Fostering Efficiency in Information Systems Support for Product-Service Systems in the Manufacturing Industry

Alexander A. Neff
University of St.Gallen
alexander.neff@unisg.ch

Florian Hamel
University of St.Gallen
florian.hamel@unisg.ch

Thomas Ph. Herz
University of St.Gallen
thomas.herz@unisg.ch

Falk Uebernickel
University of St.Gallen
falk.uebernickel@unisg.ch

Walter Brenner
University of St.Gallen
walter.brenner@unisg.ch

ABSTRACT

The ongoing shift towards stronger service orientation is leading to a rising number of industrial services offered in the manufacturing industry. In the attempt to fulfill ever-increasing service demands while at the same time reducing operating costs, manufacturing firms search for appropriate information technology (IT) solution for planning and execution. The industry has not yet reached a common understanding of product-service systems and the corresponding processes and IT systems. In order to holistically support such broad design and transformation tasks, we develop a maturity model capturing the key requirements for the information systems (IS) support of product-service systems based on a multiple case study. For a critical reflection on the extant literature, we compared those requirements with scientifically recognized maturity models and standard specifications. Being an integral part of the design science research approach, the model evaluation is organized in accordance with approved evaluation perspectives.

Keywords

Industrial Services, Service Transformation, Product-Service Systems, Design Science Research, Maturity Model.

INTRODUCTION

The paradigm shift from a product-dominant to a service-dominant logic in the manufacturing industry can hardly be refuted (Vargo and Lusch, 2004). The fraction of industrial services offered is constantly rising (Stille, 2003). Being confronted with ever-increasing service demands and shrinking margins in the product business, IT departments in manufacturing enterprises encounter problems in finding the appropriate IT solution for planning and execution (Dietrich, 2006). The service component depends on expensive proprietary systems and highly customized standard solutions (Thomas, Walter, Loos, Nüttgens and Schlicker, 2007), while legacy systems need to be replaced. Supporting management accounting and plant maintenance causes serious issues for product-service systems in manufacturing organizations (Dietrich, 2006; Thomas et al., 2007). In particular, it is difficult to obtain detailed and accurate status information on the service execution process. The situation is even more challenging, since manufacturing processes and service processes require different management approaches and are built upon different IT artifacts. So far, information systems support for service business has hardly been addressed as a dedicated research stream. Service research has focused on the front stage of service delivery, studying phenomena such as provider-client relationships, co-creation of value, service quality, and service encounters (Glushko and Tabas, 2009), while studies investigating the back stage of service systems are missing (Glushko and Tabas, 2009).

Overcoming the above mentioned challenges, a concept is needed allowing a holistic support for such broad design and transformation tasks. Turning out to be successful in the software engineering domain (Paulk, Curtis, Chrissis and Weber, 1993), maturity models are an established means that aims at the effective management for complex and heterogeneous tasks (Ahern, Clouse and Turner, 2004). Our objective is to develop a maturity model which should be capable to holistically assess the IT support of a product-service system in the manufacturing industry. Hence, we address the following research questions (RQ):

RQ.1) *What are key requirements for the IS support of product-service systems in the manufacturing industry and how are they addressed in existing models?*

RQ.2) *How could a product-service system specific maturity model be designed that targets key requirements of multinational manufacturing enterprises?*

The remainder of this paper is structured as follows. Next, foundations of product-service systems and maturity models are presented, while the following chapter describes the selected research approach. Answering RQ.1, the subsequent chapter derives exploratory requirements and analyzes their reflection in existing maturity models and publicly available specifications (PAS). The development of the maturity model is presented thereafter (RQ.2). Finally, we conclude with our major contribution, supplemented with a critical reflection and an outlook on future research.

