Digital Future Design: Designing Digital Service Systems based on Future Visions

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Abstract

Recently, initiatives that use advanced digital technologies to address social issues and drive social innovation, such as the “smart city”, have been attracting attention. While public expectations for smart city projects are high, they are often executed from a technocentric approach that lacks a human-centered perspective, which leads to various criticisms and opposition from residents. This necessitates a method for envisioning a desirable future society and designing the entire service system, including digital technologies (i.e., digital service system), from a human-centered perspective. Therefore, we have developed a novel design method, called Digital Future Design Method, that supports the designing of digital service systems for realizing the social transformation to a desirable future vision, and conducted a case study to demonstrate its usefulness. The results demonstrated its effectiveness in enabling us to have a future vision-based thinking in design from the comprehensive perspectives of the social, digital, and physical domains.

Keywords: digital future design, service design, digital service system, future vision

Introduction

Following the United Nations’ advocacy of its Sustainable Development Goals (SDGs), the need to create a sustainable society by solving various social problems has become pertinent (Hák et al., 2016). Consequently, the term “social innovation” was coined, and has been garnering growing attention around the world (Manzini, 2014; Mulgan et al., 2007). Simultaneously, the importance of digital technologies, such as Artificial Intelligence (AI), Internet of Things (IoT), and robotics, and their influence on our lives and society has been dramatically increasing. Thus, initiatives to use advanced digital technologies to address social issues and drive social innovation are attracting attention in industry and the public sector.

"Smart Cities", which aims to overcome various urban issues (e.g., energy and health care, etc.) through the use of digital technologies and related service (Eremia et al., 2017; Harrison et al., 2010), is representative of this trend. While public expectations for smart city projects to create better future societies are high, they are often executed from a technocentric approach that lacks a human-centered perspective, which leads to various criticisms and opposition from the residents (Andreani et al., 2019). The key to overcoming this difficulty lies in the following two design approaches: (1) "social transformation," where we visualize the future vision that we want to create using digital technologies based on the human-centered perspective and then implement the social transformation activities needed to achieve the desirable future; (2) changing our viewpoint from that of a digital technology to a "service system." A service system is a configuration of people, technology, and other resources interacting via value propositions to create mutual value (Maglio et al., 2009). It encourages us to not focus on digital technologies as stand-alone design objects, but as an entire service system where digital technologies are integrated as system components. In this study, we refer to this kind of service systems, where digital technologies are integrated and play important roles in value co-creation, as "Digital Service Systems (DSSs)."

These two design approaches (i.e., the designs for "social transformation" and "DSSs") and their integration are of great importance to realize the social use and implementation of digital technologies. However, these have previously been studied separately within different research communities, and have thus, rarely intersected. To address this challenge, we develop a new design method that integrates the social transformation approach with the DSS design approach. This method supports the creation of the DSSs for realizing the social transformation to a desirable future vision. We apply the proposed method to an example case of DSS design to demonstrate its usefulness.

Related Works and Research Gap

Design for Social Transformation

In the past decade, design studies that focus on the broader design object of social transformation instead of services or products have been attracting much attention. Irwin (2015) proposes the Transition Design as a design approach to tackle the so-called “wicked problems” (Rittel & Webber, 1973) and achieve social transformation toward a more desirable future. Transition design is characterized by the involvement of various stakeholders, the creation of a future vision together, and the implementation of long-term interventions and actions for addressing complex social issues, instead of creating short-term and one-shot solutions (Irwin, 2018). Burns et al. (2006) proposed the Transformation Design, a design methodology for social change that focuses on changing the behaviour of people in society. Furthermore, in the service design research community, new methodologies, such as transformative service design (Sangiorgi, 2011) and service design for social innovation (Yang & Sung, 2016), have been proposed. These approaches are based on participatory action research (Baum et al., 2006) and emphasizes the implementation of transformative interventions to achieve social change.

Key aspects that are common among these existing transformative design studies are that they adopt a collaborative approach that involves various stakeholders, create a future vision or redefine problems for social transformation, and perform long-term interventions. These existing studies are thus strongly related to the participatory design (Robertson & Simonsen, 2012) and co-design (Sanders & Stappers, 2008) approaches, which involve diverse stakeholders including users in the design process, or living labs (Akasaka & Nakatani, 2021; Kareborn & Ståhlbröst, 2009), which combine the co-creative design approaches with social experiments in real-life environments.

Service System and Digital Technologies

The rapid advancements in digital technologies have further increased the importance and role of digital technologies in service systems (Pekkala & Spohrer, 2019). Prior research has proposed several concepts to refer to a service system that includes digital technologies; two representative examples are “smart service system” (Medina-Borja, 2015) and “smart product-service system” (smart PSS) (Valencia et al., 2015). The smart service system is defined as “a service system capable of learning, dynamic adaptation, and decision making that requires an intelligent object, and involves intensive data and information interactions among people and organizations” (Lim & Maglio, 2018). Thus, the smart service system concept focuses on the intelligence of service systems that is enabled mainly by AI-based technology. Conversely, the smart PSS, is referred as “an IT-driven value co-creation business strategy that integrates products and e-services” (Valencia et al., 2015). The research on smart PSS originally emerged in the context of the digitization and servitization of the manufacturing industry (Pirola et al., 2020). Thus, the concept addresses the integration of physical products and digital services mainly in the manufacturing industry. Compared to these existing concepts, the concept of

DSS used in this study more generally and directly emphasizes the context of a service system in which digital technologies are integrated, irrespective of whether it has AI-like intelligence or a focus on manufacturing products (Watanabe et al., 2020).

Some recent studies have proposed design methods for service systems that use digital technologies. For example, Li and Lu (2021) have developed a service blueprint framework for designing AI-based service systems from the user experience (UX) perspective. Similarly, Halstenberg et al. (2019) have developed a design method for smart service systems by integrating PSS development with the systems engineering approach. Tsunetomo et al. (2022) propose a smart PSS design method that takes into account the ethical and social impacts of digital technologies.

