DESIGN SUPPORT TOOLS FOR PRODUCT-SERVICE SYSTEMS

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ABSTRACT
This paper discusses design support tools for product-service systems (PSS). During PSS design process comprising six phases such as requirement identification and value targeting, stakeholder activity design, PSS function modelling, function-activity mapping and PSS concept generation, PSS concept detailing and PSS concept prototyping, various design methods are used and many associated design information should be properly handled. Therefore, in this paper, the design support tools such as PSS DesignScape, life-cycle step modelling, stakeholder modelling, requirement modelling, PSS scenario generation, activity modelling, PSS function modelling, modified service blueprint and PSS representation are described. Sample case study is also conducted to demonstrate the effectiveness of developed design support tools for PSS.

Keywords: Product-Service Systems (PSS), PSS Design Process, PSS Design Support Tools, PSS DesignScape, Activity Modelling Tool, PSS Function-Based Design Tool, PSS Modified Service Blueprint Tool

1 INTRODUCTION
Product-Service Systems (PSS) has recently drawn significant attention since it can effectively address diverse values of consumers by integrating products and services. PSS was firstly introduced by Goedkoop et al., and they defined PSS as a marketable set of products and services, jointly capable of fulfilling a user's need [1]. In addition, PSS has been defined 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 and as an integrated body of products and services and communication strategies that was conceived, developed and promoted by (a network of) actors to generate values for society [2, 3].
As previously remarked, PSS can be complex systems, and there have been some research works to develop systematic methods and tools to support PSS design. Morelli has been a leading researcher to devise lots of design methods and tools for PSS. He has been studying the design framework considering major functions and requirements and then mapping them with the elements of products and services [4]. PSS design method involving a life-cycle oriented view was studied by Aurich et al. and they proposed the concept of technical services related to products [5]. Much research on service design methods has been conducted by Shimomura's group in their service engineering research [6-8]. In their service model, flow model, scope model, view model and scenario model were included, and a receiver state parameter (RSP) was also defined to describe value and cost. More recently, they studied the PSS development method incorporating functions, service activities, product behaviors and attributes of entities with the avoidance of conflicts [9].
To effectively support design process and manage associated design information, the computerized design support tools have been developed. There were two representative examples such as a design repository system and Service Explorer. A design repository system was developed to support product design process by Bohm and Stone [10, 11]. Their design repository system archived a number of product data with functions and flows. With their design repository system, designers can easily search products realizing specific functions and can come up with various design concepts more effectively. In the service engineering research of Shimomura's group, the computerized system, referred to as Service Explorer, was developed to support service design [12]. In Service Explorer, they could understand and represent service target, describe realization structure and evaluate service.
The Creative Design Institute at Sungkyunkwan University has proposed the PSS design process and it involves many complicated issues including stakeholders, requirements, values, activities, functions,

product/service elements, and so on [13]. Therefore, it is necessary to develop proper support tools for effective PSS design to manage a number of design information during the PSS design process.
In this paper, we discusses various design support tools for PSS such as PSS DesignScape, life-cycle step modeling, stakeholder modelling, requirement modelling, PSS scenario generation, activity modelling, PSS function modelling, modified service blueprint and PSS representation. In addition, the case example is presented to confirm the applicability of the developed computerized design support tools for PSS development.

2 PSS DESIGN SUPPORT TOOLS

We proposed the systematic PSS design process with six procedural phases such as (1) Requirement Identification and Value Targeting, (2) Stakeholder Activity Design, (3) PSS Function Modeling, (4) Function-Activity Mapping and PSS Concept Generation, (5) PSS Concept Detailing and (6) PSS Concept Prototyping [13]. In this PSS design process, various design tools and methods are generally needed.
Fig. 1 schematically shows the associated design tools during PSS design process for generation of a new PSS from a single product. As can be seen in Fig. 1, a specific product is selected and the life-cycle step (LCS) analysis is carried out to address a number of requirements of various stakeholders. In the life-cycle step analysis, the life-cycle steps on the selected product are defined, and related stakeholders are identified for each step. The requirements of all stakeholders at each step are then explored, and they are mapped with E3 value framework, which consists of economical, ecological and experience aspects [14]. After investigating stakeholders and requirements, the set of target LCS and values are identified. In this life-cycle analysis, the tools for life-cycle step modelling, stakeholder modelling and requirement modelling are needed, as can be seen in Fig. 1.

