Toward Product-Service System Engineering: New System Engineering for PSS Utilization

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Abstract. The introduction of engineering methods is considered a promising approach to the effective and efficient design of Product-Service Systems (PSSs). The authors have conducted studies on Service Engineering in Japan in order to provide a fundamental understanding of services as well as concrete engineering methods to design and develop them. This paper denotes the need to progress from Service Engineering to PSS Engineering. In addition, methods and tools that can contribute to PSS design are discussed.

Keywords: PSS Engineering, Design, Service Engineering.

1 Introduction

As society advances, services and knowledge have become increasingly important in many industries [1]. Indeed, the term servitization indicates [2] that the service and information provided through a product are more important than the product itself, even in the manufacturing industry. For this reason, Product-Service Systems (PSSs), which create value by coupling a product and a service, have attracted much attention [3]. For the effective and efficient design of PSSs, the introduction of engineering methods is considered a promising approach. However, compared with the existing research on product design, there have been fewer studies on the design of services from the engineering perspective [4-6].

2 Practical Scientific Approaches

2.1 Genesis

Due to the situation mentioned in Section 1, we began in 2001 to conduct research on Service Engineering (e.g., [7]), the aim of which is to provide both a fundamental understanding of services and concrete engineering methods to design and develop them. Here, we define a service as the provision of a means to integrate a tangible object (a physical product) with an intangible object (an action product) that realizes some required value for a customer. The goal of our work is to develop a design methodology of services under this definition.

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During the first stage of our research, from 2001 to 2005, we established a generic procedure for modeling and analyzing services based on our research background in Design Engineering. Furthermore, we developed the basic structure of a service computer-aided design (service CAD) software system called Service Explorer [8, 9]. We used scientific design methodology and service engineering to develop tools to identify the values that are required and the societal and artificial systems that are needed to achieve the values.

In the second stage, from 2005 to 2011, engineering methods to support service designers were implemented in Service Explorer as plug-in software modules. In this stage, we focused on analyzing and designing a one-to-one relationship between a provider and a receiver.

Now the door to the third stage of our research has opened. Whereas in the previous stage we focused mainly on the one-to-one relationship between two specific stakeholders, in the third stage we are concentrating on the system aspect of PSS. Our focus is the complex network of multiple stakeholders, such as product manufacturers, service suppliers, and original equipment manufacturers, in a PSS structure. In the next stage of our research, we will establish methods to design an integrated product-service business that realizes win-win relationships among multiple stakeholders.

2.2 From Service Engineering to PSS Engineering

The concept of PSS is sometimes regarded as merely the combined provision of a product and service that fulfills customer needs (e.g., machine and maintenance). However, such a view of PSS shows an insufficient understanding of the original PSS concept, the essence of which is a social system where all stakeholders, including providers and receivers, can receive sufficient values through cross-offerings of products and services. This system, represented by the last S in PSS, consists of various stakeholders who provide and / or receive products and services Thus, in the current study, a PSS can be defined as a social system that enhances social and economic values for stakeholders through the co- and cross-offering of products, services, and product-services within the system. Here, a product-service means an integrated offering of product and service.

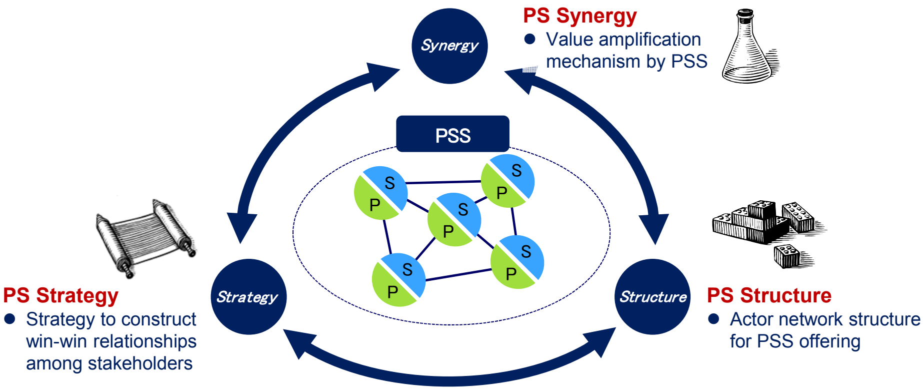


Fig. 1. The concept of PSS[3]

From this viewpoint, Service Engineering progresses to Product-Service System Engineering. In the new approach, we regard PS System design as the design of (1) PS Synergy, (2) PS Strategy, and (3) PS Structure: PSS^3. The concept of PSS^3 is illustrated in Figure 1. Here, PS Synergy is a value amplification mechanism by a PSS offering. PS Structure indicates a stakeholder network for value offering, and PS Strategy means a strategy to construct win-win relationships among stakeholders.

