Applying Value-based design to lead technology innovation towards PSS development: A case study of FamiCare in ITRI

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Product-Service System (PSS) design has become an emergent paradigm in technology innovation. However, little research addresses the two major issues in PSS development: 1) how to identify the value propositions, and 2) how to construct value constellations. Design-Driven Innovation (DDI) is an approach to lead to new meaning for technology. Based on DDI, this study constructs a concept of value-based design for technology innovation towards PSS development and conducts a case study of the FamiCare innovation project to explore the insights. Firstly, to identify the value propositions for PSS, it is critical to uncover the core functions of the technology, and interpret new meanings through collecting critiques from stakeholders. Secondly, co-creation workshops and visualized tools are able to facilitate the construction of PSS value constellations. Thirdly, both emotional and functional value should be considered during the PSS development. Finally, this study highlights the main challenges and outlines a methodological framework.

keywords: product-service system; technology innovation; value constellation; value-based design

Introduction
While innovation has become a key strategic driver for organisations to gain competitive advantages, there is growing recognition of the collaboration between design and technology (Kyffin & Gardien, 2009). Design-Driven Innovation (DDI) is an approach to lead
radical changes for technology through interpreting its core features and deriving new meanings to meet different levels of values (i.e., functional value and emotional value) (Verganti, 2008, 2009). However, with the rise of the service economy and the paradigm shift from value-in-exchange to value-in-use, the role of design has gradually changed (Mager & Sung, 2011). Whereas design was often used for value-added in product innovation (Cantarello, Nosella, Petroni, & Venturini, 2011) or function enhancement (Driver, Peralta, & Moultrie, 2011), some researches (Patricio, Fisk, Cunha and Constantine, 2011; Mager and Sung) advocate that design has gradually gained importance in creating value and value-system in service development.

PSS is an emerging innovative business model that focuses on delivering a unit of satisfaction through the combination of products and services (Ceschin, 2014; Sakao and Lindahl, 2012). Some relevant concepts (such as, complex product system and technology cross-fertilization) have become new patterns which can affect the upstream of research and development (R&D) and lead technology innovation towards PSS development (Davies, 2004; Libaers, Hichs, & Porter, 2010). Björkdahl (2009) and Velamuri, Neyer, and Möslein (2011) believe that with the introduction of PSS concepts, the outcomes of technology innovation can better meet customer needs, and can generate more value through the integration of new resources or technologies.

In essence, the success of PSS accentuates appropriate value propositions and value constellations that provide mutual beneficial interaction among various actors (Frow and Payne, 2011; Libaers, et al., 2010; Xing, Ness, and Lin, 2013). In addition, while emotional value has been proven to have greater effects on customer experience compared to functional value, Beltagui, Candi, and Riedel (2012) consider that emotional value should be more emphasized in service development. Nevertheless, in the context of technology innovation, while past studies (Björkdahl, 2009; Velamuri, Neyer, and Möslein, 2011) mainly focus on the benefits of integrating new resources for PSS development, few studies address the issues of finding the value propositions and value constellations for the technology.

Therefore, considering the challenges of PSS development and the value of design mentioned above, this study extends the approach of DDI and proposes the concept of “value-based design” (Sakao & Lindahl, 2012) for technology innovation towards PSS development. To not only discover and criticize the meaning of the technology, the value-based design emphasizes identifying the value proposition in the front-end of the innovation so as to lead value constellation establishment and PSS development. Moreover, this study conducts a case study of the FamiCare innovation project in the Industrial Technology Research Institute (ITRI) to answer the following two questions: 1) How does value-based design lead the identification of PSS value propositions for technology innovation towards PSS development? 2) How does value-based design facilitate the construction of PSS value constellations for technology?

