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State-of-Art Product-Service Systems in Japan – The Latest Japanese Product-Service Systems Developments

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Abstract

Throughout the history of Japan, manufacturing companies have supported the national economy. However, most of them have lost the competitive advantage in the global market today. To contribute to the resurgence of the Japanese manufacturing industry, the authors have conducted studies of design methodology for Product-Service Systems (PSSs) and carried out several collaborative projects with industrial and academic partners. In this paper, the latest developments of PSSs in Japan are presented by introducing the collaborative projects.

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Keywords: Product-Service System; Service Engineering; Design Methodology

1. Introduction

At one time, the Japanese economy dramatically expanded along with the growth of its manufacturing industry. "Made in Japan" was regarded as a synonym for high quality, functionality, and reliability; these products once dominated the global market. However, most Japanese manufacturers today have lost their competitive advantages due to the progress of commoditization and the rise of manufacturers in developing countries. In order to survive in the current global market, they need to find and obtain a new source of competitiveness. For this reason, the concept of Product-Service Systems (PSSs) (e.g., [1–3]), which create value by highly integrating products and services, has attracted much attention. Some Japanese manufactures are starting to consider that changing their business model from simply selling products to offering integrated products and service (i.e., the servitization of manufacturing [4–6]) would become a crucial driver of their resurgence.

Since 2001, the authors have conducted research on Service Engineering (e.g., [7]), the aim of which is to provide a fundamental understanding of services and PSSs, and to develop concrete engineering methods for developing them effectively. Furthermore, we have carried out several collaborations with industrial and academic partners to identify the issues in PSS implementation and to develop a practical methodology for PSS design and development.

In this keynote paper, we first explain the fundamentals of our methodology for PSS design and development (Section 2). In Section 3, the latest developments of PSSs in Japan are presented by the introduction of our collaborative projects with industrial and academic partners. Finally, Section 4 concludes this paper.

2. Methodology for PSS design and development

In the current study, we define a PSS 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. According to this

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definition, we regard PSS design as the design of PS Synergy, PS Strategy, and PS Structure: PSS[3] [8]. Here, PS Synergy is a value amplification mechanism by a PSS offering, PS Structure indicates a stakeholder collaboration network for value offering, and PS Strategy means a strategy to construct win-win relationships among stakeholders.

The design of PSS[3] is conducted through three design phases: value analysis, embodiment, and evaluation. Fig. 1 illustrates the world perspective of the methods and tools used in these three phases. The core modules of Service CAD, which is the most important achievement of our research [9], are shown in the center area of the map. Methods and tools that support designers in specific design phases are mapped as satellite modules (the details are shown in Table 1).

In the value analysis phase, PSS designers clearly define target customers and identify customer values. To support this operation, we have proposed a customer modeling method based on the concept of persona (Fig. 1 A) [10]. Persona is a group of virtual people created to represent target customers that works as a compass in the entire process of PSS design. Furthermore, we have proposed a well-formalized method for identifying customer values using scenarios in which we describe the activities and thoughts of a persona in pre-, during-, and post-use phases of the core product of a PSS (Fig. 1 C). This method was developed through a Japanese national project.

In the embodiment phase, designers specify how to propose a value to the customer. To visualize and design a PSS using a computer, we have proposed methods for modelling an offering (Fig. 1 E) and its delivery process (Fig. 1 F) [11]. In addition, we have proposed knowledge-based design support tools to enhance the quality of a design solution and increase design efficiency (Fig. 1 I). For example, we have established a knowledge base consisting of past PSS design solutions [12].

In the evaluation phase, designers evaluate solutions generated in the previous two phases from various points of view. These evaluation results are then applied back to the previous phases. We have proposed methods for evaluating customer satisfaction (Fig. 1 L) [13], value for multi-stakeholders (Fig. 1 P) [14], and reliability of a PSS (Fig. 1 M) [15].

3. Pragmatic Projects for PSS development

3.1. Overview

Based on the methodology mentioned in Section 2, the authors have driven several pragmatic projects for PSS development. In this paper, we explain some of them: Cases A–D. Fig. 2 illustrates the area covered by each project in the three design phases. The remainder of this section explains these cases in detail. Cases A and B are business-centered projects with industrial partners. These two cases are explained from three points of view: products and services, research issues, and implications. Cases C and D are collaborative projects aimed at promoting and educating on the concept of PSSs in manufacturing industries. We briefly present the concepts and the progress of these two projects.

