Title	脱炭素社会に向けたサービス化のためのロードマッピング手法の提案
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Citation	
Issue Date	2025-09
Type	Thesis or Dissertation
Text version	ETD
URL	http://hdl.handle.net/10119/20068
Rights	
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ABSTRACT

A XaaS Roadmapping toward a Decarbonization Society

The acceleration of global economic and industrial activities has substantially intensified the climate crisis, necessitating urgent and deep decarbonization efforts. While existing research has primarily concentrated on technological advancements in renewable energy and carbon capture as strategies to reduce dependency on fossil fuels, such approaches often overlook the multifaceted nature of achieving a decarbonized society, which requires fostering innovation, collaboration, future-oriented thinking, and changes in awareness and behavior. This dissertation introduces an innovative XaaS (Everything-as-a-Service) roadmapping framework that incorporates Futures Literacy (FL) to support the design of service-oriented systems aligned with decarbonization objectives and consumer well-being. The proposed framework expands the scope of traditional roadmapping by emphasizing ecosystem-wide collaboration and forward-looking perspectives. In contrast to traditional technology or service roadmapping approaches, which typically focus on structured planning within industry-specific boundaries , the XaaS roadmapping framework conceptualizes all value offerings as services and promotes cross-sectoral innovation.

The XaaS framework offers a transformative perspective by reimagining conventional business models into service-based operations. This paradigm shift fosters enhanced flexibility, resource circularity, and organizational adaptability. Grounded in principles of transformative knowledge management , the framework facilitates anticipatory governance , collaborative foresight , and stakeholder co-creation. These capabilities collectively empower organizations to construct dynamic and resilient service roadmaps that can respond to volatile policy landscapes, shifting consumer behaviors, and emergent environmental imperatives, enabling them to make informed decisions.

To evaluate the framework, this study adopted a sequential mixed-methods research design encompassing qualitative and quantitative components. The first phase involved the facilitation of knowledge co-creation workshops with domain experts from the engineering and social infrastructure industries. The workshops progressed through four structured stages: ideation, identification of roadmap components, roadmap drafting, and expert validation. Participants employed FL techniques to develop and prioritize service innovation ideas using criteria such as strategic relevance, desirability, viability, and feasibility. Among the concepts generated, "Carbon Credit Trading-as-a-Service" (CTaaS) was identified as a highly promising initiative due to its potential contributions to environmental sustainability, consumer well-being, and business value.

To overcome knowledge space limitations , topic modeling and patent analysis were employed to extract insights from academic publications (Scopus) and patent data. These analyses informed the construction of a multi-layered roadmap comprising four core dimensions: policy, market, technology, and service. The roadmap was further refined using a digital collaboration platform, Miro , to enable real-time feedback and consensus building among stakeholders, ensuring both practical relevance and strategic coherence over a timeline from 2023 to 2050.

In the second phase, a scenario-based simulation was conducted using System Dynamics (SD) modeling to investigate the long-term impacts of the CTaaS roadmap on CO_2 emissions in Japan. SD was selected for its robust capacity to model complex system behaviors and interdependencies, particularly those related to sustainability transitions and organizational and social change. The simulation incorporated policy incentives, technological maturity, consumer adoption rates, and financial mechanisms. Three distinct scenarios were analyzed, namely optimistic, neutral, and pessimistic , to assess the robustness of the roadmap under conditions of uncertainty. Results demonstrated that the CTaaS roadmap could significantly reduce national carbon emissions by 2040 , especially under supportive policy regimes and high public engagement. The system dynamics model provided a comprehensive view of the interactions among policy, behavior, and technology.

This research contributes to theory by extending the XaaS paradigm beyond its origins in information technology to encompass environmental and socio-economic systems. Methodologically, it offers a novel integration of foresight practices and service innovation tools through the combined application of Futures Literacy, roadmapping, and system modeling (including System Dynamics). Practically, the framework serves as a strategic guide for policymakers, enterprises, and innovation practitioners seeking to align operational models with the Sustainable Development Goals (SDGs) and climate mitigation targets. Additionally, it underscores the importance of cultivating Futures Literacy as a foundational competency for navigating complex and uncertain sustainability challenges.

In conclusion, the synthesis of XaaS and Futures Literacy within a roadmapping methodology offers a powerful mechanism for systemic innovation. This approach enables organizations to co-create actionable service strategies that not only respond to environmental imperatives but also support long-term societal transformation. Future research could explore the applicability of this framework across diverse industries and cultural contexts to facilitate global pathways toward a decarbonized future.

Keywords: XaaS roadmapping, Decarbonization, Service roadmap, Knowledge co-creation workshop, Futures literacy