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RESEARCH PAPER

How to design platform ecosystems by intrapreneurs: Implications from action design research on IoT-based platform

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Abstract

The recent technological evolution of the Internet of Things (IoT) and data sciences has created opportunities for intrapreneurs in non-platform firms to expand their businesses into platform ecosystem-related businesses. However, previous studies have typically focused on cases involving entrepreneurs. This study aims to clarify how intrapreneurs' design for platform ecosystems could be different from that of entrepreneurs. We conducted an action design research (ADR) project in collaboration with a company for 29 months, and designed a platform ecosystem structure based on technological platforms related to radio frequency identifiers (RFID). Our main contribution is the following six-step process that describes how intrapreneurs design platform ecosystems: (1) designing an initial ecosystem structure based on platform ecosystem concepts and certain concepts related to the targeted market; (2) analyzing past business cases; (3) making the ecosystem structure into concrete shape; (4) verifying its validity; (5) elaborating the ecosystem structure; and (6) proposing the designed ecosystem business. Our findings highlight the differences between intrapreneurs' and entrepreneurs' designs of the ecosystem. First, when the design processes are underway, the direction of the design of the ecosystem needs to be flexibly modified to align with the strategy of the firm. Second, evidence for the success of the proposed platform ecosystem is required to reduce uncertainty and clarify the legitimacy of the proposition. Third, the structure of a platform ecosystem designed by intrapreneurs becomes a style that supports the existing businesses and networks of the firm.

Keywords Platform ecosystem · Ecosystem design · Digital servitization · Radio frequency identification (RFID) · Internet of Things (IoT) · Intrapreneur

JEL Classification M15

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Introduction

In recent years, research on ecosystems has proliferated in the field of business management. Ecosystems are defined as "communities of interdependent yet hierarchically independent heterogeneous participants, who collectively generate an ecosystem value proposition" (Thomas & Ritala, 2022: p. 515). This study focuses on the "platform ecosystem," which is a style of ecosystems that is formed by the platform, various outside complementors, and consumers purchasing platforms and complementary goods (Gawer, 2014; Thomas et al., 2014). Platform ecosystems mainly offer benefits from the following two perspectives: the potential to exponentially expand the platform-based market through indirect network mechanisms (Clements & Ohashi, 2005; McIntyre & Srinivasan, 2017; Zhu & Iansiti, 2012) and potential to further the development of innovation by outside firms (called complementors) based on the technological commonality of the platform (Gawer, 2014). Thus, developing platforms based on core technologies and creating platform ecosystems is a potential incentive for firms to extend their businesses.

Platform ecosystems mainly emerge in the IT industry (e.g., Cennamo & Santaló, 2019; Rietveld et al., 2019). The provision of digital services based on IT platforms is typically more low-cost for firms than physical products/services (Vendrell-Herrero et al., 2017). Additionally, IT platforms can create a space where participants of the platform can interact and transact with each other (Inoue et al., 2019). These natures and advantages of IT platforms could contribute to the generation of ecosystems. Hence, the IT industry is particularly impacted by platform ecosystems. The recent evolution of sensors, the Internet of Things (IoT), data sciences, and other related areas can aid non-platform firms to expand their businesses into platform-related businesses (Paschou et al., 2020). Thus, the concept of a platform ecosystem can become more significant for future intrapreneurs and non-platform-based firms.

However, the business models of platform ecosystems can be complex. When intrapreneurs consider their business models, they need to address the following questions: Who are the appropriate complementors and consumers? What value does the platform offer to these parties? Are these parties already present in the acquired customers? How does a firm create a multi-sided market? How does a firm design a system for complementors to propose innovative ideas on the platform? Given that the answers to these questions are probably interrelated, designing a platform ecosystem structure is highly complex. Moreover, because the concept of a platform ecosystem emphasizes the benefits of interaction among actors and orchestrated value propositions (Adner, 2017; Thomas & Ritala, 2022), intrapreneurs must resolve this difficulty to realize such an ecosystem.

