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A systematic review of value metrics for PSS design

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Abstract

The notion of 'value' has become pivotal in the PSS domain, with a plethora of 'indicators', 'drivers' and 'measurements' proposed to guide the assessment of PSS concepts across the design process. This paper presents the results of a systematic literature review that maps existing contributions dealing with metrics for PSS value in early design. The findings reveal the lack of a common taxonomy to define what PSS value is, as well as differences in terms of granularity of the applied metrics, which span from very generic to highly case-study specific. This mapping aims at validating a proposed classification framework for such metrics, which balances customer and provider value perspectives in early stage PSS concept assessment activities. Its goal is to raise the cross-functional design team awareness on the multiple value types impacted by early stage design decisions when working with MADM matrixes; hence to highlight opportunities for improvement, recombination and refinement.

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Keywords: PSS value; classification framework; customer value; provider value; assessment criteria; assessment factors

1. Introduction and objectives

The ascent of a service-dominant (S-D) in the last decade is well documented in literature. Lightfoot et al. [1], for instance, describe the way several traditional manufacturing organizations have moved their position in the value-chain from selling products to providing customers with 'desired outcomes'. This shift does not come without challenges; rather servitization initiatives have been found to be often limited in extent [2] and unsuccessful [3]. These experiences have triggered several research initiatives aiming at measuring the value creation opportunities in Product-Service Systems (PSS) engineering [4]. PSS value is found to take many forms: it is often interpreted as the ability to generate new revenue streams, to gain closer relationships with customers, to increase operational performances to a level not reachable by mere hardware improvements [5], and in terms of social well-being and environmental sustainability [2]. While all these aspects are critical to guide design decisions, a systematic framework for classifying PSS value metrics is lacking in literature. The objective of this paper is to map existing contributions that deal with the definition of 'indicators', 'measurements', 'criteria' and other factors characterizing PSS 'value'. This mapping activity aims at validating a proposed classification framework for such metrics, which balances customer and provider value perspectives in early stage PSS concept assessment activities.

2. Method

The investigation has followed a process of systematic review of academic and scholarly publications in the SCOPUS, ISI Web-of-Science and EBSCO databases. The search was limited to type *Article* (journal papers), *Book chapter*, *Review* and *Conferences*. Figure 1 presents the 2 keywords sets adopted in the search, all featuring the search operator (*) to include nearby terms (e.g., 'measures' and 'measurements'). Papers were initially filtered by title and abstract. Inclusion criteria cover '*relevancy of the described metrics for PSS design*' and '*applicability to early design stage decision making*'. The list was then filtered on a full-text base, eliminating entries that did not explicitly refer to '*value metrics for customers, stakeholders or provider*'. Redundant items were removed, and

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remaining ones were complemented with other contributions through snowballing. This step was supported by a systematic procedure that featured both backwards and forward snowballing [6], adding papers from selected research communities (CIRP, Design Society and ASME). The final paper list is composed of 64 items, further categorized based on type and variety of value metrics proposed.

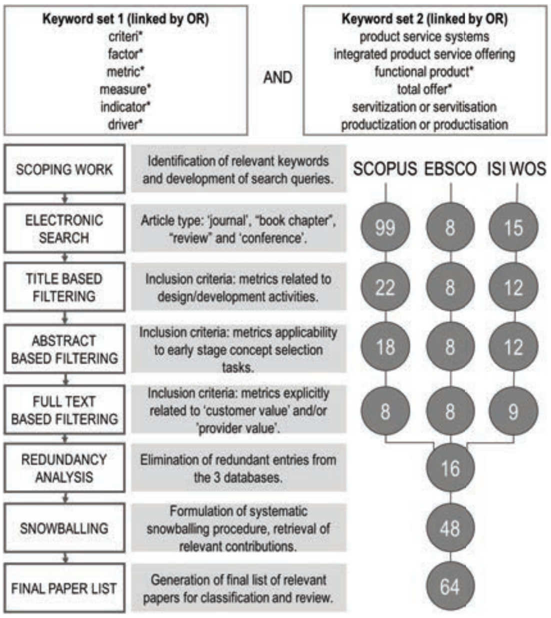

Fig. 1. Systematic review procedure.

