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► **To cite this version:**

Juliana Cavalcante, Lilia Gzara. Product-Service Systems Lifecycle Management in Industry: Interests and Exploited Data. 16th IFIP International Conference on Product Lifecycle Management (PLM), Jul 2019, Moscow, Russia. pp.389-398, 10.1007/978-3-030-42250-9_37 . hal-04444753

HAL Id: hal-04444753

<https://inria.hal.science/hal-04444753v1>

Submitted on 7 Feb 2024

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Product-Service Systems lifecycle management in industry: interests and exploited data

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Abstract. Product-Service Systems (PSS) emerged as a response to the market demand for specific solutions to meet their needs in a competitive and sustainable way. In order to manage and improve the value offered to the customer, lifecycle information needs to be gathered and exploited. In this paper, we present a survey realized among PSS providers, aiming to identify the exploitations and anticipations serving best industry's current interests. These exploitations were divided in five categories, which the respondents were invited to rank according to the pertinence to their business. The survey also covers the investigation of which data the providers dispose to achieve these exploitations. The answers were compared to general information about the PSS offered by the respondents, such as the type of PSS, product smartness level and type of services offered. The results indicate an initial stage of PSS development, with an important potential to improve. This analysis will further guide the proposition of an information system architecture for PSS lifecycle management in closed-loop, which may integrate the exploitations highlighted by the survey.

Keywords: Product-service systems, Lifecycle management, Data exploitation, Feedback data, Industrial survey.

1 Introduction

This paper fits into the context of PSS lifecycle management in closed-loop. Lifecycle management aims to efficiently handle information during the whole lifecycle, but these information flows are interrupted shortly after the PSS is delivered. The advantage of a closed-loop approach is the possibility to close these information loops, allowing the feedback and reuse of all lifecycle data. In this sense, the focus of the current work is the investigation on how lifecycle data can be used to propose improvements to the PSS offer.

The survey described in this paper confronts possible exploitations, based on literature review and theoretical methods, with the current interests of industrial PSS providers. The second section briefly describes the path to the survey motivation, from the PSS lifecycle model to a method to propose anticipations and exploitations from indicators. The survey building and the target diffusion are detailed in the third section. The survey results are presented in the fourth section and discussed in the section five.

2 Problem space

An adapted PSS lifecycle model was proposed in order to identify the activities and data involved in each stage [1]. It is composed by four main phases: Idea & Design, Realization, Use and End of Life. Idea & Design consists on the identification of product and services opportunities, selection of the best alternative and conversion into requirements. The second phase corresponds to product and service prototyping, product manufacturing and service implementation, testing and delivery. PSS assistance and monitoring are included in the Use phase. Finally, the End of Life considers product reuse, remanufacturing or recycling, and service decommissioning or redesign.

Based on this lifecycle model, a literature review was driven to identify the data exploitations, from downstream phases to upstream phases, already treated in previous works. These exploitations were divided according to the origin of the data and the phase where it is applied. Most works considered the application of realization [2,3], use [4,5] and end of life [6,7] data to improve design.

In this step, a great amount of underused use phase data was highlighted as well as the low number of exploitations performed in realization phase. It guided the choice of focusing the following steps on the exploitation of PSS use data in realization phase.

In sequence, a method to propose exploitations from use data was developed. Key use data from a semantic model representing PSS lifecycle data [8] were combined in pairs to create indicators. From these indicators, a list of exploitations to realization phase was prospected and further divided in categories.

The main goal of the survey was to identify the exploitations that best meet the industry's needs and interests. For that, the survey invites the respondents to rank the exploitations categories according to their pertinence to their business, and also to identify the data available to perform these exploitations.

3 Survey building

The proposed survey was divided into three main blocks: contextualization, categories ranking and data availability.

3.1 Contextualization

Aiming to identify possible patterns in different PSS providers, this block proposes a series of questions related to the company, the PSS offer and management, and relationship with the clients and their data. For all questions, a free space was left for further details or controversies.

Company size. Considering the number of employees (E) and the turnover (T), a company can be classified as: micro ($E \leq 10$, $T \leq 2$ million euros), small ($E \leq 50$, $T \leq 10$ million euros), medium ($E \leq 250$, $T \leq 50$ million euros), or big ($E > 250$, $T > 50$ million euros).

Type of PSS offer. There are some divergences on the types of PSS. Although [9] defends that there are at least eight types of PSS, most authors consider only three main groups [10–12]: product-oriented, use-oriented and result-oriented PSS. In a product-oriented PSS, the business model is mainly geared towards the sale of products, having extra services being added to them. A use-oriented PSS offer does not include a product being sold and the ownership remains with the provider. In this case, the product is made available in a different form, and sometimes it is shared by a number of users. The result-oriented PSS is offered through an agreement between client and provider on the result, and there is no pre-determined product involved.

