A Product-Service Systems Design Method Integrating Service Function and Service Activity and Case Studies

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Abstract

This paper proposes a design framework of Product-Service Systems (PSS) using both functional modelling and service activities. In the functional modelling of PSS, the function decomposition approach is used with specification of service providers and service receivers. The overall function of PSS is decomposed into various sub-functions and service providers/receivers are also decomposed into sub-providers/receivers, which are later appropriately assigned to sub-functions. Each sub-function is linked with the service activities based on the information on its service providers and receivers. The linkage between sub-functions and service activities is represented in the modified service blueprint through the introduction of the function layer. The pairs of sub-functions and service activities are mapped to product and service elements to produce PSS concepts. Case studies are conducted to confirm the applicability of the proposed methodology for effective PSS design.

Keywords

Product-Service Systems (PSS), Functional Modelling, Service Blueprint, Service Function, Service Activity

1 INTRODUCTION

A number of researches on a novel and innovative value proposition through the integration of products and services – product-service systems (PSS) – have been conducted over the last decade. The concept of PSS has been firstly introduced by Goedkoop et al. in 1999 to deal with the environmental and economical challenges, and it was defined as a marketable set of products and services, jointly capable of fulfilling a client's need [1]. In their research work, the advantages of PSS were also discussed such as creating value of clients with quality and comfort, customizing offers or delivery of the offer to clients, decreasing the cost of initial investment by sharing, leasing and hiring, decreasing environmental load, and so on. Mont also defined PSS as a system of products, services, supporting networks and infrastructure that is designed to satisfy customer needs and have a lower environmental impact than traditional business models [2, 3]. In addition, a theoretical framework for PSS reflecting societal infrastructure, human structures and organizational layouts was proposed to enhance environmental values.

The research on the methodological framework to design PSS from the views of designers was conducted by Morelli [4]. The case study for the development of PSS – an urban telecenter – was carried out. In the case study, the major functions and requirements for the PSS were extracted, and they were then mapped to the elements of products and services. Aurich et al. researched the life-cycle oriented design processes of products and services [5]. They proposed the systematic design process of technical services associated with products, which would be later integrated with the product design process. They also introduced the concept of process modularization for integrating of product and service design processes by selecting, combining and adapting appropriate process modules [6]. Matzen and McAloone proposed a tool for conceptualizing the development of PSS by introducing the activity modelling cycle (AMC) model to address many issues identified as central for PSS development [7]. They investigated the effectiveness of the AMC model by conducting case study on service delivery in the container ship industry. In their more recent work, they structured modelling scheme to differentiate and categorize different development tasks towards product/service oriented business with the case study of maritime equipment [8].

Shimomura et al. have conducted substantial research on service engineering [9-13]. They introduced the service model, including several sub-models such as flow model, scope model, view model and scenario model, and receiver state parameters (RSPs) representing value and cost to be implemented into the service design process. They also developed the prototype system as the computer-aided design tool for service design, which was called Service Explorer. Their concept was borrowed by Maussang et al. to develop the model for designing PSS [14]. They modified engineering product design process into PSS design process by introducing the service model of Shimomura's group. In their case study, the feasibility of the proposed method based on functional analysis and agent-based value design was examined by considering the bike rental system – Velo'v. In more recent work, Maussang et al. proposed the modified PSS design method incorporating users' activity and operation sequence [15]. They also studied the evaluation of PSS concepts in the early design phase.

Although considerable researches for the effective design of PSS have been conducted, none of the above research works have presented any systematic approach to address functions of PSS. Functions could be regarded as the neutral term to realize the values to satisfy the customer needs, which could be of much significance to effectively realize PSS. In the product design domain, the considerable research works have been conducted to address functional modelling and analysis. The verb-noun pair expression of functions was firstly proposed by Miles [16] and Rodnacker [17]. They considered the product functionality to develop the functional representations and models of transformations of energy, material and information flows. Koller then proposed twelve basic functions to describe the product functionality [18], and Hundal refined Koller's work to produce the set of function

and flow classes [19]. To provide the universal language for the functional modelling, the research efforts to propose the standardized sets of functions and flows have been made by Szykman [20] and Stone [21]. Their works were later reconciled by Hirtz et al. to result in the Functional Basis [22]. Nagel et al. proposed the function design framework combining process and function modelling to deal with complex systems [23].

On the other hand, a number of parallel researches on the development of functional modelling techniques could be found. Umeda and Tomiyama proposed the Function-Behavior-State modelling approach to reflect the designers' intent when addressing behaviour as the realization of the function [24]. The Function-Behaviour-Structure framework was proposed by Gero to represent various steps in the design process and capture associated transformation among these three classes [25]. He also extended the above framework into the situated Function-Behaviour-Structure to reflect dynamic context related to the environment [26]. In Gero's research works, the concept of behaviour was regarded as more detailed descriptions of high-level functionality. The mappings from function to behaviour to physical structures were addressed in Gero's research.