THEORETICAL FOUNDATION

Over the last thirty years, academics as well as practitioners have begun to investigate services as a distinct phenomenon with its own body of knowledge and rules of practice (Spohrer and Kwan, 2009). Their approaches are being revitalized under the emergent discipline of service science, management, and engineering (SSME). Requirements for planning, operating and disposing of customer solutions are discussed in several academic disciplines such as in SSME, information systems, marketing and operations management (Bardhan, Demirkan, Kannan, Kauffman and Sougstad, 2010; Rai and Sambamurthy, 2006). Recently, the notion of the "*service system*" has been put forward as the basic abstraction of service science, representing "*a dynamic value co-creation configuration of resources, including people, organizations, shared information […], and technology*" (Maglio, Vargo, Caswell and Spohrer, 2009).

Due to the broad conception of the service system and the industry focus of this study, we considered the body of knowledge in operations management. Scholarly literature combines products and services in terms of systems, solutions and bundles (Oliva and Kallenberg, 2003). We decided to apply the definition of product-service systems, since it achieves most hits in a literature search (as compared to the terms *bundle and solutions*) and fits best with the manufacturing focus (Neff, Herz, Uebernickel and Brenner, 2012). The definition refers to the "*customer life cycle oriented combinations of products and services, realized in an extended value creation network*" (Aurich, Fuchs and Wagenknecht, 2006). Current research in SSME tends to focus on customer value, such as value creation in service marketing issues or service encounters, as well as value co-creation with customers (Clarke and Nilsson, 2008). However, little insight into business processes (Glushko and Tabas, 2009), enterprise systems and software applications that are required to integrate manufacturing and service processes in service systems has yet been provided. Information asymmetries are well-accepted as a challenging problem in SSME, since the co-generation aspect leads to new levels of coordination complexity (Chesbrough and Spohrer, 2006). Nonetheless extant literature shows considerable deficits in designing and explaining IT artifacts that are capable of providing the appropriate information through the life cycle stages (Becker, Beverungen, Knackstedt, Matzner and Müller, 2011). In order to develop an integrated solution with selected information exchange, the authors begin with the requirements of product-service systems and the corresponding IS / IT implementations.

The term "*maturity*" constitutes a state of completeness, perfectness or readiness (Simpson and Weiner, 1989). Researchers and managerial experts have developed maturity models to guide an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target from an initial to a desired end stage. Scholarly literature in IS understands maturity as an evaluation measure for corporate capabilities (Rosemann and De Bruin, 2005). Accordingly Becker, Knackstedt and Pöppelbuß (2009) suggest that a maturity model helps designing and using IT efficiently and effectively. Multiple archetypal levels for a class of objects form together the evolutionary path in a particular domain (Rosemann and De Bruin, 2005). Being part of corporate steering practices, maturity models typically serve as benchmarking instruments which ensure continuous improvement of enterprise capabilities (Paulk et al., 1993). Since IS scholars assume a strong association between the maturity level of a particular capability and the effectiveness of the IT providing that capability, maturity models outline how the contribution of IT to that particular capability can be optimized along an evolutionary path.

RESEARCH APPROACH

We selected the design science research (DSR) approach (Hevner, March, Park and Ram, 2004; Peffers, Tuunanen, Rothenberger and Chatterjee, 2007) to build a maturity model and thereby addressing the RQs of this paper. This type of research is well suited to engage relevant problems, while simultaneously ensuring a contribution to the scientific body of knowledge (Baskerville and Myers, 2009). DSR aims at the construction and evaluation of artifacts in order to overcome existing capability limitations (Hevner et al., 2004). Being the outcome of the DSR process (Peffers et al., 2007), a maturity model is an artifact that describes an anticipated, desired or typical evolution path (Becker et al., 2009).

