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DIAGNOSIS OF CURRENT SMART HOME APPLIANCE DEVELOPMENT PROCESS FOR APPLICATION OF PSS DESIGN METHODOLOGY

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1. Introduction

1.1 Background

Initiated by smartphones, smartness is emerging as one of the essential values of IT products and home appliances. Home appliances to which smart technology was applied have been called Smart Home Appliances (SHA). The global market for SHA is expected to grow from 3.06 billion USD in 2011 to 15.12 billion USD in 2015 [Zpryme 2010]. This indicates that SHA business can be an opportunity for home appliance manufacturing companies to revitalize their stagnant market. In fact, many international home appliance manufacturers are introducing state-of-the-art technologies and products related to SHAs. This trend is evident at the international electronics fairs where the latest trendy SHAs are exhibited [Yoon and Jang 2012].

While the major home appliance manufacturing companies possess the advanced technologies and many things became possible (e.g. users can turn on an air conditioner out of the house or shop for groceries using a smart refrigerator) it is doubtful whether their smart solutions are indeed beneficial in users' daily life. Sciacca [2013] argues that some features of SHAs are beneficial and attractive, but many functions of them are not desirable. Using the food management function of a smart refrigerator, for example, users can input the name, amount and expiration date of food by the touchscreen. The food inventory list prevents users from an unnecessary purchase of food and therefore contributes to reducing food wastes. In addition, notification of the expiration date will lead the users to consume their food while they are fresh. If the food management function is fully utilized, it can contribute to the efficient use of food. In reality, however, as a refrigerator is often used by multiple users and contain different types of food, the food management function using a touchscreen input system may be an additional annoying task for users. During the interviews for a smart refrigerator development project, smart refrigerator users mentioned that the food management system is attractive but operating a touchscreen, especially dragging-and-dropping icons, is inconvenient and complicated. Because of the ineffective input method, some users gave up using the function and the others utilized the function only for long-term food storage or rarely-used items [Jung 2012]. The case of smart refrigerator suggests that successful SHAs cannot be developed simply through the high-end technologies like a touchscreen or cloud computing. In order to develop products that provide values to users, the notion of SHAs and how to develop them need to be clarified.

1.2 Smart home appliances and smart home

Although there is not a consensus on what SHA is or how it should be in home appliance industry or research field yet, a number of practitioners and researchers have suggested the definition and the

features of SHAs according to their experiences and perspectives. Rijsdijk and Hultink [2009] and Kango et al. [2002] focus on the sensing functions and the communication ability of SHAs. According to Rijsdijk and Hultink, SHAs are defined as "products that contain information technology and therefore able to collect, process and produce information." In addition, they suggest 7 dimensions of product smartness: autonomy, adaptability, reactivity, multi-functionality, ability to cooperate, humanlike interaction and personality. Kango et al. define a SHA as "an appliance whose data are available to all concerned (all the actors in the appliance life cycle) at all times throughout its life cycle." Kango et al. [2002] regard SHAs as the sources of data required to provide the users and producers with various services. In order to play such a role, advanced ICT technologies should be applied. Association of Home Appliance Manufacturers [2009] identifies SHAs in terms of the smart grid system. They describe SHAs as "a modernization of the electricity usage system of a home appliance so that it monitors, protects and automatically adjusts its operation to the needs of its owner." Moreover, they point out some key features of SHAs involving automatic adjustment, communication and customized functions. Meanwhile, Yoon and Jang [2012] define SHAs as "home appliances which can provide customized contents and smart home service functions with the network connection and various service controlling functions," and can automatically adjust to the situation to provide optimized performance. In summary, SHAs are home appliance products which can fulfill users' needs better by providing customized services through the communication with users, other products or service providers in society, and reaction or automatic adjustment to the changes caused by users or environmental factors.