As one of the major non-profit research and development (R&D) organisations in Taiwan, the goal of ITRI is to help industries in Taiwan stay competitive and sustainable (ITRI, 2015). Due to rapid market change, ITRI discovered that delivering the latest technology to industries was no longer sufficient, and started to introduce the knowledge of PSS development into the R&D process. FamiCare technology is an innovative applied
technology developed in ITRI, and was originally designated to enhance functions for home security monitoring. However, when lacking a systematically approach, the R&D team found that it was difficult to discover appropriate innovative directions for PSS development. Thus, the R&D team assigned responsibilities to the Design team in ITRI to boost the efficiency and effectiveness of the FamiCare innovation project in ITRI for PSS development. After three months, the Design team proposed a PSS concept of Home Pet Care services and led a transformation of the FamiCare technology’s meaning from home security monitoring functions to recording and sharing the precious moments of pets, which contains emotional value. It also attracted new types of stakeholders for the PSS value constellations of Home Pet Care services. Furthermore, the Design team cooperated with the R&D team to determine the directions for future development of the FamiCare technology. Currently, the concept of Home Pet Care services has completed user testing at the end of 2016 and is now ready for commercialization.

In conclusion, firstly, this study proposes the research questions and conceptual framework through the literature review on the function of design in PSS, the role of design in technical innovation, and the methodology of DDI. Secondly, this study describes the research methods. Thirdly, this study illustrates the development process of the case. Fourthly, this study responds to the proposed questions and develops a methodological framework of value-based design for technology innovation towards PSS development as a reference for similar projects in the future.

**Literature Review**

*The changing role of design in innovation*

With the rapidly changing market, Lettl (2007) considers that organisations cannot rely on incremental innovations alone. Radical innovation, which would cause market shifts and user behaviour change, has been recognized as a crucial strategy to sustain long-term competitiveness. In addition, both Norman (2004) and Beltagui et al. (2012) find that technology and functional innovation no longer constitute a basis for competitive advantages in innovation, and organisations should pay more attention to emotional value. For example, people use the iPhone is not only because the functional value from latest technology, but also the emotional value that trigger through the experience of sharing photo with family, listening music, etc.

Design, as a process of making sense of things, has been recognized as a critical means to pursue successful product innovation (Cantarello, et al., 2011). Other than the two innovation models of technology push and market pull in the past, Verganti (2008, 2009) proposes Design-Driven Innovation (Figure 1), and claims that design can lead radical innovation through perspectives of emotional value. It assumes that based on a deeper understanding of society and culture, design can help innovators envision new meaning from emotional perspectives and lead to technology epiphanies.
However, while service has been increasingly regarded as a crucial direction for innovation in the era of the service economy, design has gradually changed its role. Beltagui et al. (2012) advocates that as emotional value has greater influence than functional value, design should be involved to reconcile disparate elements or interests and to improve the overall experience of service delivery (e.g. tangible objects, employees, supporting systems). Moreover, both Mager and Sung (2011) and Patricio et al. (2011) argue that with a holistic viewpoint, design has been applied as a strategic approach to help organisations synthesize the needs from different stakeholders, and create values and new frame for the service system in the front end of innovation. Therefore, this study considers that in service development, design is not only to integrate functional and emotion values, but also to create and form the new value-system.

The paradigm shift from technology innovation towards PSS development

Velamuri et al. (2011) argue that technology innovation is one of the key strategies to stay competitive. Many countries have established national-level R&D organisations (e.g., Dutch Toegepast Natuurwetenschappelijk Onderzoek, TNO) to stimulate the improvement of industry capacity. However, in recent year, Finne and Holmström (2013), and Libaers et al. (2010) notice that some of the R&D organisations have found the benefits of integrating resources and functions from new types of stakeholders, and started to implement methods such as technology downstream integration and technology cross-fertilization. Accordingly, Davies (2004) explains that concepts related to PSS (such as, dematerialization, servitization) have gradually gained attention and become a new pattern in the field of technology innovation.

