Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 107 (2022) 113–118

www.elsevier.com/locate/procedia

55th CIRP Conference on Manufacturing Systems

A Maturity Model for Smart Product-Service Systems

Daniel Heinz[a,*], Carina Benz[a], Rainer Silbernagel[b], Begoña Molins[a], Gerhard Satzger[a], Gisela Lanza[b]

[a]*Karlsruhe Service Research Institute (KSRI), Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, 76131 Karlsruhe, Germany*
[b]*wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, 76131 Karlsruhe, Germany*

* Corresponding author. Tel.: +49-721-608-45633; fax: +49-721-608-45655. *E-mail address:* daniel.heinz@kit.edu

Abstract

Smart Product-Service Systems (sPSS) offer the opportunity to create additional value by combining smart products with smart services. However, industry players often lack resources, know-how, and practical guidance to develop, introduce, and maintain such complex solutions. To support their innovation efforts, research first needs to understand the implications of applying these emerging technologies. Hence, we present a maturity model for sPSS to describe and compare such solutions using twelve dimensions and conduct a case study to illustrate the model. Our research combines insights from a systematic literature review, 20 real-world use cases, seven interviews with sPSS experts, and a focus group.

Keywords: Smart Product-Service Systems; Maturity Model; Smart Services; Internet-of-Things; Industry 4.0, Advanced Systems Engineering.

1. Introduction

In a time of digitalization and servitization, the economic marketplace has become an open platform for new players and products. Facilitated by current technological advancements in collecting and processing the abundance of data available [1] and with companies heavily investing in the corresponding IT infrastructure [2], an array of new services and business opportunities is emerging [3–5], and the focus is shifting from tangible products to intangible services [6]. The emergence of smart product-service systems (sPSS) [7] in the manufacturing industry has established a way to take advantage of these trends and differentiate oneself from competitors by allowing new value propositions and adapting to customer needs [4,8,9]. sPSS demonstrate how a product's value can be significantly enriched or even dominated by digital services, in this case through increasingly data-driven, connected, and communicative (i.e., "smart") physical objects [10].

Some of the most common examples of sPSS in consumer markets are wearable activity trackers as offered by Fitbit or Garmin [11]. Their built-in sensors allow for the collection of a broad spectrum of health and activity-centered real-time data (e.g., steps taken, heart rate). Smart services wrapped around the product use this data and employ analytical techniques to offer individualized insights into their customers' everyday activity, health status, and health-related recommendations [11]. Similarly, sPSS can be found in many different industries, with one of the most common examples in the manufacturing industry being predictive maintenance services enabled by smart components [10,12]. Recent studies aim to capture this shift towards the engineering and offering of sPSS instead of physical products as a new paradigm of "advanced systems engineering" [13,14]–a combination of the wide-spread paradigm of systems engineering [15] and recent technological and methodological advancements towards "advanced systems" such as sPSS.

However, so far, only a few works have been reported in the field of advanced systems engineering. Also, the concept of sPSS yet lacks a fundamental understanding and thorough differentiation from traditional product-service systems (PSS) [16]. Additional research on sPSS can not only contribute to this academic discourse but also assist practitioners who currently often fail at successfully developing sPSS. The reasons for these difficulties are manifold, e.g., the increased complexity of sPSS development or the challenge of acquiring qualified

10.1016/j.procir.2022.04.019

employees [14]. Further, competitive market structures prevent necessary collaboration and raise concerns regarding data security and preserving intellectual property [17].

To better understand the emerging sPSS phenomenon, this work examines the defining dimensions and maturity levels of sPSS solutions and presents the resulting findings in a maturity model. Maturity models are a widely used type of artifact in research and can guide decision-makers in developing, introducing, and maintaining sPSS solutions [18]. However, after reviewing existing literature, we find that research yet fails to fully explain how to assess, describe, or compare the maturity of sPSS. The presented model aims to close this gap and extend existing maturity models in similar contexts (e.g., for PSS [19]).

Our research applies a multi-method approach to identify the various facets that need consideration when designing and engineering sPSS instead of conventional products. In this process, we follow an established procedure guideline [19] to develop a maturity model that can be used to assess the state of development of sPSS solutions systematically–whether they are already marketable or still in a proof-of-concept stage. We intend to increase our work's applicability by collecting and analyzing empirical data of real-world use cases in multiple steps of the maturity model development process.