2.3 Research Strategy Map

As mentioned in 2.2, we regard PSS^3 as the set of PSS design dimensions. In PSS design, a PS Strategy is designed by determining the concrete values to be provided to stakeholders by integrating product and service. Thus, a Value Analysis is needed. The design of a PS Structure is performed through a discussion of how to embody the PSS offering structure (i.e., PSS Embodiment). PS Synergy can be clarified and the design improved through the evaluation of the synergy effect. Based on these discussions, Value Analysis, Embodiment, and Evaluation are regarded as practical realization phases of PSS^3.

Figure 2 illustrates the research strategy map of our research team. On the map, methods and tools that have already been developed or that are now being developed are classified in the PSS design phases and from a design perspective. The PSS design phases are composed of three steps: Analysis, Embodiment, and Evaluation. However, the three design perspectives—those of the Customer, Business, and Environment—are included in the map. The core modules of Service Explorer, which is the most important achievement of our research, are shown in the center area of the map. Methods and tools that support designers in specific design phases are mapped as satellite modules. Methods and tools illustrated as satellite modules are explained in Sections 3, 4, and 5.

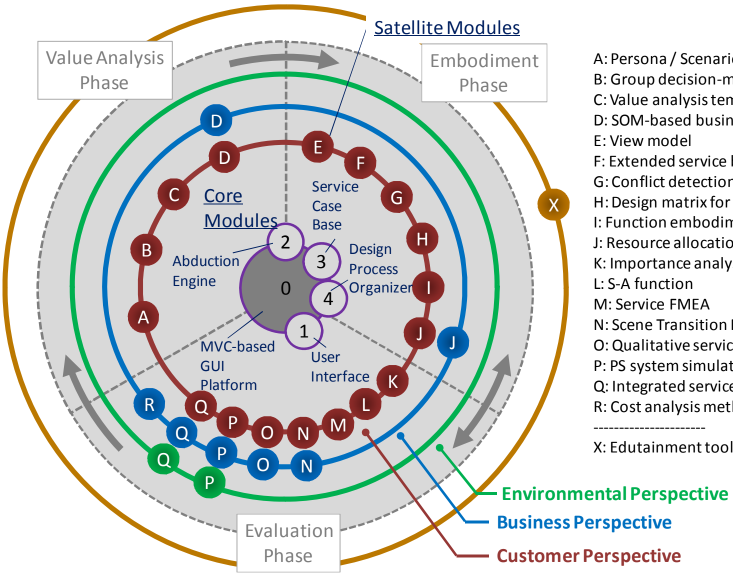


Fig. 2. Research strategy map

3 Value Analysis Phase

3.1 Customer Perspective

Module A: Persona / Scenario Analysis. To extract the requirements of service receivers, a persona is described for each agent that works as a receiver in the service. The persona is a tool used mainly for software interface design to give a simplified description of a customer. It works as a compass in a design process [10]. According to this persona, subsequently, a scenario is developed to clarify the context in which the service is received. The scenario is described in the form of a graph representing a scene transition. For each described scene, the receiver's state is represented as a set of parameters (Figure 3).

