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Performance Indicators for the Evaluation of Product-Service Systems Design: A Review

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Abstract. Recently, industries have shifted their focus on the combined ecosystem of products-services. The innovative business strategy of PSS provides an integrated solution that gives the potential for sustainability gains for both company and customer. Similarly to other business aspects, the PSS efficiency design is evaluated through performance indicators, during the phase of concept evaluation, which is the last phase before launching a product-service. This phase plays a critical role for the success of a PSS. A successful evaluation prevents design modifications or redesign, significantly reduces the cost and lead time of PSS development. There is however, limited work on integrated evaluation approaches for PSS design models, and also a lack of a collective accounting of the most important key performance indicators (KPIs) devoted on PSS. The present work attempts to contribute in these directions, and proposes a conceptual framework for the effective evaluation of PSS design using important KPIs.

Keywords: Product Service System (PSS), Key Performance Indicators (KPIs)

1 Introduction

The intensive global competition and technological advances force the actors of a supply chain to optimize their activities in order to deliver high-value products-services with low costs and diminished time-to-market. This optimization relies on waste elimination, improved process control, efficient manpower utilization, and employment of smart and flexible systems [1]. PSS is a value proposition strategy that offers products-services and is designed to be: competitive, satisfy customer needs, and have a lower environmental impact than traditional business models [2]. The importance of the shift towards selling functionality instead of products is illustrative by the fact that software and electronics add nearly 40% to the cost of a new car nowadays, while this figure is bound to increase [3]. Moreover, measuring the performance of a PSS offering is crucial for a firm, since it influences its competitiveness in the market, its cost-effectiveness, and finally, its overall business performance [2], [4,5]. Following the principle of “what cannot be measured cannot be improved” and

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the plan-do-check-act methodology [6], continuous monitoring of the implemented processes is required during the entire lifecycle of the system. Thus, the use of KPIs is necessary. KPIs can provide insights about the performance of a company and can facilitate decision making. Moreover, KPIs can be employed to reduce non-adding value activities, which comprise approximately the 60% of a company's activities [7]. Due to the significant differences between products and services, the concept evaluation of PSS differs from ordinary evaluation problems. Product characteristics and service activities influence one another, creating difficulties in defining the weight factors of each evaluation criterion. However, there are few works concerning PSS performance indicators [8].

Except for limited research on integrated evaluation approaches for PSS models [9], there is a lack of studies that collect the main KPIs for measuring the efficiency of a PSS. The proposed work contributes with a collection and discussion of major PSS design models and existing KPIs that are appropriate for the PSS design activity.

2 PSS design models

The design models are simplified descriptions of the design process to assist the designer accomplishing the task. Although a great amount of literature work has been focused on PSS design models [10-32], there are surprisingly limited studies on integrated evaluation models for PSS [9], as well as collective accounting KPIs that could be used on PSS. In order for such a collection to be accomplished, the literature devoted to PSS design models and KPIs, is taken into account under a comparative review.

The review methodology that is followed to identify and collect KPIs for specific PSS designs is shown in **Fig. 1**. After examining the PSS design models, requirements for performance measurement are extracted, and finally, the KPIs that satisfy these requirements are classified. As **Fig. 1** illustrates, the light gray area includes the major PSS design models, applicable and representative in the category that they belong to. The dark gray area consists of the requirements derived from these models. It is noted that some models belong to more than one category. The color coding is used to group KPIs under four general representative classes, namely KPIs for Business, Customers, Leanness, and Sustainability.

PSS is strongly related to sustainability and customer, thus, increasing sustainability and satisfying the customers should be the target of every PSS design model [2], [4,5]. Several models [10-13] have been developed with dominant aims these two aspects, thus, evaluation approaches measuring them through PSS are of great importance. Sustainability has three pillars: (i) Environment, (ii) Economy, and (ii) Society [14], while customer perspective mainly contains requirements associated to satisfaction and acceptability [15]. Indeed, **Fig. 1** depicts that the most frequent requirements of PSS models are Customer and Sustainability.

One of the first approaches to model PSS design [16], aims to synchronize the development processes of the products and the services, incorporating the input from the customer in the process. Under the same concept, the Propensity Framework [17]

attempts to enable a synergy between products and services, via the Front-End of Innovation (FEI) process, and using evaluation criteria based on customer's expectations and user experience.

According to many researchers [18-20], in order to achieve a competitive PSS, the integration of physical product and services should be considered in the early phase of design. At these models, the customer value is also identified in the first phase of design. Similarly, in the Shell model [21], which is proposed for PSS Engineering development, the customer is considered in the beginning of the design giving explicit feedback to the design procedure of the model.