Another approach to understanding SHA is the perspective regarding SHAs as "the components of Smart Home." Yoon and Jang claim that Smart Home has evolved from home automation, and the home appliances constructing a Smart Home are also transforming into SHAs [Yoon and Jang 2012]. While appliances in the home automation system were developed focusing on function implementation rather than user benefits or usability, many SHAs have also suggested the new lifestyle patterns to consumers. Harper [2003] argues that the role of the consumer electrics manufacturers as one of the new main players of the smart home market needs to be emphasized. Traditionally, electrical equipment suppliers who provide switches, sockets, distribution boards and the rest have dominated the smart home market. Nonetheless, the high initial investment for the smart home construction was regarded as one of the obstacles of the popularization of smart home. People realized that changing their home appliances into SHAs one by one is more affordable and easier way to set up a smart home than building or remodeling a house. As the SHA manufacturers are leading the innovations of the smart home industry, exploring the properties and the issues of smart home will help them understand and develop SHAs.

In addition to the high initial investment cost, the following factors impede the growth of the smart home market [Gann et al. 1999], [Harper 2003]: The first factor is technology push without deep understanding of users' needs. To stimulate users to invest in smartizing their homes, it is necessary to understand the user requirements and to satisfy them through their value propositions rather than developing the technology-oriented products. Smart home solutions should be able to fulfill the real user needs [Barlow and Gann 1998], and understanding the users' needs will be a challenge for the manufacturers and the suppliers in market development [Gann et al. 1999]. In this context, the importance of services as an effective means to fulfill the user needs was addressed in several studies. In considering the elements of smart homes, service field which indicates the connection to external services was counted as one of them [Harper 2003]. Suppliers have to contrive how to make the customers realize the benefits of smart homes through delivering products and services [Gann et al. 1999]. From the smart home strategy of an international home appliance manufacturing company dealing with not only the product-related benefits but also the service-related values, it can be inferred that a service is being perceived as a necessity for the competitive smart home solutions from the industrial perspective as well as the academic view point [Gärtner 2006]. The most essential condition to establish consumer trust and develop market is "the ability to provide services to support the use of new products and systems." Reflecting its dominant position, service providers are nominated as another new main player of the smart home market [Harper 2003].

The second barrier of the smart home market is a challenging integration of different stakeholders and products. Basically, building and remodeling a house require the participation of stakeholders from designers and engineers to installers and financiers. Furthermore, the ability to provide a new and beneficial service including the required functions is significant for smart homes to satisfy users' need. In order to provide diverse services, various stakeholders are also involved in the smart home business: social services providers, healthcare experts, telecommunication companies and others [Gann et al. 1999]. The integration among home appliances is also indispensable. Manufacturers have concentrated on improving the internal intelligence of the standalone products without adequate consideration of the costs and benefits of integrating home appliances. However, lately some smart products and future scenarios of home appliance companies began to display the capability of the communication and the cooperation among SHAs and home systems: for example, automatic interaction between a cooking stove and an extractor fan [Gann et al. 1999]. For harmonious cooperation among diverse stakeholders and high functionality of SHAs through the interactive cooperation, smart home should be treated as an integrated system, and intercorporating standards or protocols for the smooth communication and the cooperation is necessary.
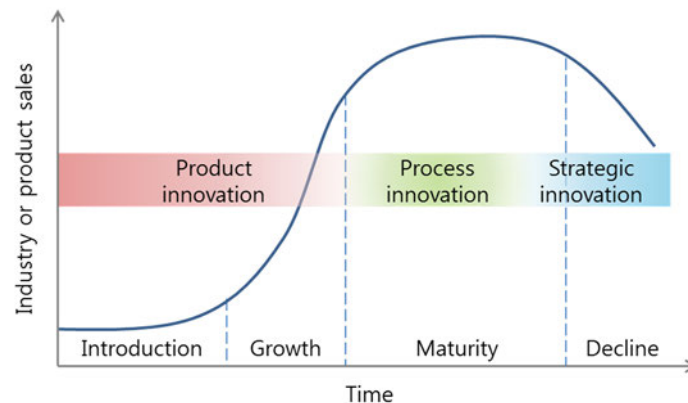
1.3 PSS approach to SHA development

Figure 1. Industry life-cycle and innovation per stage [Tukker and Tischner 2006]

