



INTERDISCIPLINARY INSIGHTS FOUND FOR PRODUCT/SERVICE SYSTEM DESIGN

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1. Introduction

A number of manufacturing companies currently offer the Product/Service System (PSS), which can be defined as “a marketable set of products and services capable of jointly fulfilling a user’s needs” [Goedkoop et al. 1999]. Service here includes operation, maintenance, repair, upgrade, take-back, and consultation. PSS is motivated mainly by economic reasons for companies but is expected to contribute to improvements in environmental performance, although this improvement has rarely been the major focus of PSS research [Tukker 2015]. Importantly to the design community, service activity has been increasingly incorporated into the design space; e.g. (Sakao and Lindahl [2009]) an area which was traditionally dominated by physical products in manufacturing industries (see conventional theories for mechanical design, e.g. Pahl and Beitz [1988]). However, those manufacturing companies seem to face challenges in carrying out PSS design effectively and efficiently.

A main reason for that, in addition to the fact that PSS design research has received much less efforts than that of product design, may be that PSS is by definition more complex than a physical product. The definition of PSS above uses the term “jointly”, implying the need for managing inter relations between product and service elements in PSS in order to effectively provide PSS. To effectively design PSS, the inter-relations need to be carefully designed. However, the literature about PSS design does not provide sufficient insight for how to do so. This insight often falls into an interdisciplinary research area. Namely, interdisciplinary research in PSS is presumed to be insufficient.

Motivated by this observation, this paper aims to clarify the current status of research related to PSS design by focusing on interdisciplinary insights and, based on the clarification, to present relevant future research issues. The research method is based on quantitative and qualitative approaches. It makes use of a structured literature review and levels of utilization of insights in the literature. The paper focuses on the disciplines of Engineering Design and Industrial Marketing as two major disciplines. Industrial Marketing was chosen because value and business model aspects are often discussed as essential parts of PSS [Meier et al. 2010] and addressed in this discipline.

The remainder of this paper consists of the following. Section 2 describes the importance of interdisciplinary research for PSS. Section 3 describes the research method. Next, Section 4 explains the results. Following that, Section 5 describes the implications found for each discipline. Finally, Section 6 concludes the paper.

2. Interdisciplinary research in PSS

According to Marttila and Kohtala [2014] “Interdisciplinarity” aims at a more unified understanding of a given issue as it attempts to share and combine frameworks, methods and mental models. Moreover,

in academia there is a general belief that progress in knowledge and innovation as well as achieving excellence in research occur when different disciplines work together [Bruun 2005]. Interdisciplinary research can therefore provide improved theories, frameworks, methods, and tools.

Interdisciplinary work in PSS has been so far difficult to achieve. Tukker and Tischner [2006] 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” (pp. 1554). This lack of interdisciplinary work is not only in PSS, Andreasen and Hine [2000] 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” (pp 14). PSS adds to the complexity and poor collaboration between marketing and engineering design since the bundle of products and services needs to be designed in unison as a system of products, services, networks and infrastructures [Cavalieri and Pezzotta 2012]. Furthermore, in their analysis of PSS definitions in Business Management, Engineering Design and Information Systems, Boehm and Thomas [2013] concluded that exchange between these disciplines could be beneficial for the PSS discipline as a whole, calling for more interdisciplinary work since PSS can gain from looking at the discipline from different perspectives. One of the few examples is found in Sakao and Shimomura [2007], who present the concept of Service Engineering and call for a “much bigger framework” in Engineering Design to tackle design in the sustainability paradigm. Finally, there have also been calls from the Marketing literature to develop the necessary capabilities in companies interested in implementing PSS (see for example: Ulaga and Reinartz [2011]).

In order to clarify interdisciplinary insights and the level of utilization in Engineering Design and Industrial Marketing this research postulates the following questions:

- Which insights coming from the Industrial Marketing discipline have been utilized in the Engineering Design discipline? And vice versa.
- What has been the level of utilization of insights?

3. Method and scope

3.1 Method

The research method is based on a systematic literature review [Jesson et al. 2011], which is a quantitative-oriented method. It consisted in the systematic search of articles with keywords and later the identification of insights and their level of utilization.

The search with keywords related to PSS included other terms commonly used in each discipline. For instance, in engineering design it is common to see interchangeable terms such as “industrial service”, “hybrid offering”, “functional product” and “servitization”. With regards to industrial marketing, terms often used include “service infusion” and “service transition”, among others.

