sustainability

MDPI

Article

A Strategic Planning Method to Guide Product—Service System Development and Implementation

Yuya Mitake *, Kenshiro Hiramitsu, Yusuke Tsutsui, Mar'atus Sholihah and Yoshiki Shimomura

Department of Systems Design, Tokyo Metropolitan University, Tokyo 191-0065, Japan; flatsword217@gmail.com (K.H.); tsutsui-yusuke@ed.tmu.ac.jp (Y.T.); sholihah-mar'atus@ed.tmu.ac.jp (M.S.); yoshiki-shimomura@tmu.ac.jp (Y.S.)

* Correspondence: mitake-yuya@ed.tmu.ac.jp

Received: 5 August 2020; Accepted: 14 September 2020; Published: 16 September 2020

check for updates

Abstract: The societal and environmental crises in recent decades have promoted a social awareness of existing challenges to sustainability. While product–service systems (PSS) are considered a promising way to achieve a sustainable future, PSS features also create barriers that hinder the widespread implementation of PSS in society. Recent studies have therefore increasingly focused on the challenges to PSS implementation. However, the existing literature fails to facilitate a strategic plan or practical guide for PSS design activity despite taking into account the importance of visioning in PSS design. This paper, therefore, proposes a strategic planning method for PSS development and implementation by combining technology roadmap and transition scenarios. To illustrate its applicability and validity, the proposed approach is applied to a PSS development project for solving wildlife damage in a suburban city of Tokyo. The case study was conducted as a participatory workshop, which involved relevant stakeholders to develop a roadmap toward a sustainable future PSS vision based on the proposed method. The result of this application demonstrates that the proposed approach enables the formulation of a long-term PSS design strategy, while comprehensively converging the perspectives and knowledge of each stakeholder participating in the PSS development.

Keywords: product–service system; socio-technical system; transition management; technology roadmapping; transition scenario; strategic planning

1. Introduction

A systemic and fundamental transformation of current production and consumption patterns to more sustainable ones is necessary to address the urgent sustainability challenges of the 21st century. However, such a transition potentially requires radical changes in the current regulations, norms, values, and lifestyles as a "window of opportunity" for new sustainable values—for instance, customers are showing interest in sharing or pay-per-use solutions instead of owning a product. To promote this transition, the adoption of product–service systems (PSS) has attracted attention as a promising approach to achieve sustainable value from both academic and industrial perspectives [1–5]. PSS is described as a radical innovation because it has the potential to change customers' habits, companies' corporate mindsets and organizations, and governmental frameworks [1,2,4,6]. However, these PSS features also hinder the widespread introduction and implementation of PSS in society [5–8] because they require a cultural shift by both the producers and customers, expressed as "acceptance from customers" and a "shift in companies' culture/resistance to change" [9,10]. Moreover, the implementation of PSS requires a social system or infrastructure that will accept or support the suggested product–service scenario [2].

It is therefore necessary to understand the contextual conditions in which they are introduced and explore the most suitable strategies that lead to design activity and development pathways to embed these concepts in society [5,6].

To take advantage of potential PSS benefits considering the abovementioned barriers, recent PSS design research focuses increasingly on new design challenges: how to realize the implementation of PSS [5,6,11–13]. This research regarding the nature of PSS as a socio-technical system acknowledges that PSS is not a simple functional offering but that it can be regarded as a social innovation or large-scale socio-technical change [6,11,14–17]. To ensure the successful adoption of PSS, the consensus among recent PSS research indicates that adapting socio-technical transition studies (transition management, strategic niche management) is beneficial for fostering the maturity of the PSS design research field, based on the need for a deep redefinition of consumption and production patterns [5,6,11,13,15,16,18]. In particular, some existing literature specifically focuses on "socio-technical experimentation and learning" [19,20], one of the core elements of transition studies, to involve stakeholders in the early development, evaluation, and testing process [6,11,15]. Socio-technical experiments protect the incubation and maturation of radical innovation, such as PSS, by partly separating them from the mainstream market environment.

Meanwhile, "strategic planning for long-term vision" is another key concept in transition studies [19,21,22]. Many stakeholders involved in the process of PSS development may strive to realize different alternative futures and fundamental values. Therefore, the convergence of stakeholders' perspectives and expectations in the early phase of PSS development is fundamental to facilitate and give strategic orientation for working on PSS design activity [6]. However, existing PSS literature fails to address how to facilitate a strategic plan or practical guide for PSS development despite the importance of such visioning [6,15].

This paper aims to provide a practical guide for the strategic planning of PSS development and implementation for sustainability following the nature of PSS as a socio-technical system. To achieve this purpose, this study develops a PSS strategic planning method, which enables the collaborative formulation of a PSS design strategy by converging the perspectives of each stakeholder participating in the PSS development and by adopting technology roadmapping (TRM) and transition scenarios from transition studies. TRM is a well-established technique to develop and visualize strategic planning in the industry. The transition scenario is a flexible tool used to develop a narrative toward a sustainable future with the participation of relevant stakeholders. Incidentally, it has to be underlined that the proposed method is intended to be applied to particular development cases of PSS, which has a socio-technical nature and is oriented to solve social issues and daily life problems. Thus, this study is different from the design approach for industrial PSS development that likely focuses on acquiring a competitive advantage for a company's businesses.

The remainder of this paper is structured as follows. Section 2 provides the research method of this study, and Section 3 presents the results of the literature review on transition studies and TRM. Section 4 describes the integration of the transition scenario and TRM as a method for PSS strategic planning used in the proposed approach. Section 5 applies the proposed method to a case study of a PSS development project for solving wildlife damage in the suburbs of Tokyo, and Section 6 discusses the major implications for PSS development, remaining issues, and future works.

2. Research Method

The present paper is built on the research stages of a design research methodology (DRM) [23], which is a set of supporting methods and guidelines for design research. This approach has been broadly adopted by extant PSS design research [24–29]. The research stage consists of (1) a literature review to understand previous knowledge and existing theories, (2) the development of methodology based on a theoretical foundation, and (3) the application of the developed method to an actual case study. The following sections present a detailed description of each stage.

2.1. Stage 1: Literature Review to Understand Previous Knowledge and Existing Theories

This study conducted a literature review to analyze and comprehend previous knowledge and existing theories on the transition study and TRM. Specifically, this stage acquires knowledge of the strategic planning concept in each discipline and provides a theoretical basis for undertaking the research and developing the PSS strategic planning (Section 3). The output of this stage guides the definition of criteria required for PSS strategic planning.

2.2. Stage 2: Development of Methodology Based on Theoretical Foundation

The DRM provides an understanding of the design research for enhancing the design process in both theory and practice. Likewise, this study develops a method to improve the PSS design and raise designers' consciousness in designing PSS. In particular, this paper combines and tailors TRM and transition scenarios to support the strategic planning of PSS development. The proposed method comprises distinctive aspects of PSS envisioning and planning, which differ from the transition study, as well as general scenarios and the TRM method. Hence, based on the theoretical foundation acquired in stage 1, this stage identifies the criteria that should be fulfilled by the proposed method by comparing the differences between (1) general scenarios and transition scenarios; (2) the envisioning in transition studies and PSS studies; and (3) the focus of strategic planning in TRM and PSS development. Then, this study develops a strategic planning method to guide PSS development toward its implementation. Section 4 presents the developed method.

2.3. Stage 3: Application of the Developed Method to an Actual Case Study

This study applies the developed method to a case study and make empirical observations. This study evaluated the applicability and validity of the proposed method to determine whether the proposed method can be used for the task for which it is intended and whether the expected impact is realized. This stage applies the proposed method to a PSS development project for solving wildlife damage in a suburban city of Tokyo. The observations were then reflected upon to evaluate their validity and applicability to PSS strategic planning. Applying the method to a case study enabled us to identify the necessary improvements for future research.

3. Theoretical Foundation

3.1. Strategic Planning from Transition Studies

3.1.1. Transition Management Framework

Transition studies are a discipline that provides insights into how to understand and facilitate radical innovations for achieving sustainability. In this discipline, "transitions" are described as processes of structural change in societal (sub-) systems for sustainability [19,21,22]. Transitions come about when the dominant structures in societal (sub-) systems are put under pressure by external changes in society, as well as endogenous innovation. A transition management framework is developed to facilitate and orient the transition process toward sustainable outcomes by combining theoretical reasoning with practical experiment and observation in society [19,21,22,30]. This framework has two key contents: a descriptive distinction level divided into strategic, tactical, and operational activities; and a prescriptive cycle of four development phases: (1) problem structuring, which involves establishing the transition area and envisioning (strategic); (2) developing coalitions and transition agendas (tactical); (3) executing projects and experiments (operational); (4) monitoring, evaluating, and learning (tactical) (Figure 1). The three activity levels in the descriptive distinction level of this framework are described as follows:

- Strategic activities

Transition arenas and transition visions are the main instruments in this activity level. The transition arena is a small network of stakeholders with different backgrounds, within which various perceptions of a persistent transition issue and possible directions for solutions can be deliberately confronted with each other and subsequently integrated [19]. In this level, the development of transition visions (long-term visions for sustainability), an important management instrument for achieving new insights and formulating starting points, can synthesize actors' discussions and work toward the convergence of perspectives, assumptions, and ambitions. The convergence of diversity is important to give strategic orientation and legitimacy to innovation development [30]. Envisioning processes are labor- and time-intensive, but they are crucial to achieving sustainable development in the desired direction.

- Tactical activities

A "transition agenda" development process is initiated based on the developed transition visions. The transition agenda contains common objectives, action points, projects, and instruments to realize these objectives. The tactical level therefore also focuses on understanding barriers that may inhibit the advancement of the transition visions and on proposing necessary adjustments. The transition agenda is the compass for stakeholders in the transition arena, which they can refer to during their research and learning process [22,31]. The change in perspective, described by the transition visions, should be further translated to find roots within various networks, organizations, and institutions.