3. Development of a framework for value metrics classification

"Value has been considered to be a cognitive trade-off between benefits and sacrifices" [7]. Consequently there isn't shared and well known framework to classify the value metrics associated to it. Several contributions stand out in the quest for a systematic framework from which value metrics can be categorized. One well-known approach is the Value Proposition Canvas (VPC) [8], which describes value creation in terms of *Customer Gains* and *Customer Pain*s and considers all negative emotions and undesired costs, situations and risk that customers could experience before, during and after getting the job done.

The empirical study underlying this review points also to the value equation proposed by Lindstedt and Burenius [9]. The equation is inspired by the VPC and defines customer value in the broader perspective of "perceived customer benefit", described in terms of 'main', 'additional', 'supporting' and 'unwanted' functions. This numerator is then divided by the "use of customer resources", intended as money, time and effort. The basic concepts expressed in both [8] and [9] were used as basis for defining 2 broad families of value metrics, through which literature contributions were analyzed. These are 'Total Functionality' and 'Total Expenditure'. The main rationale for considering both aspects since the early assessment of PSS concepts is that decision makers need to realize that any design decision will always impact multiple value types at the same time. The two families were then doubled as suggested by [10], to collect metrics addressing both customer and provider viewpoints. These were further broken down to more specific value categories so that design decisions (e.g., selection of features that shall be included in the PSS offer) could be taken based on concrete needs and opportunities. The Design Thinking methodology [11] provides a further mental model to specify these categories. The intersecting "constraints" in the "feasibility", "viability" and "desirability" (FVD) framework ("what can be done" - "what you can do successfully within a business" – "what people want or will come to want") were elaborated and adapted to derive a total of 20 metrics categories, 11 for 'customer' and 9 for 'provider', as described in Table 1.

Table 1. Classification framework based on [8], [9], [10] and [11].

Customer Value (CV)		Provider Value (PV)	
TOTAL FUNCTIONALITY	TOTAL EXPENDITURE	TOTAL FUNCTIONALITY	TOTAL EXPENDITURE
(C1) Product/ service value in use	(C8) Ownership cost	(P1) Business opportunity and ROI	(P6) Product/ service lifecycle cost
(C2) Business opportunity and ROI	(C9) Operational cost	(P2) Brand strategy	(P7) System/ infrastructure cost
(C3) System convenience	(C10) Financial and opportunity cost	(P3) Customer and Stakeholder relationship	(P8) Financial and opportunity cost
(C4) Intangibles	(C11) Effort	(P4) Capability creation and retention	(P9) Effort
(C5) Capability creation and retention		(P5) Uncertainty/ risk	
(C6) Brand/ strategy			
(C7) Uncertainty/ risk			

4. Literature review results

Table 2 summarizes the literature review results in alphabetical order, mapping all retrieved contributions against the categories defined in Table 1. The mapping highlights which categories are addressed with detail (✓), and which ones are only implicitly or partially (*p*) mentioned by each publication. In case the reviewed metrics did not find a direct mapping into the proposed categories, they were classified as 'uncategorized' (U). Examples of such metrics include several criteria for environmental sustainability, health and other social-related aspects. Overall, the results highlight a stronger focus on CV metrics than on provider ones when it comes to early stage design decision making (Figure 2).

More than ¾ of the reviewed papers include metrics for design concept evaluation that mirror the CV creation opportunity, while less than ¼ deal only with a provider perspective. Importantly, less than 1/3 of the retrieved contributions focus on both perspectives (customer and provider) when defining metrics for PSS concept evaluation.

