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ScienceDirect

Procedia CIRP 47 (2016) 156 – 161

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Product-Service Systems across Life Cycle

PSS Design Considering Feedback from the Entire Product-Service Lifecycle and Social Media

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Abstract

In the globally competitive market landscape, companies, in order to remain sustainable, must shift their focus towards constantly improving their PSS offerings by incorporating lean thinking approaches. PSS are complex, dynamic, and multi-dimensional systems, which are supported by appropriate infrastructure and networks. At the same time, PSS require robust engineering methods and tools for their design, which allow multi-dimensional exchange of knowledge between the designers and the relevant stakeholders across the value chain. Currently, enabling technologies such as Cloud technology, social media and networking, knowledge management, and context sensitivity present new possibilities to enhance the knowledge exchange and the collaborative process of PSS design. These technologies allow the gathering and analysis of big volumes of data from scattered heterogeneous IT systems and, at the same time, allow PSS design improvements by processing the experiences of the business customers, consumers, designers, shop-floor, and provide feedback to the design phase. However, a number of challenges are encountered during the gathering, visualization, monitoring, and assessment of related data, such as the lack of context sensitivity. Simultaneously, PSS evaluation approaches are still immature and there is limited work that correlates the impact of the entire PSS lifecycle with the performance assessment of the PSS design. The present work includes a review of the aforementioned technologies from academic, market, and industrial perspectives. Based on an extensive literature review and on constructive discussions with three European SMEs, several barriers and limitations of adopting the aforementioned technologies in practice are identified. Finally, a conceptual eco-innovative framework for lean PSS design is presented, explaining how these technologies could be combined for the improvements of PSS design and evaluation procedures.

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle

Keywords: Lean PSS, Social-media Networking, Context Sensitivity

1. Introduction

Following the evolution of manufacturing systems from craftsmanship to customer-oriented manufacturing paradigms [1], the servitisation of manufacturing has been globally observed the past few years, making it vital for industrialized countries to shift to the Industrial Product Service System (IPSS) paradigm [2] in order to achieve competitiveness and to provide sustainable and ecological solutions. Recent research confirms this transition from the customers perspective, showing that the global customer willingness to pay a subscription fee for connected services in a car increased from 21% in 2014 to 32% in 2015 [3]. Creating value for customers is no longer a matter of providing physical products only. In such a context, lean product development comes to the fore as it is not circumscribed by the conventional processes, such as engineering, of traditional product development [4]. The hybrid solution of PSS [5] has clear heritage in the Lean Product Development methodology [6], but until now limited tools which support the Lean PSS design have been developed. Similarly to other business aspects, the efficiency of a PSS design is evaluated through performance indicators, during the phase of concept evaluation, which is the last phase before releasing a product / service to the market, aiming to eliminate waste, better

Peer-review under responsibility of the scientific committee of the 8th Product-Service Systems across Life Cycle
doi:10.1016/j.procir.2016.03.092

process control, higher utilization, flexibility [7]. However, there are very few works concerning PSS performance indicators, as well as integrated methodologies for PSS evaluation [8][9]. The recent IT advances are promising for manufacturing, in reducing the development time, in eliminating a significant part of the design and build cycles, as well as in providing more customized product/service variants [7][10]. In the last 5 years, the internet usage presents an exponential growth estimated close to 740% [11], and rightfully it is assumed as one of the primary enablers of globalisation, leading to new disruptive purchasing models [12], and it contributes to the creation of a situation where opinions are provided everywhere around the web: blogs, social networking sites such as Facebook and Twitter, news portals, e-commerce sites, etc. Concurrently, the recent software services support the social networking and context sensitivity analysis of big volumes of data, gathered over the globally distributed customers, but the adoption of these technologies in the development of appropriate tools which support the product-service designer to easily obtain information/knowledge are really rare [13].

Motivated from the above, the present work performs a review on all the aforementioned technologies, in order to bring to the surface the current status in the research, market and practice, through identifying the gaps of the literature and the practice in European SMEs. Finally, aiming to contribute in the identified gaps, a cloud-based Eco-Innovative Lean PSS design framework is presented, which is developed under the DIVERSITY European project of H2020. The DIVERSITY engineering conceptual environment shows how all these technologies could best be combined in order to develop a strong tool to support the PSS design which takes into account feedback from shop-floor experts, the production / manufacturing procedure, business customers and final consumers, and overall from entire PSS lifecycle.