Inspired by the similarity between service design and hardware design process, the fast-track design process is proposed in [22]. Importantly, the authors stress that the use of this methodology ensures that the customer becomes fully aware of the value of the total care product business solution. Moreover, they present many PSS oriented requirements for performance measurement, namely service reliability, maintenance, stability, uncertainty, average waiting times, and reliability (short- and long-time). Finally, they outline the importance of quantitative performance measurements in the functional product provision.

Similar requirements are extracted by IPS² models [20], [23,24], Service models [25, 26], ServiceCAD/CAD PSS [26-28], Life Cycle Simulation (LCS) [26],[29] design models, Knowledge-sharing network for PSS design [30], and web PSS [31] design models. In addition to the aforementioned requirements, the necessity of measuring the server's availability, risk, and knowledge-sharing aspects, has been also considered.

Moreover, lean product-service design approaches are another requirement for competitiveness. The lean approach focuses on eliminating non-value activities from processes by applying a robust set of performance change tools, and emphasizes on excellence in operations to deliver superior customer service. To grasp the lean approach in a service-company, senior managers must recognize that all organizations-manufacturing and non-manufacturing-ultimately deliver value to a customer in the form of a product and/or service [32]. Indicators of how lean is the system [33] are significant to establish such a design.

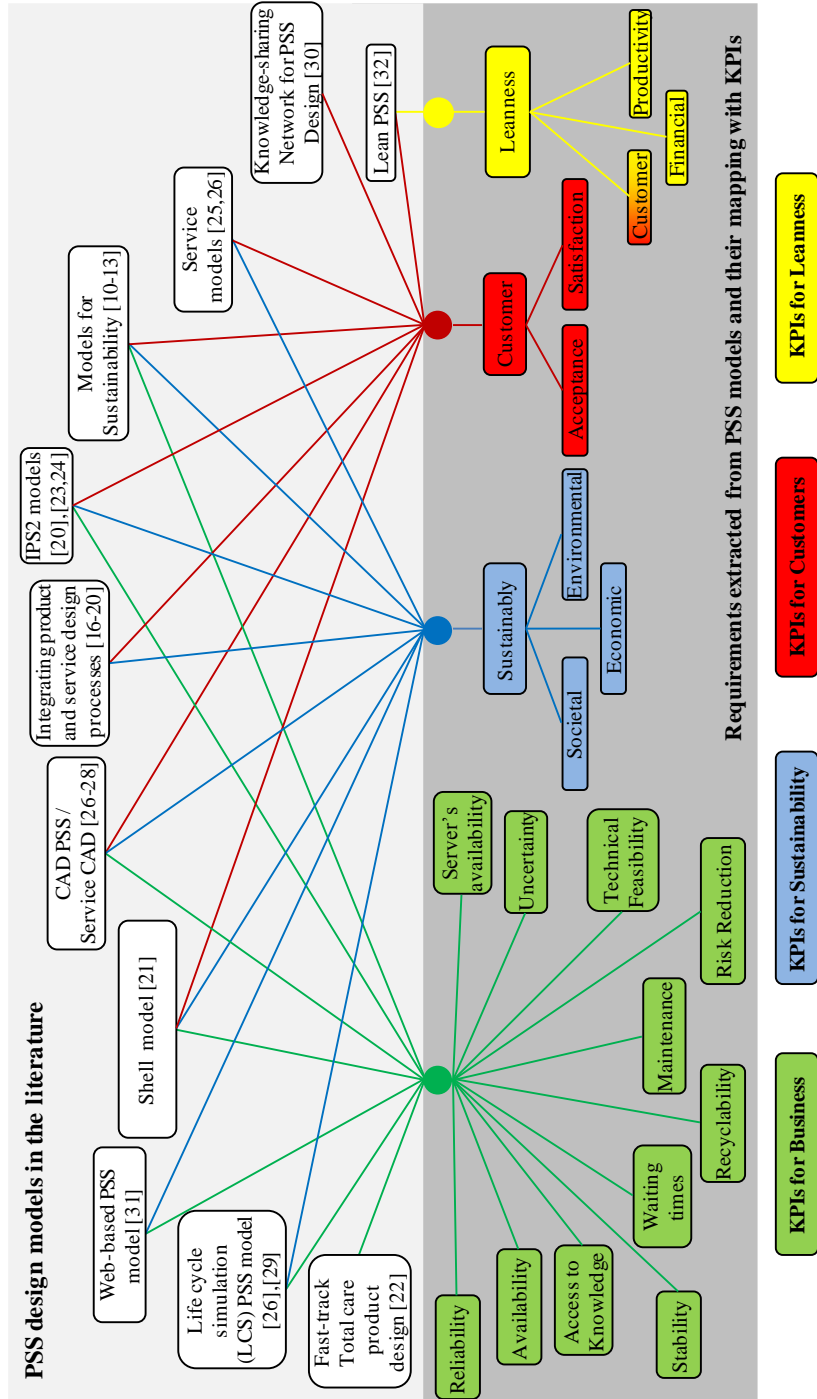


Fig. 1. PSS design models, evaluation requirements, and mapping of KPIs

3 KPIs for assessment of PSS design

This section discusses the most appropriate KPIs for PSS assessment. The definition of KPIs depends on each problem's specific objectives, goals, and criteria [1]. Academic research has proposed a number of methodologies for developing and selecting KPIs according to the objectives of each company. The development of KPIs can follow the SMART principle i.e. being specific, measurable, attainable, realistic, and timely [34]. It is also crucial to notice that performance measurement systems should focus on what is important to measure and not simply what is easily measurable [35, 36]. According to these principles, an attempt to collect the appropriate KPIs for PSS design evaluation is carried out. KPIs are classified with respect to the direction of fulfillment requirements. These classes are the following: Customers (C), Business (B), Sustainability (S), and Leanness (L). Summarizing, **Table 1** lists the KPIs that are associated to PSS design. It is commonly accepted that the realization of value in a PSS can only be achieved when customers are on focus and if services' evaluation is strongly connected to them [37]. Customer satisfaction and customer acceptance are among the most useful measures for several business strategies, and many researchers have developed measurement approaches and indicators for these purposes [38-45]. In this direction, the SERVQUAL scale [38] is introduced for assessing customer perception of service quality in service and retail companies. Additionally, another evaluation approach is proposed using importance-performance analysis, since the attributes of performance and importance are not independent variables, and the performance has a non-linear relationship with the overall satisfaction [44].

