INTERNATIONAL DESIGN CONFERENCE - DESIGN 2022
https://doi.org/10.1017/pds.2022.196

Inquiry and Analysis of Challenges in the Development of Smart Product-Service Systems

Y. Paliyenko ✉, G.-J. Tüzün, D. Roth and M. Kreimeyer

University of Stuttgart, Germany

✉ yevgeni.paliyenko@iktd.uni-stuttgart.de

Abstract

In a smart product-service system (smart PSS), non-tangible services are bundled with tangible products as well as options for information and communication technologies. Enterprises offer smart PSS in order to provide added value for customers and deal with increasing competitive pressure. However, the development of these complex systems also presents enterprises, especially SMEs, with challenges. In order to identify the challenges in the development of smart PSS and requests for corresponding support, a multi-method study was conducted with eighteen participants from German SMEs.

Keywords: design process, product-service systems (PSS), smart products engineering, smart service, challenges

1. Introduction

Enterprises nowadays are faced with increasing competitive pressure and shifting customer needs, which make it difficult for the enterprises to differentiate themselves from competitors (Verhoef et al., 2021). This leads to a change in business models – especially in producing enterprises – from solely product-oriented business models towards more service-oriented ones, in a process that is also termed "servitization and productization" (Reim et al., 2015). Producing enterprises try to provide additional value and satisfy their customers through product service bundles that are also known as product-service systems (PSS) (Zheng et al., 2019; Sutanto et al., 2015). In addition to the product ownership PSS provide higher value through the use of assets. PSS aim to increase the value proposition by providing non-tangible services alongside the tangible products, thus enabling enterprises to meet market needs and distinguish themselves from competitors.

In addition, advances in information and communication technologies have changed the way enterprises operate, produce and sell their goods, and even the products themselves adapt to this. As a result, "smart products" have emerged as part of Industry 4.0 (Pessôa and Becker, 2020). These products comprise embedded sensors, integrated actuators, software and electronic components that enable them to communicate with external entities and objects (Vogel-Heuser, 2014). The generated data can be used to extend existing services and offer additional smart services. Due to this evolution of products and services, the core concepts of PSS must be extended.

Smart products and services can be combined creating a new domain referred to as "smart PSS". The emerging system is typically described as a specific type of system, which can learn, perceive, self-organize, be aware of the context and its environment, communicate with and inform other entities. (Böhmann et al., 2018; Kuhlenkötter et al., 2017; Vogel-Heuser, 2014)

2. Problem clarification and goal

Hagen et al. (2018) investigated the applicability of PSS engineering methods for the development of smart PSS. The authors conclude that the methods and frameworks are in general applicable for developing smart PSS, however the specific requirements of "smartness" need to be integrated with fitting methods. Further research by Kuhlenkötter et al. (2017) and Böhmann et al. (2018) work out the necessity of reconsidering and adapting the existing methods for the development of smart PSS. Over all, the presented literature concludes that an integrated approach for the development of smart PSS remains a research problem.

Due to the high complexity of smart products and smart PSS, enterprises face new and unfamiliar challenges in their development (Cong et al., 2020; Schuh et al., 2019). In order to tackle such challenges during the product development process, enterprises generally rely on manuals or norms that provide guidelines and best practices. Due to the novelty of smart PSS, there is a lack of appropriate methods, models, tools and strategies for developing smart PSS (Kuhlenkötter et al., 2017). Existing research on smart PSS primarily relates to production and logistics, with only a few publications focusing on the product development of smart PSS (Toller and Bertoni 2021; Abramovici, 2018; Mendes et al., 2015). In particular, there is a noticeable lack of industrial (non-academic) viewpoints on smart PSS and their development (Filho et al., 2017). This hits SMEs (small and medium-sized enterprises) particularly hard, because SMEs often lack knowledge and resources to adapt efficiently to such new developments, and today they rely heavily on guidelines. As a result, enterprises struggle with developing smart PSS (Lee and Kao, 2014).

In order to provide appropriate support and guidelines, it is crucial to identify and address the challenges currently faced by enterprises. We have therefore undertaken an explorative multi-method study conducted with German SMEs, the main objective of which is to expand existing literature by adding a practical viewpoint and exploring existing challenges faced by German SMEs in relation to the development of smart PSS. In order to identify the current challenges and what kind of support the SMEs desire, we conducted a multi-method study. Our efforts focused correspondingly on following research questions: What are the challenges faced by German SMEs in developing smart PSS? And what support do German SMEs want for the development of smart PSS?

This paper is structured as follows: Section 3 describes the applied methodology, namely a multi-method study, and presents the findings of that study in detail. Section 4 provides a discussion of the findings in the context of existing literature. And Section 5 notes the limitations of this paper and suggests potential areas for further research.

3. Methodology and findings

In order to identify the current challenges faced by German SMEs in the development of smart PSS, we conducted an explorative multi-method study that began with a written questionnaire and followed up with in-depth interviews. This approach allowed us to gather and analyze quantitative and qualitative data for detailed insight into the current development processes at German SMEs.