Table 2. Systematic literature review results

Reference	CV	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	PV	P1	P2	P3	P4	P5	P6	P7	P8	P9	U
Akasaka et al. 2011 [12]	✓	✓		✓				✓	*p*	*p*													
Alix et al. 2009 [13]	✓	✓							*p*	*p*			✓	✓	✓	✓	✓				✓		
Bertoni et al. 2011 [14]	✓	✓		✓	✓				✓	✓	✓		✓		*p*	*p*	✓		✓	✓	✓		
Ceschin 2013 [15]	✓							*p*		*p*		*p*	✓	✓				✓	✓	✓	✓	✓	
Chen et al. 2015 [16]	✓	✓		✓					*p*	*p*													✓
Cherubini et al. 2015 [17]	✓	✓		✓		*p*			*p*		*p*												✓
Chirumalla et al. 2013 [18]													✓			✓	✓				*p*		✓
Chou et al. 2015 [19]	✓	✓		*p*	✓	✓			✓	✓	✓	✓	✓				✓		✓	✓			✓
Chun et al. 2011 [20]	✓								✓	✓	*p*												
Estrada & Romero 2016 [21]	✓	✓																					
Everhartz et al. 2014 [22]	✓	*p*		*p*	*p*	✓		✓			✓	*p*											
Felber 2015 [23]	✓		*p*	*p*	✓								✓	✓	✓		✓		✓	*p*	*p*		
Geng & Chu 2013 [24]	✓	✓		*p*	*p*				✓	✓		✓											
Geng et al. 2010 [25]	✓	✓							✓	✓													
Goncalves et al. 2015 [26]	✓	*p*		*p*				✓		✓	*p*												
Hu et al. 2012 [27]	✓	✓				✓			✓	✓	✓	*p*	✓	✓	✓	✓	✓	*p*	*p*		✓	*p*	✓
Khumboon et al. 2011 [28]	✓	✓		✓				*p*		✓			✓					*p*	*p*	*p*			
Kim et al. 2011 [29]	✓	✓							✓	✓			✓	✓	*p*	✓	✓	*p*	✓	✓			✓
Kim et al. 2011 [30]	✓	*p*			✓				✓	✓			✓	✓	✓				✓	✓			
Kim et al. 2015 [31]	✓	✓		✓					✓	✓			✓	✓		*p*	✓		✓	✓			✓
Kimita et al. 2009 [32]	✓	*p*		✓				*p*		✓													
Kimita et al. 2013 [33]	✓	✓																					
Kuntzky et al. 2013 [34]	✓	✓											✓	✓					*p*	✓			✓
Kurita et al. 2013 [35]													✓						✓	✓			
Lagemann & Meier 2014 [36]													✓	*p*			✓	*p*	*p*	*p*			
Lee et al., 2012 [37]													✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Lee et al. 2015 [38]	✓	✓		✓	✓		✓			✓		✓											
Lindström et al. 2013 [39]	✓	✓		*p*	*p*				✓	✓	*p*		✓		✓	✓	✓	✓					
Long et al. 2011 [40]	✓	✓		*p*				✓	*p*														
Matschewsky et al. 2015 [41]													✓		*p*	✓		✓	✓	✓			
Mattes et al. 2013 [42]													✓	✓	✓	*p*	✓		*p*		✓		
Mazo et al. 2014 [43]	✓	✓		*p*	✓			*p*				*p*											✓
Mert et al. 2014 [44]	✓	✓		✓		✓																	
Mourtzis et al. 2015 [45]	✓	✓		✓	✓			*p*	✓	✓			✓	✓		✓	✓	✓	✓	✓	*p*		
Mourtzis et al. 2016 [46]	✓	✓		*p*					*p*	✓			✓				✓	✓	✓	✓	*p*		✓
Müller et al., 2010 [47]	✓	✓	✓	✓	*p*	✓				✓		✓											
Nemoto et al.,2013 [48]	✓	✓		✓	✓			✓	*p*	*p*		✓											
Neugebauer et al., 2013 [49]													✓	✓	✓	✓	✓	✓		*p*		*p*	✓
Ng et al., 2013 [50]	✓	✓		✓	✓		*p*		✓	*p*													
Pan & Nguyen, 2015 [51]													✓	✓	✓	✓	✓	*p*	*p*	✓			✓
Peruzzini et al. 2015 [52]	✓	✓		*p*	*p*				*p*	*p*		✓											
Reim et al. 2016 [53]													✓			✓	✓	✓					
Rodrigues et al. 2016 [54]													✓	✓		✓	✓	✓	✓	*p*			✓
Roy & Cheruvu 2009 [55]	✓		✓						*p*				✓	✓				✓	✓	✓			✓
Sakao & Lindahl 2012 [56]	✓	✓		✓																			
Sakao et al. 2011 [57]	✓	✓		✓		*p*			✓	✓		*p*											
Schenkl et al. 2014 [58]	✓	*p*		✓	✓			✓	✓		*p*												
Shimada et al. 2011 [59]	✓	*p*																					
Shimada et al. 2012 [60]	✓	*p*																					
Shimomura et al. 2009 [61]	✓	✓		✓	✓																		
Shimomura et al. 2011 [62]	✓	✓		✓	✓																		
Song et al. 2013 [63]	✓	*p*								✓			✓	✓				*p*					✓
Song & Sakao 2017 [64]	✓	✓		✓					✓		✓												✓
Stafano et al. 2015 [65]													✓	*p*		*p*	*p*	*p*	*p*	*p*			✓
Storey et al. 1998 [66]													✓	✓	✓	✓		✓		*p*	✓	*p*	✓
Sundin et al. 2015 [67]													✓						✓				✓
Taabodi & Sakao 2011 [68]	✓	✓																					
Tan et al., 2011 [69]	✓	✓		✓	*p*		✓		✓	✓													
Van Ostaeyen et al. 2013 [70]	✓	✓																					
Weißfloch et al. 2016 [71]													✓	✓	✓	✓	*p*	✓	*p*		✓	✓	
Williams 2006 [72]													✓	✓	✓								✓
Xiao-rong et al. 2009 [73]	✓	*p*		✓	✓								✓			✓	✓						
Yang et al. 2009 [74]	✓		✓	✓	✓	✓		✓	✓	✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Yoon et al. 2012 [75]	✓	*p*		*p*									✓		✓		*p*	✓	✓	✓	*p*		✓
Total	49	44	4	32	19	8	3	12	26	28	10	11	34	22	16	20	23	21	25	23	14	7	22