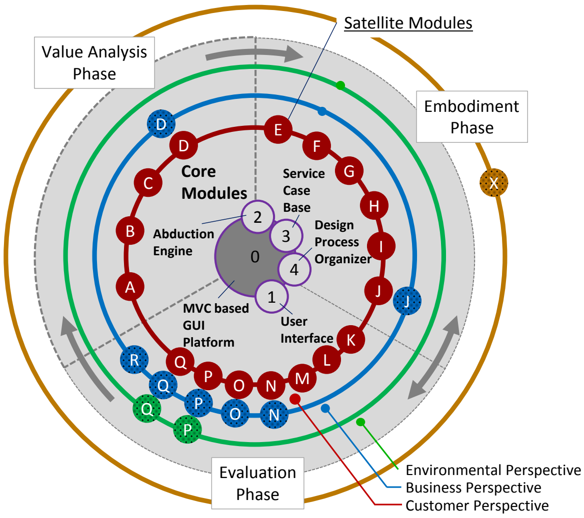

Fig. 1. Map of PSS design methods

Table 1. Satellite modules in Fig.4

Phases	Modules	Methods/ Tools
Value analysis	A	Persona / Scenario analysis
	B	Group decision-making method
	C	Value analysis template
	D	SOM based business chance finder
Embodiment	E	View model
	F	Extended service blueprint
	G	Conflict detection
	H	Design matrix for modular service design
	I	Function embodiment knowledge base
	J	Resource allocation method
Evaluation	K	Importance analysis
	M	Service FMEA
	N	Scene Transition Net simulator
	O	Qualitative service simulator
	P	PS system simulator
	Q	Integrated service evaluation method
	R	Cost analysis method
All phases	X	Edutainment tool for PSS philosophy

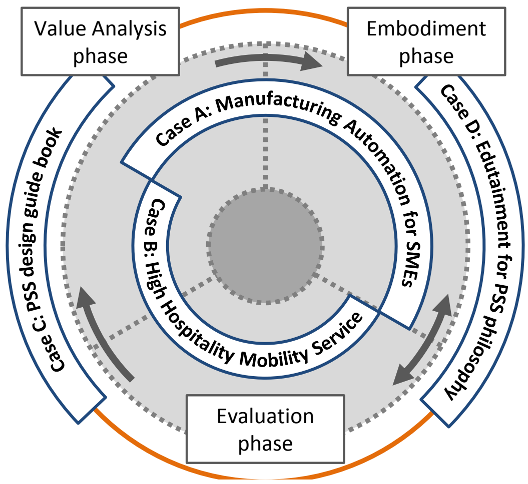

Fig. 2. Overview of the pragmatic projects

3.2. Case A: Manufacturing Automation for SMEs

The products and services

To enhance productivity and reduce manufacturing costs, automation of the manufacturing process is indispensable. For example, because turning the work piece onto the machine tool and taking the product out from the machine tool are dangerous operations, automation of the manufacturing process is extremely important not only for productivity enhancement but also for improving the work environment. However, automation of the small to midsize manufacturers who are the heart of manufacturing in any advanced country is still inadequate, and the work of supplying machine tools in such small to midsize manufacturers is still mostly performed with manual labor. This is because the current style offering of the robot necessary for automation is extremely uniform and is not responsive enough to the needs of small to midsize manufacturers. In many cases, a robot would be too expensive for these potential customers, or the support after the robot's introduction would be insufficient.

To solve this problem, it is valid to offer a PSS that effectively combines the robot and service and that responds flexibly to customer needs. The goal is to meet customer needs flexibly, including low introductory costs and highly hospitable support afterward by offering the robot as a service in a lease / rental form, in which the donor provides service, executing automation work as a proxy or providing required maintenance service at an appropriate cost. Such automation is not only needed domestically, but it is also foreseen in emerging countries where labor costs currently continue to soar. The basic idea of this project is a business strategy for advanced manufacturing countries that can be used enough for horizontal development in the overseas market.

Research issues

The purpose of this project is to establish a manufacturing automation business that corresponds to the customer's need for flexibility by offering a highly integrated robot and service system, namely, a PSS. In order to make a "highly integrated robot and service system" a business and to accelerate the automation of small to midsize manufacturers' manufacturing processes, a pragmatic PSS development technology for appropriately designing the system concerned is necessary. This project performs design and development of a PSS for automation of the manufacturing process and performs PSS industrialization in the Chukyo area, which is a typical industrial area in Japan. By executing this project, a new policy of industrial activation centering on manufacturing automation is established. Additionally, by arranging and generalizing the design / development procedure of an integrated robot service system, it is expected that a general-purpose PSS developmental technique that is not restricted to the manufacturing robot system will be built.

