Understanding Smart Product-Service System Value Offerings: A Comparative Case Analysis

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Short Paper

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Abstract

Although smart product-service systems (SPSS) have attracted increasing interest from manufacturers in recent years, their commercialization can pose major challenges. This study aims to advance the SPSS literature by examining the pillars of manufacturers' SPSS value offering strategies. Using a sociotechnical perspective and a configurational approach, this study examines how manufacturers configure SPSS value offerings. A fuzzy-set qualitative comparative analysis based on data from a qualitative study reveals three different configurations of sociotechnical factors that are consistently sufficient to achieve an attractive SPSS value offering. From a theoretical perspective, insight into these configurations advances the understanding of complementarities among sociotechnical factors for SPSS. From a managerial perspective, the configurations provide templates for evaluating existing organizational work systems as well as design options for developing new ones.

Keywords: Smart product-service systems, fsQCA, sociotechnical perspective, offering

Introduction

Smart product-service systems (SPSS) have attracted increasing interest in recent years from manufacturing companies in a wide range of industries. SPSS integrate physical products, digital technologies and the provision of services to create value for users throughout the lifecycle of a product (Chen et al. 2020). Embedded within the 'Internet of Things' (IoT), SPSS use sensors, electronics and software to fulfil diverse functions such as data analytics, system monitoring, or process adjustment (e.g., Zheng et al. 2019). In addition, they facilitate manufacturers' servitization strategy, which encompasses the shift from a product-centric to a service-centric business model (Kowalkowski et al. 2017). Although SPSS have received strong interest, their commercialization can pose significant challenges (e.g., Hohmann and

Posselt 2019; Martinez et al. 2010) and involve a complex sociotechnical process (e.g., Charro and Schaefer 2018; Zheng et al. 2019).

The purpose of this study is to advance the SPSS literature by examining the pillars of SPSS value offering strategies. Value offering strategies define the value that firms aim to provide to customers through their offerings and affect firms' value creation activities and value capture opportunities (O'Cass and Ngo 2011). Drawing on a sociotechnical perspective (Bostrom and Heinen 1977), the research objective is to investigate profiles of SPSS value offerings. Our study adopts the perspective of SPSS providers and pursues a design approach (Díaz Andrade et al. 2021) to uncover gestalt constellations (i.e., configurations of conditions) for successful SPSS value offering strategies. We focus on organizational alignment and managerial digitalization capabilities as elements of the social system and system tasks and integrative infrastructure as elements of the technical system. The research question of this study is: How do manufacturers configure effective SPSS value offerings?

To answer this question, we conducted an exploratory study using a configurational approach. Configuration theory has been highlighted as a useful inquiring system to approach complex phenomena and further advance IS research (e.g., El Sawy et al. 2010; Papert et al. 2017; Park et al. 2020). In this study, we analyze qualitative data from interviews with executives in 20 different manufacturing firms. We use fuzzy-set qualitative comparative analysis (fsQCA; Ragin 2008) to analyze the data. FsQCA is a useful method for disentangling configurations of factors that are sufficient for an outcome of interest. FsQCA considers causal complexity, defined as a situation "in which a given outcome may follow from several different combinations of causal conditions—from different causal 'recipes'" (Ragin, 2008, p. 124). The results of the analysis show different configurations of sociotechnical factors for successful SPSS value offering. While the composition of these configurations differs, they are all conceivable as equally sufficient paths to SPSS value offering. In summary, the findings of this study make a theoretical contribution by describing different recipes for successful SPSS value offering and by delineating complementarities among sociotechnical factors for achieving it. In addition, this study is one of the few to conduct a comparative case analysis based on qualitative data (e.g., Nishant and Ravishankar 2020). Thus, this study makes a methodological contribution by illustrating how researchers can analyze qualitative data using fsQCA.