Basically, PSS is defined as “a marketable set of products and services, jointly capable of fulfilling a customer’s needs” (Goedkoop, Halen, Riele, and Rommens, 1999, p. 3). Valencia, Mugge, Schoormans, Schifferstein (2015) assert that through the combination of services and products, PSS integrates and delivers various functions within a total solution to the customers via value-in-use. Thus, for a single organisation, Livaers, et al. (2010) uphold that it is difficult to possess all of the assets, and Xing, et al. (2013) consider that it is crucial to integrate new resources and construct value constellations for mutual beneficial interaction among various stakeholders. As a result, it implies that before
integrating more functions into PSS, as shown in Figure 2, value propositions should be identified in the first place as a base to attract stakeholders for value constellations construction (Frow & Payne, 2011; Osterwalder, Pigeur, Bernarda, and Smith, 2014).

However, creating and identifying value propositions for PSS development is not easy for traditional technology organizations (Björkdahl, 2009). Whereas most of the studies (Finne and Holmstrom, 2013; Libaers et al., 2010; Valencia, et al., 2015) focus on integrating new functions or resources to technology for PSS development, few studies address the issue of how to identify appropriate value propositions and construct value constellations. In addition, while Beltagui et al. (2012) has pointed out the significance of emotional value in service development, the empirical studies related to PSS development have emerged very slowly and in a more scattered way. Therefore, in order to lead technology innovation towards PSS development, new approaches should be involved.

In technology innovation, design has been applied to lead radical innovative meaning and new product development (Verganti, 2009). On the other hand, Morelli (2002) advocated that design, as a holistic approach, should be introduced into PSS development to guide the direction via identifying value proposition and integrating values from different stakeholders. Accordingly, this study extends the approach of DDI and proposes the model of value-based design (Figure 3) (Sakoa & Lindahl, 2012). Firstly, value-based design is value centred that considers different level of values, and value proposition is the guidance for innovation. Secondly, it adds a new axis of “different stakeholders”, and assumes that there should be more than one layer of value propositions to include different perspective values of stakeholders for further PSS value constellation establishment. In sum, the concept of value-based design provides a framework for identifying value propositions to meet different level of values, and constructing the value constellations to benefit different perspectives of stakeholders involved in the PSS.

**Figure 2  PSS Value Constellation**

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Figure 3  Model of Value-based Design to Drive Technology Innovation towards PSS development

Furthermore, in order to understand the dynamic process of value-based design to drive technology innovation towards PSS development, this study constructs a conceptual research framework (Figure 4), and proposes the following two questions: 1) How does value-based design lead the identification of PSS value proposition for technology innovation towards PSS development? and 2) How does valued-based design further facilitate the construction of the PSS value constellation for the technology? Through the following case study, this study hopes to answer the two questions proposed.

Case Study Research Method

Description of Case Study Research Methods

For preliminary or exploratory research topics, especially the “why” and “how” questions, Rowley (2002) points out that the case study research method provides a structured framework, and allows researchers to understand the problems and observe the complicated dynamic insights that were originally hard to explore. Thus, in order to answer the aforementioned issues, this study selected the FamiCare innovation project in ITRI as the case study subject. There are two reasons for selecting the FamiCare innovation project: Firstly, compared to R&D divisions in corporations or academic research organisations, ITRI is a non-profit technology research division that is close to the industry yet with fewer issues of confidentiality; therefore, it allows research to uncover deeper insights and contribute to both the academics and the industries. Secondly, the
FamiCare innovation project is a case that applies design to drive technology innovation towards PSS development, which is in alignment with the purpose of this study. Triangulation research (Shanks & Parr, 2003) was employed in the case study to support the rigorous inquiries for data collection, which includes observation, document analysis, and in-depth interviews with the team members (Table 1) of the FamiCare innovation project.