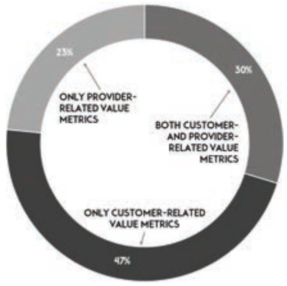

Fig. 2. Number of customer value metrics in the category.

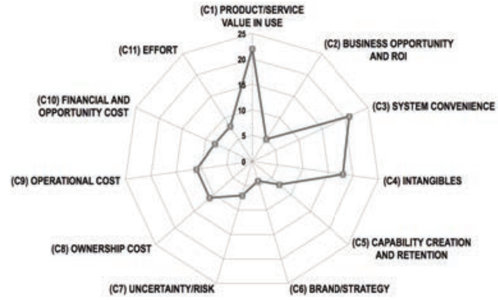

Fig. 3. Number of customer value metrics in the category.

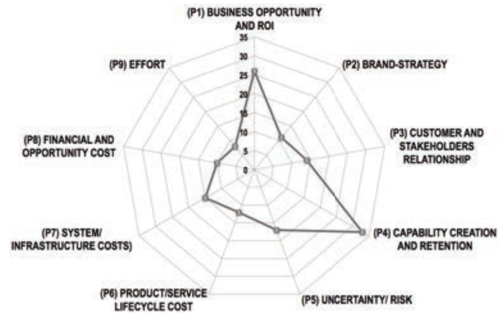

Fig. 4. Number of provider value metrics in the category.

With regards to validating the proposed framework, it is noticeable that all the proposed 20 categories are mentioned in literature by at least 3 items. However none of the reviewed contributions captures all value categories defined in Table 2. Most contributions assess PSS goodness from a 'value in use' (C1) – defined as performances, quality, etc. - 'system convenience' (C3) – defined as availability, customizability, etc. - and cost (C8-C9-C10) perspectives. Only few shift the focus towards a customer-of-customer perspective (C2). It is also surprising to find a general lack of metrics that capture the opportunity of leveraging customer's brand and strategy (C6) through PSS provision. From a provider viewpoint, a more homogeneous distribution is observed. Still, only few contributions highlight the organizational effort (P9) linked with an S-D logic transformation.

4.1. Analysis of value metrics inside each category

Each category, from C1 to P9, was subject to further scrutiny to list specific metrics inside each category, and to analyze their level of granularity and homogeneity. A total of 122 metrics for CV, together with 146 metrics for PV, were identified (Figure 4). The results obtained reflects the analysis discussed before. It is noticeable that, even if the number of papers focusing on PV is lower, the number of indicators identified is higher, which may indicate a need for creating 'arguments' to justify the transition towards PSS internally in the organization. Concerning specific categories, C1 (product/service value in use), C3 (system convenience) and C4 (intangibles) are those with the largest number of metrics defined from a customer/stakeholder viewpoint (Figure 3). Literature is more aligned in terms of metrics reflecting business opportunity, brand and strategy, effort and, in general, cost matters.