Before the questionnaire was issued and subsequently the interviews were conducted, an extensive, literature-based glossary was compiled. The glossary comprised essential definitions of relevant terms and concepts such as smart products, smart services, PSS, smart PSS and many more. All participants received the glossary in advance, whereby an uniform understanding and basis for the inquiry were created.

The glossary, the questionnaire and the interview script based on a literature review and were verified by two different research institutes focusing on collaborations and smart services in the development of smart PSS. Figure 1 shows the design process of the documents, which underwent multiple reviews and a trial run before being used in the survey.

The collaborating research institutes as well as the SMEs are part of the research alliance "bi.smart", which aims to investigate the integrated design of smart PSS in SMEs. The SMEs differ in size, sector and line of business (see Table 1). Overall eighteen participants from five different German SMEs were selected for our survey. All survey participants were selected carefully and were experts in relevant areas, such as product development, service development, low-level to high-level management or

https://doi.org/10.1017/pds.2022.196 Published online by Cambridge University Press

software development. Table 1 provides an overview of the most important characteristics of the enterprises, the number of participants from each enterprise and the role of each participant.

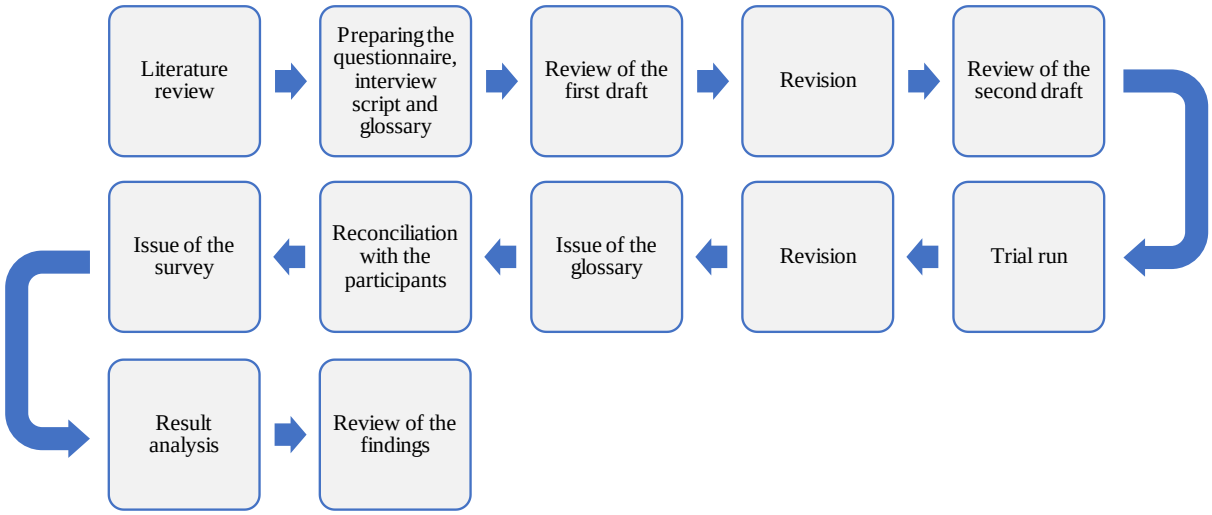

Figure 1. Procedure for the design of the questionnaire and interview script

Table 1. Overview of enterprises and participants (data has been anonymized)

	SME 1	**SME 2**	**SME 3**	**SME 4**	**SME 5**
Employee size	< 250	< 50	< 250	< 15	< 250
Sector	Plastics	Construction	Electronics	Electronics	Laser technology
Line of business	Parts supplier	Service provider	Parts supplier	Manufacturer	Parts supplier
Number of participants	5	3	5	2	3
Role of participant #1	Director of digital transformation	Chief technical officer	Software developer	Chief executive officer	After sales manager
Role of participant #2	Service manager	Project manager	IoT developer	Product manager	Product manager
Role of participant #3	Director of technology & innovation	Project manager	Director of product development		Product manager
Role of participant #4	Product developer		Director of software development		
Role of participant #5	IoT developer		Product manager		

3.1. Questionnaire

3.1.1. Approach

For the first part of the empirical study we issued a written questionnaire, which was fully answered by seventeen (n=17) participants. The questionnaire itself was designed based on a literature review and verified by two different research institutes focusing on collaborations and smart services in the development of smart PSS. It included the following topics: demographic data, current role and tasks,

https://doi.org/10.1017/pds.2022.196 Published online by Cambridge University Press

knowledge regarding smart PSS, expertise in relevant areas, smart services, smart products, PSS, smart PSS, current development processes, customer integration, challenges in the development of smart PSS, requests for support in the development of smart PSS and many more. To confirm that the participants had the required knowledge to partake in our study, we surveyed prior experiences in developing smart products, smart services or (smart) PSS as well as the participants' expertise in relevant areas, such as advanced systems engineering, digitization, PSS or service engineering. The participants could rank their abilities on individual five-point Likert scales ranging from (1) particularly low to (5) particularly high; they could also state that they had no expertise (0) in a particular area. Figure 2 shows the results of the self-assessment.

