Design Science

Bridging the gap between engineering design and marketing: insights for research and practice in product/service system design

Sergio A. Brambila-Macias[1], Tomohiko Sakao[1] and Christian Kowalkowski[1,2]

1 *Linköping University, Department of Management and Engineering, Linköping, 581 83, Sweden*
2 *Hanken School of Economics, Department of Marketing, CERS—Centre for Relationship Marketing and Service Management, Helsinki 00100, Finland*

Abstract

Over the last decade, product/service systems (PSSs) have become a research issue in several disciplines, such as engineering design and marketing. The inherent interdisciplinary nature of this research issue has however remained unexploited. In order to bridge these silos and foster more interaction across relevant disciplines, this research examines PSSs from an interdisciplinary angle by analyzing how engineering design and marketing inform one another, as well as presents insights for PSS design. The research is carried out using a three-stage process for analyzing and evaluating interdisciplinary research: first, through a systematic literature review to identify relevant papers and their level of utilization across disciplines; second, by using a qualitative thematic analysis looking for different perspectives in order to find themes to bridge the gap between the disciplines; and third, by providing a research agenda to advance research by moving from silos to synergy. The results show a limited use of theories, frameworks, methods and tools across disciplines thus far, while the major contribution of this article lies in the implications derived for PSS design for academics and practitioners alike, which are categorized into seven specific themes: business orientation, collaboration, cost aspects, flexibility, performance indicators, requirements and services.

Key words: business orientation, collaboration, flexibility, performance indicators, services

Received 2 September 2017
Revised 1 February 2018
Accepted 8 February 2018

Corresponding author
S. A. Brambila-Macias
sergio.brambila@liu.se

Des. Sci., vol. 4, e7
journals.cambridge.org/dsj
DOI: 10.1017/dsj.2018.3

1. Introduction

Manufacturing companies are increasingly offering product/service systems (PSSs) to their customers (Tukker 2015). While many definitions of PSSs exist in the literature, two of the most highly cited (Beuren, Ferreira & Miguel 2013) are 'a marketable set of products and services capable of jointly fulfilling a user's needs' (Goedkoop *et al.* 1999, p. 3), and 'a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models' (Mont 2002*a*, p. 239). Examples of PSSs in industry are numerous. For instance, Ricoh, a multinational imaging and electronics company, provides a package deal called *Pay per Page Green* which installs, maintains and collects printers and photocopiers at the end of their life, while the customer only pays

for pages and copies delivered (Vezzoli *et al.* 2014). Another example is Toyota Industries, a leading supplier of material handling equipment. Toyota Industries offer trouble-free material handling operations. An example of their offerings is the rental of forklift trucks, where the customer pays for their use while Toyota Industries look after maintenance, upgrade or remanufacturing, and eventual disposal (Kowalkowski & Ulaga 2017).

The rationale for such PSS business models can be economic (e.g., revenue and profit growth), competitive (e.g., differentiation and closer customer relations), and environmental (e.g., resource efficiency and reduced carbon footprint) (Baines & Lightfoot 2014). In addition, drivers of PSS business models can be both proactive and reactive. Whereas some manufacturers lead change by proactively designing new PSSs, others act in a reactive manner and change due to pressure from legislators and competitors as well as resource scarcity and environmental concerns (Mont 2002*b*; Kowalkowski & Ulaga 2017).

Despite the well-justifiable rationale, several scientific reports confirm that manufacturing companies face various challenges when designing PSSs (e.g., Annarelli, Battistella & Nonino 2016). In particular, Durugbo (2013) and Matschewsky, Kambanou & Sakao (2017) reported problematic separation between product and service departments in PSS providers in industry, and several studies have focused on how to address these challenges in an efficient and effective manner (Andreasen 2011; Vasantha *et al.* 2012). A main root cause for this issue may be that designing a PSS is more complex than designing only its physical product part and the need to jointly manage the integration between product and service elements (Kimita, Sakao & Shimomura 2017). PSSs can benefit from interactions across departments in industrial companies (Lightfoot, Baines & Smart 2013; Eisenbart, Gericke & Blessing 2017), since the bundle of products and services needs to be designed in unison as a system of products, services, networks and infrastructures (Morelli 2003).

Scientific knowledge across disciplines is lacking to realize such improved integration between departments in a company (Lightfoot *et al.* 2013; Eisenbart *et al.* 2017). In particular, while the PSS is a research issue in both engineering design (e.g., Goh, Giess & McMahon 2009; Ki Moon *et al.* 2009) and marketing (e.g., Tuli, Kohli & Bharadwaj 2007; Ulaga & Reinartz 2011), there is limited knowledge transfer between the two. Many of the challenges that manufacturers face when designing a PSS derive from the goods-centric engineering design models prevailing in these firms (Isaksson, Larsson & Rönnbäck 2009; Matschewsky *et al.* 2017) (see conventional theories for mechanical design, e.g., Pahl & Beitz 1988). Prior research has also shown that many manufacturers, including world-leading ones, fail to commercialize their PSS offerings because marketing aspects, such as sales and pricing, are insufficiently addressed during the design phase (Kindström & Kowalkowski 2014). Hence, from both a scientific and practical view, we lack sufficient knowledge about how marketing can inform engineering design to provide PSSs that are desired by customers, financially viable, and technologically and environmentally feasible.

Motivated by these observations, this paper aims to reveal the current insights related to PSS design in quantitative and qualitative terms by focusing on interdisciplinary insights in engineering design and marketing. Based on the results obtained, implications and a research agenda for PSS design are provided.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

In order to arrive at this goal, this research postulates the following research questions:

(1) To what extent have insights coming from the marketing discipline been used in the engineering design discipline, and vice versa?
(2) What are the implications of insights in marketing for engineering design in order to more effectively and efficiently design PSSs?

The significance of this research resides in its methodology and its findings. The methodology takes an original approach that could be replicated in the future, while the findings contribute to building the necessary bridges across the two disciplines for further discussion within the design community and practical applications in industry.

The remainder of this paper is structured as follows: Section 2 describes the importance of interdisciplinary research in general, and for PSSs in particular; Section 3 describes the research method used; Section 4 explains the results and research agenda and finally, Section 5 presents the conclusions.

2. Interdisciplinary research

2.1. Motivation for interdisciplinary research

Interdisciplinary research can be understood as one of the answers to an increasingly complex world, one in need of integrating several disciplines to tackle complex problems or phenomena (Ledford 2015). Indeed, *wicked problems* in the current sustainability paradigm are unique, complex and need to be continuously managed through collaboration (Rittel & Webber 1974; Brown, Deletic & Wong 2015). Interdisciplinary research, therefore, integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines to further understand or solve problems beyond the scope of a single discipline (Wagner *et al.* 2011).

2.2. Engineering design and marketing

The lack of interaction between engineering design and marketing in general is not a new issue. Krishnan & Ulrich (2001) review the literature in engineering design, marketing and operations management to look at product development and fundamental decisions made by intention or default. Of special interest are Krishnan & Ulrich's (2001) differences between the engineering and marketing academic fields with respect to products. Marketing tends to see a product as a bundle of attributes, while engineering sees it as a complex assembly of interacting components. Furthermore, in engineering design, Chen, Hoyle & Wassenaar (2012) have noted that different functions in a firm tend to optimize their own objectives with limited input from other functions. They highlight the limited communication between the engineering design and marketing domains, and suggest that there is a need to consider customer behavior and demand (the marketing domain) along with the costs and performance of an engineering system (the engineering design domain), while Andreasen & Hein (2000, p. 14) recognize in integrated product development the poor interplay between marketing and design and the 'ignorance of, and lack of mutual respect between, the departments concerned'. Even earlier, Kahn (1996) found

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

that interdepartmental collaboration makes the difference between product development success and failure, while Souder & Song (1997) showed in their research of companies in the electronics sector that one of the keys to success in new product development resides in finding the right combination of product design and market choice decisions.

To further clarify the domain of engineering design and marketing, the following definitions are used throughout this paper.

Engineering design is 'The process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs' according to US Accreditation Board for Engineering and Technology (ABET 2016).

Marketing is 'The activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large' according to American Marketing Association (AMA 2016).

2.3. Need for interdisciplinary research in PSSs

Regarding PSS practice, the literature has shown that PSS providers have struggled to fully capture the benefits of PSS offerings. One reason could be that PSS providers are failing to capture the value from various customers' perspectives effectively (Kuijken, Gemser & Wijnberg 2016), which is a central issue in marketing based on the definition above. Morelli (2003) argued that designing a PSS is a multidimensional activity that requires interaction between the designer, social actors (including those involved in marketing) and technological artifacts. Such necessary interactions in PSS design are, however, insufficiently achieved in industrial practice (see Matschewsky *et al.* 2017).

There have been several calls by researchers to look for more interdisciplinary work among academia for PSS design and even design in general (Papalambros 2015). In PSS research, a number of articles support the need for interdisciplinary research between engineering design and marketing, although their scopes in terms of disciplines do not match exactly. Isaksson *et al.* (2009) argued it fruitful to combine the engineering and marketing fields to deepen the understanding of the PSS design process. Tukker & Tischner (2006, p. 1554) reported that 'the PSS community (has) paid only limited attention to business management literature, where well-founded theories about the business sense of servicing had been developed'. Sakao & Shimomura (2007) have another example calling for more interaction across disciplines; the authors call for a *much bigger framework* in PSS design to tackle design in the sustainability paradigm. Moreover, there have also been calls from the marketing literature to develop the necessary capabilities in companies interested in implementing PSSs (see, for example, Ulaga & Reinartz 2011). Furthermore, in their analysis of PSS definitions in business management, engineering design and information systems, Boehm & Thomas (2013) concluded that exchange between these disciplines could be beneficial for the PSS discipline as a whole, calling for more interdisciplinary work since PSSs can gain from looking at the discipline from different perspectives. Additionally, in *A Research Manifesto for Services Science*, Chesbrough & Spohrer (2006) highlight the importance of integration across academic silos in order to

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

understand modern services. Lightfoot *et al.* (2013) identified five major research areas in servitization (i.e., service marketing, service management, operations management, PSSs and service science) while also suggesting the opportunity for knowledge production by increasing interactions across these disciplines, as well as suggesting a deeper analysis of this cross-fertilization. Qu *et al.* (2016) suggest that methodologies from other disciplines, namely, environmental, engineering and business management could support PSS design. Finally, Baines *et al.* (2017) call for more ambitious research, suggesting to engage in multidisciplinary, interdisciplinary and transdisciplinary future research.

3. Method

3.1. Overview

The research method followed in this paper is new to our knowledge in that it proposes levels of utilization of insights across disciplines. The method involves three stages. Stage I consists of a systematic literature review, which is a quantitative-oriented method (Jesson, Matheson & Lacey 2011), and later the identification of insights and their level of utilization. Stage II involves a qualitative thematic analysis (Robson 2011) in order to find possible discrepancies between concepts or terms and examine how marketing can inform engineering design. Finally, Stage III identifies a future research agenda for PSS design.

The first two stages correspond to the two research questions. The major benefit of how Stage I is conducted lies in its objective and quantitative manner, determining as accurately as feasible the current extent to which knowledge was used across the disciplines in the literature; for Stage II, that exists in its concise representation of issues for future research in this vast area based on in-depth discussion. The method with its steps is depicted in Figure 1.