In PSS design, due to the nature of its service elements, associated service activities should be considered as well as functions. Therefore, in this paper, a design framework of PSS including both functional modelling and service activities is proposed. In the functional modelling of PSS, new scheme to represent the function of PSS adding service provider and service receiver will be proposed. The overall function and service provider/receiver will be decomposed into sub-functions and sub-service providers/receivers, and they are appropriately associated to each other. The modified service blueprint will also be proposed by adding the layer of functions and relating them with various activities of service providers and receivers. In addition, PSS concept generation scheme will be addressed by borrowing the notion of morphological chart. In PSS concept generation template, functions, service providers/receivers, service activities and product/service elements are combined together to effectively generate the alternative PSS concepts. Finally, the case study on handcrafting PSS design is conducted to examine the applicability of the proposed methodology for effective PSS design.

2 FUNCTIONAL MODELLING OF PSS

PSS design can be different from the product design since it involves the service elements. It has been known that service greatly involves the human elements [27]. In addition, the service usually requires providers and receivers, and its quality and contents highly depend on their interactions. Therefore, it is necessary to include the information of service providers and receivers in the functional modelling of PSS. The functional language used in the PSS functional modelling was the Reconciled Functional Basis proposed by Hirtz et al., which was such an example including the standardized sets of functions and flows [22].

The representation scheme for the functional modelling of PSS is shown in Figure 1. As can be seen in Figure 1, three flow classes – energy, material and information – are still used to connect the function blocks, which is similar to the case of product design. Function classes used in this framework are also same as those in the reconciled functional basis. The service provider and service receiver are represented as folded lines in upper left corner and lower right corner of the function block, respectively.

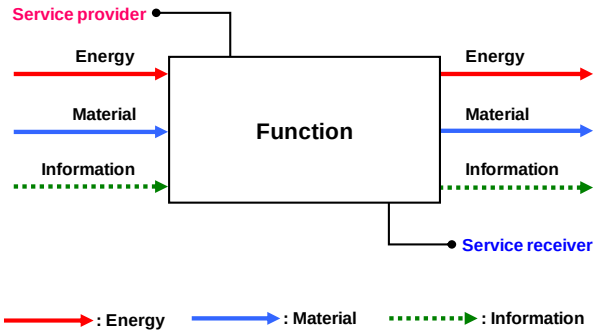


Figure 1: Schematic of Functional Modelling of PSS

Once the overall function is defined, the decomposition into the related sub-functions will be conducted, and the associated flows connect the sub-function blocks based on their causal and logical relations. These causal and logical connections among the sub-function blocks can later be used to define the PSS components or functional modules. The procedures for the PSS function decomposition are similar to those in the case of the product design. The illustrative example of the function decomposition diagram is shown in Figure 2. Several sub-function blocks can be grouped together to form a function module. As can be seen in Figure 2, the sub-function blocks are connected via three flows, and therefore, these flows could play an important role for building up the interfaces among product and service elements in the whole PSS. The functional modelling framework can facilitate the arrangement of product and service elements to produce various PSS concepts. When overall function of service is decomposed, the service providers and receivers are also decomposed. As can be seen in Figure

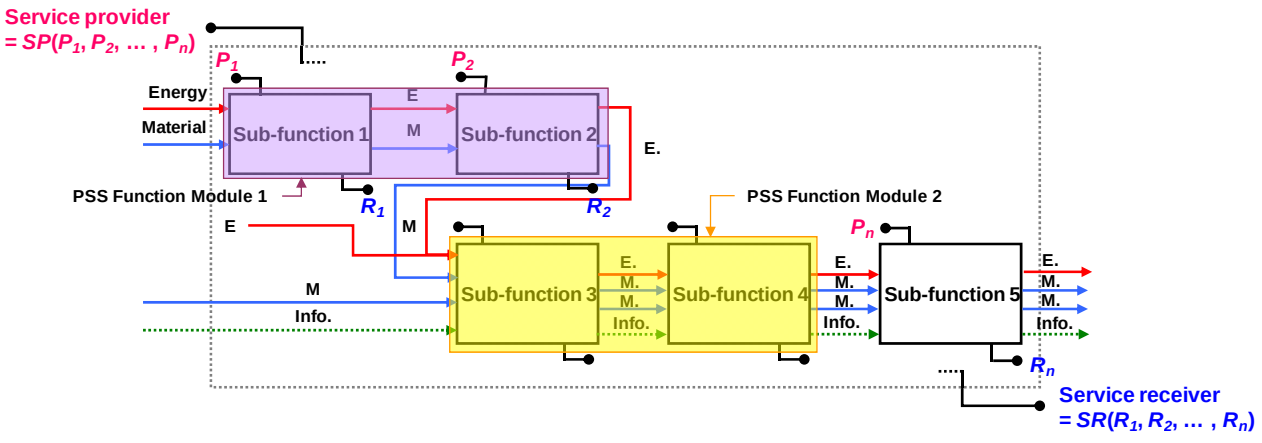


Figure 2: Function Decomposition of PSS and Functional Module Grouping

2, each block of sub-functions has its own service provider and receiver, which are elements of sets of overall service provider (SP) and service receiver (SR). They are called by sub-service providers and sub-service receivers, and appropriately assigned to sub-function block.