**Table 1 Description of the FamiCare innovation project team members**

<table>
<thead>
<tr>
<th>Category</th>
<th>Duty</th>
<th>Role</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology team</td>
<td>Management of overall project timeline and quality management</td>
<td>Engineer Manager</td>
<td>A1</td>
</tr>
<tr>
<td>Technology team</td>
<td>Management of overall technology development direction</td>
<td>Senior Engineer</td>
<td>A2</td>
</tr>
<tr>
<td>Technology team</td>
<td>Execution of technology development</td>
<td>Junior Engineer</td>
<td>A3</td>
</tr>
<tr>
<td>Technology team</td>
<td>Execution of technology development</td>
<td>Junior Engineer</td>
<td>A4</td>
</tr>
<tr>
<td>Design team</td>
<td>Design project timeline and quality management</td>
<td>Design Manager</td>
<td>B1</td>
</tr>
<tr>
<td>Design team</td>
<td>Execution of design research, ideas generation, strategy planning, value constellation establishment, and stakeholders’ invitations.</td>
<td>Designer</td>
<td>B2</td>
</tr>
</tbody>
</table>

**Case Description**

The FamiCare technology was a video cloud processing applied technology aiming at incrementally improving the functions of security-monitoring solution for smart homes. As shown in Figure 6, it includes various functional modules, including: IP cam, wireless transmission, cloud data management, and smart APPS. Originally, the Technology team focused on the integration of technologies from different fields to build up a total solution in hopes of finding innovative applications (including: homes, communities, and shops). However, due to the lack of systematic methods, it was hard to discover which direction had the most potential opportunity. Hence, the Technology team assigned responsibilities to the Design team in ITRI in hopes of applying design to lead the innovation project.
The progress of the FamiCare innovation project, as shown in Figure 6, combines the 4D (Discover, Define, Develop, and Deliver) design process (Design Council, 2005) and the PSS design methods proposed by Morelli (2002). Firstly, in the Discover stage, the goal is to discover the core features and interpret into new possible meanings of the technology through the co-creation of the Design team and Technology team. Secondly, in the Define stage, based on the meanings, it aims at identifying the suitable value proposition through critiques from related experts. Thirdly, in the Develop stage, the related organisations or stakeholders are invited to co-create the visions and possible PSS concepts. Finally, in the Deliver stage, through the collaboration among the design, technology, and related stakeholders, the final value constellation of PSS is constructed.
Applying value-based design to drive FamiCare technology innovation towards PSS development

Discover and Define: to uncover the core features and identify the PSS value proposition of the technology

In the Discover stage, in order to identify the value proposition, the Design team proposed four questions to uncover the core features of the FamiCare technology, including: 1) What is the core of the FamiCare technology? 2) What are possible applications that have been identified? 3) What are possible substitute solutions? 4) What are the visions for technology development in five years? Through debating the four questions with the Technology team, the Design team found that to solve all of the home security monitoring problems (ex. real-time video, event analysis and recording, two-way communication, etc.), the FamiCare technology had already become an overly complex system. However, without systematically value analysis, it was hard to determine the major competitive advantages. After a thorough discussion, the two major modules, including “Smart image capturing and labelling” and “FamiCare Cloud Service”, were uncovered to be the core features of the FamiCare technology. The features of the two modules are described in Table 2.

Then, in order to find the potential applications for the FamiCare technology, the Design team listed different types of family groups (such as, three generations living together, home of nannies, and families with pets) and analysed their needs according to the two features. Based on the results, the Design team interpreted the core features into a set of meaning assumptions for the FamiCare technology, as shown in Table 3.
### Table 2  Descriptions of the Two Major Modules of FamiCare and Its Features

<table>
<thead>
<tr>
<th>Modules</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart image capturing and labelling</td>
<td>to intelligently analyse and capture dynamic images that suddenly change in the video record</td>
</tr>
<tr>
<td></td>
<td>to automatically label the video record clips being captured as dynamic images</td>
</tr>
<tr>
<td>FamiCare Cloud Service</td>
<td>to encrypt and quickly access video files in the cloud</td>
</tr>
</tbody>
</table>

