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A Guideline for Product-Service-Systems Design Process

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Abstract

Product-Service Systems (PSS) has been regarded as an attractive business concept that create high added value by integrated provisions of products and services. Since both products and services are included in the design object, the PSS design process has become increasingly complicated. Thus, the designers need to organize reliably what they should accomplish during the PSS design process. However, it is difficult for designers to grapple what they need to focus on during PSS design process. To support such PSS design process, this paper proposes a PSS design guideline which based on Software Engineering Methods and Theory (SEMAT). The proposed guideline provides the designers with PSS design perspective, milestones through the design process, and the way to manage the design process.

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Keywords: Product-Service Systems(PSS); Design guideline; SEMAT

1. Introduction

Due to intensified global competition and market maturity, it is necessary for manufacturing firms to adopt a more competitive and sustainable business model. In this context, Product-Service Systems (PSS) [1-4], which is characterized by a combination of tangible products and intangible services, has been attracting much attention from both academic and industrial sides.

To realize PSS business model, numerous researchers have proposed PSS design method and evaluation tools such as [5-7]. For the PSS “design” point of view, Shimomura et al have proposed service CAD system [8]. Nicolas, M. et al have proposed a PSS design method based on functional analysis and agent-based value design model [9].Berkovich, M. et al have applied Requirement Engineering approach to reveal essential criteria of PSS design process [10]. However, a practical framework which enables PSS designers to manage organized essential tasks or criteria of PSS design process have not proposed.

In this article, the authors propose PSS design guideline as a framework to manage PSS design process. The guideline provides the designers with PSS design perspective, milestones through the design process, and the way to manage the design process.

2. Related Work

2.1. Product/service-system Tools for Ensuring User-oriented Service (PROTEUS)[11]

PROTEUS is a PSS development project that was conducted fully cooperated with Danish maritime industry. Objectives in this project are as follows.

- To understand the basic conditions in the maritime branch, for delivering PSS solutions.
- To create deep cases from other industry branches, to show how similar companies have servitised.

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- To understand the individual companies' readiness to servitise.
- To create a framework for PSS development and equip this framework with a toolbox of PSS methods.
- To understand the organizational challenges and necessary activities to aid the servitisation process.
- To explore how partnerships - both producer-to-customer and producer-to-producer can strengthen PSS concepts.
- To create and try out PSS business models in the maritime branch.

So as to correspond to each project purposes, they published seven workbooks as a project outcome. Since the project purposes are significantly comprehensive for PSS development, the PROTEUS research project focused on all phases of the PSS development life cycle.

2.2. Software Engineering Methods and Theory (SEMAT)

SEMAT is a practical software development framework that aimed at re-founding software engineering based on a solid theory, proven principles and best practices [12][13]. In software engineering field, because various stakeholders are involved in the software development process, a framework that enables software designers to facilitate information sharing or decision-making has been required. To clarify software developer's tasks, SEMAT provides the "Kernel" that represents essential elements for software developers must be mindful and assess for progress and health. In particular, the most important kernels, which express the viewpoints of managing the software design, are called "Alpha". As shown in Fig 1, SEMAT defines seven alphas; Opportunity, Stakeholders, Requirements, Software System, Team, Work, and Way of Working and each alpha is organized into three discrete "areas of concerns"; customer, solution and endeavor. Moreover, each alpha provides a card set that summarizes the software developers should tackle. This card set enabled software developers to manage their software development progress and health.