Therefore, the keywords searched were: Product service system, Functional product, Integrated solution, Hybrid offering and manufacturing, Industrial service, System solution and manufacturing, Customer solution, Marketing solution, After-sales service and manufacturing, Servitization, Service infusion, Service engineering, Service transition AND manufacturing AND Service strategy AND manufacturing. The selected publications were thereafter analysed to discover relevant insights and their level of utilization using

Table 1. This table is read as follows: L1 was assigned one count if a citation from the opposite discipline was used in the publication. L2 was assigned one count if there was “insight” used, that is, using the understanding, suggestion or critique from an author in the opposite discipline. L3 was assigned one count only if there was enough evidence to suggest that the authors had made use of a model, framework, method or tool from the opposite discipline.

Table 1. Levels of utilization

Level	Meaning
L3	A model, framework, method, or tool directly used
L2	Insight used
L1	Cited

3.2 Scope

The scope consisted in the selection of journals with high impact relevant to each discipline. Web of Science was chosen because of the impact factor of journals. The search was then limited to publications in the Web of Science Core Collection where only the databases SCI-Expanded and SSCI were selected as these are most relevant to the topic of interest. The articles found were then categorised as belonging to either Engineering Design or Industrial Marketing based on the following classification of the 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.

In Industrial Marketing (IM):

European Journal of Marketing, Industrial Marketing Management, International Journal of Research in Marketing, Journal of Business & 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.

This selection was performed using a priori knowledge of the journals and whether they were more relevant to Engineering or to Marketing, although the disciplines of articles are sometimes not so easy to cut clearly. Since the objective of the research was to capture insights in publications with high impacts, the number of articles reviewed from each discipline was limited to 10. This number of publications was considered sufficient to function as an initial indicator of the state of interdisciplinary work carried out so far.

4. Results

4.1 Systematic search

The results are described in the Figure 1 below. It shows how the final articles were obtained through a systematic process.

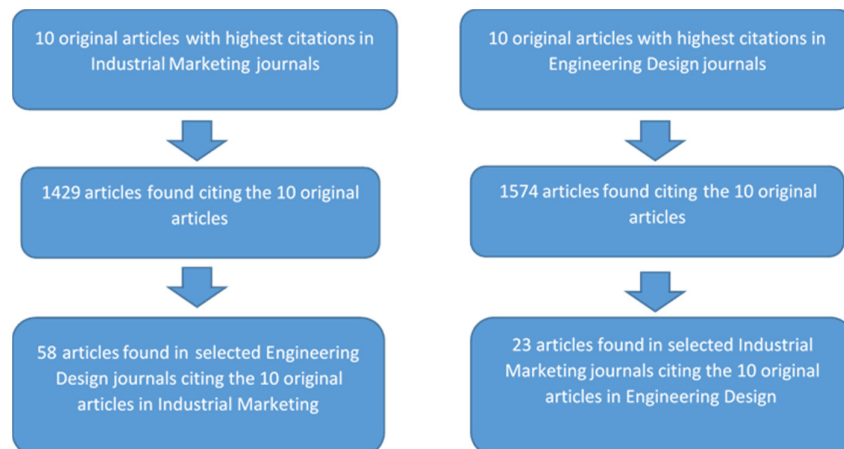


Figure 1. Articles nominated in the research

4.2 Nominated articles

The results of the literature search with the selected keywords yielded the articles in Table 2 and Table 3. These results are time specific, i.e. results obtained during the month of November 2015. The total number of citations for the 10 articles in each discipline was 1574 in Engineering Design and 1429 in Industrial Marketing, a total of 3003.

Table 2. 10 highly cited articles in Engineering Design

	Number of times cited
E1 [Mont 2002]	330
E2 [Baines et al. 2007]	271
E3 [Meier et al. 2010]	185
E4 [Aurich et al. 2006]	145
E5 [Tukker and Tischner 2006]	135
E6 [Maxwell and Van der Vorst 2003]	129
E7 [Manzini and Vezzoli 2003]	112
E8 [Sakao and Shimomura 2007]	97
E9 [Morelli 2006]	91
E10 [Alonso-Rasgado et al. 2004]	79