Socio-Cyber-Physical Systems

Cyber Physical System (CPS) refers to a system that focuses on complex interdependencies and interactions between cyberspace and the physical world (Chen, 2017). A DSS can be regarded as a type of CPS as it includes various interactions between the digital and physical world. In the social sciences, scholars have traditionally used the Socio-Technical System (STS), which states that all technological systems are embedded in a relationship with the social system that consists of people, organizations, and rules (Bijker, 1997). Inspired by the STS, several scholars have argued the importance of introducing social domain perspective when designing and developing a CPS. Rijswijk et al. (2021) proposes the "Socio-CPS" concept, which is defined as “a system composed of the social world (people), the digital world (data), and the physical world (things),” as a new system concept that combines STS and CPS. In Socio-CPS, these three domains influence each other, which results in specific outcomes and adaptations to the systems (Figure 1).

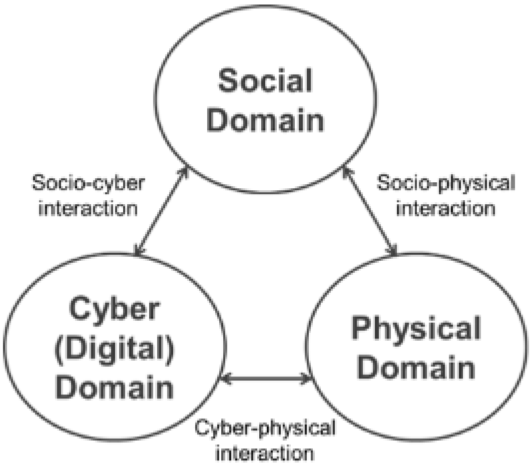

Figure 1. Socio-Cyber-Physical System

This study focuses on DSSs in the context of societies and cities (smart cities). Therefore, in designing such DSSs, it is important to introduce the socio-CPS perspective, which comprehensively considers the social (urban vision, rules, policies, etc.), digital (digital technology, data, etc.), and physical (products, urban resources, infrastructure, etc.) domains, rather than just the CPS perspective.

Research Gap

As reviewed in this chapter, several design and service studies have focused on the two design approaches that are key to achieving the social use of digital technologies: designs for “social transformation” and “DSSs.” However, the existing research has dealt with these two approaches separately.

We developed a novel design method, called “Digital Future Design Method (DFDM),” that integrated the two design approaches of “social transformation” and “DSSs” to address this research gap. The DFDM supports the design of DSSs to realize the social transformation towards a desirable future. Note that this paper only focuses on the early phases of the overall process of DFDM, that is, the conceptual design of DSSs. Subsequent phases for more detailed designs (e.g., service system architecture design, prototyping, social experiments, etc.) are beyond the scope of this paper.

Principles of the Digital Future Design Method

Figure 2 illustrates the three core principles of the DFDM. This chapter explains the details of the principles.

From Future Vision to Service Concept

The first principle of DFDM is that it begins with envisioning and articulating a desirable future vision. The view of designing only a DSS, which is merely one component of the future society, is insufficient to achieve the social transformation to a desirable future. Instead, we should adopt a future-oriented process that first envisions the desirable future society, which is the object of the transformation, and then embodies the DSS concepts and architecture required to realize this future.

Therefore, DFDM begins with the "future visioning" process, where we articulate the image of the desired future society. Subsequently, on the basis of the future vision, the core concept of the DSS is embodied by identifying its key functions (Figure 2-a).

Social, Digital, and Physical Perspectives

The second principle is to design both future visions and DSS concepts from the comprehensive perspectives of the social, digital, and physical domains (Figure 2-b). These three domains correspond to the domains of the socio-CPS; this suggests that the DFDM led the designers to utilize a socio-CPS thinking in their design. Here, the “social domain” includes the city (or society) perspective (e.g., culture, rules, policies, and city visions) and the citizen (or user) perspective (e.g., needs and mindsets); the “digital domain” contains digital systems and data that are potentially to be used in the project; and the “physical domain” includes urban resource (e.g., physical infrastructure, equipment, and buildings in the city), as well as physical products (e.g., devices, robots, and sensors, etc.).

Design Models for Collaborative Design

Previous related studies have argued that a collaborative design approach that involves various relevant stakeholders is essential for achieving social transformation (Sangiorgi, 2011). Therefore, we adopted collaborative design activities with various stakeholders as the fundamental approach of DFDM when designing future visions and DSS concepts. However, it is not easy to effectively promote a collaborative design approach as there are several difficulties, for example, discrepancies in perception among various participants and the influences of the political power of the participants. Thus, in order to achieve more effective collaborative design, we introduce the Model-Based Design (MBD) approach (e.g., Barbieri et al., 2014) in

DFDM (Figure 2-c). Note that we refer here to a primitive approach that supports designers by visually describing the design object using design models; however, there are several approaches in MBD.

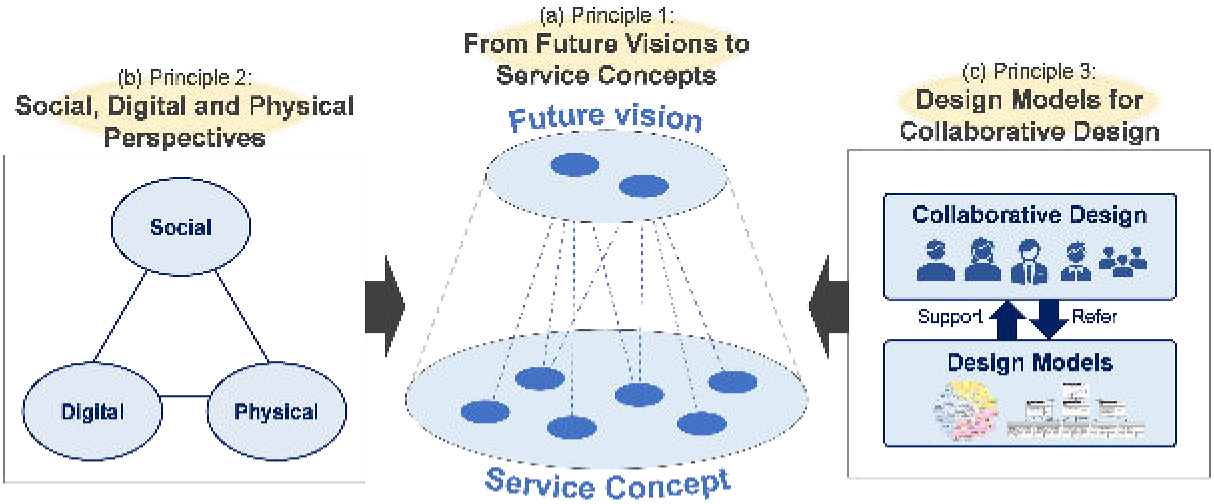

Figure 2. Core principles of the proposed DFDM

The most important benefit of using design models in co-creative design activities is that they provide a basis for shared understanding in collaborative discussions among various stakeholders. This leads to better co-creative designs as it reduces discrepancies in understanding among participants, encourages logical and systematic thinking of participants, and enables better management of multiple workshops and discussion results.