In the context of sustainability assessment of a PSS, most studies stress the 'environmental' aspect, probably since this aspect is measured relatively easily. There are limited methods that focus on measuring simultaneously all three sustainability components [45]. Environmental performance is usually connected with energy efficiency [46-49] and the level of material use in lease / reuse the PSS systems for waste prevention [50]. However, the consideration of social and economic dimensions are also important measures of sustainability [45]. In this direction, the Analytical Hierarchy Process is used in [51] to weight the importance of the indicators for each company under sustainability terms. The authors propose the use of sustainable product-service efficiency indicator, as to ratio of the product service value to its sustainability impact.

As shown in **Fig. 1**, the class of KPIs for Business is the most literature-stressed approach for the evaluation of PSS. The five phases of the PSS lifecycle, i.e. the planning, development, implementation, delivery and use, and closure are defined in [52]. Usually, the performance measure of these five phases falls under the customer-based measures. Particularly, the planning of the PSS is closely related to the customer as it includes the requirements, specifications, and the offer of a customised PSS. An indicator framework is the foundation of the measurement and monitoring of Industrial PSS (IPS²) in the use-oriented business model [34].

Table 1. KPIs for PSS design assessment (Customer:C, Buisness:B, Sustainability:S, Lean:L)

KPIs	Reference	Class	KPIs	Reference	Class
Satisfaction	[37-44]	C	Overall Equipment Effectiveness	[34]	B
Acceptability	[15],[39]	C	Technical availability	[34]	B
Acceptance rate	[42, 43]	C	Flexibility	[34]	B
Availability for production plan	[34]	C	Stability	[34]	B
Number of identified customer needs	[41]	C, L	Machine Reliability	[34]	B
Consideration of customer needs	[41]	C, L	Service Reliability	[34]	B
On-time delivery	[40],[42]	C	Service Assurance	[34]	B
Rescheduling quota	[42, 43]	C	Team Qualification	[34]	B, C
Efficiency of need identification	[41]	C, L	Feeling quality	[34]	B, C
Customer Needs rate	[41]	C, L	Knowledge Management	[54-57]	B
Requirement Inconsistency	[41]	C, L	PS Maintenance Efficiency	[42],[52]	B
Efficiency of collaboration	[41]	C, L	Development cost	[34]	B
Privacy	[41]	C, L	Service delivery costs	[43]	B
Product flexibility	[34]	C, B	Environmental quality cost function	[49]	S, B
Expansion flexibility	[34]	C, B	No. of bottlenecks	[40]	L
Energy Efficiency	[46-51]	S	Scheduling Inefficiency	[40]	L
Sustainable product-service efficiency	[51]	S	Defects detected in development stages	[40]	L
Lease/ Reuse	[50]	S	Requirement Inconsistency	[40]	L

While developing the indicator framework, the PSS performance, PSS lifecycle cost, and influencing factors have to be identified as major aspects for the provider. In order to evaluate better the IPS² delivery, a classification of performance indicators under the areas of delivery planning and delivery performance has been carried out [42]. The performance dimensions identified are: resource planning, management of the network partners, and IT system efficiency. The concept has been enhanced by introducing feedback loops in an IPS² control model.