Conceptual Background

The sociotechnical perspective is a useful lens for studying and designing complex work systems and considers two interacting facets: the technical system and the social system (Bostrom and Heinen 1977). While the technical system refers to tasks and technologies, the social system refers to the people and structures of a work system. The interplay between both systems affects the outputs or outcomes of a work system. To explain and predict the nature and outcomes of a work system, it is essential to understand the interdependencies between the two systems (e.g., Bostrom et al. 2009). We aim to achieve this goal in the context of SPSS by illuminating tasks, technology, structure, and people as pillars of SPSS commercialization. More specifically, we conceptualize the generic sociotechnical pillars of a work system as system tasks (tasks), integrative infrastructure (technology), organizational alignment (structure) and managerial digitalization capabilities (people) for SPSS and treat them as antecedents to explain SPSS value offering strategy as the focal outcome of interest.

Regarding *SPSS value offering*, the strategy literature shows that comprehensiveness and extensiveness are two important variables to describe strategic processes (Hutzschenreuther and Kleindienst 2006). They are thus included as dimensions of SPSS value offering in this study. While comprehensiveness refers to a firm's efforts to be exhaustive and inclusive when strategizing, extensiveness refers to the extent to which strategizing reflects a long-term horizon and forward thinking (Miller et al. 1998). With regard to SPSS value offerings, comprehensiveness describes the extent to which SPSS offers use value to address diverse current business needs of clients. Extensiveness describes the extent to which a SPSS may provide value for not only current, but also future demands of clients.

Structure is an important element of the social system of a work system (Bostrom and Heinen 1977) and has been conceptualized as *organizational alignment* in this study. We considered three dimensions to further contextualize organizational alignment to the SPSS context under investigation: organizational inertia, cross-functional coordination, and customer-oriented mindset. Firms that seek to benefit from new opportunities (such as providing SPSS) often face challenges due to organizational inertia (Kelly and

Amburgey 1991) and legacy systems that may hinder change processes and the alignment of existing organizational structures with new requirements. In addition, the provision of SPSS may require coordination between multiple units of a firm. SPSS are typically characterized by broad integrated functionality (Chen et al. 2020). Thus, cross-functional coordination, which focuses on managing units in such a way that necessary resources, knowledge, or entities are available (Gosain et al. 2005), gains relevance. Finally, manufacturers offer SPSS to provide customer solutions that go beyond mere product-centric approaches. In this context, prior work underlines a customer-oriented mindset, which relates to a firm's customer orientation and engagement (Chakravarty et al. 2014), as an asset to learn from and about customers and optimize value creation and proposition processes.

People are another critical element of the social system (Bostrom and Heinen 1977). People are embedded in a work system and use their skills and abilities to perform tasks. We have conceptualized this element in the context of SPSS as *managerial digitalization capabilities*. Advanced digital services require individuals to possess specific sets of digitalization capabilities (Rönnberg Sjödin et al. 2016), which can be further differentiated into development, implementation, and usage or application capabilities (Zheng et al. 2019). Development capabilities focus on the smart design of physical and cyber infrastructure, implementation capabilities focus on the realization of SPSS for customer interaction, and usage or application refers to the management of SPSS adoption on the customer side (Chen et al. 2020; Zheng et al. 2019).

Tasks or activities are an integral part of the technical system of a work system and involve the transformation of inputs into outputs (Bostrom and Heinen 1977). We conceptualized this element in the SPSS context as *system tasks* and distinguished between internal and external tasks. Prior work suggests that hybrid offerings consisting of product and service components often involve internal and external tasks for service design and delivery (e.g., Forkmann et al. 2017). While internal tasks refer to, for example, development, manufacturing, or controlling activities, external tasks refer to, for example, market intelligence generation or sales activities. SPSS combine physical and digital elements to provide services that deliver value to customers throughout the lifecycle of a product (Chen et al. 2020). As such, they require different internal activities, such as effectively combining physical and cyber domains (Chen et al. 2020). They also perform external tasks, such as integrating customers or enabling data exchange processes.

In addition to tasks, technology is part of the technical system (Bostrom and Heinen 1977). In this study, we conceptualized this element as an *integrative infrastructure* with three dimensions: data management, digital resources and interfaces, and protection and security. SPSS are based on infrastructures that integrate physical and cyber domains. The generation, exchange, and processing of data are at the heart of SPSS (e.g., Machchhar et al. 2022). Therefore, SPSS providers need to define data management procedures, establish governance mechanisms (e.g., access rules), and ensure data protection (e.g., Cichy et al. 2021; Zheng et al. 2019). Prior work suggests that IS and digital architectures can influence the trajectory of organizational change processes (Besson and Rowe 2012).