Studies of SHAs and smart homes, suggested that developing SHAs is not just about manufacturing electronic products, but designing and implementing a system consist of products and services. Therefore developing SHAs or smart homes through traditional product development process or methods has several limitations, and instead, an approach to designing a coordinated product service mixes is needed. Product-Service System (PSS) indicates 'marketable systems of products and services capable of fulfilling a user's demand' [Brezet et al. 2001] and a strong relationship with users enhances the market competitiveness of a company. The industry life-cycle stage of home appliance also supports this assertion. On the industry life-cycle (Figure 1), home appliance market can be positioned between maturity and decline [Tukker and Tischner 2006]. For instance, lately refrigerator manufacturers are competing mainly on capacity or design rather than the functions or performances of products, and this phenomenon implies that there is little room for improvement through innovation in product or process. In this context, the home appliance industry requires strategic innovation that enables companies to explore new sources of additional value and extend the life-cycle of home appliance market, and adding products and services is a form of strategic innovation [Tukker and Tischner 2006]. For this reason, PSS development methodology is suggested as an alternative solution for SHA development. PSS development methodology can contribute to SHA development at three levels: enhancing the relationships a) between the SHA products and the user, b) between the SHA products and c) between the SHA products and stakeholders (Figure 2).

a) Between a product and user

Based on the definitions of SHAs focusing on their ability to sense and communicate, SHAs can be categorized as an "ICT product or system that processes, stores or communicates information".

Although the development of ICT generally brings about convenience systems for users, it can easily be technology-driven rather than needs-driven because little time to recognize customers' needs and demands is allowed for technology or product developers [Tukker and Tischner 2006]. From the perspective of user needs, PSS is thought to be an effective approach because it can lead providers toward a novel solution to satisfy users' demands and needs through a combination of efficient products and effective services [Kang 2009]. Moreover, providers of products or services can have longer interaction with customers in PSS so that they can co-create values with their customers and increase customer loyalty.
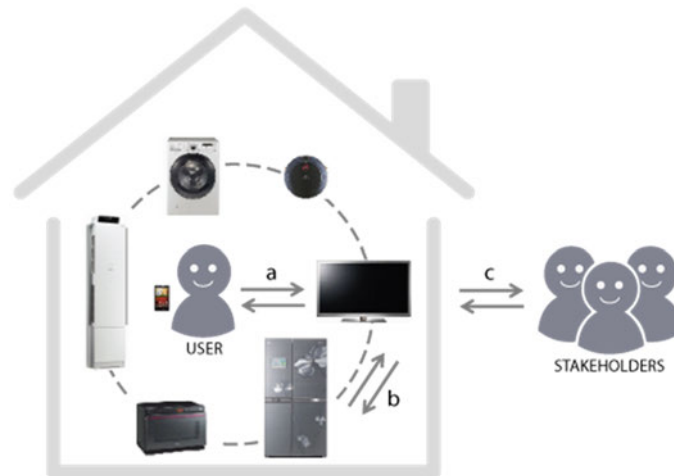

Figure 2. Relationships among products, user and stakeholders in smart home

b) Between products

The capability of processing, storing and communicating information of SHAs can enhance the satisfaction of consumer needs [Tukker and Tischner 2006]. Smart products share the information about users through communication and cooperate for the same purpose to offer better services and values to users [Rijsdijk and Hultink 2009]. In order to design and develop a cooperative ecosystem of SHAs, systematic approach is required [Brezet et al. 2001], [Tukker and Van Halen 2003], [Burger et al. 2011]. Systematic approach of PSS, which enables developers to integrate products and services in a smart way and contribute to providing users with coherent experiences and values, will thus promote the cooperation among SHAs.

c) Between a product and stakeholders

Smart home scenarios [Eberl 2002] suggests that service elements are important for fulfilling user needs and offering values. As developing the high technology for SHAs and providing various services are realized through partnership, synergies among stakeholders from diverse areas are required. In this context, PSS development methodology can encourage cooperation among various stakeholders. Constructing multi-dimensional partnership allows stakeholders to take advantage of professional knowledge, advanced technology and high quality products or services of other companies and lower system costs at the same time [Tukker and Tischner 2006], [Kang 2009]. PSS development tools or methods to analyze stakeholders' needs and to help their communication and involvement can contribute to SHA development involving a variety of stakeholders.