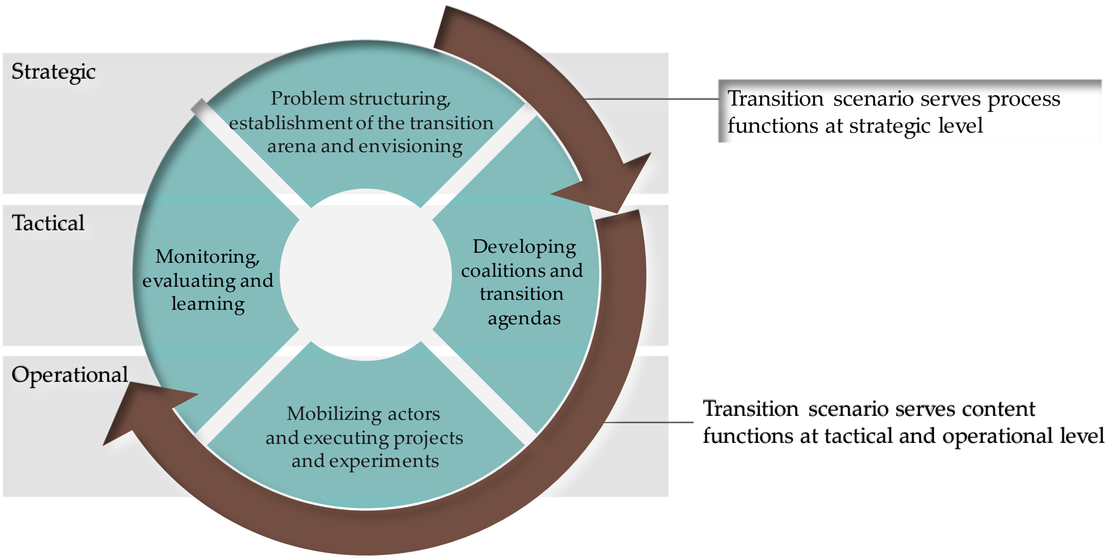

Figure 1. Transition management framework with transitions scenarios (adopted from [32]).

- Operational activities

This activity level relates to the experiments and learning-by-doing. The developed transition visions derive socio-technical experiments for testing innovation alternatives, which fit within the established transition visions. The experiments learn the technical, social, political, and economic configurations of the innovation and enhance its societal embedding. The main aim of this activity level is to create a portfolio of related experiments that complement and strengthen each other, contribute to the objective, can be scaled up, and are significant and measurable [19].

This framework includes activities and the continuous monitoring and evaluation of transition management. The integration of monitoring and evaluation within each phase and at every level of transition management stimulates a process of social learning that arises from the interaction and cooperation between the different actors involved [19].

3.1.2. Transition Scenarios as a Conceptual Tool for Transition Management

At all three levels, but particularly at the strategic activities level, the design of "transition scenarios" is an important conceptual tool that is increasingly highlighted in the literature. Transition scenarios are defined as participatory explorations of possible development trajectories that incorporate a structural system change towards a desired, sustainable, future state of the system [33]. As plausible, coherent narratives toward achieving transition visons, these scenarios can be embedded in the process of envisioning the transition management cycle (process functions) (Figure 1). The developed transition scenarios can also support downscaling long-term desirable future visions at the strategic level into transition agendas at the tactical level as well as practices and experiments at the operational level (content functions) (Figure 1). Transition scenarios can not only help engage and align stakeholders, but they can also prepare more resilient strategies by anticipating deviations from current trends [32–36].

Sondeijker [32] developed a method to design transition scenarios, which consists of seven iteratively linked generic steps: (1) identifying barriers for structural change, (2) defining transition visions and scope of the system, (3) envisioning a desirable, sustainable system, (4) developing the necessary structural change process described in transition visions, (5) identifying and structuring drivers for structural change, (6) anticipating strategies of the transition arena, and (7) framing the transition scenario. In terms of reflection, the development process can modify cyclically and iteratively instead of following sequential processes based on learning experiences. Information gathered in subsequent steps will lead to a more detailed insight into this scope. Moreover, during the development process, participants continuously go back and forth between different steps to ensure consistency and alignment between steps. The development of transition scenarios is finished when the facilitators can point out the characteristics for a transition process, and when the engaged participants realize that the ideas played out in the transition scenarios are innovative compared to their daily practice. The development process can be rounded off when both aims are completed [32].

3.2. Technology Roadmapping

3.2.1. General Description of Technology Roadmapping

TRM is a widely implemented flexible technique for industry and practitioners to support long-term strategic planning and R&D [37–40]. TRM aims to forecast social, market, and technology changes to develop strategies that ensure its survival in the current dynamic and uncertain environment. While TRM can be defined as a roadmapping process, i.e., a set of activities to develop a "roadmap," the roadmap is the outcome of the process. The generic architecture of a roadmap consists of a two-dimensional concept: a horizontal axis timeline and vertical axis multi-layers [38] (Figure 2). The roadmaps serve as graphical means for exploring and communicating dynamic interplay among technological resources, organizational objectives, and changing environment [38,41]. These structures can be customized to align with the specific requirements associated with roadmapping activities.

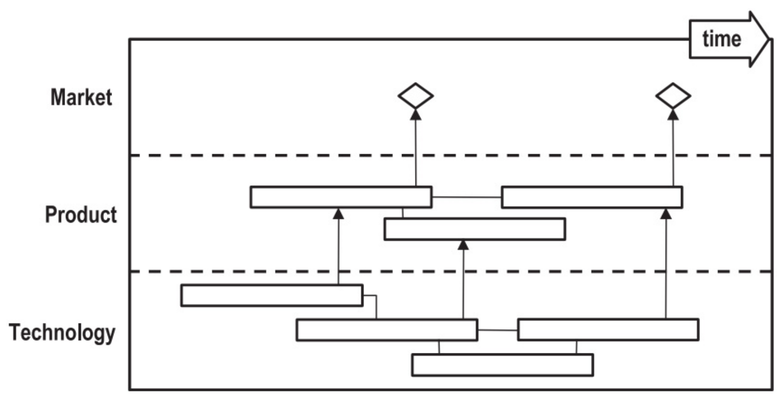

Figure 2. The generic architecture of technology roadmap (adopted from [38]).

According to the TRM literature, the roadmapping process is more vital than the roadmap itself [38,41]. This process synthesizes actors from diverse backgrounds, providing them an opportunity to share knowledge and perspectives, and offers a vehicle for holistic consideration of problems, opportunities, and new ideas [38]. The generic roadmapping process consists of three different phases: (1) a preliminary activity (i.e., planning, problem recognition, and setting up the team), (2) the development of technology roadmap, and (3) follow-up activities (i.e., updating and adjustment of roadmap) [42]. The roadmapping process should also be customized to fit the objectives, given situation, and context and accommodate any uncertainty associated with emerging technologies [38,41].

Recent research has suggested an integrative approach to develop scenario-based roadmapping [43–46]. These endeavors are conducted to leverage the characteristics of both approaches in terms of the flexibility of scenario planning together with the clarity of TRM. Scenario-based roadmapping offers a significant capability for decision-making in strategic planning and forecasting to respond to complex and uncertainly changing environments [45]. To take advantage of these strengths, researchers and practitioners are now increasingly focusing their attention on scenario-based roadmapping.

3.2.2. TRM for PSS Planning

Extant literature has identified the advantages of TRM as a planning tool for product–service integration. Initially, An et al. [47] proposed an integrated roadmap for the strategic management of product–service integration. Geum et al. [48,49] contributed to the promotion of TRM research for PSS strategic planning by highlighting the role of technology as a significant interface for the configuration of PSS. Geum et al. [48] defined six types of roadmap and provided relevant guidance for the strategic management of the proposed roadmap, highlighting the roadmapping process, planning procedure, and the supporting tools—linking grid and quality function deployment (QFD). Subsequently, Geum et al. [49] proposed a customization framework for product–service integration based on each type of TRM by applying a case study. Hybrid TRM procedures have since been developed in combination with other management techniques, such as patent analysis [50], system dynamics [51], and design structure matrix [52]. This study integrates TRM and transition scenarios as facilitation tools for sustainable development.

4. The Proposed Method

4.1. Toward the Integration of Two Strategic Planning Techniques for PSS Planning

This study provides a strategic planning method for PSS development and implementation. In particular, this paper combines and tailors TRM and transition scenarios to support the strategic planning of PSS development. Based on the theoretical foundations discussed in Section 3, this section identifies the criteria that the proposed method should fulfill, and clarifies the differences between (1) general scenarios and transition scenarios; (2) the envisioning in transition studies and PSS development; (3) the focus of strategic planning in TRM and PSS development.

4.1.1. Differences Between General Scenarios and Transition Scenarios

According to related literature [32–36], transition scenarios have two main distinctive characteristics. First, compared to general scenarios, which are either explorative or normative [53], transition scenarios are explorative (“what can happen”) and normative (“what should happen”). A normative approach is based on subjectivity, expressing preferences, and adding a positive or negative implication to a scenario; whereas, an explorative approach needs to be as objective as possible to map a possibility space and inform decisions of the present state. A transition process departs from current persistent problems, and it is therefore necessary to explore how these barriers to transformative change can be overcome and how they can subsequently orient short-term projects and activities towards a more sustainable future [19,35,54]. Moreover, a transition scenario needs to explore the drivers of change that already exist in society and that will be ongoing in the future to determine how they can be influenced or anticipated in guiding future sustainability [32,33]. Also, transition scenarios serve as process functions, as they are embedded in the transition management process [32,33], while general scenarios emphasize content as outputs of strategic planning [53,55]. As mentioned above, the transition approach presupposes that short-term actions should be carried out in the light of long-term aspirations of sustainability in transition scenarios. However, project practitioners frequently face problems and influences that need to be dealt with in the short term. To prevent experiencing problems with what seem to be promising or optimal choices in the short-term perspective, the development process is important for linking previously unknown people in networks by challenging mental models and mindsets, learning to recognize and anticipate patterns of structural change, and creating a foundation for future sustainability. This function aligns with TRM by emphasizing the importance of providing a common foundation among actors for sharing perspectives, specific knowledge, and new ideas.

4.1.2. Differences Between Envisioning in a Transition Study and PSS Development

Regarding the PSS development project, the aim of developing a vision is not to simultaneously focus on different potential paths as it is in transition management, but to plan specific PSS development [6]. Moreover, while for transition management the typical central actor is the policymaker, in this study the PSS development process is seen from a company perspective. In other words, transition scenario-based roadmapping is seen here as a potential strategic planning technique for companies (and partners) to orient the projects and activities for the implementation of PSS. Additionally, the visions developed in the PSS development project are different from the perspective of a transition study. PSS ideas or concepts represent the goal for stakeholders to achieve [6,15]. These visions are mainly used to communicate the PSS concept among stakeholders within the company and outside actors (e.g., project partners, customers, policymakers, and local authorities).