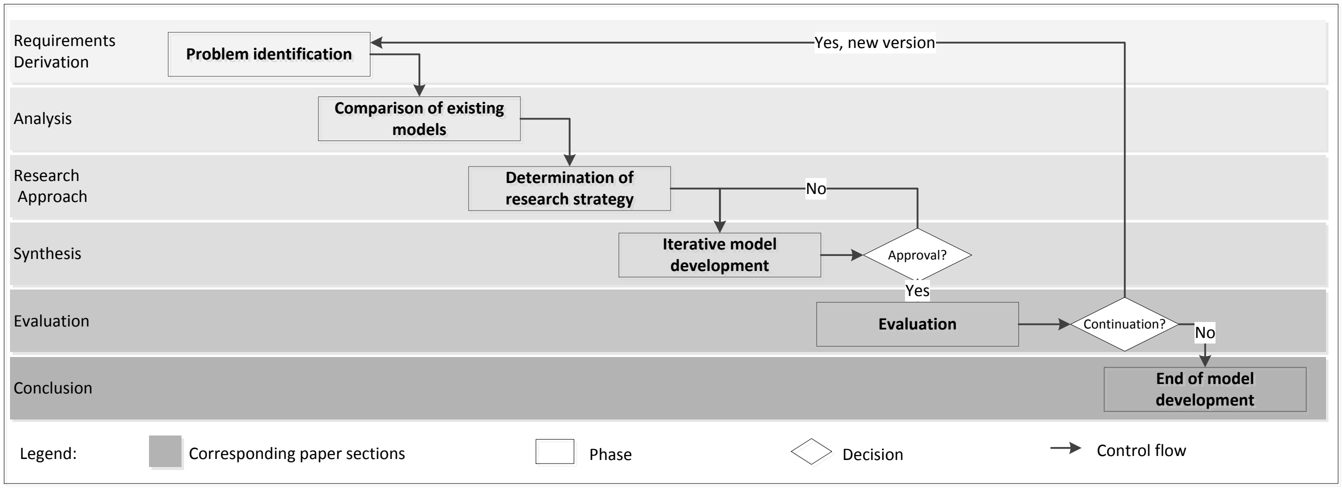

Figure 1. Procedure model based on Becker et al. (2009)

In order to investigate heterogeneous phenomena (product-service systems) with a homogenous model, a maturity model is well-suited to guide our research. Driven by the success of popular models such as the capability maturity model (CMM) (Paulk et al., 1993), IS scholars developed and published numerous instantiations (Becker, Niehaves, Poeppelbuss and Simons, 2010; Mettler, Rohner and Winter, 2010). Anyway, "*the procedures and methods that led to these models have only been documented very sketchily*" (Becker et al., 2009), since IS most scholars seldom expose their development process. Addressing the requirement of a stringent and transparent development process, we decided to follow a maturity development approach (Becker et al., 2009) that is subject to the DSR guidelines (Hevner et al., 2004).

For the development of our maturity model we slightly adapted the process model (Figure 1). In order to increase the understandability of the eight-step procedure model (in terms of complexity of the model and alignment between the process and the structure), we decided to combine three process steps in the evaluation step. Starting with the *problem identification* (step 1), we specified the research problem, provided practical relevance and justified the value of the artifact. A case study research design was selected because the boundaries between service and manufacturing processes and their contexts (i.e. the service systems in which they are embedded) have not been explored evidently (Yin, 2009). In summer 2012, two researchers conducted seven exploratory case studies at worldwide leading manufacturing firms. The data collection can be traced back to semi-structured interviews as our primary method. The multiple case study approach is favorable to the single case study approach in terms of enhanced validity (Eisenhardt and Graebner, 2007). We documented interview transcripts for each case analyzed and supplemented the data collection with corporate reports. Due to the differences in firm-specific terminologies, tailored service processes and custom-built IT systems, we had to acquire additional information sources such as system landscapes and process maps in order to make the cases comparable. For example, data are distributed throughout the entire organization in terms of product and service division as well as different systems (i.e. operative and analytical). The final results were documented in a case study report.

Based on the *problem identification* (1) and the identification of shortcomings or lack in transferability in the analysis of existing maturity models, we continued with the *comparison of existing maturity models* (2). Part of this second step was a structured literature review in accordance with vom Brocke et al. (2009). Our aim was to identify existing maturity models devoted to the same or similar domains. After that, we analyzed the maturity models according to their domain and functionality as well as their capability to address the research problems. During the third step, *determination of the research approach* (3), we defined the research approach that is outlined within this section of the paper. As part of the *iterative maturity model development* (step 4), we used model adoption mechanisms (i.e. configuration, instantiation, aggregation, specialization, analogy (vom Brocke, 2007)) in a rigorous creation of a maturity model (structure and content). For the *model evaluation* (step 5), we merged the three process steps, conception of transfer and evaluation, implementation of transfer media and the evaluation, into one step (Becker et al., 2009).