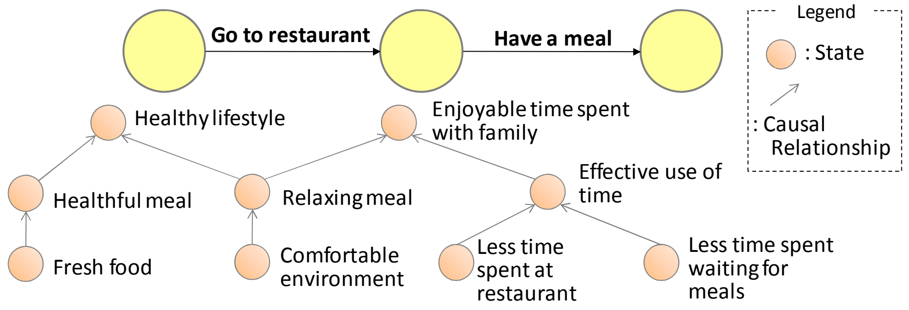


Fig. 3. Scenario model

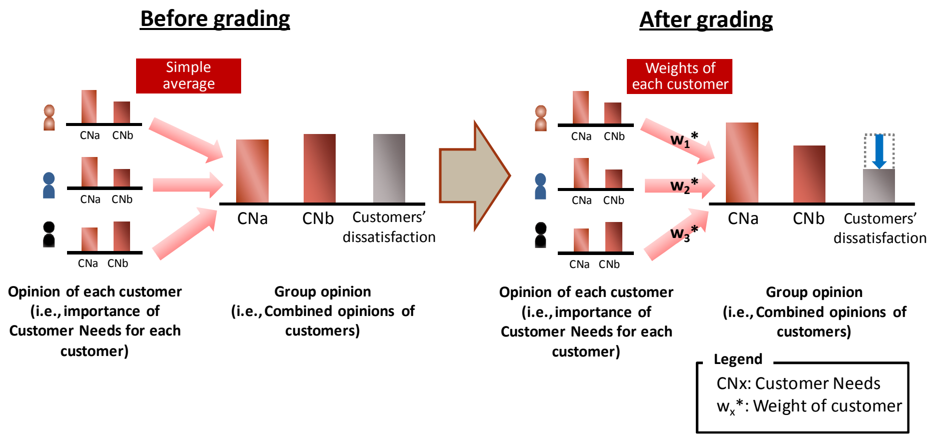


Fig. 4. Group decision-making method

Module B: Group Decision-Making Method. This method attempts to derive the group opinion and to minimize customer dissatisfaction by using grading scores [11]. The grading score is the weighted value of each customer that would influence the total opinion of the group [12]. The total dissatisfaction of all the customers is defined as the sum of the distances between individual opinions and the group opinion, which is affected by the grading score. This method is used to derive the requirement values for a target service by minimizing the dissatisfaction of all the customers. It is particularly effective for the design of public services (Figure 4).

Module C: Value Analysis Template. While the persona model and scenario model are scientific methods for extracting receivers' requirements, they use a form of representation based on natural language. Their use, therefore, requires a certain amount of training given the diversity of vocabulary selection and the difficulty of determining synonymy. To describe these models more simply, we developed templates as a convenient means of preparing data corresponding to each stage of model building. We developed a framework consisting of five templates, shown in Table 1, that assist in the tasks of (1) describing personas, (2) describing scenarios, and (3) extracting receivers' requirements. We are, thus, able to implement a system that supports the comprehension and analysis of personas, scenarios, and provided values.

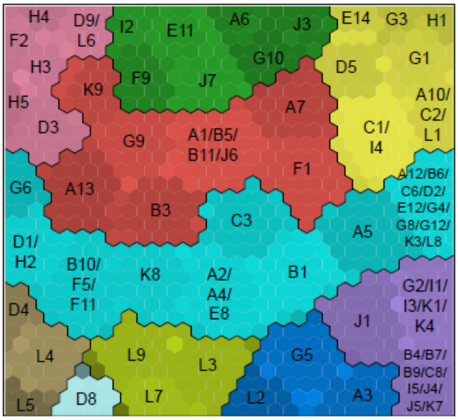
The original value analysis template was developed for B2C service design. Akasaka et al. [13] extended the original template and developed one for B2B service design.

3.2 Business Perspective

Module D: SOM-Based Business Chance Finder. We have developed a method to support designers in generating business design ideas [14]. In this method, the similarities of business seeds are visualized on a two-dimensional map using the Self-Organizing Map (SOM) technique [15] (Figure 5). The similarities of business seeds are calculated as the similarities of values offered with business seeds. By using the map, designers can identify business seeds that may fulfill receivers' requirements. For example, the green cluster includes business seeds A6, E11, F9, G10, I2, J3, and J7. These business seeds can provide values such as Reduction of Noise, Flexibility of Installation Space, and Reduction of Operating Cost. Therefore, if a designer has to design a way to reduce operating costs, the business seeds in this cluster can be applied.

Table 1. Value analysis template

Template	Summary
Persona template	A template to define a persona that represents a hypothetical client as an individual. A persona is defined by describing demographic data, e.g., name, gender, and carrier, as well as psychological data, e.g., personality and life-style.
Character / Intent template	A template to configure the character / intents of the defined persona using a prepared vocabulary list.
Script template	A template to describe detailed behaviors (including the service-receiving context) that the persona, defined in the persona template, performs to achieve specific goals or objectives.
Keyword template	A template to convert the described script into unified lexical expressions by arranging keywords based on six phases in the Phases of Service Encounter and 4W1H (What, What like, Where, When, How).
RSP extraction template	A template to associate required items / qualities and quality elements with the keywords identified in the keyword template.