While addressing these challenges, intrapreneurs could face specific restrictions that are different from those faced by entrepreneurs. When intrapreneurs take high-risk decisions to start a new business and seek innovations, they utilize their firms' resources, work under the firms' cultures and rules, and require organizational consensus (Camelo-Ordaz et al., 2012; Davis, 1999; Honig, 2001). Unlike entrepreneurs, intrapreneurs share the risks with the firms they work in (Martiarena, 2013). Therefore, the performance ability and potential of intrapreneurs is largely dependent on the perspectives of the firms' decision makers, like top management teams, and the presence or absence of their support (Menzel et al., 2007). The decision-makers could restrain the intrapreneurs' innovative initiatives through many factors such as operational routines, strategic complexity, organizational inertia, or the established power and authority of a dominant internal or external coalition (Brenk et al., 2019). Additionally, the decision-makers of established firms hesitate to adopt complex and innovative business models (Brenk et al., 2019). Therefore, intrapreneurs' business creation should not be the same as that of entrepreneurs. Similarly, the necessary processes for designing platform ecosystems could differ between intrapreneurs and entrepreneurs. Thus, intrapreneurs face the following difficulties in designing platform ecosystem businesses: designing the structure of platform ecosystem-styled businesses under organizational restrictions and proposing persuasive plans to firms' decision makers. These challenges do not largely concern entrepreneurs, but intrapreneurs must address and resolve them. Thus, this study focuses on how intrapreneurs can start such businesses in established non-platform firms.

Although some studies have focused on the design processes of platform ecosystems at the initial stage (Daiberl et al., 2019; Fürstenau et al., 2019; Hein et al., 2019; Otto & Jarke, 2019; Shi et al., 2021), they have emphasized situations in which entrepreneurs or alliances establish platform businesses, and the results and implications are fragmented (Shi et al., 2021). Therefore, previous studies have ignored intrapreneurs' perspective and insufficiently addressed the specific characteristics and restrictions discussed above. Against this backdrop, this study focuses on intrapreneurs trying to propose businesses that are related to platform ecosystems and designing their business models. Thus, we have identified a crucial research gap and propose the following research question:

> RQ: (A) If intrapreneurs want to introduce platform ecosystem businesses in established non-platform firms, what processes should they follow? (B) What capabilities do they require to accomplish the process? How do these differ from those of entrepreneurs? (C) How does the nature of the platform ecosystems designed by intrapreneurs differ from those by entrepreneurs?

To explore these research questions, we conducted an action design research (ADR; Sein et al., 2011) project in collaboration with a company that addressed the design of a platform ecosystem based on technological platforms related to radio frequency identifiers (RFIDs). When we speak of designing a "platform ecosystem structure," we indicate developing a strategy, considering the governance model, designing technical architecture, selecting standards, and performing activities required to build a platform ecosystem. After 29 months, we completed the design, summarized the implications of the project, and proposed viable processes for the design of a platform ecosystem structure in established non-platform firms. The ADR project addressed and completed the first two stages among the following four stages proposed by Fürstenau et al. (2019) for the initial development of platform ecosystems: (1) developing strategy and governance models; (2) designing technical architecture and selecting standards; (3) facilitating participation and community building; and (4) engaging with the platform ecosystem and wider environment. Given the restrictions on confidentiality, we show only the publicly available part within the project in this paper.

This study makes three major contributions. First, we illuminate the following six-step process for intrapreneurs designing platform ecosystems: (1) designing an initial ecosystem structure based on platform ecosystem concepts and certain concepts related to the targeted market; (2) analyzing past business cases; (3) making the ecosystem structure into concrete shape; (4) verifying its validity; (5) elaborating the ecosystem structure; and (6) proposing the designed ecosystem business. Second, we identify two necessary capabilities of intrapreneurs to complete the design of platform ecosystems. These capabilities also complement the four capabilities proposed by Shi et al. (2021) for entrepreneurs. These two capabilities of intrapreneurs include the flexibility in securing consistency of the proposition within their firm and ability to acquire appropriate knowledge and information for legitimizing the proposition. Third, we show the structure of platform ecosystems designed by intrapreneurs essentially becomes a style that supports the existing businesses and networks of the respective firms. The traditional form of the platform ecosystem has been majorly adopted across markets and industries (Inoue & Tsujimoto, 2018a). However, because business proposals by intrapreneurs should consider the firms' resources and environment (Camelo-Ordaz et al., 2012), their proposed style of ecosystem be different than that of entrepreneurs. Thus, this study expands the research area related to platform ecosystem design to cover the differences between intrapreneurs and entrepreneurs.