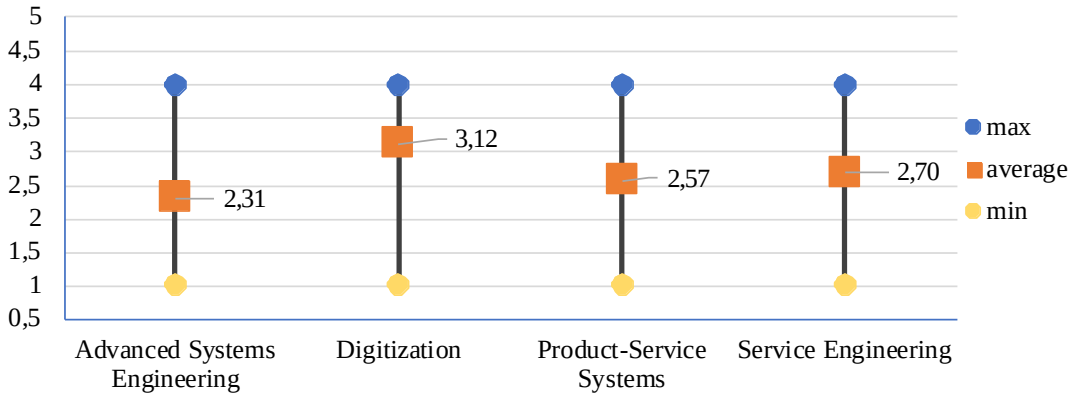

Figure 2. Self-assessment of the survey participants in relevant areas (n=17)

In addition to the self-assessment the questionnaire included explicit questions addressing prior experiences in developing (smart) PSS. Some exemplary questions were: "Do you have prior expertise in developing smart PSS? If so, state the specific context and example.", "Are you currently developing smart products? If so, describe the product.", "Are you currently developing smart services? If so, describe the service." and "Are you currently offering any added (smart or classical) services for your products? If so, describe the service.".

We only included participants with expertise in at least three relevant areas and prior experience in the development of smart products, services or PSS. None of the surveyed experts rated themselves with "no expertise" or "particularly high" and all of them had the necessary prior experience.

One of the main objectives of this questionnaire was to identify the challenges relating to the development of smart PSS. We therefore asked the participants explicit and implicit questions about the challenges they face and what kind of support they desire to such end. Most questions allowed open answers, while for some questions predefined answers were given. Overall, the questionnaire comprised twenty predefined and literature-based answers regarding areas of support. The participants were free to choose multiple answers. Figure 3 shows all answers and the corresponding number of mentions. Several of the identified challenges will be discussed in detail in Section 4, but we will nevertheless provide a brief outline of the challenges in the following chapter.

3.1.2. Findings

On average, each participant checked off eight out of twenty areas in which they needed support. The most frequently requested area of support was the "integration of product and service development", which received fourteen mentions. The integration of the customer and the product user into the development process also received many mentions, with fourteen and eleven mentions respectively. Requirements analysis during product and service development scored moderately highly (n=8). Other frequently requested areas of support were the development of data-based services (n=12) and the integration of smart components into new products (n=11) or existing products (n=9). In general, methods for supporting the development of smart PSS and support for the utilization of such methods enjoyed moderate popularity (n=8, n=9).

https://doi.org/10.1017/pds.2022.196 Published online by Cambridge University Press