2. Objective and methods

2.1 Objective

The aim of this research is to propose a methodology dedicated to SHA development by adopting PSS development methodology. In SHA industry, market cycle is so fast and market competition is so harsh that practitioners cannot afford to spend much time and effort on changing their development

process or adopting new development methods. Therefore a methodology to be proposed should be easy and simple to apply. The research question was set as follows: How to identify the section of the existing SHA development process in need of supplementation and/or reinforcement through the adaptation of the PSS development process?

To discuss the research question, existing SHA development process were diagnosed based on a unified PSS development process. A number of PSS development processes were selected and integrated into a unified process through literature review. Then, the unified PSS process was shown to SHA developers in the interviews to ask about how it could complement their SHA development process.

2.2 Methods

In order to compare PSS development process with conventional SHA development, a unified PSS development process which can be employed as a representative of diverse processes is required. For the first step, existent PSS development processes and activities on each phase were collected and analyzed through literature reviews. The criteria for selecting the methodologies are: 1) PSS development processes of which the division and description of the stages are clear and specific enough to understand the activities undertaken on each phase were selected for analysis and 2) the processes which add service elements on complete product were excluded because product elements and service elements can influence each other in development process so simultaneous development of products and services is important for a holistic approach [Brezet et al. 2001], [Meier 2013]. Finally 7 processes were selected to be analyzed. Table 1 displays the selected processes.

Table 1. List of selected PSS development processes

Process	Author
NSD	[Burger et al. 2011]
IPSE	[Lindahl et al. 2007]
MEPSS	[Van Halen et al. 2005]
Tukker	[Tukker and Van Halen 2003]
Kang	[Kang 2009]
IPSS	[Bochnig et al. 2013]
Brezet	[Brezet et al. 2001]

After selecting the processes, the stages of PSS development process were segmented, grouped and rearranged to the following process: Exploration, Concept Generation, Idea Development, Preparation for Realization and Realization. The name of each phase came from the most representative name of grouped stages. Then the activities performed during each phase were analyzed based on the keywords and tasks. Figure 3 depicts the entire stages of the unified PSS development process.

Based on the unified PSS development process, interviews were designed to diagnose current SHA development process. In the interview, the interviewees were asked to answer the following questions for each activity included in process stages:

1. Is this activity conducted in current SHA development process?
2. Is this activity necessary for your SHA development?
3. Through this activity, how do you expect your SHA development process to be improved?