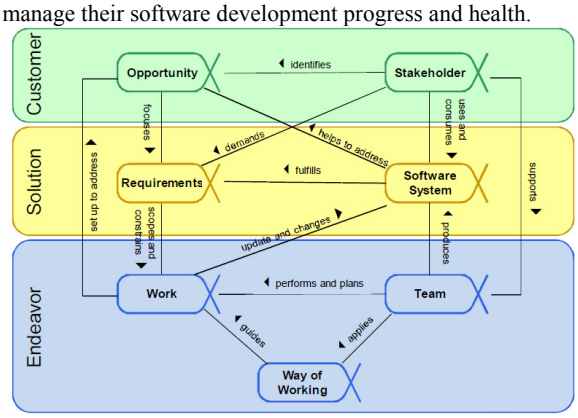
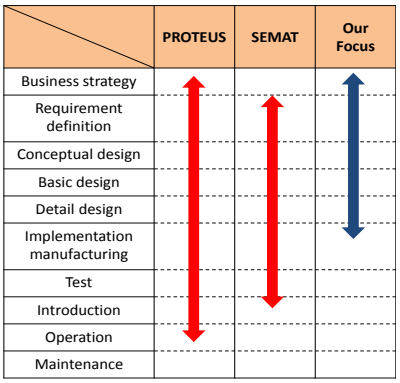


Fig 1 Software engineering alpha

2.3. Scope of this study

Table 1 shows a comparison of the existing research. In this table, the vertical axis shows the general development phase and the horizontal axis shows the existing research. As shown in table 1, PROTEUS and SEMAT cover a wide range from the requirement definition to the introduction phase. In particular, PROTEUS focuses on the Danish maritime industry and they propose practical PSS design and development process. However, since the specific area of the maritime industry is targeted in PROTEUS, some considerations and/or outputs in design process are not strictly defined in terms of versatility. Thus, PROTEUS is not sufficient for practical design.

Table 1 Comparison of the focus of related work



In product development, the product developers define the complete development process in detail at the early stages of development. On the other hand, in service development, the service developers need to repeat the service design cycle and continuously improve the design solution. This is because, in comparison to product development, service development includes various human factors, which influence overall service development. Therefore, we focus on a wide range of development, from business strategy to detailed design.

Since multiple stakeholders must be involved in the PSS, the PSS design process has become increasingly complicated. To support such PSS design process, it is effective to clarify PSS design object and manage the design object by task-based process management. SEMAT is one of task-based process management since various stakeholders are involved in the software development process. Considering such features of PSS design, we develop a PSS design kernel by applying the concept of SEMAT format. In "areas of concerns" of SEMAT, "customer" and "solution" describes design object, indicating what software designers should tackle on. On the other hand, "Endeavor" describes design subject, meaning how designers should perform. As the first step of the research, we focus on "customer" and "solution" area and clarify PSS design object.

3. Research Methodology

3.1. Methodology for building the PSS design kernel

In the same manner as the development process of SEMAT, we build the PSS design kernel. There are 2 steps for consolidating SEMAT kernel as shown in Fig 2. At the

first step, SEMAT defined software systems practice and patterns by methods to design, to evaluate and to operate software systems. Thus, we firstly review PSS literature to assemble PSS design practice and patterns. At the second step, SEMAT defined the universals and the kernel language for software system. Thus, we secondly compare the practices and patterns of SEMAT and PSS to clarify the difference between SEMAT and PSS.

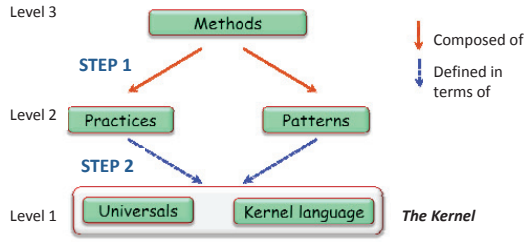


Fig 2 The SEMAT diamond [10]

3.2. Essential characteristics in PSS design

As mentioned in 3.1, we reviewed PSS literature and identified PSS design practice and patterns. To extend the original SEMAT, in particular, we found the two essential characteristics in PSS design; Actor Network and Continuous Improvement. The details of these characteristics are as follows.

- *Actor Network*

The PSS provider requires many resources because the PSS delivery process needs to cover not only the phase of use of the products and/or services, but also other customer activities. In order to prepare resources for them, new and varying types of actors must be involved as a part of a network. The network is called Actor network. Constructing an actor network plays an important role in the PSS design [14]. For example, Morelli proposed the method to develop actor network [15]. To construct an actor network, designers need to consider the benefits and risks among the stakeholders involved in the network. For example, Akasaka developed a simulation-based design method for realizing values for several stakeholders simultaneously [16].