Our results contribute to both the academic and practical discourse: by combining scientific articles from multiple disciplines with state-of-the-art empirical insights, we reconcile and evolve recent theoretical findings on sPSS, which can benefit future academic research on this relevant phenomenon. In addition, the developed maturity model can be used by managers, project leaders, or other decision-makers to gain strategical insights by measuring their offerings' current maturity, obtaining guidelines for further improvement, and performing internal or external benchmarking [19].

2. Theoretical background and related work

The concept of PSS was first coined by Goedkoop et al. [20] as a "system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive and satisfy customer needs". Soon, this notion was used as a new strategy to shift away from pure product-selling and, thus, differentiate from other competitors [21]. Unlike pure service offerings, in PSS, a product or tangible commodity becomes the boundary object for the interaction between a service consumer and service provider to network resources and align activities [12,20]. "Service" can be defined as the application of resources for the benefit of others with an economic value and is often done on a commercial basis [6,20].

In today's increasingly connected world, the concept of PSS becomes particularly interesting, as smart products offer IoT-enabled capabilities such as remote access and control, thus allowing a wide range of innovative service offerings [12]. Such smart PSS (sPSS) have recently gained popularity among scholars in multiple academic disciplines (e.g., technology & innovation management, production, or information systems) [16]. Typical features of smart products are (physical or virtual) sensors, a unique ID, data storage and processing, actuators, interfaces, and connectivity [12,22]. These features allow for increasing intelligence through the combination of monitoring, control, and optimization capabilities to empower autonomy [10]. This autonomy can involve autonomous product operation, self-coordination with other systems, or self-diagnosis [10]. The dimensions of smartness can also be described by using the "5Cs": connection, collection, computation, communication, and co-creation [23]. Further manifestations of smartness are context awareness, self-organization, and the proactivity of the system [24]. In our work, we define sPSS as follows:

Smart Product-Service System (sPSS): An IT-enabled business solution consisting of a system of smart products and services to generate a mutual benefit [7,16].

Maturity describes "the state of being complete, perfect or ready" [25]. It implies the evolutionary progress from an initial to the desired stage of a specific ability or a target accomplishment. A maturity model consists of "a sequence of maturity levels for a class of objects [and] represents an anticipated, desired, or typical evolution path of these objects" [19, p. 213]. Hence, the application-specific purposes of a maturity model can be described as 1) applying it as a self-measurement tool of the current maturity status ("descriptive"), 2) providing guidelines for improvement steps ("prescriptive"), and 3) allowing for internal and external benchmarking ("comparative") [18]. Maturity models entail characteristics or dimensions used to describe degrees of maturity along these attributes.

As for now, no maturity model explicitly addresses the sPSS concept. However, maturity models have gained significant interest in related research fields: several maturity or readiness models exist around Industry 4.0 (I4.0) and the digitalization of companies [26–29], which can be understood as umbrella concepts for topics including the transformation towards providing sPSS. These models' scope ranges from the distinct I4.0 development phases through the main drivers of and strategies for the I4.0 transformation to a guideline on achieving digitalization with lower costs and risks. Related work also examines how a "digital servitization" can be an appropriate strategy for small and medium-sized enterprises (SMEs) to internationalize their business [30]. Another maturity model considers these drivers and strategies and develops a self-assessment tool to guide SMEs in the manufacturing sector through digitalization processes and the accompanying technology choices [31].

Further, we review existing maturity models on the more general and well-established concepts of servitization and PSS. Some aspects of these models can also be considered for this work's model and extended by highlighting the particularities of *smart* PSS. For example, these models address important service-related aspects such as individualization, the integration of the customer, and PSS-typical business processes, pricing mechanisms, or data access [19,33,34]. Also, some examine requirements for a successful servitization process, for example, grouped by the business model canvas components (e.g., value proposition, key resources, or partnerships) [35].

3. Methodology

We ground our methodological approach towards a maturity model for sPSS solutions in the step-by-step process proposed by Becker et al. [19]. Their suggested procedure for maturity model development includes eight phases. We completed the first four phases by systematically designing the maturity model, whereas we continue to transfer, implement, and evaluate the maturity model in the future (phase 5-8).