Research Model

Figure 1 shows the research model and uses a Venn diagram to illustrate the configuration approach used to examine the interplay between factors. While the sociotechnical perspective guides the selection of domains and conditions to be studied, configuration theory helps to explain the mechanisms between them. Configuration theory has its roots in the organization literature and is based on the idea that the elements of a system (e.g., the strategic, structural, and procedural factors of an organization) combine into a limited number of patterns with superior performance (Ketchen et al., 1997; Meyer et al., 1993). Configuration theory holds that a particular outcome has not only a single, but multiple antecedent conditions that work together to produce the outcome (i.e., conjunctural causality), that different combinations of the antecedent conditions can produce the same outcome (i.e., equifinality), and that conditions that are "found to be causally related in one configuration may be unrelated or even inversely related in another" (asymmetry; Meyer et al. 1993, p. 1178; Misangyi et al. 2017). The analysis of configurations has the potential to generate novel insights into the patterning of conditions and complementarities between them (Furnari et al. 2021). Complementarity occurs when the elements of a system reinforce each other synergistically, that is, in such a way that "doing more of one thing increases the returns to doing more of another" (Milgrom and Robert 1995, p. 181). In summary, configuration theory helps to understand how manufacturers configure sociotechnical factors for attractive SPSS value offerings.

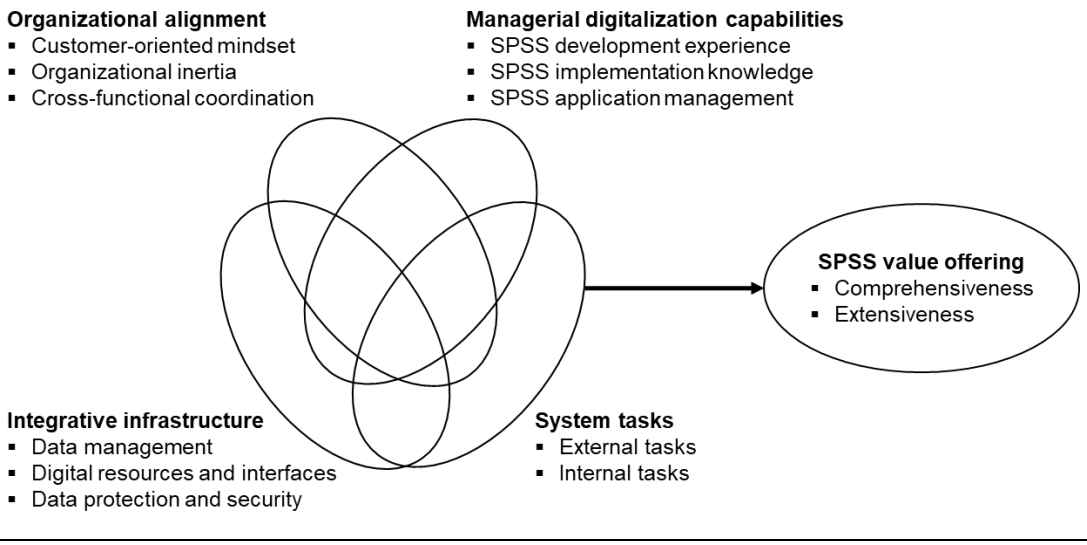

Figure 1. Research Model

Research Design

Data Collection and Definition of Fuzzy Sets

We conducted in-depth interviews with key informants from different manufacturers operating in the machinery and equipment industry in a multi-case study setting (Eisenhardt 1989) (see Table 1). The manufacturers are based in European countries, serve international markets, and have experience with SPSS. Theoretical sampling guided the selection of cases. The data collection process included 20 interviews, supplemented by site visits, observations at the sites, and key informant documentation. We used an interview guide to structure the interviews and collect rich qualitative data. The average interview length was 81 minutes. In total, the interviews lasted 26 hours and 53 minutes. All interviews were audio-recorded and then transcribed. The transcript consisted of 410 pages. We used data triangulation to combine the data drawn from the different sources outlined above. We analyzed the data using fsQCA (Ragin 2008). FsQCA is a set-theoretic method that uses Boolean algebra to analyze superset and subset relations between conditions, which can provide insight into necessity and sufficiency. FsQCA requires that the conditions under investigation are represented as fuzzy sets, which implies that each empirical case should have a membership score in a fuzzy set for a condition. Fuzzy-set scores range from 0 to 1, where 0 means that a case is fully out of a fuzzy set and 1 means that a case is fully in a fuzzy set. A score of 0.5 indicates maximum ambiguity regarding a case's (non-)membership in a set; it is referred to as the crossover point.