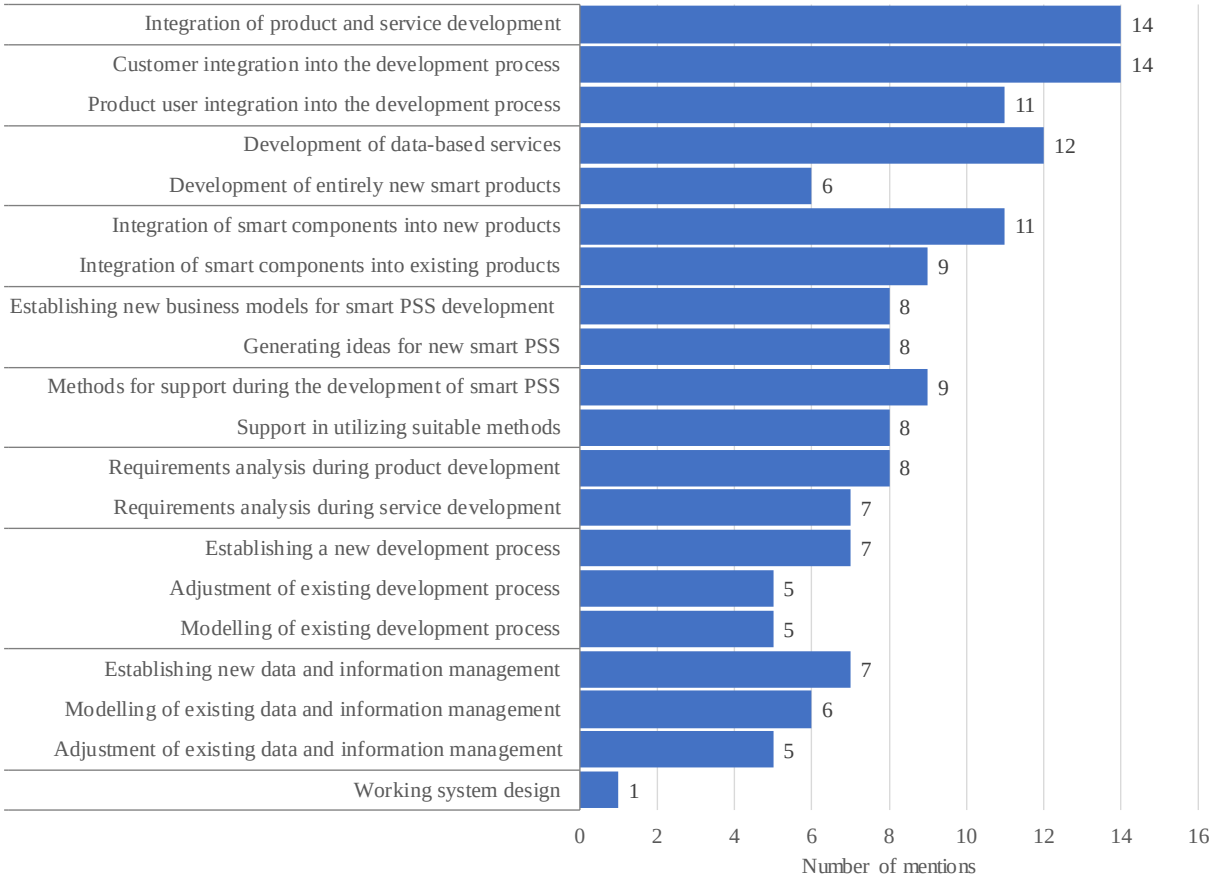

Figure 3. Areas of requested support for tackling current challenges in the development of smart PSS (n=17)

The participants were also asked which additional challenges they faced in the development of smart PSS, with only open answers being allowed. Figure 4 shows the statements and the number of mentions.

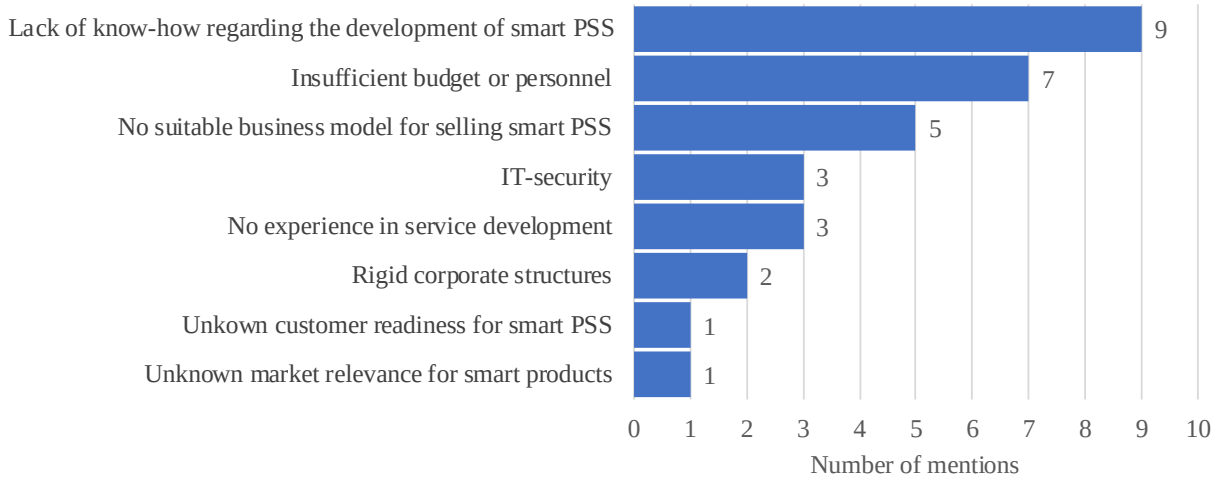

Figure 4. Challenges for German SMEs in developing smart PSS (n=17)

https://doi.org/10.1017/pds.2022.196 Published online by Cambridge University Press

The biggest additional challenge is a lack of know-how regarding the development of smart PSS (n=9), followed by insufficient budget or personnel for developing smart PSS (n=7) and the lack of a suitable business model for selling smart PSS (n=5). The remaining challenges were mentioned no more than three times.