3.2. Systematic literature review with level of insights (Stage I)

Step 1. Identify keywords. This step identifies keywords related to the subject, which include other terms commonly used in each discipline (see appendix A). The ISI Web of Science was the scientific database chosen, since it provides journals with impact factors. This database has been used in a similar way in other publications (see, for instance, Dahlander & Gann 2010). The scope for the search focuses on publications in the Web of Science Core Collection, where only the databases SCI-Expanded and SSCI were selected, as these are considered relevant to engineering design and marketing, the topics of interest. The years selected were between the earliest possible year in the database, 1975, and the most recent, 2017 (see appendix B for the list of the journals for each discipline). The chosen journals were selected according to the best knowledge of the authors about PSS-related topics and common outlets. Moreover, the selection was supported by the Web of Science's categorization of journals as either engineering or marketing. Those journals falling into multiple categories were therefore not selected in Step 1. An example is the International Journal of Production Economics, which although relevant is categorized in the Web of Science as Engineering Industrial, Manufacturing and Operations Research and Management Science. This limitation was compensated by looking again into relevant literature in Step 8. Indeed, widening the scope of the search to include

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

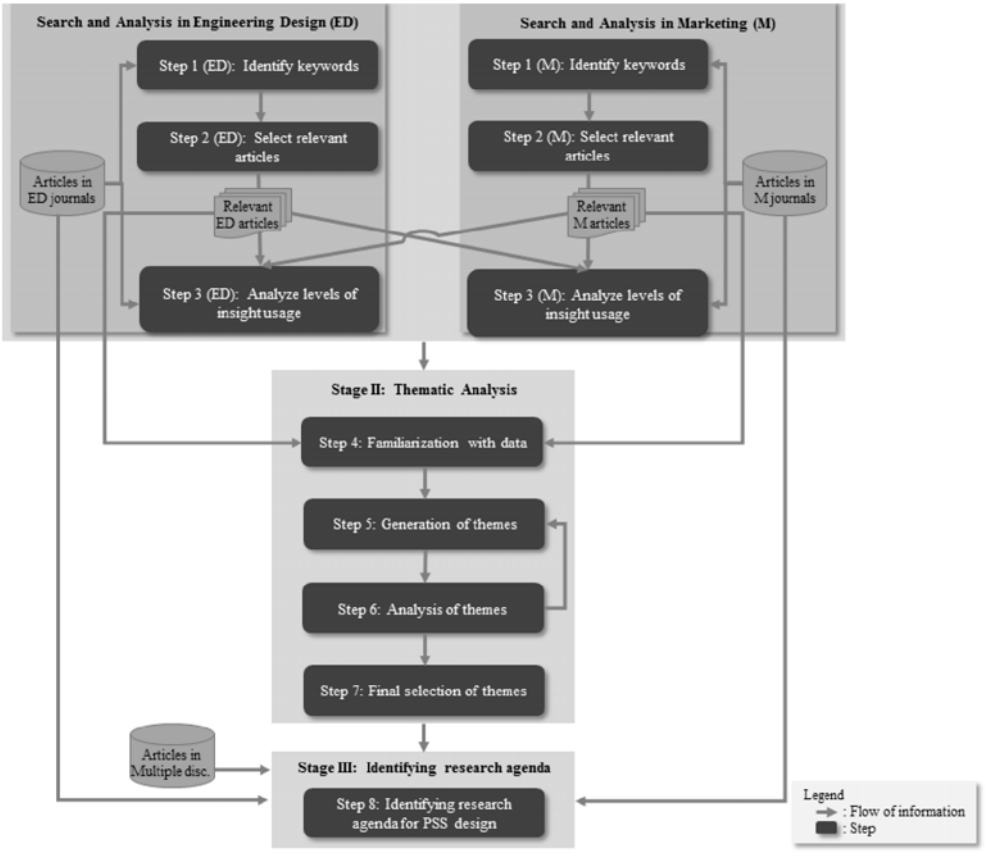

Figure 1. Steps followed for the method.

journals in multiple disciplines. Papers that fall into more *gray literature* are not covered here.

Step 2. Select relevant articles. Databases were created to make the selection of relevant articles. After the keyword search articles were arranged more highest to least cited to have a ranking measure. A criterion for their selection was that the articles had to be cited at least two times from the opposite discipline. In ED, 194 articles were first identified from the keyword search; those which were reviews, not relevant or with only one or no citations were removed. Nine articles that had been cited more than once were selected. The same process was followed in the selection of relevant articles in marketing. A database was also created with 177 articles, from which 11 were finally selected.

Step 3. Analyze levels of insight usage. After the selection of articles, 9 in ED and 11 in M, Table 1 was applied to identify how insights are being used from authors in the opposite discipline. In the selected 9 articles in ED, 19 articles (30 Level 1 citations) citing them in industrial marketing journals were reviewed. (Some articles like Rabetino *et al.* (2015) cite multiple times the opposite discipline.) From the 11 articles in M, 33 articles (50 Level 1 citations) citing them in engineering design journals were also reviewed. (Some articles like Visintin (2012) cite multiple times the opposite discipline.) Table 1 is explained as follows:

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 1. Levels of insight usage

Level	Meaning
Level 1 (L1)	Cited: Beuren *et al.* (2013), e.g., citing Oliva & Kallenberg (2003), who write 'Organizations have begun strategically shifting from selling products to providing services' (p. 224).
Level 2 (L2)	Insight used: Lingegård & Lindahl (2015), e.g., citing Oliva & Kallenberg (2003), who write 'However, to become a service provider, considerable changes have to be made within the organization, capabilities and management of the firm' (p. 167).
Level 3 (L3)	Model, framework, method, or tool directly used: Raddats *et al.* (2016), e.g., citing Oliva & Kallenberg (2003), who write 'The framework details the motivations to servitise in accordance with Oliva & Kallenberg's (2003) three motivations . . . ' (p. 573).

Level 1 is assigned one count if a citation from the opposite discipline is used in the publication. Level 2 is assigned one count if there is an insight used, that is, using the understanding or observation from an author in the opposite discipline. Level 3 is assigned one count only if there is enough evidence to suggest that the author(s) had made use of an insight for creating a model, framework, method or tool from the opposite discipline.

3.3. Thematic analysis (Stage II)

Stage II consisted of carrying out qualitative thematic analysis. Braun & Clarke (2006) suggest that thematic analysis is usually used when identifying, analyzing and reporting patterns or themes in qualitative data. Guidelines for this type of research usually follow several steps (Robson 2011; Vaismoradi, Turunen & Bondas 2013; Elo *et al.* 2014). The steps in this research are as follows:

Step 4. Familiarization with the data. This is carried out in order to understand the overall topics of each of the selected relevant articles (from Step 2) and highlight possible themes. The selected articles address related contents, and, therefore, this step entailed re-reading the selected articles.

Step 5. Generation of themes. The objective for Stage II is to find possible mismatches across disciplines, and an initial guide was found in the well-established criteria in engineering in general (quality, cost, delivery and flexibility). In this step, judgment and interpretation are needed in order to identify themes in each article.

Step 6. Analysis of themes. This step is iterative with Step 5, as some themes were regarded as repetitive across the articles. Each theme is then compared across the disciplines.

Step 7. Final selection of themes. The themes generated in Step 6 are compiled in a spreadsheet in such a way that meaningful comparisons across the disciplines are possible. Based on the themes, insights are provided as implications for engineering design and marketing.

3.4. Identifying a research agenda (Stage III)

Based on the outcomes of Stages I and II, a future research agenda for PSS design is suggested. This will be structured using the themes of relevance selected in Step 7.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Step 8. Identifying a research agenda for PSS design. The insights provided in Step 7 support the formulation of future research questions that so far have not been addressed, or only partially addressed, in the literature. The databases created in Step 2 were used to categorize the insights found into the themes from Step 7 (see appendix D). The research agenda is created after the insights are identified and a literature search for papers addressing these issues is conducted. This includes relevant journals falling into an already interdisciplinary field: Examples are journals in operations management, in particular the International Journal of Operations and Production Management and Journal of Operations Management. The same applies to the International Journal of Production Economics. (See Figure 1, the database flows into Step 8.)

4. Results

4.1. Keyword search and selection of relevant articles (Stage I, Steps 1 and 2)

Results for Stage I are time-specific, i.e., results obtained in December 2017. Keywords include other terms commonly used in each discipline. For instance, in engineering design it is common to see related terms such as *industrial service*, *hybrid offering, functional product* and *servitization*. With regard to marketing, terms often used are *service infusion* and *service transition*, among others (see appendix A for the keywords adopted). The databases for ED and M included 194 and 177 articles, respectively, ordered from the most to least cited (see Tables 2 and 3) The selected articles come from industries in capital goods, personal computers, and automotive and financial services, to mention a few, as well as different objectives of study, methods and world regions (see appendix C for further details).

4.2. Analysis of levels of insights (Stage I, Step 3)

Results of Step 3, namely, cross citations in engineering design and marketing, are shown in Tables 4 and 5, respectively.

Table 4 shows that only Maxwell & Van der Vorst's (2003) work has been cited at three levels. Their insights in the marketing literature refer to their sustainable product and service development method to meet business and industry requirements from a lifelong perspective: Level 2 citations point out that sustainable or green design (reuse/recycling/energy recovery/treatment/disposal) is usually driven by regulation (Baraldi, Gregori & Perna 2011; Chan, He & Wang 2012; Raja *et al.* 2013), while Lacoste (2016) considers Maxwell & Van der Vorst's (2003) work at Level 3 in order to depict the product lifecycle for business-to-business operations, and to show how suppliers can support the redesign or improvement of products through value co-creation with customers.

Of special attention concerning Table 5 is the number of articles that cite the work of Oliva & Kallenberg (2003). Oliva & Kallenberg's (2003) work is frequently used at Level 1 as a source to indicate how several manufacturing companies have moved from providing products to PSSs, as well as the reasons for this shift, namely economic benefits, competitive pressure, customer demand and sustainability (Cavalieri & Pezzotta 2012; Beuren *et al.* 2013). Level 2 insights are used to point out how successful delivery of PSSs needs new organizational

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 2. The selected articles in engineering design (Outcome of Step 2)

Selected engineering design articles				
Rank from 194 articles	ID	Author(s)	Year	Title
5	E1	Aurich, Fuchs & Wagenknecht	2006	Life cycle oriented design of technical Product-Service Systems
6	E2	Maxwell & Van der Vorst	2003	Developing sustainable products and services
7	E3	Manzini & Vezzoli	2003	A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize
10	E4	Alonso-Rasgado, Thompson & Elfström	2004	The design of functional (total care) products
14	E5	Cook, Bhamra & Lemon	2006	The transfer and application of Product Service Systems: from academia to UK manufacturing firms
17	E6	Maussang, Zwolinski & Brissaud	2009	Product-service system design methodology: from the PSS architecture design to the products specifications
52	E7	Stoughton & Votta	2003	Implementing service-based chemical procurement: lessons and results
82	E8	Baines *et al.*	2010	The adoption of servitization strategies by UK-based manufacturers
109	E9	Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ

principles, structures and processes (Bastl *et al.* 2012). These new considerations will imply the creation of a separate organization to handle service offerings, relational rather than transitional relations and a dedicated sales force (Biege, Lay & Buschak 2012). Raddats *et al.* (2016) make use of insights at Level 3 based on Oliva & Kallenberg (2003) as well as other authors in order to create framework matching drivers, product complexity, systems and motivations for servitization to examine their research questions.

Given its large number of citations and impact on PSS research, Kowalkowski *et al.* (2015) refer to it as the path-defining study, and this may not come as a surprise. However, these citations are mostly at Levels 1 and 2, which means that Oliva & Kallenberg's insights on the evaluation of service potential (installed base), necessary models for its quantification and when to enter the market have been only partially addressed in engineering design.

4.3. Thematic analysis (Stage II, Steps 4, 5, 6, and 7)

The results show that there are several themes that are looked at from different points of view, and that vary depending on the context used across disciplines (see appendix D). Overall, seven themes were finally selected from Stage II: business

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 3. The selected articles in marketing (Outcome of Step 2)

Selected marketing articles				
Rank from 177 articles	ID	Author(s)	Year	Title
1	M1	Oliva & Kallenberg	2003	Managing the transition from products to services
3	M2	Tuli *et al.*	2007	Rethinking customer solutions: From product bundles to relational processes
5	M3	Mathieu	2001	Service strategies within the manufacturing sector: benefits, costs and partnership
6	M4	Fang, Palmatier & Steenkamp	2008	Effect of service transition strategies on firm value
7	M5	Ulaga & Reinartz	2011	Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully
9	M6	Cova & Salle	2008	Marketing solutions in accordance with the S-D logic: Co-creating value with customer network actors
15	M7	Gebauer	2008	Identifying service strategies in product manufacturing companies by exploring environment-strategy configurations
19	M8	Kindström & Kowalkowski	2009	Development of industrial service offerings: a process framework
23	M9	Penttinen & Palmer	2007	Improving firm positioning through enhanced offerings and buyer–seller relationships
25	M10	Windahl & Lakemond	2010	Integrated solutions from a service-centered perspective: Applicability and limitations in the capital goods industry
38	M11	Bezerra *et al.*	2013	Employing the business model concept to support the adoption of product-service systems (PSS)

orientation, collaboration, cost aspects, flexibility, performance indicators, requirements, and services. For each theme, there are implications for engineering design and insights hopefully useful for academics and practitioners researching, providing, or planning to provide PSSs. How each theme was addressed in the selected articles from the two disciplines and the insights derived from that are presented in the following sections.

