



Factors Influencing the Integration of Product and Service Design in Product-Service System Development

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Abstract. The evolution of product offer towards an integrated solution combining services and products is widely considered as a competitive advantage for manufacturing companies. Consequently, the traditional stage-gate product design process has to evolve to integrate service design. The purpose of this research is to provide a better understanding on how this evolution can be taken into account in Product-Service System (PSS) design process by exploring evidences from literature and industrial cases. In this respect, a comparative analysis between the academic and industrial representative viewpoints has been conducted. Our findings show that the proposed PSS design process by PSS literature does not clearly consider customer integration in PSS design. The industrial practices identified in three case studies reveal different processes for PSS design and customer integration according to the type of PSS they are providing. The comparative study between literature and industrial practices offers some propositions to be explored in future research for distinctive features relating to PSS design process.

Keywords: Product-Service System (PSS), PSS Design Process, PSS Integration.

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1 INTRODUCTION

The core idea of Product-Service System (PSS) is to create added value by providing an integrated system of product and service with a total care throughout their lifecycle to meet the customers' requirements while reducing resource consumption and environmental impacts [1][2][3]. The traditional stage-gate product design process has to evolve to combine both product and service design to provide PSS. In this context, various models have been proposed to describe the PSS modular design process. Some authors suggested a parallel interactive method of product and service design for PSS by translating the traditional production process into a process of technical

service [4][5][6]. Others considered PSS as an integrated system of products, services, stakeholders and delivery infrastructure and proposed a unified PSS design process [7][8].

Despite the wealth of research dedicated to the PSS design, existing methodologies for PSS design are not detailed enough [9]. Existing literature does not adequately explain how product and service can be combined efficiently; how their design can be affected by factors that define the offer and how to choose the most appropriate combination modes [10][11]. Also, the PSS literature highlights the importance of setting-up collaborative partners network and increased need for communication and coordination of activities [7][8]. In this matter, it is necessary to specify that the customer integration happen how and in which phase during the PSS design.

The specification of the product-service interactions is not explained in any models; which is to say the interfaces between both artefacts when building the PSS architecture as well as the influence of each artefact design on the other one is not clear. Furthermore, the existing models do not illustrate the specific activities related to the service delivery due to the simultaneity between service production and consumption.

This paper aims to fill this gap by investigating the factors that can influence the integration mode of product design and service design during the PSS development process. In this respect, the paper provides a conceptual framework based on a set of four factors that could influence the product and service design combination modes. Then, it describes a qualitative research method based on the cross-case analysis. Next, it reports some evidence of the exploration of the three cases according to the conceptual framework. Finally, the paper concludes with the theoretical and practical implications of this work, its limits, and potential for future research.

2 THEORETICAL BACKGROUND

Making the literature survey let us to observe and describe the transition in PSS design focus from adding service to product to the integrated system design approach. A comparative analysis is conducted to highlight the peculiarities of the PSS design process. Recent approaches focus more on characterizing the different dimensions of PSS offering [12]. There are relationships among companies' strategy, business models, and tactics for PSS. Different PSS typology has different effect on the PSS development complexity and collaboration tactics as well as on the modes of components combination [5],[8].

2.1 Combination Mode of Product and Service Design

Using the Lifecycle Engineering (LCE) concept, PSS results from the design of both tangible and intangible components [5]. In this context, the final solution creates value by simultaneous combination of the products and services [12]. The success of PSS design is highly dependent on the systematic combination of product and service design with a consistent PSS design process [5]. In order to be sure whether the PSS is creating the planned value, companies need to test the synergy between product and service when they are combined [13].

In this matter, three modes of combination between product and service lifecycle design are proposed in the literature as [5],[8](Table 1):

1. Parallelizing: The product and service design tasks are identified independently and there is an interaction point.
2. Integration: The product and service design tasks are performed simultaneously based on mutual resources. Interactions take part whenever needed.
3. Linkage: The product and service design process are structured sequentially. Each lifecycle is triggered by the other one.