4.1.3. Differences Between the Focus of Strategic Planning in TRM and PSS Development

The distinctive characteristic of PSS strategic planning is that it takes account of the social and technological dimensions. PSS consists of a complex interaction between product, technologies, and service (technical dimension) but also value network, regulation, and culture, which support the implementation, diffusion, and fulfillment of specific needs (social dimension) [2,4–6]. The implementation of PSS can therefore be regarded as a new configuration of a socio-technical system. Most TRMs focus on technological innovation to fulfill market demands and develop a robust corporate strategy that will ensure a company's competitiveness in a dynamic business environment [38,56]. However, PSS is a specific type of innovation for fulfilling a specific customer need while reducing environmental impacts and improving social well-being [1,5]. PSS requires a shift in conventional customers' habits, companies' corporate mindsets and organization, and regulative frameworks [2,4–6]. The actors involved in the PSS development project should thus focus not only on the solution (the PSS development) but also on the technical, socio-cultural, institutional, and organizational contextual conditions that might favor or hinder the societal embedding process [15].

Based on the above comparative analysis, the suggested approach identified six different criteria to be fulfilled, as shown in Table 1.

Table 1. Derived criteria required for the proposed method.

Criteria	Derived From
1. The proposed method should be built on both explorative and normative approaches to describe the transition scenarios that connect the persistent problems of the current system to the future vision of a sustainable system to orient the short-term PSS development activities towards long-term sustainability visions.	Differences between general scenarios and transition scenarios (Section 4.1.1)
2. The proposed method should arrange a process that enables participants to create a common understanding and a shared vision rather than developing the roadmap itself.	Differences between envisioning the transition study and PSS development (Section 4.1.2)
3. As stakeholders related to the development and implementation of PSS, the participants should be involved in the process alongside the company designing the solution (and the network should be updated as necessary).	
4. The proposed method should focus on a specific strategy of the PSS development and should not simultaneously focus on broader potential paths for developed visions to communicate the PSS concept to all stakeholders.	
5. The transition scenarios developed using the proposed method should include a narrative of PSS ideas or concepts as well as a sketch of the journey toward the PSS vision.	
6. The roadmap format in the proposed method should articulate the interplay among the multi-dimensions of PSS, i.e., socio-cultural, institutional, organizational, and technological aspects.	Differences between the focus of strategic planning in TRM and PSS development (Section 4.1.3)

4.2. Overall of the Developed Method

This study develops a transition scenario-based roadmapping method (TSRM), supporting the strategic planning of PSS development, based on the criteria identified in the previous section. The process of TSRM is embedded in the strategic and tactical activities levels in a transition management framework. This method should be implemented at the early stage of PSS development process before the general PSS design process (requirement management, concept development and evaluation, design embodiment and evaluation, detailed design, and testing). The proposed method comprises three steps. Step 1 is the preliminary activity of roadmapping that builds a relevant stakeholder network for PSS development. Step 2 identifies persistent problems in the target system and develops a transition scenario to realize a shared vision through the implementation and diffusion of PSS. Steps 1 and 2 correspond to the strategic activities level in the transition management framework. Step 3 develops specific action plans for the vision of the PSS development project graphically visualized in a roadmap format based on the scenarios described in the first phase. This step corresponds to the tactical activities level in the transition management framework. More detailed PSS development activities will continue based on the developed PSS development roadmap. Figure 3 shows the overall process of the proposed method.

4.3. Detailed Roadmapping Procedures

4.3.1. Step 1: Formulating the Transition Arena

The first step of the strategic planning of PSS is to identify and invite actors directly or indirectly linked with the PSS development to establish and develop a proper socio-economic network. This process is essential to protect, support, and foster innovation development [6,19]. A key element is the network of stakeholders that produce and deliver the solution to customers. Therefore, network building is a crucial activity for the PSS development companies [57]. Moreover, this step should focus on the actors not only directly linked to the PSS (partners, suppliers, customers, etc.) but that also provide support for the social embedding of solutions (e.g., research centers, governmental institutions, NGOs, and special interest groups) [15].

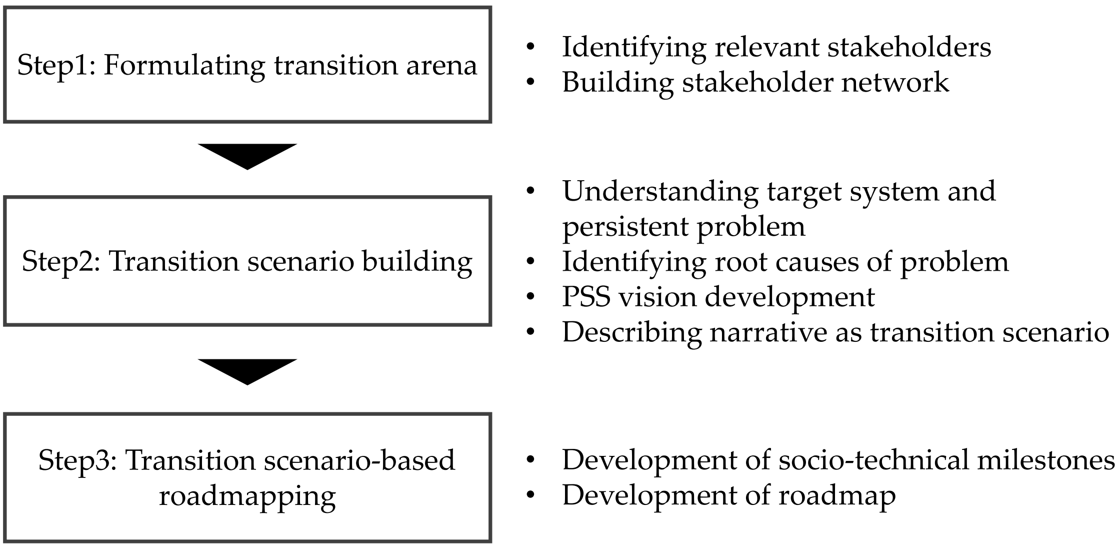

Figure 3. Overall process of the product–service systems (PSS) strategic planning method.

4.3.2. Step 2: Transition Scenario Building

Step 2 involves developing transition scenarios to promote the structural change process of PSS for realizing future sustainable systems. In conducting this process, it should be taken into account that the actors in such processes are experts in their fields but not necessarily experts in creativity and design methodologies [58]. Thus, this method adopts some practical tools to implement the activities in Step 2. This step consists of the following four activities:

Identify the target system, where the new solution should be implemented, and outline the set of causes that make the system unsustainable. The target system depends on the PSS development project's first goal. In this activity, stakeholders should exchange their knowledge and ideas through dialogue to share information and perspectives about the current condition of the target system. Nevertheless, not all actors are experts who can express their knowledge and ideas clearly, or who possess specific skills to share with others. Therefore, this step introduces Lego serious play (LSP), a toolkit for actors to express their perspectives and knowledge related to the set theme through hands-on modeling [59,60]. The LSP methodology contributes to generate shared common knowledge by storytelling of each constructed model for other participants and defining relationships among them. Then, develop a list of the causes of persistent problems that make the target system unsustainable based on the results of the LSP workshop. An example of LSP work that represents a present condition in agriculture is shown in Figure 4.

Structure the list of causes extracted in the previous activity to analyze the structure of the problem. In activity 2, this study adopted a fault tree analysis (FTA) [61], a widespread tool for analyzing and formally visualizing the target system's problems to formally structure the list of causes. To simplify the analysis for implementing this activity, this study used three nodes to structure the fault tree (Figure 5). The event node, depicted as a rectangle, indicates the state of the system that will be deconstructed to its component causes. The root cause nodes, depicted as ellipses, indicate that a cause is identified as an underlying cause that leads to the top event in this analysis. The OR gate is set when an output event occurs or at least one of the input events occurs. This result clarifies the root causes and the focus of the PSS development project to be addressed.

Develop a sustainable future vision of the PSS (the solution and the target system of its implementation). Here, participants use a normative approach (backcasting) to envision a new state of PSS that is not merely an extension of the present society in terms of socio-cultural, institutional, organizational, and technological aspects. These aspects need to be systematically and simultaneously considered in the strategic planning of the PSS implementation and diffusion [15]. LSP is also implemented to this activity to foster discussion among stakeholders.

Describe narratives as a transition scenario from the present state to the future vision state. The narratives include the PSS idea or concept and a sketch of a journey to the PSS vision.

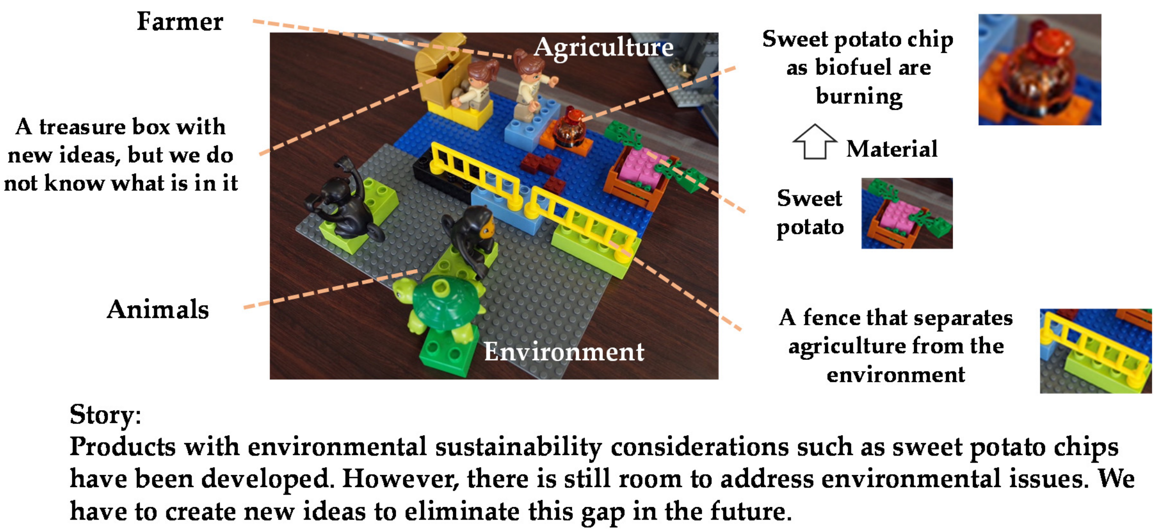

Figure 4. An example of LSP work that represents present conditions in agriculture.