- *Continuous Improvement*

PSS designers need to manage the design expertise gained thorough PSS design or reuse resources to another PSS business. This is called continuous improvement of the PSS design cycle. As mentioned in 2.3, the service developers need to repeat the service design cycle and continuously improve the design solution, because service includes number of human factors which have influence on service development. For this reasons, continuous improvement of the PSS design cycle is one of the especial and important point of PSS design. For example, Meier insisted actors involved in PSS have to cope with dynamic changes, such as resources, market demands, changing customer requirements, and continuous improvements arising from gained knowledge [17]. Schweitzer analyzed the demands on the organizational and operational structure of the value creation network in order to enable a PSS provider to implement a continuous PSS improvement process based on customer feedback [18].

4. PSS Design Kernel

4.1. Configuration of the PSS design kernel

Table 2 shows the PSS design kernel (see Appendix). The kernel alpha, which is the PSS design perspectives, contains “stakeholders”, “opportunity”, “requirement”, and “Products and Services”. Further, each kernel alpha has “state” and “checklist”. State represents the progress and health of the kernel alpha. For example, the Products and services move through the states of the PSS architecture: architecture selected demonstrable, usable, ready, operational, and continuous improvement. Each state has checklists that specify the criteria needed to achieve the state. These states and checklists enable to guide the behavior of the PSS design teams.

In order to design and operate PSS business model, PSS designers need to collaborate “stakeholders”; a group or organization that are involved in the PSS development. On “Stakeholders”, PSS designers first recognize interested party including customers and then clarify each role to play in the PSS development. Then, they prepare the communication method between stakeholders to build good relationships. After that, they encourage stakeholders to agree the system requirements and the resource procurement plan. Finally, they evaluate if the customer can accept the designed PSS.

It is important for PSS designers to grasp the “opportunity” to develop or improve PSS. On “Opportunity”, PSS

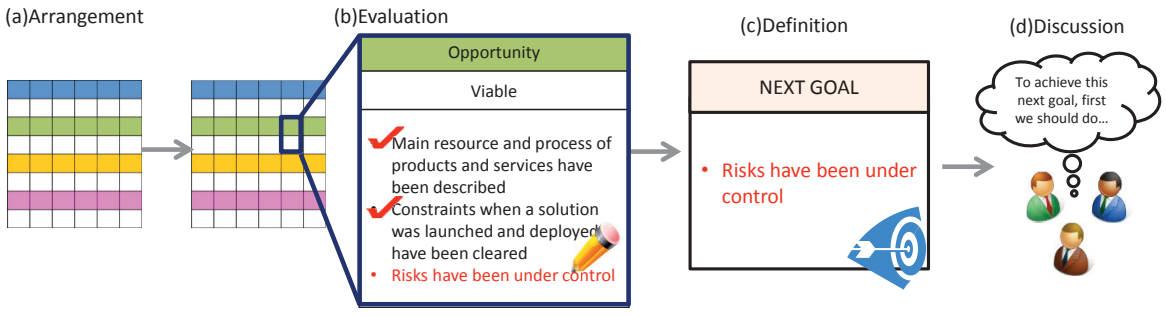


Fig 3 Flow of using PSS design kernel

designer first identify the challenges that customer wish to resolve. Then, they devise the solution for the challenges and clarify the solution value. After that, they evaluate the process or resources to realize the solution. Finally, they evaluate if the challenge actually resolved.

The PSS is developed based on the customer "requirement". On "Requirement", PSS designers first clarify all the functional requirements of the PSS. In addition, they determine the scopes of functional requirement that needs to be implemented to the PSS. After that, they evaluate if the functional requirement actually implemented to the PSS. Finally, they evaluate if the system is under controlled.