### Table 3  The Interpreted Meaning Assumptions of the FamiCare Technology towards Different Users (only partial project results are listed)

<table>
<thead>
<tr>
<th>Technology Core Characteristics</th>
<th>Interpreted Meaning Assumptions towards Different Types of Family Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three generations living together who care about the safety of the elderly and children.</td>
<td>Home of nanny who needs to watch and record the lives of the children for their parents.</td>
</tr>
<tr>
<td></td>
<td>Families with pets who hope to take care of and understand the lives of their pets.</td>
</tr>
<tr>
<td>Smart analysis and capturing dynamic images</td>
<td>to monitor one day activities and events of the elders for the family and hospital</td>
</tr>
<tr>
<td></td>
<td>to record one day courses and activities of the children for the parents</td>
</tr>
<tr>
<td></td>
<td>to record one day behaviour and activities of the pets for the family</td>
</tr>
<tr>
<td>Automatic labelling</td>
<td>to quickly select and review the video clips of the process of the unexpected events</td>
</tr>
<tr>
<td></td>
<td>To quickly review the key activities that are related to healthcare management (ex. eating, workout) for the elderly or young children</td>
</tr>
<tr>
<td></td>
<td>to help parents quickly select important video clips and review their children’s activities.</td>
</tr>
<tr>
<td></td>
<td>to quickly view and find interesting pet video images</td>
</tr>
<tr>
<td>Encryption and fast access</td>
<td>to view the situation at any place in real-time</td>
</tr>
<tr>
<td></td>
<td>to co-manage with other family members simultaneously</td>
</tr>
<tr>
<td></td>
<td>to view the activities in real-time</td>
</tr>
<tr>
<td></td>
<td>to allow the parents to share interesting images of children easily</td>
</tr>
<tr>
<td></td>
<td>to view the activities in real-time</td>
</tr>
<tr>
<td></td>
<td>to allow the family to share interesting images of pets easily</td>
</tr>
</tbody>
</table>
In the Define stage, the Design team invited the experts in the respective fields, including: elderly caregivers, nanny consultants, and pet hotel managers, to provide critiques towards the innovative meaning assumptions and co-define the value propositions of FamiCare technology based on the different family groups mentioned above. Moreover, the Design team also cooperated with the Technology team to conduct analysis from the perspective of technology feasibility.

According to the critiques and technical feasibility analysis, firstly, the Design team found that for the families with three generations living together, privacy and dignity were the main issues. It means that though the elders were gradually growing weaker, most of them still cared about their privacy and did not want to be monitored. Secondly, the nanny consultants stated that since every moment in the daily lives of children are precious for the parents, it is difficult to determine which moments are critical. In addition, as for technology feasibility, the technology team mentioned that if the children are active most of the time, it is hard for the smart dynamic image capturing technology to identify which movements needed to be recorded. Therefore, the FamiCare technology may not generate values for the families with three generations living together and the nannies.

Thirdly, the pet hotel managers mentioned that for the families with pets, enjoying adorable behaviour and having intimate interactions with their pets at home to relax has become a major pastime among pet owners. Nevertheless, due to work schedules, many people can hardly know their pets behave during the daytime. Thus, with the features of smart dynamic image analysing and capturing, the Design team found the new meaning where the FamiCare technology can help the pet owners to track, retrieve and share the precious moments that occur in the lives of their pets during the day.

In addition, in order to gain a deeper understanding of families with pets, the Design team selected a group of owners who liked to share about their pets’ lives, and visited their homes for observation and interviews. The Design team surprisingly found that besides the owners affirming the meaning mentioned above, they were also concerned with their pets’ abnormal behaviour and mental illnesses. Therefore, after analysing the potential of the application and technology feasibility, both the Design team and Technology team considered the new direction valuable, and they defined the value proposition as “to allow the families with pets to observe and share the precious moments of pets, and have a better understanding of their pets’ behaviour and psychological states”.