The question 1 and 2 were answer in 3-point scale: to a great extent (2), somewhat (1) and hardly (0). From the answers of question 1 and 2, the activities which presented strong demand for improvement were identified. Question 3 addressed the pain points of the current development process and expectations on a new method in depth.
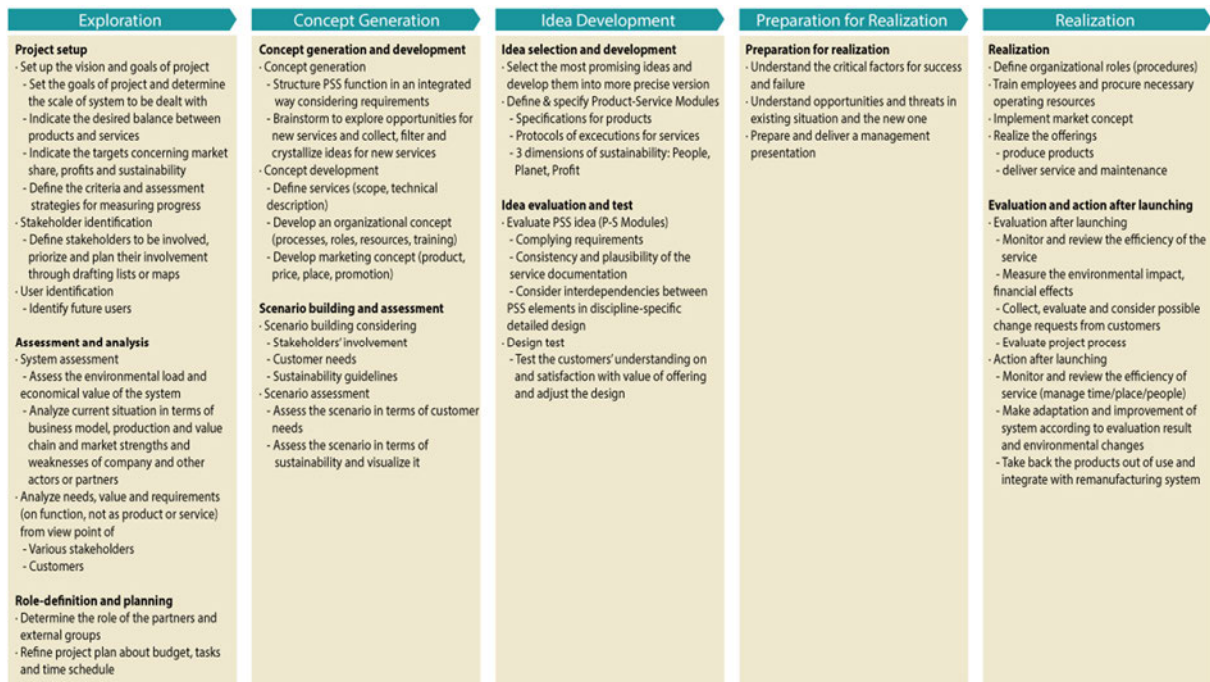
Exploration

Project setup
- Set up the vision and goals of project
  - Set the goals of project and determine the scale of system to be dealt with
  - Indicate the desired balance between products and services
  - Indicate the targets concerning market share, profits and sustainability
  - Define the criteria and assessment strategies for measuring progress
- Stakeholder identification
  - Define stakeholders to be involved, priorize and plan their involvement through drafting lists or maps
- User identification
  - Identify future users

Assessment and analysis
- System assessment
  - Assess the environmental load and economical value of the system
  - Analyze current situation in terms of business model, production and value chain and market strengths and weaknesses of company and other actors or partners
- Analyze needs, value and requirements (on function, not as product or service) from view point of
  - Various stakeholders
  - Customers

Role-definition and planning
- Determine the role of the partners and external groups
- Refine project plan about budget, tasks and time schedule

Concept Generation

Concept generation and development
- Concept generation
  - Structure PSS function in an integrated way considering requirements
  - Brainstorm to explore opportunities for new services and collect, filter and crystallize ideas for new services
- Concept development
  - Define services (scope, technical description)
  - Develop an organizational concept (processes, roles, resources, training)
  - Develop marketing concept (product, price, place, promotion)

Scenario building and assessment
- Scenario building considering
  - Stakeholders' involvement
  - Customer needs
  - Sustainability guidelines
- Scenario assessment
  - Assess the scenario in terms of customer needs
  - Assess the scenario in terms of sustainability and visualize it

Idea Development

Idea selection and development
- Select the most promising ideas and develop them into more precise version
- Define & specify Product-Service Modules
  - Specifications for products
  - Protocols of excecutions for services
  - 3 dimensions of sustainability: People, Planet, Profit

Idea evaluation and test
- Evaluate PSS idea (P-S Modules)
  - Complying requirements
  - Consistency and plausibility of the service documentation
  - Consider interdependencies between PSS elements in discipline-specific detailed design
- Design test
  - Test the customers' understanding on and satisfaction with value of offering and adjust the design

Preparation for Realization

Preparation for realization
- Understand the critical factors for success and failure
- Understand opportunities and threats in existing situation and the new one
- Prepare and deliver a management presentation

Realization

Realization
- Define organizational roles (procedures)
- Train employees and procure necessary operating resources
- Implement market concept
- Realize the offerings
  - produce products
  - deliver service and maintenance