4.3.1. Business orientation

One could argue that engineering design can be regarded as having an operational business orientation. It typically focuses on the optimal use of resources and the use of systematic methods for the design of products and services, even when referring to strategy. For instance, Alonso-Rasgado *et al.* (2004) propose a systematic process for designing a service and refer to the term optimization when working with services, and Aurich *et al.* (2006) mention the need for *systematic* design of services and processes. These studies refer to topics such as design

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 4. Levels of insight of marketing citing ED (Outcome of Step 3)

ID	Author(s)	Year	Total level of insights from ED L1	L2	L3
E1	Aurich *et al.*	2006	2	2	0
E2	Maxwell & Van der Vorst	2003	5	3	1
E3	Manzini & Vezzoli	2003	7	1	0
E4	Alonso-Rasgado *et al.*	2004	4	1	1
E5	Cook, Bhamra & Lemon	2006	4	3	0
E6	Maussang *et al.*	2009	2	0	0
E7	Stoughton & Votta	2003	2	0	0
E8	Baines *et al.*	2010	2	0	0
E9	Visintin	2012	2	1	0
Total			30	11	2

tasks, service components, and the standardization of information. Maxwell & Van der Vorst (2003) propose the sustainable product and service development method, while acknowledging that most methods focus on the operational rather than the strategic levels. Marketing, in turn, could be considered as having a more *strategic* business orientation. While marketing strategy can be regarded as one subdiscipline within marketing (others include consumer behavior, etc.), marketing research on PSSs has a strategic, business-to-business orientation. In this respect, Mathieu (2001) suggests that service strategies are a source of competitive advantage, and looks at an integrated approach to strategy formation when facing uncertainty in complex markets. The well-cited study by Oliva & Kallenberg (2003) also concerns strategic aspects and benefits. They point at the opportunities as well as challenges of increasing the service business orientation of a manufacturing firm. What is more, Cook *et al.* (2006) suggest that manufacturing companies are more receptive when concepts describing PSSs refer to achieving a company's strategic goals. Barquet *et al.* (2013) provide insights into how to combine the Business Model Canvas tool (Osterwalder & Pigneur 2010) with PSS offerings and implement a business strategy; similarly, Gebauer (2008) identifies service strategies to fit with a specific business environment. Manzini & Vezzoli (2003) in ED seem to have recognized this gap with their *strategic design* as a design activity linking products, services, communication, clients and stakeholders. Therefore, to a greater extent than in a classic manner, engineering design research becomes more effective by recognizing that PSS design is not only an activity at the operational level, it can also be strategic and a source of competitive advantage.

Insight 1: Strategic thinking when designing a PSS can contribute to the competitive advantage of the firm by expanding business opportunities in uncertain business environments.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 5. Levels of insight in engineering design citing M (Outcome of Step 3)

#M	Author(s)	Year	Total level of insights from M L1	L2	L3
M1	Oliva & Kallenberg	2003	22	5	1
M2	Tuli *et al.*	2007	4	1	0
M3	Mathieu	2001	5	3	2
M4	Fang *et al.*	2008	3	2	0
M5	Ulaga & Reinartz	2011	3	2	1
M6	Cova & Salle	2008	2	0	0
M7	Gebauer	2008	2	0	0
M8	Kindström & Kowalkowski	2009	2	1	2
M9	Penttinen & Palmer	2007	2	0	0
M10	Windahl & Lakemond	2010	2	2	1
M11	Bezerra *et al.*	2013	3	1	0
Total			50	17	7

4.3.2. Collaboration

Collaboration in engineering design has a more structured approach to optimize and facilitate communication. The provider is at the center of that collaborative effort. For example, Aurich *et al.* (2006) propose *technical service design*, where service can learn from product design in order to standardize, systematize and document the design of the service. Moreover, Manzini & Vezzoli (2003) suggest *strategic design for sustainability*, aiming at creating new stakeholder configurations which are medium and long-term sustainable, economically feasible and socially appreciable. The authors present a model for how different stakeholders can be configured and optimized around the designer. By contrast, in marketing, the customer is typically at the center of the collaborative effort. For example, Cova & Salle (2008) emphasize the *co-creation of value* in PSSs through collaboration with the supplier and its network, as well as the customer and its network. This then provides what they call *services supporting the customer network* (SSCN) to define the degree of integration with a customer and its network. Mathieu (2001) also suggests that when implementing a service strategy the provider should, in some instances, consider partnerships with potential competitors (i.e., *coopetition*) in order to better serve the customer. Windahl & Lakemond (2010) also suggest that performance offerings need to go beyond dyadic relationships to consider a network that can provide this type of offering. They further highlight that the more the offering is linked to the customer's core process, the more dependent it becomes on the supplier, and that performance offerings might be more suitable for non-core processes. The implications for ED would be that of placing the customer at the center of the collaboration, which may result in collaborating with unusual partners such as the customers' suppliers or even competitors.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Insight 2: Organizational configurations for a PSS can range from collaboration with individual customers and their suppliers to entire networks that can include competitors as part of providing solutions to the customer.

4.3.3. Cost aspects

The analysis reveals that studies in engineering design of PSSs usually attempt to optimize and reduce costs over the whole product lifecycle. For example, Aurich *et al.* (2006) suggest a feasibility analysis as part of their *technical service design process*, where it is suggested to carry out a cost–benefit analysis and technical feasibility analysis. For their part, Alonso-Rasgado *et al.* (2004) focus on cost reduction strategies like reducing functionality and deploying maintenance staff only when necessary, as well as sensitivity and cost–benefit analysis.

Marketing, on the other hand, tends to address the *hidden* aspects of costs and highlight the value of an offering. Regarding the hidden costs, Mathieu (2001) suggests that manufacturers moving into service provision can face competitive and political costs. Competitive costs relate to the unexpected competitors that may appear once a company moves into providing services; competitors may be other service providers, distributors or even customers. Political costs refer to the internal resistance that some organizational subunits might incur when transitioning into services. Fang *et al.* (2008) point out the opportunity cost when transitioning from products to services, which suggests that larger firms might incur larger costs due to the necessary realignment to support service initiatives. Additionally, Tuli *et al.* (2007) highlight the value perspective of services. A quote from a customer reads 'A solution to me is when a supplier proposes bringing in value beyond the widgets. Rather than saying that here is a widget for $10, it's more about finding what I really need . . . ' (p. 4). The study emphasizes the need for providers to focus on long-term value-creating relationships rather than only establishing relationships to sell products or systems. Finally, an important contribution from the marketing literature can be seen in the deeper knowledge in legal and contractual obligations when entering relational rather than transactional transactions. In ED, only Stoughton & Votta (2003) provide insights into contractual agreements. In this respect, Penttinen & Palmer (2007) suggest that enhanced offerings will often involve advanced information sharing and more fully articulated legal and contractual obligations. They refer to *full-service contracts*, ensuring a year-to-year steady stream of revenue from which both supplier and customer benefit, the former through customer retention and higher profitability and the latter through reduction of number of suppliers and more dedication to their core business. Drawbacks, however, can be higher relationship and coordination costs (hidden costs) and higher reliance on the customer.

Although several authors in engineering design take customer value into account (for example, Manzini & Vezzoli (2003) and Baines *et al.* (2010)), Cook *et al.* (2006) provide evidence of the poor transfer of such knowledge from academia into UK manufacturing companies, suggesting that some companies focus too much on cost reduction strategies instead of adding value. Similarly, from a marketing perspective, Ulaga & Reinartz (2011) suggest that companies should switch from selling product features to selling value. The implications for engineering design are, on the one hand, not to underestimate *hidden* costs such

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

as internal resistance and new learning and, on the other hand, to focus more on what customers really value.

Insight 3: When offering a PSS, hidden costs may arise in the form of resistance to change, re-training and other investment when creating relational rather than transactional relationships with customers.

4.3.4. Flexibility

The term flexibility in engineering design is usually implemented with the modularity and customization of products/services with a lifecycle perspective. For instance, Aurich *et al.* (2006) suggest the design of lifecycle-oriented products and services by components in order to support flexible adaptation according to customers' needs. Maussang *et al.* (2009) suggest the integration of a *supervision module*, a physical object capable of identifying and diagnosing failure of a refrigeration cable, and reflect on the importance of process *architecture* when designing services. That is, flexibility in engineering design focuses on increasing internal efficiency and is implemented by the standardization of components or modules when designing products, services or processes.

In marketing, flexibility is then more related to the organizational capabilities of the firm and how these can be adjusted according to customers' needs. Tuli *et al.* (2007) suggest multiple and flexible hierarchical structures called *contingent* to better respond to customer demands and find appropriate solutions. In ED, Visintin (2012) refers to the literature in business, management and marketing that provides different views on modularity. Visintin (2012) cites the work of Bask *et al.* (2011), who suggest that modularity has been traditionally researched from the perspective of products and product design. However, the Océ case study described by Visintin (2012) makes use of *service modularity*. The case company offers different services depending on customer needs; depending on the solution provided, which is either a product, a product/service bundle, or an integrated system, different employees will be involved in its design and delivery. Additionally, the pricing will depend on the service provided. Visintin (2012) acknowledges that the case study of Océ is an example of a vertically integrated firm, and that the literature suggests that in other cases, the identification of other suppliers may be needed in order to deliver a solution.

The implication for engineering design is to understand that flexibility includes not only modular designs to increase internal efficiency, but also the perspective of internal organizational capabilities and forming temporary projects or cooperation with other suppliers according to customers' varying needs. Flexibility in a general sense is partly practiced in industry: for instance, concurrent engineering involves flexibility, because each subgroup works in part simultaneously for an identical design project. However, the scope of cooperation concerned here is, as stated by Tuli *et al.* (2007), larger than the major internal focus of design practice.

Insight 4: In order to offer a PSS, the provider could adopt temporary teams during different stages of design and improve flexibility as required by customers.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

4.3.5. Performance indicators

Engineering design usually refers to the indicator of *efficiency* as a measure of performance. It takes into account materials and energy resources, and attempts to make use of them in an efficient manner or to an optimal degree. Terms like productivity, efficiency, optimization and dematerialization along the lifecycle of products and services are common in PSS literature (see, for example, Maxwell & Van der Vorst 2003). In contrast, the indicators usually employed in marketing seem to be more related to the *effectiveness* that products/services have on the firm and the market. For example, Fang *et al.* (2008) analyze the effect that services have on a firm's market value. The authors find that the effect of services (service intensity) can be seen in the threshold of 20% to 30% of total firm sales. They also argue that when a firm provides services related to their core product business (service relatedness), services become substantially more effective. Moreover, this effect is usually related to the success of the product/service offering. In addition, several authors (e.g., Ulaga & Reinartz 2011) report their findings of how the introduction of PSSs can be successful in the market by identifying critical capabilities and matching those with customers' needs.

Insight 5: Performance Indicators for a PSS offering should cover both the efficiency and effectiveness to reflect the impact of the offering on firm value and customer value.

4.3.6. Requirements

In engineering design, the terms used for requirements are usually based on technical or functional artifacts and tend to focus on the provider's side. For instance, Alonso-Rasgado *et al.* (2004) emphasize the importance of functionality and describe functional products as a combination of hard and soft elements, namely hardware combined with a service support system. They focus on the design of the service system and make suggestions on hardware design and its remanufacturing. Furthermore, engineering design tends to concentrate on tangible resources such as finances, material, and energy. Studies such as Manzini & Vezzoli (2003), Maxwell & Van der Vorst (2003) and Aurich *et al.* (2006) refer to optimal use of natural resources as one of the main priorities.

However, in marketing, requirements often go beyond functional needs. Tuli *et al.* (2007) suggest that requirements go beyond asking the customer for functional specifications, but understanding the customers' current business needs including internal operating processes, labor situation and business model: requirements are also about knowing the customers' current and future needs, since these needs may change over time. They suggest that a provider should then identify its customers' recognized, unrecognized and even future needs. Furthermore, marketing often places more emphasis on intangible resources, such as the personnel in a company and their skills or capabilities that can support the marketing of products/services, rather than tangible ones. Capabilities of the company are a recurring theme in marketing, typically building on dynamic capabilities theory or the resource-based view of the firm. For instance, Fang *et al.* (2008) divide resources into tangible (e.g., office space and call centers) and intangible (e.g., customer relationships and brand image) and provide the

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

term *resource slack*, referring to excess resources that a firm may possess. Both Cova & Salle (2008) and Tuli *et al.* (2007) emphasize the interactive nature of PSS development and provision by suggesting that customers and suppliers co-create value through resource integration. The implications for engineering design would be to consider personnel capabilities when designing PSSs, since these can limit the type of offering provided.

Insight 6: For a successful PSS offering, both customer and provider may need to make necessary adjustments to their tangible and intangible capabilities in order to specify, communicate and capture value.

4.3.7. Services

The literature in engineering design regarding services has a shorter history than in marketing. The inception of PSSs in the late 1990s, as well as the emerging service engineering proposed by Sakao & Shimomura (2007), attempt to integrate the design of products and services in unison. However, marketing can be regarded as having a longer history in services and being more advanced and sophisticated (see, for instance, Grönroos 1978 & Lovelock 1983). This has been reflected already in the six themes above, but here particular issues on services as such are raised. In marketing, Mathieu (2001) provides a typology of service maneuvers that could be useful in developing a service strategy. This typology shows what type of service a provider may offer (customer service, product service and service as a product) and the internal impact that service could have at the provider (tactical, strategic and cultural). Moreover, Oliva & Kallenberg (2003) provide what they call the installed based (IB) of products with a long lifecycle currently under use and how that IB should be serviced. According to the authors, IB services are the necessary services to run a product effectively during its entire useful life. The authors divide services into a matrix providing a wide range of possible services that a provider can offer. Other studies provide similar classification schemes for services and PSSs (see, for example, Zeithaml & Brown 2014). Similarly, Kindström & Kowalkowski (2009) provide a framework for new service development, which has not been extensively addressed in ED.