3.2. In-depth interviews

3.2.1. Approach

To further expand our study on challenges in the development of smart PSS, we conducted in-depth interviews with eighteen experts (n=18) from German SMEs (see Table 1). The interviews were prepared in advance and a prearranged script was compiled based on a literature review and the previously designed questionnaire (see Section 3.1). All interviews were conducted by the same interviewers in accordance with the script to prevent large deviations in data. Nonetheless, the interviewees had the chance to speak freely and were only interrupted if they did not stick to the topic.
The interviews lasted from forty-three to one-hundred-seventeen minutes, as shown by Table 2. All interviews were recorded on video, with a full transcript also being created afterwards. This approach allowed for an in-depth analysis of the interviews and prevented any important statements from being overlooked. The transcripts were then manually screened and analyzed using a qualitative approach based on the style of Meuser and Nagel (2009). The transcripts were screened for any explicit statements as well as implicit statements fitting the narrative. A coding scheme with codes derived from the questionnaire and interview script was used for analyzing and categorizing all identified statements. Finally, our findings were presented and discussed with the interviewees as well as additional researchers from two different research institutes focusing on collaborations and smart services in the development of smart PSS.

Table 2. In-depth interview durations

	SME 1	SME 2	SME 3	SME 4	SME 5
Participant #1	1:26h	1:23h	1:23h	1:22h	1:41h
Participant #2	1:20h	0:48h	1:22h	1:01h	1:18h
Participant #3	1:47h	0:43h	1:24h		1:18h
Participant #4	1:46h		1:35h		
Participant #5	1:16h		1:02h		

3.2.2. Findings

In general, the interviews showed that the enterprises differed significantly with respect to their expertise in the development of smart PSS. While some SMEs have already been developing smart PSS for a couple of years, others have just recently started their journey toward the development of smart products, smart services or even smart PSS. The current development processes undertaken by SMEs differed accordingly, as these processes depended on the individual line of business of each enterprise and their respective progress in business development. Enterprises that recently began developing smart PSS often lacked the personnel, the resources and the necessary knowledge specific to this field, which corresponds with the challenges outlined in the questionnaire. The participants stated that they had to educate themselves in entirely new areas in order to tackle the development of smart PSS. Furthermore, many interviewees mentioned that, since they were fully engaged in their day-to-day business, any significant changes to their product/service development process posed a challenge. This because the personnel were already fully occupied with their existing workload.
An in-depth interview analysis provided a variety of statements on the challenges in the development of smart PSS. Though some of the mentioned aspects are closely related to the findings from the questionnaire, others are completely new. Figure 5 shows an overview of the identified challenges based on the interviews.

https://doi.org/10.1017/pds.2022.196 Published online by Cambridge University Press

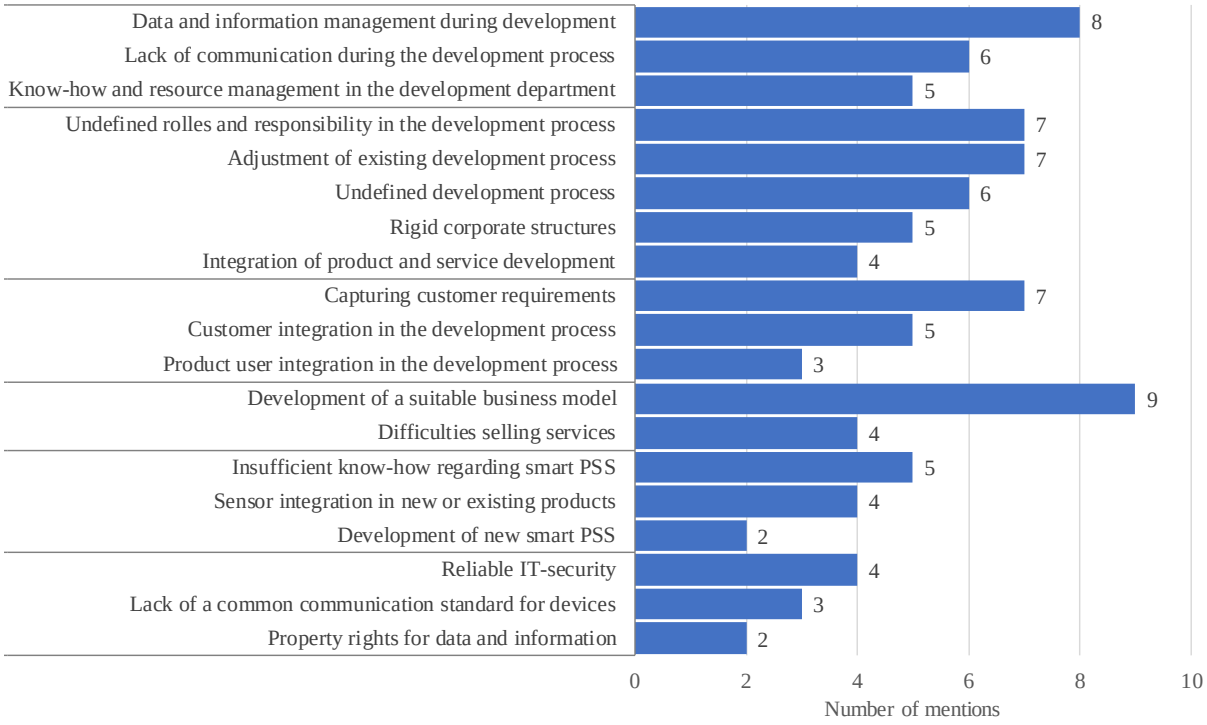

Figure 5. Challenges derived from the in-depth interviews (n=18)

As shown in Figure 5, the number of mentions counts the number of interviewees who referred to a particular challenge. Each statement was only included once per interviewee, even if the challenge was mentioned multiple times during the interview. In addition, we have removed any challenges that were only expressed by a single interviewee, because a single statement would not be representative for our sample.