Design Process and Models

Design Process in the Concept Design Phase

Figure 3 illustrates the design process for the concept design phase in DFDM. Note that, as mentioned above, the scope of this paper is limited to the concept design phase, which is the early stage of DFDM; thus, the phases for more detailed design are beyond the scope of this paper. As shown in the figure, the concept design phase consists of three steps: (1) multi-perspective context analysis, (2) Future visioning, and (3) Vision-based concept design.

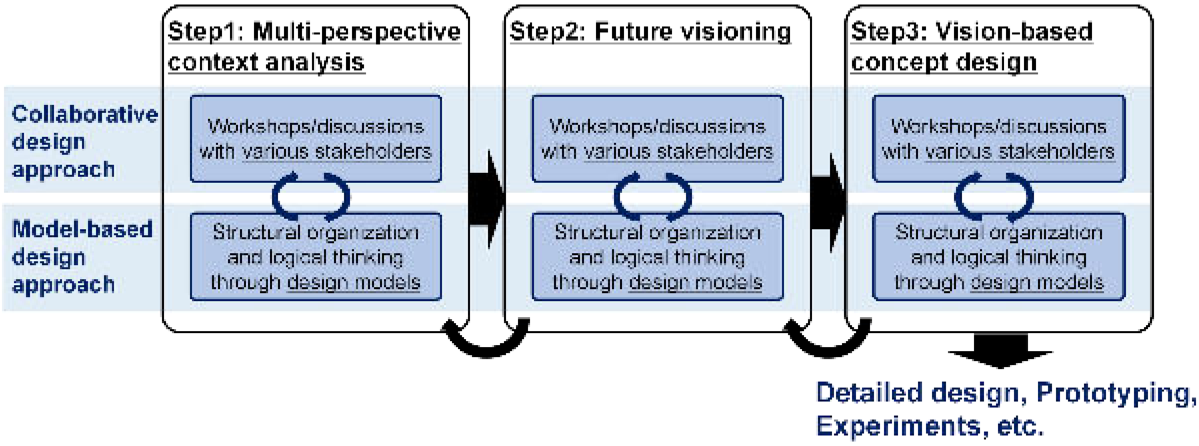

Figure 3. Design process of the concept design phase

Each step involves both the collaborative design approach, in which discussions and workshops with various stakeholders are carried out, and the MBD approach, where the results of the designers' thinking as well as the workshops/discussions are represented as forms of design models. The MBD approach is implemented by the core members of the project. Note that the core members could include various stakeholders, such as technology companies, designers, local governments, and also citizens, depending on the project. Meanwhile, the collaborative design approach is implemented through collaborative work (e.g., workshops, discussions, etc.) between the core members and other stakeholders in the city or region. The key to generating synergistic effects is to perform the iterative process between the MBD and collaborative design approaches as shown in Figure 3. The DFDM does not stipulate detailed restrictive rules on how to combine these two approaches, such as which of them to use as the first step or which to focus on as the main approach. The combination the two approaches should be determined on a project-by-project basis depending on the nature of projects, and the expertise and experience of the core members of the project.

Step 1: Multi-perspective Context Analysis

The DFDM design process begins with a multi-perspective context analysis based on the three domains of the socio-CPS concept: the social, digital, and physical domains. A framework proposed for this analysis is the Digital Future Hexagon (Figure 4); it consists of six diverse perspectives: society/city, citizen/user, digital system, data, physical product, and resources, that are used in the preliminary analysis for creating future visions and service system concepts. Of these six perspectives, society/city and citizen/user correspond to the social domain; digital systems and data correspond to the digital domain; and physical products and resources correspond to the physical domain.