A1-13: Technologies in gas turbine business
B1-11: Technologies in motorcycle business
C1-9: Technologies in robot business
D1-9: Production technologies
E1-17: Technologies in plant business
F1-13: Technologies in ship business
G1-12: Technologies in machinery for ships and motor cycle
H1-5: Technologies for fluid power systems
I1-5: Technologies for environmental consciousness
J1-8: Technologies in train business
K1-10: Technologies for aerospace
L1-11: Technologies for robot systems

Fig. 5. An example of a map of PSS business seeds

4 Embodiment Phase

4.1 Customer Perspective

Module E: View Model. The view model [7-9] is a model to design a functional structure of a service that fulfills receivers' requirements. Figure 6 shows an example of a view model consisting of functions, described as 'verb + noun' (e.g., 'brew + coffee'), and entities that have been used in product design methodologies (e.g., [16]). In this model, preliminary functions that fulfill receivers' requirements are described and deployed into sub-functions. Human resources (e.g., staff) and physical products (e.g., monitoring camera and sensor) are associated with the lowest-level functions as function carriers.

Module F: Extended Service Blueprint. The extended service blueprint is a modeling method to describe a service process which consists of service activities and product behaviors [17]. The origin of the concept is the service blueprint, which is commonly used in service marketing to describe service activities undertaken by a customer, a front-line [Note: What is meant by a "front-line"? Please clarify], and a support team in the performance of a service [18]. However, no service blueprint is available to describe the role of products in a service process. Thus, the extended service blueprint was developed to describe not only service activities performed by human resources and related software but also product behaviors performed by hardware and related software. The notation of the extended service blueprint is based on Business Process Modeling Notation (BPMN) [19]. The extended service blueprint represents the parallel and interactive activities and behaviors of employees, customers, and product. In Figure 7, the interactions among the activities of floor staff and kitchen staff and the behavior of a coffeemaker are illustrated using BPMN.

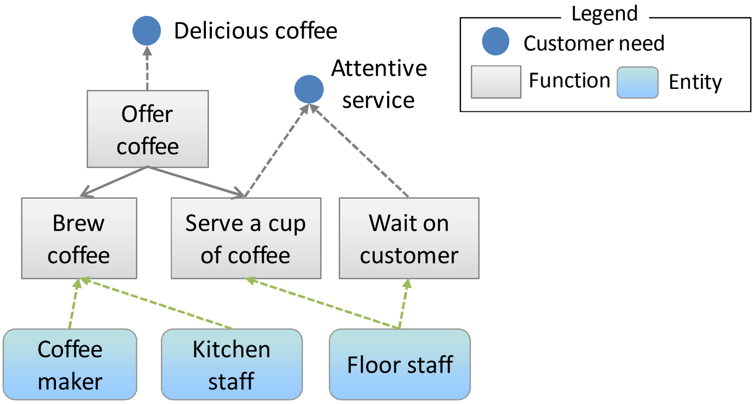


Fig. 6. View model

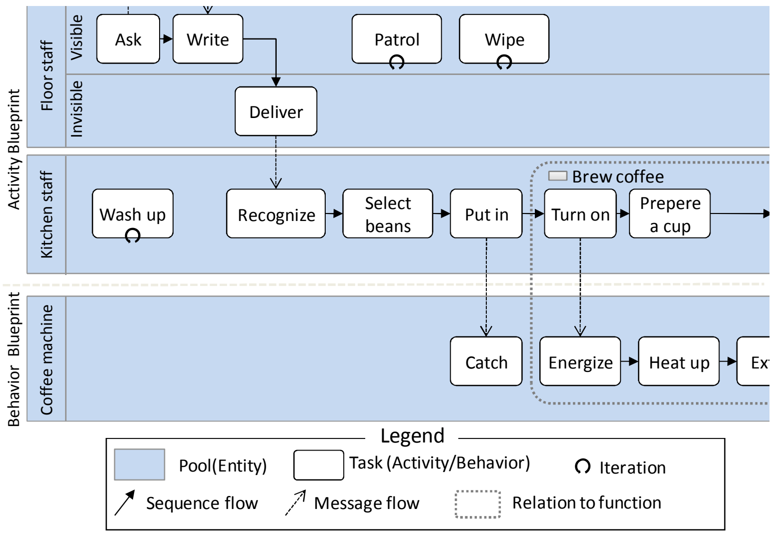


Fig. 7. Extended service blueprint model

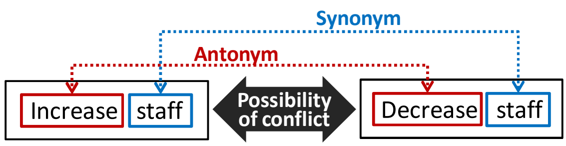


Fig. 8. Conflict detection with the lexical expression of functions

Module G: Conflict Detection. When a service that fulfills receivers' requirements is designed, conflicts can be found. For example, two functions, 'increase staff' and 'decrease staff,' may exist in separate service models of the same service. To avoid this problem, the conflict-detection method analyzes objects and predicates of functional expressions using the lexical expression database [9] (Figure 8). In addition, a method to solve the extracted conflicts with TRIZ [20] has also been proposed.