Moreover, as mentioned above, the effect of services is a highly recurring topic in marketing, in contrast to its limited attention in engineering design. As an example, Tuli *et al.* (2007) address effective solutions and how to successfully achieve them. They suggest that effective solutions are the extent to which relational processes (what they call *supplier variables*) provide what the customer needs. Both supplier and customer variables need to be addressed properly for successful solutions. The implication for engineering design is to look at the expertise developed in marketing regarding services and solutions.

Insight 7: Engineering design can adopt, from the marketing discipline, classifications, guidelines, frameworks and tools on how to successfully provide services and solutions.

4.4. Research agenda for PSS design (Stage III, Step 8)

As implied from the derived insights, there are a number of research opportunities for designing PSSs in industry. This section proposes further research agenda for

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

PSS design per each theme and insight (detailed in appendix D). Deriving the research agenda has been enabled by the in-depth analysis with the two disciplines up to Step 7. This type of interdisciplinary or transdisciplinary research (see a definition for this in Sakao & Brambila-Macias 2018) is still recognized as an interesting opportunity as a result of several recent thorough reviews: concerning PSS design, evaluation, and operation (see Qu *et al.* 2016) as well as in operation management concerning servitization (see: Baines *et al.* 2017) which is a process of organizational change involving PSS. Table 6, summarizes the identified themes and insights (from Section 4.2) as well as the proposed research questions for PSS design. The research questions are intended to be in a high level to stimulate further research but still described with tight connection to the insights and other existing research about PSS. This future research agenda not only is based on the selected relevant articles but also takes into account literature published in engineering design and marketing (as shown in Figure 1).

(1) Business orientation – **Insight 1: Strategic thinking when designing PSSs can contribute to the competitive advantage of the firm by expanding business opportunities and securing long-term profitability in uncertain business environments.** The thematic analysis shed light on the contrast in business orientation between engineering design's operational focus and marketing's strategic focus as explained in Section 4.3.1. The knowledge gap in engineering design has been addressed as follows. In engineering design, Meroni (2008) suggests eight main pillars in strategic design for PSSs. These range from co-designing and scenario building to social innovation and strategic dialog. Reim, Parida & Örtqvist (2015) carry out a literature review and suggest that PSS strategy can be adopted at a strategic level by considering business models (i.e., product, use and result-oriented models) and at operational level by understanding tactics that can create value. In marketing, Gebauer *et al.* (2010) explore service strategies, which success will depend on the right alignment with corporate structures in terms of culture, human resource management, and the organizational structure itself. However, knowledge on how these aspects can be integrated into useful tools remains unsolved. Supporting designers with a tool or a method is highly effective (Gericke, Kramer & Roschuni 2016). Based on this, the following research question is proposed: **How can strategic thinking be integrated into tools to design PSSs?**

(2) Collaboration – **Insight 2: Organizational configurations for a PSS can range from collaboration with individual customers and their suppliers to entire networks that can include competitors as part of providing solutions to the customer.** According to Stark *et al.* (2010) customers are increasingly asking for complete solutions instead of single products. The authors suggest using *virtual production creation* which may offer engineering designers capabilities to collaborate and compete successfully. Pagoropoulos, Maier & McAloone (2017) investigate transformation of relationships between the customer and the supplier concerning PSS and digital capabilities using a case from the maritime sector. Geum & Park (2011) review tools for sustainable PSS design and propose the *product–service blueprint*, while Chandrasegaran *et al.* (2013) carry out research mainly in trends of computer tools for capturing knowledge and its representation in product design. Clegg *et al.* (2017) documented a transformation process to a PSS provider involving, for instance, closer collaboration with

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

suppliers accessing to a common information system. Gebauer *et al.* (2016) identify organizational capabilities necessary for pay-per-use services concerning collaboration with customers based on studies with small and medium-sized companies: e.g., insight into customer behavior and comprehensive customer support. However, little research shows how non-engineering experts can also be part of these trends. Specially, as implied by the results of Stage I, little knowledge for effective collaboration between engineering design and marketing is available since engineering design tends to see the designer at the center of the collaborative effort instead of the customer as in marketing. This lack of knowledge is valid with the other actors, too. Therefore, a proposed research question in the future is: **How can collaboration between engineering design and marketing as well as external actors be carried out for efficient and effective design of PSSs?**

(3) Cost aspects – **Insight 3: When offering PSSs, *hidden costs* may arise in the form of resistance to change, re-training and investment when creating relational rather than transactional relationships.** In the current literature on PSS design, research on lifecycle cost (Lindahl, Sundin & Sakao 2014), uncertainty associated with cost (Erkoyuncu *et al.* 2010) and cost of service contracts (Datta & Roy 2010) has been reported. Further, in industrial engineering, limitations of the current techniques for through-life costing of PSS in terms of the object, scope, and computation have been pointed out (Settanni *et al.* 2014). For instance, the scope is argued to be extended so that functioning of the system in question is understood systematically (ibid). For their part, Kreye, Newnes & Goh (2014) look at competitive bidding from manufacturing companies and propose a framework depicting the influence of various uncertainties in the bidding strategy. However, scarce research has been reported in the engineering discipline on the costs addressing organizational *changes* that have been frequently addressed in the marketing discipline as explained in Section 4.3.3 (Mathieu 2001; Tuli *et al.* 2007; Fang *et al.* 2008). Therefore, little knowledge in engineering design is available to calculate the cost, for instance, for a provider focusing on sales of a product at present to provide a result-oriented service based on the product. This calculation needs to consider not only the cost for a transition to PSS but also the cost of PSS provision after the transition. In more general, an interesting research question is proposed as: **How can soft and hard costs be quantified to reflect the total costs of designing PSSs?**

(4) Flexibility – **Insight 4: In order to offer PSSs, the provider could adopt temporary teams during different stages of design and delivery and improve flexibility as needed by an external customer.** In Section 4.3.4, the focus of engineering design research on internal efficiency was contrasted with that of marketing on organizational capabilities. In particular, Tuli *et al.* (2007) in marketing describe contingent hierarchies as a way in which providers can adopt flexible hierarchical structures to provide solutions depending on varying customer need. Fischer *et al.* (2010) suggest that service literature has usually focused on operational capabilities regarding services, namely, service orientation in corporate culture, human resource management, organizational structure, service development, IT infrastructure and measurement and reward systems. The authors suggest however a framework to address the necessary dynamic capabilities to change operational routines. Reim *et al.* (2015) suggest that result-oriented business models for PSSs are highly flexible and with high

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

degree of customization. The current literature in engineering design seldom exploits these insights from marketing. Applying these insights has therefore potential to provide a new perspective to solving problems with PSS design identified in Engineering Design literature (e.g., Matschewsky *et al.* 2017). Interestingly, the research by Tuli *et al.* (2007) is followed by Batista *et al.* (2016) in industrial engineering, who point out, in outcome-based contracts, that an issue originating from varying customer need lies mainly in an internal variety implying the need of flexibility. Therefore, the need for more research is supported regarding the following research question: **How can companies organize their internal operations effectively to external customer needs yet efficiently to design PSSs?**

(5) Performance Indicators – **Insight 5: Performance indicators for PSS offerings should cover both the efficiency and effectiveness to reflect the impact of the offering on firm value and customer value.** Indicators to evaluate PSS customer satisfaction (Kimita, Shimomura & Arai 2009), a framework criterion to describe the influence of a service to multiple stakeholders (Watanabe *et al.* 2012) and guidelines to measure costs (Colen & Lambrecht 2013) have been described in the literature. More recently, however, Lütjen, Tietze & Schultz (2017) have reported that performance effects of servitization are mixed, with some companies withdrawing from such efforts. Among their case companies studied Lütjen *et al.* (2017) found that firms do not seem to have specific key performances indicators for measuring service innovation at the organizational level or project level. Settanni *et al.* (2017) present a case study from the defense industry showing the use of indicators for technical activities to ensure availability suggesting that manufacturers should also include more qualitative measures, a broader criterion. Among these many criteria or factors to consider, clarity is needed to further develop useful indicators when designing PSSs. This is in contrast to the marketing discipline, where an offering's matching customer need has been researched for a longer time as exemplified by Ulaga & Reinartz (2011) in Section 4.3.6. Therefore: **What indicators need to be taken into account to measure the efficient and effective design of PSSs?**

(6) Requirements – **Insight 6: For a successful PSS offering, both customer and provider may need to make necessary adjustments to their tangible and intangible capabilities in order to specify, communicate and capture value.** Literature in engineering design seems to be richer in this area of research. Several contributions point at different aspects of requirements for successful PSSs. From identifying, understanding and mitigating uncertainties when offering PSSs (Erkoyuncu *et al.* 2010; Erkoyuncu, Durugbo & Roy 2013; Durugbo & Erkoyuncu 2016) to the need of scenario analysis that addresses the needs of different stakeholders (Beuren *et al.* 2013) and the organization of human resources to provide high quality PSSs (Shimomura *et al.* 2013). Coltman & Devinney (2013) provide operational capabilities (customer engagement, cross-functional coordination, creative solutions, operations improvement, IT infrastructure and professional delivery) and show how managers can allocate these capabilities to new or existing business opportunities. A more comprehensive list or guidelines for companies planning or already offering PSSs seem necessary. Hence: **What are the necessary prerequisites for establishing successful customer–provider relationships based on the intended value?**

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 6. Themes, perspectives, insights, research agenda and additional literature

Themes identified across disciplines	Engineering design perspective	Marketing perspective	Insights for engineers and managers that address the design and delivery of PSS	Research question for PSS design	Literature partially addressing the research agenda
(1) Business orientation	It is usually more operational. It follows systematic methods and standardized processes.	It looks at the strategic level and effect on the firm value.	Insight 1: Strategic thinking when designing PSSs can contribute to the competitive advantage of the firm by expanding business opportunities and securing long-term profitability in uncertain business environments.	How can strategic thinking be integrated into tools to design PSSs?	(Meroni 2008) Gebauer *et al.* (2010) Reim *et al.* (2015) Gericke *et al.* (2016)
(2) Collaboration	Often looks at optimal collaboration with other functions.	Considers collaboration with external actors and their corresponding networks.	Insight 2: Organizational configurations for PSSs can range from collaboration with individual customers and their suppliers, to entire networks that can include competitors as part of providing solutions to the customer.	How can collaboration between engineering design and marketing as well as external actors be carried out for efficient and effective design of PSSs?	(Stark *et al.* 2010) (Geum & Park 2011) (Chandrasegaran *et al.* 2013) (Gebauer *et al.* 2016) (Clegg *et al.* 2017) (Pagoropoulos *et al.* 2017)

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 6. (continued)

(3) Cost aspects	Costs are quantifiable and tend to be about materials or energy use.	Can take into account hidden or unquantifiable costs when transitioning to providing services such as internal structure of the firm, internal operating processes and labor and cultural factors inside the company.	Insight 3: When offering PSSs, *hidden costs* may arise in the form of resistance to change, re-training and investment when creating relational rather than transactional relationships.	How can soft and hard costs be quantified to reflect the total costs of designing PSSs?	(Erkoyuncu *et al.* 2010) (Datta & Roy 2010) (Lindahl *et al.* 2014) Settanni *et al.* (2014) (Kreye *et al.* 2014)
(4) Flexibility	Refers to the modularity of design and its adaptation to customer needs.	Refers to organizational capabilities (labor skills) of the firm to either form temporary projects or cooperation with other suppliers according to customer needs.	Insight 4: In order to offer PSSs, the provider could adopt temporary teams during different stages of design and improve flexibility as required by customers.	How can companies organize their internal operations effectively to external customer needs yet efficiently to design PSSs?	(Tuli *et al.* 2007) (Fischer *et al.* 2010) (Reim *et al.* 2015) (Reim *et al.* 2015) (Batista *et al.* 2016)
(5) Performance indicators	Takes into account the efficient use of energy and materials.	Looks at productivity as the effect of the offerings on different stakeholders.	Insight 5: Performance indicators for PSS offerings should cover both the efficiency and effectiveness to reflect the impact of the offering on firm value and customer.	What indicators need to be taken into account to measure the efficient and effective design of PSSs?	(Kimita *et al.* 2009) (Watanabe *et al.* 2012) (Colen & Lambrecht 2013) (Lütjen *et al.* 2017) (Settanni *et al.* 2017)

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 6. (continued)

(6) Requirements	Looks at functional and technical requirements.	Can look at recognized and unrecognized customer needs.	Insight 6: For a successful PSS offering, both customer and provider may need to make necessary adjustments to their tangible and intangible capabilities in order to specify, communicate and capture value.	What are the necessary prerequisites for establishing successful customer–provider relationships based on the intended value?	(Erkoyuncu *et al.* 2010) (Erkoyuncu *et al.* 2013) (Durugbo & Erkoyuncu 2016) (Anttonen 2010) (Beuren *et al.* 2013) (Shimomura *et al.* 2013) (Coltman & Devinney 2013)
(7) Services	These are often add-ons to the product and more traditional services.	Wide range of services which are more sophisticated.	Insight 7: Engineering design can rely on the marketing discipline for guidelines, frameworks and tools on how to successfully provide services and solutions.	How can service offerings be incorporated in the early stages of PSS design and be marketed successfully?	(Aurich, Mannweiler & Schweitzer 2010) (Cherubini, Iasevoli & Michelini 2015) (Ostrom *et al.* 2015) (Chen *et al.* 2016)

(7) Services – **Insight 7: Engineering design can rely on the marketing discipline for guidelines, frameworks and tools on how to offer services successfully.** Research in ED suggests that systematizing the design of services contributes to their successful offering (Aurich *et al.* 2010). Moreover, Cherubini *et al.* (2015) identify critical success factors in marketing when designing PSSs in the electric car industry while Ostrom *et al.* (2015) identify research priorities for service research through an extensive study. Moreover, Chen *et al.* (2016) address successful service commercialization and service innovation as an intangible resource. As it has been proposed before, service research seems a more developed area of research in marketing than in engineering design and many lessons can be learned. In this regard, the following question is proposed: **How can service offerings be incorporated in the early stages of PSS design and be marketed successfully?**

5. Concluding remarks

This research shows quantitative evidence that there are few insights in terms of the number of citations and their level of utilization across engineering design and marketing. This means that so far, there has been little impact across the two selected domains. The results are in line with those found in previous research, which show that the interaction between disciplines is generally low. This means that there can be many potentially fruitful linkages which have not yet been fully explored and exploited. Scientific value of the paper also exists in the new method of applying levels of utilization that enables a more quantified and deeper analysis of interdependencies than in earlier research. The method is generic and therefore applicable to analysis of other interdisciplinary endeavors. The practical value can be seen in the implications for engineering design and the insights for practitioners planning or currently involved in offering PSSs.

