Applying Platform Design to Improve Product-Service Systems Collaborative Development

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Abstract. The promise of Product-Service Systems (PSS) is that it might revolutionize the consumer experience, increase the manufacture's profits and reduce environmental impacts by providing comprehensive solutions instead of pure physical products or services. However, most of the existing researches and applications on PSS are focus on the new PSS development (NPD) which could increase the customer satisfaction but could not enhance the profits of an enterprise effectively. Therefore, the platform design theory is adopted to support collaborative development of PSS. The customer requirements are forecasted by Kano model. Instead of completely innovation design, existing products and services are analyzed by function decomposition methods and the modular technology to support the PSS development. Finally, a case study of the crane machine PSS portfolios shows the effectiveness of the proposed approach.

Keywords: Product-Service Systems platform; platform design; collaborative development; modular technology

1 Introduction

Product-Service System (PSS) is emerging as an important method for the manufactures to realize servitization. However, most manufacturing enterprises suffered drops in profits when increasing investment in services. One of the important reasons is that the manufacturing company's core competitiveness still stays on product design and manufacturing, and cannot expand its capabilities to all the services in the product life cycle to keep superior competitiveness. Cooperation with companies who have complementary core competitiveness has become mandatory for the PSS offers to obtain competitive advantage. For example in the communications industry, smartphone manufactures, operating-system developers, application developers and mobile operators often collaborate together to provide wireless service. Long-term collaborative relationships result in fast project development times, lower development and production costs, increased cooperators originated innovation and better product quality. At the same time, it also challenges the cooperators to rearrange their business models in terms of developments, manufacturing, sales, and so on to adapt to the collaborative environments.

PSS conceptual design plays an important role in PSS development, because most life cycle cost and critical performance of a product or service is determined in this stage, and it is very difficult to correct the fundamental shortcomings in the later embodiment and detail design phases [1]. In spite of the pivotal role of conceptual design, companies find it difficult to design a PSS, especially in the collaborative environments where different organizations take charge different components of the PSS. Companies tend to design their components separately, and then an authoritative company or an third party takes on the role of system integrators and integrates the sub-systems into a whole PSS. When the sub-systems are not compatible, redesign is inevitable. Besides, many innovative parts exist in the new developed PSS and the customer requirement changes quickly. Thus, the design cycle of PSS is very long. Although there are some researches dealing with PSS conceptual design approaches [2,3,4], little considered this problem in the collaborative environments. This article adopts the platform design methods and the modular technology to solve the collaborative development of PSS.

In product design area, platform strategies provide sufficient derivative products for the market while maintaining economies of scale and scope within their manufacturing processes. Platform-based product development offers a multitude of benefits including reduced development time and system complexity, reduced development and production costs, and improved ability to upgrade products. Platforms also promote better learning across products and can reduce testing and certification of complex products [5]. Therefore, platform strategies are adopted to assist the system integrators with developing PSSs in the collaborative environments. Evans et al. [6] argues that platform strategies can also be a significant enabler to multi-actor PSS. By considering the product-service system as being made of multiple elements, potentially delivered by different actors and integrated through a platform architecture, it may be feasible to create high-performing PSSs. However, no studies have shown clearly how to develop a PSS platform. This paper is dedicated to answering these questions:

(1) What is a PSS platform? What constitutes a PSS platform?

(2) What is the different among the PSS platform, the product platform and the service platform?

(3) What are the procedures to develop a PSS platform? Are there any methods that can be used to support the development?

(4) How can the platform methods assist the collaborative development of PSS?

2 PSS Platform

2.1 Definition of PSS platform

Synthesizing the definitions of product platform [7], service platform[8] and PSS[9], we define PSS platform as: A set of common assets such as components, modules, parts, processes, knowledge, people and relationships from which a stream of derivative product-service systems can be efficiently developed and launched.

The PSS platform is designed, manufactured and operated in a value created network involved many stakeholders. The PSS provider is the system integrator who develops platform plans, selects cooperative partners, integrates subsystems or modules and offers a whole solution to customers. The customers take a more important and active role in the PSS development. Elaborate requirements and timely feedback help the provider to adjust planning and other partners, ensure the quality of the final solution. Local providers adjust the service contents or frequency to customers' personalized needs. For example, rust-proof is more important in humid areas than arid areas. Local service providers, especially the maintenance centers, usually need components from component manufactures.

2.2 Comparison among PSS platform, product platform and service platform

The main differences among PSS platform, product platform and service platform are the component and interface (see Table 1).

Table 1. Comparison among PSS platform, product platform and service platform.