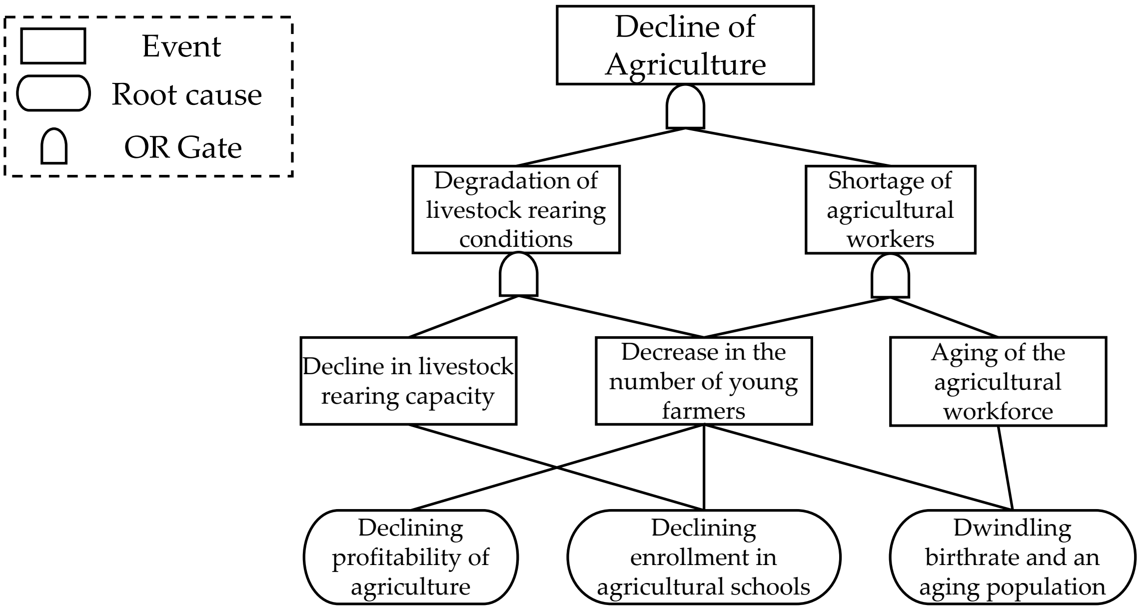

Figure 5. General structure of the fault tree in this study with an agriculture case example.

4.3.3. Step 3: Transition Scenario-Based Roadmapping

In this step, the transition scenarios developed in the previous phase are translated into a roadmap for PSS development. This step forecasts and visualizes a more concrete strategy that stakeholders serve by linking short-term operational planning to the long-term vision (explorative approach). The format of the roadmap is customized as shown in Figure 6. The suggested roadmap consists of four layers (socio-culture/institution/organization/technology) on the vertical axis and a timeline on the horizontal axis, based on one of the roadmap types identified in [38]. The general components of PSS in TRM—product, service, and technology—correspond to the technology layer. The contents described in the layers are different between the socio-culture layer and the other three layers. In the socio-culture layer as a top layer, milestones of the PSS development are described, whereas the institution/organization/technology layers describe the action plans of the stakeholders for PSS development. This difference is because the passive nature of socio-cultural situations is gradually fostered under the influence of institutional/organizational/technological actions. Moreover, the final aim of the PSS development is to redesign the patterns of production and consumption ("lifestyles") to make them more sustainable. Cultural shifts in provider, customer, and support networks are vital successful causes for PSS development [5,7]. In other words, the newly formed socio-culture can serve as the driver that fosters the implementation of other institutional, organizational, or technological activities. This step comprises the following three activities:

1. Develop socio-cultural milestones that are pursued intermediately through PSS development and implementation.
2. Identify the main actors responsible for implementing the action plans in the institution/organization/technology layers, and actors individually develop roadmaps for each layer in a parallel manner.
3. Analyze interdependency among action plans in each layer and complete the roadmapping. If this analysis identifies new action plans to be implemented, they will be added to the roadmap as appropriate.

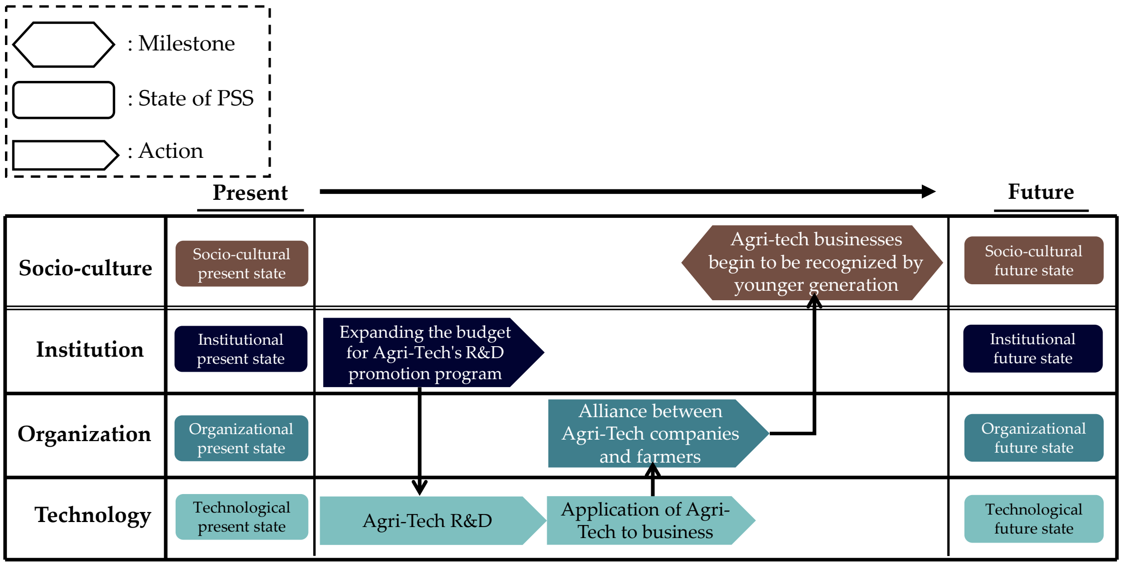

Figure 6. The customized roadmap format in this study with an agriculture case example.

5. Application

5.1. Background of the Case Study

To illustrate the applicability of the proposed approach, the TSRM was applied to a PSS development project for solving wildlife damage in Akiruno City of Tokyo. Agricultural damage from wildlife, such as wild boars, is spreading in the suburban area. As a countermeasure against this issue, the local authority is trying to control the damage through wide-area observation by introducing fixed-point cameras. However, effective measures have not been taken due to a lack of human resources and a deficiency of efficient control systems and organizations. Additionally, wildlife has started to appear around the city, which is expected to cause serious damage to the residents. On the other hand, Akiruno City has been implementing initiatives such as the establishment of a biodiversity conservation strategy to protect the abundant natural resources in the surrounding area. Therefore, measures are required to realize a sustainable city that ensures the safety and security of its residents while preserving the surrounding natural environment. The city needs systemic change that not only develops technologies but also transforms the lifestyle of residents, as well as the institutional framework related to wildlife protection. With this background, a project was launched to develop a PSS to control wildlife damage through industry–government–academia collaboration.

5.2. Step 1: Formulating the Transition Arena

First, this step identified the stakeholders related to the wildlife damage problem and formulated the transition arena (stakeholder network) in this project. Since this project aims to systemically transform the city, it was necessary to involve not only PSS developers but also actors who have specific knowledge of the city's administration, agriculture, and surrounding environment. As a result, the transition arena consisted of six representatives from (1) the policy planning division, which is responsible for the city's administration, (2) the agriculture and forestry division, which manages local agriculture, (3) the forest ranger, who conducts surveys of the surrounding environment and ecosystems, (4) the university that the authors of this paper belong to, (5) the company providing wildlife damage research and management services, and (6) the industrial technology research institution, which provides technical and financial support for the project.

5.3. Step 2: Development of Transition Scenario

5.3.1. Activity 1: Understanding the Target System and Persistent Problem

To define the starting point of the transition scenario, step 2 started by identifying the causes of difficulties in measuring the extent of the wildlife damage based on knowledge sharing among the stakeholders. In this case study, Akiruno City was set as the target system because the main purpose of this project is to resolve the wildlife damage occurring in this city. The LSP was held under two themes: (1) wildlife damage in Akiruno City and (2) difficulty implementing countermeasures to curb wildlife damage. Two models were created for each participant, and 10 models were created and shared. Figure 7 shows an example of the LSP model, which shows that wildlife has invaded the human living areas and are destroying crops. The red blocks represent traps installed by local residents, and the human block is placed inside the red blocks to show that the crops are protected. Consequently, 29 causes of wildlife damage were extracted by analyzing the results of the LSP and discussions based on it. The causes include the current state of wildlife damage, such as animal invasion into the human living areas, and those led by social problems, such as aging and population decline.

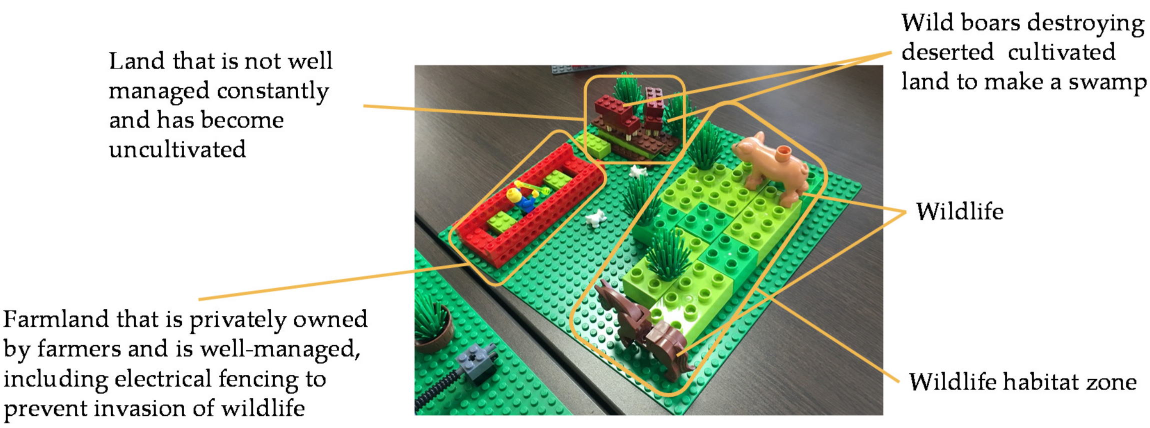

Figure 7. Example of the Lego serious play (LSP) model created using blocks.