REQUIREMENTS DERIVATION

The interviews constitute a large number of specific challenges and requirements for product-service systems. After analyzing all of our data thoroughly, the authors aggregated and consolidated the aforementioned requirements. This process resulted in the derivation of a list of six highly relevant requirements (Table 1).

Requirement	Description	Case study participant [CASE COMPANY] *Quotation*
[R1] Business model	• The business model influences the service portfolio and hence the business processes • Keeping heavy equipment goods operating at the customer site is essential to succeed	**Process Automation IS Manager** [ALPHA] *Within the ALPHA group the shift from rudimentary spare parts services to more sophisticated business model stereotypes such as life cycle service and full service is undisputable. The big challenge is now to bring productivity into the service operations.*
[R2] Controlling objects	• Since the value of industrial services lies in the customer usage; service quality must be controlled along the entire value chain • Applied methods: roll-out global service processes, establishing audits and certifications, and performance indicators	**CIO** [DELTA] *Service processes have to be executed across organizational borders involving subsidiaries and subcontractors, since service locations in small markets are often not profitable. Hence, we rolled out standardized service processes worldwide and check the service locations in a comprehensive audit program once a year.*
[R3] Installed base management	• Managing the installed base is salient • Generates critical insights about customers and the machines in operation	**Vice President Service Division** [BETA] *Equipped with the comprehensive source of information, business analytics are able to perform extensive analyses that generate deep insights about the customer usage of their productive machinery equipment.*
[R4] Mobile solution	• Service technicians need to be supported during the customer visit • Providing master data, historical data, service catalogs, access to the knowledge base, and triggering the billing and accounting processes	**Head of IT Strategy & Transformation** [EPSILON] *Traditional mobile CRM solutions obtain replication-based and technically limited information on the installed equipment, but our service technicians need full access to back stage information.*
[R5] Enterprise integration	• Larger production entities, smaller service entities and local subcontractors form a comprehensive service network that requires appropriate architectural solutions • The resulting complexity provides additional challenges to the IT architecture	**Process Automation IS Manager** [ALPHA] *Locations with production and service hubs require substantially more information systems support than smaller locations with less budget. Hence we started to provide cloud-based solutions for small entities.*
[R6] Data quality	• Ensuring high efficiency in the service processes requires substantial investment in corporate data quality to establish standards • A set of profound and reliable master data is crucial for automated service processes	**Vice President Service Division** [BETA] *We have built large-scale proprietary systems for service support that combine detailed knowledge of the heavy equipment (bill of material) with the customer knowledge which is buried in the CRM.*

Table 1. Exploratory requirements

ANALYSIS

We analyzed the existing literature that seemed promising for addressing the discussed requirements based on a structured literature review approach (vom Brocke et al., 2009). More concretely, we conducted a *keyword search* in which, using relevant keywords from literature reviews (Bardhan et al., 2010; Berkovich, Leimeister and Krcmar, 2011; Spohrer and Kwan, 2009), we performed the searches of certain databases (*EBSCOhost, ProQuest (ABI/INFORM), Emerald, ScienceDirect, Web of Science, and AISeL*. We limited our search to title, abstract, and keywords, and it resulted in 57 matches for in-depth analysis. After the actual content analysis, 53 articles were excluded, since they did not include maturity models in the targeted domain or they referred to previous models instead. The findings can be narrowed down to four articles. Since these maturity models do not address two requirements (R4 and R6), we continued the literature search with a *forward / backward search* that yields four PAS developed by the German Standards Institute (referred from now on as the DIN).

Ensuring a critical reflection, the authors mapped the explored requirements with the identified models and specifications (Table 2). Each article was assessed for every requirement whether the requirement is *analyzed*, *mentioned* or *not mentioned*.