2. Literature Review

The present section presents the examination of recent approaches in the domains of product-service systems (PSS) design, lean design, KPIs, cloud manufacturing, social media-networking analysis, knowledge manipulation, and context sensitivity in manufacturing, as well as performance indicators modelling and monitoring.

2.1. PSS design and Lean PSS design

PSS design is strongly related to sustainability and the customer [6]. Several models have been developed with a primary focus on these two aspects. Customer perspective mainly contains requirements associated to satisfaction and acceptability [14]. One of the first approaches for the modelling of a PSS design [15] aims to synchronize the development processes of the products and the services by incorporating the input from the customer in the process. Pursuing this concept [16], in order to enable a synergy design between products and services, the Front-End of Innovation (FEI) process is used. There are numerous research works regarding the integration of physical products and services in the early phase of design with concurrently identified customer value for achieving a competitive PSS [17]-[20]. Similar requirements are extracted from IPS2 models [19],[21], ServiceCAD/CAD PSS [22]-[24], Life Cycle Simulation (LCS) [22]-[25] design models, Knowledge-sharing network for PSS design [26], and web PSS [27] design models. In addition to the aforementioned works, the necessity of measuring the product-service availability, risk, and knowledge-sharing aspects has also been outlined.

The application of lean philosophy and principles to support PSS development is emerging in literature [28]. The majority of existing methodologies for PSS design have “a clear heritage in concurrent engineering and lean product development methodologies” [6]. The core lean idea of creating value and eliminating waste materializes in lean PSS literature as well, e.g. the 5C approach (Clear out, Configure, Clean and Check, Conformity, Custom and Practice) [29]. Continuous improvement consciousness is promoted within the PSS development through the adoption of standard practices, i.e. common processes (e.g. BPMN [17],[23]), standard models (e.g. QFD [17],[23])), and templates (View model [17], Service Requirement Tree [30]). The role played by effective knowledge management becomes paramount in PSS design, and it is ideally supported by IT solutions. However, specific IT tools do not yet exist to support PSS design, and literature and practice adopt IT solutions specifically defined for Service Engineering [28]. Set-Based Concurrent Engineering seems appropriate to manage the PSS design process in terms of evaluation of means to integrate product components and services, and to solve possible design trade-off during the whole development process [28], [31]. Despite the increasing attention given to lean PSS design, more research is needed in order to both introduce proper lean PSS design tools and methods, and to understand how Lean could be beneficial to PSS design, since the initial expectations are considerably high.

2.2. PSS Evaluation using KPIs

Recent literature survey shows that there is limited work on PSS evaluation [9], while the existing works are in preliminary stages [32], [33]. Most of the PSS evaluation approaches target to the assessment of PSS sustainability [34]-[36]. In particular, a proposed framework is introduced which controls the sustainability performance based on appropriately defined KPIs, which guides the stakeholders’ actions [34]. Lifecycle Assessment for Value Assessment through measures of life cycle performance, life cycle cost, and life cycle environmental impact through a sustainability-oriented value assessment model is proposed [35]. In the direction of the entire PSS lifecycle, an evaluation scheme is proposed, in which all the phases of the PSS lifecycle are taken into account, from both customer and company perspectives, by using appropriate KPIs [36]. Concentrating on the sustainability and quality of PSS offerings of a machine tool manufacturer, a software tool is developed based on a KPI monitoring framework [37], which measures among other: PSS quality, Process Stability, On Time Delivery, Mean Down Time. Finally, after gathering and classifying from the literature of the most appropriate KPIs for PSS design, a conceptual framework for an effective PSS design model is proposed [8].

2.3. Cloud Technology

Cloud Computing emerges as the latest computing paradigm that promises flexible IT architectures, configurable software services, and quality of service (QoS) guaranteed service environments [38]. Moreover, it enables organizations to obtain on-demand self-service, broad network access, resource pooling, rapid elasticity and measured service [39]. Cloud technology offers strong potential for collaborative design through enhanced coordination of design activities performed by users across the globe and integration of multiple CAx tools [40]. To this end, cloud computing has a great capability for providing knowledge management services that can be used extensively for business and competitive intelligence. Currently, these capabilities are not utilized fully for knowledge management in manufacturing companies [41]. In the context of product-service development, cloud computing is recognized for its utmost importance contribution in the collaborative design networks that contains actors distributed anywhere in the globe [42]. Various methods and platforms have been suggested, which aid the design and the development of Cloud manufacturing systems, aiming to: (i) the collaborative product design [43], (ii) the control and optimization of the manufacturing process [44][45], as well as (iii) the management of the decentralized and distributed manufacturing resources [46][47]. However, none of previous contributions is associated with Product-Service Systems design.