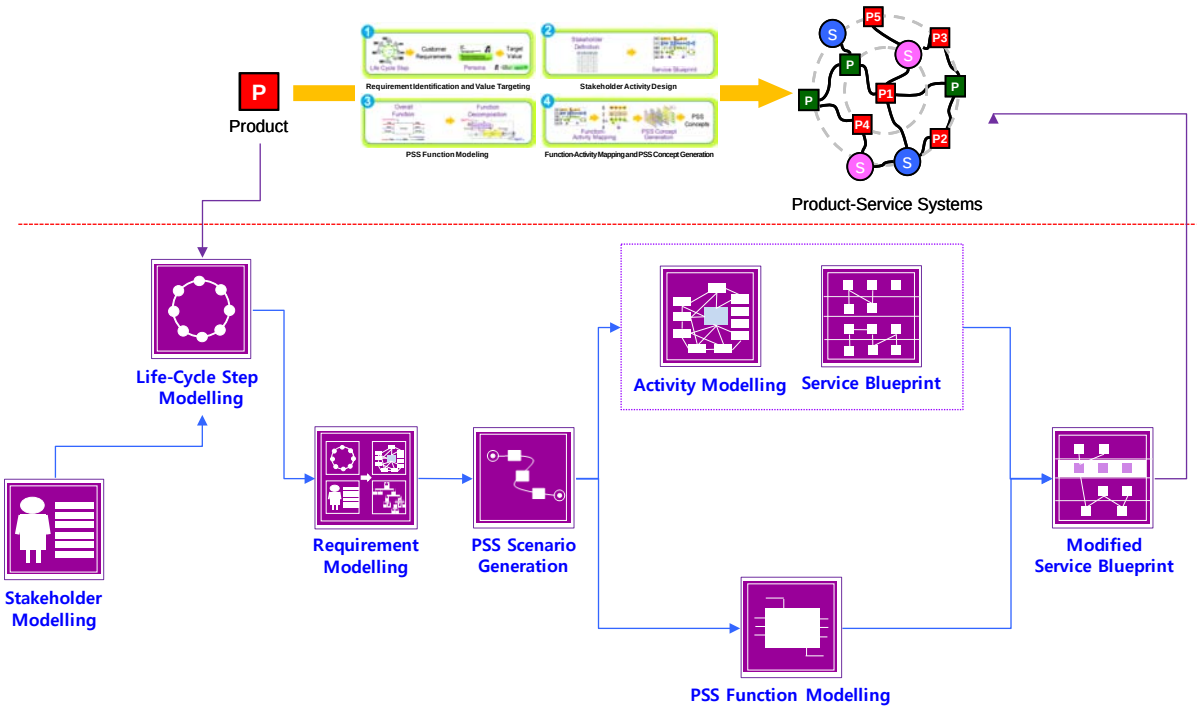


Fig. 1 Schematic diagram of design support tools for PSS design process

Once the target LCS and values are identified, a current scenario of PSS involved the selected product in the beginning is explored with the PSS scenario generation tool. In this phase, the activities of related stakeholders are modelled by using the context-based activity modelling tool, and their relations are visualized and analyzed by the service blueprint tool. During this phase, new stakeholders and activities reflecting target values can be added to explore the possibilities to enhance current PSS or to generate new PSS.
In order to support various activities of stakeholders, critical functions of product and service elements should be properly addressed. Therefore, the definition of overall function of PSS and subsequent

function decomposition should be conducted with the PSS function modelling tool. The critical sub-functions derived from function decomposition also have their own stakeholders as sub-service providers and sub-service receivers. To realize these functions, appropriate product/service elements are explored and they are properly configured.
The activities and functions obtained from previous phases are associated in the modified service blueprint tool having the function layer between customer activity layer and service provider activity layer. In the modified service blueprint tool, stakeholders and activities to be related to specific functions can be added and located in diverse way, and as a result, alternative PSS concepts can be created, analyzed and compared.
The abovementioned various tools are needed for effectively handling a great number of information generated during PSS design process. More detailed descriptions on design support tools will be given below.

2.1 PSS DesignScape Tool

To effectively support entire PSS design process, PSS DesignScape tool was proposed. PSS DesignScape helps designers to access all individual design support tools during PSS design process. It can also visualize and capture various PSS design process information, and can be used for manage and review whole PSS design process. PSS DesignScape tool can capture and visualize designers' information, design projects' information, design process patterns, design information usage patterns, and so on. For instance, whenever designers finish a period of distinct design process, they can capture their design information. They can also code their activities based on the coding scheme of PSS design process. This system can keep track of all the information, and store them into a form of XML file. Once designers terminate the capturing tool, the visualization tool gets ready to display the design process. The design process is represented as a successive chain of color rectangle nodes along the timeline.