The upper three challenges relate to the management of data, information, know-how and resources, as well as a lack of communication during the development of smart PSS. The following five challenges are process-related, regarding the general development process of smart PSS, such as adjustment of the existing process or integration of product and service development. Subsequent three challenges are also process related, but they emphasize the integration of customers and product users in the development process as well as the pinpointing of customer requirements. Especially SMEs and part suppliers have trouble reaching and understanding the end user due to their position in the value chain.

The next two challenges relate to economic concerns, namely the development of a suitable business model for smart PSS and difficulties in selling services. The latter one is not surprising, since four out of the five enterprises surveyed are producers and have more expertise in the development and sale of products. In keeping with this, the participants requested more support during the service development process than during the product development process (see Figure 3). Lastly, the remaining challenges related to miscellaneous areas, such as know-how regarding smart PSS or sensor integration in products, as well as IT-related challenges, like reliable IT-security or lack of common communication standards.

4. Discussion

The multi-method study has identified a broad variety of challenges relating to the development of smart PSS as well as various requests for support concerning these challenges from an industrial perspective. The most significant request for support arising from the questionnaire was the integration of product and service development, which received fourteen mentions (n=14) (see Figure 3). This may indicate that the enterprises have already established two separate development processes, one each for the development of products and services respectively. Such conditions may be observed in the context of servitization or productization, when enterprises shift their line of business and integrate new services or products into their portfolio. However, we discovered from the interviews that four out of the five SMEs have not yet established an additional development process. The interviewees stated that they

https://doi.org/10.1017/pds.2022.196 Published online by Cambridge University Press

would prefer to integrate a process for service development into the existing process for product development. And since the SMEs attempt to develop smart PSS within their existing setup prior to establishing new processes, the developers are educating themselves in relevant areas and attempting to fill the gap created by a lack of personnel (see Figure 4).

Both surveys show that the most relevant challenges relating to the development of smart PSS are the integration of the customer (n=14) and integration of the product user (n=11) in the development process (see Figure 4). Requests for support in the requirements analysis stage during product development and services development were also mentioned moderately often (n=8). These requests reflect the enterprises' efforts to create a user-centric development process, which is also crucial for the successful development of smart PSS (Maleki et al., 2018; Zheng et al., 2018). Especially parts suppliers face particular difficulties when it comes to reaching the product user: As their product is upstream in the value chain, the customer and product user often differ. It is therefore necessary to make a clear distinction between the customer and product user. And since part suppliers sometimes don't even know who their product user is or the applications in which the products are deployed, this poses an additional challenge for the establishment of a user-centric development process for smart PSS.

Some challenges stated by the participants seem to be solely related to "regular" and not "smart" PSS, however those challenges are highly interlinked and inherent to smart PSS. Our findings present the current state of the development process of smart PSS in German SMEs. In general, the surveyed SMEs are currently at the beginning of a restructuring process aimed at adjusting to the development of smart PSS. This restructuring process poses a multi-dimensional challenge, because the SMEs have to analyze their current development process in detail, which often focuses either on product development or service development. Subsequently a new development process that integrates both product and service development has to be designed. Therefore, integration points in the development processes have to be identified and connected. Such tasks at the integration points are often performed by a fitting role with diverse skills and interdisciplinary expertise. However, the enterprises are not aware of how the integration has to take place and which steps of the product development process are intersecting with the service development as well as how possible intersection points may be connected. It is also not known which roles are necessary, if existing personnel has the required skills and expertise to fill in the gap. Such obstacles explain the high level of readiness and requests for support relating to the establishment of new processes and structures (see Figure 3).

One surprising result is that the development of new smart PSS was only mentioned twice (n=2) (see Figure 5), which could lead some to conclude that this isn't a major issue for German SMEs. However, our findings suggest that the SMEs are currently struggling to adjust their organizational structures and development processes in line with smart PSS – and that they are striving to acquire the relevant knowledge and trying to form specialized development teams. This indicates that the relevance of certain challenges is highly dependent on the state of the individual enterprise and is influenced by factors such as time and business progression.

We also identified IT-related challenges affecting the development of smart PSS in areas such as IT security, property rights and device communications. These have been also identified by Marquardt (2017).

Overall, interviewees emphasized different challenges corresponding to the progress made by the SME in question. The study therefore indicates that the challenges in the development of smart PSS are highly dependent on the progress made by each enterprise in gearing their business towards the development of smart PSS; these challenges may shift as further progress is made.