2.4. Social Networking Analysis and Social Media generated Knowledge Manipulation

Social networking analysis is associated with the study of social relationships though social media by analyzing what users share and how they share it. As defined by Montoyo, “Sentiment Analysis (SA) is a task of detecting, extracting and classifying opinions, sentiments and attitudes concerning different topics, as expressed in textual input” [48]. The fundamental principle of SA is classifying the polarity of the text under analysis as positive, negative or neutral [49] related to a product or a service. Nowadays, companies are becoming aware that their most important consultants for success are the consumers themselves, and they are trying to understand what they want from a product or a service [50]. Sentiment analysis uses Natural Language Processing (NLP), Statistics, or machine learning methods to extract, identify, or otherwise characterize the sentiment content of a text unit [51] for tracking the mood of the public about a particular product or topic. According Serrano-Guerrero et al., many tasks arise linked to Sentiment analysis such as sentiment classification and summarization [52]. Classification aims at classifying a piece of text, with one of two opposing sentiments and it includes the determination of the semantic orientation of words, sentences, and documents and separating the parts which present opinions from those that present factual information [53]. Summarization attempts are being made in order to generate a concise and understandable summary of a large number of opinions. Along the years, different techniques and software tools have been developed to implement Sentiment Analysis. In the web, we can find some of these tools with free access services such as HubSpot and Google trends.

The notion of social media refers to characteristics of the knowledge generation and manipulation process within social media software used within enterprises, such as wiki systems, as a collaborative way of generating, using, reading and editing feedback where all stored knowledge is internally used, managed and provided, and is not public to the internet community (e.g. Facebook, Twitter, etc.). The first Wiki-Website of all, went internationally online in 1995 by Cunningham. Cunningham’s intention was to give people the opportunity to create, edit, refactor layout and link webpages to each other (hyperlinks) within their web browser in order to exchange knowledge and neglect the centralized publication of knowledge on the web. Since then, wiki systems are perceived as tools to manage content online in a fast and easy way by modifying simple syntax with the help of a markup language. In traditional wiki systems, such as in the famous Wikipedia for example, knowledge of all different kinds is intensively created, used, modified, refactored and linked [54].

2.5. Context Sensitivity Analysis

The intention of this section is to provide context sensitive solutions for collaborative PSS design, in order to assist the users to cope with enormous amount of knowledge to be managed within the collaborative PSS design processes, and allow for higher re-usability of components and services. To achieve this, context models of dynamic collaborative work in industry, relevant for PSS collaborative design, have to be defined [55]. Novel ways for dynamic, real-time extraction of context from different data sources, the so-called context extractor, as described in [56], are needed as well. Context sensitivity can be understood as an add-on, i.e. support in using the data/knowledge for building PSS by adapting the results based on the identified context of the user.

Based on the analysis of current research, it can be concluded that the good basis for context modelling to support PSS design would be ontology-based context modelling [57]. The solutions suggested in the previous research provide context models for collaborative work, but these context models do not address PSS aspects, i.e. they do not include modelling of context under which PSSs are collaboratively developed in the manufacturing industry.

3. Gaps Between Academia Research and Practice

The identity gaps between literature and practice, regarding the aforementioned technologies, are identified through literature review of section 2 and the investigation of three European SMEs of equipment manufacturing and control systems for HVAC/R (Heating, Ventilation, Air-Conditioning and Refrigeration). The identified gaps are listed in classified form according to their context, in Table 1.

Table 1 Identified classified gaps between literature and industrial practice

Category	Gaps
PSS Design	• Lack of a critical and in-depth evaluation of PSS methodologies. • Very few methodologies consider real-time monitoring during the entire PSS lifecycle and lack of feedback between the phases