In order to complete this project, the following subtasks were executed.

(A-1) Inquiry into the subject of manufacturing automation and the demand for robots and related services among small to midsize manufacturers

This project offers an effective combination of robots and service to respond flexibly to the needs of various customers concerning manufacturing automation. To do so, the problems of small to midsize manufacturers connected to their manufacturing automation and demands for robots and the related services must be met without excess or deficiency. We investigated the problems related to manufacturing automation of small to midsize manufacturers in the Chukyo area and the demands for robots and all related services. The size of the companies, their target products, production quantities, the production period, the ratio of automation, etc. were investigated, and the enterprises were classified. In addition, interviews with the customers helped us understand their needs for automation of the manufacturing process. Then, based on the understood needs, we probed variations of the robot unit configurations and services to be offered. According to the results of this investigation, regardless of the product, common non-automated work of small to midsize manufacturers was mainly transporting work pieces between the manufacturing processes. In general, a picking robot is used to automate such transportation work. However, we found that several factors obstruct the introduction of such picking robots from small to midsize manufacturers, for example, extremely uniform robot style offerings, expensive robot prices, insufficient support after introduction, and so on. Based on this fact, we designed a new economical and easily customized robotic work piece supply picking system by combining devices such as an image sensor, a worktable, and a conveyer with a small, cheap scalar robot at the heart of the system (Fig. 3). In addition, we sufficiently cleared up the variation of the component of this system that fulfils customer needs and then designed the layout proposal, consulting, education, consumables offering, maintenance, and controller adjustment services, etc. required by the robot before operation, in operation, and after operation.

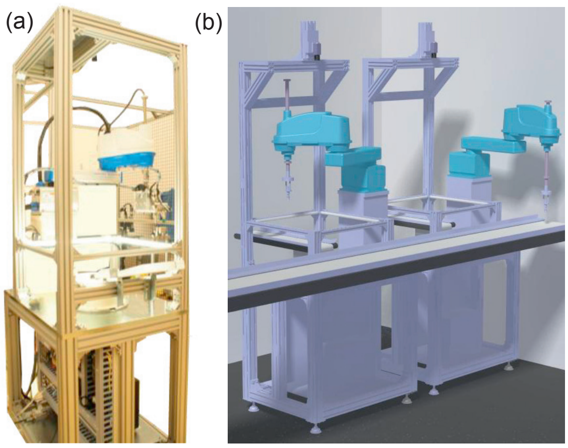

Fig. 3. The developed picking robot (a) Overview and (b) Layout

(A-2) Design and profitability / cost analysis for a robot / service combination: PSS

The business model of the PSS, the size and the continuance of obtained earnings, and the needed business costs differ according to how the product and service are combined and the form of the contract with the customer. Therefore, to make a developed PSS a real business, it is necessary to design multiple basic business packages based on variations of the robot and services and to analyze the profitability and cost of each business package. Based on the (A-1) results above, we designed basic business packages of the PSS to be offered after analyzing the profitability and the cost of the business. First, we designed a combination of product and service that fulfils the customer's need based on the composition of the robot and variations of service. In this phase, we executed the design of the robot and the required service by concurrently using the service CAD software that we developed and commercial 3D-CAD software for the robot design. Moreover, we also executed the following design tasks in our robot design.

(A-2a) Customer needs fulfillment by applying unit architecture

It is extremely inefficient to develop a robotic unit to fit a customer individually. In this project, we aimed to develop unit architecture that uses the techniques of architecture design, classifies a variety of customer needs, and covers them. We commonized the interface of each unit composition module that had been defined based on this design policy and achieved enough flexibility in user requirements by limiting the variety of unit compositions.

(A-2b) Facility layout design

Having a robotic picking system that is additionally set up for existing manufacturing equipment is the general style of introduction from a small to midsize manufacturer; therefore, the miniaturization of the robotic picking system is extremely important. We developed a general-purpose robot layout / orbit simulator which can be used by common-to-different makers and sizes of robots. By using this simulator, we designed beforehand the robot layout and operation orbit so that it did not interfere with existing equipment at the picking (palletizing) operations, enabling the miniaturization of the robotic picking system.