These representations of product and service activities combination reflects the PSS development start point, structure and point of view of the organization during the PSS design project.

Product and Service design combination modes [5]	Schema
“Parallelizing”: independently and there is an interaction point.	
“Integration”: simultaneously based on mutual resources. Interactions take part whenever needed.	
“Linkage”: structured Sequentially. Lifecycles trigger each other.	

Table 1: Product and Service design combination modes [5].

2.2 The Influencing Factors

From the existing literature, three main classes of the influencing factors as the adoption strategy, type of offer and customer integration approach can be distinguished [4][14].

1. PSS adoption strategy:

Recent approaches focus more on characterizing the different dimensions of PSS offering [14]. There are relationships among companies' strategy, business models, and tactics for PSS [15][8]. Companies' core competence is a base for their PSS adoption strategy [15] and the type of PSS they propose [14]. When the adoption strategy is defined clearly, the type of PSS they propose will be clarified with a set of tactics to accomplish it [14]. Companies adopt various approaches beside using their own tools to design PSS [4]. As a result, PSS development must follow a flexible and dynamic roadmap [16]. Considering the market and the core competence of the company, OEMs define their strategy to adopt PSS. This strategy affects the PSS offer type.

2. PSS offer type:

The PSS typology has different effects on the PSS development complexity, collaboration tactics, customer integration, and the level of integration of PSS components [17][14]. There are various propositions for PSS typology distinguishing different categories of PSS provider [19][20]. The proposed typology for PSS by Tukker [18] is considered as the most preferred classification in PSS literature [19]. This typology proposes three type of PSS as Product-Oriented, Use-Oriented, and Result-Oriented [18]. Considering all the above, the next important influencing factor is customer integration in design.

3. The customer integration in PSS design process:

With PSS offer, the company provides additional value for the customer through a long-term relationship covering a large part of the PSS lifecycle. The complexity of PSS offer increases the need for “more personal communication and implement new working routines” in coordination activities, “low formalization and highest complexity” in responsibilities of stakeholders [14]. It raises the question about the role of the customer in design and how they integrate their customer in the PSS design process [22]. Consequently, PSS design process should involve steps to review and improve the design process [4]. In this matter, customer integration is a critical issue that gives essential specificities for PSS design process regarding traditional product design processes [21].

2.3 Conclusion of Theoretical Background

Figure 1 presents the conclusion from the theoretical background to guide the cross-case analysis. According to the literature, product and service design combination during PSS design is affected by influencing factors as PSS adoption strategy, typology, and customer integration (Fig. 1).

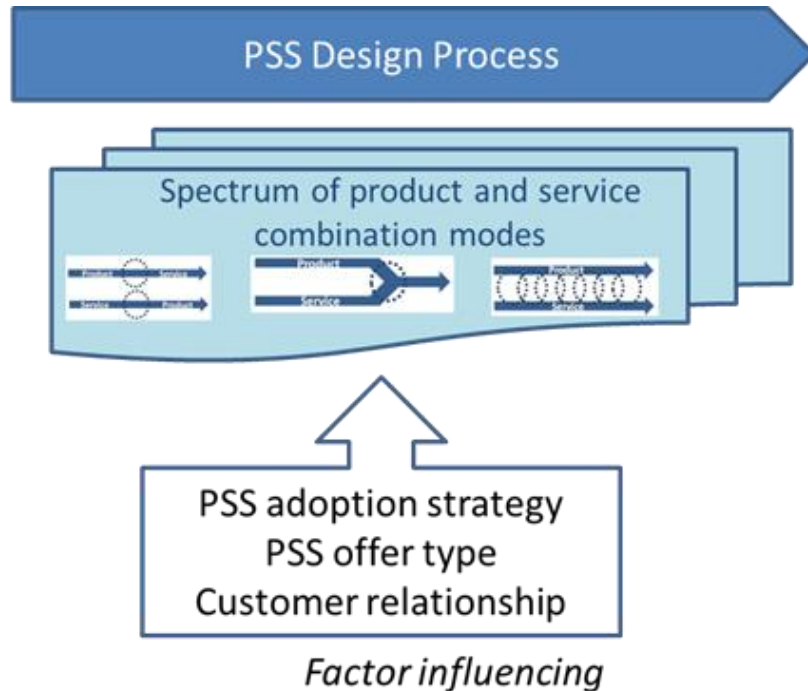


Figure 1: The theoretical background conclusion.