5.3.2. Activity 2: Identifying the Root Cause of the Problems

Based on the discussion in activity 1, activity 2 structured the causal relationships between the causes of the wildlife damage to identify the root causes of the target problem. Figure 8 shows the structured results. In the problem analysis, the top event is set as difficulties in preventing and managing wild damage. The root causes of failing to deter wildlife damage were identified as “few merits for managing the buffer zone,” “measures rely on citizens’ initiative and positiveness,” “measures for wild damage are not approved as work,” “legal restrictions,” and “any efficient management system in the city.” Although “low birthrate and aging population” and “global warming” were also identified as causes, they are excluded from the focus of this project because they are wide-scale phenomena that require global and national efforts.

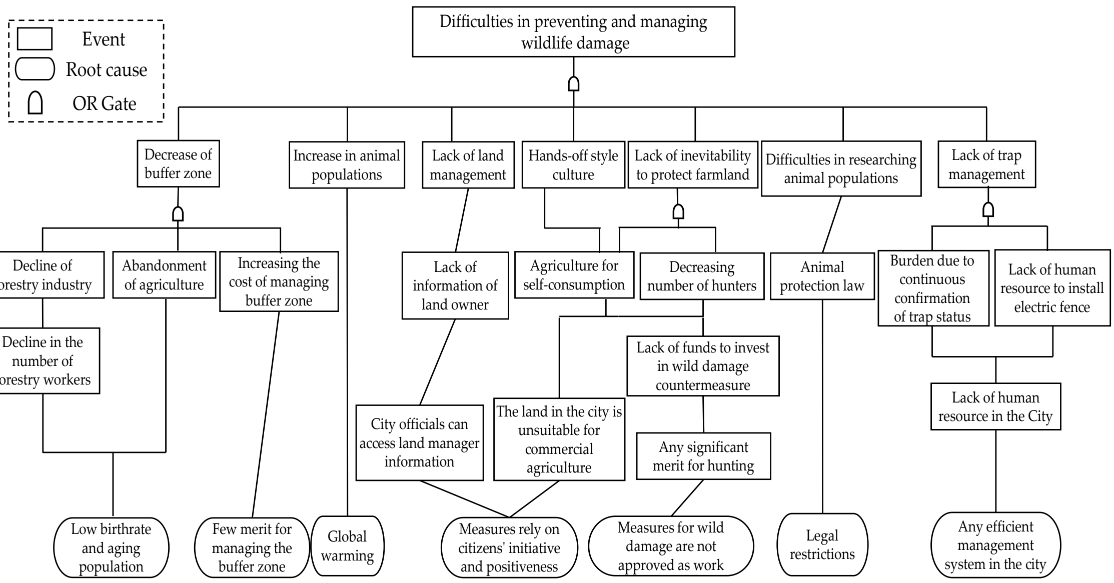

Figure 8. The structured fault tree of the wildlife damage problem in Akiruno City.

Owing to the decline of the forestry industry, the abandonment of farmland, and the low number of full-time farmers in the city because agriculture is mainly for home consumption, the increase in buffer zones is affected by the root causes. Furthermore, the administrative costs of the buffer zone are high, and there is no clear benefit to manage this zone. Electric fences were provided to residents as a countermeasure for wildlife damage. However, the residents failed to perform the required continuous maintenance, which prevented them from realizing the full capacity of the countermeasure. In addition, the lack of a dedicated animal damage control department and an efficient animal damage control system in the local government are root causes for the failure to function countermeasure adequately. Regarding institutional perspectives, the city has no authority to access information held by the state, which makes it difficult to identify and manage landowners. Moreover, the current legal restrictions under animal protection law make it difficult to know the exact number of animals in the surrounding environment.

5.3.3. Activity 3: PSS Vision Development

A PSS vision—a future system that has resolved the root causes identified in the previous activity—was developed through dialog based on the LSP in the same way as activity 1. Specifically, this project envisioned the city in 2040 (20 years later) and anticipated the socio-cultural, institutional, organizational, and technological states of that future without the constraints (Figure 9). As a socio-cultural vision, project members set the goal of fostering a cultural value that enables residents to coexist with wildlife by raising awareness of animal damage control measures. The institutional vision included (1) indirect measures against wildlife damage by inviting tourists to participate in nature classes and second home experience in the buffer zone, (2) the establishment of a dedicated financial resource system for wildlife damage prevention, (3) a clear division of residential and non-residential areas, and (4) the establishment of a circular system to utilize captured wildlife. Accordingly, the establishment of a department dedicated to wildlife damage countermeasures and an environmental symbiosis division to work on ways to coexist with the natural environment were developed as part of the organizational vision. Regarding the technological aspects, an efficient management system dedicated to wildlife damage control was developed and the agricultural technology business was diffused in the city.

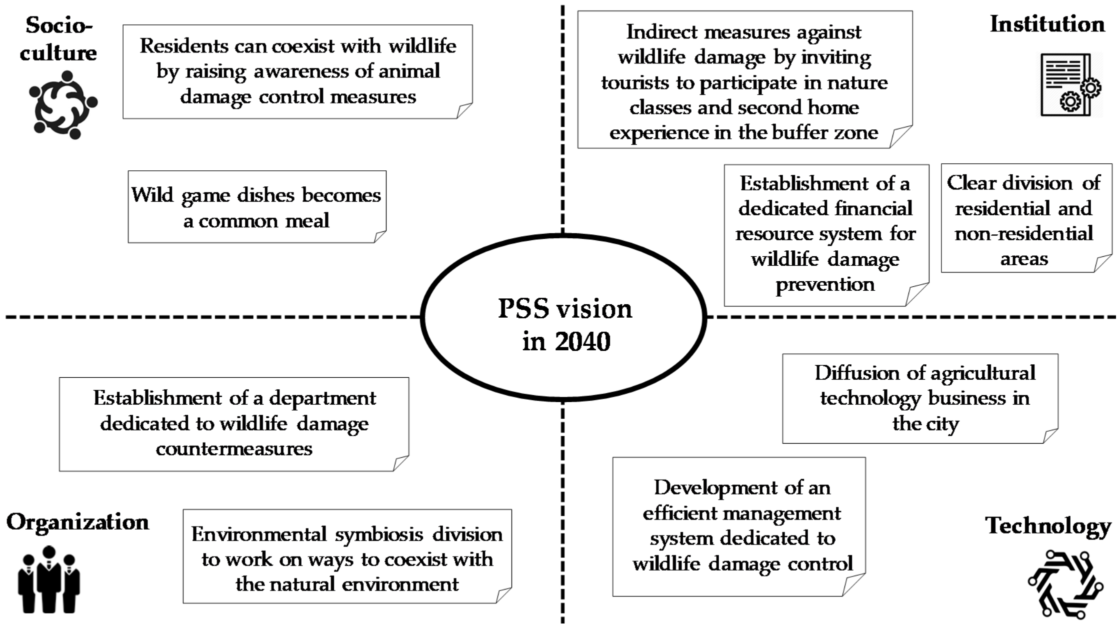

Figure 9. The developed PSS vision in 2040.

5.3.4. Activity 4: Describing Narrative as a Transition Scenario

This step describes the transition scenario from the present state to the developed future vision state. The transition scenario was described as bellow.

The development and introduction of a system that enables observations of wildlife in the surrounding environment of Akiruno City will foster residents' understanding of the surrounding ecosystem. Subsequently, appropriate measures will be taken by establishing methods to utilize the data accumulated by the system by expanding the scope of observation. As a result, the total damage caused by wildlife will be reduced by about 20%. Furthermore, the data collected by the ecosystem monitoring system will be applied to ecosystem management and local nature education. This will lead to the establishment and diffusion of a cyclical system, where hunted animals are processed into game cuisine and local production is eliminated. Ultimately, an information platform will be built to help the residents of Akiruno City live in harmony with nature, plants, and wildlife.

5.4. Step 3: Roadmapping Based on the Transition Scenario

To plan a specific strategy to drive the day-to-day activities based on the described transition scenario, the second phase developed a roadmap to guide the PSS development project with a target period of 2019—2024 (possible future). The following sections detail the outcome.

5.4.1. Activity 1: Development of Socio-Technical Milestones

The first activity in step 3 developed a refined short-term vision for 2024 and formulated socio-cultural milestones to realize the short-term vision. Table 2 shows the short-term vision for each aspect (socio-cultural future state (S-CF)/institutional future state (IF)/organizational future state

(OF)/technological future state (TF)) in the five-year period. In light of the established socio-cultural vision, the city is currently implementing a voluntary nature experience initiative and raising the residents' interest in surrounding nature. The socio-cultural milestones (S-CMs) are thus formulated in order as (1) improving citizens' understanding of wild animal damage (S-CM1), (2) improving citizens' understanding of the surrounding nature (S-CM2), (3) considering ways to co-habit with surrounding nature (S-CM3), (4) penetrating local production for the local consumption of hunting animals (S-CM4), and (5) organizing the buffer zone for effective use (S-CM5).

Table 2. Elements of the developed short-term vision toward 2024 for each (socio-cultural, institutional, organizational, technological) aspect.