5. Limitations and future research

This paper identifies a wide range of challenges relating to the development of smart PSS and expands on existing literature (e.g. Zheng et al., 2019; Chowdhury et al., 2018; Valencia et al.; 2014). We have also been able to identify a variety of requests for support in the development of smart PSS. Our investigation has backed up the findings of existing literature and provides profound insight into industrial perspectives on the development of smart PSS in German SMEs.

Due to the specific formulation of the research questions, this study is subject to a few limitations. Firstly, as we surveyed only German enterprises, findings may vary for enterprises from other countries.

https://doi.org/10.1017/pds.2022.196 Published online by Cambridge University Press

Secondly, as we investigated only those challenges faced by SMEs, findings may differ for large enterprises. For example, large enterprises may have better access to know-how regarding the development of smart PSS, a bigger budget or more personnel for exploring and establishing new business practices. And thirdly, in spite of a relatively large sample size of eighteen participants for this survey, there may be other important challenges that were not mentioned by the participants. Additionally, the eighteen participants were not evenly distributed between the enterprise. Some SMEs had more participants than others, which may cause a bias in the number of mentions of certain challenges. Due to the fact, that enterprises face different challenges that for example depend on their line of business, prior expertise in the development of (smart) PSS or organisational structures.

Future research may focus on key challenges relating to the development of smart PSS and the most frequently requested areas of support. For example, one possible research question could be as follows: How can customers and product users be integrated into the development process for smart PSS? This question is in accordance with the findings stated by fellow authors (Zheng et al., 2019; Abramovici, 2018; Song, 2017) and emphasizes the need for an investigation into a development process for user-centric development of smart PSS.

In addition, this study uncovered many challenges relating to the development process itself. Another research questions could therefore be: How can a SME integrate the product development process and the service development process? And what is the current situation regarding the process for the development of products and for the development of services for smart PSS? Research into this topic could focus on establishing the present process for product development and the present process for service development while searching for possible ways to integrate both of them. Furthermore, this research could be extended to investigate the management of know-how, resources, data and information for the development of smart PSS. The goal should be to create a defined and systematic development process, which is very important to the success of smart PSS (Zheng et al., 2019).

Last, a promising research question could be derived from our findings: How can smart components be integrated into existing products and newly developed products for application in smart PSS? Smart components are an essential part of smart PSS and crucial for their success and the value creation (Beverungen et al., 2017).

Answering these research questions will ensure that the designed methods and strategies for developing smart PSS provide appropriate support to SMEs. This approach will also maximize the impact of the support provided.

Acknowledgements

Our study was conducted within the research alliance "bi.smart", which aims to investigate the integrated design of smart PSS in SMEs. We therefore wish to thank our research partners, the participants in this study and the financial support by the Federal Ministry of Education and Research of Germany.

References

Abramovici, M. (2018), *Engineering smarter Produkte und Services Plattform Industrie 4.0 STUDIE*, acatech – Deutsche Akademie der Technikwissenschaften, Munich, Germany.

Beverungen, D., Müller, O., Matzner, M., Mendling, J. and vom Brocke, J. (2017), "Conceptualizing smart service systems", *Electron Markets*, Vol. 29 No. 1. https://doi.org/10.1007/s12525-017-0270-5

Böhmann, T., Leimeister, J. M., and Möslein, K. (2018), "The New Fontiers of Service Systems Engineering", *Business & Information Systems Engineering*, Vol. 60 No. 5, pp. 373–375. https://doi.org/10.1007/s12599-018-0553-1

Chowdhury, S., Haftor, D. and Pashkevich, N. (2018), "Smart Product-Service Systems (Smart PSS) in Industrial Firms: A Literature Review", Procedia CIPR, Special Issue: 11th CIRP Conference on Industrial Product-Service Systems, Vol. 73, pp. 26-31. https://doi.org/10.1016/j.procir.2018.03.333

Cong, J., Chen, C. and Zheng, P. (2020), "Design entropy theory: A new design methodology for smart PSS development", Advanced Engineering Informatics, Vol. 45. https://doi.org/10.1016/j.aei.2020.101124

Filho, M.F., Liao, Y., Loures, E.R. and Junior, O.C. (2017), "Self-Aware Smart Products: Systematic Literature Review, Conceptual Design and Prototype Implementation", Procedia Manufacturing, Vol. 11 Special Issue: 27th International Conference on Flexible Automation and Intelligent Manufacturing, pp. 1471-1480. https://doi.org/10.1016/j.promfg.2017.07.278

Hagen, S., Kammler, F. and Thomas, O., (2017), "Adapting Product-Service System methods for the digital era - requirements for Smart PSS engineering", 9th World Conference on Mass Customization, Personalization and Co-Creation (MCPC 2017), Aachen, Germany.

Kuhlenkötter, B., Bender, B., Wilkens, U., Abramovici, M. and Göbel, J.C. et al. (2017), "Coping with the challenges of engineering smart product service systems - Demands for research infrastructure", *Proceedings of the 21st International Conference on Engineering Design (ICED 17), Vol. 3: Product, Services and Systems Design, Vancouver, Canada, 21-25.08.*2017, The Design Society, Glasgow, Scotland.