The analysis further highlights that P4 (Capability creation and retention) and P1 (Business opportunity and ROI) are the most heterogeneous from a provider point of view (Figure 4), while literature is more aligned with regards to cost aspects, brand/ strategy issues and risk.

It can be observed that value metrics are frequently linked to the specific case study under analysis. On the one hand, this means that often value assessments do not cover all range of possible value creation aspects, which may lead to misleading conclusions and consequently rework in a later design phase.

On the other hand, the proposed metrics cannot often be easily generalized and applied in new contexts. For instance, category P4 ('Capability creation and retention') includes heterogeneously defined criteria, ranging from 'staff training', 'employee education', 'qualification of field service engineering', 'team qualification', 'employee professional ability', etc., which mirror the jargon of specific industrial sectors or applications.

5. Conclusions

The paper proposes a classification framework for PSS value metrics, which is validated by mapping existing literature contributions against the frameworks' proposed categories. Importantly, all categories defined in the framework are covered by a significant amount of publications in literature, which proves its relevancy and soundness to guide early stage assessment activities. Still, the work reveals that none of the reviewed contributions captures all categories of value defined in the framework. Furthermore, the large variety of items emerging from the review spotlights the fundamental lack of agreement on what aspects of value shall be considered to guide the assessment of the early stage design activities for PSS. Further examination of the granularity of such metrics reveals the need for defining a common taxonomy to describe the value creation opportunities related to servitization initiatives. Future work will aim at adapting and refining the framework to support Multi Attribute Decision Making (MADM) activities at operational level. The framework is intended to work as backbone for a 2-step method for early PSS design concept assessment based on the Importance Performance Analysis (IPA) method and the *Technique for Order of Preference by Similarity to Ideal Solution* (TOPSIS) matrix [76]. The proposed value categories will support design teams in ranking PSS solutions in TOPSIS and IPA from both a customer and a provider perspective. The main long-term effect of the utilization of the 2-step assessing method is to reduce reworks and costs associated to late stage design modification caused by misleading assessments in an early stage. The framework will be tested in heterogeneous case studies to verify both the applicability and effectiveness of the proposed categories of metrics and its ability to raise the PSS cross-functional design team awareness on the multiple value types impacted by early stage design decisions.