Firm	SPSS application areas	Key informant positions
A	Printing machines	Head of Innovation Management & Senior Manager IoT Solutions
B	Corrugated board production lines	Head of Service Product Management
C	Machine tools	Global Customer Manager
D	Power plants and engines	Head of Product Strategy
E	Heating systems	Head of Venture Development
F	Spinning machines	Chief Technology Officer
G	Gear cutting machines	Director Business Development
H	Painting systems	Full-Service Manager
I	Power tools	Head of Tool Development Service
J	Gas systems	Senior VP Advanced Services

K	Washroom systems	Product Development Manager
L	Cleaning machines	Manager Digital Products
M	Robots	Digital Services Team Leader
N	Cigarette machines	Manager Marketing & Digital Business Developer
O	Load carriers	Product Manager Digital Applications
P	Packaging machines	Global Product Manager
Q	Compressors	Digital Innovation Manager
R	Textile machines	Head of Digital and Strategy Development
S	Shop floor machines	Head of Product Strategy and Digitization
T	Printers	Director Corporate Development

Table 1. In-depth Interview Partners

To obtain the fuzzy-set scores for all cases on each condition under investigation, we analyzed the qualitative material following the recommendations in the QCA literature (Basurto and Speer 2012; Schneider and Wagemann 2010; Tóth et al. 2017). More specifically, we used the generic membership evaluation template (GMET) as proposed by Tóth et al. (2017) to structure the assignment of fuzzy-set scores and define fuzzy-set memberships. In order to prevent possible ambiguity problems regarding case membership, we defined 6-value fuzzy sets (i.e., each case could obtain a score of 0, 0.2, 0.4, 0.6, 0.8 or 1 in a fuzzy set, thus avoiding the 0.5 score of maximum ambiguity). Based on the analysis of the qualitative material, we created 100 GMETs (i.e., 5 templates for the 4 antecedent conditions and the outcome condition for each of the twenty empirical case). Table 2 shows an example GMET for case 1 (Firm A) and SPSS value offering. Two researchers were involved in data preparation and used a stepwise approach, including plausibility checks when assigning the fuzzy-set scores (Basurto and Speer 2012). In situations of divergent interpretations, case- and condition-based discussions and the consultation of supporting data (if available) were used and the templates were re-evaluated.

Data Analysis using Fuzzy-set Qualitative Comparative Analysis

After having obtained the fuzzy-set scores for all conditions and cases, we analyzed the data using the fs/QCA software program (version 4.0; Ragin and Davey 2022). We performed a sufficiency analysis (Ragin 2008) and generated a truth table that shows all logically possible combinations of the 4 antecedent conditions as well as their empirical representation. The QCA literature suggests refining the truth table based on frequency and consistency thresholds (Ragin 2008). While the frequency threshold refers to the minimum number of cases (i.e., empirical representation) that a configuration should have, the consistency threshold refers to the minimum degree to which the cases in a configuration set should agree in displaying the outcome under investigation (Ragin 2008). Our study is a small-N investigation based on 20 cases.