3 SERVICE BLUEPRINT AND SERVICE ACTIVITIES

The concept of service blueprint was originally proposed by Shostack to describe service roadmaps [28]. In the service blueprint, how and where customers (Service Receiver, SR) and employees of company (Service Provider, SP) interact is tangibly and visually documented. More specifically, the service blueprint is an information-laden document which consists of five components, and can help make customer-company relationship clear. The five components in the service blueprint are customer actions, onstage/visible contact employee actions, backstage/invisible contact employee actions, support processes and physical evidence. Those five components are arranged into the table form, which is shown in Figure 3.

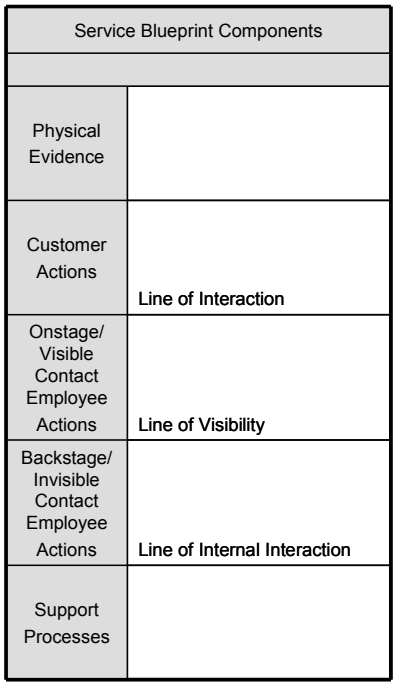


Figure 3: Service Blueprint Schematic Diagram [28]

Customer actions include all of the steps that customers take as part of the service delivery process. Onstage/visible contact employee actions are the actions of frontline contact employees that occur as part of a face-to-face encounter with customers. Backstage/visible contact employee actions are non-visible interactions with customers, such as telephone calls, as well as other activities employees undertake in order to prepare to serve customers or that are part of their role responsibilities. Support processes are all activities carried out by individuals in a company who are not contact employees, but whose functions are crucial to the carrying out of services processes. Physical evidence represents all of the tangibles that customers are exposed or collect to during their contact with a company.

In the traditional service blueprint schematic diagram, the interactions between customer actions and onstage/visible employee actions are expressed as a single line. However, the connection of activities between service provider and receiver can be made more clearly by introducing functions, since they establish the relationship between service provider and receiver, which is shown in Figure 1. Therefore, in the modified service blueprint, the function layer was inserted between service provider activity and on-stage service receiver activity. In addition, the component of physical evidence was also modified into the layer of product and service elements to effectively generate PSS concepts by linking them with functions and activities. The schematic diagram of the modified service blueprint is shown in Figure 4. As can be seen in Figure 4, the interactions between SR activity and on-stage SP activity can be described by the function layer.

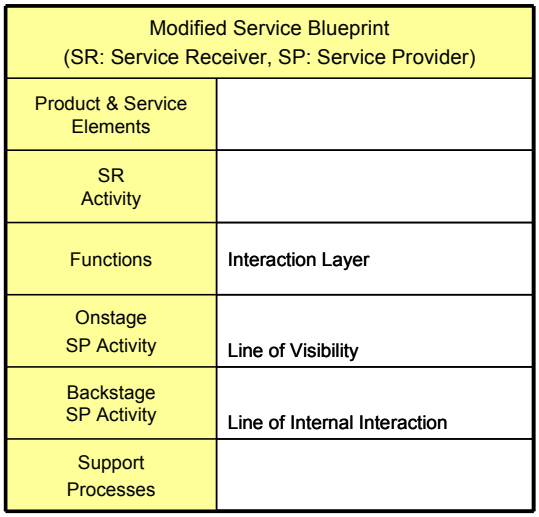


Figure 4: Modified Service Blueprint Schematic Diagram

4 PSS CONCEPT GENERATION

In the case of PSS concept generation, function, service provider/receiver, service activities and product/service elements should be considered as a whole, which is much different from the case of product design. Therefore, the template to generate alternative PSS concepts integrating above components was proposed by borrowing the notion of morphological chart, which is shown in Figure 5. In this template, functions, service providers/receivers, service activities and possible product/service elements can be combined together to generate several alternative PSS concepts. In the column of product/service elements, the regular rectangles mean product elements, and the rounded rectangles denote the service elements.

The functions in the PSS concept generation template are identified from the functional modelling framework described in section 2. Possible service providers and receivers are assigned to the function, and the appropriate service activities are mapped to service providers and receivers, respectively. Finally, potential product and service elements are associated with the service activities to generate the PSS concepts.