Module H: Design Matrix for Modular Service Design. The design matrix method is used to optimize the composition of service modules based on Suh's axiomatic design [21]. In service engineering, a module is determined in terms of the (function / attribute) relationship. Table 2 is the design matrix for service design which shows the (function / attribute) relationship with the character 'X.' To determine service components, service designers first determine modules from the (function / attribute) relationship. A module uncoupled from the others is defined as a single component which is the minimum subset of decoupled modules to satisfy the Independence Axiom [21]. By means of this matrix, service designers can configure a flexible and reliable service structure.

Module I: Function Embodiment Knowledge Base. We have developed a method and prototype system for knowledge-based PSS design [22] to support the acquisition of new PSS design solutions by integrating design knowledge managed within a knowledge base. In this method, a unit of information is represented by a set of three elements--function, entity, and delivery process--which enables designers to manage knowledge of both product and service shares in PSS cases. The desired knowledge is sought based on similarities between functions and is provided in catalog form. By using this system, designers can find alternatives to PSS design solutions.

Table 2. A simple example of a design matrix

	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5		
Function 1	X					M1*	Component 1
Function 2		X				M2	Component 2
Function 3		X	X			M3	
Function 4				X	X	M4	Component 3
Function 5				X	X	M5	

*M: Module

4.2 Business Perspective

Module J: Resource Allocation Method. Resource distribution is not easily designed because of the vast search space and the complexity of the problem to be solved. Therefore, a method to determine the optimal value of the resource distribution by means of the Genetic Algorithm (GA) has been proposed [23]. This method optimizes resource distribution from two viewpoints: customer satisfaction and internal resource constraints.

5 Evaluation Phase

5.1 Customer Perspective

Module K: Importance Analysis. Based on the view models, a method to analyze the importance of design parameters by means of Quality Function Deployment

(QFD) [24] and the Analytical Hierarchy Process (AHP) [25] to improve a service structure has been proposed. QFD is a systematic analysis method to translate customer needs into the requirements and specifications of a design object. Meanwhile, the AHP method numerically computes the importance weights of receivers' requirements according to bilateral comparisons among parameters. After the importance of receivers' requirements is obtained, it is converted into the importance of functions and entities by using the matrix of the QFD [24]. The matrix is created based on the specifications described in the view models.

Module L: S-A Function. Unlike the importance analysis method, which evaluates the relative importance of requirements, the function of S-A (Satisfaction-Attribute) is to evaluate directly the satisfaction of service receivers [26, 27]. The S-A function describes the condition of service receivers' satisfaction in terms of their expectations of the service and the type of service function. The receivers' expectations are used as comparison standards to determine whether the receiver is satisfied or dissatisfied. Namely, the function is divided into a gain side and a loss side at the expectation value. This type of service function was originally proposed by Kano [28], who identified three categories of product or service functions: attractive, one-dimensional, and must-be. Figure 9 shows the differences in the shapes of functions. The shape of an S-A function is determined by the analysis of the service function type. By means of S-A functions, the numerical evaluation of a service receiver's satisfaction can be performed.

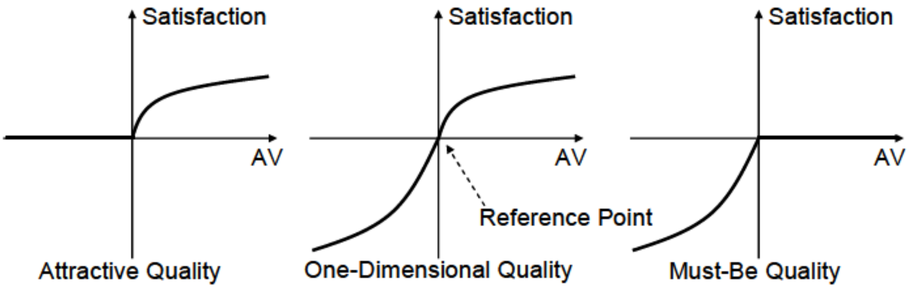


Fig. 9. S-A functions

Module M: Service FMEA. Failure Mode and Effect Analysis (FMEA) [29] is a method to analyze the failure mode, which may cause a product or service to malfunction. Since the structure of a service is complicated, various causes of malfunctions can be considered. Service FMEA (Table 3) attempts to analyze and prevent potential malfunctions. In Figure 9, failure modes of a service are listed in the far left column. Influences on and causes of the failure modes are also listed.