With regard to the first research question, namely to what extent insights coming from the marketing discipline have been used in the engineering design discipline and vice versa, the results show that the levels of utilization for engineering design citing marketing insights are mainly concentrated at Level 1, only citing, and to a lesser degree make use of Level 2, taking into account insight from the opposite discipline. This means that most citations do not integrate insights into models, frameworks or theories; the number of Level 3 citations found in few instances reflects this. With regard to marketing making use of engineering design, the analysis shows that this is difficult to find too, as most citations remain at Levels 1 and 2. These results are found useful to differentiate the extents of utilizing insights from published literature. Semi-quantifying these extents has not been carried out in an existing review article to the authors' knowledge. Thus, a different process for the quantification may be tested in the future and compared with the method adopted in this article for further development.

The importance of engineering design and marketing when designing PSSs suggests that there is a need for bridging the gap between these two disciplines. While each discipline would certainly continue disciplinary work to advance and provide further insights, the design of PSSs does require interdisciplinary work, as noted by experts in the field and reviewed in this article.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

The results for the second research question addressed this. The implications are provided in the form of themes for more effective and efficient design of PSSs: business orientation, collaboration, cost aspects, flexibility, indicators, requirements and services. These themes provide insights for academics and practitioners aimed at providing clearer guidance into PSS implementation in industry. The value of the insights derived in this article originates in the novel approach adopted for the literature review (depicted in Figure 1) for this article. The themes can also provide opportunities to further advance the understanding of how to effectively and efficiently design PSSs.

Future research could involve the corroboration and expansion of the themes found in this research. It can also expand the findings into what marketing can learn from engineering design. Interdisciplinary research into other relevant disciplines such as operations management and information systems could enhance the overall understanding of different views, theories, tools and methods.

Acknowledgments

This research was supported by the Mistra REES (Resource Efficient and Effective Solutions) program (No. 2014/16), funded by Mistra (The Swedish Foundation for Strategic Environmental Research). An earlier and shorter version of this paper was presented at the International Design Conference in Dubrovnik, Croatia in 2016 with the title 'Interdisciplinary Insights Found for Product/Service System Design'.

Appendix A

Key search for engineering design:
(TS=("product service system") OR TS=(product-service system) OR TS=(product/service system) OR TS=("product service systems") OR TS=(product-service systems) OR TS=(product/service systems) OR TS=("functional *product*") OR TS=("integrated *solution*") OR TS=("hybrid *offering*" AND "manufacturing") OR TS=("industrial *service*") OR TS=("system *solution*" AND "manufacturing") OR TS=("customer *solution*") OR TS=("marketing *solution*") OR TS=("after-sales service" AND "manufacturing") OR TS=("servitization") OR TS=("service infusion") OR TS=("service engineering") OR TS=("service transition" AND "manufacturing") OR TS=("service *strateg*" AND "manufacturing") OR TS=(solution? provider?)) AND (((SO=(cirp annals manufacturing technology) OR SO=(computer-aided design) OR SO=(computers in industry) OR SO=(design studies) OR SO=(AI-EDAM) OR SO=(journal of cleaner production) OR SO=(journal of engineering design) OR SO=(advanced engineering informatics) OR SO=(research in engineering design) OR SO=(proceedings of the Institution of Mechanical Engineers part b-journal of engineering manufacture)))).

Key search for marketing:
(TS=("product service system") OR TS=(product-service system) OR TS=(product/service system) OR TS=("product service systems") OR TS=(product-service systems) OR TS=(product/service systems) OR TS=("functional *product*") OR TS=("integrated *solution*") OR TS=("hybrid *offering*"

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

AND "manufacturing") OR TS=("industrial *service*") OR TS=("system *solution*" AND "manufacturing") OR TS=("customer *solution*") OR TS=("marketing *solution*") OR TS=("after-sales service" AND "manufacturing") OR TS=("servitization") OR TS=("service infusion") OR TS=("service engineering") OR TS=("service transition" AND "manufacturing") OR TS=("service *strateg*" AND "manufacturing") OR TS=(solution? provider?)) AND ((SO=(european journal of marketing) OR SO=(industrial marketing management) OR SO=(international journal of research in marketing) OR SO=(journal of business research) OR SO=(journal of business-to-business marketing) OR SO=(journal of marketing) OR SO=(journal of marketing research) OR SO=(journal of service management) OR SO=(international journal of service industry management) OR SO=(journal of service research) OR SO=(journal of the academy of marketing science) OR SO=(journal of service theory and practice) OR SO=(managing service quality))).

Appendix B

Selected journals in engineering design (ED): CIRP Annals – Manufacturing Technology, Computer-Aided Design, Computers in Industry, Design Studies, International Journal of Advanced Manufacturing Technology, International Journal of Computer Integrated Manufacturing, International Journal of Operations and Production Management, International Journal of Production Research, Journal of Cleaner Production, Journal of Engineering Design, Journal of Operations Management, and Research in Engineering Design, Proceedings of the Institution of Mechanical Engineers Part B-journal of Engineering Manufacture.

Selected journals in marketing (M): European Journal of Marketing, Industrial Marketing Management, International Journal of Research in Marketing, Journal of Business and Industrial Marketing, Journal of Business Research, Journal of Business-to-Business Marketing, Journal of International Marketing, Journal of Marketing, Journal of Marketing Research, Journal of Product Innovation Management, Journal of Service Management (formerly International Journal of Service Industry Management), Journal of Service Research, Journal of Services Marketing, Journal of the Academy of Marketing Science, Journal of Service Theory and Practice (formerly Managing Service Quality: An International Journal), Marketing Letters, Marketing Science and Marketing Theory)

Appendix C

See Tables 7 and 8.

Appendix D

See Tables 9 and 10.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 7. Selected articles in engineering design

Article attributes					Characteristics of study*			
Rank from 194 articles	ID	Author(s)	Year	Title	Industry	Objective of study	Method	Country or Region where study was carried out or applied to
5	E1	Aurich *et al.*	2006	Life cycle oriented design of technical Product-Service Systems	Investment goods (heavy road construction machines)	To introduce a process for the systematic design of product-related technical services for linkage with corresponding product design processes	Single case study	Not specified, application for worldwide operations
6	E2	Maxwell & Van der Vorst	2003	Developing sustainable products and services	Examples of the ESP initiative are electronic automotive components and personal computers	To present the Sustainable Product and Service Development (SPSD) method for sustainable product development and service development	Review of the Environmental Superior Products (ESP) initiative in Ireland to develop a method in conjunction with industry and practitioners	UK

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 7. (continued)

7	E3	Manzini & Vezzoli	2003	A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize	Textile flooring service Lubricants for machines and components Detergents and cosmetics Gas and lighting	To present the concept of strategic design for sustainable PSS innovation	Review of examples from the 'environmentally friendly innovation' Italian prize and method development	Italy
10	E4	Alonso-Rasgado *et al.*	2004	The design of functional (total care) products	Example of hardware design and remanufacturing	To present a method for the design of functional products, and in particular design of services in the context of Total Care Products	Review of the literature in design, specially service design for Total Care Products	Non-stated
14	E5	Cook *et al.*	2006	The transfer and application of Product Service Systems: from academia to UK manufacturing firms	Manufacturing	To develop a framework to help UK-based intermediaries complete the transfer of the PSS concept	Pilot study with 20 firms, semi-structured interview and focus groups	UK

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 7. (continued)

17	E6	Maussang *et al.*	2009	Product-service system design methodology: from the PSS architecture design to the products' specifications	Superconductors	To provide engineering designers with technical engineering specifications in relation to the whole system's requirements as precise as possible through a proposed method	Development of method through review of literature and authors' insights and a case example	US
52	E7	Stoughton & Votta	2003	Implementing service-based chemical procurement: lessons and results	Chemicals	To present lessons learned from business cases regarding Chemical Management Services (CMS)	Synthesizes lessons learned from hands-on work with 15 chemical-using firms over 5 years	US

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 7. (continued)

82	E8	Baines *et al.*	2010	The adoption of servitization strategies by UK-based manufacturers	Manufacturing	To explore the extent, motivations, challenges and successes of servitization within the B2B sector	Survey	UK
109	E9	Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ	Capital goods	To contribute to the discussion about the delivery of integrated solutions in the capital goods industry	In-depth case study of printing company Océ	Italy Netherlands

*Note: Characteristics of the study were mostly inferred since some articles do not specify all categories in this table.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 8. Selected articles in marketing

Article attributes					Characteristics of study*			
Rank from 177 articles	#M	Author(s)	Year	Title	Industry	Objective of study	Method	Country or Region where study was carried out or applied to
1	M1	Oliva & Kallenberg	2003	Managing the transition from products to services	Capital equipment (machine manufacturing)	To identify the dimensions considered when creating a service organization in the context of a manufacturing firm, and successful strategies to navigate the transition	Study of 11 capital equipment manufacturers developing service offerings for their products	Germany
3	M2	Tuli *et al.*	2007	Rethinking customer solutions: From product bundles to relational processes	Information technology Healthcare Real estate Financial services Others	First objective: to compare and contrast the extant view in the literature with that of suppliers and customers of solutions and to identify their implications for suppliers Second objective: to develop insights into the variables that affect a supplier's ability to provide effective solutions to organizational customers	In-depth interviews with 49 managers in customer firms and 55 managers in supplier firms and on discussions with 21 managers in two focus groups	Database from US

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 8. (continued)

5	M3	Mathieu	2001	Service strategies within the manufacturing sector: benefits, costs and partnership	Manufacturing	To present a typology for service maneuvers	Literature review and business examples	Business cases, mainly from European operations
6	M4	(Er) Fang *et al.*	2008	Effect of service transition strategies on firm value	Manufacturing	To investigate the effectiveness of service transition strategies for generating shareholder value	Hypothesis testing by evaluating secondary data from 477 publicly traded manufacturing firms during 1990–2005	US
7	M5	Ulaga & Reinartz	2011	Hybrid Offerings: How Manufacturing Firms Combine Goods and Services Successfully	Industrial gas Material handling equipment	To examine key success factors for the design and delivery of combinations of goods and services	2 pilot case studies and in-depth interviews	Europe
9	M6	Cova & Salle	2008	Marketing solutions in accordance with the S-D logic: Co-creating value with customer network actors	Electrical distribution and industrial control Defense	To apply the conceptual framework of S-D logic to offering strategies with greater precision	2 case studies	France Australia

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 8. (continued)

15	M7	Gebauer & Heiko	2008	Identifying service strategies in product manufacturing companies by exploring environment-strategy configurations	Manufacturing	To identify service strategies that correspond with specific environment–strategy fits	Exploratory factor and cluster analysis	Western Europe
19	M8	Kindstrom & Kowalkowski	2009	Development of industrial service offerings: a process framework	Manufacturing	To propose a service development process and to discuss its implications	Ten exploratory case studies	Sweden
23	M9	Penttinen & Palmer	2007	Improving firm positioning through enhanced offerings and buyer–seller relationships	Elevator manufacturing Bearing manufacturing Oil spill cleaning	To bring together two research streams on the completeness of an offering and the nature of a relationship to formulate a theoretical framework for analyzing company positioning	Four case studies	US Finland Sweden

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 8. (continued)