The *business model requirement (R1)* achieves the highest coverage (*4 points*) of all investigated requirements. After dealing with transaction-based services, manufacturing organizations shift their focus to relationship-based business models (Oliva and Kallenberg, 2003). Hildenbrand et al. (2006) break down the strategic service management of industrial organizations into five stages of service orientation. Nägele and Vossen (2006) posit a customer-oriented view during the service development. Spath and Demuß (2006) consider the organizational design and engineering capabilities to realize customer-individual solutions. DIN PAS 1082 emphasizes the development phase of product-service systems in networks, while innovative business models are not taken into account. DIN PAS 1091 addresses component-based interface specifications for supporting controlling, sales and organization but neglects the implications on business models. DIN PAS 1094 remains on a very generic level. Being addressed in two articles, the lowest coverage (*0.5 points*) was achieved by the *mobile solution requirement (R4)*. The IS requirements specified by DIN PAS 1090 are based on a particular case study analysis merely and, hence, lack in validity (Thomas et al., 2007). Further, the document does not incorporate latest technological shifts such as cloud computing, refers to custom-built software for the service technicians and does not address billing transactions. Summing up, the analysis revealed that the majority of maturity models only partially address these requirements, while the DIN specifications make up a broader set but remain very generic.

Framework [Source]	**Orientation**		**Requirements**					
	Standard	*Maturity*	*R1*	*R2*	*R3*	*R4*	*R5*	*R6*
Hildenbrand et al. (2006)	-	✓	◐	◐	○	○	◐	○
Nägele & Vossen (2006)	-	✓	◐	◐	○	○	○	○
Oliva & Kallenberg (2003)	-	✓	●	○	◐	○	○	○
Spath & Demuß (2006)	-	✓	◐	◐	◐	○	○	○
DIN PAS 1082 (2008)	✓	-	◐	○	○	○	○	◐
DIN PAS 1090 (2009a)	✓	-	○	○	○	◐	◐	○
DIN PAS 1091 (2010)	✓	-	◐	◐	○	○	○	◐
DIN PAS 1094 (2009b)	✓	-	◐	◐	◐	○	○	○
Assessment*			**4**	**2.5**	**1.5**	**0.5**	**1**	**1**
Legend: ○ *not mentioned [0];* ◐ *mentioned [0.5];* ● *analyzed [1]* **) Points are summed up for assessment*								

Table 2. Model fit assessment

SYNTHESIS

The authors considered the development of a new maturity model preferable, since the relevant requirements are not adequately addressed in extant literature. However, we based our maturity model on the well-established dimensions, elements, levels, and functions of the investigated models. The maturity model was developed within two iterations. In the first iteration, we defined the basic characteristics and the structure of the model. Drawing from popular maturity models such as the CMM (Paulk et al., 1993), we conceptualized five levels: prepared, engaged, established, managed, and optimized. In order to create a holistic perspective, we structured the requirements according to three segments (*strategy, process, and information systems*) (Österle, 2010). The first iteration satisfies the need for relevance through the content analysis of the case study reports and concluded with the inclusion of the following elements: *safeguarding approach* (based on R1 & R2), *installed base management* (based on R3), *mobile solutions* (based on R4), *data integration* (based on R5 & R6) and *data reconciliation* (based on R6). The element data integration addresses R5 implicitly, since e.g. [C.1.4] refers to "*data integration with major business entities*". By assessing the requirements against prevailing models and standards, also rigor is ensured in the first iteration. This assessment leads to a better alignment and specification of the maturity model. Consequently a lack of coverage of the analyzed maturity levels was pointed out, why the maturity levels had to be further specified. Therefore the scope was extended to the DIN PAS. The focus group (comprising a senior researcher and two case study participants) analysis in the second iteration generated the elements *business model* (R1) as well as the specifications for the *installed base management* and *mobile solution* maturity levels and allowed a slightly adjustment of the model in terms of details and wording. Finally, the contributions of the discussion were consolidated and aligned the model (Table 3).