5.2 Business Perspective

Module N: Scene Transition Nets Simulation. The evaluation of a service should be done in both a static and a dynamic manner. We adopt the Scene Transition Nets

(STN) as a simulation model of a service process [30]. STN is a graphic modeling method for discrete-continuous hybrid systems [31]. Figure 10 shows the components of STN, which uses tokens called actors to describe discrete state changes and differential equations triggered by the movements of the actors to describe continuous state changes. STN is suitable for a service process simulation since it can describe both the process transition and the state change of each stakeholder simultaneously. For example, in Figure 11, the service processes of a nursing case service is modeled as a discrete event system. At the same time, the dynamic nurse walking distance in a scene is modeled as a continuous system.

Table 3. Service FMEA

Failure Mode	Time				Result		
	External cause				Cause of the fault		
	Influence			Elapse effect			
	Input	External influence	Structural Influence		Relative cause	Absolute cause	
Information is not shared among staff members	･lack of communication skills ･failure to convey information ･rush	･customer's erroneous order ･unexpected rush	･staff's erroneous order ･conflict among staff members ･coercive behavior	･failure to communicate ･Many new employees	･inadequent training for new employees	･insufficient staffing	･
The situation is not understood properly	･Failure to understand customer's order	･an objection ･unexpected congestion ･inapprpriate placement of lighting	･lack of information sharing ･lack of teamwork	･lack of attention ･a lot of newcomers	･insufficient staffing	･inappropriate positioning of refueling aircraft	
Cash register is jammed with bills and coins	･diffusion cash card ･forget filling up	･increase exchange ･unexpected congestion ･payment with bills			･cannnot express "near empty"	･Insufficient number of staff member available for restocking	･ s
Staff member cannot responsibly serve customer	･lack of responsibility ･disinclination for sales of goods ･no consequences	･interruption of other work	･have poor support		･insufficient staffing	･lack of responsibility ･inadequent training manual	

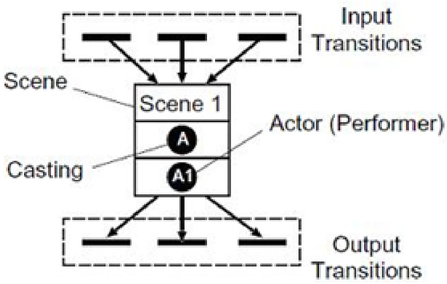


Fig. 10. Components of Scene Transition Nets Simulator

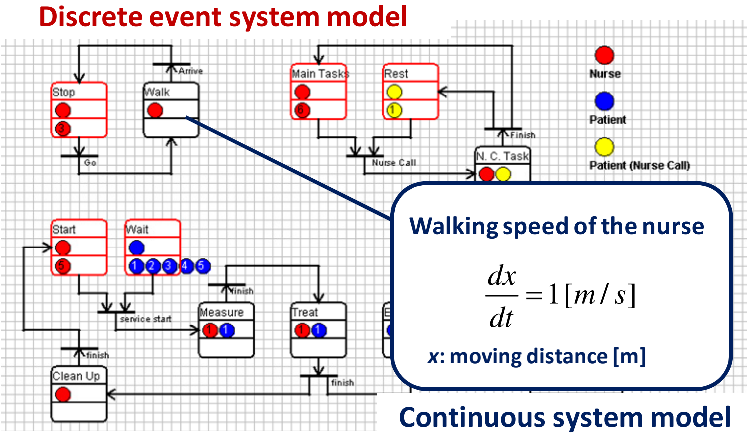


Fig. 11. Scene Transition Nets Simulator

Module O: Qualitative Service Simulator. We have developed a qualitative service simulator that enables designers to evaluate the designed service qualitatively. Qualitative simulation predicts the set of possible behaviors consistent with a qualitative differential equation model of the world. Its value comes from the ability to express natural types of incomplete knowledge and the ability to derive a provably complete set of possible behaviors in spite of the incompleteness of the model [32-34].

Module R: Cost Analysis Method. In order to make services successful, service designers need to consider economic costs. A cost evaluation method [35] has been proposed on the basis of Activity-Based Costing (ABC) [36], which is used to trace overhead costs for objects such as products, processes, and departments. Unlike the original ABC, which is a method to calculate costs of business processes, our proposed method enables designers to calculate the cost of each function and entity, with the entity including both human resources and physical products.