Product nature. The product component of a PSS can be a manufacture or a software example, which might influence on the preferred exploitations and on the data access.

Product smartness level. Considering the rise of smart products, it is necessary to identify the level of connectivity and information management of products that are part of PSS. According to [13], the simplest type of integration would be physical products with embedded simple sensors, such as a refrigerator with a thermostat. In a higher level, these products embedded with sensors would have memory and data process capabilities, as in a car with an ETS system. Finally, the most connected would include not only sensors but also information devices (e.g. RFID tags, sensors networks and on-board computers), such as airplanes with tagged components and networks that allow Predictive Maintenance.

Services offered. A PSS might offer a cascade of services, each layer including the previous services and new ones. From the lowest to the highest level, it could be based on monitoring, controlling, optimization or autonomy-related services.

Type of use. Individual use stands for products that are used by only one customer for the whole duration of PSS lifecycle. Shared use includes the cases of renting and leasing, such as most city bikes offers.

Type of installation. A huge part of known PSS examples is based on mobile products, such as transport solutions. This kind of offer must consider not only the product identification but also the different uses of it – client type of use and location. Otherwise, many PSS are based on physically installed products, such as industrial machines or Xerox's copiers leasing business [14].

Access to product. Considering the access to the product, the PSS provider usually have three different alternatives: accessing the product on the customer site, taking the product to their own site or having remote access to the product.

Software tool used for PSS management. Commercial information tools dedicated to PSS lifecycle management are not available yet. For this reason, PSS providers might use PLM (Product Lifecycle Management) or SLM (Service Lifecycle Management)

tools, combined or separately, to perform PSS management. Providers might also dispose of a customized software dedicated to PSS management.

Access to data on the PSS during use phase. PSS providers might have different levels of access to PSS data. The access can be autonomous to all data or part of it, or it can be given under request to the customer. The under request access can concern the integrality of data or only a pre-defined part. In the most restrictive scenario, the provider may not have access to PSS data at all.

3.2 Categories ranking

As previously discussed, this work focuses on the possible exploitations of PSS use data to improve PSS realization. According to the PSS lifecycle model in [1], the use phase includes all data related to the monitoring of the product status, product replacement, part changes, product transport, service request, service offerings, service adaptation, consumable management etc. The activities of the realization phase, on which the improvements will be focused, are: manufacturing and assembly of products, implementation of services, product use training, service realization training, tests of products and services, scheduling for product and service demand, delivery of PSS etc.

In section 2, a method to combine data into indicators, and to use indicators to prospect exploitations was discussed. From this method, an important list of possible exploitations was proposed. This list was divided in five main categories of exploitation:

- Adapt PSS offer according to the customer: replace product, replace service, replace both;
- Improve product realization: improve product prototyping, improve product manufacturing, improve training for product use, improve product testing;
- Improve service implementation: improve service simulation, improve resources allocation, improve training for service realization, improve service testing;
- Manage PSS demand: predict product demand, predict service demand, predict PSS demand, improve product demand scheduling, improve service demand scheduling;
- Manage PSS contract: change the number of products and/or services per contract, change the diversity of products and/or services per contract, change the availability of products and/or services per contract.

In this block, the respondents were asked to rank the categories from the most to the least pertinent to their business.

3.3 Data availability

In order to arrive at the exploitations identified as important, it is essential to determine the data available for this purpose. In this part of the survey, the respondents were asked to identify, from the proposed lists of internal data and data from the customer, whether the data is available or not. For the unavailable data, the providers might specify how difficult it would be to have them (easy, medium, difficult, and unknown).

Data from the customer. Includes: product identification, product location, product operating state (e.g. normal, disturbed, off.), data recorded by product sensors (e.g. pressure, temperature, vibration), type of event trigger (e.g. max temperature exceeded, max vibration exceeded, expected duration exceeded), date/hour of event trigger, customer feedback after service intervention, and material resource stock at the customer (e.g. spare parts, tools, consumables).

Internal data. Includes: date/hour of intervention, activities performed at each service intervention, duration of interventions, material resources used during intervention, software resources used during intervention, human resources used during intervention, contract conditions, material resource availability for service execution, software resource availability for service execution, human resource availability for service execution, human resource availability for product realization (e.g. manufacture, delivery), product availability at the provider, spare parts availability at the provider, production planning, delivery planning, data recorded by sensors installed in the material components of service (e.g. location of the intervention vehicle), service performance indicators, reference values (expected behavior) for product sensors, PSS offer configuration (e.g. possible combinations of product-service, relationships between services).