Element	Component	Element	Component
S-CF1	Develop an understanding of animals/environment through elementary and junior high school nature experience learning	OF1	Establishment of natural symbiosis division
S-CF2	Research the ecosystem around the city	OF2	Establishment of wildlife symbiosis team
S-CF3	Establish utilization method after hunting	OF3	Measures and organization that unite the country, the capital, and the municipalities
S-CF4	Establish knowledge of biodiversity and surrounding environment	OF4	Collaboration with residents
S-CF5	Clarify protection airspace and buffer zone	OF5	Maintenance promotion of hunting association
IF1	Expand forest environmental tax utilization measure, the target of utilization	OF6	Professional business operator responsible for wildlife harm measures
IF2	Expand subsidies from the national government for measures against animal harm	OF7	Large-scale business model dealing with a game dish
IF3	Establish the national game qualification system for game dish chefs	TF1	Countermeasures by planting Japanese narcissus
IF4	Establish a safe and secure game dish	TF2	Wide area can be identified with one image scan
IF5	Establish a natural volunteer training system	TF3	A system that can grasp the position information of wildlife
IF6	Forest management	TF4	Alarm notification system for wildlife crossing the buffer zone
IF7	Year-round hands-on education in a natural environment	TF5	Completion of AI technology for individually distinguishing wildlife

5.4.2. Activity 2: Development of PSS Roadmap

Based on the above envisioning activity, this project developed a PSS development roadmap toward realizing a short-term vision and S-CMs. Figure 10 shows the developed roadmap used in this case study. To derive the activities to carry out at each layer, this step first analyzed the present state of each aspect (socio-cultural present state (S-CP)/institutional present state (IP)/organizational present state (OP)/technological present state (TP)) in light of the short-term vision and sets them as the starting point of the roadmap (Table 3). Next, the activities to be implemented for each layer in this project are identified in a parallel manner by assigning main actors to each layer. In this project, the policy planning division was assigned to the institution layer, the agriculture and forestry division and forest rangers were assigned to the organization layer, and the service provider company and industrial technology research institution were in charge of the technology layer. Table 4 lists the identified activities in each layer.

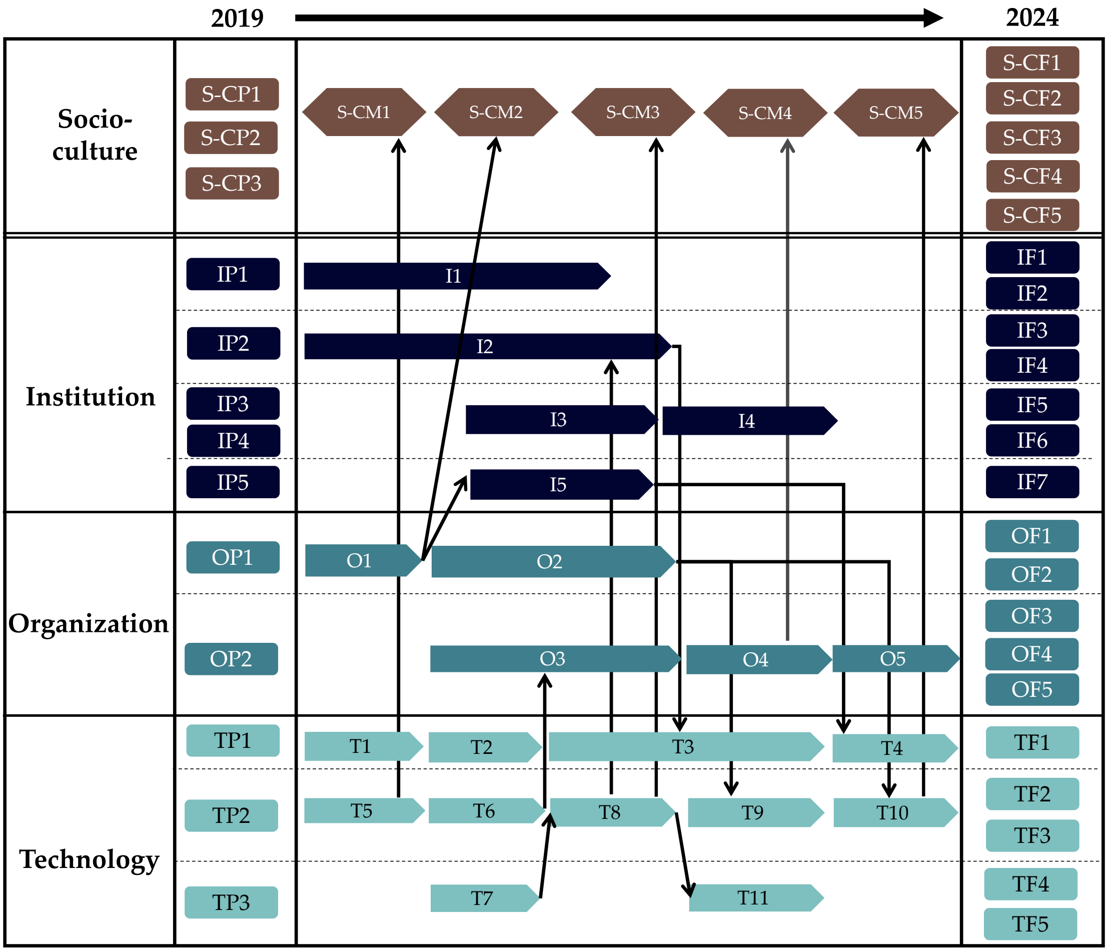

Figure 10. The PSS roadmap developed in the case study.

Table 3. Elements of the present state of the city for each (socio-cultural, institutional, organizational, technological) aspect.

Elements	Component	Element	Component
S-CP1	Voluntary experiential learning	IP5	Nature experience learning initiatives
S-CP2	Increase game dishes in restaurants	OP1	Work across organizational sections
S-CP3	Increased interest in surrounding nature	OP2	An organization that implements agricultural harm in cooperation with citizens
IP1	Start funding measures such as forest environmental tax	TP1	Plant fences are already implemented
IP2	Deer meat processing factory	TP2	Wildlife observation system has not been introduced in Akiruno City
IP3	Wildlife hunting association	TP3	Wildlife distinguishing system has not been introduced in Akiruno City
IP4	Mechanism for citizens to manage box traps	-	-

Table 4. The elements of the developed roadmap.

Element	Component	Subsequent Elements	Element	Component	Subsequent Elements
I1	Promote the use of forest environmental tax	-	T1	Secure farmland for Japanese narcissus	T2
I2	Consider safe and secure provision method of game dishes	T3	T2	Grow Japanese narcissus	T3
I3	PR of trap lending system and new farming	I4	T3	Establish and manualize growth method	T4
I4	Hold an electric fence installation class	-	T4	Distribute Japanese narcissus	-
I5	Introduce Japanese narcissus into hands-on nature learning	T4	T5	Develop prototype of smart wildlife automatic discrimination system	T6
O1	Policy decision on how to interact with wildlife	S-CM2, I5	T6	Expand target wildlife species	T8, O3
O2	Organizational revision	T9, T10	T7	Demonstrate experiment of trap monitoring system	T8
O3	Consultation on environmental policy and animal damage control within the agency	O4	T8	GIS (Geographic information system) trial	S-CM3, I2, T9, T11
O4	Alliance with game dish operators	O5, S-CM4	T9	Joint development of individual recognition system	T10
O5	Recruit Hunting Association members	-	T10	Develop power-saving GPS	S-CM5
-	-	-	T11	Wildlife ecology observation technology	-

After a separate information-gathering activity for each layer, this step identified the interdependency among the activities and S-CMs and adjusted the order of each activity in the timescale. An example of the roadmap development process is shown below. To improve citizens' understanding of the surrounding nature (S-CM2), a policy decision on how to interact with wildlife (O1) needs to be conducted in advance. Additionally, the implementation of O1 will mitigate implementation barriers to holding an electric fence installation class (I5), reorganization (O2), and promoting these activities toward the achievement of the next milestone. The reorganization (O2) to establish a natural symbiosis division will promote the development of the individual recognition system (T9) and the power-saving small global positioning system (GPS) (T10), which are required to carry out daily operations using the wildlife observation system. Finally, a flow of interrelating activities will contribute to the achievement of S-CM5.

By developing the roadmap, stakeholders shared a common understanding of the importance of mitigating organizational and institutional barriers to the systemic change of the city for reducing wildlife damage by implementing a PSS with a wildlife observation system and other technical activities, such as the continuous development of image analysis techniques and the application of the observation data obtained from the system.

5.5. Evaluation Result

In the roadmapping process, it is not possible to develop a definitive form of the roadmap before it has been completed, even for the experts who drafted it [37,62]. This study thus conducted a questionnaire for project members to evaluate the applicability and validity of the proposed method and to verify the application results. The questionnaire consists of nine items about the application result and the proposed TSRM. The number of respondents for each question item is not constant because the number of project members who participated in each step was different due to personal time constraints. Table 5 summarizes the project members' responses to the questions asked in the evaluation questionnaire. In terms of the applicability of TSRM, all respondents evaluated their understanding of the purpose of each phase and were able to carry out the activities. This result demonstrates the validity of the content of the proposed method. Moreover, all respondents in question 4 realized both explorative and normative thinking through this method, indicating that the identified criteria were satisfied at a certain level. In terms of the application results, four out of five respondents to questions 8 and 9 evaluated that they could derive the PSS concept for wildlife damage control and indicated that the output would foster future project activities. However, no significant value relating to the concreteness and feasibility of the developed roadmap was given by respondents (questions 5 and 6). Furthermore, one respondent reported that the suggested approach does not directly support the resolution of organizational, budgetary, and personnel constraints and does not guarantee the feasibility of generated ideas. The results revealed the need to embody a practical process of implementing activities based on the developed roadmap.

Table 5. Summary of the evaluation results for the proposed method.

Question	Response	Number of Response/Total Respondents
About the proposed TRSM		
The roadmap development proceeded with an understanding of the purpose of each step.	Yes	6/6
	No	-
	Neither	-
This method can create a common understanding of the root causes of wildlife damage.	Yes	4/6
	No	-
	Neither	2/6
This method can clarify the vision of Akiruno City for controlling wildlife damage.	Yes	3/5
	No	1/5
	Neither	1/5
This method can guide explorative/normative thinking.	Yes	6/6
	No	-
	Neither	-
About the application result		
The developed transition scenario-based roadmap is concrete.	Yes	1/4
	No	3/4
	Neither	-
The developed transition scenario-based roadmap is feasible.	Yes	1/4
	No	2/4
	Neither	1/4
The role of yourself (or your organization) in this project to control wildlife damage is clarified through the application of this method.	Yes	3/5
	No	1/5
	Neither	1/5
Ideas were derived for products, technologies, and services for the control of wildlife damage in Akiruno City.	Yes	4/5
	No	1/5
	Neither	-
The output is beneficial for your future work in this project.	Yes	4/5
	No	-
	Neither	1/5

6. Discussion and Conclusions

6.1. Implications for PSS Development

This paper proposed a strategic planning method for PSS development and implementation. Specifically, this study incorporated a TRM approach with a transition scenario method adapted from transition management studies. Existing studies that regard PSS as a socio-technical system have analyzed the relationship between the concepts of each system and developed conceptual frameworks for the social embedding of PSS with reference to the findings of transition studies. However, these studies did not provide a method that could be practically implemented by PSS designers and stakeholders. In contrast, this study focused on the design strategic planning process of PSS and developed its practical and referable processes and tools as a first step in supporting design for the social implementation of PSS. This study is significant in that it translates the knowledge on social implementation of PSS addressed by extant studies into a practical form that can be referred by PSS designers. By applying TSRM to an actual PSS development case, the following implications were identified, which are relevant to the PSS development project.