2.2 Life-Cycle Step Analysis Tool with Stakeholder and Requirement Modelling

In the LCS analysis, once a specific product is selected, its life-cycle steps, stakeholders and requirements are mainly considered. Therefore, to support this design activity, generation, view, modification and deletion of each item should be possible. Fig. 2 shows the schematic view of life-cycle step modelling, stakeholder assignment to each life-cycle step and requirement identification of each stakeholder at specific life-cycle step. This schematic view represents the requirements of the stakeholder of "clothes store manager" in the life-cycle step of "sale/purchase" in pre-phase.

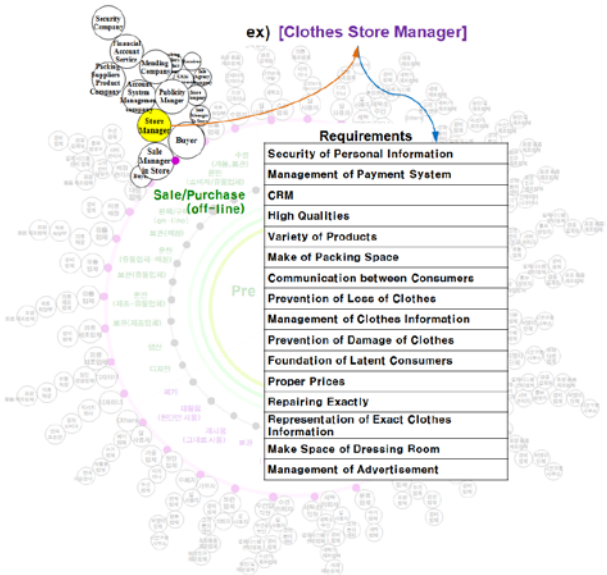


Fig. 2 Schematic view of requirement modelling – case: clothes

The generation of stakeholders can be supported by independent design support tool, referred to as a stakeholder modelling tool that includes a number of various stakeholders and their attributes. Similarly, a requirement modelling tool can also be needed to properly express and manage

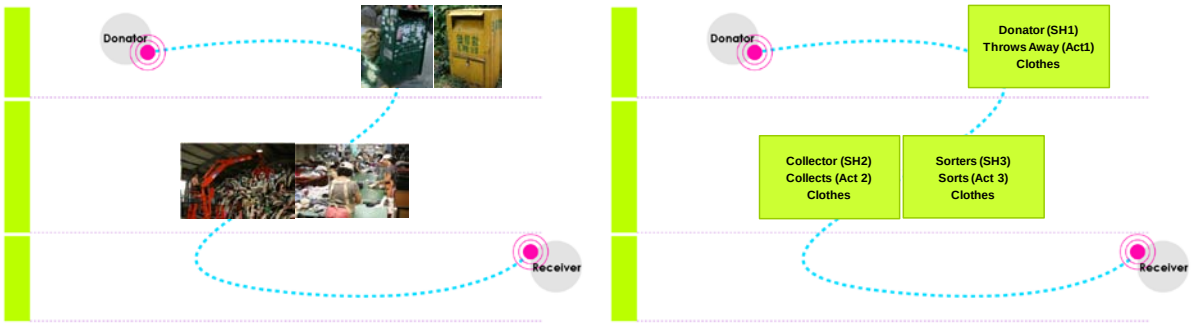
requirements. The requirements can be represented as activity, value and user keywords, and they are tagged with PSS, LCS, stakeholder and E3 values.
E3 value assignment to requirements can be conducted by the E3 value framework [14]. Each requirement can have the attributes of multiple E3 values, and the degree of strength of each E3 value can be different. Therefore, some values can be considered as “strong” and others as “medium” or “weak”. This procedure can be done with a tabular form, which is shown in Table 1.

Table 1 Template for assigning E3 values to requirements (S: strong, M: medium, W: weak)

R	Economic Value	Ecological Value	Experience Value					
			Extrinsic		Intrinsic			
			Functional	Extrinsic social	Emotional		Intrinsic social	Epistemic
					Active	Reactive		
R1	S		W				M	
R2		S		M	W			
…								
Rn	W	M			S			

2.3 PSS Scenario Generation Tool

The current PSS involving the selected product can be analyzed by building up corresponding scenario. The PSS scenario generation tool can help designers to analyze current PSS and to create new or enhanced PSS. In this tool, the scenario can be represented as the sequence of images for intuitive understanding of designers, which is shown in Fig. 3(a). In addition, as can be seen in Fig. 3(b), the images can be replaced with stakeholder-activity pairings for the scenario representation, and there exists three stakeholders and associated activities for the case of the used clothes bin PSS.
This PSS scenario can be redrawn in the service blueprint [18], which generally describes the interactions among activities. In addition, the activities can further be modelled by the context-based activity model, which is described in next section.