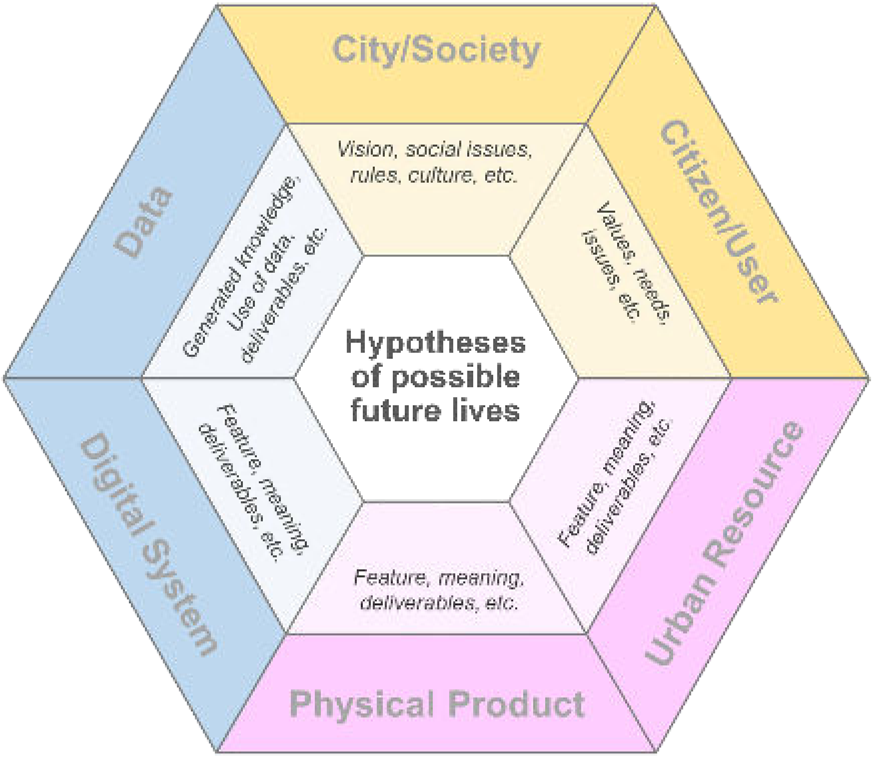

Figure 4. Digital Future Hexagon

For the context analysis, the core members of LL projects first collect information related to each of the hexagon's spaces through discussions, workshops, and interviews with a variety of relevant stakeholders. They then select the distinctive or notable elements from the information collected and describe them to the spaces in the hexagon. The details of the content to be described in the spaces (outer and inner layers) are shown in Table 1. They then identify some hypotheses about the possible opportunities for the future, while comprehensively considering the elements described in the six perspectives. The identified hypotheses are described in the central area of the hexagon. Note that this potential opportunity exploration should be carried out through collaborative work among various stakeholders, rather than by core members alone.

Domain	Perspective	Content to be described in each space
Social	City/Society	[Outer layer] City or region addressed in the project
		[Inner layer] Policies, city visions, important social issues to be addressed, culture, and institutions (rules), etc.
	Citizen/Users	[Outer layer] Main categories of citizens and/or potential users
		[Inner layer] Values, needs, and challenges that are important for citizens and/or potential users
Physical	Urban resources	[Outer layer] Characteristic urban resources (buildings, facilities, utilities, physical infrastructure, natural environment, etc.)
		[Inner layer] Features, social meaning, and deliverables of the urban resources
	Physical products	[Outer layer] Physical products that are intended to or could be used in the project (Note that products that are already installed in the city, e.g., local buses, should be described as “urban resources,” not here.)
		[Inner layer] Features, social meaning, and deliverables of the physical products
Digital	Digital systems	[Outer layer] Digital systems that are intended to or could be used in the project. “Digital systems” here refer to technical systems that cannot be seen directly as physical entities from citizens or users, e.g., databases or PFs in the cloud.
		[Inner layer] Features, social meaning, and deliverables of the digital systems
	Data	[Outer layer] Digital data that are intended to or could be used in the project.
		[Inner layer] Knowledge generated from the digital data, as well as the analysis results and deliverables of the data

Table 1. Six perspectives on the hexagon

Step 2: Future Visioning

In step 2, LL project members (including the core members and other stakeholders) envision the images of a desirable future society and articulate or visualize them as the future vision. First, images of the desirable future society is envisioned by referring to the results of the multi-perspective context analysis, especially the opportunity elements described in the center of the hexagon.

Here, we recommend ideating as many snapshots as possible of desirable future life scenes (hereafter, future life snapshots) and describe them using the worksheet shown in Figure 5(a). The ideation process for generating the future life snapshots will be conducted as a divergent process using brainstorming and other related methods. As Dunne and Raby (2013) point out in their study on the speculative design, the divergent exploration of various levels of possibilities, including not only "probable" future life snapshots, but also "plausible" and "possible" futures, is significantly important. After the divergent ideation of various snapshots, some are selected through voting and/or discussions by the core members and relevant stakeholders. Subsequently, the selected snapshots are summarized to create a future vision using the worksheet shown in Figure 5(b).

This study adopts this bottom-up approach to future visioning, which is similar to the future visioning process in the Transition design research (Irwin, 2018), as specific life scenes are generally easier to imagine and describe than a holistic and comprehensive social vision.

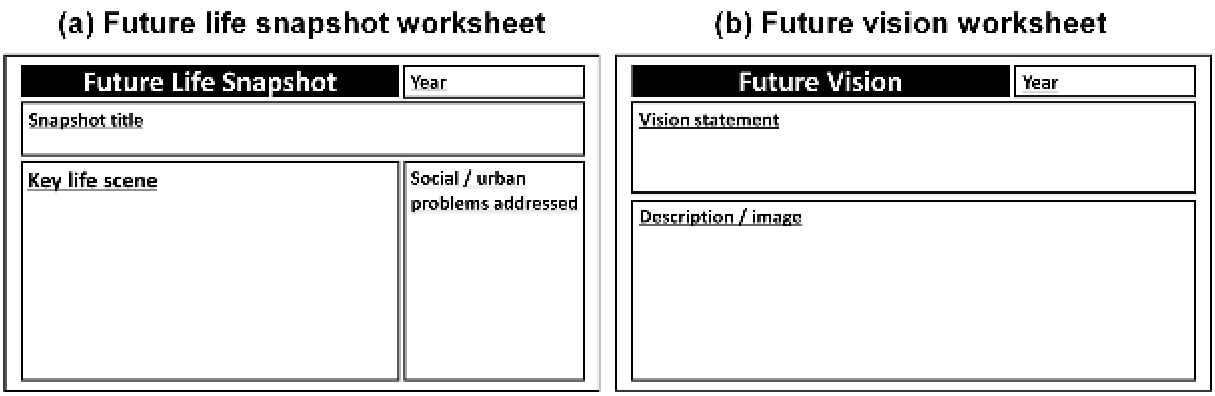

Figure 5. Worksheets used in DFDM

Step 3: Vision-based Concept Design

In step 3, the LL project members design the concepts of the DSS based on the future vision and future life snapshots created in step 2; the concepts here can be represented as a set of key functions for value creation. In this step, they use a design model called Vision-Life-Function Model (VLF Model) to hierarchically structure the relationship between the future vision, future life snapshots, and key functions (Figure 6). The VLF model is used to identify the key functions that directly relate to or contribute to the future vision identified in step 2. Especially, this kind of the hierarchical design model enables us to relate design elements at different levels of abstraction (in this case, future vision, future life snapshot, and key features). Furthermore, it encourages the logical and systematic thinking because it requires us to explicitly describe the means-ends relationship during the design process.