Platform ecosystems

Basic definition

An "ecosystem" has recently been defined as "communities of interdependent yet hierarchically independent heterogeneous participants who collectively generate an ecosystem value proposition" (Thomas & Ritala, 2022: p. 515). Ecosystem-related research is gaining momentum in the field of business management, especially the study of the platform ecosystem concept (Jacobides et al., 2018). Platform ecosystems are sometimes called "platform-based business ecosystems." The following two books on platform ecosystems have garnered significant academic and practical attention. *The Keystone Advantage* by Iansiti and Levien (2004) formulates the concepts related to business ecosystem and explains the core role of platform technologies in the ecosystem. *Platform Leadership* by Gawer and Cusumano (2002) introduces the concept using case studies and emphasizes the ecosystem aspect. Currently, many researchers are exploring platform ecosystem concepts empirically (e.g., Ceccagnoli et al., 2012; Cennamo & Santaló, 2019; Chen et al., 2022) and theoretically (e.g., Jacobides et al., 2018; Rietveld & Schilling, 2021; Thomas & Ritala, 2022).

In terms of defining a platform ecosystem, the formulation of a standardized definition is underway in the management field. A recent study (Thomas & Ritala, 2022) has defined the platform ecosystem as communities of interdependent yet hierarchically independent heterogeneous participants who collectively generate an ecosystem value proposition on the standardized technological platform. Although the ADR project discussed in this study started in 2017, this definition is consistent with the definition assumed in the project.

Platform ecosystems and multi-sided platforms

It is important to understand how a platform ecosystem differs from a "multi-sided platform" (MSP). A multi-sided platform connects multiple groups or sides that mutually seek to access or connect with each other (Ansari et al., 2016). The concept of a platform ecosystem partly shares commonalities with the concept of a multi-sided platform, but there is an obvious difference. The commonality is that the platform plays a role in mediating multiple groups or sides. The multi-sided platform concept emphasizes this aspect, while the platform ecosystem focuses on the degree of technological, productive, and consumptive interdependences between platforms and external actors (Jacobides et al., 2018). Given that the platform ecosystem deals with such interdependencies, researchers tend to focus on the aspects of open innovation between platform owners and external actors (Bogers et al., 2017; Eckhardt et al., 2018). Therefore, some researchers refer to platforms in platform ecosystems as "innovation platforms" (Shi et al., 2021).

The differences between these concepts can be illustrated using the following examples: transaction platforms such as Amazon simply mediate finished products and, by definition, are not included in the range of platform ecosystems (Jacobides et al., 2018); however, they match multi-sided platforms. Hardware platforms, such as video game hardware, can be investigated from the perspective of platform ecosystems because their market has technological interdependency between complementary goods (video game software) and platforms (Inoue, 2021). Thus, these concepts can be regarded as having a complementary relationship, and should be properly used in accordance with the characteristics of the platform and its market. However, gathering consensus about the usage of these concepts seems to be ongoing. Therefore, papers studying the concept of multi-sided platforms often use the term "ecosystem" (e.g., Koch & Siering, 2019; Pousttchi & Gleiss, 2019; Taeuscher, 2019; Wallbach et al., 2019). Additionally, if a study focuses on platforms that are essentially platform ecosystems, such as video game markets or smartphone applications, the term "multi-sided platforms" may be interchangeably used with the "platform ecosystems."

Dynamics in the platform ecosystems and the benefits of forming them

The platform ecosystem mainly comprises the platforms and their owners, and complementary goods and their providers (complementors; Jacobides et al., 2018). It also consists of a platform, a system or architecture, and a collection of supporting complementary assets (Gawer & Cusumano, 2014; Thomas et al., 2014). Complementary asset providers that produce complementary goods for the platform are called complementors (Boudreau & Jeppesen, 2015). In the platform ecosystem, the platform acts as an intermediator among actor groups (Gawer & Cusumano, 2014; Thomas et al., 2014). When it intermediates between two groups, the market is referred to as a two-sided market on the platform (Gawer & Cusumano, 2014). A significant mechanism in a two-sided market is the indirect network effect, which suggests that the benefit of group A (or B) depends on the size of another group B (or A) (Armstrong, 2006; Evans, 2003; Hagiu & Wright, 2015; Rochet & Tirole, 2003, 2006). This effect contributes to the growth of platform-based markets and can give rise to a winner-take-all phenomenon in platform competition (Eisenmann, 2007; Eisenmann et al., 2006; Frank & Cook, 1995). Here, owing to the nature of the indirect network effect, a chicken-and-egg problem also arises (Caillaud & Jullien, 2003). Platform owners must consider solutions to this problem in the introductory stage of platform design. For example, providers of video game hardware typically try to provide killer software on platforms to acquire a large installation base by themselves or by collaborating with strong complementors (Inoue & Tsujimoto, 2018b). However, even if they succeed, their platform ecosystem may decline if they cannot acquire a large scale of complementary goods in the ecosystem (Schilling, 2002). Thus, platform owners need to maintain beneficial ecosystems for complementors and consumers. Continuous generation of innovative complementary goods with sufficient appropriation for complementors (Shi et al., 2021) and appropriate pricing schemes (Inoue et al., 2019), may contribute to achieving the required conditions.