(A-2c) Quick robot hand design

It is necessary to customize the robot hand according to the object manufacturing process. However, unique knowledge of the object manufacturing process is necessary for this design; this is a big barrier for customers with little technological understanding of the robotic picking system. To solve this problem, we serviced design / production of the custom robot hand, sped up the hand shape design / change, made it low cost, and enabled customers' steady equipment operation in the short term.

In addition, we examined the form of the contract with customers (product use rights, property rights, accounting methods for products and services, etc.) on this PSS, designed multiple business packages, and analyzed the profit and loss of each business package. In this analysis, we analyzed not only short-term profit and loss but also mid- and long-term aspects. We evaluated the designed PSS from the perspective of both economy and sustainability and improved each business package accordingly.

Implications

In this PSS development, we aimed at smooth equipment installation and operation with the developed robotic picking system that required as little initial work by customers as possible. We included turbulence optical measures, burr processing, work and environment matching, operation optimization, and labor-saving services in our PSS package. For these services, we are developing additional log collection / analysis systems for work recognition and holding failures. By utilizing obtained log data from this system, we can offer prompt support services to customers according to their situations almost equal to residing on the sites, and we save labor for the system's introduction. The price of the basic system configuration is around 19,000 euros, but its part-picking ability is extremely generalized, and the system can pick various kinds of work pieces by simply changing its robot hand. We are now executing pilot installations for several companies in the Chukyo area and roughly estimating the profitability. Our experiences with these companies have greatly enhanced the reputation of our PSS.

3.3. Case B: High Hospitality Mobility Service

The products and services

The taxi business is a typical service that offers customers mobility to their destination. Recently, excess supply in the Japanese taxi market caused a decrease in the earnings of each car and, thus, the salary of drivers. To survive in this situation, some Japanese taxi providers have started evolving their business model to specialize in a certain customer category and a certain purpose of use.

This project focuses on a taxi business for vulnerable road users (Fig. 4). This business targets elderly people, mothers with babies or toddlers, and children without their parents as customers and offers them transportation service with high hospitality only by advanced reservation. For example, the drivers help elderly or pregnant customers to get in and out of the taxi, mount a child safety seat and nursery items in response to customer needs, and contact children's parents after they get in and out the taxi. In this business, additionally, the customized cars and information system provided by the alliance partner are used. They are trying to differentiate themselves from other taxi businesses by this combination of customized products and high hospitality services.

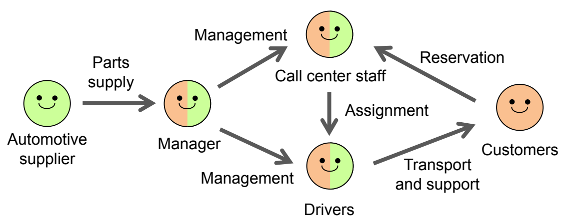

Fig. 4. Stakeholders involved in the target taxi business

Research issues

In this project, we address improvement of the PSS business impact. In order to discuss improvement plans, it is obviously effective to utilize employees' experience and knowledge acquired from actual contact with customers. In the real world, field-driven improvement has been carried out in advance. For instance, quality control activity is representative of the field-driven improvement. These activities, however, often result in a partial improvement focusing excessively on a certain opinion and standpoint. To realize an effective improvement, it is necessary to introduce a clear and easy method for enabling various employees involved in the improvement activity to understand issues in the business holistically and have productive discussions.

From the perspective of PS Synergy design, we focused our attention on the relations among various stakeholders' requirements for the PSS. Each stakeholder, including customers, employees, managers, and partners, has various requirements; there are several types of relations among each requirement: common relations, collision relations, and no relations. In the case of common relations, the requirements are synergistically fulfilled by providing products and/or services, but collision relations cause a trade-off between related requirements.

Based on these discussions, we developed a matrix tool for visualizing common and collision relations among various stakeholders' requirements. Fig. 5 shows part of the evaluation result using the matrix. From this result, we could identify many issues between the taxi drivers and their managers; namely, at first, internal services (e.g., pleasant working environment, efficient information sharing, rich operation manuals, etc.) should be improved to enhance the value created in the system.

Employees		Customers: C1 Surer reservation	C2 More flexible utility time	C3 Favourable seatmate in share-ride taxi	C4 Less burden of preparation to go out	C5 Less frequency of forgetting something	C6 Hospitable support for inconvenience	C7 Safer boarding and exiting	...
E1	Less burden of car allocation		△	△					
E2	Lower frequency of declined reservations	○							
E3	Lower frequency of last-minute cancellations		×						
E4	Efficient sharing of operational information		○						
E5	Aggressive customer support				○	○	○	○	
E6	Lower stoppage time on public roads		△				△	△	

Fig. 5. Result of visualizing the relations between requirements

Implications

In PSS development and operation, organizational issues often occur, such as differences of opinion and gaps in perception. We can say that the tool developed in this project would help to identify latent organizational issues in as-is PSSs from the aspect of multi-stakeholders' requirements. However, it is also difficult to solve identified issues. Since the value of a PSS is amplified by mutually increased values for stakeholders involved in the system, effectively solving those organizational issues would be a key requirement for implementing and operating a PSS successfully.