When using the VLF model, our thinking process basically proceeds in a top-down direction (i.e., from future vision / future life snapshots to key functions). However, this direction is not the only appropriate thinking approach. We should also review the identified design elements in the opposite direction, i.e., from a bottom-up perspective, so that we can update and revise the future vision and future life snapshots. This zigzagging process of moving back and forth between abstract and concrete space is important for thoughtful design.

More detailed architecture (service process, business model, data use model, social systems such as rules and culture, etc.) can be designed based on the VLF model described, although, as mentioned earlier, such process for more detailed design is beyond the scope of this paper.

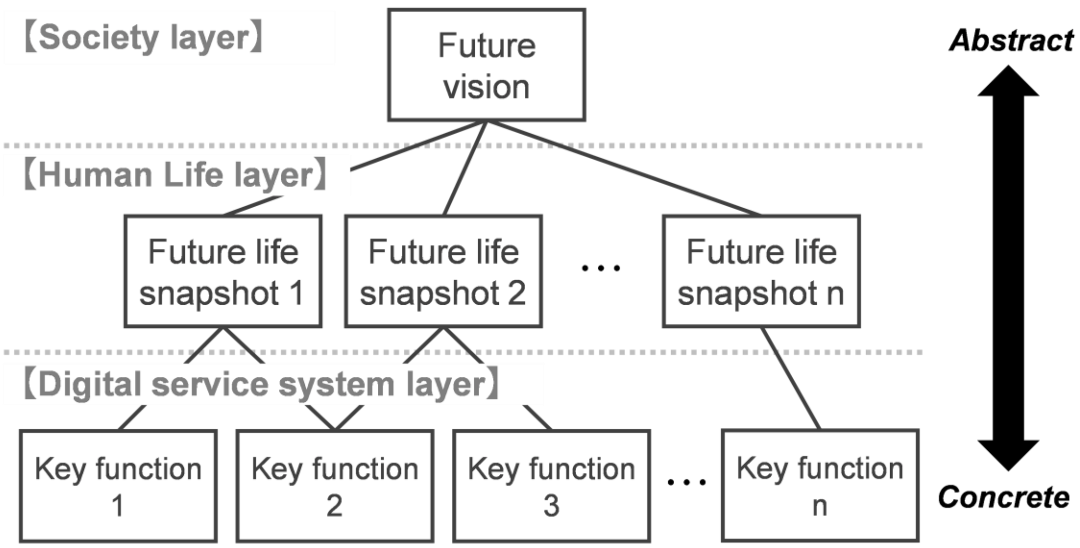

Figure 6. Vision-Life-Concept Model

Application to an Examle Case

Overview

In this study, we applied the proposed method to an example case of DSS design. This study followed the case application approach proposed in the Design Research Methodology (DRM) (Blessing and Chakrabarti, 2009). In this approach, the proposed design support method was applied to an actual design case to verify its applicability to support as well as usefulness. The case we applied involves a project to design next-generation smart mobility services in the Kashiwa-no-ha Smart City, one of Japan's leading smart cities. In Kashiwa-no-ha, an R&D project to develop Level-4 automated buses is currently in progress as a government-funded national project. Some of the authors are participating in this project as part of a team responsible for designing a new DSS that combines various types of mobility, including the Level 4 automated buses, with various types of data in the smart city.

In this application, a service design researcher (first author) and technical researchers developing a smart mobility management system corresponded to the core members who formed a team to design a future vision and the concept of smart mobility service. The smart mobility service was designed as a DSS that involves advanced mobility vehicles. In this project, we (the core members) applied the DFDM design model to structure individual thinking and ideas, as well as the results of intensive discussions within the core members for generating future visions and service concepts. Furthermore, in this case study, we involved various stakeholders at several points in the design process to have collaborative discussions; they included a real estate company developing the smart city, a professional organization working on urban planning and community development, local governments, university researchers on automated driving technology, shopping center operators, and so on.

For ethical considerations, the study was conducted on the basis of the internal regulations, according to the determination of non-applicability by the Committee on Ergonomic Experiments of National Institute of Advanced Industrial Science and Technology (H2021-1179).

Application Results

Step 1: Multi-perspective context analysis

We first conducted several surveys, such as a large-scale questionnaire survey, discussions with stakeholders, and fieldwork to uncover the current state of mobility in the area, as well as resident needs, related urban policies, and urban resources. Concurrently, we also had discussions on mobility technology with technical researchers inside and outside the core team to identify digital technologies and digital data that should be used in the future for this project.

We filled in each space of the digital future hexagon based on the results of these surveys and discussions. Subsequently, we developed various hypotheses about the opportunities for future lives, which correspond to the central part of the hexagon, through a divergent thinking process. We particularly adopted the forced-relationship idea generation approach in which we selected a few of the elements in the hexagon and combined them to generate new ideas. We also had several discussions with stakeholders to update our hypotheses. The final result of the hexagon is illustrated in Figure 7.