	• Consideration of customer satisfaction only, without balancing or reviewing it from a company perspective • Lack of standard PSS ontology which would fulfil the requirements in order to serve as semantic bonding element among the tools within an environment for collaborative PSS design. • Small number of PSS-oriented software tools, although there is an abundance of PDM/PLM dedicated to product which have been established for many years now in the industry, no PDM/PLM tools were identified for PSS • Small number of companies adopt PSS methodologies. Occasional adoption from multinational companies involved in research projects • The existing PSS examples tend to emphasize the environmental and social gain without considering the economic impact • Lack of quantitative methods to help organizations understand the perceived value that a potential customer may hold, and to evaluate the level of service that is required • Cultural barriers to the PSS adoption from the consumer's side. Cultural shift is necessary to place value on fulfilment of a need, instead of the "ownership" of a product • Barriers to the PSS adoption from the organizations' side: (i) limited experience in pricing such an offering, (ii) fear of absorbing risks, and (iii) lack of experience in structuring
Lean PSS	• Lack of clear and systematic identification of the typical *muda* in a PSS design process, as well as the definition of what is a value-added activity is often vague and generally lacks detail guidelines on how Lean Thinking could be implemented in the PSS design • Set-based Concurrent Engineering (SBCE) is much quoted along with product design, while never quoted in literature relating to PSS design, even if most approaches propose / suggest a design process structured according to the SBCE concept • Lack of literature contributions to investigate the role and the value of computer-aided design and engineering tools toward achieving leanness. There are not too many tools for Lean product development, and none of them specifically devoted to Lean product-service development
Cloud Technology	• Cloud technology has already been used by large companies, but not sufficiently from SMEs and not for the development and deployment of services. In the equipment manufacturers of injection moulds and footwear machinery even fewer companies have moved to Cloud solutions • Lack of security and trust for application of this technology in the industrial environment of medium size companies • Lack of collection / analysis of feedback from the customers and consumers using cloud technology
Social Networking Analysis	• No complete understanding of benefits for SMEs from using social networking analysis in their businesses • None of the industrial partners have implemented a clear approach to use social media solutions to establish feedback directly from their customers and use it for improving PSS offerings • No clear strategy in using feedback from the end-customers by the medium sized companies producing machines/equipment for mass customised products manufacturing
Context sensitivity analysis	• A generic context model (ontology) to describe context of collaborative PSS design which can be customized for specific business cases is not available • No methodology for definition/customization of context models for PSS design in various industrial environments. • Ontology tools adapted for the development of a generic context model (ontology) to describe collaborative PSS design, which can be customized for specific business cases is not available
	• No tool/service serving as a context extractor for real-time identification of the current context of the various users, various stakeholders in the PSS design process • No specific tools/services for context sensitive search for similar PSS design, and other knowledge relevant for PSS design. • None of the previous EU relative projects examines the problem of context sensitivity and analysis of feedbacks from both customers' and consumers' perspective in the manufacturing industry • A generic context model (ontology) to describe PSS, which can be customized for specific business cases, is not available. A challenge will be to provide the ontology-based context model to represent circumstances (context) under which the customers use the machines / equipment and produce mass customized products, as well circumstances under which the consumers use final (customized) products (and provide their feedback)
KPIs evaluation framework for PSS	• Lack of a collective accounting of key performance indicators (KPIs) that could be applied on PSS evaluation • Little research on how to measure the performance of a PSS development process • Absense of cutting-edge IT systems that enable extensive monitoring of indicators • Common practice for companies is to focus on indicators that are easily measurable, and not those that are most important according to the needs and objectives. KPI monitoring for data collection requires so much effort, that it discourages the SMEs from adopting such systems • Customer-related measures are missing from industrial practice

4. Conceptual Framework for Eco-Innovative Lean PSS Design

In the attempt to fill the previously identified gaps, the DIVERSITY project aims to develop an engineering environment which intends to combine several cutting-edge technologies for constructing a Cloud-based Eco-Innovative Lean PSS design tool. A combination of classical product design engineering tools, cloud technologies that support the SBCE, and social software solutions, as illustrated in Fig.1., is likely to meet the requirements of an effective collaborative PSS design, utilizing the manufacturing intelligence and experience of all actors in the value chain, including both business customers/companies and product/service consumers. More specifically, the main concept includes five steps, as illustrated in Fig.1. On top of that, a large amount of knowledge is gathered (step 1) from a wide spectrum of actors involved (eg. shop-floor experts and consumers) and from different type of sources such as hardware and software sensors that allow real time monitoring of data. These heterogeneous data monitoring, collection, storage, and later their interpretation for supporting the PSS design procedure, is missing from the literature and practice, as highlighted in Table 1. The collected feedback, from customer's posts on social media about their experience with the product/service or from inspection inter-organizational digital documents between engineers and Business customers, will be processed in step 2 via feedback analysis tools (sentiment analysis) and context sensitivity analysis. Although the exponential growth of internet usage and the wide development of context sensitivity and sentiment analysis tools, these technologies have not been adequately examined yet on how could be exploited by the manufacturing industry and specifically for