**Develop and Deliver: to use design to connect stakeholders and establish a PSS value constellation**

In the Develop stage, the main objectives of the FamiCare project was to collect different critiques from the related professions to modify the value proposition and generate the details of the PSS concept for FamiCare. Based on the value proposition, the Design team and Technology team proposed new value-systems and identified the possible stakeholders, including a family with pets and a pet psychologist, and invited them to join the co-creation workshop. Moreover, the Design team created a visualized storyboard to illustrate the customer journey of the PSS concept for the stakeholders.

During the workshop, while the family with pets considered that the meaning of the concept as valuable for them, the pet psychologist approved the idea of applying
abnormal behaviour detection and recording to improve psychological diagnosis and treatment; also, the records could become rich data and contribute to pet psychological research in the future. Thus, after co-creation, the Design team proposed the PSS concept of Pet Care service and revised the storyboard as shown in Figure 7.

After analysing and organising the feedback from the interviews and co-creation workshop, the Design team discovered that the Pet Care service can benefit different stakeholders from three perspectives: 1) for families with pets, it allows the users to examine and share interesting segments of their pet’s lives and understand the mental status of pets; 2) for pet psychologists, it can improve the quality of medical services and contribute to the medical research through the recorded data; 3) for the Technology team, it can become a sustainable service platform through extending the interaction with different stakeholders. Finally, the Design team established a value interaction map to illustrate the value constellation of Pet Care services (Figure 8) and planned the future development direction for FamiCare technology, which includes 1) T1: the way to detect abnormal pet behaviour; and 2) T2: the method to collect the data of abnormal pet behaviour.
Discussions

How does value-based design identify the PSS value proposition for the technology?

Björkdahl (2009) declares that many R&D organisations have started integrating different technologies from other fields for PSS development in order to stay competitive and enhance the value of the technology. However, this study finds that without systematic process to define the appropriate meaning and value propositions for the PSS, the integration may cause confusion. For example, the FamiCare technology was originally developed as an incremental improvement for home security monitoring and the Technology team aimed to integrate functions to enhance its value. Nevertheless, the
Technology team found that not only were the features out of date, the directions of development were lost. The interviewee A1 mentioned: “We found that without a clear core value, integrating technology only made the FamiCare technology resemble other products.” It corresponds to the statement of Osterwalder et al. (2014) that without a clear value proposition to guide the direction, the innovation may lead to unwanted results such as misalignment of resources.

Basically, value is the centre of *value-based design*, and value propositions is the guide for PSS development. With the appropriate meanings and corresponded value propositions, this study regards that the supporting resources can be meaningful to the users and stakeholders. According to the findings of the FamiCare innovation project, this study regards that the following two steps are crucial to generate radical innovative value propositions for PSS development: 1) to uncover the core features of the technology; and 2) to map them into value assumptions based different groups of users. Through these two steps, the project team were able to rethink the core features of the technology and generate meanings to meet emotional value and functional value in a systematic process. In addition, by collecting critiques from both users and stakeholders, it allows the project team to establish a holistic view towards the PSS development. For instance, the Design team did not only identify the innovative value for the family with pets, but also established the system that are needed to support the service.

This finding support the extension of Verganti’s (2009) methodology from product innovation to service innovation. Also, as Beltagui et al. (2012) argued, design is the key to enhance the effectiveness of service innovation through combining emotional value and reconciling disparate interests of stakeholders. Therefore, as shown in Figure 9, in the context of technology innovation towards PSS development, this study regards that *value-based design* plays a critical role for value creation and value proposition identification in three manners: 1) to dig out the core features of the technology; 2) to interpret the core features into innovative meanings through considering both emotional and functional values; 3) to iterate the process of analysing technology feasibility and collecting critiques from different stakeholders (organisation, customers, and partners) to establish a holistic view for identifying the appropriate value proposition.