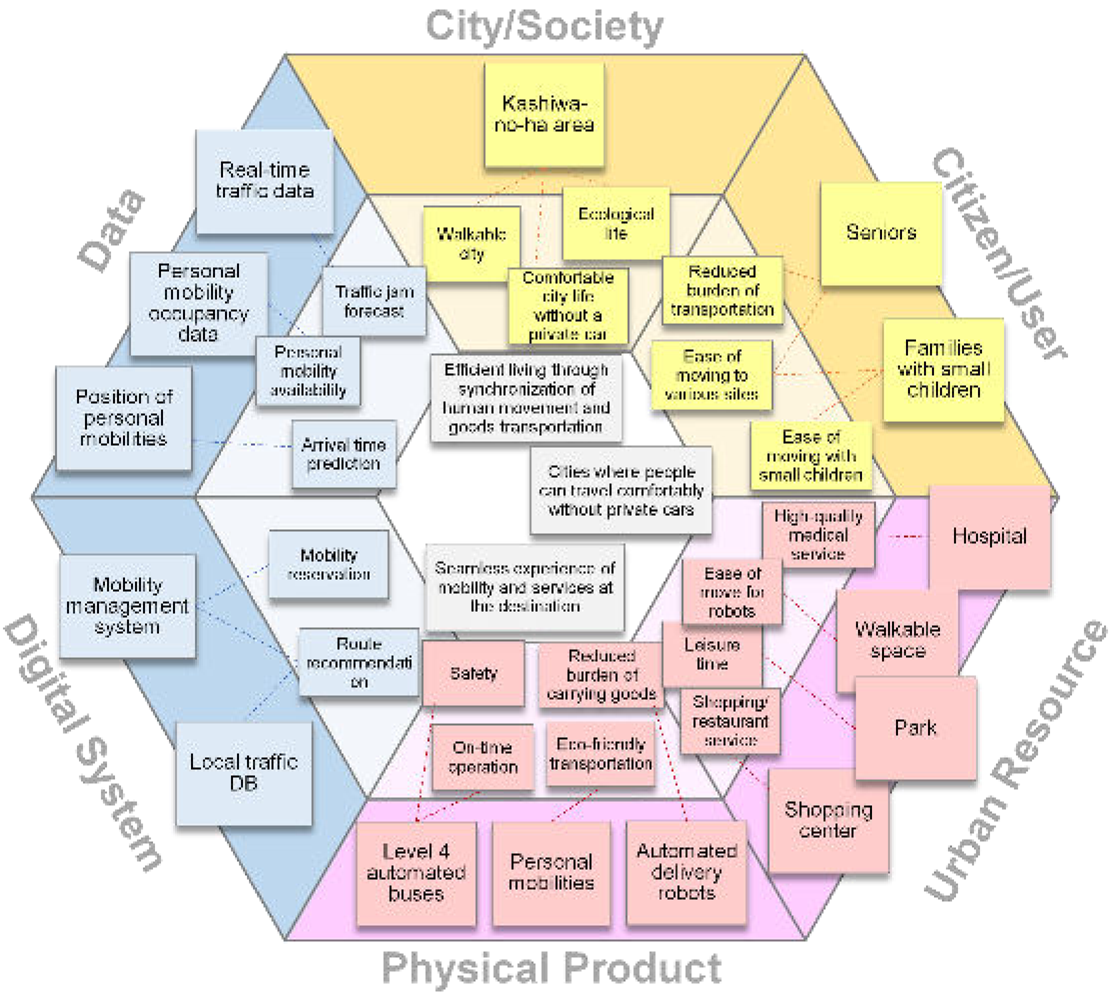

Figure 7. Results of the analysis using digital future hexagon

Step 2: Future visioning

We generated ideas of future life snapshots, which represent desirable future life scenes, based on the hypotheses in the central part of the digital future hexagon, with supplementary consideration of other elements within the hexagon. These generated life snapshots, which were then summarized to clarify and articulate the future vision. Since the COVID-19 pandemic prevented in-person discussions and workshops, the future visioning process was conducted through online meetings and discussions. The results of the future life snapshot and future vision are presented in Figure 8 (elements of the top two layers). Due to space limitations, we have excerpted only passages important for understanding the content regarding the future vision and future life snapshots.

Step 3: Vision-based concept design

In this final step of the concept design phase, we designed key functions of the DSS to realize the future vision. We first explored the key functions based on the future vision and future life snapshots. Subsequently, we associated these three layers (i.e., future vision, future life snapshots, and key functions) using the VLF model. Each of the key functions was then visualized in a form of discussion papers, which were used in the collaborative discussions with other stakeholders to collect some additional ideas or comments for updating or revising the future vision and key functions. The VLF model we created through this process are shown in Figure 8.

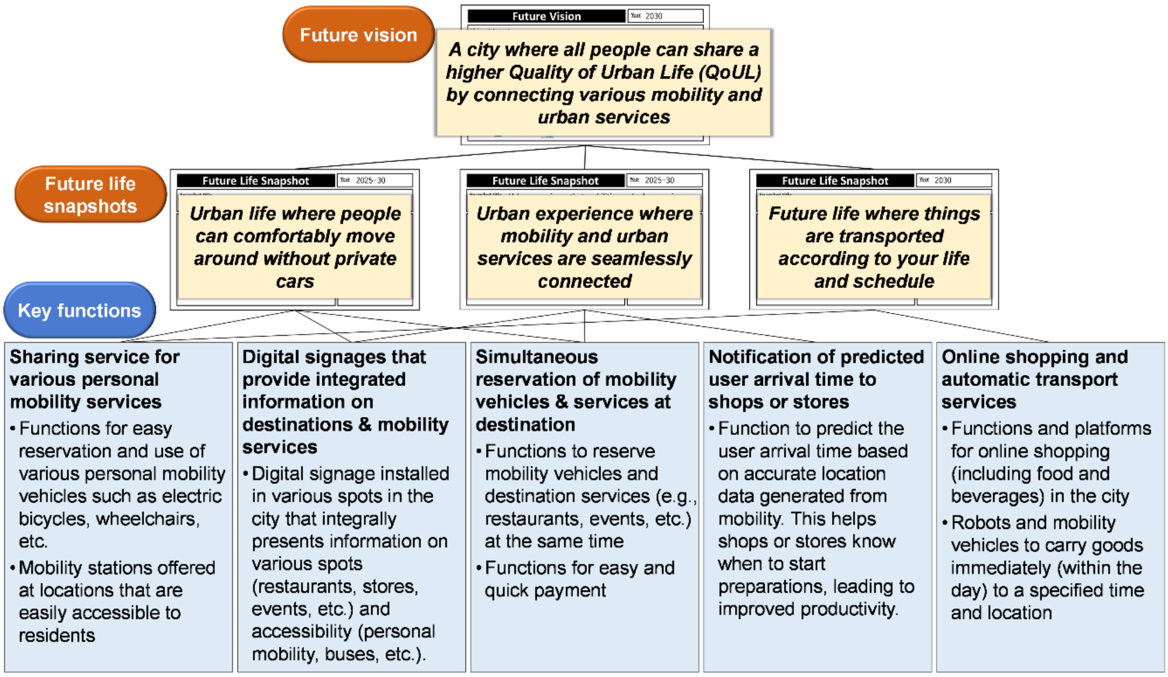

Figure 8. Results of the VLC model

Discussion

Connecting Future Vision to Service Concept

Achieving a sustainable future society by solving social problems using digital technologies requires both the "social system-level perspective," which creates a desirable future society/city, and the "service system-level perspective," which develops and offers DSSs to realize such a future society/city. The results of the case study demonstrated that the proposed DFDM aided in ensuring a future vision-driven design thinking. In addition, the VLF model was effective in designing the key functions of the DSS on the basis of the future vision and life scenes. For example, in the case study, the VLF model helped us identify key functions that have strong or consistent relationships with upper-layer elements (i.e., future visions and future life snapshots) from a variety of function ideas that we divergently generated. These results suggest that DFDM is useful for the integrated design of two systems that have different levels of abstraction: future vision and DSSs.