We start the maturity model development process with a problem definition (phase 1) and an initial comparison of existing models (phase 2) before determining a maturity model development strategy (phase 3). In these first three phases, we explore the current body of literature to inform our understanding of sPSS, define our research scope, and initially search for existing related maturity models. Phase 4 reflects the main design phase of our procedure, in which we iteratively develop the maturity model combining multiple data sources (Table 1).

Table 1. Data sources included in the maturity model development process.

Iteration	Sample	Ref.
1. Systematic literature review	23 scientific articles	[36]
2. Use case analysis	20 sPSS use cases	[38,39]
3. Interview study	7 expert interviews	[37]
4. Focus group	10 experts (6 academia, 4 practice)	[40]

In the fourth phase, we first conduct a systematic literature review [36] and identify 23 relevant articles. Relevant articles combine the two trends of offerings becoming digitalized (e.g., smart, IoT, data-driven) and servitized (e.g., PSS, servitization, hybrid value creation). Further, they present their results in an aggregated format (e.g., literature reviews or frameworks such as taxonomies or typologies). In a second iteration, we add an empirical perspective and screen 20 publicly available and purposively sampled sPSS use case descriptions (e.g., Trumpf's Equipment-as-a-Service [36]). Third, we conduct seven expert interviews (39-66 minutes) with industry representatives [37], which we record and subsequently transcribe. All experts report on the current characteristics and future development potential of sPSS implemented by their companies.

All data (including the 23 scientific articles) is coded and analyzed following established qualitative content analysis methods [39], supported by the software MAXQDA. We screen for *dimensions*, i.e., distinct characteristics of sPSS solutions, and corresponding *items*, i.e., characteristic attributes building a maturity scale. The actual synthesis of the multiple data sources is performed iteratively: we begin with a set of dimensions and items derived from literature, which we then assess, substantiate, and enrich with empirical data in a step-wise procedure [19], resulting in twelve dimensions grouped in three "meta-dimensions". For the fourth iteration, we invite six academics and four industry representatives to form a focus group. During a 90 minutes session, we present, discuss, and collaboratively refine the maturity model. For example, based on their feedback, we decide to model the maturity scale by specifying the two extreme scales instead of discrete maturity items.

After the design phase, we tap into validating the maturity model and its practical usability (phase 5-8) by interviewing two industry experts who work on sPSS solutions in different stages of maturity. The experts employ the maturity model to assess a real-life sPSS use case, which they work on in their role as decision-makers (see section 5). In doing so, we observe the potential and challenges of using the maturity model as a tool for practitioners and collect feedback for further improvements as part of the overall "instantiation stage".

4. A maturity model for smart product-service systems

In this section, we propose a model consisting of twelve dimensions as a tool to describe, improve and compare the maturity of sPSS solutions. We recommend rating the solution on a 0-100 maturity scale for each dimension to assess a specific use case. Along with each dimension, we provide additional material (academic papers, real-world manifestations, and a more detailed breakdown of the maturity scale) throughout the assessment. While developing and discussing the maturity model with potential users, we face a trade-off between costs and benefits regarding the different dimensions' manifestations. We acknowledge that most cases do not require achieving "100" on each maturity scale. Nevertheless, by comparing the current maturity with a target state, the model helps to identify focus areas to advance the sPSS solution.

Table 2. Dimensions and maturity items of the sPSS maturity model.