(a) (b)

Fig. 3 PSS scenario representations in the case of a used clothes bin PSS: (a) image representation, (b) stakeholder-activity representation

2.4 Activity Modelling Tool

The activities given in Fig. 3 are modelled by the context-based activity model. In the context-based activity model, the activity is more detailed with its diverse contexts. To appropriately describe activities in more detail, the context-based activity model has been proposed [13] by borrowing some meaningful elements from [15], and its schematic diagram is given in Fig. 4.
In the context-based activity model, there are seven elements such as Activity, Actor, Object, Tool, Event, Context and Environment. The element of “activity” is defined by a goal-oriented behavior of “actors”, and the “actor” is composed of “active actor”, “passive actor” and “third-party actor”. The “object” is the subject of “activity” and “tool” is a means to achieve the goal. The element of “event” drives and changes the “activity” in the various “context”. The element of “context” consists of goal context, relevant structure, physical context and psychological context. The “activity” occurs in the “environment”, which includes inner space, outer space and virtual space.

The context-based activity model can help designers to come up with different activity concepts by changing its elements. Therefore, the computerized tool can be helpful to generate, modify and store various activities. Based on the context-based activity model given in Fig. 4, the Activity Modelling Tool (AMT) was developed, and various activities in PSS scenario given in Fig.3 could be modelled with the developed AMT.

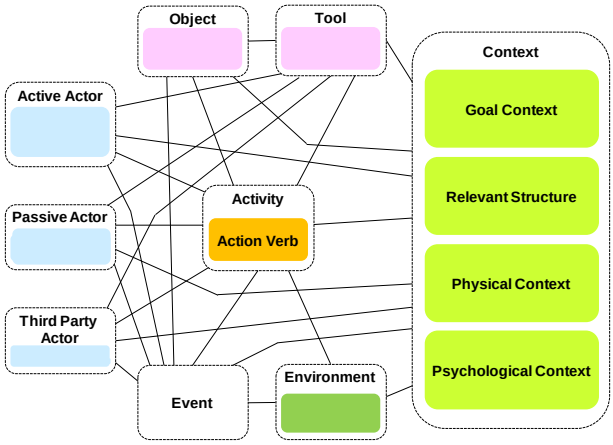


Fig. 4 Context-based activity model [13]

2.5 PSS Function Modelling Tool

To appropriately support stakeholders' activities, critical functions should be defined. In addition, associated overall service provider and receiver are defined and they are represented as the block. For each function block, input and output flows are defined in the categories of energy, material and information. The overall function and overall service provider/receiver are decomposed into sub-functions and sub-service providers/receivers, and each function can play an important role to be mapped to suitable product/service elements. These operations can be conducted in the developed PSS functional modelling tool, referred to as PSS Function Based Design (FBD) tool.

2.6 PSS Modified Service Blueprint Tool

Alternative PSS concepts can be created by combining functions and activities in the modified service blueprint. These functions and activities are obtained from PSS functional modelling and stakeholder activity design, respectively. The modified service blueprint was proposed by inserting the layer of functions between customer activity layer and service provider activity layer of the traditional service blueprint. As previously discussed, the PSS function has its own service provider and service receiver, and therefore, this stakeholder information of function enables designers to link functions and activities. With the modified service blueprint, alternative PSS concepts can be generated and compared by mapping and locating different activities that are conducted by different stakeholders to realize same functions.

The computerized PSS modified service blueprint tool was developed. The activities are obtained from the PSS scenarios generation tool and AMT, and the functions are imported from the PSS FBD tool. In the PSS modified service blueprint tool, activities, stakeholders and functions can be added, deleted, modified, reordered and reconnected to generate alternative PSS concepts. Then, the generated PSS concepts are translated into new PSS scenarios in the PSS scenario generation tool.

2.7 PSS Representation Tool [16]

The critical sub-functions should be realized as sub-PSS. This sub-PSS is composed of a number of product elements and service elements, and they are connected together in order effectively to realize the corresponding function. There are two domains such as service element domain and product element domain in the PSS representation method. To represent a service element, stakeholders (who), activities (what) and product elements (how) were introduced. In general, service required specific providers and receivers, and their specific activities can also be followed. In addition, proper product elements should be accompanied as media to completely realize service. The multiple service elements are connected via flows of material and information, and the associated product elements are also connected via flows of material and information.

