Smart Product-Service Systems (Smart PSS) in Industrial Firms: A Literature Review

Soumitra Chowdhury\textsuperscript{a,}\textsuperscript{*}, Darek Haftor\textsuperscript{a,}\textsuperscript{b}, Natallia Pashkevich\textsuperscript{a}

\textsuperscript{a}Linnaeus University, Department of Informatics, Växjö, Sweden
\textsuperscript{b}Uppsala University, Department of Informatics and Media, Uppsala, Sweden

* Corresponding author. Tel.: +46470708820. E-mail address: soumitra.chowdhury@lnu.se

Abstract

During the last few decades, the PSS literature has documented industrial firms’ transformation from the product dominant logic of business to product-service bundles constituted by machines and related services. This transformation has had several dramatic implications on firms’ profitability, strategy, operations, organizational setting, sales and marketing approaches, and R&D practices. However, more recently, industrial firms have started to adopt various smart technologies that are embedded within the PSS. The use of smart technologies in PSS gives rise to the new types of PSS that are referred to in this paper as Smart PSS. Based on a literature review of 43 papers from relevant academic fields, this paper seeks answer to the following research question: what are the value creating features of smart product service systems (Smart PSS) in industrial firms? We synthesize the knowledge on Smart PSS to provide a definition and show the distinctive features of Smart PSS and propose an agenda for future research.

© 2018 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Industrial Product-Service Systems.

Keywords: Smart PSS, smart technologies, value systems and business models, digital boundary objects, intelligent dynamic capabilities

1. Introduction

In this continuously changing global market where firms are moving from product sales dominant business to service oriented logic [1], many industrial firms have made a transition from machine sales oriented business model towards product-service systems (PSS) oriented business model [2,3]. By bundling products and services in PSS, firms aim to differentiate from competitors by combining products and services. PSS have implications on firms’ profitability, strategy, operations, organizational setting, sales and marketing approaches, and R&D practices. Although many existing manufacturing companies have designed product-service systems (PSS) to find ways to innovate their solutions, surviving through conventional PSS seems to be difficult in this digital era. Together with wireless connectivity, the smart components such as sensors, control systems and machine-embedded software have “unleashed a new era of competition” for the manufacturers” [4, p. 64].

The challenges brought forward by the smart technologies are forcing the machine manufacturing firms to make innovative solutions for their customers instead of relying on traditional products and services. For example, Toyota and General Motors embed smart technologies with many of their high-end vehicles to transform the vehicles as enabling media for designing and offering services such as roadside assistance during accidents, stolen vehicle identification, remote diagnostics for reducing sudden breakdowns [5,6]. Due to this apparent change of the role of industrial machines, manufacturers have to find ways to exploit digitalization to meet current needs of this digital era. Therefore, the companies have embarked on a journey to incorporate digital technologies in the design and delivery of new PSS.

This new type of PSS is referred to as Smart PSS in this paper. With the trend toward intelligent machines, digital
systems are increasingly being used by various industries for creating totally new industrial product-service offerings. Thus, machine manufacturers cannot afford to ignore these emerging forces, which have the power to completely reshape the industrial landscape. Companies that do not keep up with these developments may find themselves threatened with extinction in the near future. Competitors with more customized and responsive smart offerings gain advantage [7].

Existing research has highlighted the design and business model aspects of PSS. However, the conceptualization about the role of digital technologies on PSS is very limited (see e.g., [8], [9]). Although PSS has been well researched, the effect of the digital revolution on this PSS pathway has been less well explored [7].

Therefore, this paper seeks answer to the following question: what are the value creating features of smart product service systems (Smart PSS) in industrial firms? In this paper, we use the term “Smart PSS” where smart digital technologies are incorporated in the design and delivery of PSS. Despite increasing instances of Smart PSS in industrial firms, previous research on PSS has tended to take digital technology somewhat for granted [10]. Existing research on Smart PSS is very limited (see e.g.[11], [12]). Synthesizing the knowledge on Smart PSS is important to understand the interrelationship between smart technologies and PSS business. Based on a literature review, this paper synthesize knowledge on Smart PSS to show their distinctive features and propose an agenda for future research.

This paper is structured as follows. We begin by explaining our methodology for the systematic literature review. We present the conventional knowledge on PSS within the categories PSS design and PSS business models. Next, we synthesize the knowledge on Smart PSS using the identified themes from the review. Later, we present a comprehensive definition of Smart PSS and their distinctive features for advancing the understanding of Smart PSS in industrial firms. We then propose a future research agenda before concluding the paper.