Considering the scope of this paper, we decided to focus on the two extreme levels of the developed model. *Level 1, product-service systems prepared,* implies that, in addition to the heavy equipment goods only basic spare parts services are offered

[A1.1]. There is no safeguarding approach in place [A.2.1]. Service processes are not adequately covered in the IS landscape, so that neither an installed base management [B.1.1] nor a mobile solution [B.2.1] can be provided. The required data for the analytical functions and sophisticated business processes are collected on an ad hoc basis [C.1.1] and a stringent quality assurance has not yet been introduced [C.2.1]. In contrast, *level 5*, *product-service systems optimize*d, implies a customer-driven, highly integrated and real-time organization. On this level, the business model is extended by managing the entire customer operation [A.1.5], instead of managing particular functions associated with the installed base. Through a variety of financial, non-financial and customer-oriented safeguarding mechanisms, the organization fully integrates customer's need [A.2.5]. By real-time monitoring the customer's operation, efficient procession and velocity in managerial decision-making are ensured [B.1.5]. Service technicians are equipped with fully integrated mobile devices, allowing them to update installed base data, trigger billing transactions and access the knowledge database [B.2.5]. It is essential, that data from the production and service divisions are automatically integrated on a real-time basis [C.1.5]. Particularly, efficiency and effectiveness in the product-service system depends on a consistent data quality combining vertical and horizontal reconciliation [C.2.5].

Dimension	Sub-dimension	Level 1 [Prepared]	Level 2 [Engaged]	Level 3 [Established]	Level 4 [Managed]	Level 5 [Optimized]
[A] Strategy	[A.1.] Business model	[A.1.1] Rudimentary spare parts service	[A.1.2] In addition to*[A.1.1]*, reactive maintenance	[A.1.3] In addition to *[A.1.2]*, predictive maintenance	[A.1.4] In addition to *[A.1.3]*, performance contracting	[A.1.5] In addition to *[A.1.4]*, managing customer's operations
	[A.2.] Safe-guarding approach	[A.2.1] No safe-guarding approach in place	[A.2.2] Safe-guarding focuses on financial aspects	[A.2.3] In addition to *[A.2.2]*, non-financial aspects are added	[A.2.4] In addition to *[A.2.3]*, financial and non-financial aspects are balanced	[A.2.5] In addition to *[A.2.4]*, aspects are aligned regularly to the customer needs
[B] Process	[B.1.] Installed base management	[B.1.1] No coordinated interaction	[B.1.2] Basic electronic reports are exchanged	[B.1.3] In addition to *[B.1.2]*, remote calls on machines are supported	[B.1.4] In addition to *[B.1.3]*, continuous monitoring based on sensory data is established	[B.1.5] In addition to *[B.1.4]*, maintenance for competing brands is done
	[B.2.] Mobile solution	[B.2.1] No mobile support	[B.2.2] Access to customer data is provided	[B.2.3] In addition to *[B.2.2]*, access to knowledge database is provided	[B.2.4] In addition to *[B.2.3]*, transactions of billing is provided	[B.2.5] In addition to *[B.2.4]*, a full integration of mobile device is given
[C] Information Systems	[C.1.] Data integration	[C.1.1] Data is collected on ad-hoc basis without an integrated approach	[C.1.2] Data collection is done manually with basic integration applications	[C.1.3] In addition to *[C.1.2]*, data collection is partially automated with partial data integration	[C.1.4] In addition to *[C.1.3]*, data collection is fully automated, data integration with major business entities	[C.1.5] Data integration is fully automated and optimized as real-time integration for the whole enterprise
	[C.2.] Data reconciliation	[C.2.1] Data will be not reconciled	[C.2.2] Rudimentary data reconciliation is in place	[C.2.3] In addition to *[C.2.2]*, data is reconciled horizontally	[C.2.4] In addition to *[C.2.3]*, data is reconciled vertically	[C.2.5] In addition to *[C.2.4]*, continuous optimization of reconciliation process

Table 3. Maturity model (after second iteration)

EVALUATION

The evaluation step is an essential part of DSR to prove the "*utility, quality, and efficacy of a design artefact*" (Hevner et al., 2004). This was conformed by following a multi-perspective approach. Since maturity models are particular instances of references models, the four evaluation perspectives of Frank (2006) were applied to structure and document the evaluation results. These perspectives and the evaluation results are listed below (Table 4).