Case number:		1		
Membership in the set of:		SPSS value offering		
Overall case description:		Case 1 (Firm A) is an engineering company and a leading manufacturer of innovative presses and related comprehensive solutions for the media industry.		
Dimensions	**Evaluation**	**Effect on membership**	**Context-specific description**	**Illustrative quote(s)**
Compre-hensiveness	High	Positive	Compre-hensive offering (package), including consulting	*"That is the real value proposition, and we do it with data. And when we track that OEE data continuously and make a bet with the customer that together with lean management consulting here and the right consumables and the right use of professional services." //*

				"On the one hand, this package includes a guarantee of technical availability of the machines after their level two. This component is already included in the subscription, because without technical availability there is no OEE. (…) Yes, and now the stage beyond that, we have another consulting force that says: I'm not only interested in what the machine could produce, but we'll also say what it produces for this performance parameter. You build another consulting force for that."
Extensive-ness	High	Positive	Value offering addresses diverse current and future demands	*"Our value proposition is that we sustainably increase the customer's OEE, i.e. the way they produce on a permanent basis." // "And this is then the total package for the subscription, which is billed on an output basis, again there is a base fee … and a price per sheet that comes out the back, but the whole thing is based on the fact that this calculation achieves this OEE …" // "Company A started more than 20 years ago to offer a very high level of service with service contracts and to provide the customer with value-added services around this capital good. Away from repair, towards service consulting, predictive monitoring (…) Data plays a role everywhere, this is all the capability available to the company."*
Supporting data:		n.a.		
Set membership score:		1 (in a 6-value fuzzy set)		
Reason for score:		Positive dimensions with high evaluation demonstrate that this case is fully in the fuzzy set of firms with an effective SPSS value offering.		

Table 2. Exemplary GMET for Case 1

Therefore, and in line with the QCA literature, we set the minimum frequency threshold to 1 (i.e., 100% of the cases were included in the analysis). To obtain the consistency threshold, we examined the ordered consistency scores of the truth table to identify a dip (Schneider and Wagemann 2010). We set the consistency threshold at 0.95. In addition, we examined proportional reduction in inconsistency (PRI) scores and set the PRI threshold at 0.75.

Table 3 shows the results of the sufficiency analysis and reveals three configurations of sociotechnical factors for an attractive SPSS value offering. The overall solution consistency score is 0.965 and the overall solution coverage score is 0.889. Coverage indicates what proportion of the outcome set is covered by a solution or particular configurations that are part of a solution (Ragin 2008). For the specific configurations raw and unique coverage can be distinguished. While raw coverage indicates what proportion of the outcome set is covered by a particular configuration set, unique coverage indicates what proportion of an outcome set is exclusively covered by a particular configuration set (i.e., excluding overlaps with other configuration sets that are part of the solution) (Ragin 2008; Schneider and Wagemann 2010).

Configuration 1 indicates the presence of all four sociotechnical factors is a sufficient path to achieve an attractive SPSS value offering. Of the four conditions, managerial digitalization capabilities and integrative infrastructure are core conditions, as they are part of both the intermediate and the parsimonious solutions obtained by the fsQCA (Fiss 2011); organizational alignment and system tasks are peripheral conditions. Configuration 1 suggests that manufacturers' investments in social systems (here, organizational alignment

and strong managerial digitalization capabilities) and technical systems (here, an established integrative infrastructure and clearly defined system tasks) pay off in in the form of attractive SPSS value offerings. Configuration 1 has the highest consistency and coverage scores. The high coverage scores underscore the empirical relevance of this configuration of sociotechnical factors. *Configuration 2* represents an alternative path to an effective SPSS value offering. Configuration 2 combines the presence of managerial digitalization capabilities and an integrative infrastructure with the negations of organizational alignment and system tasks. In Configuration 2, managerial digitalization capabilities, integrative infrastructure, and the negation of system tasks are core conditions, whereas the negation of organizational alignment is a peripheral condition. This configuration suggests that manufacturers can generate an attractive SPSS value offering when prioritizing people- and technology-related factors over structure- and task-related factors. Examination of the consistency and coverage of Configuration 2 shows, however, that this solution has lower scores for both indices in comparison to Configuration 1. Finally, *Configuration 3* reveals that the presence of organizational alignment and integrative infrastructure in combination with the negation of managerial digitalization capabilities and system tasks reflects a sufficient path to an effective SPSS value offering. In Configuration 3, integrative infrastructure and the negation of system tasks are core conditions, while organizational alignment and the negation of managerial digitalization capabilities are peripheral conditions. As with Configuration 2, the consistency and coverage scores for Configuration 3 are lower than those for Configuration 1.