3 CASE EXAMPLE-CLOTHES TAKEIN PSS

The case study on using the developed design support tools during the clothes TakeIN PSS design is illustrated in this chapter. This design project was conducted by the team consisting of six designers for more than six months. During the design process, all design information in every meeting was saved with the developed prototype PSS DesignScape tool. Fig. 5 shows the partial view of the design process of the clothes TakeIN PSS design project. The vertical axis represents six PSS design phases shown in Fig.1, and horizontal axis represents time. The snapshot given in Fig. 5 denotes the design process pattern for first 15 days.

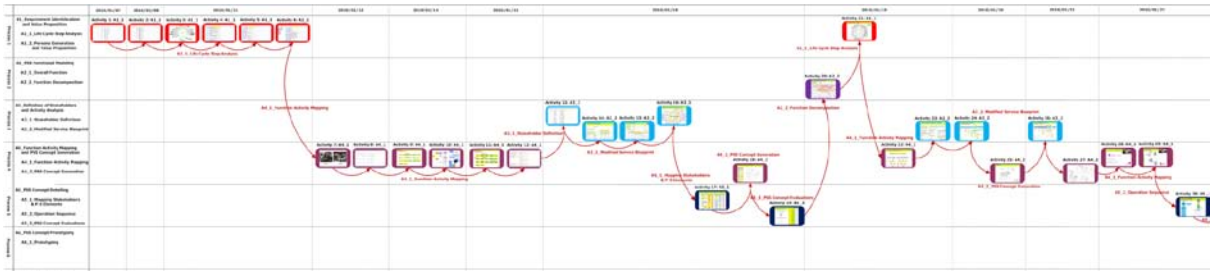


Fig. 5 Parital view of design process pattern of clothes TakeIN PSS design project

As can be seen in Fig. 5, the PSS design process was visualized and its pattern could be intuitively understood by PSS DesignScape users. The PSS DesignScape users can be designers, reviewers, instructors, clients, and so forth. With the aid of the PSS DesignScape tool, the design process and information during any PSS design project can be effectively captured, visualized and analyzed.

During the clothes PSS design process, the developed design support tools were actively used. Fig. 6 shows the sample picture of the activity of “package donating clothes” that was created by the AMT. The activity of “package” given in Fig. 6 did not exist in the current used clothes bin system. The donator usually throws the clothes away to the current clothes bin like trash, since this bin is located in a secluded corner of back alley streets with trash cans. Therefore, people usually do not want to use this current used clothes bin system due to its negative reactive emotional value – unsafeness and unpleasantness. To convert this negative reactive emotional value into positive one, we could change the location context from the secluded corner of back alley streets to the convenience store. In addition, we could add the activity of “package donating clothes” to create a new active emotional value. The context-based activity of “package” given in Fig. 6 has the relevant structure of “clothes TakeIN station” and “convenience store (CVS) structure”, the physical context of “daytime” and “noisy”, and the psychological context of “pleasant” and “safe”. Therefore, the AMT can help designers to effectively create, save, modify and retrieve diverse activities by changing the context elements.