2. Methodology

A systematic literature review was carried out for developing insights on Smart PSS in industrial firms. Systematic literature review is different from a traditional general review as it follows a replicable, scientific, and transparent process [13]. Systematic reviews assist in developing collective understanding based on theoretical synthesis of available research. This kind of reviewing of literature can reduce bias and enhance the legitimacy of subsequent evidence which can provide reliable results for drawing conclusions [14].

We have carried out systematic literature review using Scopus and Web of Science databases. These two databases are now widely used and they include all major peer-reviewed articles from all the academic fields. Only academic journals and conferences were included in the search.

A set of closely related keywords were used as search terms. All keywords were searched using quotation marks to retrieve precise results during the search. The search terms were: “smart product service systems”, “connected product-service systems”, “product service systems”, “smart service systems”, “service systems”, “digital service systems”, “digital services”, “digitalization”, “digital product service systems”, “servitization”, “e-services”, “IT services”, “internet of things”, “industrial internet of things”, “e-maintenance services”, “digital business services”, “digital business models”, etc. The search results are shown in Table 1. During the time of our search, the search term “Smart Product Service Systems” itself gave only five hits on Scopus and two on Web of Science. This shows a current lack of research particularly focusing on Smart PSS, although there exists research on concepts that have similarities with Smart PSS. Therefore, results with other search terms were significant.

Each article was first screened by reading its title, abstract and keywords. The articles that empirically illustrated digital product service systems, digital products, digital services, digitalization, etc. in relation to the industrial firms were given special emphasis and included for the review. Empirical papers were chosen as they show the applications of digital technologies which provide a comprehensive picture of Smart PSS in different industrial firms. A significant number of articles on conventional PSS were included in the review even though they were not explicit about either digital technologies or industrial firms. This was done to identify the past and present trends in PSS literature and to identify knowledge gaps.

After following the screening process, we finally included 43 papers to review conventional PSS and Smart PSS. Among the papers, 25 papers empirically illustrate the aspects related to Smart PSS, i.e., digital servitization, smart technologies, digitalization, etc. in the context of industrial firms. We grouped them to review the research on Smart PSS. While reviewing the papers on Smart PSS, we identified some recurring themes. We identified ten papers that explicitly discussed digital resource driven value systems and business models, six papers that are focusing on boundary spanning with digital boundary objects, and nine papers that emphasized on intelligent dynamic capabilities. In the following sections, we will first discuss the conventional wisdom on PSS and the existing knowledge gap on Smart PSS. Later, we will discuss some of the selected papers on Smart PSS.

Table 1: Search results

<table>
<thead>
<tr>
<th>Database</th>
<th>Total number of hits</th>
<th>After screening titles, keywords and abstracts</th>
<th>Papers that empirically illustrate Smart PSS in industrial firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scopus</td>
<td>1042</td>
<td>43</td>
<td>25</td>
</tr>
<tr>
<td>Web of Science</td>
<td>649</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Due to space constraints, selected papers are discussed here. The full list can be obtained from the authors.
3. Conventional PSS studies

Usually, a PSS is described as an integrated product and service offering that delivers value for the customers and product manufacturers. An overview of PSS definitions from the last three decades is given in Table 2.

Table 2: PSS definitions (adapted from Tukker [15] and Baines et al. [2])

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition of PSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goedkoop et al. [16, p. 18]</td>
<td>A product-service system is a marketable set of products and services capable of jointly fulfilling a user’s needs</td>
</tr>
<tr>
<td>Mont [17, p. 239]</td>
<td>A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact then traditional business models</td>
</tr>
<tr>
<td>Manzini and Vezzoli [18, p. 4]</td>
<td>An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands</td>
</tr>
<tr>
<td>Berkovich [19, p. 369]</td>
<td>PSS is an integrated bundle of hardware, software, and service elements to solve customers’ problems</td>
</tr>
<tr>
<td>Zhang et al. [20, p. 1579]</td>
<td>PSS is a systematic package in which intangible services are attached to tangible products to finish various industrial activities in the whole product life cycle</td>
</tr>
</tbody>
</table>

If we look carefully at the definitions of PSS in Table 2, only one definition includes the role of digital components (hardware and software). Previously, Baines et al. [2] provided the example of connected and remotely monitored laundry machines of Electrolux while discussing about successful PSS. However, they had a broader focus on exploring the state of the art in PSS. Similarly, while reviewing the PSS literature published between 2000 and 2012, Tukker [15] mentions that remote monitoring can be enable of many types of PSS. In spite of recognizing the importance on digital technologies or digitalization in PSS literature, little effort has been given to delineate the features of digitally-enabled PSS or Smart PSS.