The developed roadmap comprehensively converged the perspectives of each stakeholder participating in the PSS development project. At the beginning of the project, the development of PSS for wildlife damage control was promoted without fully understanding the unique situation of Akiruno City. As a result, there was no common understanding of the essential issues to be solved or the future vision to be achieved. As mentioned in Section 4.1, the suggested approach emphasizes the importance of creating a common understanding of the problem and visions of the target system through the TSRM process rather than creating the output of the roadmap itself. In the PSS development project, the results of the evaluation showed a common understanding among the stakeholders about the underlying causes of wildlife damage and the vision of the city. The developed roadmap can thus serve as a strategic resource and knowledge platform to orient and foster PSS development for Akiruno City's countermeasures for wildlife damage.

Furthermore, the proposed approach enables the development of a design strategy with a medium- to long-term perspective, which has been relatively neglected in conventional PSS design research by introducing the TSRM at the early stage of PSS development. Most extant research that has focused on generating PSS design methodologies lack a long-term perspective for the PSS to treat strategic issues [18]. Likewise, other life cycle phases, such as implementation and monitoring, are not addressed sufficiently [57,63]. In PSS development, which involves various stakeholders in the lifecycle from design to operation, it is necessary to build common knowledge and maintain consensus on the values and functions needed to realize the PSS because of cultural and normative differences among each actors' goal and interests. The proposed method contributes to the development of a PSS that is capable of achieving sustainable values not based on short-term rationality by establishing a strategic plan to orient the innovation through agreement on uncertainties and future potential issues related to PSS.

Moreover, the roadmap as an output of the TSRM can contribute to the gradual change towards the vision of PSS and identify the requirements and functions to be fulfilled. For example, focusing on the action to develop a prototype of a smart wildlife automatic discrimination system (T5), the functions necessary to implement this action can be deployed to allow automatic identification of the observed animal breeds and automatic reporting of observation data. These functions could be derived based on the requirements of the agriculture and forestry division to improve the efficiency of wildlife damage control operations and reduce labor costs. In this way, the proposed method can embody how to design detailed PSS components.

Finally, the proposed method was incorporated with several practical tools to implement the proposed method and facilitate different stakeholders' perspectives and interests. The LSP was applied to express and share with other members the actual situation of damage caused by wildlife, the difficulties of countermeasures against wildlife damage, and ideas for future lifestyles. In using this technique, mutual understanding was supported by mitigating participants' psychological and skill barriers in the roadmapping process and generating active discussions among the participants through formal steps. Furthermore, based on the results of the discussions in the LSP, the FTA was applied to analyze and visualize the causal structure of animal damage. This tool helped to foster the sharing and understanding of the root causes beyond mere discussions by structuring the results formally in the FTA method. This feature took extant PSS roadmapping research a step further by not only suggesting roadmapping processes but also providing a practical guideline to apply TSRM to actual PSS development cases.

6.2. Remaining Issues and Future Works

Despite its meaningful contributions to PSS strategic planning, there are some remaining limitations that future research should address. Based on the results of the evaluation of concreteness and feasibility, the developed roadmap is insufficient as a strategic resource that can be utilized for PSS development because of the lack of formal procedures and follow-up steps in the roadmap development process. Roadmapping in this study was based solely on discussions among the project stakeholders, with no formal procedures for building interdependencies between each layer of the roadmap format or determining the sequence of actions to be implemented. There is still room to polish the proposed method to converge the knowledge of various experts in a systemic and formal way. Several existing studies of TRM have applied analysis grids such as QFD [47], design structure matrix [52], analytic hierarchy process [64], system dynamics [51], and fuzzy cognitive maps [65] to conduct qualitative and quantitative assessments and to formally construct the interdependencies of each layer in a roadmap format. Applying these methods and techniques to this study will enhance the quantitative evaluation of the interdependencies among the elements of each layer and prioritize the implementation activities in the PSS development strategy.

During the roadmapping process, the follow-up stages—continuous updating and adjustment of the roadmap—are important for making the quality of the roadmap more credible and feasible [37,62]. However, the evaluation of the validity and feasibility related to the roadmap result was not satisfied due to the lack of follow-up activities. To address this, it is advisable to implement activities to adjust the roadmap based on feedback from relevant external experts and residents in the city who did not participate in the workshop by inviting open seminars. In addition to the above roadmap development, it is also necessary to establish a consistent methodology for identification of functional requirements and specific PSS concept generation based on the roadmap. It would allow PSS designers and stakeholders to link long-term strategies with short-term design activities in PSS development.

Finally, while this study aims to develop a long-term strategic plan for PSS development toward its implementation, the case study in this paper was conducted using only one linear process. A more concrete and valid PSS strategy design requires the development of process-based roadmapping that feeds back the results into iterative enforcement as the PSS development project progresses. Future work will address the aforementioned remaining issues by improving the methodology and its continuous application to PSS development projects. This further development could gain insights into how the developed roadmap promotes the development and implementation of PSS.

Author Contributions: Conceptualization, Y.M., K.H. and Y.S.; Data curation, Y.M. and K.H.; Formal analysis, Y.M. and K.H.; Investigation, Y.M. and K.H.; Methodology, Y.M.; Project administration, Y.M., K.H. and Y.S.; Resources, Y.M., Y.T. and M.S.; Supervision, Y.S.; Validation, Y.M., K.H. and Y.S.; Visualization, Y.M., K.H. and Y.T.; Writing—original draft, Y.M.; Writing—review & editing, Y.M., Y.T., M.S. and Y.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Japanese Society for the Promotion of Science (JSPS) KAKENHI, grant number 20J12381.

Acknowledgments: The authors appreciate the participation of project members (representatives from policy planning division, agriculture and forestry division, forest ranger, the company providing wildlife damage research and management services, and industrial technology research institution) for its engaged collaboration, opportunity, and cooperation that made this research project happen.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Manzini, E.; Vezzoli, C.A. *Product-Service Systems and Sustainability Opportunities for Sustainable Solutions*; United Nations Environment Programme (UNEP): Paris, France, 2002.
2. Mont, O. Clarifying the concept of product–service system. *J. Clean. Prod.* **2002**, *10*, 237–245. [CrossRef]
3. Manzini, E.; Vezzoli, C. A strategic design approach to develop sustainable product service systems: Examples taken from the 'environmentally friendly innovation' Italian prize. *J. Clean. Prod.* **2003**, *11*, 851–857. [CrossRef]
4. Tukker, A.; Tischner, U. Product-services as a research field: Past, present and future. Reflections from a decade of research. *J. Clean. Prod.* **2006**, *14*, 1552–1556. [CrossRef]

5. Vezzoli, C.; Ceschin, F.; Diehl, J.C.; Kohtala, C. New design challenges to widely implement 'Sustainable Product-Service Systems'. *J. Clean. Prod.* **2015**, *97*, 1–12. [CrossRef]
6. Ceschin, F. Critical factors for implementing and diffusing sustainable product-Service systems: Insights from innovation studies and companies' experiences. *J. Clean. Prod.* **2013**, *45*, 74–88. [CrossRef]
7. Mont, O. Drivers and barriers for shifting towards more service-oriented businesses: Analysis of the PSS field and contributions from Sweden. *J. Sustain. Prod. Des.* **2002**, *2*, 89–103. [CrossRef]
8. Baines, T.S.; Lightfoot, H.W.; Evans, S.; Neely, A.D.; Greenough, R.; Peppard, J.; Roy, R.; Shehab, E.; Braganza, A.; Tiwari, A.; et al. State-of-the-art in product-service systems. *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.* **2007**, *221*, 1543–1552. [CrossRef]
9. Mont, O.; Singhal, P.; Fadeeva, Z. Chemical Management Services in Sweden and Europe: Lessons for the Future. *J. Ind. Ecol.* **2008**, *10*, 279–292. [CrossRef]
10. Sakao, T.; Rönnbäck, A.Ö.; Sandström, G.Ö. Uncovering benefits and risks of integrated product service offerings—Using a case of technology encapsulation. *J. Syst. Sci. Syst. Eng.* **2013**, *22*, 421–439. [CrossRef]
11. Liedtke, C.; Baedeker, C.; Hasselkuß, M.; Rohn, H.; Grinewitschus, V. User-integrated innovation in Sustainable LivingLabs: An experimental infrastructure for researching and developing sustainable product service systems. *J. Clean. Prod.* **2015**, *97*, 106–116. [CrossRef]
12. Kanda, W.; Sakao, T.; Hjelm, O. Components of business concepts for the diffusion of large scaled environmental technology systems. *J. Clean. Prod.* **2016**, *128*, 156–167. [CrossRef]
13. Annarelli, A.; Battistella, C.; Nonino, F. Product service system: A conceptual framework from a systematic review. *J. Clean. Prod.* **2016**, *139*, 1011–1032. [CrossRef]
14. Hermann, R.R.; Kohler, J.; Scheepens, A. Innovation in product and services in the shipping retrofit industry: A case study of ballast water treatment systems. *J. Clean. Prod.* **2015**, *106*, 443–454. [CrossRef]
15. Ceschin, F. How the design of socio-technical experiments can enable radical changes for sustainability. *Int. J. Des.* **2014**, *8*, 1–21.
16. Cook, M. Product service system innovation in the smart city. *Int. J. Entrep. Innov.* **2018**, *19*, 46–55. [CrossRef]
17. Kanda, W.; Matschewsky, J. An exploratory expansion of the concept of product-service systems beyond products and services. *Procedia CIRP* **2018**, *73*, 185–190. [CrossRef]
18. Mitake, Y.; Hiramitsu, K.; Nagayama, A.; Muraoka, N.; Sholihah, M.; Shimomura, Y. A Conceptual Framework of Product-Service Systems Design for Sustainability Transitions. *Proc. Des. Soc. Des. Conf.* **2020**, *1*, 2069–2078. [CrossRef]
19. Loorbach, D. Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. *Governance* **2010**, *23*, 161–183. [CrossRef]
20. Sengers, F.; Wieczorek, A.J.; Raven, R. Experimenting for sustainability transitions: A systematic literature review. *Technol. Forecast. Soc. Chang.* **2019**, *145*, 153–164. [CrossRef]
21. Loorbach, D.; Rotmans, J. Managing Transitions for Sustainable Development. In *Understanding Industrial Transformation*; Springer: Dordrecht, The Netherlands, 2006; pp. 187–206. [CrossRef]
22. Rotmans, J.; Loorbach, D. Complexity and Transition Management. *J. Ind. Ecol.* **2009**, *13*, 184–196. [CrossRef]
23. Blessing, L.T.; Chakrabarti, A. *DRM, a Design Research Methodology*; Springer: London, UK, 2009.
24. Tan, A.R. Service-Oriented Product Development Strategies. Ph.D. Thesis, Technical University of Denmark (DTU), Kongens Lyngby, Denmark, 2010.
25. Tan, A.; Matzen, D.; McAloone, T.C.; Evans, S. Strategies for designing and developing services for manufacturing firms. *CIRP J. Manuf. Sci. Technol.* **2010**, *3*, 90–97. [CrossRef]
26. Shimomura, Y.; Nemoto, Y.; Ishii, T.; Nakamura, T. A method for identifying customer orientations and requirements for product–service systems design. *Int. J. Prod. Res.* **2017**, *56*, 2585–2595. [CrossRef]
27. Pezzotta, G.; Sassanelli, C.; Pirola, F.; Sala, R.; Rossi, M.; Fotia, S.; Koutoupes, A.; Terzi, S.; Mourtzis, D. The Product Service System Lean Design Methodology (PSSLDM). *J. Manuf. Technol. Manag.* **2018**, *29*, 1270–1295. [CrossRef]
28. Bertoni, A.; Bertoni, M.; Panarotto, M.; Johansson, C.; Larsson, T.C. Value-driven product service systems development: Methods and industrial applications. *CIRP J. Manuf. Sci. Technol.* **2016**, *15*, 42–55. [CrossRef]
29. Bertoni, M. Multi-Criteria Decision Making for Sustainability and Value Assessment in Early PSS Design. *Sustainability* **2019**, *11*, 1952. [CrossRef]
30. Kemp, R.; Loorbach, D.; Rotmans, J. Transition management as a model for managing processes of co-evolution towards sustainable development. *Int. J. Sustain. Dev. World Ecol.* **2007**, *14*, 78–91. [CrossRef]