Dimension	Definition of maturity scale
I. Technical enablers (smart product)	
Live data availability	0: No live data remotely available 100: Continuous (high frequency) availability of data
Automation of data processing	0: Processing of data not implemented in the system 100: Data is automatically cleaned and processed
Remote connectivity	0: No remote access possible 100: Low-latency, high-reliability, and high-throughput remote connectivity
Digital representation of product	0: No digital model available 100: Bi-directional continuous communication between physical and digital space
II. Realization of value (smart service)	
Smartness of service features	0: No additional value offered by using the product's capabilities via smart services 100: Integrated service features to monitor, control, and optimize the product usage autonomously
Analytical complexity	0: No analytics applied to the data 100: Combination of descriptive, diagnostic, predictive, and prescriptive analytics
Standardized individualization	0: Each smart service offering is designed and engineering individually for the respective user 100: Automatized configuration of customer-individual smart services via modularization
Permission to access customer data	0: Smart service is only developed by using test data 100: Smart service accesses user-individual live data
III. Integration into business (product-service system)	
Degree of value co-creation	0: Users of the product are not involved in the value creation process, provider not in the usage process 100: High interaction, shared access to processes/behaviors, and shared decision power
Value capturing mechanism	0: Value capturing is solely product-oriented 100: Delivered added value is distributed among stakeholders in the system (e.g., use-oriented/ result-oriented revenue models)
Operational responsibility	0: No responsibility for operation after "shipment" 100: Provider accompanies user before, during, and after using the solution and is responsible for delivering results and productivity
Openness towards third parties	0: No third parties can participate in value creation 100: High openness for third parties to join the ecosystem to provide value for other parties

The twelve sPSS dimensions are further categorized into three “meta-dimensions” highlighting different sub-concepts of the sPSS phenomenon: 1) technical enablers (smart product), 2) realization of value (smart service), and 3) integration into business (product-service system). These categories emerge throughout the iterative development and refinement of the model and are discussed in detail throughout the focus group with experts from practice and academia. Table 2 depicts the maturity model’s twelve dimensions and two extremes of each maturity scale. In the following section, we discuss our results in more detail.

4.1. Technical enablers (smart product)

Creating value through smart services requires technical requirements built into the product and its operating environment, thus making it “smart”. Hence, this category focuses on the technical enablers of sPSS. We deliberately focus on the capabilities of certain technical elements rather than describing hardware requirements, which are typically use-case-specific and quickly become out-of-date. While the technical implications of smart products are manifold and widely discussed on a more granular level, our data analysis reveals four dimensions that are particularly relevant to describe the maturity of the overall sPSS solution.

First, the technical availability of continuous or high-frequency live data (e.g., from sensors or process logs) is typically a prerequisite of mature sPSS. Our empirical sample includes different state-of-the-art designs ranging from low-frequency push models to continuous data availability through on-demand pull models for live and historical data.

Second, more mature sPSS typically apply automated handling, cleaning, and processing of data instead of manual processes to convert raw data to structured information, which are common in early-stage projects. Thus, this dimension entails a system’s ability to process data automatically.

Third, sPSS strongly rely on the connectivity of smart products, which can be enabled via different technical solutions in different use case scenarios (e.g., local communication networks vs. globally accessible Internet-based interfaces). Our maturity model describes the most mature sPSS as having a “low-latency, high-reliability, and high-throughput” connection at hand, recognizing that the exact parameters (e.g., transmission frequency) differ between application scenarios.

Fourth, an essential requisite for mature sPSS applications is a digital representation of a product. A simple realization would be providing access to a static CAD model of the specific product. However, more mature sPSS build on digital twins that continuously translate between the physical and digital space and autonomously trigger events to maintain the physical product or update the digital representation.

4.2. Realization of value (smart service)

This second category focuses on “smart service” as the realization of value potentials enabled by smart products [41]. Smart service requires designers and engineers to take a holistic, “socio-technical” perspective, which is reflected in the four dimensions included in the maturity model.

First, we include a widely recognized dimension to describe the maturity or “smartness” of smart service, depending on the value offered to its beneficiary: smart service can provide value by monitoring, controlling, or optimizing, e.g., the condition or operation of the product. Further, more mature sPSS can handle these tasks more autonomously [e.g., 10].

Second, the repertoire to analyze data provides “descriptive, diagnostic, predictive, and prescriptive” analytical methods [42], which imply an increasing level of complexity in smart service design and engineering.

Third, a common dilemma in developing a smart service is the trade-off between providing a service tailored to the individual customer and a mostly standardized value creation process to achieve economies of scale. However, as smart products can serve as boundary objects between provider and customer, mature sPSS can resolve this dilemma: The combination of modular solution architecture and a pre-configured analytical data pipeline adaptable to customer-individual data allows self-reconfiguration by the customer can enable a largely automated yet customized provision of smart service.