3 THE RESEARCH METHODOLOGY

This paper seeks to investigate how the effective integration of product and service design during the PSS development process depends on the influencing factors (Fig. 1). A comparative case study is adopted, which is the most appropriate approach to investigate the research question and to emphasize the validity of findings [23].

Three B2B cases from different industries (energy equipment, automotive equipment, and machinery) have been considered in this research (Table 2).

<i>Cases</i>	<i>Company Field</i>	<i>Company Type</i>	<i>PSS Design Project Manager</i>	<i>PSS Type</i>
A	Energy Equipment	OEM	Engineering Department	Result-Oriented
B	Automotive Equipment	Supplier	Customer Relation Department	Result-Oriented
C	Machinery	OEM	Engineering Department	Product-Oriented

Table 2: Main characteristics of the industrial cases.

The above-mentioned industries intend to change their business model from product to PSS. Thus, while the three case studies come from different industries, they are similar regarding PSS adoption strategy. The empirical data has been collected from individual interviews with PSS project managers (two hours of the interview).

Interviews are semi-structured, recorded, and entirely transcribed. This source of data collection enabled us to reach a triangulation approach. The theoretical background analysis (Fig. 1) is applied as a guideline for acquiring information from the industrial cases and analyzing the cases. During the interviews, the practitioners have been asked to describe their PSS offer regarding their strategy for PSS adoption and PSS definition for them, PSS offer type and customer integration during design. They are also asked to report their practices regarding PSS design and more specifically how they combine product and service design activities and how, when and why they involve their customers.

4 THE INDUSTRIAL CASES ANALYSIS RESULTS

4.1 Case A

Case A is an energy equipment manufacturer, which has evolved from an electro-mechanical producer to a solution provider and became a global leader in energy management technologies and services.

4.1.1 PSS adoption strategy

Despite the fact that company A has debates on solution definition, the elements of this solution are similar to the PSS definition in the literature. Providing PSS is categorized into "predefined solutions" for similar projects and "customized solutions" for a particular customer.

Now, company A puts more energy on the product because it is their profession and they consider the service mostly as a mean to deliver a final solution, but they tend to focus on service and consider the product as a complementary element to provide service.

4.1.2 PSS offer type

Company A provides three different types of solutions and tries to move to the "result-oriented" PSS:

4. Business Project Contracts: In many projects, company A builds and provides the solution to the customer. In this case, the customer is the owner.
5. Performance contracts with provider ownership: In some cases like equipping large buildings, company A is the owner and commits to the performance and efficiency management. If some benefits were gained, they would be shared with the customer.
6. Performance contracts with third-party ownership: In some cases, the bank will finance the project, so the owner is the bank. The customer is interested in the value but neither the customer nor Company A has the required financial resources, or they do not want to invest in the solution.

4.1.3 Customer involvement

To propose the solutions, knowing the customer is always the first step, which the marketing team is in charge of. However, the project manager reported that their most basic difficulty, as a B2B, is gathering information about the market because the company does not have access to the end user.

Company A follows the classic waterfall model of the system design process. The design process of PSS is defined with requirement analysis, concept design, detail design, solution installation and production phases. It does not have a formulated step of customer integration. Instead, it has some interaction moments with customers that happen during the primary steps of requirement analysis, ideation and concept design (Fig. 2). During these steps, company A develops demonstrators to test and validate with the customer. After the conceptual design with

close collaboration with the customer, the company is responsible for the solution production and installation.