Evaluation and action after launching
- Evaluation after launching
  - Monitor and review the efficiency of the service
  - Measure the environmental impact, financial effects
  - Collect, evaluate and consider possible change requests from customers
  - Evaluate project process
- Action after launching
  - Monitor and review the efficiency of service (manage time/place/people)
  - Make adaptation and improvement of system according to evaluation result and environmental changes
  - Take back the products out of use and integrate with remanufacturing system

Figure 3. Unified PSS development process

The requests for interviews were made to 20 SHA experts, and 5 of them responded. Interviews were conducted for 1 to 1.5 hours and every interview was recorded and transcribed. As one interviewee was belong to different company from the others, his interview data were excluded in this analysis. The information of 4 interviewees is summarized in table 2.

Table 2. Interviewee information

|		Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4
Department		UX design	UX design	Product planning	Product planning
Position		Assistant Manager	Assistant Manager	Senior Manager	Manager
Years of service		3	2	13	6
Involving stages					
Exploration	Project setup	○	○	○	○
	Assessment and analysis	○	○	○	○
	Role-definition and planning	-	○	○	○
Concept Generation	Concept generation and development	○	○	○	○
	Scenario building and assessment	○	○	○	○
Idea Development	Idea selection and development	○	○	○	○
	Idea evaluation and test	○	○	○	○
Preparation for Realization	Preparation for realization	-	-	○	○
Realization	Realization	-	-	-	-
	Evaluation and action after launching	-	-	○	○
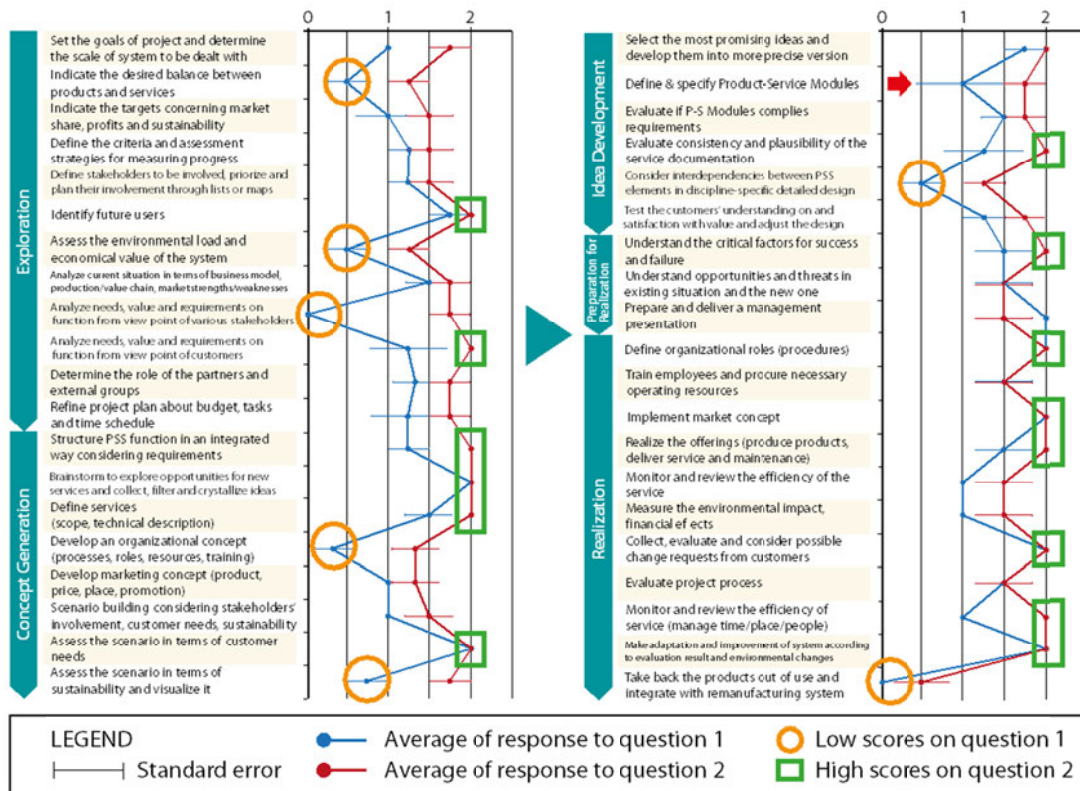
Figure 4. Response of question 1 and question 2

3. Results

In terms of the entire flow of process, the practitioners commented that existing SHA development process was not so different from PSS development process. However, when it comes to specific activities involved in each stage, the interviewees presented differences in development process.