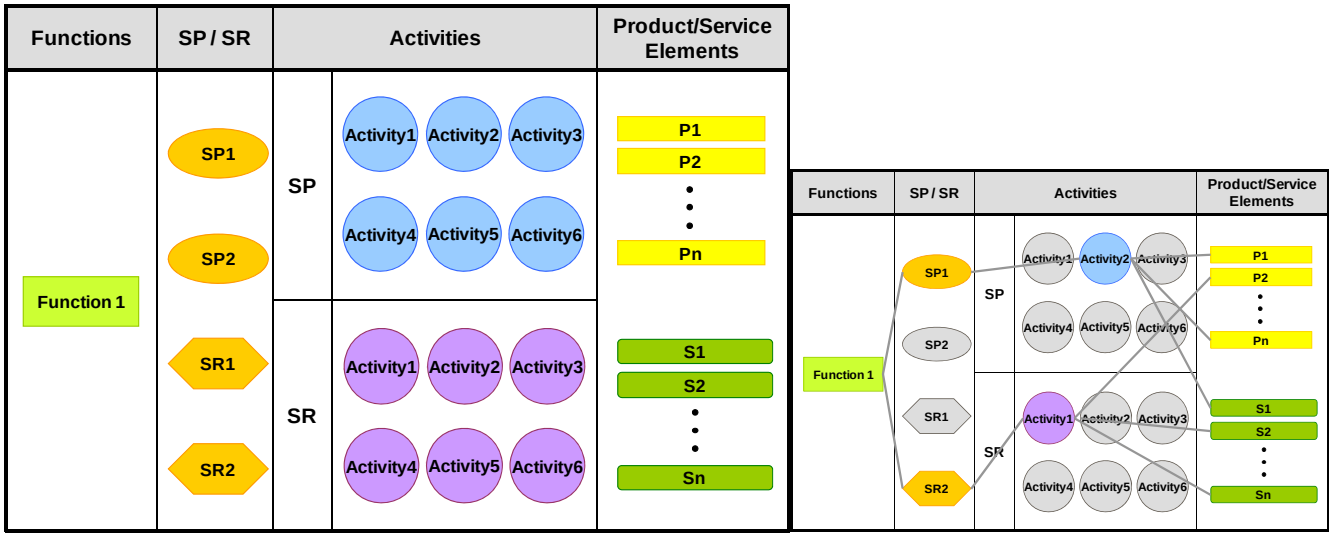


Figure 5: PSS Concept Generation Template and Mapping for PSS Concept Generation

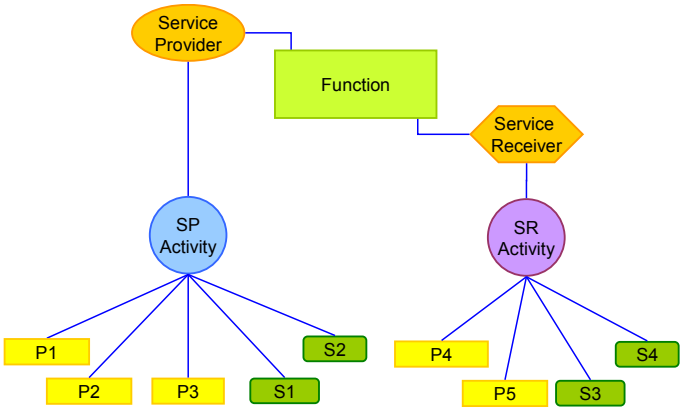


Figure 6: Schematic Representation of PSS Concept

The schematic diagram of the PSS concept was also developed to effectively represent the relationship among functions, service providers/receivers, service activities, and product/service elements, which is given in Figure 6. The schematic given in Figure 6 can systematically represent the structure of the PSS concept, and help understand the components consisting of the PSS concept and their relations.

5 CASE STUDY: HANDCRAFTING PSS

To examine the effectiveness of the proposed PSS design framework, the case study to design handcrafting PSS was conducted. In the handcrafting PSS, the customers' need to carry out handcrafting work can be satisfied in various ways

5.1 Functional Modelling

The overall function of the handcrafting PSS was defined as "provide handcrafting service", as shown in Figure 7. The input and output flows were listed according to the classes of energy, material and information. The service provider was defined as "handcrafting PSS management" and service receiver was defined as "handcrafting PSS service receiver". The function decomposition of the overall function of the handcrafting service was conducted and is shown in Fig. 8. As can be seen in Fig. 8, critical sub-functions are appropriately arranged and connected according to the logical relations of flows. In addition, the service provider and receiver were decomposed into sub-service providers and receivers and appropriately assigned to each sub-function block. For instance, when considering the function of "process handcrafting work", the service provider and receiver were handcrafting service station and customer, respectively. These sub-service provider/receiver were subset of overall service provider and service receiver. The PSS function modules could also be generated by grouping several sub-function blocks, as shown in Fig. 8. Seven (7) PSS function modules were identified such as reservation module, import module, handcrafting service provision module, export module, procurement module, cleaning module and repair module. The grouping of sub-function blocks could be conducted by considering logics of flow connections, sub-service provider/receiver, and so on.