Finally, a related organizational prerequisite for mature sPSS is the permission to access customer data to 1) customize the service for the specific customer, 2) ensure service quality throughout the operation, and 3) improve the overall model across different customers.

4.3. Integration into business (product-service system)

Finally, we include organizational aspects of sPSS, discussing the solution’s integration into business and ensuring the sPSS’s economic feasibility built on the previously discussed technology- and value-oriented dimensions.

First, mature sPSS imply a high degree of value co-creation, i.e., an interaction between a service consumer and provider through which the consumer becomes better off in some respect [42]. In the case of sPSS, this can result in the involvement of the product user in the value creation process (e.g., providing data) as well as the product provider in the usage process (e.g., making decisions for the user or receiving usage data to improve their offering) [43].

Second, a more mature sPSS might require novel ways to distribute the created value among the involved parties. Providers of early-stage sPSS rather focus on product-oriented revenue models, offering smart services as a free or optional add-on. However, sPSS pioneers such as Rolls-Royce, Heidelberger Druckmaschinen, or Trumpf leverage data availability and connectivity to establish more advanced value capturing mechanisms such as use-oriented (leasing, sharing) or result-oriented (“pay-per-x”) revenue models [44].

Third, the discussed technological advancements allow companies to differentiate themselves by assuming more operational responsibility for their product. In this context, a commonly discussed service type is “predictive maintenance”, where a product manufacturer applies its expert knowledge on the product’s expected behavior over the lifetime and available sensor data to detect anomalies and prevent breakdowns. Another option is to take operational responsibility post-usage, which can be beneficial for both parties, as the case of MatCorp in the subsequent section illustrates.

Finally, larger-sized manufacturers have already moved from providing smart service towards providing a platform for third-party services [45–47]. Inspired by successful examples in B2C settings (e.g., Apple AppStore), this openness towards third parties offers the potential to increase customer value and reach (or preserve) market leadership.

5. Illustrative industrial case study

The presented sPSS maturity model is demonstrated in the following by applying it to sPSS solutions of two different industrial companies (see Fig. 1). PolyCorp is a global leader in polymer solution engineering, whereas MatCorp is specialized in cutting tools and hard material solutions. Both companies have already developed and (partially) implemented sPSS solutions. Two experts of PolyCorp and MatCorp were asked to categorize one specific sPSS with the help of our maturity model. The maturity model–including a detailed description of the dimensions and scale and an assessment questionnaire–was provided in advance to allow for reflected assessment.

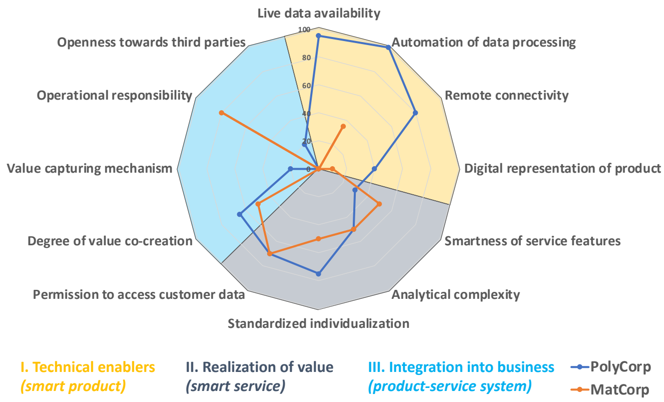

Fig. 1 Application of the maturity model to assess two industrial sPSS cases.

PolyCorp's sPSS is a sensor-equipped C-part solution for condition monitoring. Their solution relies on live data automatically processed and displayed within a control dashboard at their customer's facilities. They offer a control service with a medium smartness level and apply a "diagnostical" complexity of analytics, i.e., they can diagnose the product's condition. The service uses customers' operational data but runs solely on the customer's site.

MatCorp's sPSS solution relies on a post hoc analysis of machine tools using image recognition. After their usage phase, tools are inspected by MatCorp to detect process and setting errors. MatCorp's support technicians can propose process improvements and make tool recommendations to their customers based on this analysis. As the tools themselves are not equipped with data sensing or processing capabilities, their product's smartness levels are comparatively low. Also, there is still manual effort necessary for data processing (e.g., taking 360 pictures). Concerning the realization of value, MatCorp's solution relies on diagnostical analytics, which provides the basis for an optimization service–with manual decisions still being necessary. Hence, their service is less automated. Neither of the companies currently captures value by selling the smart service separately. Also, openness to third parties is low in both cases.