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References

[1] Lightfoot H, Baines T, Smart P. The servitization of manufacturing: A systematic literature review of interdependent trends. Int J Oper Prod Man. 2013; 33(11/12):1408-34.
[2] Vezzoli C, Ceschin F, Diehl JC, Kohtala C. New design challenges to widely implement 'Sustainable Product–Service Systems'. J Clean Prod. 2015;97:1-2.
[3] Benedettini O, Neely A, Swink M. Why do servitized firms fail? A risk-based explanation. Int J Oper Prod Man. 2015;35(6):946-79.
[4] Cavalieri S, Pezzotta G. Product–Service Systems Engineering: State of the art and research challenges. Comput Ind. 2012;63(4):278-88.
[5] Mathieu V. Service strategies within the manufacturing sector: benefits, costs and partnership. Int J of Serv Ind Manag. 2001 Dec 1;12(5):451-75.
[6] Wohlin C. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering 2014 (p. 38). ACM.
[7] Sánchez-Fernández R, Iniesta-Bonillo M. Á. The concept of perceived value: a systematic review of the research. Marketing theory. 2007. 7(4):427-451.
[8] Osterwalder A, Pigneur Y, Bernarda G, Smith A. Value proposition design: how to create products and services customers want. John Wiley & Sons; 2014.
[9] Lindstedt P, Burenius J. The value model: how to master product development and create unrivalled customer value. Nimba; 2003.
[10] Xing K, Wang HF, Qian W. A sustainability-oriented multi-dimensional value assessment model for product-service development. International Journal of Production Research. 2013.51(19):5908-33.
[11] Leavy B. Design thinking-a new mental model of value innovation. Strategy & leadership. 2010 May 11;38(3):5-14.
[12] Akasaka F, Chiba R, Shimomura Y. An engineering method for supporting customer-oriented service improvement. In Functional Thinking for Value Creation 2011 (pp. 87-92). Springer Berlin Heidelberg.
[13] Alix T, Ducq Y, Vallespir B. Product service value analysis: two complementary points of view. In Proceedings of the 19th CIRP Design Conference–Competitive Design 2009. Cranfield University Press.
[14] Bertoni M, Eres H, Isaksson O. Criteria for assessing the value of Product Service System design alternatives: an aerospace investigation. In Functional Thinking for Value Creation 2011 (pp. 141-146). Springer Berlin Heidelberg.
[15] Ceschin F. Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. J Clean Prod. 2013;45:74-88.
[16] Chen, D., Chu, X., Sun, X., & Li, Y. A new product service system concept evaluation approach based on Information Axiom in a fuzzy-stochastic environment. I J Comp Integ Manuf, 2015; 28(11): 1123-1141.
[17] Cherubini, S., Iasevoli, G., & Michelini, L. Product-service systems in the electric car industry: Critical success factors in marketing. J Clean Prod, 2015; 97, 40-49.
[18] Chirumalla K, Bertoni A, Parida A, Johansson C, Bertoni M. Performance measurement framework for product–service systems development: a balanced scorecard approach. Int J Technol Int Plan. 2013;9(2):146-64.
[19] Chou, C. J., Chen, C. W., & Conley, C. An approach to assessing sustainable product-service systems. J Clean Prod, 2015; 86, 277-284.
[20] Chun, Y. Y., Kondoh, S., Mishima, N., & Lee, K. M. A study on comparison of different PSS concepts based on value creation efficiency. In Functional Thinking for Value Creation 2011 (pp. 303-308). Springer Berlin Heidelberg.
[21] Estrada A, Romero D. A System Quality Attributes Ontology for Product-Service Systems Functional Measurement based on a Holistic Approach. 2016. Procedia CIRP.2016. 47:78-83 [22] Everhartz J, Maiwald K, Wieseke J. Identifying and analyzing the customer situation: Drivers for purchasing Industrial Product Service Systems. Procedia CIRP. 2014;16:308-13.
[23] Felber H, von Bischhoffshausen JK. Interrelations of Success Factors for Selling Product-Service Systems from a Solution Sales Perspective. In International Conference on Exploring Services Science 2015 (pp. 301-313). Springer International Publishing.
[24] Geng X, Chu X. Research on customer value in PSS design for design driving and concept evaluating. In The Philosopher's Stone for Sustainability 2013 (pp. 471-475). Springer Berlin Heidelberg.
[25] Geng X, Chu X, Xue D, Zhang Z. An integrated approach for rating engineering characteristics' final importance in product-service system development. Computers & Industrial Engineering. 2010;59(4):585-94.
[26] Goncalves CD, Kokkolaras M. Value-Driven Modeling of Tactical and Operational Decisions in Support of Aerospace Product-Service Systems Design. In ASME 2015 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference 2015, American Society of Mechanical Engineers.
[27] Hu HA, Chen SH, Hsu CW, Wang C, Wu CL. Development of sustainability evaluation model for implementing product service systems. Int J Environ Sci Te. 2012;9(2):343-54.
[28] Khumboon R, Kara S, Ibbotson S. A simplified decision making model for employing product service system in industry at a preliminary planning stage. In Functional Thinking for Value Creation 2011 (pp. 177-182). Springer Berlin Heidelberg.
[29] Kim KJ, Lee DH, Lim CH, Heo JY, Hong YS, Park KT. Development of an evaluation scheme for product-service systems. In Functional Thinking for Value Creation 2011 (pp. 255-260). Springer Berlin Heidelberg.
[30] Kim YS, Cho CK, Ko YD, Jee H. E3 Value Concept for a New Design Paradigm. InDS 68-2: Proceedings of the 18th International Conference on Engineering Design (ICED 11), Impacting Society through Engineering Design, Vol. 2: Design Theory and Research Methodology, Lyngby/Copenhagen, Denmark, 15.-19.08. 2011.
[31] Kim KJ, Lim CH, Heo JY, Lee DH, Hong YS, Park K. An evaluation scheme for product–service system models: Development of evaluation criteria and case studies. Service Business. 2015:1-24.
[32] Kimita K, Shimomura Y, Arai T. Evaluation of customer satisfaction for PSS design. J Manuf Technol Manag. 2009 ;20(5):654-73.
[33] Kimita K, Shimomura Y. A Method for Exploring PSS Technologies Based on Customer Needs. In Product-Service Integration for Sustainable Solutions 2013 (pp. 215-225). Springer Berlin Heidelberg.
[34] Kuntzky K, Herrmann C. Developing New (Industrial) Product Service Systems with a Case-based Reasoning Approach. InThe Philosopher's Stone for Sustainability 2013 (pp. 43-48). Springer Berlin Heidelberg.
[35] Kurita Y, Uei K, Kimita K, Shimomura Y. A Method for Supporting Service Cost Analysis. In The Philosopher's Stone for Sustainability 2013 (pp. 517-522). Springer Berlin Heidelberg.