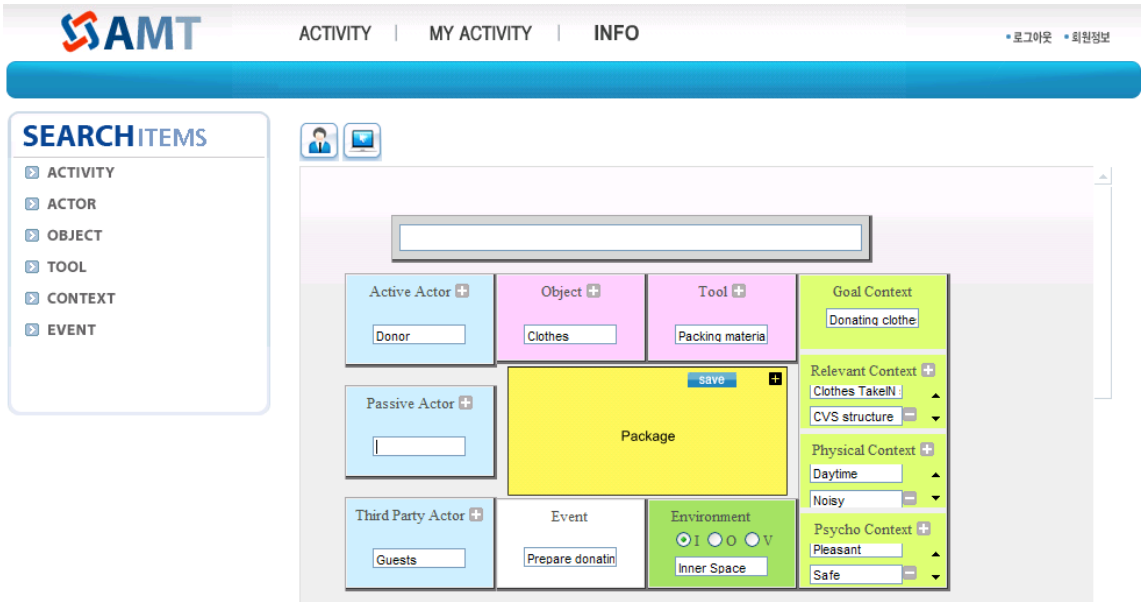


Fig. 6 Snapshot of activity of ‘package donating clothes” created in the AMT

The PSS FBD tool was used to identify critical sub-functions and their relations. Total 27 functions were identified for the new clothes TakeIN PSS and the block diagram connecting those functions with flows was created. Fig. 7 shows the function decomposition diagram of for the new clothes TakeIN PSS that was created by the PSS FBD tool.