PSS satisfies the customer requirements with the synergistic value realized by integrating "products and services". On "Products and Services", PSS designers first consider the combination of products and services and develop the actor network. After that, they evaluate if the developed actor network can be operated. In addition, they begin to operate the PSS after the actor network is authorized among all the stakeholders. Finally, to continuously improve the PSS, they repeat the development cycle and adapt the know-how acquired through the PSS development process. In addition, based on the essential characteristics in PSS design mentioned in 3.2, we extend the Alpha "Products and Services" from the original SEMAT. Specially, the state "Actor network Selected" is added instead of "Architecture Selected" in the original SEMAT. Checklists for this state includes "criteria for selecting actors agreed", "actors are identified" and "plan for contracts defined". In addition, the state "Continuous improvement" is added instead of "Retire". Checklists for this state includes "system for observing information about customers established", "team for continuous improvement organized" and "process for continuous improvement defined".

4.2. How to use the PSS design kernel

- *The target user*

PSS development project is conducted in cooperation with multiple development teams because multiple stakeholders need to be involved in the development process. Each development teams are organized the members with diverse roles, such as project manager, designer, and operator. In such a developing environment, each project team needs to manage the development tasks and minimize development rework. To do so, it is important for project members to share project goal and respective roles. In this study, therefore, project managers are regarded as one of the main target users. The PSS design kernel enables them to share the information about project goal and respective roles among relevant PSS development teams.

- *How to use*

According to the features of the PSS design kernel practical, we propose the card set for project managers to manage design process in a tangible way. This card set can be used in three ways as follows. First, project managers understand the current state of the design process. Second, project managers set a next goal in the PSS design process. Finally, project managers set the team task to achieve the next goal in the PSS design process.

To understand the current state of the design process, managers arrange each card in the order shown in Table 2, Appendix (Fig3 (a)). After that, they evaluate which checklists they have not yet fulfilled (Fig3 (b)). The checklists that are not fulfilled will be a next goal in the design process (Fig3 (c)). To achieve the next goal, they prioritize the tasks and select the techniques or methods to support completing the tasks (Fig3 (d)).

5. Case study

We applied the proposed method to the developing support services of basic software that is utilized in automobile parts development. This service facilitates the interactions between product line development team and the manager, supporting software developers by providing product specification data. The purpose of this case study is to verify that proposed method can comprehensively organize tasks for the development support service. Specifically, through an interview with a software developer, the checklists in the proposed method were associated with actual development tasks. Table 3 shows the example of associated checklist. As shown in table 3, we could associate the entire checklist with actual development tasks. This result indicates the proposed method is able to provide the guideline for development support services.

Table 3 An example of replaced checklist

Actor network	
before	after
Criteria for selecting actors agreed.	Criteria for selecting manager, product line development team and product development team agreed.
Actors are identified.	Manager, product line development team and product development team identified.
Plan for contracts defined.	Plan for contracts defined.
Continuous Improvement	
before	after
System for observing information about customers established.	System for observing information about software users established.
Team for continuous improvement organized.	Team for continuous improvement of software installation services organized.
Process for continuous improvement defined.	Process for developing software installation services defined.

6. Discussion

As shown in the case study, we apply proposed method to the developing support services of basic software for automobile parts development. As shown in table 3, the checklist of PSS design kernel could be associated with actual tasks of car parts manufacturer. By replacing checklists of the PSS design kernel with actual tasks, it is expected to provide PSS designers perspectives for organizing actual business tasks. Further, PSS designers could be develop a guideline for particular business by organizing business tasks. To verify the effectiveness of proposed guideline, we had an interview to a practitioner of the business. As the result, the proposed guideline could also be used as a tool for identifying the PSS development barriers in advance. Specifically, PSS designers could identify the PSS development barriers by reviewing all the checklists of the guideline when launching PSS development.

However, the business which we applied proposed method as case study was not a truly PSS business; general and abstract development task. Thus, we should verify the checklists of the PSS guideline again by setting concrete PSS design tasks. In addition, for the specification of the guideline, designers need to consider the PSS maturity level. This is because tasks that should be accomplished in a PSS business model will vary from the PSS maturity level. For example, companies that aims to develop a PSS with low maturity level is not necessary to consider whole tasks. Therefore, future works include defining the PSS maturity level and identifying the tasks that companies should addressed depending on each PSS maturity level.