	Component	Interface
Product platform	Product module, interface	Industry standards determines the interfaces and technologies
Service platform	Service module, interface	Little influence form industry standards
PSS platform	Product module, service module, interface, support system	between the product platform and the service platform

3 The Process of PSS Platform Development

In order to assist PSS providers to develop a PSS platform in a collaborative environment, an integrated approach is proposed (Shown in
Fig. **1**).

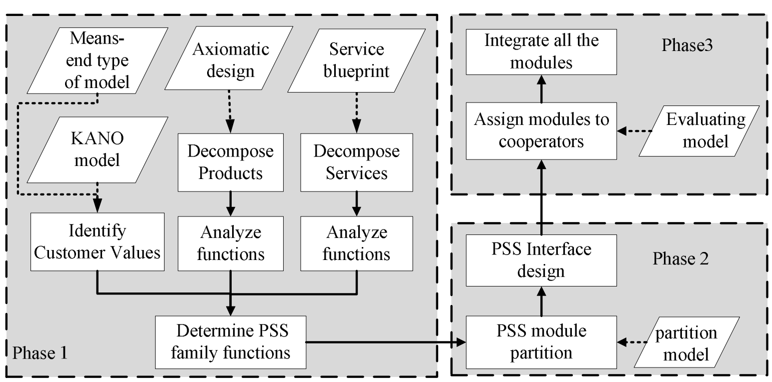

Fig. 1. The process of PSS platform development.

3.1 Phase 1. Determine PSS family functions

A PSS family is a group of individual PSSs that share common subsystems and yet possess specific functional features to satisfy a variety of market niches. A platform may support one or more PSS families. In this paper, we constructed a PSS platform from one product family and relative services. One of the most important objectives of PSS is to maximize the customer value. The customer values must be analyzed before determining PSS family functions. Customer value is a customer's perceived preference for and evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations.

Step 1. Define customer value elements

The means-end type of model is used to capture the customer value. Firstly, customers' goals and purposes are described. Then, considering use situations customers' desired consequences are analyzed. Finally, customer expected value elements are obtained.

Customer value often changes based on time, technology and market niches. These changes will influence the platform's component. Kano model is adopted to classify the customer value elements into basic value elements, expectable elements and adjunctive elements.

Step 2. Analyze the functions of existing products

Axiomatic design has been widely used in new product design, and it can also assist the product redesign[10]. The function decomposition process is a zig-zagging process. Functional requirements (FR) are mapped to design parameters (DP). A product's total FR is first specified, and then the corresponding DP satisfying this FR is found. This DP leads to the analysis of lower lever of FRs. Thus, the product's function is decomposed into a hierarchy structure.

Step 3. Analyze the functions of existing services

Existing services are analyzed by service blueprint. Service is in nature a process thus its function is constructed in the form of a process structure [11].Every action performed by the customers and activity performed by the staff are analyzed to obtain the function.

Step 4. Determine PSS family functions

(1). Construct the mapping matrix between PSS family required function and existing product and service's function (as shown in Fig. **2**). The columns are PSS family required functions obtained in Section 3.1.1, and they are classified into basic functions, expectable functions and adjunctive functions. The rows are functions of existing products and services. If a FR can deliver a customer value element, the corresponding cell is filled with 1.

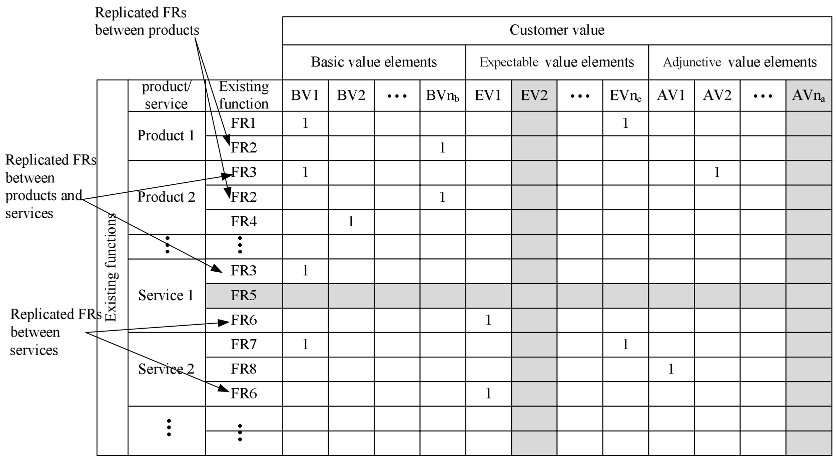

Fig. 2. The mapping matrix between customer value and existing product and service's function (modified from [12])

(2). Check the rows to find the replicated functions, which may be between two products, two services or a product and a service. The first two kinds of replication are caused by the lack of commonality between different products/services in the sense that different components/activities are used to deliver similar functions [12]. These replicated functions should be redesigned to be delivered by uniform components/activities. The replicated functions between products and services should be considered in a different way. In PSS, product and service may support or replace each other, in which situation there is no need to abandon one of them. For example, although both the automatic teller machine and the bank staff can provide accepting deposits service, a bank may retain both of them to serve the customer. Besides, some FRs may have no relation with any customer value elements (see FR5 in Fig. **2**). These functions may no longer be needed by customers, and should be abandoned in the new developed PSS family.