Configurations	**Consis-tency**	**Raw coverage**	**Unique coverage**	**Overall solution consistency**	**Overall solution coverage**
1 oa • *mdc* • *ii* • st +	0.981	0.825	0.46	0.965	0.889
2 ~oa • *mdc* • *ii* • *~st* +	0.955	0.333	0.016		
3 oa • ~mdc • *ii* • *~st*	0.958	0.365	0.032		
Notes: oa = organizational alignment; mdc = managerial digitalization capabilities; ii = integrative infrastructure; st = system tasks; intermediate and parsimonious solutions based on Quine-McCluskey algorithm; conditions in italics are conditions in both the intermediate and the parsimonious solutions.					

Table 3. Results of the Analysis

Conclusion and Discussion

Theoretical Contributions and Avenues for Further Research

The commercialization of SPSS can come with major challenges for manufacturers that seek to benefit from increased servitization (Hohmann and Posselt 2019; Martinez et al. 2010). This study aims to contribute to the SPSS literature by illuminating manufacturers' approaches to configuring organizational elements to achieve attractive SPSS value offerings. Drawing on a sociotechnical perspective (Bostrom and Heinen 1977; Bostrom et al. 2009), we suggest conceptualizations of social and technical elements of SPSS as work systems and investigate their interplay to produce an effective SPSS value offering. The results of our initial investigation suggest alternative, equifinal configurations of sociotechnical factors. Consistent with prior work, the results of our study suggest that a well-established work system with strong social and technical elements provides a sufficient recipe for an attractive SPSS value offering (Configuration 1). However, the results of the analysis also suggest that other recipes coexist (Configurations 2 and 3). Examining the composition of these configurations offers insight into complementarities between the sociotechnical factors. While Configuration 2 shows an emphasis on people- and technology-related factors, indicating that strong managerial digitalization capabilities and diverse system tasks, including internal and external tasks, play a central role, Configuration 3 emphasizes an integrative infrastructure and well-established data handling routines in combination with a less diverse and more focused system task approach. Interestingly, all configurations include the presence of at least one social and one technical condition. Distinguishing between core and periphery conditions within a configuration (Fiss 2011), however, the results show that the core conditions in Configuration 3 are only elements of the technical system, while the core conditions in Configurations 1 and 2 are both social and technical elements. In summary, the initial results of this analysis suggest that there is no single best approach to achieving an attractive SPSS value offering, but that alternative recipes coexist that differ in their composition and the complementarity effects

they unleash. These findings are consistent with previous work indicating that SPSS can vary in terms of complexity, underlying business model, and application domain (e.g., Zheng et al. 2019), thus producing different organizational requirements for providers.

Further research could provide more nuanced insights by examining configurations of sociotechnical systems for different types of SPSS. In addition, future studies could consider the roles of different actors in SPSS ecosystems (e.g., Papert and Pflaum 2017) and examine configurations of activity systems that produce attractive SPSS. Finally, future work could investigate SPSS from the customer perspective.

Managerial Implications

For executives in manufacturing firms that aim to provide and commercialize SPSS, the configurations obtained by the analysis may serve as templates to evaluate the existing organizational setup in terms of its social and technical systems. The configurations are conceivable as profiles of sociotechnical factors that may serve as benchmarks. Depending on the results of benchmarking the existing organizational setup against the configurations obtained by the analysis, revisions or reprioritizations to achieve fit may be identified. In addition, the results of the analysis help manufacturers to structure firm-internal value-creation processes. The configurations suggest equifinal recipes that provide design choices for manufacturing firms. Thus, manufacturers may consider alternative pathways (and investment decisions) when they decide how an attractive SPSS value offering should be generated.

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