5.3 Environmental Perspective

Module P: PS System Simulator. To realize a sustainable business through PSS, it is important to create a business situation in which each stakeholder receives values through the provision of PSS. The designers must have a holistic view and consider the total value created within the system. Therefore, a design method for a PSS that has a high value for each stakeholder has been proposed. In this method, a PSS is designed using System Dynamics simulation [37] under the simultaneous consideration of values received by various stakeholders. Here, the global environment is also regarded as a stakeholder in the system so that the designers can consider the environmental impact of PSS provision.

Module Q: Integrated Service Evaluation Method. The Integrated Service Evaluation Framework (ISEF) is used to evaluate service design solutions from the viewpoints of multiple stakeholders in an integrated and quantitative manner. In ISEF, service processes of stakeholders are described based on IDEF0 [38], a well-known functional system modeling method used to describe the influences of various stakeholders. This service process model covers the entire service process, which includes pre-activities before the main service activity, such as manufacturing, distribution of products, hiring, and training of employees, and post-activities, such as maintenance, disposal, and after-sales service. The service is evaluated through the STN-based simulation technique (see Module N in 5.2).

6 Crossover Phase

We have developed an edutainment tool for PSS design called EDIPS (Edutainment for Integrated Provision of Product-service System) (Figure 12(a)). This tool is illustrated as Module X in Figure 2. EDIPS is a kind of business game through which players can learn the importance of the integrated provision of product and services to gain profit and learn how to integrate product and services. Figure 12(b) shows a picture taken in an international test game played by PSS researchers.

(a) Overview of the EDIPS

(b) Playing the EDIPS

Fig. 12. EDIPS: An edutainment tool for PSS design

7 Concluding Remarks

This paper denotes the need to progress from Service Engineering to PSS Engineering. Our idea is to design a PSS with three dimensions: (1) PS Synergy, (2) PS Strategy, and (3) PS Structure (PSS^3). We have provided an overview of methods and tools that can contribute to PSS design. However, few methods have been proposed that support value analysis and embodiment from the environmental perspective. To design a PSS that helps to reduce environmental impact, it is important for designers to consider environmental friendliness in the early stage of PSS design. Therefore, our future research will include the development of methods to support designers' consideration of environmental impact in the value analysis and embodiment phases of PSS design.

References

1. Tomiyama, T.: A Manufacturing Paradigm Toward the 21st Century. Integrated Computer Aided Engineering 4, 159–178 (1997)
2. Vandermerwe, S., Rada, J.: Servitization of Business: Adding Value by Adding Services. European Management Journal 6, 314–324 (1988)
3. Goedkoop, M.J., van Halen, J.G., te Riele, H., Rommens, P.J.M.: Product Service Systems, Ecological and Economic Basics. Report for Dutch Ministries of Environment (VROM) and Economic Affairs, EZ (1999)
4. Spohrer, J., Maglio, P.: The Emergence of Service Science: Toward Systematic Service Innovations to Accelerate Co-creation of Value. Production and Operations Management 15, 329–343 (2006)
5. Aurich, C., Fuchs, C., DeVries, F.: An Approach to Life Cycle Oriented Technical Service Design. Annals of the CIRP 53(1), 151–154 (2004)
6. Tukker, A.: Eight Types of Product-Service System: Eight Ways to Sustainability? Experiences from Suspronet. Business Strategy and the Environment 13, 246–260 (2004)
7. Shimomura, Y., Tomiyama, T.: Service Modeling for Service Engineering. In: Proceedings of the 5th International Conference on Design of Information Infrastructure Systems for Manufacturing, DIISM 2002, pp. 309–316 (2002)
8. Shimomura, Y., Hara, T.: Method for Supporting Conflict Resolution for Efficient PSS Development. CIRP Annals-Manufacturing Technology 59(1), 191–194 (2010)
9. Shimomura, Y., Hara, T., Arai, T.: A Service Evaluation Method using Mathematical Methodologies. CIRP Annals - Manufacturing Technology 57(1), 437–440 (2008)
10. Cooper, A.: The Inmates Are Running the Asylum: Why High Tech Products Drive Us Crazy and How to Restore the Sanity, Sams (1999)
11. Yamamoto, S., Kimita, K., Shimomura, Y.: An Importance Decision Method of Customer's Demands for Highly Public Service. In: Proceedings of the 15th Design for Manufacturing and the Lifecycle Conference -DFMLC 2010. CD-ROM, The American Society for Mechanical Engineering, ASME (2010)
12. Nakanishi, M., Kinoshita, E.: An Application of the Group Decision Making Stress Method to the Analytic Hierarchy Process. Journal of the Operations Research Society of Japan 41(4), 560–571 (1998) (in Japanese)
13. Akasaka, F., Hosono, S., Yamamura, K., Shimomura, Y., Arai, T.: A Method for Analyzing Customer Requirements in a B2B Service. In: Proceedings of the 9th Japan Korea Design Engineering Workshop, pp. 7–12 (2009)
14. Akasaka, F., Fujita, K., Shimomura, Y.: PSS Business Case Map: Supporting Idea Generation in PSS Design. In: Proceedings of the 2012 International Design Engineering Technical Conference -IDETC 2012. CD-ROM, The American Society for Mechanical Engineering, ASME (2012)
15. Kohonen, T.: Self-Organizing Maps. Springer Series in Information Science, vol. 30. Springer (1997)
16. Pahl, G., Beitz, W.: Engineering Design: A Systematic Approach. Springer (1988)
17. Shimomura, Y., Hara, T., Arai, T.: A Unified Representation Scheme for Effective PSS Development. CIRP Annals –Manufacturing Technology 58(1), 379–382 (2009)
18. Shostack, G.L.: How to Design a Service. In: Donnelly, J.H., George, W.R. (eds.) Marketing of Services. American Marketing Association (1981)
19. Havey, M.: Essential Business Process Modeling. O'Reilly Media, Inc. (2005)
20. Mann, D.: Hands On: Systematic Innovation. CREAX Press, Ieper (2002)