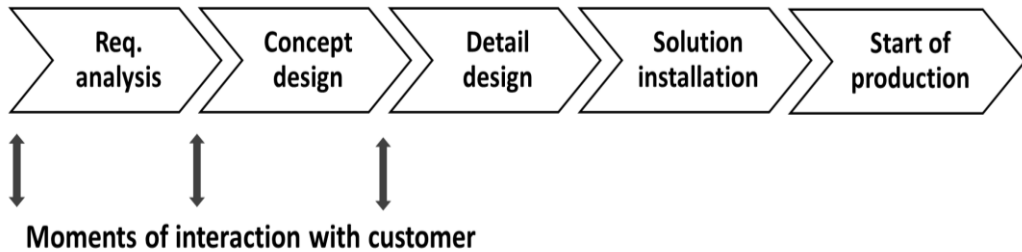


Figure 2: PSS design process and customer involvement in Case A.

4.1.4 Combination mode of product and service

Considering the different combination modes for product and service design, company A chooses a different combination mode according to the offer type. The integrated mode has the most added value for their customer, especially in the performance contracts. For the business contracts, the combination mode is parallel because it is an ad hoc adaptation between product and service lifecycle to provide the PSS offer. In both cases, for integration of product-service, company A sets-up a mixed project team for development of PSS and the mingling inside the project team is as vital as product-service integration.

4.2 Case B

Case B is an automotive equipment supplier that has moved from manufacturing the parts using bonding technology to provide a bonding solution to advance in the market of solution providing.

4.2.1 PSS adoption strategy

They use "Turn Key Solution" expression for their bonding solution. This bonding solution includes providing raw material required for bonding technology, the bonding equipment and the managerial packages such as the solution commissioning, maintenance and training. The customer account manager plays the role of the project manager for solution providing.

4.2.2 PSS offer type

Company B focuses on the solution contract by modifying the product design, which needs sometimes numerous changes. They integrate their lessons learned and the new capabilities they have gained from the previous projects. Finally, they do not even mention the product or equipment on the invoice and the customer pays for the whole package of the solution.

Their business model is mostly result-oriented PSS because the customer pays per service, and they are committed to customer satisfaction, but at the same time, their risk management strategy makes their contract different from the performance contract. They propose a service that also benefits customers while at the same time reduce their risk. The complexity of the contract and boundaries of the work seems high, and change and risk management need to be well defined and well managed.

4.2.3 Customer involvement

The whole process of solution offer contains two interdependent processes: engineering process and customer integration process. The latter defines the necessary input to perform the engineering process. For company B, the objective of this collaboration with the customer is firstly, to understand their need and secondly, to validate the proposed solution according to its life cycle in the development process. For this purpose, the customer integration process is composed of four steps as follows:

1. Understanding and analyzing customer needs performance specifications, process integration, and services (maintenance, supply chain, assistance...).
2. Validation of interest: economic analysis, technical feasibility, service feasibility.
3. Solution approval: economic, technical, services, planning.
4. Solution installation: quality control, operators training.

Each step requires numerous exchanges before finalizing an acceptable solution. In their solution, the customer need is considered according to all aspects of the solution like technology, process, equipment, test, and validation, method, logistic, environment and workers. The customer satisfaction is measured by the validation plan that is the successful final solution as well as feedback from the continuous relationship with the customer (Fig. 3).

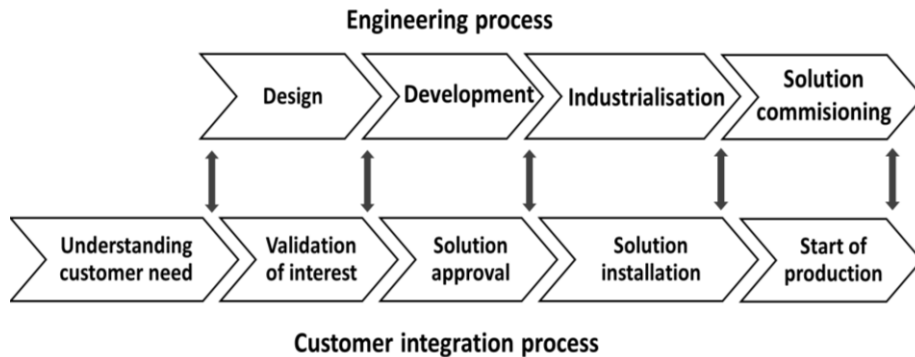


Figure 3: PSS design process and customer integration in case B.