25	M10	Windahl & Lakemond	2010	Integrated solutions from a service-centered perspective Applicability and limitations in the capital goods industry	Capital goods	To explore relational consequences of integrated solutions	Three case studies	Sweden
38	M11	Bezerra *et al.*	2013	Employing the business model concept to support the adoption of product-service systems (PSS)	Tooling machine manufacturing	To propose a framework based on the Canvas business model and to define actions to implement it	Single case study	Brazil

*Note: Characteristics of the study were mostly inferred since some articles do not specify all categories in this table.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 9. Articles in marketing citing engineering design

Rank out of 194	ED article	Cited in Marketing by				Levels of insight			Themes
		Author	Year	Title	Journal	L1	L2	L3	Empty cells mean no insight was found
5	Aurich *et al.* (2006)	Rabetino *et al.*	2015	Developing the concept of life-cycle service offering	Industrial Marketing Management	1	1	0	Collaboration (Terms included in long-term agreements are key tools for aligning parties' divergent incentives) p. 57.
		Nudurupati *et al.*	2016	Eight challenges of servitisation for the configuration, measurement and management of organizations	Journal of Service Theory and Practice	1	1	0	Flexibility (A process of modularization to enable organizations to create a portfolio of elementary building blocks for the product and service design process has been proposed) p. 751–752.
6	Maxwell & Van der Vorst (2003)	Chan *et al.*	2012	Green marketing and its impact on supply chain management in industrial markets	Industrial Marketing Management	1	0	0	
		Raja *et al.*	2013	Achieving Customer Satisfaction through Integrated Products and Services: An Exploratory Study	Journal of Product Innovation Management	1	1	0	Performance indicators (product design should consider the whole lifecycle of product usage.) p. 1131.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 9. (continued)

		Baraldi *et al.*	2011	Network evolution and the embedding of complex technical solutions: The case of the Leaf House network	Industrial Marketing Management	1	0	0	
		Rabetino *et al.*	2015	Developing the concept of life-cycle service offering	Industrial Marketing Management	1	1	0	Costs, Performance indicators (life cycle stages: 1) Function/product conception, 2) raw materials, 3) production process, 4) distribution, 5) consumption and 6) end-of-life (reuse/recycling/energy recovery/treatment/ disposal) p. 55.
		Lacoste	2016	Sustainable value co-creation in business networks	Industrial Marketing Management	1	1	1	Performance indicators (Product life cycle in BtoB, Figures 2 and 3) p. 152 and 153.
7	Manzini & Vezzoli (2003)	Barquet *et al.*	2013	Employing the business model concept to support the adoption of product-service systems (PSS)	Industrial Marketing Management	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 9. (continued)

	Ng & Nudurupati	2010	Outcome-based service contracts in the defence industry - mitigating the challenges	Journal of Service Management	1	0	0	
	Raja *et al.*	2013	Achieving Customer Satisfaction through Integrated Products and Services: An Exploratory Study	Journal of Product Innovation Management	1	0	0	
	Rabetino *et al.*	2015	Developing the concept of life-cycle service offering	Industrial Marketing Management	1	0	0	
	Nudurupati *et al.*	2016	Eight challenges of servitisation for the configuration, measurement and management of organizations	Journal of Service Theory and Practice	1	1	0	Performance indicators (Whether the value to the customer is delivered through products or services . . . the value chain should be viewed including its impact on the environment) p. 746.
	Kuijken *et al.*	2016	Effective product-service systems: A value-based framework	Industrial Marketing Management	1	0	0	
	Gebauer *et al.*	2017	Competing in business-to-business. . .	Journal of Service Management	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 9. (continued)

10	Alonso-Rasgado *et al.* (2004)	Barquet *et al.*	2013	Employing the business model concept to support the adoption of product-service systems (PSS)	Industrial Marketing Management	1	0	0	
		Hypko *et al.*	2010	Clarifying the concept of performance-based contracting in manufacturing industries A research synthesis	Journal of Service Management	1	1	0	Collaboration, (Table 1) p. 631. Costs (the customer as one party of the long-term business-to-business contractual relationship) p. 637.
		Hypko *et al.*	2010	Benefits and uncertainties of performance-based contracting in manufacturing industries An agency theory perspective	Journal of Service Management	1	0	0	
		Rabetino *et al.*	2015	Developing the concept of life-cycle service offering	Industrial Marketing Management	1	0	0	
14	Cook *et al.* (2006)	Barquet *et al.*	2013	Employing the business model concept to support the adoption of product-service systems (PSS)	Industrial Marketing Management	1	1	0	Business Orientation (a fundamental shift is also required in the organizational culture and market engagement, which necessitates time and resources) p. 697.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 9. (continued)

	Luoto *et al.*	2017	Critical meta-analysis of servitization research: Constructing a model-narrative to reveal paradigmatic assumptions	Industrial Marketing Management	1	1	0	Collaboration (create key partnerships and alliances with technology and service suppliers) Flexibility (create a customer-centric organization structure and units) p. 94.
	Benedettini *et al.*	2017	Examining the influence of service additions on manufacturing firms' bankruptcy likelihood	Industrial Marketing Management	1	0	0	
	Nudurupati *et al.*	2016	Eight challenges of servitisation for the configuration, measurement and management of organizations	Journal of Service Theory and Practice	1	1	0	Costs, Business Orientation (the customer purchases 'utility' as an outcome instead of the 'function' of the product and typically, under the result-oriented PSS, there is no predetermined product involved) p. 750.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 9. (continued)

17	Maussang *et al.* (2009)	Rabetino *et al.*	2015	Developing the concept of life-cycle service offering	Industrial Marketing Management	1	0	0
		Glas & Kleemann	2017	Performance-based contracting: contextual factors and the degree of buyer supplier integration	Journal of Business and Industrial Marketing	1	0	0
52	Stoughton & Votta (2003)	Kowalkowski *et al.*	2013	Any way goes: Identifying value constellations for service infusion in SMEs	Industrial Marketing Management	1	0	0
		Spring & Araujo	2017	Product biographies in servitization and the circular economy	Journal of Business and Industrial Marketing	1	0	0
82	Baines *et al.* (2010)	Brax & Visintin	2017	Meta-model of servitization: The integrative profiling approach	Industrial Marketing Management	1	0	0
		Neto *et al.*	2015	What problems manufacturing companies can face when providing services around the world?	Industrial Marketing Management	1	0	0

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 9. (continued)

109	Visintin (2012)	Brax & Visintin	2017	Meta-model of servitization: The integrative profiling approach	Industrial Marketing Management	1	1	0	Flexibility (Whilst marketing models have a tendency to start from the customer require-ments, solutions are created by integrating and customizing common subsystems, modules and components . . .) p. 22. Requirements (In complex cases, a further technical analysis precede solution design because customer's other systems set boundary conditions and requirements for the new system and its infrastructure and implementation) p.23. Other L2's exist in this paper.
		Salminen *et al.*	2014	Managerial implications in solution business studies: analysis of type of relevance addressed	Journal of Business and Industrial Marketing	1	0	0	
					Total	30	11	1	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. Engineering design citing marketing

Rank out of 177	Marketing	Cited in Engineering Design by				Levels of insight			Themes
	M article	Author	Year	Title	Journal	L1	L2	L3	Empty cells mean no insight was found
1	Oliva & Kallenberg (2003)	Beuren *et al.*	2013	Product-service systems: a literature review on integrated products and services	Journal of Cleaner Production	1	0	0	
		Cavalieri & Pezzotta	2012	Product-Service Systems Engineering: State of the art and research challenges	Computers in Industry	1	0	0	
		Isaksson *et al.*	2009	Development of product-service systems: challenges and opportunities for the manufacturing firm	Journal of Engineering Design	1	0	0	
		Sakao *et al.*	2009	Modeling design objects in CAD system for Service/Product Engineering	Computer-Aided Design	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

	Boehm & Thomas	2013	Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design	Journal of Cleaner Production	1	0	0
	Erkoyuncu *et al.*	2010	Understanding service uncertainties in industrial product-service system cost estimation	International Journal of Advanced Manufacturing Technology	1	0	0
	Amini & Bienstock	2014	Corporate sustainability: an integrative definition and framework to evaluate corporate practice and guide academic research	Journal of Cleaner Production	1	0	0

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

	Gaiardelli *et al.*	2014	A classification model for product-service offerings	Journal of Cleaner Production	1	1	0	Business orientation, Flexibility (categorizing the ways in which firms may position themselves during the transition from selling products to selling services) p. 509.
	Baines *et al.*	2009	Servitized manufacture: practical challenges of delivering integrated products and services	Proceedings of the Institution of Mechanical Engineers Part-B Journal of Engineering Manufacture	1	0	0	
	Ball *et al.*	2008	An approach to accessing product data across system and software revisions	Advanced Engineering Informatics	1	0	0	
	Greenough & Grubic	2011	Modelling condition-based maintenance to deliver a service to machine tool users	International Journal of Advanced Manufacturing Technology	1	1	0	Costs (condition monitoring per se does not add any value to the end-user, but it is only when this technology leads to higher equipment availability (for which the customer will pay) that its value can be made tangible) p. 1119.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

	Lee & Abuali	2011	Innovative Product Advanced Service Systems (I-PASS): methodology, tools, and applications for dominant service design	International Journal of Advanced Manufacturing Technology	1	1	0	Business orientation (The transition from product to service requires a change in focus in terms of changing both the customer focus and the value proposition) p. 1162.
	Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ	Computers in Industry	1	0	0	
	Annarelli *et al.*	2016	Product service system: A conceptual framework from a systematic review	Journal of Cleaner Production	1	0	0	
	Lingegård & Lindahl	2015	Integrated Product Service Offerings for rail infrastructure - benefits and challenges regarding knowledge transfer and cultural change in a Swedish case	Journal of Cleaner Production	1	1	0	Requirements (to become a service provider, considerable changes have to be made within the organization, capabilities and management of the firm) p. 167. Costs (the IPSO also reduces unpredictability and variability of demand during the contract time, which makes risk reduction a driver for the business model) p. 169.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

	Conway & Ion	2013	Enhancing the design dialogue: an architecture to document engineering design activities	Journal of Engineering Design	1	0	0
	Gonzalez-Prida & Crespo Marquez	2012	A framework for warranty management in industrial assets	Computers in Industry	1	0	0
	Ceschin & Gaziulusoy	2016	Evolution of design for sustainability: From product design to design for system innovations. . .	Design Studies	1	0	0
	di Tollo *et al.*	2015	Using online textual data, principal component analysis and artificial neural networks to study business and innovation practices in technology-driven firms	Computers in Industry	1	0	0

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

		Zheng *et al.*	2017	An integrated modular design methodology based on maintenance performance consideration	Proceedings of the Institution of Mechanical Engineers Part-B Journal of Engineering Manufacture	1	0	0	
		Pereira *et al.*	2017	Barriers to shifting to a servicized model of crop protection in smallholding viticulture	Journal of Cleaner Production	1	1	1	Requirements (Potential barriers Table 1. Lack of trust concerning the economic potential of the service. Lack of competence in service provision) p. 703.
		Päivärinne & Lindahl	2016	Combining Integrated Product and Service Offerings with Industrial Symbiosis - a study of opportunities and challenges	Journal of Cleaner Production	1	0	0	
3	Tuli *et al.* (2007)	Reim *et al.*	2015	Product-Service Systems (PSS) business models and tactics - a systematic literature review	Journal of Cleaner Production	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

	Boehm & Thomas	2013	Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information. . .	Journal of Cleaner Production	1	0	0	
	Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ	Computers in Industry	1	0	0	
	Pagoropoulos *et al.*	2017	Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: Learnings from the maritime industry	Journal of Cleaner Production	1	1	0	Costs (implementation of integrated products and services can only be successful because both suppliers and customers deploy them, not just because a supplier offers them) p. 371. Collaboration and Costs (This close cooperation is, in many cases, necessary in order to successfully navigate the political and operational difficulties within customer organization) p. 372.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

5	Mathieu (2001)	Tukker	2015	Product services for a resource-efficient and circular economy - a review	Journal of Cleaner Production	1	0	0	
		Cavalieri & Pezzotta	2012	Product-Service Systems Engineering: State of the art and research challenges	Computers in Industry	1	0	0	
		Gaiardelli *et al.*	2014	A classification model for product-service offerings	Journal of Cleaner Production	1	1	1	Services (services include i) services supporting the product and ii) services supporting the actions of the customer) p. 508. Collaboration and Services (intensity of the relationship (the involvement and commitment of both the customer and the PS provider) and service customization increase, the focus changes from the product to the process. The types and characteristics of the focus of the PS offering are shown in Table 3.) p. 510–511.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

		Gaiardelli *et al.*	2007	Performance measurement of the after-sales service network - Evidence from the automotive industry	Computers in Industry	1	1	0	Performance indicators (The after-sales strategy literature surprisingly neglects the area of performance measurement) p. 700.
		Baines *et al.*	2009	Servitized manufacture: practical challenges of delivering integrated products and services	Proceedings of the Institution of Mechanical Engineers Part-B Journal of Engineering Manufacture	1	1	1	Services (services supporting the product (SSP) and services supporting the customer (SSC) Figure 2) p. 13.
6	Fang *et al.* (2008)	Boehm & Thomas	2013	Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design	Journal of Cleaner Production	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

		Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ	Computers in Industry	1	1	0	Costs (despite the opportunities it can offer, venturing into the integrated-solutions business is risky and can be detrimental to a company's financial performance) p. 379.
5		Pagoropoulos *et al.*	2017	Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: Learnings from the maritime industry	Journal of Cleaner Production	1	0	0	
7	Ulaga & Reinartz (2011)	Reim *et al.*	2015	Product-Service Systems (PSS) business models and tactics - a systematic literature review	Journal of Cleaner Production	1	1	1	Business orientation (Tables 7 and 9) p. 67 and 69.
		Lindahl *et al.*	2014	Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases	Journal of Cleaner Production	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

		Pagoropoulos *et al.*	2017	Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: Learnings from the maritime industry	Journal of Cleaner Production	1	1	0	Collaboration, Costs (customer process data can enable suppliers to design and sell value-added services that assist customers in gaining productivity improvements and cost reductions in their own operations) p. 371.
9	Cova & Salle (2008)	Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ	Computers in Industry	1	0	0	
		Bititci *et al.*	2010	High value manufacturing: a case study in transformation	Proceedings of the Institution of Mechanical Engineers Part-B Journal of Engineering Manufacture	1	0	0	
15	Gebauer (2008)	Ueda *et al.*	2015	Value creation and decision-making in sustainable society	CIRP Annals-Manufacturing Technology	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

		di Tollo *et al.*	2017	Using online textual data, principal component analysis and artificial neural networks to study business and innovation practices in technology-driven firms	Computers in Industry	1	0	0	
19	Kindström & Kowalkowski (2009)	Song & Sakao	2017	A customization-oriented framework for design of sustainable product/service system	Journal of Cleaner Production	1	1	1	Flexibility (lack of a systematic and comprehensive support for PSS customization. . . Comparison of frameworks Table 11) p. 1683.
		Xu *et al.*	2014	Towards a new framework: Understanding and managing the supply chain for product-service systems	Proceedings of the Institution of Mechanical Engineers Part-B Journal of Engineering Manufacture	1	1	1	Collaboration (The customer is no longer regarded as a passive transaction-oriented actor but rather an active relationship-oriented actor with a long-term perspective in the interaction) p. 7.
23	Penttinen & Palmer (2007)	Gaiardelli *et al.*	2014	A classification model for product-service offerings	Journal of Cleaner Production	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

		Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ	Computers in Industry	1	0	0	
25	Windhal & Lakemond (2010)	Gaiardelli *et al.*	2014	A classification model for product-service offerings	Journal of Cleaner Production	1	1	1	Collaboration (dimensions of PSS offerings Table 1) p. 509.
		Visintin	2012	Providing integrated solutions in the professional printing industry: The case of Océ	Computers in Industry	1	1	0	Business orientation (companies in the capital-goods industry need to manage an integrated solution business alongside an established business made of goods and support services, 'which is often still important and profitable') p. 381.
38	Bezerra *et al.* (2013)	Qu *et al.*	2016	State-of-the-art of design, evaluation, and operation methodologies in product service systems	Computers in Industry	1	0	0	

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Table 10. (continued)

	Annarelli *et al.*	2016	Product service system: A conceptual framework from a systematic review	Journal of Cleaner Production	1	1	0	Requirements (other important barriers are 'Lack of technological info and know-how', 'Lack of experience in service design' and 'Lack of skilled personnel in service development') p. 109.
	Corvellec & Stal	2017	Evidencing the waste effect of Product-Service Systems (PSSs)	Journal of Cleaner Production	1	0	0	
					50	17	7	

References

ABET, 2016 Criteria for Accrediting Engineering Programs, 2016 – 2017. Retrieved April 2017 from http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/.

Alonso-Rasgado, T., **Thompson, G.** & **Elfström, B.-O.** 2004 The design of functional (total care) products. *Journal of Engineering Design* **15** (6), 515–540.

AMA, 2016 Definition of Marketing. Retrieved April 2017 from https://www.ama.org/AboutAMA/Pages/Definition-of-Marketing.aspx.

Andreasen, M. M. 2011 45 Years with design methodology. *Journal of Engineering Design* **22** (5), 293–332.

Andreasen, M. & **Hein, L.** 2000 *Integrated Product Development*, 2nd edn. IPU.

Annarelli, A., **Battistella, C.** & **Nonino, F.** 2016 Product service system: a conceptual framework from a systematic review. *Journal of Cleaner Production* **139**, 1011–1032.

Anttonen, M. 2010 Greening from the front to the back door? A typology of chemical and resource management services. *Business Strategy and the Environment* **19** (3), 199–215.

Aurich, J. C., **Fuchs, C.** & **Wagenknecht, C.** 2006 Life cycle oriented design of technical Product-Service Systems. *Journal of Cleaner Production* **14** (17), 1480–1494.

Aurich, J., **Mannweiler, C.** & **Schweitzer, E.** 2010 How to design and offer services successfully. *CIRP Journal of Manufacturing Science and Technology* **2** (3), 136–143.

Baines, T. & **Lightfoot, H. W.** 2014 Servitization of the manufacturing firm Exploring the operations practices and technologies that deliver advanced services. *International Journal of Operations & Production Management* **34** (1), 2–35.

Baines, T., **Lightfoot, H.**, **Benedettini, O.**, **Whitney, D.** & **Kay, J. M.** 2010 The adoption of servitization strategies by UK-based manufacturers. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* **224** (5), 815–829.

Baines, T., **Ziaee Bigdeli, A.**, **Bustinza, O. F.**, **Shi, V. G.**, **Baldwin, J.** & **Ridgway, K.** 2017 Servitization: revisiting the state-of-the-art and research priorities. *International Journal of Operations & Production Management* **37** (2), 256–278.

Baraldi, E., **Gregori, G. L.** & **Perna, A.** 2011 Network evolution and the embedding of complex technical solutions: the case of the Leaf House network. *Industrial Marketing Management* **40** (6), 838–852.

Barquet, A. P. B., **de Oliveira, M. G.**, **Amigo, C. R.**, **Cunha, V. P.** & **Rozenfeld, H.** 2013 Employing the business model concept to support the adoption of product–service systems (PSS). *Industrial Marketing Management* **42** (5), 693–704.

Bask, A., **Lipponen, M.**, **Rajahonka, M.** & **Tinnilä, M.** 2011 Framework for modularity and customization: service perspective. *Journal of Business & Industrial Marketing* **26** (5), 306–319.

Bastl, M., **Johnson, M.**, **Lightfoot, H.** & **Evans, S.** 2012 Buyer–supplier relationships in a servitized environment: an examination with Cannon and Perreault's framework. *International Journal of Operations & Production Management* **32** (6), 650–675.

Batista, L., **Davis-Poynter, S.**, **Ng, I.** & **Maull, R.** 2016 Servitization through outcome-based contract–A systems perspective from the defence industry. *International Journal of Production Economics* **192**, 133–143.

Beuren, F. H., **Ferreira, M. G. G.** & **Miguel, P. A. C.** 2013 Product-service systems: a literature review on integrated products and services. *Journal of Cleaner Production* **47**, 222–231.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Biege, S., **Lay, G.** & **Buschak, D.** 2012 Mapping service processes in manufacturing companies: industrial service blueprinting. *International Journal of Operations & Production Management* **32** (8), 932–957.

Boehm, M. & **Thomas, O.** 2013 Looking beyond the rim of one's teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design. *Journal of Cleaner Production* **51**, 245–260.

Braun, V. & **Clarke, V.** 2006 Using thematic analysis in psychology. *Qualitative Research in Psychology* **3** (2), 77–101.

Brown, R. R., **Deletic, A.** & **Wong, T. H.** 2015 Interdisciplinarity: How to catalyse collaboration. *Nature* **525** (7569), 315–317.

Cavalieri, S. & **Pezzotta, G.** 2012 Product–service systems engineering: state of the art and research challenges. *Computers in Industry* **63** (4), 278–288.

Chan, H. K., **He, H.** & **Wang, W. Y.** 2012 Green marketing and its impact on supply chain management in industrial markets. *Industrial Marketing Management* **41** (4), 557–562.

Chandrasegaran, S. K., **Ramani, K.**, **Sriram, R. D.**, **Horváth, I.**, **Bernard, A.**, **Harik, R. F.** & **Gao, W.** 2013 The evolution, challenges, and future of knowledge representation in product design systems. *Computer-Aided Design* **45** (2), 204–228.

Chen, K.-H., **Wang, C.-H.**, **Huang, S.-Z.** & **Shen, G. C.** 2016 Service innovation and new product performance: The influence of market-linking capabilities and market turbulence. *International Journal of Production Economics* **172**, 54–64.

Chen, W., **Hoyle, C.** & **Wassenaar, H. J.** 2012 *Decision-based Design: Integrating Consumer Preferences into Engineering Design*. Springer Science & Business Media.

Cherubini, S., **Iasevoli, G.** & **Michelini, L.** 2015 Product-service systems in the electric car industry: critical success factors in marketing. *Journal of Cleaner Production* **97**, 40–49.

Chesbrough, H. & **Spohrer, J.** 2006 A research manifesto for services science. *Communications of the ACM* **49** (7), 35–40.

Clegg, B., **Little, P.**, **Govette, S.** & **Logue, J.** 2017 Transformation of a small-to-medium-sized enterprise to a multi-organization product-service solution provider. *International Journal of Production Economics* **192**, 81–91.

Colen, P. & **Lambrecht, M.** 2013 Product service systems: exploring operational practices. *The Service Industries Journal* **33** (5), 501–515.

Coltman, T. & **Devinney, T. M.** 2013 Modeling the operational capabilities for customized and commoditized services. *Journal of Operations Management* **31** (7), 555–566.

Cook, M. B., **Bhamra, T. A.** & **Lemon, M.** 2006 The transfer and application of Product Service Systems: from academia to UK manufacturing firms. *Journal of Cleaner Production* **14** (17), 1455–1465.

Cova, B. & **Salle, R.** 2008 Marketing solutions in accordance with the SD logic: Co-creating value with customer network actors. *Industrial Marketing Management* **37** (3), 270–277.

Dahlander, L. & **Gann, D. M.** 2010 How open is innovation? *Research Policy* **39** (6), 699–709.

Datta, P. P. & **Roy, R.** 2010 Cost modelling techniques for availability type service support contracts: a literature review and empirical study. *CIRP Journal of Manufacturing Science and Technology* **3** (2), 142–157.

Durugbo, C. 2013 Competitive product-service systems: lessons from a multicase study. *International Journal of Production Research* **51** (19), 5671–5682.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Durugbo, C. & **Erkoyuncu, J. A.** 2016 Mitigating uncertainty for industrial service operations: a multi case study. *International Journal of Operations & Production Management* **36** (5), 532–571.

Eisenbart, B., **Gericke, K.** & **Blessing, L. T.** 2017 Taking a look at the utilisation of function models in interdisciplinary design: insights from ten engineering companies. *Research in Engineering Design* **28** (3), 299–331.

Elo, S., **Kääriäinen, M.**, **Kanste, O.**, **Pölkki, T.**, **Utriainen, K.** & **Kyngäs, H.** 2014 Qualitative content analysis. *Sage Open* **4** (1), 2158244014522633.

Erkoyuncu, J. A., **Durugbo, C.** & **Roy, R.** 2013 Identifying uncertainties for industrial service delivery: a systems approach. *International Journal of Production Research* **51** (21), 6295–6315.

Erkoyuncu, J. A., **Roy, R.**, **Shehab, E.** & **Cheruvu, K.** 2010 Understanding service uncertainties in industrial product–service system cost estimation. *The International Journal of Advanced Manufacturing Technology* **52** (9–12), 1223–1238.

Fang, E., **Palmatier, R. W.** & **Steenkamp, J.-B. E.** 2008 Effect of service transition strategies on firm value. *Journal of Marketing* **72** (5), 1–14.

Fischer, T., **Gebauer, H.**, **Gregory, M.**, **Ren, G.** & **Fleisch, E.** 2010 Exploitation or exploration in service business development? Insights from a dynamic capabilities perspective. *Journal of Service Management* **21** (5), 591–624.

Gebauer, H. 2008 Identifying service strategies in product manufacturing companies by exploring environment–strategy configurations. *Industrial Marketing Management* **37** (3), 278–291.

Gebauer, H., **Edvardsson, B.**, **Gustafsson, A.** & **Witell, L.** 2010 Match or mismatch: strategy-structure configurations in the service business of manufacturing companies. *Journal of Service Research* **13** (2), 198–215.

Gebauer, H., **Haldimann, M.** & **Saul, C. J.** 2017 Competing in business-to-business sectors through pay-per-use services. *Journal of Service Management* **28** (5), 914–935.

Gebauer, H., **Saul, C. J.**, **Haldimann, M.** & **Gustafsson, A.** 2016 Organizational capabilities for pay-per-use services in product-oriented companies. *International Journal of Production Economics* **192**, 157–168.