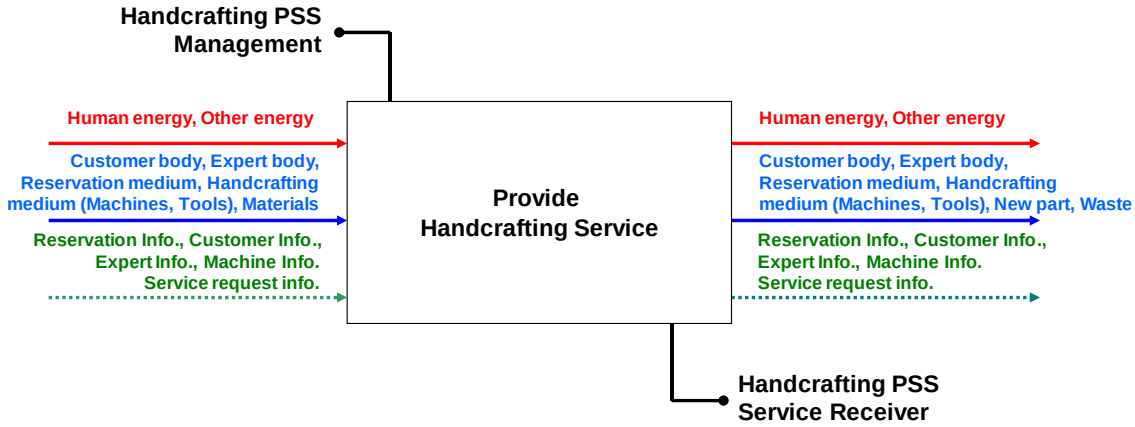


Figure 7: Overall Function and Associated Input/Output Flows of Handcrafting PSS

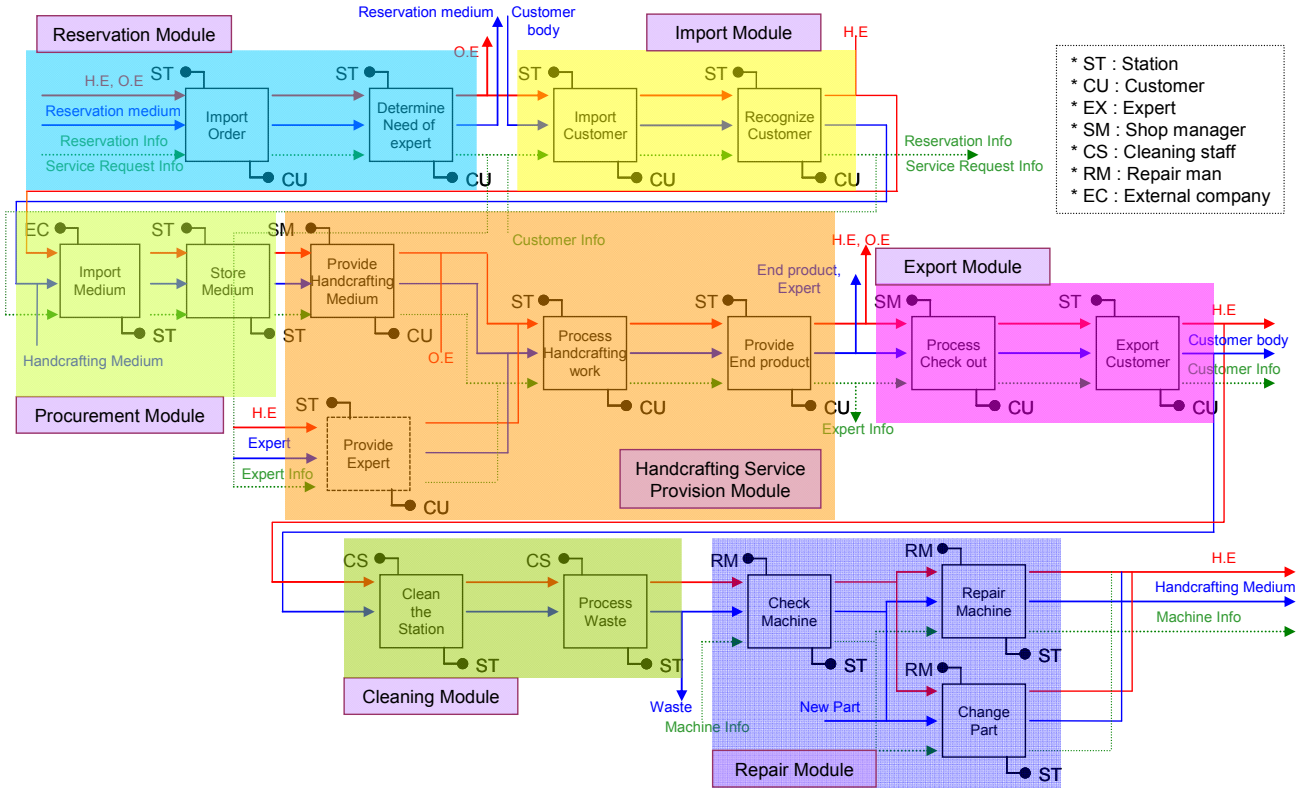


Figure 8: Function Decomposition of Handcrafting PSS and Functional Module Grouping