Perspective	Detailed Criteria	Evaluation
Economic	• Cost • Benefit • Coordination	As the model has not been broadly applied yet, costs and benefits are hard to measure at the current state. It has been observed, that the model eases the alignment of service initiatives of manufacturing firms by framing the analysis of the actual situation. It supports the establishment of a unified terminology and thus can foster inter-organizational standardization. The model appears to be useful to deduce roadmaps for improvement activities by identifying and analyzing the capabilities of the next higher level.
Deployment	• Understandability • Appropriateness	Due to the applied business engineering framework (Österle, 2010) and the DIN PAS, the model presents a holistic and integrated approach for assessing and improving organizations that implement product-service systems. It even provides first ideas for developing a reference model for mapping the functional requirements with an appropriate IT support.
Engineering	• Purpose • Application domain	The research approach was appropriate for the intended purpose of the maturity model (defining and explaining) and the application domain (heavy investment goods industry). The requirements are aligned with the elements of the artifact. The mix of business-related and technical items supports the comprehensiveness of the model.
Epistemological	• Theoretical foundation • Scientific value	The applied literature review framework ensured a sufficient coverage of existing maturity models. Case study research seems to be an appropriate research methodology to explore the requirements, followed by an established procedural model for the development of maturity models. As a result, the model is embedded into the design science approach and critically evaluated in accordance with approved evaluation perspectives. Our contribution to the scientific body of knowledge is the application of the maturity model to the IS support of product-service systems.

Table 4. Evaluation perspectives

For managerial practitioners, in turn, the contribution lies in the assessment of their organization and the identification of levers for corporate improvement. Managers are able to draw a preliminary roadmap to increase the performance of the product-service systems.

CONCLUSION

The authors proposed a maturity model for the IS support of industrial product-related services. In contrast to the traditional focus on customer value such as co-creation with customers in SSME, we emphasized the needs of manufacturing firms offering an integrated product-service portfolio. Our maturity model is a management instrument, which can be used to analyze the current setup in order determine possible areas of improvement. It reduces the effort needed to unleash the full potential of the product-service system and the corresponding information systems support. Therefore, this paper answers two RQs in line with the DSR approach. The first part of this paper investigates key requirements for the IT support of product-service systems and their coverage in extant literature [RQ.1]. Our research indicates that existing maturity models and DIN PAS only partially address the exploratory identified requirements, and hence that none of the models is capable of assessing the problem holistically. Hence, an appropriate maturity model was developed in the second part of this paper [RQ.2]. It follows the structure of existing maturity models and inherits conceptualizations and methodologies from extant literature. Consistent with the fundamental principle in DSR of addressing real-world problems and simultaneously contributing to the scientific and practitioners' body of knowledge, we produced consumable results for literature scholars and managerial practitioners.

One possible limitation of the presented study is the case selection. The generalization and validation of the results could be improved by examining more cases and applying a quantitative research design. A further limitation is the focus on German and Swiss companies as the derived requirements are influenced by the multinational setting of the firms. The maturity model presents an important step in understanding why manufacturing firms struggle with the IS implementation of product-service systems and why they apply proprietary systems. The model development follows a top-down approach in which levels are first defined, while the characteristics are derived afterwards. A bottom-up approach, however, first derives characteristics, dimensions and levels and assigns afterwards the level of maturity. Since top-down approaches are often criticized for weaknesses in the theoretical foundation, we plan to follow the bottom-up approach by using an explicit maturity concept and empirical data. These data are then transformed into maturity levels by applying the Rasch algorithm in combination with rating scales (Cleven, Winter and Wortmann, 2012). This combined approach of behavioral and of DSR methods allows a more rigorous derivation of the underlying maturity concept and makes the relationships between different parts of the model more comprehensible.

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