7. Conclusion

In order for companies to realize PSS business, this paper proposed PSS design guideline. Specifically, we defined the PSS design perspectives that designers must consider to evaluate design progress and health. In addition, we organized designer's tasks from each defined perspectives and provided the way to manage designer's tasks. On the other hand, we have not verified the effectiveness of proposed method. To verify and evaluate the effectiveness of this study, we will apply this study to other actual PSS business.

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Appendix:

Table 2 PSS design kernel

Kernel Alphas	State/Checklist 1	State/Checklist 2	State/Checklist 3	State/Checklist 4	State/Checklist 5	State/Checklist 6
Stakeholder	Recognized: - Agents on Flow model (potential provider, receiver, relay agent)have been identified - Representatives of all agent have been agreed - Functions or scopes that each agent have been defined	Represented: - A planner (mediator between agents) have been assigned - A planner have agreed own functions or scopes - How to collaborate between agents (how to realize the function) has been agreed - Agents respect each effort	Involved: - Agents have played their role - Agents have respective feedback and involve decision-making - Communications between agents have been well	In Agreement: - Value for each agents have been defined and other agents have agreed it - All agent have been agreed functions that will be realized with the priority - All agent have been agreed minimum expected value	Satisfied for Deployment: - Feedbacks have been provided to the entire system from each agent's point of view - A ready to operate the system have been confirmed	Satisfied in Use: - A system has been exceeded minimum expected value of agents - Needs and expectations of the agents are satisfied
Opportunity	Identified: - Receiver's activities that can be supported by solutions of products and services have been identified - Receivers have grasp the potential value and have wishes to invest - Agents that share the supportable receiver's activities have been identified	Solution Needed: - Needs for solutions of products and services have been promised - Receiver's demand have been identified - Potential problems and root causes have been found - At least one solution of products and services have proposed	Value established: - Value-in-use have been defined when a solution succeeded - Receivers have understand the secondary effects of solutions - Receivers have understand the value in exchange of products and services	Viable: - Main resource and process of products and services have been described - Constraints when a solution was launched and deployed have been cleared - Risks have been under control	Addressed: - A demonstrated solution have been provided - Effective systems have been available - Receivers have agreed to the provide function - Receivers have been satisfied the solution	Benefit Accrued: - Obvious benefits in the operation has been created - Predictable investment effects have been obtained.
Requirement	Conceived: - Requirements and functions of the system have been clear - Users have been identified - First capital investor have been identified	Bounded: - The range of requirements and functions that should be implemented have been agreed - The Criteria for succession (KPIs) have been clear - The change management of requirements and functions have been agreed - The non-functional requirements have been identified	Coherent: - The overall picture of the PSS have been shared to the agents - The critical usage scenario have been shared - The priority of requirements and functions have been clear - Collision of requirements and functions have been eliminated - The effect of requirements and functions have been understand	Acceptable: - Acceptable solutions for agents have been provided - The agreed requirements and functions have had low probability to change - Value have been clear	Addressed: - A necessary and sufficient requirements and functions have been implemented - Agents have agreed the system can be operated	Fulfilled: - The system have satisfied the requirements and needs - There have been no unsolved requirement to interfere with the completion
Products and Services	Actor network Selected: - Criteria for selecting actors agreed. - Actors identified. - Plan for contracts defined.	Demonstrable: - Features of actor network are verified by using simulations or reefing prior case. - Stakeholders agree the adequacy of actor network. - Important service encounter and process are verified.	Useable: - Products and services have been available and the required quality attributes have been achieved - The user have been able to operate the products and services - Functions and performance have been tested and demonstrated - The defect level have been acceptable to receivers - The contents of the products and services are well-known in each version	Ready: - The products and services manual have been available - Receivers have accepted the products and services - Receivers have prepared the use of products and services	Operational: - Products and services have been used in the receiver environment - Products and services have been used by supposed operator - There have been a use case that all functions of products and services have been operated - The maintenance level of products and services has been agreed	Continuous improvement: - System for observing information about customers established. - Team for continuous improvement organized - Process for continuous improvement defined