5.2 Service Activities and Modified Service Blueprint

Possible service activities of customer and service provider of the handcrafting PSS were listed, and they were mapped with the functions identified from the functional modelling. Figure 9 shows the modified service blueprint for the handcrafting PSS. For simplicity, the layer of product/service elements was omitted. When closely observing the modified service blueprint, the critical relationship among functions and service activities can be identified. In addition, the elements in the support process were related to the activities of service provider. For instance, the part of service blueprint corresponding to the handcrafting service provision module is given in Figure 10. As can be seen in Figure 10, four (4) sub-functions consisted of the handcrafting service provision module, and each sub-function was associated with the activities of customer and service provider, and the activities of service provider were related to the system in support process. Specifically, in Figure 10, the function of "provide expert" was linked to the customer activities of "receive expert service" and "use machine" and the service provider activities of "provide expert", "provide professional help" and "call expert". These service provider activities were associated with "expert provision system" in the support process. These relations can allow the designers to know which service activities should be considered to realize specific functions of PSS.

5.3 PSS Concept Generation

To generate alternative PSS concepts, the PSS concept generation template given in Figure 5 was used in the case study. In particular, the case study was focused on the generation of PSS concepts corresponding to the sub-functions of the handcrafting service provision module. The PSS concept generation template for the handcrafting services provision module is given in Figure 11. As can be seen in Figure 11 (a), in each column, functions, service providers and receivers, activities and product/service elements were located, respectively.