Table 3. 10 highly cited articles in Industrial Marketing

	Number of times cited
M1 [Oliva and Kallenberg 2003]	386
M2 [Tuli et al. 2007]	231
M3 [Mathieu 2001]	137
M4 [Davies 2007]	121
M5 [Fang et al. 2008]	107
M6 [Cova and Salle 2008]	105
M7 [Neu and Brown 2005]	99
M8 [Windahl and Lakemond 2006]	88
M9 [Jacob and Ulaga 2008]	78
M10 [Gebauer 2008]	77

4.3 Interdisciplinary work

Once the list of these 10 articles per discipline was obtained, the search continued into looking at those papers that have cited them. Taking as an example the case of the article by Mont [2002], from the total number of 330 citations we only looked into those citations coming from the journal list in section 3.2 for Industrial Marketing. The same process was followed for each article and its citations, always looking at citations coming from the opposite field and from the selected list of journals.

This resulted in 133 articles. Since some articles referred more than once to the original 10 per discipline, the final analysis was carried out for 81 articles only. 58 articles for Engineering Design using Industrial Marketing and 23 for Industrial Marketing using Engineering Design. Table 4 and Table 5 below show the level of interdisciplinary work between Engineering Design and Industrial Marketing. These tables are read as follows. M1 (Oliva and Kallenberg [2003]) was cited by Engineering Design 35 times, from those 35 citations 13 were considered to be at Level 2 (L2) and only 1 was at level 3 (L3). The same reasoning is followed in each row.

Table 4. Different levels of interdisciplinary work in Engineering Design

Used by IM	ED		
	L1	L2	L3
M1	35	13	1
M2	9	4	0
M3	17	8	1
M4	8	6	0
M5	6	5	1
M6	1	0	0
M7	3	1	0
M8	8	3	0
M9	2	0	0
M10	4	1	0

Table 5. Different levels of interdisciplinary work in Industrial Marketing

Used by ED	IM		
	L1	L2	L3
E1	8	1	0
E2	7	3	1
E3	4	2	0
E4	1	1	0
E5	9	3	1
E6	3	1	0
E7	3	2	0
E8	0	0	0
E9	1	0	0
E10	4	1	0

From the tables above, it can be noted that Engineering Design cites more literature from Industrial Marketing than vice versa. It is important to note that the analysis showed that two articles in particular made the most use of interdisciplinary work. In Industrial Marketing, Rabetino et al. [2015] in “Developing the concept of life-cycle service offering” cite the work from Engineering Design at different levels of utilization. They cite at L1 Mont [2002], Manzini and Vezzoli [2003] and Alonso-Rasgado et al. [2004], while at L2 the authors cite Maxwell and Van der Vorst [2003], Aurich et al. [2006] and Baines et al. [2007]. Tukker and Tischner [2006] was found at L3. In regard to Engineering Design, Benedettini et al. [2015] in “Why do servitized firms fail? A risk-based explanation” also showed the highest level of interdisciplinary work. They make use of L1 citations from Windahl and Lakemond [2006], Jacob and Ulaga [2008] and Gebauer [2008]. The authors cite at L2 Mathieu [2001], Oliva and Kallenberg [2003] and Fang et al. [2008] at L3. It is important to notice that Level L3 was rare to find, no clear and direct use of models or frameworks was encountered. However, some authors made explicit use of insights or gaps from the opposite discipline for their own models, hypotheses or frameworks and therefore counted as L3. Furthermore, environmental issues addressed in the articles reviewed were rare to find. This finding corroborates Tukker's [2015] findings which suggest that the environment has been still underdeveloped in PSS research.

4.4 Insights used in Engineering Design coming from Industrial Marketing

Oliva and Kallenberg [2003] are often cited as source for how companies have moved into PSS and how successful PSS needs new organizational processes, structures and principles. Cova and Salle [2008] are also cited as source to show the obsolescence of goods-centred business models.

Tuli et al. [2007] is often used as means to show how companies can use servitization as a value-based strategy for differentiation and how this entails long-term relationships between manufacturers and customers. Insights by Mathieu [2001] used in Engineering Design often show how services in manufacturing have transitioned from being considered “a harmful necessity” to a source of added value. Mathieu’s [2001] insights also suggest that providing integrated solutions require relational, rather than transactional interaction with customers. Moreover, authors in Engineering Design often use Davies’ et al. [2007] and Gebauer’s [2008] way of classifying products/services. For instance, according to Davies’ et al. [2007] servitization can be categorized into system sellers responsible for the entire design of system and system integrators responsible for externally integrating products and services. Gebauer’s [2008] classification consists of after sales services, customer support, outsourcing partners and development partners. Fang et al. [2008] are often cited through the valuable input that customers can have in co-producing services and how such services can be difficult to imitate by competitors. The authors’ insights argue that establishing services that can generate customer loyalty can and in turn increase customer cooperation. The work by Neu and Brown [2005] used in Engineering Design suggest that service offerings need to be properly designed and not offered as independent elements. Companies will need qualified resources for service offerings. Windahl and Lakemond [2006] importance of relationships and key business partners in the delivery network is an often cited insight in Engineering Design. Finally, Jacob and Ulaga [2008] is cited as motivation for more quantitative studies in PSS.