(3). Check the columns to find the value elements which are delivered by no functions, such as EV2 and AVn_a. For basic value elements and expectable elements, new functions should be added to achieve these value elements for all customers, while for adjunctive elements, new functions could be added as optional functions for those customers who are willing to pay for that.

(4). Arrange the remaining functions in step2 and the new functions added in step 3. The functions of new developed PSS family are obtained. Classify the functions into basic functions, expectable functions and adjunctive functions based on their corresponding value elements.

3.2 Phase 2. Modularize PSS

Step 1. Partition PSS module

(1). Product module partition. There are many mature approaches for product partition, such as heuristic methods and clustering methods. This paper will not designate one approach, and the reader can choose any based on the concrete case.

(2). Service module partition. Analyze the correlation coefficient between the service activities from the viewpoint of function correlation, class correlation and process correlation [13]. The function correlation describes the closeness of two activities in achieving the same function. The correlation coefficient has five levels (1.0, 0.7, 0.5, 0.3, 0). The definition of class correlation is that some service activities have the same characteristics, and these activities can be put into the same service groups and form a module, which will facilitate the service management and provide more similar services [13]. The correlation coefficient has four levels (1.0, 0.8, 0.4, 0). The process correlation describe that whether the service activities are continuous or not.

Establish correlation integration analysis matrix, M [13].

$$M=\{m_{ij}\} \quad (1)$$

$$m_{ij}=\sum r_{ij}F_f+\sum r_{ij}F_c+\sum r_{ij}F_p \quad (2)$$

where r_{ij} is the correlation between the service activities respectively. According to the correlation integration analysis matrix, we can calculate the correlation between service activities and get the service module partition scheme at different levels [13].

(3). Determine the basic module, the indispensable modules and optional modules. The modules that deliver the basic functions are basic modules, the modules that deliver the expectable functions are indispensable modules, and the modules that deliver adjunctive functions are optional modules.

Step 2. Design PSS interface

Design the interface between different modules. In a PSS platform, there are three kinds of interface, the interface between product modules, the interface between service modules, and the interface between product and service modules. The interface between product modules has been fully discussed by many scholars [14,15]. This article concentrates on the interface between service modules and the interface between product and service modules. These interfaces are classified into two categories: one is the customer interface, which has direct interaction with customers, and the other is the module interface. Design the customer interface could be performed in the following dimensions: purpose, duration and time delay; breadth and depth of options, nature of contact and media employed [16]. The service blueprint is a good tool to find interactions. The module interface should be designed considering its purpose. For example, designing the interface between product modules and its corresponding maintenance service modules, equipment failure information is important.

3.3 Phase 3. Assign and Integrate modules

After module partition and interface design, the modules detailed design tasks are assigned to cooperators. Lead times, prices, quality, credibility and other factors should be considered when selecting cooperators. The system integrators configure these modules according to customer's requirements.

4 Case Study

This case (crane machine PSS concept evaluation) comes from an engineering machine manufacturer (company H) in Shanghai, which provides overall solution (including product and service) for customers. Company H has five industrial parks in China and four R&D and manufacturing bases in America, Germany, India and Brazil. The main products consist of concrete machinery, excavator, crane machinery, pile driving machinery, road construction machinery, port machinery, and wind turbine. In order to respond rapidly to changing demands in today's competitive markets, company H launched PSS platform plan. The crane machinery PSS with well structured product modularization and extensive service experience is selected as a pilot project. Fig. **3** shows the hierarchical structure of a crane machine. Company H defines the crane machinery characteristics and select appropriate internal and external suppliers for corresponding product modules. The crane machine family has 6 kinds of lifting capacity, 450,500,600,650,900 and 1400 tons, and 28 types of crane machine.