4.2.4 Combination mode of product and service

They need to know their customer, but at the same time, they need to consume a lot of energy discussing with customers to extract the real need and to translate this need to the input information of solution design. Their focus is on the integrated mix of product and service. This point of view makes their collaborative design process continuous and integrated.

4.3 Case C

Company C is a machinery manufacturer, which traditionally provides maintenance services on site. To reduce travel costs and maintenance delays as well as extending product life, Company C offers a new solution based on remote maintenance.

4.3.1 PSS adoption strategy

Their offer is enhanced by the use of Augmented Reality (AR) platform. The customer may visualize its machine in its environment, and then select the components that should be replaced. The AR platform managed by Company C generates the appropriate AR scenes and supports the remote maintenance procedure.

Company C adds software to PSS to facilitate the product remote maintenance as well as to provide further information about the product lifecycle to improve the company competitive knowledge. So, the PSS adoption strategy is strongly based on avoiding any radical changes in the machine. Meanwhile, one of the main incentives to monitor the machine's whole lifecycle is to increase their knowledge about the machine during the usage phase as a critical input for their machines' improvement program. On the other hand, the customer needs maintenance and other after-sales services. Conducted by the engineering team, the proposed PSS is a win-win strategy to fulfil the customer needs as well as to improve the OEM competitiveness in the machinery market.

4.3.2 PSS offer type

The most critical challenge in company C to move from product-oriented to the result-oriented PSS is to remove the barriers related to the project culture, which is strongly focused on reducing risk. There is still some confusion in PSS concept adoption. On the one hand, maintenance is part of the offer and considered during PSS production phase and not after. On the other hand, company C still distinguishes between PSS design, delivery, and after-sale services. What differentiates between the classical machine producing and PSS in such a company is not the addition of the platform, it is the use of information acquired from the platform. The ownership of the product is the same, but the ownership of the information has been changed. In this case, company C is now the owner of the information and can use this information to propose additional services.

4.3.3 Customer involvement

For company C, the design of the solution is driven by the specificities of the machine which is implemented within the customer environment. The process of PSS design is highly collaborative and IT-centered. Due to the IT-based platform, the company is connected with customers and has real-time data and feedbacks from different stages. By analyzing the customer requirements, they extract the required information to acquire during the product lifecycle. Next steps are design, testing and final solution commissioning. They do not have a formulated moment of customer integration in design, but they interact with the customer during requirement analysis and solution testing (Fig. 4).

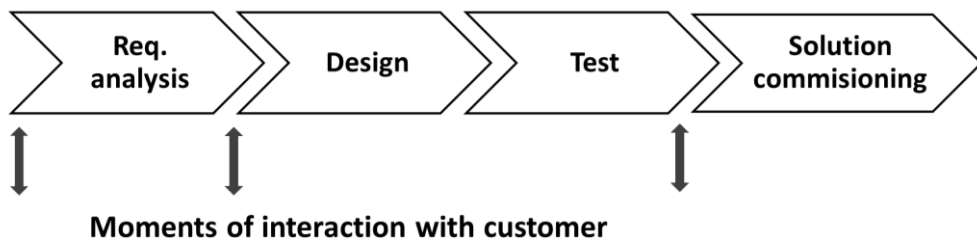


Figure 4: PSS design process and customer integration in case C.

4.3.4 Combination mode of product and service

The combination mode of the product and service is parallel. Company C creates the AR-based service parallel to their product.

4.4 Cross-analysis

Comparing the three mentioned companies, their similarities and differences in PSS design and integration is distinguished. According to the comparison of the cases, the industrial cases use parallelizing mode when the PSS offer is built by designing new services and adapting existing products or by adapting existing services and products. While all companies start their SS design in a parallel mod, the linkage mode, as the classical model of after sale services has limited usage in PSS providing (Table 3). Company A uses integration mode with ad-hoc interactions between product design and service design activities whereas interaction are made in a continuous way in Company B. Company C uses only this mode by adapting existing product progressively with the new service design.