3.4 Target and diffusion

This survey was intended for industrial PSS providers, who were reached through LinkedIn community. In the absence of a group dedicated to PSS, other pertinent groups were selected for investigation: Product Information Management Professional Association, Service Lifecycle Management and Service in Industry – Management | Servitization | Innovation | Digitalization.

Product Information Management Professional Association unites near 5,5k members, among professionals and people interested not only in Product Information Management (PIM), but also Product Data Management, Product Resource Management, Product Lifecycle Management and Product Catalogue Management. Service Lifecycle Management is a group whose access is made by invitation only, has more than 7k members. It is a collaboration group that puts together professionals from different fields to discuss and collaborate on solutions to industry challenges and opportunities. Service in Industry and its 2k members incite discussions and share insights and news on services and its advantages for industrial companies, focused on Business to Business activities.

The diffusion was made, at first, by sharing the survey in public discussions in these groups. After that, a research among the members of the group took place, targeting professionals working with product and/or service lifecycle management subjects or in companies that provides PSS. One-hundred-twelve potential respondents were contacted by private message on the LinkedIn platform.

4 Results

The complete responses received (21) will be detailed in the following sub-sections.

4.1 Respondents' profile

Type of PSS offered. The majority of the respondents offers product-oriented PSS (11), which is the most established type of PSS. It is followed by result-oriented (2) and use-oriented PSS (1). Some of the respondents offer more than one type of PSS: product and result-oriented (2); use and result-oriented (1); product, use and result-oriented (1). Three of the respondents selected "other" as an answer. Two of them are consulting companies offering support for clients having the three types of PSS and they compromise to answer from the point of view of their clients. The third offers PLM solutions.

Nature of the products. Eleven respondents offer only manufactured products, against two offering only software ones. Two offer both types of products and three offer consulting services besides manufactured and software products.

Level of smartness of the products. Most of the respondents have only physical products with embedded simple sensors (5), followed by the ones that have also memory and data processing capabilities (3), and the ones equipped with information devices (2). Some respondents have more than one level of smartness in their products: four of them deal with all three levels of smartness and two with both, products with simple sensors and products with memory and data processing capability. Five respondents answered "other" for different reasons: offering simple products with no sensors or offering consulting services for companies having the three levels of smartness.

Type of services provided. One respondent offers only monitoring services, the others have more complete solutions such as control (5), optimization (7) and autonomy (6).

Type of use. Eleven respondents manage products for individual use, versus four having shared use. Three of them have both types of products, and the other three considered the question not applicable.

Type of installation. Thirteen respondents identified the installation of their products as fixed, while only five have mobile units. The other two have the two types of installation.

Access to product. Many respondents have access to the product exclusively on the customer site (7), and just one mentions to offer the only option to take the product to their site in case of intervention; two of them have both of the previous options. The rest of respondents have remote connection to the product, which can be the only access (2), combined with access on the customer site (6) or the three combined (3).

Software tools to manage PSS data. Most respondents have a customized software dedicated to PSS management (4), or a combination of PLM and SLM (4). They also use the combination of customized PSS management software with a commercial PLM solution (3), and one of them uses the three types of software to manage PSS. Two respondents declared to use only a commercial PLM solution and another one, only commercial SLM solution. Five respondents answer “other” for not having a software at all or because they use a different software than the ones specified.

Access to PSS use data. Considering autonomous access, eight respondents have access to all data, while three, only to part of it. For under request access, three have access to all data, while six, only to part of it.

4.2 Categories analysis

Categories ranking. Evaluating the ranking position chosen for each of the exploitation categories, we noticed that “Adapt of the PSS offers according to the customers” was strongly preferred in the first place (11). The categories that appeared the most in the second place of the ranking were “Improve service implementation” (9) and “Improve of product realization” (8), that were also the second most voted for the first place. The categories presenting other anticipations, such as “Manage PSS demand” or “Manage PSS contracts” were mostly poorly ranked from third to fifth places.

Categories per respondent profile. In order to identify possible patterns in the choice of categories, they were compared with the PSS offers information.

Type of PSS. The identification of patterns concerning the preferred exploitations according to the PSS offer was made by identifying the best-ranked categories (first and second places) per each type of PSS (product, use or result-oriented). Besides the fact that most of the respondents offer product-oriented solutions, the distribution of categories chosen is balanced between the different types of PSS.