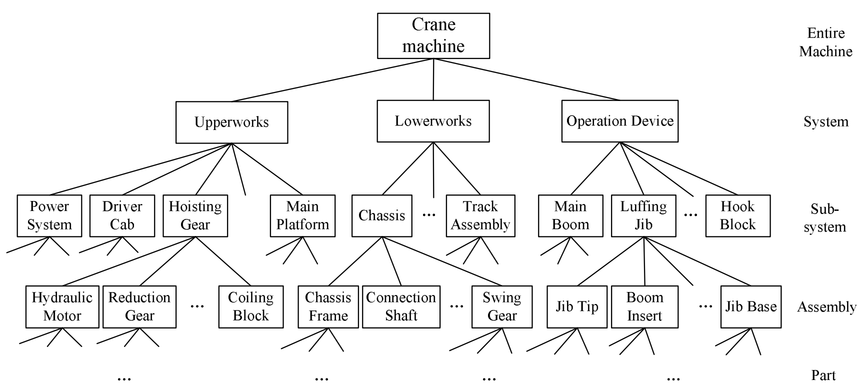

Fig. 3. The hierarchical structure of a crane machine.

4.1 Determine the functions of crane machine PSS

Customer value are collected through survey questionnaire and semi-structured interviews. The value elements are shown in Fig. 4.

Existing product (28 types of crane machine) and services (45 kinds of service) are analyzed to obtain the existing functions. According to the matrix in Fig. 2, some functions are abandoned. For example, the air conditioner is not needed in Indian, and headlight is not needed if the operating time is very shot. Some functions are added. For example, 24-hour rescue service, oil analysis service, and lending service are added to serve the customer. The family functions are as follows: core capability, module reliability, control technology, safety guard, operating mode, environmental protection and energy saving, cramped construction, operating temperature, construction guarantee, maintenance technology, maintenance cost, service professionalism, service timeliness, 24-hour rescue service, oil analysis service, and lending service.

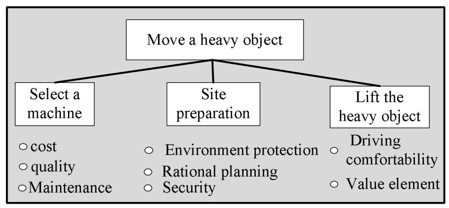

Fig. 4. Value elements of crane machine PSS.

4.2 Modularize the crane machine PSS

The crane machine has been modularized. Thus we only need to divide service modules. Construct the correlation integration analysis matrix between the 45 services (see Fig. 5), such as hydraulic motor maintenance, chassis frame maintenance, operation training service et al. Every element in line i and column j in Fig. 10 represents the correlation between activity i and activity j. For example, the number 0.76 in line 2 and column 3 means that the correlation coefficient is 0.76. This number is the weighted sum of the function correlation, class correlation and process correlation coefficient. This matrix provides a basis for module partition. Activities with bigger correlation coefficient are more likely to be clustered into a module.

After module partition, 8 service modules are obtained: maintenance module, training module, lending module, operating condition analysis module, installation module, transportation module, oil analysis module and pre-sales consulting module. Each module has more detailed modules.

The basic module contains: power system, driver cab, hoisting gear, main platform, chassis, track assembly, main boom, pre-sales consulting module, training module, transportation module, installation module, et al.

The indispensable module contains: hydraulic motor module, auxiliary jib, maintenance module, lending module, operating condition analysis module, oil analysis module et al.

The optional module contains: remote control system, 24-hour rescue service, High pressure warning, the third winding engine, fuel preheating et al.

	1	2	3	4	5	6	7	8	⋯	43	44	45
1	1							0.58			0.6	
2		1	0.76									
3	1		1	0.4						1		
4				1								
5		1			1							
6						1						0.4
7	1						1					
8								1				
⋮					1				1			
43	1							1		1		
44									1		1	
45					1							1

Fig. 5. The correlation integration analysis matrix.

Company H assign these modules to different cooperators, and integrates these modular into a whole solution. After the new developed crane PSS was put on the market, customer feedback was gathered through questionnaires and interviews. The acceptance of the new solution by the users was very high, including comments that they would like the service to continue after the pilot test. Although the cost exceeded the budget, it can be accepted by the company. The practical operating results show that the selected solution is good.

5 Conclusions

As customer requirements become more complicated and change rapidly, platform design is introduced to improve the responsibility of PSS. An integrated PSS platform development approach is proposed in a collaborative environment. The main contributions are as follows:

(1) Platform design is introduced to develop PSS in a collaborative environment. The system integrator designs the PSS platform with basic module, indispensable module, optional module and uniform interfaces. The modules are designed by cooperators separately and integrated by the system integrator.

(2) An integrated PSS platform development approach is proposed based on existing product and service. Customer value is obtained by means-end type of model and Kano model. Existing product/service function is analyzed by axiomatic design and service blueprint. Module partition approach is used to divide PSS.

Future work will concentrate on PSS module partition. When the system become complex, the matrix that represents the interdependent relationship between components or service activities will be too huge to implement the corresponding clustering algorithms effectively. The complex network will be introduced to solve the PSS module partition problem.

Acknowledgment

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