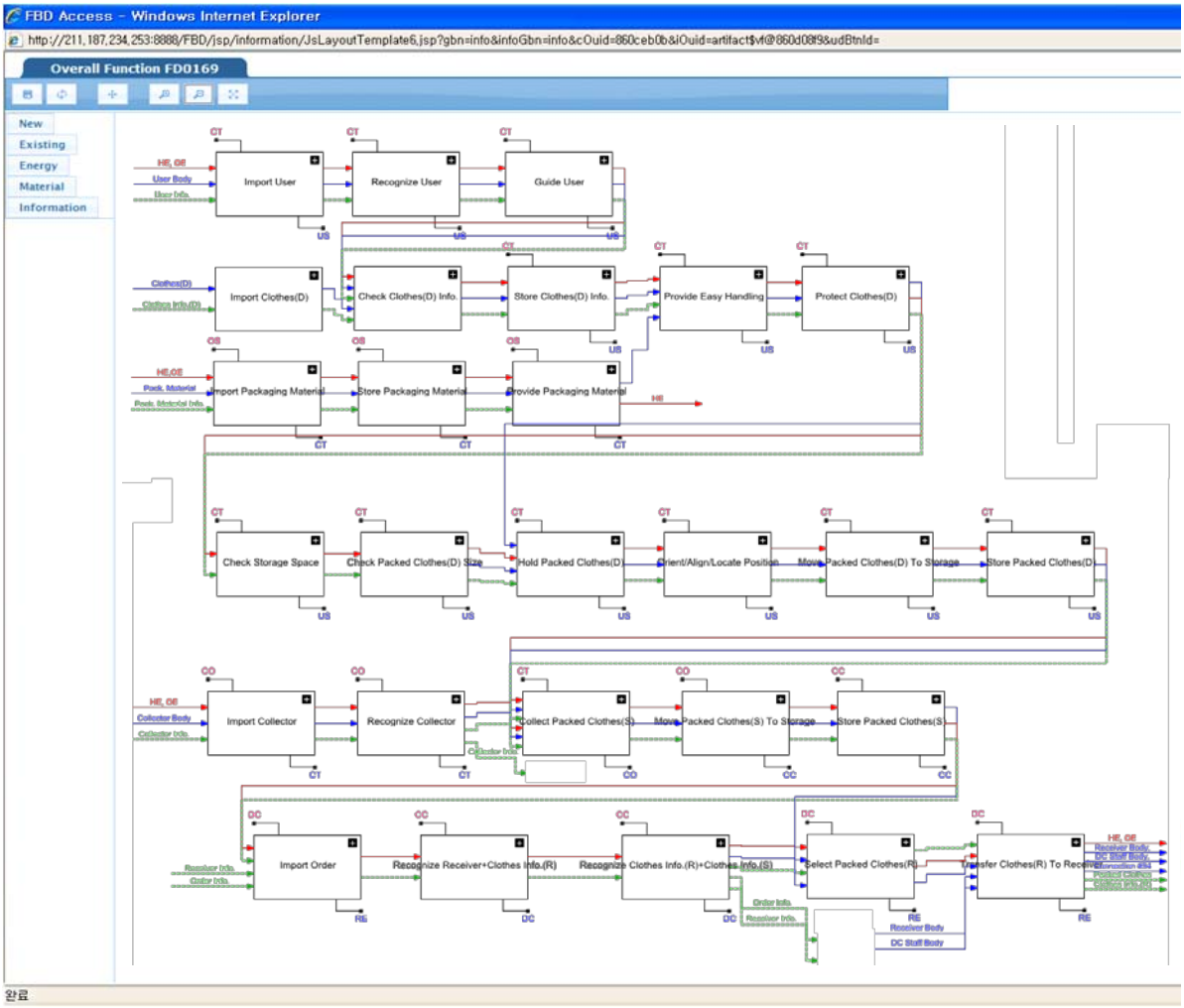
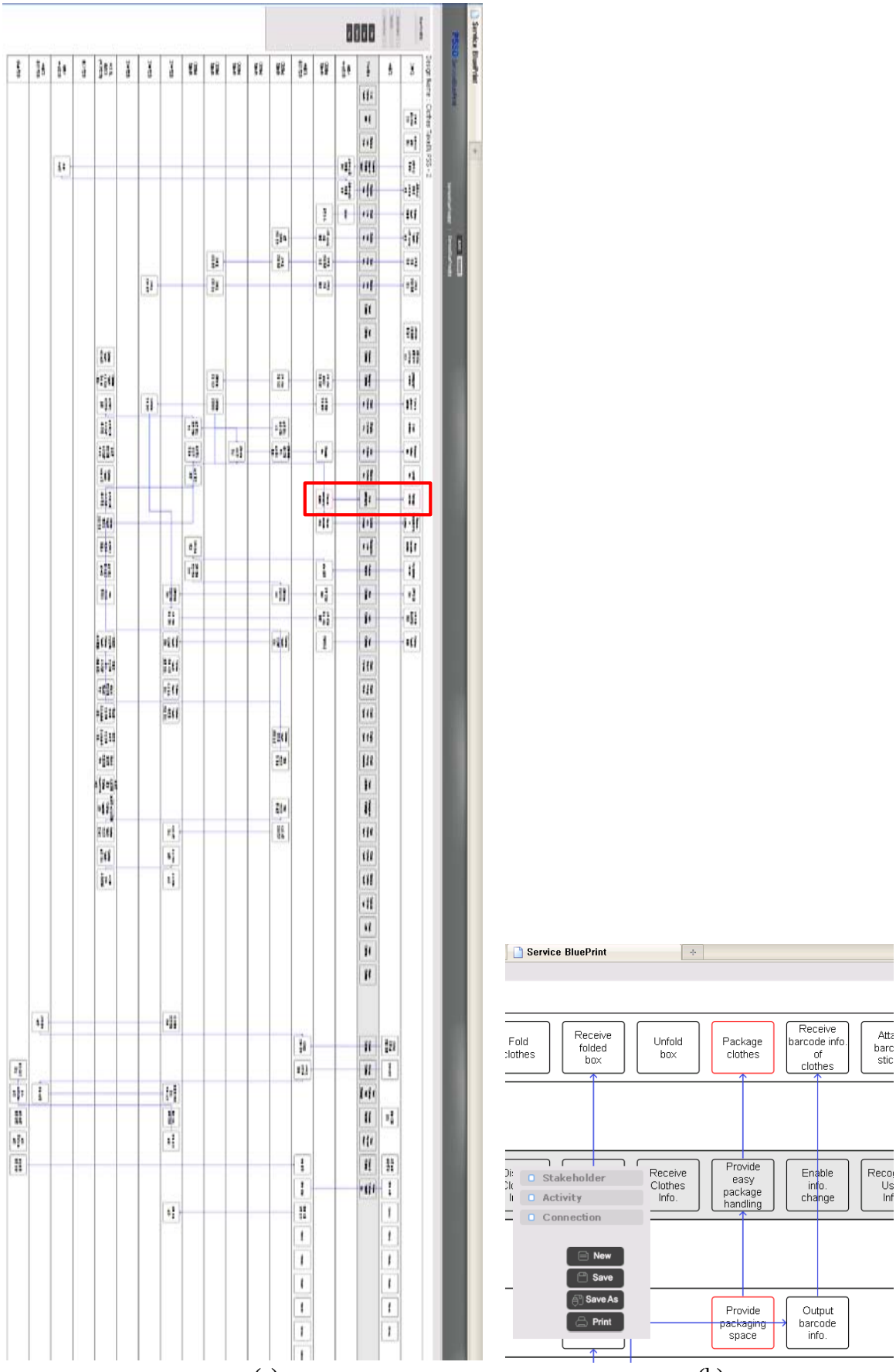