Regarding the applicability and usefulness of our maturity model, both experts emphasize that a 100% level is not always realizable or generally desirable for all sPSS characteristics. Yet, MatCorp's expert reflects that the maturity model "encourages to think about possible dimensions and how an improvement of their level can look like for our solution".

6. Conclusion and outlook

In this article, we present a maturity model to facilitate the development of sPSS. In contrast to related studies, we focus on the characteristics of the offered sPSS solution itself rather than the organizational characteristics of its provider. The model results from an iterative mixed-methods approach combining insights from a systematic literature review, the analysis of 20 real-world use cases, seven interviews with sPSS providers, and a focus group with participants from industry and academia. The model consists of twelve dimensions, which are aggregated into three categories: "technical enablers", "realization of value", and "integration into business". We validate the maturity model and its applicability by assessing two real-world sPSS through additional expert interviews.

Our results contribute to both the academic and practical discourse: By combining scientific articles from multiple disciplines with state-of-the-art empirical insights, we reconcile and evolve recent theoretical findings on sPSS, which can benefit future academic research on this relevant phenomenon. Besides that, the developed maturity model can be used by managers, project leaders, or other decision-makers to gain strategical insights by measuring their offerings' current maturity, obtaining guidelines for further improvement, and by performing internal or external benchmarking [19].

To improve the presented maturity model and complete its instantiation, we aim to collect more reference cases as the two cases discussed in the previous section. This data will allow us to develop an interactive self-assessment tool replacing the current version where an expert provides individual support during the rating process. By doing so, we hope to offer a helpful tool assisting decision-makers that navigate their organization towards becoming an sPSS provider.

Acknowledgments

This work has been supported by the German Federal Ministry of Education and Research through the research project "bi.smart" (grant no. 02J19B041). We want to thank the members of the project MoSyS (grant no. 02J19B099) for valuable feedback throughout this research.

References

[1] Chen, H., Chiang, R. H. L., Storey, V. C., 2012, Business Intelligence and Analytics: From Big Data to Big Impact, MIS Quarterly, 36/4:1165–1188, DOI:10.2307/41703503.
[2] Bughin, J., 2016, Big data: Getting a better read on performance, The McKinsey Quarterly, 1:8.
[3] Schüritz, R., Satzger, G., 2016, Patterns of Data-Infused Business Model Innovation, in *2016 IEEE 18th Conference on Business Informatics (CBI)*, pp. 133–142, DOI:10.1109/CBI.2016.23.
[4] Davenport, T. H., 2013, Analytics 3.0, Harvard business review, 91/12:64–72.

[5] Hartmann, P. M., Zaki, M., Feldmann, N., Neely, A., 2016, Capturing value from big data--a taxonomy of data-driven business models used by start-up firms, International Journal of Operations & Production Management, DOI: 10.1108/IJOPM-02-2014-0098.

[6] Vargo, S. L., Lusch, R. F., 2004, The Four Service Marketing Myths: Remnants of a Goods-Based, Manufacturing Model, Journal of Service Research, 6/4:324–335, DOI:10.1177/1094670503262946.

[7] Valencia, A., Mugge, R., Schoormans, J. P. L., Schifferstein, H. N. J., 2015, The design of smart product-service systems (PSSs): An exploration of design characteristics, International Journal of Design, 9/1:13–28.

[8] Boucher, X., Medini, K., 2016, Towards a Generic Meta-Model for PSS Scenarios Modelling and Analysis, Procedia CIRP, 47:234–239, DOI:10.1016/j.procir.2016.03.038.

[9] Lanza, G., Ferdows, K., Kara, S., Mourtzis, D., Schuh, G., et al., 2019, Global production networks: Design and operation, CIRP Annals, 68/2:823–841, DOI:10.1016/j.cirp.2019.05.008.

[10] Porter, M. E., Heppelmann, J. E., 2014, How smart, connected products are transforming competition, Harvard business review, 92/11:64–88.