31. Gaziulusoy, A.I.; Ryan, C. Roles of design in sustainability transitions projects: A case study of Visions and Pathways 2040 project from Australia. *J. Clean. Prod.* **2017**, *162*, 1297–1307. [CrossRef]
32. Sondeijker, S. Imagining Sustainability: Methodological Building Blocks for Transition Scenarios. Ph.D. Thesis, Erasmus University Rotterdam, Rotterdam, The Netherlands, 2009.
33. Sondeijker, S.; Geurts, J.; Rotmans, J.; Tukker, A. Imagining sustainability: The added value of transition scenarios in transition management. *Foresight* **2006**, *8*, 15–30. [CrossRef]
34. Wiek, A.; Binder, C.; Scholz, R.W. Functions of scenarios in transition processes. *Futures* **2006**, *38*, 740–766. [CrossRef]
35. Gaziulusoy, A.I.; Boyle, C.; McDowall, R. System innovation for sustainability: A systemic double-flow scenario method for companies. *J. Clean. Prod.* **2013**, *45*, 104–116. [CrossRef]
36. Kok, K.; Van Vliet, M.; Bärlund, I.; Dubel, A.; Sendzimir, J. Combining participative backcasting and exploratory scenario development: Experiences from the SCENES project. *Technol. Forecast. Soc. Chang.* **2011**, *78*, 835–851. [CrossRef]
37. Kostoff, R.; Schaller, R. Science and technology roadmaps. *IEEE Trans. Eng. Manag.* **2001**, *48*, 132–143. [CrossRef]
38. Phaal, R.; Farrukh, C.J.; Probert, D.R. Technology roadmapping—A planning framework for evolution and revolution. *Technol. Forecast. Soc. Chang.* **2004**, *71*, 5–26. [CrossRef]
39. Carvalho, M.; Fleury, A.; Lopes, A.P. An overview of the literature on technology roadmapping (TRM): Contributions and trends. *Technol. Forecast. Soc. Chang.* **2013**, *80*, 1418–1437. [CrossRef]
40. De Alcantara, D.P.; Martens, M.L. Technology Roadmapping (TRM): A systematic review of the literature focusing on models. *Technol. Forecast. Soc. Chang.* **2019**, *138*, 127–138. [CrossRef]
41. Lee, S.; Park, Y. Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules. *Technol. Forecast. Soc. Chang.* **2005**, *72*, 567–583. [CrossRef]
42. Garcia, M.L.; Bray, O.H. *Fundamentals of Technology Roadmapping*; Sandia National Labs.: Albuquerque, NM, USA, 1997.
43. Lee, C.; Song, B.; Park, Y. An instrument for scenario-based technology roadmapping: How to assess the impacts of future changes on organisational plans. *Technol. Forecast. Soc. Chang.* **2015**, *90*, 285–301. [CrossRef]
44. Cheng, M.N.; Wong, J.W.; Cheung, C.F.; Leung, K.H. A scenario-based roadmapping method for strategic planning and forecasting: A case study in a testing, inspection and certification company. *Technol. Forecast. Soc. Chang.* **2016**, *111*, 44–62. [CrossRef]
45. Lee, H.; Geum, Y. Development of the scenario-based technology roadmap considering layer heterogeneity: An approach using CIA and AHP. *Technol. Forecast. Soc. Chang.* **2017**, *117*, 12–24. [CrossRef]
46. Hussain, M.; Tapinos, E.; Knight, L. Scenario-driven roadmapping for technology foresight. *Technol. Forecast. Soc. Chang.* **2017**, *124*, 160–177. [CrossRef]
47. An, Y.; Lee, S.; Park, Y. Development of an integrated product–service roadmap with QFD: A case study on mobile communications. *Int. J. Serv. Ind. Manag.* **2008**, *19*, 621–638. [CrossRef]
48. Geum, Y.; Lee, S.; Kang, D.; Park, Y. Technology roadmapping for technology-based product-service integration: A case study. *J. Eng. Technol. Manag.* **2011**, *28*, 128–146. [CrossRef]
49. Geum, Y.; Lee, S.; Kang, D.; Park, Y. The customisation framework for roadmapping product-service integration. *Serv. Bus.* **2011**, *5*, 213–236. [CrossRef]
50. Saritas, O.; Aylen, J. Using scenarios for roadmapping: The case of clean production. *Technol. Forecast. Soc. Chang.* **2010**, *77*, 1061–1075. [CrossRef]
51. Geum, Y.; Lee, S.; Park, Y. Combining technology roadmap and system dynamics simulation to support scenario-planning: A case of car-sharing service. *Comput. Ind. Eng.* **2014**, *71*, 37–49. [CrossRef]
52. Son, H.; Kwon, Y.; Park, S.C.; Lee, S. Using a design structure matrix to support technology roadmapping for product-service systems. *Technol. Anal. Strat. Manag.* **2017**, *30*, 337–350. [CrossRef]
53. Börjeson, L.; Höjer, M.; Dreborg, K.-H.; Ekvall, T.; Finnveden, G. Scenario types and techniques: Towards a user's guide. *Futures* **2006**, *38*, 723–739. [CrossRef]
54. Bosch, S.V.D.; Brezet, J.; Vergragt, P. How to kick off system innovation: A Rotterdam case study of the transition to a fuel cell transport system. *J. Clean. Prod.* **2005**, *13*, 1027–1035. [CrossRef]
55. Fildes, R.; Van Der Heijden, K. Scenarios: The Art of Strategic Conversation. *J. Oper. Res. Soc.* **1998**, *49*, 773. [CrossRef]

56. Vatananan, R.S.; Gerdsri, N. The Current State of Technology Roadmapping (TRM) Research and Practice. *Int. J. Innov. Technol. Manag.* **2012**, *9*, 1250032. [CrossRef]
57. Cavalieri, S.; Pezzotta, G. Product-Service Systems Engineering: State of the art and research challenges. *Comput. Ind.* **2012**, *63*, 278–288. [CrossRef]
58. Sanders, E.B.-N.; Stappers, P.J. Co-creation and the new landscapes of design. *CoDesign* **2008**, *4*, 5–18. [CrossRef]
59. Roos, J.; Victor, B. Towards a new model of strategy-making as serious play. *Eur. Manag. J.* **1999**, *17*, 348–355. [CrossRef]
60. Kristiansen, P.; Rasmussen, R. *Building A Better Business Using the Lego Serious Play Method*; John Wiley & Sons: Hoboken, NJ, USA, 2014; ISBN 978-1-118-93137-0.
61. Lee, W.S.; Grosh, D.L.; Tillman, F.A.; Lie, C.H. Fault Tree Analysis, Methods, and Applications A Review. *IEEE Trans. Reliab.* **1985**, *34*, 194–203. [CrossRef]
62. Lee, J.H.; Phaal, R.; Lee, S.-H. An integrated service-device-technology roadmap for smart city development. *Technol. Forecast. Soc. Chang.* **2013**, *80*, 286–306. [CrossRef]
63. Vasantha, G.V.A.; Roy, R.; Lelah, A.; Brissaud, D. A review of product–service systems design methodologies. *J. Eng. Des.* **2012**, *23*, 635–659. [CrossRef]
64. Gerdsri, N.; Kocaoglu, D.F. Applying the Analytic Hierarchy Process (AHP) to build a strategic framework for technology roadmapping. *Math. Comput. Model.* **2007**, *46*, 1071–1080. [CrossRef]
65. Amer, M.; Daim, T.U.; Jetter, A. Technology roadmap through fuzzy cognitive map-based scenarios: The case of wind energy sector of a developing country. *Technol. Anal. Strat. Manag.* **2015**, *28*, 131–155. [CrossRef]