Gericke, K., **Kramer, J.** & **Roschuni, C.** 2016 An exploratory study of the discovery and selection of design methods in practice. *Journal of Mechanical Design* **138** (10), 101109.

Geum, Y. & **Park, Y.** 2011 Designing the sustainable product-service integration: a product-service blueprint approach. *Journal of Cleaner Production* **19** (14), 1601–1614.

Goedkoop, M. J., **Van Halen, C. J.**, **Te Riele, H. R.** & **Rommens, P. J.** 1999 Product service systems, ecological and economic basics. *Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ)* **36** (1), 1–122.

Goh, Y. M., **Giess, M.** & **McMahon, C.** 2009 Facilitating design learning through faceted classification of in-service information. *Advanced Engineering Informatics* **23** (4), 497–511.

Grönroos, C. 1978 A service-orientated approach to marketing of services. *European Journal of Marketing* **12** (8), 588–601.

Isaksson, O., **Larsson, T. C.** & **Rönnbäck, A. Ö.** 2009 Development of product-service systems: challenges and opportunities for the manufacturing firm. *Journal of Engineering Design* **20** (4), 329–348.

Jesson, J., **Matheson, L.** & **Lacey, F. M.** 2011 *Doing Your Literature Review: Traditional and Systematic Techniques*. Sage.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Kahn, K. B. 1996 Interdepartmental integration: a definition with implications for product development performance. *Journal of Product Innovation Management* **13** (2), 137–151.

Ki Moon, S., **Simpson, T. W.**, **Shu, J.** & **Kumara, S. R.** 2009 Service representation for capturing and reusing design knowledge in product and service families using object-oriented concepts and an ontology. *Journal of Engineering Design* **20** (4), 413–431.

Kimita, K., **Sakao, T.** & **Shimomura, Y.** 2017 A failure analysis method for designing highly reliable product-service systems. *Research in Engineering Design* 1–18; doi:10.1007/s00163-017-0261-8.

Kimita, K., **Shimomura, Y.** & **Arai, T.** 2009 Evaluation of customer satisfaction for PSS design. *Journal of Manufacturing Technology Management* **20** (5), 654–673.

Kindström, D. & **Kowalkowski, C.** 2009 Development of industrial service offerings: a process framework. *Journal of Service Management* **20** (2), 156–172.

Kindström, D. & **Kowalkowski, C.** 2014 Service innovation in product-centric firms: a multidimensional business model perspective. *Journal of Business & Industrial Marketing* **29** (2), 96–111.

Kowalkowski, C. & **Ulaga, W.** 2017 *Service Strategy in Action: A Practical Guide for Growing Your B2B Service and Solution Business*. Service Strategy Press.

Kowalkowski, C., **Windahl, C.**, **Kindström, D.** & **Gebauer, H.** 2015 What service transition? Rethinking established assumptions about manufacturers' service-led growth strategies. *Industrial Marketing Management* **45**, 59–69.

Kreye, M. E., **Newnes, L. B.** & **Goh, Y. M.** 2014 Uncertainty in competitive bidding – a framework for product–service systems. *Production Planning & Control* **25** (6), 462–477.

Krishnan, V. & **Ulrich, K. T.** 2001 Product development decisions: a review of the literature. *Management Science* **47** (1), 1–21.

Kuijken, B., **Gemser, G.** & **Wijnberg, N. M.** 2016 Effective product-service systems: a value-based framework. *Industrial Marketing Management* **60**, 33–41.

Lacoste, S. 2016 Sustainable value co-creation in business networks. *Industrial Marketing Management* **52**, 151–162.

Ledford, H. 2015 How to solve the world's biggest problems. *Nature* **525**, 308–311.

Lightfoot, H., **Baines, T.** & **Smart, P.** 2013 The servitization of manufacturing a systematic literature review of interdependent trends. *International Journal of Operations & Production Management* **33** (11–12), 1408–1434.

Lindahl, M., **Sundin, E.** & **Sakao, T.** 2014 Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. *Journal of Cleaner Production* **64**, 288–296.

Lingegård, S. & **Lindahl, M.** 2015 Integrated Product Service Offerings for rail infrastructure – benefits and challenges regarding knowledge transfer and cultural change in a Swedish case. *Journal of Cleaner Production* **98**, 166–174.

Lovelock, C. H. 1983 Classifying services to gain strategic marketing insights. *The Journal of Marketing* 9–20.

Lütjen, H., **Tietze, F.** & **Schultz, C.** 2017 Service transitions of product-centric firms: an explorative study of service transition stages and barriers in Germany's energy market. *International Journal of Production Economics* **192**, 106–119.

Manzini, E. & **Vezzoli, C.** 2003 A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize. *Journal of Cleaner Production* **11** (8), 851–857.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Mathieu, V. 2001 Service strategies within the manufacturing sector: benefits, costs and partnership. *International Journal of Service Industry Management* **12** (5), 451–475.

Matschewsky, J., **Kambanou, M. L.** & **Sakao, T.** 2017 Designing and providing integrated product-service systems–challenges, opportunities and solutions resulting from prescriptive approaches in two industrial companies. *International Journal of Production Research* 1–19; doi:10.1080/00207543.2017.1332792.

Maussang, N., **Zwolinski, P.** & **Brissaud, D.** 2009 Product-service system design methodology: from the PSS architecture design to the products specifications. *Journal of Engineering Design* **20** (4), 349–366.

Maxwell, D. & **Van der Vorst, R.** 2003 Developing sustainable products and services. *Journal of Cleaner Production* **11** (8), 883–895.

Meroni, A. 2008 Strategic design: where are we now? Reflection around the foundations of a recent discipline. *Strategic Design Research Journal* **1** (1), 31–38.

Mont, O. 2002*a* Clarifying the concept of product-service system. *Journal of Cleaner Production* **10** (3), 237–245.

Mont, O. 2002*b* Drivers and barriers for shifting towards more service-oriented businesses: analysis of the PSS field and contributions from Sweden. *The Journal of Sustainable Product Design* **2** (3–4), 89–103.

Morelli, N. 2003 Product-service systems, a perspective shift for designers: a case study: the design of a telecentre. *Design Studies* **24** (1), 73–99.

Oliva, R. & **Kallenberg, R.** 2003 Managing the transition from products to services. *International Journal of Service Industry Management* **14** (2), 160–172.

Osterwalder, A. & **Pigneur, Y.** 2010 *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons.

Ostrom, A. L., **Parasuraman, A.**, **Bowen, D. E.**, **Patricio, L.**, **Voss, C. A.** & **Lemon, K.** 2015 Service research priorities in a rapidly changing context. *Journal of Service Research* **18** (2), 127–159.

Pahl, G. & **Beitz, W.** 1988. Engineering design: a systematic approach. *NASA STI/Recon Technical Report A, 89*, 47350.

Pagoropoulos, A., **Maier, A.** & **McAloone, T. C.** 2017 Assessing transformational change from institutionalising digital capabilities on implementation and development of Product-Service Systems: Learnings from the maritime industry. *Journal of Cleaner Production* **166**, 369–380.

Papalambros, P. Y. 2015 Design science: why, what and how. *Design Science* **1**, 1–38.

Penttinen, E. & **Palmer, J.** 2007 Improving firm positioning through enhanced offerings and buyer–seller relationships. *Industrial Marketing Management* **36** (5), 552–564.

Qu, M., **Yu, S.**, **Chen, D.**, **Chu, J.** & **Tian, B.** 2016 State-of-the-art of design, evaluation, and operation methodologies in product service systems. *Computers in Industry* **77**, 1–14.

Rabetino, R., **Kohtamäki, M.**, **Lehtonen, H.** & **Kostama, H.** 2015 Developing the concept of life-cycle service offering. *Industrial Marketing Management* **49**, 53–66.

Raddats, C., **Baines, T.**, **Burton, J.**, **Story, V. M.** & **Zolkiewski, J.** 2016 Motivations for servitization: the impact of product complexity. *International Journal of Operations & Production Management* **36** (5), 572–591.

Raja, J. Z., **Bourne, D.**, **Goffin, K.**, **Çakkol, M.** & **Martinez, V.** 2013 Achieving customer satisfaction through integrated products and services: an exploratory study. *Journal of Product Innovation Management* **30** (6), 1128–1144.

Reim, W., **Parida, V.** & **Örtqvist, D.** 2015 Product–Service Systems (PSS) business models and tactics – a systematic literature review. *Journal of Cleaner Production* **97**, 61–75.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Rittel, H. & **Webber, M.** 1974 Wicked problems. *Man-made Futures* **26** (1), 272–280.

Robson, C. 2011 *Real World Research: A Resource for Users of Social Research Methods in Applied Settings*, 3rd edn. John Wiley & Sons.

Sakao, T. & **Brambila-Macias, S. A.** 2018 Do we share an understanding of transdisciplinarity in environmental sustainability research? *Journal of Cleaner Production* **170**, 1399–1403.

Sakao, T. & **Shimomura, Y.** 2007 Service Engineering: a novel engineering discipline for producers to increase value combining service and product. *Journal of Cleaner Production* **15** (6), 590–604.

Settanni, E., **Newnes, L. B.**, **Thenent, N. E.**, **Parry, G.** & **Goh, Y. M.** 2014 A through-life costing methodology for use in product–service-systems. *International Journal of Production Economics* **153**, 161–177.

Settanni, E., **Thenent, N. E.**, **Newnes, L. B.**, **Parry, G.** & **Goh, Y. M.** 2017 Mapping a product-service-system delivering defence avionics availability. *International Journal of Production Economics* **186**, 21–32.

Shimomura, Y., **Kimita, K.**, **Tateyama, T.**, **Akasaka, F.** & **Nemoto, Y.** 2013 A method for human resource evaluation to realise high-quality PSSs. *CIRP Annals-Manufacturing Technology* **62** (1), 471–474.

Souder, W. E. & **Song, X. M.** 1997 Contingent product design and marketing strategies influencing new product success and failure in US and Japanese electronics firms. *Journal of Product Innovation Management* **14** (1), 21–34.

Stark, R., **Krause, F.-L.**, **Kind, C.**, **Rothenburg, U.**, **Müller, P.**, **Hayka, H.** & **Stöckert, H.** 2010 Competing in engineering design – The role of Virtual Product Creation. *CIRP Journal of Manufacturing Science and Technology* **3** (3), 175–184.

Stoughton, M. & **Votta, T.** 2003 Implementing service-based chemical procurement: lessons and results. *Journal of Cleaner Production* **11** (8), 839–849.

Tukker, A. 2015 Product services for a resource-efficient and circular economy – a review. *Journal of Cleaner Production* **97**, 76–91.

Tukker, A. & **Tischner, U.** 2006 Product-services as a research field: past, present and future. Reflections from a decade of research. *Journal of Cleaner Production* **14** (17), 1552–1556.

Tuli, K. R., **Kohli, A. K.** & **Bharadwaj, S. G.** 2007 Rethinking customer solutions: from product bundles to relational processes. *Journal of Marketing* **71** (3), 1–17.

Ulaga, W. & **Reinartz, W. J.** 2011 Hybrid offerings: how manufacturing firms combine goods and services successfully. *Journal of Marketing* **75** (6), 5–23.

Vaismoradi, M., **Turunen, H.** & **Bondas, T.** 2013 Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nursing & Health Sciences* **15** (3), 398–405.

Vasantha, G. V. A., **Roy, R.**, **Lelah, A.** & **Brissaud, D.** 2012 A review of product–service systems design methodologies. *Journal of Engineering Design* **23** (9), 635–659.

Vezzoli, C., **Kohtala, C.**, **Srinivasan, A.**, **Xin, L.**, **Fusakul, M.**, **Sateesh, D.** & **Diehl, J.** 2014 *Product-Service System Design for Sustainability*. Greenleaf Publishing.

Visintin, F. 2012 Providing integrated solutions in the professional printing industry: the case of Océ. *Computers in Industry* **63** (4), 379–388.

Wagner, C. S., **Roessner, J. D.**, **Bobb, K.**, **Klein, J. T.**, **Boyack, K. W.**, **Keyton, J.** & **Börner, K.** 2011 Approaches to understanding and measuring interdisciplinary scientific research (IDR): a review of the literature. *Journal of Informetrics* **5** (1), 14–26.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press

Watanabe, K., **Mikoshiba, S.**, **Tateyama, T.** & **Shimomura, Y.** 2012 Service process simulation for integrated service evaluation. *Journal of Intelligent Manufacturing* **23** (4), 1379–1388.

Windahl, C. & **Lakemond, N.** 2010 Integrated solutions from a service-centered perspective: applicability and limitations in the capital goods industry. *Industrial Marketing Management* **39** (8), 1278–1290.

Zeithaml, V. A. & **Brown, S. W.** 2014 *Profiting from Services and Solutions: What Product-Centric Firms Need to Know*. Business Expert Press.

https://doi.org/10.1017/dsj.2018.3 Published online by Cambridge University Press