In case A and B, both firms manage the risk by testing the adoption of the PSS with the customer as soon as possible, and by continuously validating the PSS quality through a close collaboration with customer in different stages. In product-oriented PSS (Case C), the design is rather conducted in parallel way between product and service. The OEM of Case C mostly focuses

on the customization of the product they are already producing and there are some cultural barriers for more complicated PSS business models.

The results reveal that both firms which develop result oriented solutions (case A and B) do not consider the notion of result with the same vision. For case A, the result is more related to the performance. The company commits, through contracting, to reduce and manage the energy consumption in the building or factories of their customers. For case B, the result is more reliability oriented by acting as soon as possible if its customer encounters manufacturing problems. Company C is clearly based on product-oriented PSS.

Each company aims to develop close relationship with the customer during the whole lifecycle of solution. Even if the access to their customer is not the same; all of these companies try to capture their needs and implement validation tests with their client. For Company A, the voice of the client is represented through the marketing function. For this reason, the project team has to integrate marketing actors early to clearly understand the set of the client’s needs. Company B is a supplier; that has direct access to its customer. Company B has clearly specified the different moments of involvement of its customer in its PSS design process. Company C is trying to use a collaborative platform to manage the interfaces with the stakeholders. Its PSS design strategy is maximum function customization with minimum changes in the main product. Therefore, the product modification options are limited.

Case A	Adoption strategy	Moving from a producer to a solution provider by proposing customized and predefined solutions		
	PSS Type	Result-Oriented		
	Combination Mode	Parallelizing	Integration	Linkage
	Customer integration	To integrate the parallel working product design and customer care for the usage phase.	Interactions between Product design and service design happen whenever is needed.	As the classical product and services design method
Case B	Adoption strategy	Moving from a bonding equipment supplier to the bonding solution provider.		
	PSS Type	Result-Oriented		
	Combination Mode	Parallelizing	Integration	Linkage
	Customer integration	As the classical product and services design method	designing the product and service continuously.	Not Applicable
Case C	Adoption strategy	Moving from a producer to the remote maintenance contractor.		
	PSS Type	Product-Oriented		
	Combination Mode	Parallelizing	Integration	Linkage
	Customer integration	Adding software-based services to the product.	Not Applicable	Not Applicable

Table 2: Product and Service Combination Modes Based on literature.

All cases aim at developing result-oriented solutions, but their vision of the notion of result is different. The result, for company A is related to performance and for company B is reliability oriented. In the contrary, company C focuses on the product they are already producing and there is no sign of interests in complicated PSS business models. One possible reason for this difference

might be that since the nature of the company’s business is machine manufacturing, its interest is mostly in selling advanced services contracts than result-oriented PSS contracts.

Finally, the PSS or solution providing has two main design modes in different cases. The three case studies all have a predefined PSS or solution. Companies customize a PSS based on the special needs of a customer. Then, they can reuse and tailor these customized solutions to provide a new PSS for another customer. As a result, there are design and adaptation processes during PSS design.

Comparing these companies, it can be say that, the companies approach in PSS adoption affects the combination mode of product and service design as well as customer integration. In a global view, when the offer is closer to the result-oriented type, its design is mostly integrated and the customer is more involved throughout the PSS design process. In result-oriented PSS, firms manage the risk by testing the offer with the customer as soon as possible. They continuously validate the PSS quality with close collaboration with the customer in different stages. In product-oriented PSS, the design is more conducted in parallel implication between product and service. The results reveal that OEMs mostly focus on the customization of the product they are already producing, and there are some cultural barriers to more complicated PSS business models (Fig. 5).