In addition to the indirect network effect, if platforms mediate between actors from the same group, a direct network effect occurs (Gawer, 2014). This effect indicates that the benefits enjoyed by actors are influenced by the size of other actors belonging to the same group and participating on the same platform (Gawer, 2014). This effect is significant if the platform has certain functions that connect actors from the same group and if a larger connection, like an online meeting platform, is valuable to actors (Gawer, 2014). Conversely, if the platform does not define communication within the same group of actors as important components in the value propositions of the platforms, this effect could be weak or nonexistent. For example, the effects on video game platform ecosystems are negligible (Zhu & Iansiti, 2012).

To drive the indirect network effect on ecosystems and utilize the benefits for expanding their platform-based markets, platform owners must accept the diversity across complementors and consumers. If diverse complementors develop goods using the platform technology, the platform owners can receive greater resources of innovation from their platforms (Gawer, 2014). This increased generation of innovative complementary goods satisfies consumers' various needs and improves the value of the platforms (Ceccagnoli et al., 2012). Thus, "innovation management" is a significant aspect of platform ecosystems. The platform provides a common and core technology to all members of the product family, thereby creating a fundamental technological architecture for derivative products (Meyer & Lopez, 1995; Meyer & Seliger, 1998). This type of platform benefits firms as follows: (a) enabling them to efficiently develop different products; (b) making their manufacturing processes more flexible (Robertson & Ulrich, 1998); (c) shortening the lead time for developing new products (Muffatto & Roveda, 2000); (d) improving leverage investments in product design and development (Krishnan & Gupta, 2001); and (e) supporting them in easily designing technologically superior products (Meyer & Lehnerd, 1997).

Innovation management must be considered in conjunction with complementors. The successful innovation management of platform owners alone may not lead to the success of the ecosystem (Inoue & Tsujimoto, 2018a). Innovation in collaboration with complementors increases the strength of the indirect network effect and gives rise a barrier to entry in competitive platforms (Gawer & Cusumano, 2014). Therefore, platform owners must manage the complementary relationship between innovation by complementors and the indirect network effects on platforms (Scholten & Scholten, 2012). Additionally, the relationship between platform owners and complementors can be considered as "open innovation" (Bogers et al., 2017; Eckhardt et al., 2018), which is defined as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries" (Chesbrough & Bogers, 2014: p. 3). Accordingly, platform owners need to provide a vision for the platform, design sufficiently open or modular architecture platforms, and secure mutual benefits with complementors (Gawer & Cusumano, 2014).

Design and initial development of the platform and its ecosystem

Prior research on the design and initial stages of platform ecosystems is still scarce. Shi et al. (2021) observed the platform development processes of a business venture in tele-rehabilitation and identified four capabilities for successful platform ecosystem development: innovation leverage, market exploration, quality control, and appropriation. Hein et al. (2019) analyzed the development of innovative platforms and indicated the significance of the sense-making and bricolage processes. Otto and Jarke (2019) studied alliance-driven data platforms and found that the order of the development phase of the ecosystem was different from that of the general development phase. Fürstenau et al. (2019) investigated a consortium-driven healthcare platform and identified the following three phases in the initial stage of platform development: (1) preformation; (2) formation, setting up an organization, governance structure, and technical architecture; and (3) shifting the focus of actors from internal to external. Daiberl et al. (2019) focused on an open innovation healthcare platform in the medical tech industry cluster and demonstrated the following five design principles of the platform: collaborative onboarding, enforcing responsibilities, demonstrating appreciation, ensuring relevance, and mutual evolution. To conclude, some studies have investigated the initial stages and design of platform ecosystems, but cumulative knowledge is still sparse. Accordingly, further research is needed to understand this aspect.

Synthesis of the platform ecosystem concept

Based on the literature, we summarize the understanding of platform ecosystems that we will use in our study as follows:

(a) The word "platform ecosystem" is defined as: communities of interdependent yet hierarchically independent heterogeneous participants who collectively generate an ecosystem value proposition on a standardized technological platform. In contrast to the multi-sided platform concept, the platform ecosystem is characterized by the technological, productive, and consumptive interdependencies between platforms and outside actors.