[11] Davenport, T., Lucker, J., 2015, Running on data: Activity trackers and the Internet of Things, Deloitte Review, 16:5–15.

[12] Beverungen, D., Müller, O., Matzner, M., Mendling, J., vom Brocke, J., 2019, Conceptualizing smart service systems, Electronic Markets, 29/1:7–18, DOI:10.1007/s12525-017-0270-5.

[13] Albers, A., Lohmeyer, Q., 2012, Advanced systems engineering--towards a model-based and human-centered methodology, in *International Symposium Series on Tools and Methods of Competitive Engineering, TMCE*, pp. 407–416.

[14] Dumitrescu, R., Albers, A., Riedel, O., Stark, R., Gausemeier, J., 2021, Engineering in Germany - The status quo in business and science, a contribution to Advanced Systems Engineering, Paderborn.

[15] Walden, D. D., Roedler, G. J., Forsberg, K., Hamelin, R. D., Shortell, T. M., 2015, Systems engineering handbook: A guide for system life cycle processes and activities. John Wiley & Sons.

[16] Zheng, P., Wang, Z., Chen, C.-H., Pheng Khoo, L., 2019, A survey of smart product-service systems: Key aspects, challenges and future perspectives, Advanced Engineering Informatics, 42:100973, DOI:10.1016/j.aei.2019.100973.

[17] Pauli, T., Fielt, E., Matzner, M., 2021, Digital Industrial Platforms, Business & Information Systems Engineering, pp. 1–10, DOI:10.1007/s12599-020-00681-w.

[18] Pöppelbuß, J., Röglinger, M., 2011, What makes a useful maturity model? A framework of general design principles for maturity models and its demonstration in business process management, in *ECIS 2011 Proceedings*.

[19] Häckel, B., Huber, R., Stahl, B., Stöter, M., 2021, Becoming a product-service system provider – A maturity model for manufacturers, in *Wirtschaftsinformatik 2021 Proceedings*, pp. 169–184.

[20] Becker, J., Knackstedt, R., Pöppelbuß, J., 2009, Developing Maturity Models for IT Management, Business & Information Systems Engineering, 1/3:213–222, DOI:10.1007/s12599-009-0044-5.

[21] Goedkoop, M. J., van Halen, C. J. G., Te Riele, H. R. M., Rommens, P. J. M., Others, 1999, Product service systems, ecological and economic basics, Report for Dutch Ministries of environment (VROM) and economic affairs (EZ), 36/1:1–122.

[22] Li, A. Q., Kumar, M., Claes, B., Found, P., 2020, The state-of-the-art of the theory on Product-Service Systems, International Journal of Production Economics, 222, DOI:10.1016/j.ijpe.2019.09.012.

[23] Martin, D., Kühl, N., Satzger, G., 2021, Virtual Sensors, Business & Information Systems Engineering, 63/3:315–323, DOI:10.1007/s12599-021-00689-w.

[24] Lim, C., Maglio, P. P., 2018, Data-driven understanding of smart service systems through text mining, Service Science, 10/2:154–180, DOI:10.1287/serv.2018.0208.

[25] Kropp, E., Totzek, D., 2020, How institutional pressures and systems characteristics shape customer acceptance of smart product-service systems, Industrial Marketing Management, 91:468–482, DOI:10.1016/j.indmarman.2020.10.008.

[26] Simpsom, J., Weiner, E., 1989, The Oxford English Dictionary. USA: Oxford University Press.

[27] Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., et al., 2015, Industrie 4.0 Readiness, IMPULS-Stiftung for mechanical engineering, plant engineering, and information technology.

[28] Schuh, G., Anderl, R., Dumitrescu, R., Krüger, A., ten Hompel, M., 2020, Industrie 4.0 Maturity Index. Managing the Digital Transformation of Companies – UPDATE 2020 – (acatech STUDY).

[29] Schumacher, A., Erol, S., Sihn, W., 2016, A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises, Procedia CIRP, 52:161–166, DOI:10.1016/j.procir.2016.07.040.

[30] Peukert, S., Treber, S., Balz, S., Haefner, B., Lanza, G., 2020, Process model for the successful implementation and demonstration of SME-based industry 4.0 showcases in global production networks, Production Engineering, 14/3:275–288, DOI:10.1007/s11740-020-00953-0.