Previous studies on PSS design are either implicit about the role of smart technologies (see, e.g., [21]), or have paid little attention to the role of smart technologies. Given the fact that smart technologies are continuously being used for PSS design, investigating the role of smart technologies in PSS design will enable us to explore new characteristics [11].

Similar to the PSS design literature, the PSS business models literature also provides light emphasis on the implications of smart technologies on PSS. Among the PSS business models literature, Lerch and Gotsch [7] provide a little emphasis on the impact of digitalization on business model. Mert et al. [22] mention the role of smart components in availability oriented business model. Ehret and Wirtz [23] present a conceptual business model for industrial manufacturers with IT as a supporting element.

4. Smart PSS

The PSS that are enabled by smart technologies are referred to as Smart PSS [11]. Smart technologies are technologies that are programmable, addressable, sensible, communicable, memorizable, traceable, and associable [6]. We have synthesized our findings on Smart PSS in three themes: a) digital resource driven value systems and business models, b) boundary spanning with digital boundary objects, and c) Intelligent dynamic capabilities.

4.1 Digital resource driven value systems and business models

The first identified theme is digital resource driven value systems and business models. The existing research on this theme can be linked to the capabilities and transaction costs theory (see e.g. Jacobides and Winter [24]). The use of smart technologies in the context of PSS enables economic value creation through the establishment of new organizational capabilities and value systems that enable differentiated PSS.

With the growing instances of modularity in product architecture, indirect channels, and supply chain intermediation, industrial equipment manufacturers are now dependent on other companies for the selling and integration of products according to customer needs. This may result in losing visibility of installed base for designing and delivering PSS [25]. When a company loses its visibility of the installed base, it can turn from a PSS business into a typical product oriented business. With smart technologies like remote monitoring, manufacturers can regain visibility to the installed base as they can gain remote access to the equipment [9]. This implies that successful design of smart PSS may enable an industrial firm in gaining knowledge of the installed base. Thus, Smart PSS can influence a manufacturer’s transition in business by collecting digital temporal records of equipment that are operated in a distant physical space. This can in turn create value for the manufacturer by enabling them to design and deliver new digital solutions to customers.

The integration of smart technologies in machines is creating Smart PSS that have profound influence on the value systems and business models of machine manufacturers [26] [27]. One common smart technology that is discussed in the literature is the remote monitoring of machines (see e.g. [28], [29], [27]). Remote monitoring enables manufacturers to remotely monitor and diagnose customers’ machines using embedded sensors and wireless connectivity [29]. This technology enables real-time performance monitoring and reduces machinery breakdowns. The technology also allows the manufacturers to offer service packages to the customers and appropriate value from saved costs [26].

During a study on the construction equipment manufacturing company MacGregor Cranes, Jonsson et al. [27] observe that smart PSS based on remote diagnostics technology can enable two value systems. One value system allows the manufacturer to remotely collect all machine related data and provide necessary services to customers related to machine maintenance and repair. On the other value system, the manufacturer can install a control system at the customer’s site and allow the customer to look at all machine generated data and take decisions on their machines and seek help from the manufacturer if required. The latter value system makes the
customers more active in the decision making process. Thus, in these two value systems, the customers can either become active co-creators of value or passive receivers of created value. Thus, the value creation process is not limited to the manufacturer or customer organization.

Similar trend was observed in the case of the hydraulic motor manufacturer PowerDrive that formed a network with three customers for doing remote monitoring of their machines and share information for co-creating value [29]. The cases of Smart PSS enabled by remote diagnostics technology illustrate incremental value creation process through the customer-provider co-creation [27] [29]. The active value co-creation to some extent may depend on the customer. This co-creation comes in a form of the customer being committed to providing additional information [30].

Extant research shows that application and commercial exploitation of smart technologies such as remote monitoring and diagnostics technology are needed to be accompanied by wider organizational changes [31] [32]. Yet very little is known about the identity and nature of those changes [31]. Existing literature points to the fact that manufacturers are still struggling to articulate value propositions from remote monitoring technology that would be appealing to customers. More research is necessary to understand and address this problem [33] [31][30].