[36] Lagemann H, Meier H. Robust capacity planning for the delivery of industrial product-service systems. Procedia CIRP. 2014;19:99-104.
[37] Lee C, Lee H, Seol H, Park Y. Evaluation of new service concepts using rough set theory and group analytic hierarchy process. Expert Syst App. 2012;39(3):3404-12.
[38] Lee S, Geum Y, Lee S, Park Y. Evaluating new concepts of PSS based on the customer value: Application of ANP and niche theory. Expert Syst App. 2015;42(9):4556-66.
[39] Lindström J, Plankina D, Nilsson K, Parida V, Ylinenpää H, Karlsson L. Functional products: business model elements. InProduct-Service Integration for Sustainable Solutions 2013 (pp. 251-261). Springer Berlin Heidelberg.
[40] Long H, Wang L. Key Factors Identification of Product Service Configuration Requirement. In Management and Service Science (MASS), 2011 International Conference on 2011 Aug 12 (pp. 1-4). IEEE.
[41] Matschewsky J, Sakao T, Lindahl M. ProVa–Provider Value Evaluation for Integrated Product Service Offerings. Procedia CIRP. 2015;30:305-10.
[42] Mattes K, Bollhöfer E, Miller M. Increased raw material efficiency through product-service systems in resource-intensive production processes? Barriers, chances and an assessment approach. In Product-Service Integration for Sustainable Solutions 2013 (pp. 141-152). Springer Berlin Heidelberg.
[43] Mazo SZ, Borsato M. An Enhanced Tool for Incorporating the Voice of the Customer in Product-Service Systems. Int. J. Mech. Eng. Autom. 2014;1(2):57-76.
[44] Mert G, Waltemode S, Aurich JC. Quality Assessment of Technical Product-service Systems in the Machine Tool Industry. Procedia CIRP. 2014;16:253-8.
[45] Mourtzis D, Fotia S, Doukas M. Performance Indicators for the Evaluation of Product-Service Systems Design: A Review. In IFIP International Conference on Advances in Production Management Systems 2015 (pp. 592-601). Springer International Publishing.
[46] Mourtzis D, Doukas M, Fotia S. Classification and Mapping of PSS Evaluation Approaches. IFAC-PapersOnLine. 2016;49(12):1555-60.
[47] Müller P, Schulz F, Stark R. Guideline to elicit requirements on industrial product-service systems. InProceedings of the 2nd CIRP IPS2 Conference 2010; 14-15 April; Linköping; Sweden 2012 (No. 077, pp. 109-116). Linköping University Electronic Press.
[48] Nemoto Y, Akasaka F, Shimomura Y. A Knowledge-Based Design Support Method for Product-Service Contents Design. InThe Philosopher's Stone for Sustainability 2013 (pp. 49-54). Springer Berlin Heidelberg.
[49] Neugebauer L, Mougaard K, McAloone T, Andersen JB, Bey N. Step-by-step towards PSS–Evaluating, Deciding and Executing. InThe Philosopher's Stone for Sustainability 2013 (pp. 233-238). Springer Berlin Heidelberg.
[50] Ng F, Harding J, Rosamond E. A Customers’ Satisfaction Based Framework for Continuous Development of PSS. In The Philosopher's Stone for Sustainability 2013 (pp. 239-244). Springer Berlin Heidelberg.
[51] Pan JN, Nguyen HT. Achieving customer satisfaction through product–service systems. Eur J Oper Res. 2015;247(1):179-90.
[52] Peruzzini M, Marilungo E, Germani M. Structured requirements elicitation for product-service system. International Journal of Agile Systems and Management. 2015;8(3-4):189-218.
[53] Reim W, Parida V, Sjödin DR. Risk management for product-service system operation. Int J Oper Prod Man. 2016;36(6):665-86.
[54] Rodrigues VP, Pigosso DC, McAloone TC. Process-related key performance indicators for measuring sustainability performance of ecodesign implementation into product development. J Clean Prod. 2016;139:416-28.
[55] Roy R, Cheruvu KS. A competitive framework for industrial product-service systems. International Journal of Internet Manufacturing and Services. 2009;2(1):4-29.
[56] Sakao T, Lindahl M. A value based evaluation method for Product/Service System using design information. CIRP Annals-Manufacturing Technology. 2012;61(1):51-4.