(b) Indirect network effects are a major driver of market expansion in platform ecosystems. If the platform has a certain function, such as enabling communication among actors which leads to an increase in platform value, the direct network effect also becomes the driver of the platform ecosystem.

(c) Complementors can generate new value by utilizing platform technologies. This mechanism contributes to innovation initiatives on the platforms and strengthens indirect network effects.

Research methodology and process

We adopted the ADR methodology (Sein et al., 2011) in our study. It deals with the following two challenges: (1) addressing a problem encountered in a specific organizational setting by intervening and evaluating, and (2) constructing and evaluating an artifact that addresses this problem. Following the typical stages and tasks of the ADR (Sein et al., 2011), we conducted an ADR project in collaboration with Fujitsu Frontech Limited to design a platform ecosystem structure.

Case study firm characteristics

Fujitsu Frontech Limited (hereafter called FTEC) is a firm in Japan that belongs to the Fujitsu Group. It deploys various businesses in finance, logistics, and private and public industries. Some of its major competitive products include automatic teller machines, devices in retail stores, point-of-sale systems, handheld terminals, RFID devices and systems, digital signage systems, and other additive services. The firm's consolidated sales in 2019 FYI were 90,941 million JPY, and the number of employees was 3,603 in March 2020.

FTEC conventionally deploys various hardware products as its core business, but the firm is challenged by the decreasing prices of such hardware products in recent years. Therefore, FTEC is attempting to change its business structure from being hardware-oriented to service-oriented, and RFID is one of its major targets. FTEC has traditionally focused on the technological superiority (specifically, high performance and durability) of RFID tags. In recent years, RFID tags have reached technological maturity and technological differentiation has become difficult. Therefore, FTEC (and other competitive RFID firms) must reduce the price of RFID tags and profit from additive solutions and/or services. To address this challenge, FTEC has considered adopting servitization, strategically making platforms based on their own RFID-related technologies, and structuring the platform ecosystem to expand the business scale. Before starting the ADR project, FTEC already completed constructing a digital platform system using RFID. However, the strategy for diffusing the platform has been set aside for future work. The next step was to design an ecosystem structure and develop a strategy for becoming a future platform leader in the RFID service industry.

Research design

The ADR project was formally conducted as a joint research project between the National Institute of Advanced Industrial Science and Technology (AIST) and FTEC. It aimed to complete the design of ecosystems based on the RFID product/technology/platform provided by FTEC. The term of the contract was from November 2017 to March 2020 (29 months). The project was proposed by Practitioner A from FTEC, a manager who understood the firm's situation and problems (described in the Case Study Firm Characteristics section), and sought opportunities to solve them.

Practitioner A's previous entrepreneurial experience, gained from managing his own business, helped them to address the problems faced by FTEC. In July 2017, Practitioner A participated in a research presentation on platform ecosystems by Researcher A (1st author of this paper) from AIST. They considered that the presented platform ecosystem concepts might be suitable for solving FTEC's problems and consequently contacted Researcher A. After several meetings, they decided to start the ADR project as a joint research between AIST and FTEC and drafted a contract accordingly. Hence, this project was initiated by Practitioner A, whose career and characteristics reflected that of an intrapreneur. Practitioner A's lack of expertise on platform ecosystems was compensated by with the expertise of Researcher A. Therefore, this ADR project satisfies our research goal of studying how intrapreneurs can design platform ecosystems for established non-platform firms.

The constant members of the project consisted of two researchers from AIST, including Researcher A and two to four practitioners, including Practitioner A. The expression "two to four" indicates that there was a change in the number of members excluding Practitioner A due to staff reassignment of the firm. Other AIST researchers and FTEC practitioners participated in the project when they were required (on demand). Project meetings were held once physically or thrice virtually every month. FTEC practitioners provided information about technologies and businesses under a non-disclosure agreement, and sometimes interviewed employees or customers to acquire more information when required.

We summarize the ADR project procedure in Table 1. In stage 1, we identified the problem that motivated the ADR project and concluded the contract for the joint research project. The design of the platform ecosystem structure was conducted in stage 2, in three cycles. Here, "one cycle" of the ecosystem design was defined as a period that begun with the consideration or reconsideration of the design to submission of the proposition for approval by FTEC's managers and executives. After the completion of each cycle, we moved to stage 3 and analyzed the process to identify the implications for formulating the platform ecosystem structure. If our proposition was denied, we returned to stage 2. If our proposition was approved, we moved to stage 4 and formulated the processes for designing the platform ecosystem structure based on the implications examined in stage 3.