21. Suh, N.P.: Axiomatic Design Theory for Systems. Research in Engineering Design 10(4), 189–209 (1998)
22. Nemoto, Y., Akasaka, F., Chiba, R., Shimomura, Y.: Establishment of a Function Embodiment Knowledge Base for Supporting Service Design. Science China Information Sciences, Special Focus on: Design and Digital Engineering 55(5), 1008–1018 (2012)
23. Holland, J.H.: Adaptation in Natural and Artificial Systems. Univ. of Michigan Press (1975)
24. Akao, Y.: Quality Function Deployment. Productivity Press (1990)
25. Saaty, L.: The Analytic Hierarchy Process. McGraw-Hill (1980)
26. Tateyama, T., Shimomura, Y., Kawata, S.: Development of Scene Transition Nets (STN) GUI Simulator for Service Flow Simulation. In: Proceedings of the 17th International Conference on Engineering Design - ICED 2009, pp. 337–346 (2009)
27. Yoshimitsu, Y., Kimita, K., Hara, T., Shimomura, Y., Arai, T.: Proposal of a Measuring Method of Customer's Attention and Satisfaction on Services. In: Proceedings of the 14th CIRP International Conference on Life Cycle Engineering - LCE 2007. CIRP, pp. 417–422 (2007)
28. Kano, N., Seraku, N., Takahashi, F., Tsuji, S.: Attractive Quality and Must-Be Quality. Journal of the Japan Society of Quality Control 14(2), 39–48 (1984)
29. Stamatis, D.H.: Failure Mode Effect Analysis: FMEA from Theory to Execution. ASQ Quality Press (2003)
30. Tateyama, T., Kawata, S., Shimomura, Y.: Service Flow Simulation Using Reinforcement Learning Models and Scene Transition Nets. In: Proceedings of International Conference on Instrumentation, Control and Information Technology 2008 (SICE Annual Conference 2008), pp. 2056–2061. CD-ROM (2008)
31. Kawada, S., Kawata, S., Watanabe, A.: A Manufacturing System Modeling Using a Scene Transition Net. New Direction in Simulation for Manufacturing and Communication (1994)
32. Kuipers, B.: Qualitative Simulation. Artificial Intelligence 29(3), 289–338 (1986)
33. Fobus, K.: Qualitative Process Theory. Artificial Intelligence 24(3), 85–168 (1984)
34. de Kleer, J., Brown, J.S.: A qualitative physics based on confluences. Artificial Intelligence 24(1), 7–83 (1984)
35. Kimita, K., Hara, T., Shimomura, Y., Arai, T.: Cost Evaluation Method for Service Design Based on Activity Based Costing. In: Proceedings of the 41st CIRP Conference on Manufacturing Systems. CIRP, pp. 477–480 (2008)
36. Cooper, R.: The Rise of Activity-Based Costing-Part One: What is an Activity-Based Cost System? Journal of Cost Management 2(2), 45–54 (1988)
37. Sterman, J.D.: Business Dynamics: Systems Thinking and Modeling for a Complex World. McGraw-Hill (2000)
38. FIPS PUB 183, Integration Definition for Function Modeling (IDEF0) Federal Information Processing Standards. United States National Institute of Standards and Technology (NIST), Computer Systems Laboratory, Gaithersburg, MD (1984)