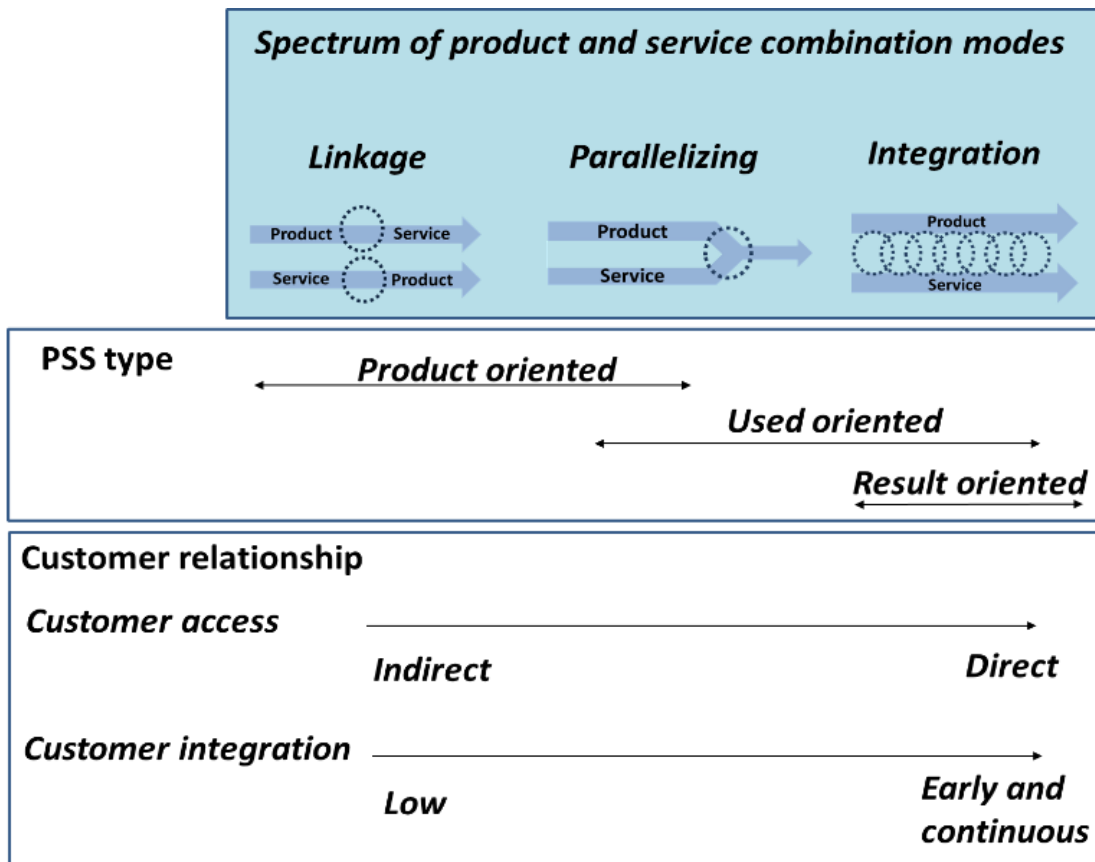


Figure 5: The effect of the PSS type and customer relationship on the modes of product service design combination.

5 DISCUSSION AND CONCLUSION

This research made a literature review to extract the product and service design integration mode in PSS and the factors influencing this integration. The result of this literature analysis is then used as a guideline for an industrial case study.

The results of this research reveal some significant gaps between the theory and practices in PSS design. These gaps allow identifying some theoretical and managerial implications. From a managerial point of view, PSS providers need to consider the influencing factors to define the PSS design process. These factors are PSS type, the company position on the market, the customer accessibility, and the offer creation strategy. From the theoretical viewpoint, PSS design should be evolved based on the integration modes and according to the offer's specifications.

Companies evolve to PSS providers based on their core competences. As a result, the PSS type they adopt is according to their actual business. This adopted typology has a crucial effect on the product and service design combination. Beside these factors, the collaborative nature of PSS affects its design and integration process. Comparing to the classical product design process, PSS design process consists of more customer integration phases to increase the performance as well as to reduce the risk. Which is to say, an iterative process to integrate PSS elements and stakeholders is necessary?

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