Summary of the ADR project, its achievements, and findings

Initial stage model of a platform ecosystem

This project aimed to complete the design structure of the platform ecosystem based on FTEC's RFID technologies and gain acceptance from FTEC executives. As basis for the project, we constructed an initial stage model of a platform ecosystem by combining the concepts of platform ecosystem and digital servitization. Digital servitization can be explained as follows:

"Servitization" is a way of adding new value by bundling services with products (Vandermerwe & Rada, 1988). Implementing servitization can be beneficial to the firm because it improves consumer loyalty and mitigates the risk of customers switching to competitors (Vandermerwe & Rada, 1988). In recent years, "digital servitization" has garnered significant attention (Cenamor et al., 2017; Kohtamäki et al., 2019; Opresnik & Taisch, 2015; Sklyar et al., 2019). Digital services have the following three advantages over traditional services: (1) their marginal cost is almost zero, (2) they can substitute for products, unlike traditional services, which can only be complemented, and (3) they can cultivate new business opportunities, especially in the hardware and software business fields (Vendrell-Herrero et al., 2017).

Digital servitization has high affinity to IoT (Naik et al., 2020; Paiola & Gebauer, 2020; Rymaszewska et al., 2017; Suppatvech et al., 2019). Rymaszewska et al. (2017) have suggested that IoT-utilizing services could improve firms' profitability by extending the firm's value chain and providing better services to customers. Suppatvech et al. (2019) have argued that IoT technology could allow firms to provide innovative service businesses, including add-on (adding new functions or services), sharing (sharing use or access to products), usage-based (measuring amount of use), and solution-oriented (providing solutions corresponding to customer needs) services. Thus, development of IoT technologies provide a new digital servitization approach to firms. Given that FTEC can provide IoT digital services based on RFID technology, these perspectives can be applied when the FTEC model of a platform ecosystem is being considered.

To highlight the differences between the traditional digital servitization and proposed structures, we show the transition from traditional digital servitization to platform ecosystem digital servitization in Fig. 1. Figure 1 a shows a simple form of digital servitization, where firm A provides several products, including sensors and digital services, to customer α (B2B). Figure 1 b shows a simple form of platform-based digital servitization that corresponds to previous platform-related studies on digital servitization (e.g., Cenamor et al., 2017; Kamalaldin et al., 2020; Paschou et al., 2020). In this case, Firm A can use its platform to provide additive services to customers. The following two patterns are considered as forms of additive services: (α) a data-driven approach that analyzes pooling sensor data from the platform and uses the results to provide digital services; and (β) a modular architecture approach that creates digital service modules and provides them based on customers' needs. In this study,

Table 1 Summary of ADR project procedure of this study

ADR stage	Descriptions	Achievement
Stage 1: Problem formulation (July–November 2017)	• The researcher explored the following research questions. How can intrapreneurs in established firms propose a platform ecosystem structure based on the firm's technologies by referring to the platform ecosystem concept? What differences exist between intrapreneurs and entrepreneurs about the necessary processes, capabilities, and nature of the designed ecosystems? • The intrapreneur from FTEC wanted to structure the platform ecosystem based on FTEC's RFID technologies, but the way accomplishing it was unclear. This was the "problem" for the firm, and it was consistent with the researcher's research questions • To address the problem, the joint research project, considering platform ecosystem structure based on RFID technology, was established by researchers from AIST and practitioners including an intrapreneur from FTEC	Identification of the problem addressed in the ADR project Conclusion of the contract for the joint research to implement ADR project
Stage 2: Building, intervention, and evaluation (first cycle: November 2017–July 2018; second cycle: July 2018–July 2019; third cycle: July 2019–March 2020)	• Project members structured the initial model of platform ecosystem centering RFID technology as the core technology of the platform • The model was then applied FTEC's business to identify a promising platform ecosystem structure • Once the ecosystem structure was formulated, it was evaluated by the managers and executives of FTEC • When the approval to adopt the proposed ecosystem structure was obtained from managers and executives, the ADR project was deemed complete. If approval had not been obtained, this stage was repeated. Ultimately, such cycle was repeated three times • The three-cycle outline was as follows • First cycle: We conducted analysis of RFID business cases of both FTEC and competitors to identify the competitive advantage of FTEC's RFID business. Next, we set the apparel market as the target, and designed initial platform ecosystem structure considering the B2B2B style. The value propositions in the ecosystem were based on the identified competitive advantage. However, the initially proposed ecosystem structure was not approved by managers and executives because of lack of evidence about future success of the ecosystem • Second cycle: To acquire evidence to support the success of the proposition, we distributed questionnaire surveys to apparel and apparel-related logistics firms as potential participants in the proposed ecosystem. We confirmed the existence of their sufficient motivation to participate the ecosystem and refined the proposing ecosystem structure based on the analytical results of the survey data. We further simulated the growth of the market by the proposing platform ecosystem and demonstrating its probability of success. However, we did not acquire approval by the managers and executives because the ecosystem did not consider the apparel firms the FTEC could not strategically ignore • Third cycle: To include the overlooked apparel firms, we revised the ecosystem structure to include both the B2B2B and B2B2C styles. Next, we distributed a questionnaire survey regarding RFID systems and services among apparel consumers. We confirmed the existence of demand and identified the promise of RFID-based services among consumers. Finally, we obtained the approval for the adoption of the proposed ecosystem structure from FTEC's managers and executives	Completion of the design of the platform ecosystem structure based on FTEC's RFID technology
Stage 3: Reflection and learning (Periods are corresponding to those from stage 2)	• At the end of each cycle, we analyzed the process to identify the implications for the necessary processes and formulated the platform ecosystem structure	Acquisition of components that will enable intrapreneurs to design the platform ecosystem structure
Stage 4: Formalization of learning (March–July 2020)	• At the end of joint research project, we summarized implications from Stage 3 and formulated the necessary processes that will help intrapreneurs in designing the platform ecosystem structure	Completion of formulation of intrapreneurs' design processes for platform ecosystem structure

