling method poses additional challenges on their users like cognitive effort to learn and apply the method. Considering the existence of already established methods, a new development from scratch might face acceptance problems. Thus, by following the chosen strategy we build on techniques that are already well-accepted in several domains and are able to integrate existing knowledge from different stakeholders efficiently.

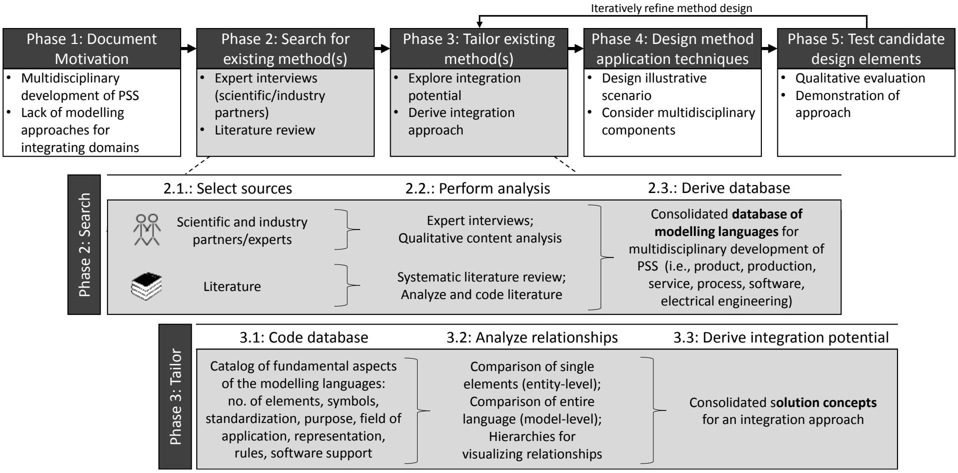

Fig. 1: Research design for an integrated PSS modelling approach (based on Mayer et al. [Ma95])

4 Current Results, Research-in-Progress and Challenges

In the following, the first three phases of our design (Fig. 1) are described in more detail.

Phase 1: document motivation. Due to a current deficit of integrated approaches for PSS, this study explores how modelling languages might provide a shared understanding and coordination between multiple disciplines (cf. Section 1 and 2).

Phase 2: search for existing method(s). For gathering a useful set of modelling techniques, we conducted expert interviews (i.e., five scientific partners as well as 18 industry partners from diverse domains such as software development, steel production and mobility) and an extensive literature analysis. We consider a person an expert due to her/his expertise in a certain domain and not because of the particular modelling skills. During the interviews, we focused on general challenges regarding PSS modelling as well as on concrete models and modelling languages that are used (for details refer to [Ha18]). By performing a qualitative analysis of the interview transcripts and the literature (i.e., coding concrete modelling languages), we build a consolidated database that comprises 44 languages from the following domains: *product-oriented* (n=6, e.g. Design Structure Matrix), *production-oriented* (n=5, e.g. Causal Loop Dia.), *service-oriented* (n=12, e.g. Service Blueprint), *process-oriented* (n=8, e.g. EPC), *software-oriented* (n=10, e.g. Use Case Dia.), and *electrical-oriented* (n=3, e.g. Circuit Dia.).

Phase 3: tailor existing method(s). We first explored the identified modelling languages by analyzing fundamental aspects of the languages such as standardization, fields of application, and modelling rules (with the help of related literature and the languages itself). For representing the results, we build a fact sheet for each language in our sample including the fundamental aspects as well as an example to allow discussing the results with involved persons (e.g., our partners). Next, we analyzed dependencies (e.g., similar elements, representations, and purposes) between modelling languages from a certain domain (intra) as well as from different domains (inter), and created a structured visualization in form of hierarchy-trees. For comparison, we differentiated two main perspectives: First, single elements/entities of a modelling language (i.e., detailed level), and second, entire purposes of modelling languages (i.e., abstract level). Currently, we are finishing the representation of these dependencies, derive potential solution concepts, and discuss our findings with researchers from different domains to early verify results.

As a first insight, especially modelling approaches from electrical engineering are often very specific and elements (e.g., diode) do not initial fit on corresponding elements of other languages. Thus, we are investigating whether a joining approach is needed which allows collocating different model parts/modelling languages to best fit an individual PSS configuration. Nonetheless, therefore an ‘umbrella’ has to be specified that ensures possibilities of integrating diverse elements, for example: configurable building blocks or competence modelling (e.g., which competencies are needed to offer a certain PSS).

Conclusion and Future Research

For future research, we are planning to design illustrative scenarios to demonstrate the applicability and usefulness of our approach as well as discuss the results with experts from industry and scientific partners. In doing so, we aim to verify whether different domains are adequately integrated, and of course, if the approach allows efficient and effective construction of new models. As our research design is limited to literature and expert statements, we further plan to explore (PSS) modelling tools too (e.g., *PS3M* from OMiLAB or *Cooperation Manager* from Cooperation Experience). Overall, we expect that our work provides a valuable starting point for (in depth) research regarding multidisciplinary developing and representing PSS to handle new arising challenges (e.g., increased digitalization) that require different domain-specific expertise.

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