3.4. Case C: PSS Design Guidebook

Since 2002, the authors have organized and operated an industry-academia-government collaboration scheme for service and PSS design research called The Service Engineering Forum (SEFORUM) [16]. As an achievement of the 4th period of this scheme, we have developed a guidebook for PSS design.

This guidebook aims to support understanding of the entire process of a PSS design and report engineering methods for the PSS design (most of these methods are introduced in Fig. 1). This book is composed of the following six design phases: environmental analysis, customer analysis, content channel design, PSS network design, process design, and PSS preparation. In each phase, as shown in Table 2, the objective of the phase (why), outputs in the phase (what), and methods and tools used in the phase (how) are explained briefly. Here, both general and our original methods and tools are included.

Moreover, readers of the book can understand feed-forward and feed-back loops in the PSS design process by descriptions of the input-output relationship between the methods and tools.

We have conducted a PSS design workshop using the guidebook for Japanese manufacturers. Based on results and reflections from the workshop, we will make revisions and then publish it for application to more manufacturers.

Table 2. An example from the guidebook for PSS design

Step 3: Content Channel Design
Objectives: The value of a PSS is determined by customers. Therefore, PSS providers cannot provide value but only offer a proposition of value to customers. Value propositions can be achieved by PSS content and channels. In this step, designers need to determine the content and channels as well as the resources consumed to realize them.
Outputs of this step: - Contents include not only tangible products but also intangible offerings, such as rights to use products and results of human activities. - Channels are a means of delivering content to customer, such as the activities of employees and the behavior of infrastructure. - Resources, which include technologies of tangible products, skills of employees, etc., are consumed to realize content and channels.
Tools for determining these outputs: - View model represents the relationship between the value for customers and the required resources for the value proposition.

3.5. Case D: Edutainment for PSS Philosophy

The designers who will lead the manufacturing industry in the future need to have a new viewpoint of amplifying the value with a combination of products and services. For designers who have only learned traditional engineering, it is difficult to obtain this multi-disciplinary viewpoint spontaneously. For this reason, many companies have not shifted their business models from product-oriented to PSS. To promote the shift to providing PSSs in the manufacturing industry, the educational methods or tools that enable designers to learn such viewpoints easily and effectively are required. We have developed an educational business game named EDIPS (Edutainment for Designing Integrated Product-Service Systems) [17, 18] (Fig. 6). EDIPS enables players to effectively and enjoyably learn the viewpoint of value amplification by combining products and services through active thinking in a simulated business environment..

EDIPS is a turn-taking board game developed by simplifying the market in which products are sold and services are offered. The game includes three colors of products (red, blue, and yellow) and four kinds of service cards (training, monitoring, repairing, and reuse). Game players are designated as product providers or service providers, and they aspire to gain the most points (i.e., revenue) to win. In order to gain points, product providers sell their own products. Sold products pass through the following life cycle phases: installation, use, maintenance, and disposal. When a product arrives at each phase, service providers can offer their own services related to the product and the phase. By paying a certain amount of points, only one player can become a PSS provider in the middle of the game. The PSS provider can effectively score many points by performing both the actions of product and service provider. To cope with the PSS provider, a product provider and a service provider can establish an alliance. When and with whom players establish alliances will be essential to winning the game.

We have started applying the game to industrial and academic partners. In the 5th IPS^2 conference held in Bochum, we jointly hosted the IPS^2 Games Day and introduced this game. As a result, the concept and contents of our edutainment tool earned good reviews from the participants. Currently, trials of the game have been started in several universities in various countries.

Fig. 6. Components of EDIPS

4. Concluding Remarks

This paper explores the latest developments of PSS in Japan by the introduction of four pragmatic projects that we have driven. Cases A and B presented business-centered projects concerning manufacturing automation and a specialized taxi business. Cases C and D explained the PSS design guidebook and educational business game which are developed in collaboration with partners. Future work will include synthesis of all implications obtained from these projects toward the systematization of PSS Engineering.

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