Lee, J. and Kao, H.A. (2014), "Dominant Innovation Design for Smart Products-Service Systems (PSS): Strategies and Case Studies", 2014 *Annual SRII Global Conference (SRII)*, San Jose, CA, USA, 23-25 April 2014, IEEE, Piscataway, NJ, USA. https://doi.org/10.1109/SRII.2014.25

Maleki, E., Belkadi, F. and Bernard, A. (2018), "Industrial Product-Service System modelling base on Systems Engineering: Application of sensor integration to support smart services", *IFAC-PapersOnLine, Vol. 51 No. 11 Special Issue: 16th IFAC Symposium on Information Control Problems in Manufacturing*, pp. 1586-1591. http://dx.doi.org/10.1016/j.ifacol.2018.08.270

Marquardt, K. (2017), "Smart services – characteristics, challenges, opportunities and business models", *Proceedings of the International Conference on Business Excellence*, Vol. 11 No. 1, pp. 789-801. https://doi.org/10.1515/picbe-2017-0084

Mendes, G. H. S., Oliviera, M. G., Rozenfeld, H., Marques, C. A. N. and Costa, J. M. H. (2015), "Product-Service System (PSS) Design Process Methodologies: A Systematic Literature Review", *Proceedings of the 20th Internatinal Conference On Engineering Design (ICED15), Vol. 7*, pp.291-300.

Meuser, M. and Nagel, U. (2009), "*Das Experteninterview - konzeptionelle Grundlagen und methodische Anlage*", VS Verlag für Sozialwissenschaften, pp. 465-479. https://doi.org/10.1007/978-3-531-91826-6_23

Pessôa, M.V.P., Becker, J.M.J. (2020), "Smart design engineering: a literature review of the impact of the 4th industrial revolution on product design and development ", *Research in Engineering Design*, Vol. 31, pp. 175-195. https://doi.org/10.1007/s00163-020-00330-z

Reim, W., Parida, V. and Örtqvist, D (2015), "Product-Service Systems (PSS) business models and tactics - A systematic literature review", *Journal of Cleaner Production*, Vol. 97, pp. 61-75. https://doi.org/10.1016/j.jclepro.2014.07.003

Schuh, G., Kuntz, J., Stich, V. and Jussen, P. (2019), "Managing Complexity in Product Service Systems and Smart Services", *Procedia CIPR, Vol. 83 Special Issue: 11th CIRP Conference on Industrial Product-Service Systems*, pp. 410-414. http://dx.doi.org/10.1016/j.procir.2019.03.093

Song, W., (2017), "Requirement management for product-service systems: Status review and future trends", *Computers in Industry* , Vol. 85, pp. 11-27. http://dx.doi.org/10.1016/j.compind.2016.11.005

Sutanto, A., Yuliandra, B., Tjahjono, B. and Hadiguna, R. A. (2015), "Product-service system design concept development", *Journal of Design Research*, Vol. 13, No. 1, pp. 1-19. http://dx.doi.org/10.1504/JDR.2015.067224

Toller, C. N. K. and Bertoni, M. (2021) "The Research Domain of Product-Service Systems and Voice of the Customer: A Systematic Mapping", *Proceedings of the International Conference on Engineering Design (ICED21), ICED21 1*, Gothenburg, Sweden, 16-20 August 2021. DOI:10.1017/pds.2021.571

Valencia, A., Mugge, R., Schoormans, J.P.L. and Schifferstein, H.N.J. (2014), "Challenges in the design of smart product-service systems (PSSs): Experiences from practitioners", *Proceedings of the 19th DMI: Academic Design Management Conference.* Design Management in an Era of Disruption, London, UK, September 2-4, 2014, Design Management Institute, Cambridge, MA, USA. Availible at: http://resolver.tudelft.nl/uuid:03453047-d336-470e-9290-a1bbf5bb6b32

Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J. et al. (2021), "Digital transformation: A multidisciplinary reflection and research agenda", *Journal of Business Research*, Vol. 122, pp. 889-901. https://doi.org/10.1016/j.jbusres.2019.09.022

Vogel-Heuser, B. (2014), *Herausforderungen und Anforderungen aus Sicht der IT und der Automatisierungstechnik*, Springer Vieweg, Wiesbaden, Germany, pp. 37-48. https://doi.org/10.1007/978-3-658-04682-8_2

Zheng, P., Lin, T., Chen, C.H. and Xuc, X. (2018), "A systematic design approach for service innovation of smart product-service systems", *Journal of Cleaner Production*, Vol. 201, pp. 657-667. https://doi.org/10.1016/j.jclepro.2018.08.101

Zheng, P., Wang, Z., Chen, C.H. and Khoo, L.P. (2019), "A Survey of Smart Product-Service Systems: Key Aspects, Challenges and Future Perspectives", *Advanced Engineering Informatics*, Vol. 42. https://doi.org/10.1016/j.aei.2019.100973