[57] Sakao T, Paulsson S, Müller P. Integrated evaluation of a PSS business case and a PSS design method–application of the PSS layer method to an industrial drilling solution. In Functional Thinking for Value Creation 2011 (pp. 153-158). Springer Berlin Heidelberg.
[58] Schenkl SA, Rösch C, Mörtl M. Literature study on factors influencing the market acceptance of PSS. Procedia CIRP. 2014;16:98-103.
[59] Shimada S, Taira K, Hara T, Arai T. Customers’ Satisfaction on Estimates of Queue Waiting Time in Service Delivery. In Functional Thinking for Value Creation 2011 (pp. 266-271). Springer Berlin Heidelberg.
[60] Shimada S, Aratani K, Ota J, Hara T. Analysis of Design by Customers: Customers Expectation as a Substitute for Design Knowledge. In Product-Service Integration for Sustainable Solutions 2013 (pp. 75-84). Springer Berlin Heidelberg.
[61] Shimomura Y, Hara T, Arai T. A unified representation scheme for effective PSS development. CIRP Annals-Manufacturing Technology. 2009;58(1):379-82.
[62] Shimomura Y, Watanabe K, Akasaka F, Kimita K. Fan Out of Japanese Service Engineering-the State of the Art. In Functional Thinking for Value Creation 2011 (pp. 15-20). Springer Berlin Heidelberg.
[63] Song W, Ming X, Han Y, Wu Z. A rough set approach for evaluating vague customer requirement of industrial product-service system. Int J Prod Res. 2013;51(22):6681-701.
[64] Song W, Sakao T. A customization-oriented framework for design of sustainable product/service system. J Clean Prod. 2017;140:1672-85.
[65] Stefano NM, Casarotto Filho N, Barichello R, Sohn AP. Hybrid Fuzzy Methodology for the Evaluation of Criteria and Sub-criteria of Product-service System (PSS). Procedia CIRP. 2015;30:439-44.
[66] Storey C, Easingwood CJ. The augmented service offering: a conceptualization and study of its impact on new service success. J Prod Innovat Manag. 1998;15(4):335-51.
[67] Sundin E, Nässlander E, Lelah A. Sustainability Indicators for small and medium-sized enterprises (SMEs) in the transition to provide product-service systems (PSS). Procedia CIRP. 2015;30:149-54.
[68] Taabodi A, Sakao T. Integrating PSS Design Methods with Systems for Customer Value Management and Customer Satisfaction Management. In Functional Thinking for Value Creation 2011 (pp. 99-104). Springer Berlin Heidelberg.
[69] Tan Y, Chu X, Zhang Z, Geng X. Customer value optimization in product service system design. In Functional Thinking for Value Creation 2011 (pp. 93-98). Springer Berlin Heidelberg.
[70] Van Ostaeyen J, Kellens K, Van Horenbeek A, Duflou JR. Quantifying the economic potential of a PSS: methodology and case study. In The Philosopher's Stone for Sustainability 2013 (pp. 523-528). Springer Berlin Heidelberg.
[71] Weißfloch U, Geldermann J. Assessment of product-service systems for increasing the energy efficiency of compressed air systems. European Journal of Ind Engineering. 2016;10(3):341-66.
[72] Williams A. Product-service systems in the automotive industry: the case of micro-factory retailing. J Clean Prod. 2006;14(2):172-84.
[73] Xiao-rong J, Sui-cheng L, Lang Z. The Study on the Influencing Factors on Relationship Performance in Servitization of Manufacturing. In 2009 International Conference on Information Management, Innovation Management and Industrial Engineering (Vol. 4, pp. 480-484). IEEE.
[74] Yang JH. A balanced performance measurement scorecard approach for product service systems. In Business Intelligence and Financial Engineering, 2009 (pp. 548-551). IEEE.
[75] Yoon B, Kim S, Rhee J. An evaluation method for designing a new product-service system. Expert Syst App. 2012;39(3):3100-8.
[76] Rondini A, Bertoni M, Pezzotta G. An IPA based method for PSS design concept assessment. Procedia CIRP 2017, in press.