The VLF model has similarities to the Systems Engineering (SE) approach (e.g., Maier, 2009) in terms of designing a system by structurally describing the functions required to achieve a certain objective. However, while the "problem to be solved" or the "user needs" is generally on the highest-level element (namely, the objective to achieve in design) of functional modelling in the traditional SE, the "future vision" is the starting point in DFDM. Thus, the VLF model encourages us to think systematically in a future vision-oriented approach. We believe this to be one of the novelties of DFDM that broadens the scope of design compared to the traditional SE and related methods.

Designing with Comprehensive Perspectives

The digital future hexagon in DFDM enabled us to explore future visions, life scenes, and key functions from six comprehensive perspectives (i.e., society/city, citizen/user, digital system, data, physical product, and resources), which relates to the social, digital, and physical domains. Through the case study, we found that these perspectives acted as "constraints" to limit the direction of idea generation regarding future visions, life scenes, and key functions. For example, in the case study, the existing city visions "walkable city" and "Comfortable city life without private cars," that were described in the society/city perspective in the hexagon, which worked as constraints to define the idea exploration space. Further, the main categories of residents (i.e., families with small children and seniors), which were described in the citizen/user perspective, were also constraints in idea generation and guided our thinking in certain directions. We found that these six perspectives also functioned as "clues" for generating new ideas. For example, in this case study, by focusing on two elements, "restaurant service" in the urban resources perspective (pink area) and "arrival time prediction" in the data perspective (blue area), a new idea of "providing reservation customer arrival times to restaurants" was generated as a possible opportunity for future life scenes.

These results indicated that the digital future hexagon, which provides "constraints" and "clues" in idea generation, is effective in supporting creative thinking to explore new opportunities for social transformation. In particular, the hexagon clearly included the perspectives of "society and city" and "urban resources;" thereby enabling us to tailor our idea generation and opportunity exploration to the local context. This suggests that the proposed hexagon is also useful for reflecting the local situation and context when designing future visions, life scenes, and important functions.

The existing research on future vision creation, such as transition design research has proposed the use of a workshop method for imagining future life scenes (Irwin, 2018); similarly, a workshop method for exploring visions by using the phrase "what if?" has been developed in the participatory design research (Baumann et al., 2017). However, these existing methods do not include context analysis as DFDM does. They rely only on the imagination, skills, and creativity of the participants. Therefore, providing a variety of perspectives to support opportunity exploration and idea generation is an important feature of DFDM and one of its novelties.

The Power of the Design Models

In this case study, we had multiple workshops and discussions with diverse stakeholders. In collaborative design projects, the results of these multiple workshops and discussions are often recorded in forms of, e.g., sticky note photos, minutes, etc. However, they often remain stored in the recording devices (such as PC, phone, and camera, etc.), and the strategic reflection and integration of these recorded results is often not effectively performed.

In contrast, the DFDM design models made it possible to visualize and manage the results of multiple workshops and discussions on the model. Furthermore, by gradually reflecting and updating the results of multiple workshops and discussions in the design model, we could integrate the ideas or comments generated in the workshops and discussions on the model; this led to the creation of higher quality ideas (Figure 9).

From these results and discussions, we found that integrating the MBD approach into the co-design process was useful in supporting the co-creation process with diverse stakeholders. This can be called as the power of design models in DFDM, which we believe is one of the advantages of our method.

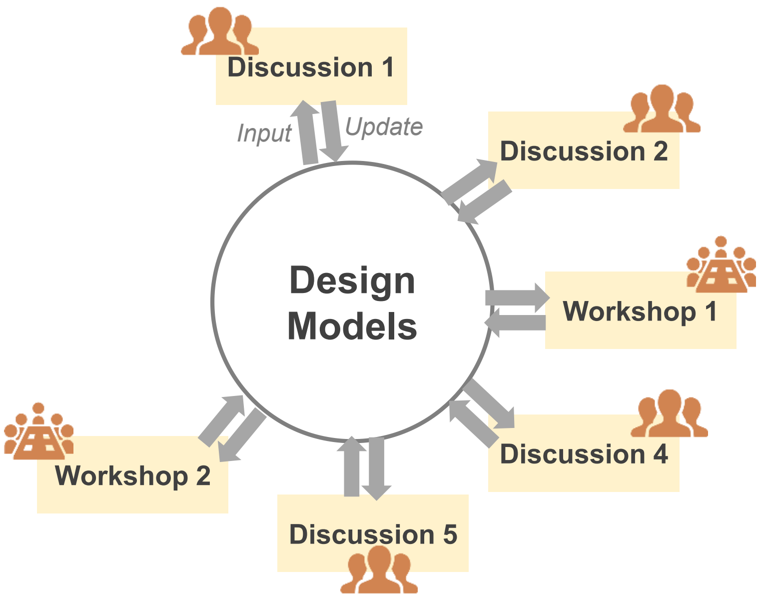

Figure 9. Design models as an intermediate for integrating collaborative works

Limitations

As mentioned above, this paper covers only the early phases of the overall process of DFDM (i.e., the conceptual design of the DSS). Therefore, the more downstream design phases, such as architecture design, prototyping, and social experiments, are beyond the scope of this paper. This is one of the limitations of this research. Thus, our future research will include the development of design methods and processes in the latter phase of the DSS design. Although we conducted a case study on an actual project, this project is still at the stage where only the concept design phase was completed. Therefore, hereafter, we will also actively promote the project itself in parallel with the method development for the phases after the concept design. By reflecting on the results of that project practice, we can update and further expand the DFDM. In addition, we also have plans to apply the DFDM to other cases for verifying its general usefulness.