- To evaluate technology feasibility
- To identify application in different field
- To criticize and create meaning for different customer

*Figure 9  The Process of Defining the Technology Value Proposition of value-based design*
How does value-based design further facilitate the construction of the PSS value constellation for the technology?

Basically, the concept of PSS is to integrate the resources from different stakeholders to develop a system that can satisfy different users (Goedkoop et al., 1999; Xing et al., 2013). Nevertheless, gathering the insights from different stakeholders is not an easy task (Vasantha, Roy, Lelah & Brissaud, 2012). Based on the case study, this study suggests that applying visualized storyboards and co-creation workshops could be effective tools to communicate the value propositions. The interviewee B2 mentioned: “The workshop environment and visualized storyboard allowed the stakeholders to easily understand the value propositions and provide critiques from their perspectives.” This result is in line with the statements of Brown (2009) and Osterwalder, et al. (2014) that designers often apply methods, such as visualization and role-play, to illustrate the details of the concepts, and improve the communication with stakeholders from different backgrounds.

In addition, since PSS is often accompanied by various types of stakeholders, it is necessary to make connections among the resources, interests and shared visions (Xing et al., 2013). This study applied the value interaction map proposed by Morelli (2006) and found that it is a useful tool for the development of the value constellation of the FamiCare technology. The interviewee A1 mentioned: “The value interaction map not only allowed us to understand the roles and resources in the PSS, but also defined how the mutual beneficial interactions occurred in the value constellations.”

In summary, this study considers that value-based design is a strategic approach centred on value. It can help organisations identify value proposition from a holistic view that covers various stakeholders’ values. Although the FamiCare innovation project is based on the context of the technology industry, this study believes that the results could also be applied in other fields (e.g. retailing industry). As shown in Figure 10, this study develops a methodological framework and tools applied in the process of value-based design for technology innovation towards PSS development. Firstly, the core features must be explored to identify critical roles of the technology in the development of PSS. Secondly, through the repeated exploration of the different levels of values from different stakeholders (including end-users and partners), and the function of technology, the most potential value proposition of PSS is determined. Finally, through the co-creation among the stakeholders, the value constellation can be built. In addition, the techniques and tools of design was found to be useful throughout the process of PSS development. The workshops, story board, and value interaction maps are important to facilitate co-creation and communication. Also, the mapping matrix of technology core features and meanings and collecting critiques from stakeholder interviews can uncover the hidden problems and possibilities.
Conclusion and Future Research Direction

With the rise of the service economy, the relevant concepts of PSS have attracted the attention of some R&D organisations, and the role of design in technology innovation has gradually changed. However, few studies have addressed the two key elements of value propositions and value constellations in the field of technology innovation towards PSS development. The contributions of this study are to extend the DDI (Verganti, 2009) to the model of value-based design, and conduct a case study research to explore the insights.

Basically, value-based design places value in the centre, and value proposition is the base for value constellation construction and PSS development. And, according to the case study of the FamiCare innovation project, this study suggests the process of value-based design as followed: 1) to uncover the core features of technology; 2) to define new meaning for the core features, and collect critiques from various stakeholders to identify the appropriate value proposition through a holistic view; 3) to engage the stakeholders to co-create the value constellation and PSS concept. It is worth noting that both emotional value and functional value should be considered in the whole process. In addition, visualized tools can effectively facilitate the development of value constellations.

Since this research is a single case study, the future research directions are as follows: firstly, this study expects the findings to be applied to different cases for verification. Secondly, the result of this study is based on FamiCare technology, which originates from a type of applied research (Stoke, 1997), and it is unclear whether the technology generated from basic research will cause impact on PSS development. Thirdly, due to the limited length of this article, this study only selects and discusses the tools that are critical to the two questions mentions above, so it is worth discussing other possible tools to facilitate the value-based design process. Fourthly, the work of interpreting the meaning of the technology is largely reliant on a long developed database of design research.

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**About the Authors**

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