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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.



*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 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.

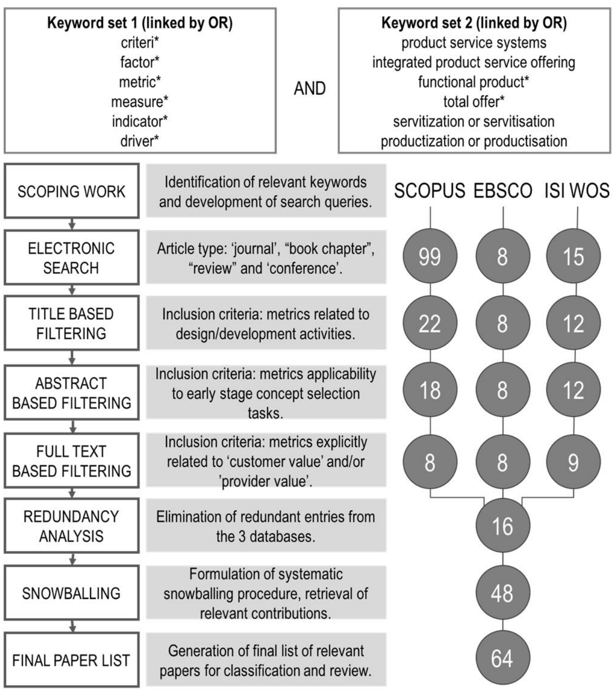


Fig. 1. Systematic review procedure.

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

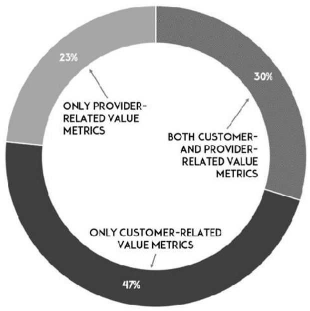


Fig. 2. Number of customer value metrics in the category.

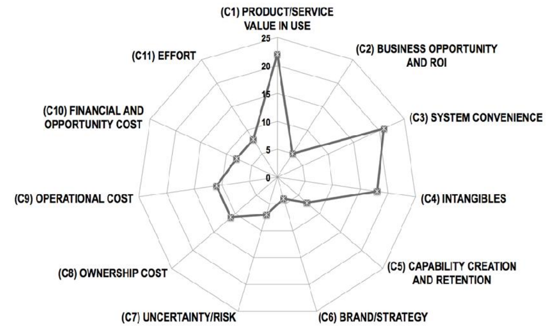


Fig. 3. Number of customer value metrics in the category.

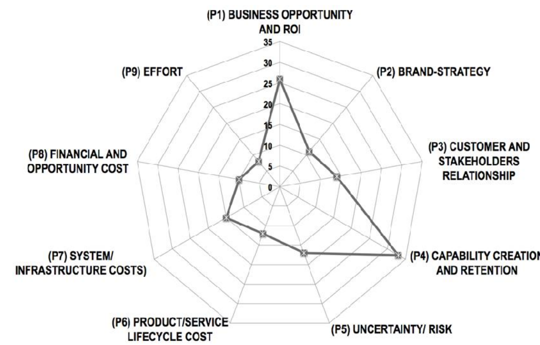


Fig. 4. Number of provider value metrics in the category.

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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