[31] Kolagar, M., Reim, W., Parida, V., Sjödin, D., 2021, Digital servitization strategies for SME internationalization: the interplay between digital service maturity and ecosystem involvement, Journal of Service Management, 33/1:143–162, DOI:10.1108/JOSM-11-2020-0428.

[32] Wiesner, S., Gaiardelli, P., Gritti, N., Oberti, G., 2018, Maturity Models for Digitalization in Manufacturing - Applicability for SMEs, in *Advances in Production Management Systems. Smart Manufacturing for Industry 4.0*, pp. 81–88, DOI:10.1007/978-3-319-99707-0_11.

[33] Exner, K., Balder, J., Stark, R., 2018, A PSS maturity self-assessment tool, Procedia CIRP, 73:86–90, DOI:10.1016/j.procir.2018.04.013.

[34] Gudergan, G., Buschmeyer, A., Krechting, D., Feige, B., 2015, Evaluating the Readiness to Transform Towards a Product-service System Provider by a Capability Maturity Modelling Approach, Procedia CIRP, 30:384–389, DOI:10.1016/j.procir.2015.02.134.

[35] Adrodegari, F., Saccani, N., 2020, A maturity model for the servitization of product-centric companies, International Journal of Manufacturing Technology and Management, 31/4:775–797, DOI:10.1108/JMTM-07-2019-0255.

[36] Webster, J., Watson, R. T., 2002, Analyzing the past to prepare for the future: Writing a literature review, MIS Quarterly, 26/2:xiii–xxiii, DOI:10.2307/4132319.

[37] Yin, R. K., 2009, Case Study Research: Design and Methods. SAGE.

[38] Mayring, P., 2004, Qualitative content analysis, A companion to qualitative research, pp. 159–176.

[39] Gläser, J., Laudel, G., 2009, Experteninterviews und qualitative Inhaltsanalyse: als Instrumente rekonstruierender Untersuchungen. Springer-Verlag.

[40] Gibson, M., Arnott, D., 2007, The Use of Focus Groups in Design Science Research.

[41] Trumpf, 2020, Pay-per-part: TRUMPF und Munich Re planen neues Geschäftsmodell für die produzierende Industrie.

[42] Heinz, D., Benz, C., Hunke, F., Satzger, G., 2022, An Affordance-Actualization Perspective on Smart Service Systems, in *Wirtschaftsinformatik 2022 Proceedings*, DOI:10.5445/IR/1000140996.

[43] Hunke, F., Heinz, D., Satzger, G., 2021, Creating customer value from data: foundations and archetypes of analytics-based services, Electronic Markets, DOI:10.1007/s12525-021-00506-y.

[44] Knote, R., Janson, A., Söllner, M., and Leimeister, J. M., 2021, Value Co-Creation in Smart Services: A Functional Affordances Perspective on Smart Personal Assistants, Journal of the Association for Information Systems, 22/2:418–458, DOI:10.17705/1jais.00667.

[45] Stamer, F., Steinke, M., Silbernagel, R., Häfner, B., Lanza, G., 2020, Using Smart Services as a Key Enabler for Collaboration in Global Production Networks, Procedia CIRP, 93:730–735, DOI:10.1016/j.procir.2020.04.065.

[46] Beverungen, D., Kundisch, D., Wünderlich, N., 2020, Transforming into a platform provider: strategic options for industrial smart service providers, Journal of Service Management, DOI:10.1108/JOSM-03-2020-0066.

[47] Riefle, L., Eisold, M., Benz, C., 2021, Industrial Corporation's Transformation into a Digital Platform Provider: A Case Study on Enablers, in *2021 IEEE 23rd Conference on Business Informatics (CBI)*, pp. 131–140.

[48] Guggenberger, T. M., Hunke, F., Möller, F., Eimer, A.-C., Satzger, G., et al., 2021, How to Design IIoT-Platforms Your Partners are Eager to Join: Learnings from an Emerging Ecosystem, in *Wirtschaftsinformatik 2021 Proceedings*, DOI:10.1007/978-3-030-86800-0_34.