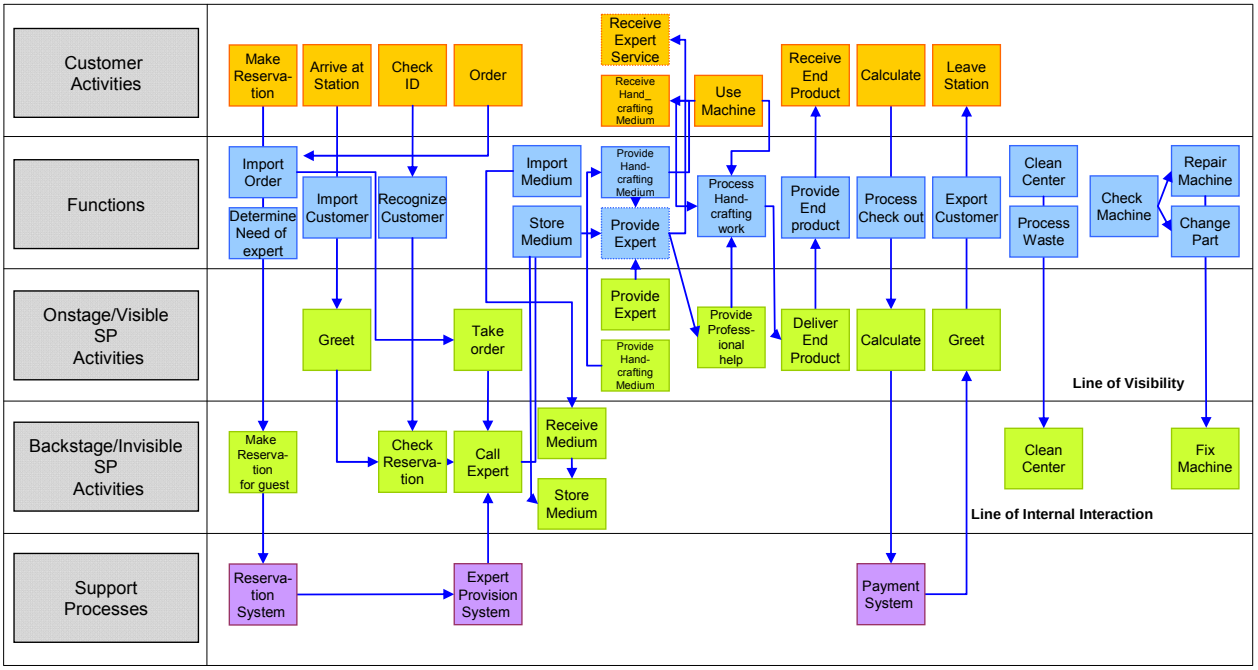


Figure 9: Modified Service Blueprint of Handcrafting PSS

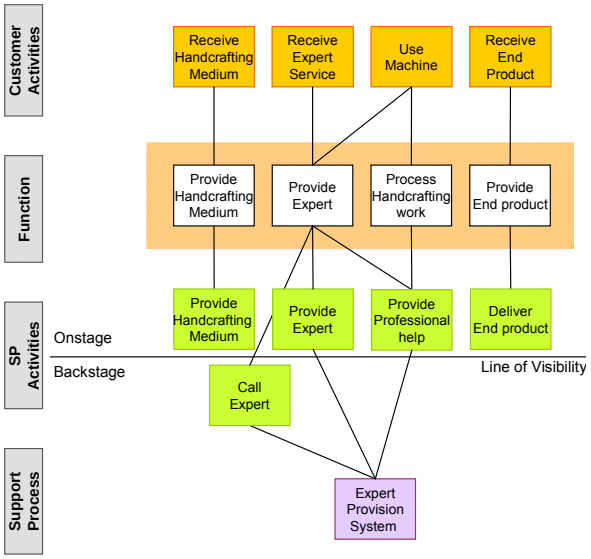


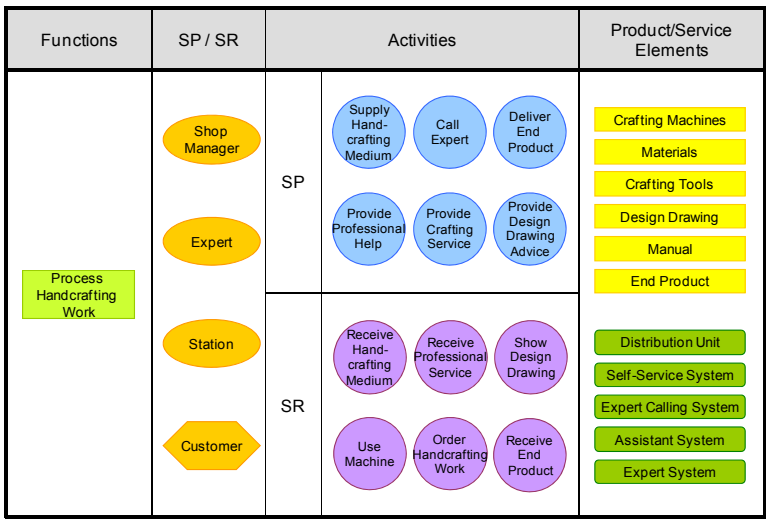
Figure 10: Part of Modified Service Blueprint: Handcrafting Service Provision Module

For each function, specific service provider and receiver would be selected from the template. Then, possible activities were assigned to service provider and receiver. Finally, the product and service elements were mapped to the activities. The various combinations of function, service provider/receiver, their activities and product/service elements would become the PSS concepts. In Figure 11 (b) and (c), the generation of two alternative PSS concepts realizing the function of "process handcrafting work" is illustrated.

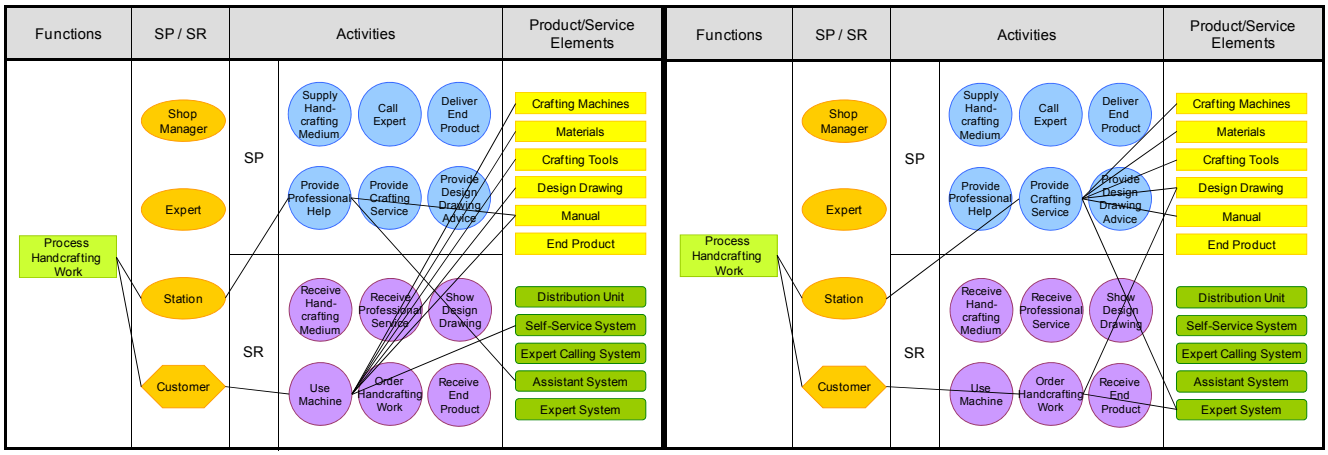
In the case of the PSS concept 1 shown in Figure 11 (b), the customer uses the crafting machine, tools and materials to conduct his/her own crafting work with the help from an assistant system of the handcrafting service station. In this concept, the activity of "provide professional help" was related to the service provider of "station", and the product element of "manual" and the service element of "assistant system" were associated with the activity. On the other hand, the activity of "use machine" was mapped to the service receiver of "customer" and was related to the product elements of "crafting machine", "crafting tools", "materials", "design drawing" and "manual" and the service element of "self-service system". The corresponding schematic representation to the PSS concept 1 is given in Figure 12 (a).