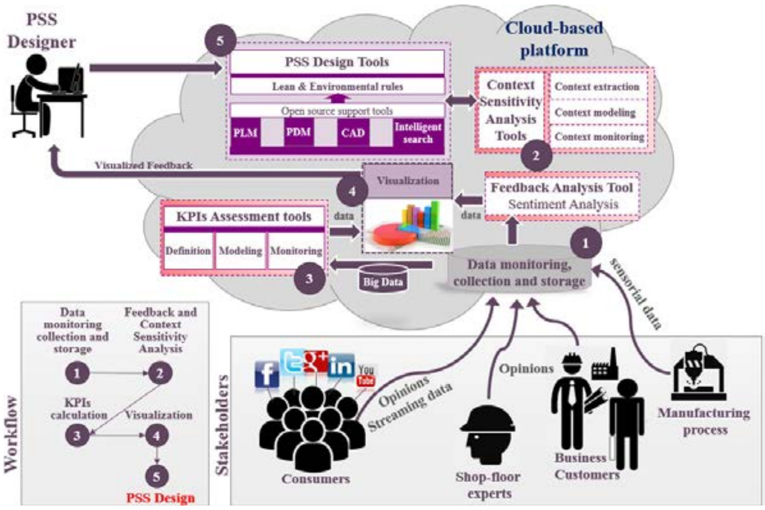

Fig.1. Conceptual framework for Eco-Innovative Lean PSS design.

the PSS design. On the other hand, the gathered raw data from step 1 and the processed data from step 2, can be used in step 3 for the calculation of KPIs for the PSS evaluation. To this end, the proposed PSS engineering environment attempts to contribute to the limited works related to the PSS evaluation, especially using real-time monitored KPIs. The visualization of stakeholder feedback in order to be translated in a useful form to support the designer is very challenging. Thus, the present approach will attempt to contribute to this direction by developing appropriate enhanced dashboards capable of visualizing the heterogeneous collected data (step 4). Finally, (step 5), the engineering environment could be an open environment which would combine open PDM/PLM and engineering systems as well as social software, which are both wiki-based solutions for knowledge-capturing of knowledge/experience of experts from the manufacturing sector, of maintenance/service providers and of business customers and social networks/multimedia. The key element of the new environment will be PSS ontology, also contributing to standardization aspects. At this step, Lean PSS design will be supported by providing several lean and environmental rules from a pool, and they would be suggested to the PSS designer at each stage of PSS design lifecycle. The concept of Lean PSS is very new and very limited literature work have been devoted on that. Moreover, a tool which will support such a design, as it is clearly stated in Table 1, has not been considered yet.

5. Conclusions

This survey investigates the previous areas from academic, commercial - market, and industrial perspectives. Finally, the gaps between the research academia, and practice, are identified in this analysis, and the opportunities for the DIVERSITY Eco-Innovative Lean PSS design framework to go beyond the current state and contribute towards bridging the identified gaps are outlined. Since customers will no longer be satisfied with only provision of simple products (or services), innovation cannot be limited to physical-product. Lean product development will increasingly support the investigation and exploration of solution alternatives over simple product-design alternatives; in this regard, SBCE will support the definition of a wider solution design space. In particularly, the proposed framework is a Cloud-based engineering environment for Lean PSS design, evaluation and improvement, taking into account feedback from shop-floor experts, production/manufacturing procedure, business customers and final consumers. One of the most important identified gaps is the limited adoption of the aforementioned technologies from SMEs. The root causes of that can be traced back to the fact that SMEs do not yet completely understand the adding-value flow from the adoption of such PSS offerings, as well as, to the lack of comprehensive methodologies, commercial tools, and a generic context model (ontology), devoted to PSS collaborative design, evaluation, and risk assessment. Moreover, the three real-life case studies from a mould-maker, a shoe machinery, and a control-system manufacturer SME, producing machines and equipment, and delivering them at the global market in various mass production sectors, require new design PSS solutions for effective collaboration and knowledge exchange among various actors.

The future work includes the development of the proposed conceptual framework and its application and evaluation in the three EU SMEs, a comprehensive domain ontology for PSS design, a KPIs evaluation framework for Lean PSS design, and automated lean and environmental rules extraction based on real-time KPIs monitoring.

Acknowledgements

This work has been partially supported by the H2020 EC funded project “Cloud Manufacturing and Social Software-based Context Sensitive Product-Service Engineering Environment for Globally Distributed Enterprise - DIVERSITY” (GA No: 636692).

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