Conclusion

In this study, we proposed the DFDM, a novel design method that supports the designing of DSSs for realizing the social transformation to a desirable future. More concretely, we also developed the design models (i.e., digital future hexagon and VLC model) and design processes used in the DFDM. The DFDM was applied to a case of smart mobility service concept design. The results demonstrate that it enables us to have the future vision-based thinking in design and the comprehensive perspectives including the social, digital, and physical domains. The future works will include the development of additional method for designing more detailed architecture of DSSs.

Acknowledgments

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References

Akasaka, F. & Nakatani, M. (2021). Citizen Involvement in Service Co-creation in Urban Living Labs. In Proc. the 54th Hawaii International Conference on System Sciences, 10 pages

Andreani, S., Kalchschmidt, M., Pinto, R., & Sayegh, A. (2019). Reframing technologically enhanced urban scenarios: A design research model towards human centered smart cities. *Technological Forecasting and Social Change*, 142, 15–25.

Barbieri, G., Fantuzzi, C., & Borsari, R. (2014). A model-based design methodology for the development of mechatronic systems. *Mechatronics*, 24(7), 833-843.

Baum, F., MacDougall, C., & Smith, D. (2006). Participatory action research. *Journal of epidemiology and community health*, 60(10), 854.

Baumann, K., Stokes, B., Bar, F., & Caldwell, B. (2017). *Infrastructures of the imagination: Community design for speculative urban technologies*. In Proc. the 8th International Conference on Communities and Technologies (C&T '17), 266–269.

Bergvall-Kåreborn, B., & Ståhlbröst, A. (2009). Living Lab: an open and citizen-centric approach for innovation. *International Journal of Innovation and Regional Development*, 1(4), 356-370.

Bijker, W. E. (1997). *Of bicycles, bakelites, and bulbs: Toward a theory of sociotechnical change*. MIT press.

Blessing,L.& Chakrabarti, A.(2009). DRM: A Design Reseach Methodology, Springer.

Burns, C., Cottam, H., Vanstone, C., & Winhall, J. (2006). *RED paper 02: Transformation design*. UK Design Council.

Chen, H. (2017). Applications of cyber-physical system: a literature review. *Journal of Industrial Integration and Management*, 2(3), 1750012.

Dunne, A., & Raby, F. (2013). *Speculative everything: design, fiction, and social dreaming*. MIT press.

Eremia, M., Toma, L., & Sanduleac, M. (2017). The smart city concept in the 21st century. *Procedia Engineering*, 181, 12-19.

Halstenberg, F. A., Lindow, K., & Stark, R. (2019). Leveraging circular economy through a methodology for smart service systems engineering. *Sustainability*, 11(13), 3517.

Harrison, C., Eckman, B., Hamilton, R., Hartswick, P., Kalagnanam, J., Paraszczak, J., & Williams, P. (2010). Foundations for smarter cities. *IBM Journal of research and development*, 54(4), 1-16.

Hák, T., Janoušková, S., & Moldan, B. (2016). Sustainable Development Goals: A need for relevant indicators. *Ecological indicators*, 60, 565-573.

Irwin, T. (2015). Transition design: A proposal for a new area of design practice, study, and research. *Design and Culture*, 7(2), 229-246.

Irwin, T. (2018). *The Emerging Transition Design Approach*. In Proc. the DRS International Conference 2018, 22 pages.

Li, F., & Lu, Y. (2021). *Engaging end users in an ai-enabled smart service design-the application of the smart service blueprint scape (SSBS) framework*. In Proc. the International Conference on Engineering Design 2021, 1363-1372.

Lim, C., & Maglio, P. P. (2018). Data-driven understanding of smart service systems through text mining. *Service Science*, 10(2), 154-180.

Maglio, P. P., Vargo, S. L., Caswell, N., & Spohrer, J. (2009). *The service system is the basic abstraction of service science*. Information Science and e-Business Management, Springer- Verlag, 395-406.

Maier, M.W. (2009). *The Art of Systems Architecting*. CRC Press.

Manzini, E. (2014). Making things happen: Social innovation and design. *Design issues*, 30(1), 57-66.

Medina-Borja A (2015) Smart things as service providers: A call for convergence of disciplines to build a research agenda for the service systems of the future. *Service Science*, 7(1), 2-5.

Mulgan, G., Tucker, S., Ali, R. & Sanders, B. (2007). *Social Innovation: what it is, why it matters, how it can be accelerated*. London: University of Oxford, Young Foundation.

Pekkala, D., & Spohrer, J. (2019). *Digital Service: Technological Agency in Service System*s. In Proc. the 52nd Hawaii International Conference on System Sciences, 10 pages.

Pirola, F., Boucher, X., Wiesner, S., & Pezzotta, G. (2020). Digital technologies in product-service systems: a literature review and a research agenda. *Computers in Industry*, 123, 103301.

Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I., & Brunori, G. (2021). Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation. *Journal of Rural Studies*, 85, 79-90.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4(2), 155–169.

Robertson, T., & Simonsen, J. (2012). *Participatory Design: an introduction*. Routledge international handbook of participatory design, Routledge.

Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *CoDesign*, 4(1), 5-18.

Sangiorgi, D. (2011). Transformative services and transformation design. *International Journal of Design*, 5(2), 29-40.

Tsunetomo, K., Watanabe, K., & Kishita, Y. (2022). Smart product-service systems design process for socially conscious digitalization. *Journal of Cleaner Production*, 368, 133172.

Valencia, A., Mugge, R., Schoormans, J., & Schifferstein, H. (2015). The design of smart product-service systems (PSSs): An exploration of design characteristics. *International Journal of Design*, 9(1), 16 pages.

Watanabe, K., Kishita, Y., & Tsunetomo, K. (2020). *Conceptual design framework for digital technology assisted service system*. In Proc. the ServDes.2020, 190-202.

Yang, C. F., & Sung, T. J. (2016). Service design for social innovation through participatory action research. *International Journal of Design*, 10(1), 16 pages.