Figure 4 shows the summary of the response data to the question 1 and 2. In this graph, blue points and red points indicate the answers to question 1 and 2 respectively. According to the response of question 1, the activities with circle marks which scored lower than 1 can be regarded as the activities which are not being undertaken sufficiently. As described in figure 4, they are concentrated on the earlier phases of entire process. Meanwhile, the activities framed rectangle shows the high necessity of adoption of PSS development activities. The activities which got high scores on both question 1 and 2 imply that these activities are so important that they are still in need for improvement although they are currently being conducted well.

With respect to the standard error described by error bars, the second activity of the idea development stage 'defining and specifying product-service modules', which was marked with a red arrow, displays outstandingly large value. For this activity, UX designers gave 0 as the answer while product planners gave 2 points. This difference seems to be caused by the different perspectives of UX designers and product planners on services. UX designers claimed that the projects were principally prone to be focused on product improvement from the stage for investigating needs and requirements, so the service modules were not developed as well as product modules were. On the contrary, product planners were recognizing service modules as the modules which were utilized to contact customers like software, applications and infra servers and they thought that it is natural to develop product modules and service modules separately for parallel development.

The interview analysis revealed 3 main pain points in the current SHA development process.

The difficulty of handling service

The most evident problem was that the practitioners were not familiar with developing, evaluating or managing services. As the corporate culture is manufacturing-oriented, the company has had few

projects on integrated products and services. Therefore, practitioners hardly had opportunities to learn how to develop services. Interviewee 1 said "Although we think about combining products with services and contents, what have been launched on the markets is usually product-oriented. There is no one who has an integrative perspective on both products and services in our team." Without an integrative perspective, it is hard to achieve a balance between products and service. As a result, services for SHA are usually developed through product-oriented approach to improve the quality of products such as providing or managing media contents. About developing an organizational concept, interviewee 3 mentioned "As the company is manufacturing-centered, we are not used to defining services. To define how to use a product, for instance, which button the users should push, is easy, but specifying services, especially building or training service organization is challenging".

The interviewees assessing service elements also had difficulty. Interviewee 4 told us that the criteria to evaluate services were obscure and therefore absolute evaluation of services was difficult. Under the condition that how the services for SHA should be is not clearly defined, setting the criteria is not easy. Interviewee 3 also noted "We are currently establishing a service development process. Evaluating the degree of service completion and acceptance to the market is very difficult." He emphasized the need for evaluation tools prior to the stage of assessing interdependencies between products and services.

Lack of consideration for sustainability

Another problem is that sustainability is not taken into account in the development process. In PSS development process the sustainability of a system is evaluated from 3 different perspectives: social, economic and environmental aspects. According to the interviews, however, the sustainability considered by SHA companies is mainly about economic feasibility and usability. Interviewee 2 commented on assessment of environmental load and economical value that they investigated profitability of new ideas continuously through user evaluation to ask willingness to pay or preference, but they did not consider how the SHA would affect the environment yet. When it comes to scenario assessment, interviewee 1 said "To tell the truth, some functions of smart refrigerators are more annoying than convenient. A refrigerator itself is nothing but an icebox. When smart functions are added to it, users only try them a few times and stop using them in the end." Interviewee 3 also admitted that the products after use were undermined. The tendency to underestimate social and environmental issues in development process may have been established due to product-centered business model; as their major profit comes from selling products, they naturally focus on how to deliver by selling more products.