In the case of the PSS concept 2 given in Figure 11 (b), the customer asks the station fully complete crafting service to produce an end product. In this concept, the customer places an order of crafting service through expert system, and the station then conducts complete crafting work using crafting machine, crafting tools and materials based on the design drawing provided by customer. Therefore, the schematic diagram corresponding to the PSS concept 2 is given in Figure 12 (b). As can be seen in Figure 12 (b), the activity of "order handcrafting work" was mapped to customer and the product element of "design drawing" and the service element of "expert system" were assigned to that activity. In addition, the activity of "provide crafting service" was mapped to the service provider of "station" and was associated with the product elements of "crafting machine", "crafting tools", "materials", "design drawing" and "manual and the service element of "expert system".

As can be seen in Figure 12 (a) and (b), the different mapping of the activities to the service provider/receiver and product/service elements to the activities makes two PSS concepts distinctive. With this kind of diverse mappings, various PSS concepts could be generated. In addition, the different service elements such should be introduced and appropriately assigned to the activities to effectively develop each concept.

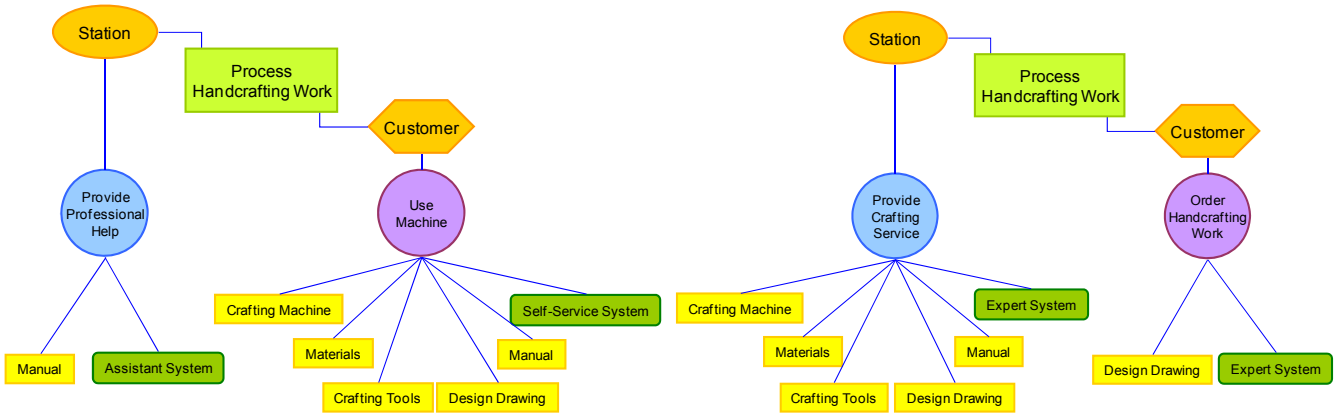


(a) PSS Concept Generation Template for Handcrafting Service Provision Module



(b) Generation of PSS Concept 1 (c) Generation of PSS Concept 2

Figure 11: PSS Concept Generation Template: “Process Handcrafting Work”



(a) PSS Concept 1 (b) PSS Concept 2

Figure 12: Schematic Representations of PSS Concepts Corresponding to Function of “Process Handcrafting Work”

6 SUMMARY

This paper proposed a PSS design framework incorporating functional modelling and service activities. In addition, a novel PSS concept generation scheme combining functions, service providers/receivers, service activities and product/service elements was proposed.

In the functional modelling of PSS, a new representation scheme of function was devised by adding service provider and service receiver. The function decomposition approach was also applied to obtain critical sub-functions and sub-service providers/receivers.

While considering service activities of PSS, the layer of functions identified from the functional modelling was inserted, resulting in a modified service blueprint. The modified service blueprint could help clarify the interactions between service providers and receivers, which could be of much significance in the PSS design.

A new PSS concept generation template was also proposed. This template enabled the systematic mapping

among functions, service providers/receivers, service activities and product/service elements. As a result, several alternative PSS concepts could be generated. In addition, a novel schematic diagram representing PSS concept was developed to effectively investigate the structure of PSS concepts by understanding its components and their relations.

In order to verify the applicability of the proposed PSS design framework, the case study on designing handcrafting PSS was conducted. The results from the case study confirmed the usefulness of the proposed PSS design framework.

7 ACKNOWLEDGMENTS

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