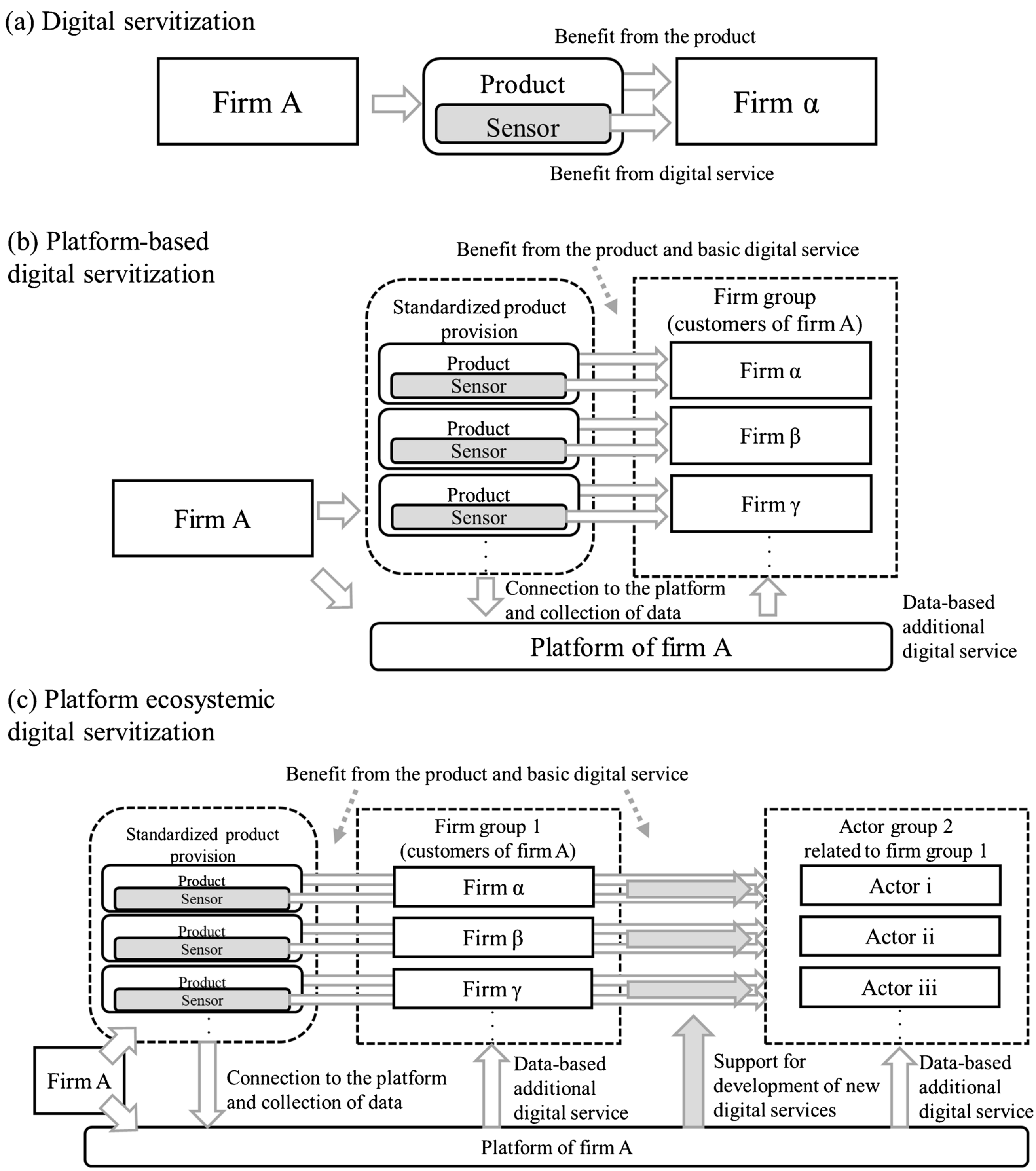


Fig. 1 Transition from a simple digital servitization to a platform ecosystem-based digital servitization

we focused on pattern (α). Finally, Fig. 1 c shows a simple digital servitization platform ecosystem. A new actor group is included in this form, and the business model of firm A changes from "B2B" to "B2B2B" or "B2B2C." This form has the following three premises: (i) products and sensors must reach the added actor groups, (ii) the relationship between the actors in groups 1 and 2 (as in Fig. 1) must not be dyadic and can change based on their profits, and (iii) firm A leaves room for new value (corresponding to new digital services in this situation) provided by potential complementors (corresponding to group 1 in Fig. 1) to their customers. Premise (i) is obvious because new actors cannot participate in the ecosystem if the products and sensors do not reach them. Based on the mechanisms of indirect network effects, premise (ii) is necessary to drive the indirect network effect between the actors in groups 1 and 2. Given the mechanisms for the creation of innovation by complementors in the ecosystems. Premise (iii) is necessary to gain opportunities for the creation of additional innovations by the complementors in the ecosystem.

Conversely, satisfaction with the three premises will provide benefits to firm A from the formation of platform ecosystems. We conceptually modified Fig. 1 c to emphasize these benefits, as shown in Fig. 2. First, actors in the ecosystem can generate new digital service variations based on products and platforms. This could be implemented in the following two ways: (a) development by the platform owner to adapt to the increasing needs by including new actor groups; and (b) development by firms introducing the products to acquire new opportunities for providing improved services on the platform (i.e., actors in Group 1). Second, if new digital service variations are generated, they (i.e., the platform owner firm and actors in Group 1) can acquire customer loyalty from the success of the servitization patterns (Vandermerwe & Rada, 1988). Additionally, the success of generating new digital services using the actors from Group 1 could result in virtuous cycles between actors from Groups 1 and 2. This highlights the benefits of participating in the platform for the actors in Groups 1 and 2, which drives the indirect network effect in the ecosystem and contributes to the growth of the platform-based market.