Weak relationship with stakeholders

The interview revealed a low level of involvement of stakeholders in the development process. In the current process, the concepts or ideas for SHA are generated and developed internally, and only after they have been specified enough, shared with external stakeholders. As the stakeholders do not participate in the early phases of development process, understanding their needs or requirements is not necessary, either. Regarding this aspect, interviewee 3 stated "We look for the most appropriate third party which are advantageous for us to cooperate with or which can fulfill our needs easily. The most difficult thing is producing an agreement to create a mutually profitable relationship." As saying by interviewees, cooperation with external stakeholders from the initial phase is usually avoided because of security issues tricky distribution of profit. Unless the cooperative project is set by top-down decision-making or based on MOU relationship, those problems become a powerful barrier to idea development which requires the involvement of external stakeholders.

4. Discussion

In this research, it was verified that the unified PSS development process can be used as a diagnosis framework to find out weak points of the SHA development process which can be overcome by applying PSS development methodology through the expert interviews. Through comparing existing SHA development process and PSS development process, and answering to the questions about current conditions of operation, necessity of and expectations on activities involved in PSS

development process, the limitations of current SHA development process and the stages which need to be enhanced were identified.

Based on the result of diagnosis, the expected benefits of improving SHA development process through adoption of PSS methodologies are elaborated as below.

Cooperation with external stakeholders

Through exploring and understanding the needs of stakeholders in an SHA ecosystem, greater values can be generated through a business model as such a model addresses their demands more effectively and thus satisfy them better. In such a model, participation and cooperation of the stakeholders are encouraged and greater social values are generated.

Moreover, user information shared by various stakeholders can act as a good stimulus for idea generation. The problem scope of conventional SHA development has been limited the usage of home appliances. However, the manufacturer can discover hidden needs of users and generate innovative solutions by sharing the view points and experiences with other stakeholders. Unexpected needs or problems introduced by other stakeholders can be a source of inspiration for SHA developers, or the user needs failed to be addressed by them could be fulfilled by the solutions from other stakeholders.

Support for the service approach

Most activities related to defining services are not going well and it is caused by the practitioners' lack of experience in dealing with service in a manufacturing-centered company. When we consider the alternative, getting help from service-specialized companies is easier and more effective way to develop service elements. In addition, developing organizational concepts and marketing concepts together with other stakeholders will contribute to maintaining consistency of their offerings. However, collaborating with external stakeholders from the early phases is almost impossible in reality because of the issues related to information leak and profit distribution. Before suggesting inter-stakeholder collaboration, manufacturing companies can utilize PSS development methods to explore business opportunities and conceive business models which can fulfill users' needs better by combination of product and service elements. Being assured about their business model, they would be able to make decision to work with others with confidence.

Proactive stance on sustainability

While the SHA manufacturer has a team dedicated dealing with environmental regulations and corporate social responsibility (CSR), collaboration between the sustainability team and developers does not occur. In other words, sustainability is not at the core of business model but exists at the peripheral as CSR. However, a more positive approach to social and environmental sustainability can give a new perspective on their business and lead to product and service innovations. Adopting PSS methodology, companies can consider sustainability issues from earlier phases of the development process and find out solutions for both their own business and sustainability.

Although the interview needs to be complemented with more interviewees from various companies to generalize these findings, this research can be valued as an attempt to identify the needs of practitioners on the development process and encourage the application of PSS development methodology in practice.

5. Conclusions

This paper aims at improving the development process of smart home appliances whose core competence lies in offering customized services through an integrated solution connecting users, products and stakeholders. It argues that the conventional process can be improved by adapting product-service system methodology. As the first step, literature studies were conducted to identify the characteristics of SHA, and to develop a unified PSS development process. Based on the interviews with practitioners, activities of development process practiced in the field and in need of improvement were identified. The earlier stages of development process need to be supplemented by PSS development methodology, especially in terms of dealing with services, communication and

collaboration with other stakeholders and consideration on social and environmental sustainability. This study provides useful information on the SHA development process in the field and how it can be improved through adaptation of PSS methodology.

For the future works, SHA development methods based on PSS development methods will be developed based on literature reviews and the findings from the interviews. The methods will be evaluated by the practitioners through a workshop.

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