4.5 Insights used in Industrial Marketing coming from Engineering Design

The results show that the work from Mont [2002], Manzini and Vezzoli [2003], Morelli [2006] and Tukker and Tischner [2006] are often cited in two ways. The first one to show the reason behind the existence of PSS, mainly globalization, increasing competition and environmental regulations. The second way in which their insights are used is to show the different ways in which “value” can be delivered, i.e. product oriented, use oriented and result oriented PSS. Their insights used also highlight the need and possible barriers for companies to change their mind set from product centred to delivering solutions and customer satisfaction. Baines et al.’s [2007] insights often address the need for greater responsibility from providers throughout the life cycle of products/services. The insights used also stress the benefits that PSS can have for customers and companies. For customers these benefits can be more functionalities, responsibility transfer, and higher value by increasing services. For companies benefits can be new market opportunities, competitive advantage, access to information during the use phase of the product, higher profit margins and increase customer loyalty. The insights from Meier et al. [2010] show the challenges that might be encountered when implementing PSS. These include cost estimation, cultural change, supply change integration and designing services. Other challenges often cited are the systematic development of components and solutions, transfer of risk and relationship management as well as the configuration of customer specific solutions. An insight addressed in the literature mentions Aurich et al.’s [2006] better alignment of incentives to address the provider’s concern when transferring risk and how terms included in long-term agreements can align the incentives of different stakeholders. Maxwell and Van der Vorst [2003] usage in Industrial Marketing literature point out that sustainable design (reuse/recycling/energy recovery/treatment/disposal) is usually driven by regulation. Sakao and Shimomura’s [2007] insights are not shown in the Industrial Marketing literature.

Finally, Alonso-Rasgado et al. [2004] are often cited regarding the transfer of risk from customer to provider and the importance of training personnel for improving the service support and optimization of services. Their insights suggest that access to information of machinery or equipment may not only drive continuous improvement but also possible new product development.

5. Discussion

PSS can be described as an interdisciplinary field of study. However, when looking at the 10 articles from each discipline and the research articles that cite them, this is difficult to find. This has important implications which are described as follows.

Engineering Design shows a higher degree of interdisciplinarity, out of the 81 articles reviewed, 58 were found to make use of Industrial Marketing literature. However, it does not make extensive use of models, frameworks, methods or tools at L3. This could mean that business models, marketing insights and the ultimate contact with the customer can be overlooked.

Industrial Marketing has little insight from Engineering Design, only 23 articles from the total 81 were found to cite Engineering Design literature at some level. There is potential thereof for integrating much more insight from Engineering Design into Industrial Marketing when addressing issues in PSS. Another important aspect to discuss is that although there is some use of insights at levels L1 and L2, the level of utilization at L3 is poor. Most cited material does not actually use the frameworks and models from other authors. The highest level of utilization was difficult to find while environmental issues are seldom addressed. There seems to be a preference in PSS research to look at definition of concepts, engineering design and business models only. It could also be argued that interdisciplinary research lacks visualisation: that is, it is difficult to determine or explicitly see how an insight has been used. Further research could communicate this in a clearer manner so the academic community can follow how central ideas, concepts, models and frameworks have been developed and used across disciplines.

6. Conclusion

This research shows evidence that there are few insights in terms of number of citations and level of utilization across the discipline boundary, i.e. little impact so far between the two selected domains. This means that there are many potentially fruitful linkages, although they have hardly been explored and exploited. Research builds on what others have done in the past. For the PSS community, this means more interaction between Engineering Design and Industrial Marketing. This endeavour is needed in order to develop more knowledge about PSS and implement it more effectively and efficiently in industry. This is the gap found by the paper and to be addressed in future work, where more cross-collaboration has the potential to improve methods, tools, frameworks and theories.

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