Smartness level. The profile of the respondents in terms of smartness level was also analyzed considering the categories ranked in first and second places. When comparing the choice of categories with the level of smartness offered by the PSS providers, it is possible to notice that for “Adapt PSS offer according to the customer”, “Manage PSS contracts” and “Manage PSS demand”, the ranking is well distributed between the different levels of smartness. On the other hand, the categories related to the improvement of service implementation and product realization are less demanded by the providers offering products with higher levels of smartness.

Service level. The levels of service proposed in this survey are considered as having increasing complexity. It means that monitoring represents the simplest type of service offer and autonomy the most complete, frequently grouping the functionalities of the previous levels (monitoring, control and optimization). In this analysis, the highest level

of service offered by PSS providers was compared to their preferred categories (the ones ranked in first and second places). The unique respondent offering only monitoring services considers “Improve product realization” and “Improve service implementation” the most important categories. This preference is shared with providers offering control-level services, having voted three times for each of these two categories. On the other hand, PSS providers offering more complete services, such as optimization and autonomy highlight the importance of “Adapt PSS offer to the customer” and “Improve service implementation” categories (5 votes from optimization level and 3 from autonomy, for both categories).

4.3 Data availability

In order to evaluate the general access to data, the comparison was made between data assigned as already available or easily accessible versus data having medium, difficult or unknown access. Product operating state, sensors data, material resource stock at the customer, software resource availability, product availability at the provider, sensor reference values and PSS offer configuration were voted as hardest to access.

5 Discussion

5.1 Respondents’ profile

The responses about the provider’s profiles and the type of PSS they offer, indicate an initial stage of PSS development. Most respondents classify their PSS as product-oriented and offer manufactured individual (non-shared) products with low smartness level, i.e. products having embedded simple sensors. These providers might go through a process similar to the productization, developing their products to respond to the needs of services in terms of data and connection [15].

The services provided, on the other hand, correspond to more complex solutions, such as optimization and autonomy, instead of simple monitoring. This might represent that former product providers have been moving towards servitization: the evolution of product identity to a position where it is inseparable from the service system, becoming a PSS [10].

Considering the access to the product and to PSS data, there are some barriers to the provider’s autonomy in lifecycle management. An important part of the respondents declared depending on visiting the customer site to have access to the product. The management of PSS data is also a delicate subject since it is mostly handled by a combination of two or more software tools. PLM, SLM and customized PSS lifecycle management tool have to be combined to cover PSS lifecycle data.

However, part of the respondents claims to have remote access to the product, and the types of access are divided in two main groups: the ones that have autonomous access to all data and the ones having partial access to the data under request.

As discussed, the products are still the core of the PSS offer and the simple sensors they dispose do not allow complete access to their data. It limits the type of data analytics they can perform.

5.2 Categories analysis

The highest ranked category is the one offering exploitations that allow the adaptation of the PSS offer according to the customer. Besides this fact, some other information can be gathered from the respondent's profile and the categories they chose.

Considering the categories preferred by the different types of PSS, the results were quite balanced. Which means that PSS providers believe that the five exploitations categories could be equally beneficial for all three types of PSS.

On the levels of product smartness and services offered, however, there are some clear differences. Providers offering lower levels of smartness are frequently more interested in improving the process of product realization and service implementation. It might be explained by the fact that they remain focused on an offer in one of the two components, product or service, instead of improving the offer as a system. On the other hand, those proposing smarter products and more complex services, might think on how to improve the offer as a whole.

5.3 Data availability

As expected, the majority of data previously classified as internal data was identified as available or easy to access by the respondents. This group of data is mostly related to the services offered by the providers.

On the other hand, part of the product-related data coming from the customer, was identified from medium-difficulty to unknown access. This might relate to the fact that an important part of the respondents has access to the product only on the customer site and only partial access to product data under request.

Another remarkable information is that few of them have access to the PSS offer configuration or to the expected values for product sensors. These facts might be linked to the great majority of product-oriented PSS providers who responded to the survey, which signalizes an eventual initial stage of PSS development.

6 Conclusions

The survey results will be used to align the next steps of this project on closed-loop PSS lifecycle management. The following step consists in proposing an information system architecture for PSS lifecycle management. This architecture should integrate the exploitations identified as important for the PSS providers, considering the data they have available.

Following the current results, the architecture will be focused on the exploitations of the category "Adapt PSS offer according to the customer", proving decisions on when and how to replace products and/or services for different clients.

It was also noticed that the data coming from the customers is limited, probably due to the early stage of PSS offers development. The decision is to consider these data in the IS architecture, previewing their future availability. However, data such as PSS offer configuration can be put aside with no major prejudice.

Most respondents use a mix of PLM and other software to manage PSS data. For this reason, the architecture must consider data from different sources and ensure interoperability between them.

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