4.2 Boundary spanning with digital boundary objects

Boundary spanning is the second theme that has been found on the literature review on smart PSS in industrial firms. The research on boundary spanning with digital boundary objects have roots in strategic network formation (see e.g. Jackson [34]). Smart technologies in the context of PSS enable economic value creation and appropriation in a network of actors across organizational boundaries rather than in a single firm.

A boundary-spanner is traditionally defined as a person located at the ‘boundaries’ of an organizational unit or another organization and engaged in a task in relation to the unit or the other organization [35]. For example, full-time maintenance technicians employed by an equipment manufacturer at a customer site are boundary spanners between the organizations of the manufacturer and the customer. Digital systems can also function as boundary objects that allow spanning across organizational boundaries when they are shared between two or more organizational units. The systems can enable boundary-spanning as they enable the organizations’ members to share information across functional, geographic and temporal boundaries [36][35].

Two similar studies of sensor technologies in two equipment manufacturers show the instances of boundary spanning [37][35]. The technological features in the cases are remote sensing and data collection, wireless connectivity and data analytics [37]. As the systems are embedded in customers’ machines and can send operational data to the manufacturer, these systems work as digital boundary objects. Digital features of these systems enable richer inter-organizational knowledge flows as the systems are integrated with new knowledge sharing practices, within and between the local and the remote sites. The features such as remote data collection, analysis and wireless communication can reinforce existing boundaries as either the provider or customer can have control over the whole system to conduct their businesses. On the other hand, the features cross or create new organizational boundary as some activities that previously needed to be done onsite can be performed remotely [35].

Another study highlights the role of digital technologies as boundary objects when a German machine tool manufacturer collaborated with a recycling service provider [38]. Based on three action research cycles, prototypes of digital objects acted as boundary objects for knowledge sharing among these two organizations. The recycling service provider was facilitated by the digital objects in planning and decision making due to available data on machines and operational processes and for disassembly and treatment.

Although Smart PSS have opened up opportunities for boundary spanning, the opportunities can be constrained by some factors. Lack of standardization in sharing and integration of sensor data, skepticism about its reliability, the gap between physical and digital worlds, etc. can create barrier in boundary spanning and value co-creation with customers and stakeholders [31]. Very little is known about overcoming these challenges which is essential for success in Smart PSS.

4.3 Intelligent Dynamic Capabilities

The third theme that is identified from the extant research on Smart PSS is intelligent dynamic capabilities. The research on intelligent dynamic capabilities can be traced back to the early dynamic capabilities research (see e.g. Teece et al. [39]). Smart technologies enable value creation from the very processes that reconfigure the resources and capabilities both within the firm and within its strategic network. New capabilities and offerings are established to enable the generation of smart PSS that differentiate the establishment of new resources and value systems that enable new business models. Dynamic capabilities are capabilities for sensing, seizing and reconfiguring [40]. Sensing means perceiving opportunities and threats, seizing points at taking advantage of opportunities identified and reconfiguring means adapting a business’ assets to create competitive advantages [41][40].

While carrying out research on ICT enabled service innovation in eight manufacturers of equipment related to aircrafts, mining, material handling, industrial pumps, etc., Kindström et al.[42] find that companies sense opportunities with technology such as RFID (Radio frequency identification) and develop it. Engagement with external specialists for building digital capabilities is also noticeable in the machinery industry.

Digital technologies such as Internet of Things (IoT), cloud computing and analytics are key enablers of information management capabilities in relation to user and equipment identification, timing assessment, intensity assessment, condition monitoring, usage monitoring, prediction, autonomy, adaptive control, and optimization [8]. The digital dynamic capabilities are intelligence capability, connect capability, and analytic capability [43]. These capabilities of a smart PSS can provide affordances such as optimization of equipment operations, control and manage equipment remotely, predict and trigger service activities, remote diagnostics and reducing field services, information and data-driven services, and developing better equipment based on operational data [44].

In the material handling equipment industry and the industrial gas sector in Europe, Ulaga and Reinartz [45] find
that digital data derived from the usage of firms’ installed base is one of the critical resources for building service related data processing capability, design to service capability, hybrid offering sales capability, etc. The authors present four classes of industrial services for hybrid offerings: product life cycle services, process support services, asset efficiency services, and process delegation services.