Fig. 7 Function decomposition diagram of the new clothes TakeIN PSS concept created by the PSS FBD tool

The functions given in Fig. 7 and various activities modelled in the AMT can be associated in the modified service blueprint tool. The snapshot of the modified service blueprint corresponding to the new clothes TakeIN PSS concept is given in Fig. 8. The shaded layer in Fig. 8 represents the function layer. Fig. 8(a) represents the overall view of the modified service blueprint, and the magnified view in the case of the function of “allow packaging” is shown in Fig. 8(b). The activity of “provide packaging space” of the clothes TakeIN staff – service provider – and that of “package clothes” of the donator – service receiver – are correlated via the function of “allow packaging”.

With the aid of various design support tool, the clothes TakeIN PSS design project was completed, and Fig. 9 shows the final scenario of the new clothes TakeIN PSS. As can be seen in Fig. 9, the donator repairs and cleans the used clothes, and he/she packages them at the clothes TakeIN station. The donated clothes can be properly stored in the clothes TakeIN station. Then, the stored clothes are collected by collectors and they are classified and properly kept in the warehouse. Afterwards, appropriate receivers are selected, and the donated clothes are delivered to them.

During designing the new clothes TakeIN PSS from the product of cloth, a number of design information was generated and effectively managed by the developed design support tools. The clothes TakeIN PSS designers were able to search, retrieve, save and update a number of information with the aid of the developed design support tools. Therefore, they could more effectively carry out the design process without missing necessary and important design information.



(a) (b)

Fig. 8 Snapshot of modified service blueprint of the new clothes TakeIN PSS concept created by the PSS modified service blueprint tool: (a) overview, (b) magnified view of red rectangular region in (a)

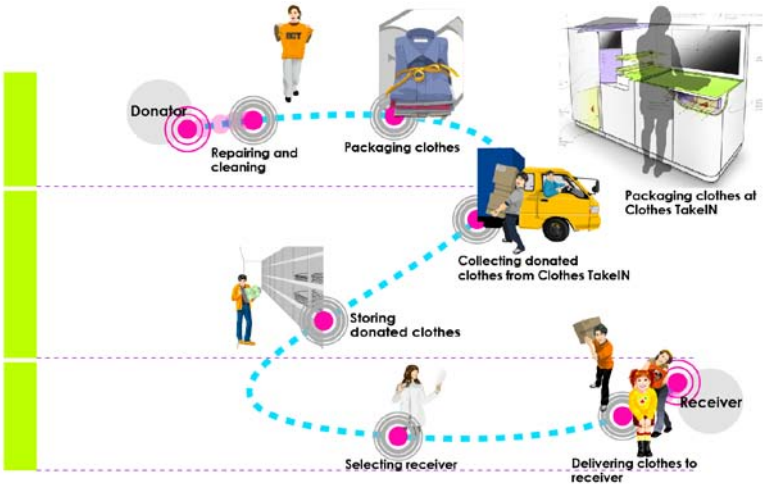


Fig. 9 Final scenario of the new clothes TakeIN PSS [13]

4 CONCLUDING REMARKS

In this paper, various design support tools for PSS have discussed. To effectively support PSS design process and manage a great deal of design information, it is necessary to develop proper design support tools such as PSS DesignScape, life-cycle step modelling, stakeholder modelling, requirement modelling, PSS scenario generation, activity modelling, PSS function modelling, modified service blueprint and PSS representation.

PSS DesignScape tool enables capturing and visualization of PSS design process, and it is helpful to monitor and review the PSS design process. The LCS analysis tool allows designers to effectively identify target life-cycle steps and values with the aid of stakeholder modelling and requirement modelling tools. The representation and analysis of current PSS can be effectively conducted with the PSS scenario generation tool, and possible enhancement can be explored by adding and modifying stakeholders and activities in this tool. The context-based activity modelling tool enables designers to effectively create new activities by changing their context elements, and the relationships among activities can be modelled and analyzed via the service blueprint tool. The critical functions to realize product and service elements for supporting stakeholders' activities can be identified via the PSS function modelling tool. Alternative PSS concepts can easily created, visualized and compared with the modified service blueprint tool. In addition, the PSS representation tool can help designers to appropriately configure product and service elements to effectively realize functions.

Sample case study on the clothes TakeIN PSS was also conducted. The case study results confirmed the applicability and effectiveness of them during the clothes TakeIN PSS design process.

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