Moreover, knowledge has a high importance for PSS providers and its availability is a challenge. The provider needs an adequate knowledge about the end-user's process as well as a concrete knowledge about the product. To satisfy these requirements, an approach for evaluating the knowledge within a company and to specify the re-

quired knowledge for providing a specific PSS is proposed in [54]. Furthermore, a conceptual model for assessing the readiness of collaborative networked organizations for PSS delivery is proposed in [55]. Finally, the terms risk and uncertainty have often been used interchangeably in industry [56]. A conceptual representation of risk and uncertainty is provided in [57]. The study proposes risk representation in relation to knowledge indeterminate and probabilistic or deterministic outcome.

4 Conclusions

This research work presents a collection of PSS design models and identifies the role and importance of KPIs in the PSS design. Secondly, it provides a collection of existing KPIs that are appropriate for PSS design, classifying them into customer-, business-, sustainability-, and leanness-based measures. This work could be a guideline for supporting the selection of appropriate KPIs for the evaluation of PSS. Further to that, taking into account the reviewed PSS design models [10-32], and their systematic reviews [5, 9], a conceptual framework for effective PSS design using KPIs is proposed (Fig. 2). According to this framework, the design procedure contains two main stages: (i) PSS design process, and (ii) PSS design expectations.

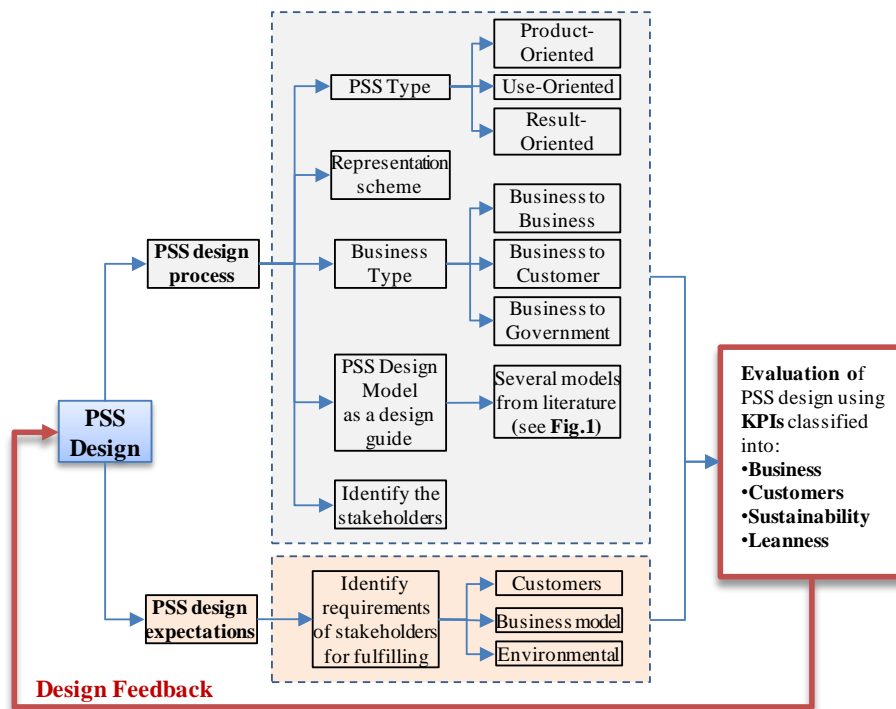


Fig. 2. The conceptual framework proposed for effective PSS design

The first stage contains the specifications of the PSS type (product-, use-, and result-oriented [5]) according to the product/service to be developed, also contains the Business type (Business to Business, Business to Customer, Business to Government), as well as the identification of stakeholders involved in the PSS. Furthermore, for an effective design procedure, a comprehensive PSS representation schema should be included [9].

The second stage focuses on what requirements the stakeholders have, and which of these have to be considered and fulfilled. This stage sets the basis of the evaluation strategy that has to be followed. For an effective PSS model, the fulfilling of the requirements of: Customers, Business model (e.g. Leanness, Sustainability, financial aspects), and Environment (e.g. energy consumption, CO₂ emissions), has to be the main care. For this reason, the implementation of a comprehensive evaluation of the developed PSS model is needed, throughout their life-cycle, using appropriate KPIs. These KPIs give feedback to the designer for improving the PSS design.

Future work involves a systematic classification of evaluation approaches for PSS design and the formulation of KPIs in mathematical expressions together with mechanisms for their measurement.

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