Based on three German equipment manufacturers, Lerch and Gotsch [7] recognized that a digitalized PSS or Smart PSS can bring competitive advantage at present and in the future and positively influence company’s innovation process. The cases show that Smart PSS differ from traditional service offerings due to their high degree of automation and in their ability to forecast possible failures and maintenance needs. Another study with a different group of equipment manufacturers showed that digital capabilities possessed the ability to use smart and connected physical products to facilitate service innovation [46]. These capabilities arise since Smart PSS integrate tangible products, intangible services, and digital architectures.

To summarize, Smart PSS has profound implications on dynamic capabilities of manufacturing companies. The firms are now challenged to develop digital capabilities. Simultaneously, they are supposed to exploit the affordances provided by the digital technologies. The companies may also need to develop network capabilities to successfully innovate their digital capabilities [4].

5. Discussion

Based on our literature review, we can define Smart PSS on the basis of the combinations and interactions between smart technologies, physical products, services, and business models. The interactions are essential to fulfill customers’ needs.

- Smart technologies: Technologies that are programmable, addressable, sensible, communicable, memorizable, traceable, and associateable [6].
- Physical products: A physical product (for example, an industrial equipment embedded with digital objects) that is sold, rented, leased or temporarily handed over to a customer as part of a contract.
- Digital and non-digital services: An activity that is done to offer digital and non-digital solutions to meet customer needs.
- Digital business models: A mechanism for using smart technologies, products and services for creating and capturing value.

Smart PSS have implications for value systems and business models, boundary spanning and dynamic capabilities. Both the aspects of boundary spanning and dynamic capabilities can be categorized under Smart PSS design. Table 3 shows the distinctive value creating features of Smart PSS. Features related to the aspect of value systems and business models are active value creation, digital platform for value co-creation, new business models, and digital data-driven value creation and value capture. The aspect of boundary spanning in Smart PSS can be observed with digital boundary objects such as sensors, embedded software and analytical tools that work as boundary spanners among the organizations of the customer and the provider. Finally, dynamic capabilities can be observed with digital dynamic capabilities for the design and redesign of Smart PSS.

### Table 3: Distinctive value creating features of Smart PSS

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Features of Smart PSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Systems and Business models</td>
<td>• Active value creation with customers through digital resource integration</td>
</tr>
<tr>
<td></td>
<td>• Digital platform for value co-creation</td>
</tr>
<tr>
<td></td>
<td>• New business models based on: a) Smart PSS packages for industrial product performance, b) cost saved from smart automation services</td>
</tr>
<tr>
<td></td>
<td>• Digital data driven value creation and value capture, i.e., using product generated data for improved customer relationship and PSS redesign</td>
</tr>
<tr>
<td>Design</td>
<td>Digital objects (sensors, embedded software, analytical tools etc.) as boundary spanners among provider and customer organizations to facilitate digital service design and delivery of smart PSS.</td>
</tr>
<tr>
<td>Dynamic capabilities for design/redesign</td>
<td>Digital dynamic capabilities (intelligence capability, connect capability and analytic capability) for the design and redesign of smart PSS</td>
</tr>
</tbody>
</table>

6. Limitations and Future Research

This literature review investigates the value creating features of Smart PSS. The identified three themes, i.e., digital resource driven value systems and business models, boundary spanning with digital boundary objects, and intelligent dynamic capabilities particularly focus on value creation for customers by industrial firms. However, there may exist other themes that can highlight how, when and for whom value is created. As this review focuses on Smart PSS in industrial firms, the value creation aspect for the Smart PSS enabled by mobile and cloud platforms in the consumer market has not been discussed. Such Smart PSS in the B2C context may encompass a different set of themes for value creation. Therefore, an in-depth literature review is required.

Although smart PSS have distinctive features, there are challenges associated with the features as identified in the literature review. Future research on Smart PSS can focus on the following aspects:

- How can the product generated data be used for designing Smart PSS packages to capture value?
- What are the required changes in organizational settings to facilitate the design and delivery of Smart PSS?
- What are the operational routines to successfully deploy dynamic digital capabilities for delivering Smart PSS packages?
- How can the barriers of physical and digital in spanning organizational boundaries be overcome in the design and delivery of Smart PSS?

Research on these aspects will delineate salient features of Smart PSS for creating and capturing value.
References