Based on these structures, we sought to complete the design of the platform ecosystem, which was based on the FTEC's RFID technologies in the ADR project.

First cycle of ecosystem design

After establishing the conceptual model for the platform ecosystem, which incorporated digital servitization, we had to understand the RFID products and related digital services of FTEC and its competitors. We needed this to identify the competitive advantage of FTEC's RFID business and create a business structure that incorporated a strong platform ecosystem.

FTEC practitioners collected and provided us with information such as the technical specifications of each product, its transaction volume, and details of approximately 180 RFID-related businesses. We further investigated 241 RFID business cases from 56 RFID-related firms' websites in Japan. We combined this data with FTEC business data (only success cases) and analyzed them in the following manner. First, we discussed the collected business cases and characterized them according to their components. A summary of the extracted components is presented in Table 7 in the Appendix. Second, to identify and understand the business patterns based on the component data, the cases were classified using cluster analysis (the labels of components were converted to binary data). Here, we used a hierarchical clustering technique, specifically Ward's method, which is widely used as a representative classification method (Murtagh & Legendre, 2014). A dendrogram was obtained using Ward's method and based on the coherence of the combination of cases. The cases were divided into eight clusters, as shown in Table 2. FTEC success was observed for classes 1, 2, 3, and 7. Thus, we identified the competitive areas of FTECs' RFID businesses and typical digital service patterns.

After understanding the RFID business patterns and competitive positioning of FTEC, we began to consider a detailed platform ecosystem structure based on the initial model of platform ecosystems incorporating digital

Fig. 2 Benefits of creating platform ecosystem-based digital servitization

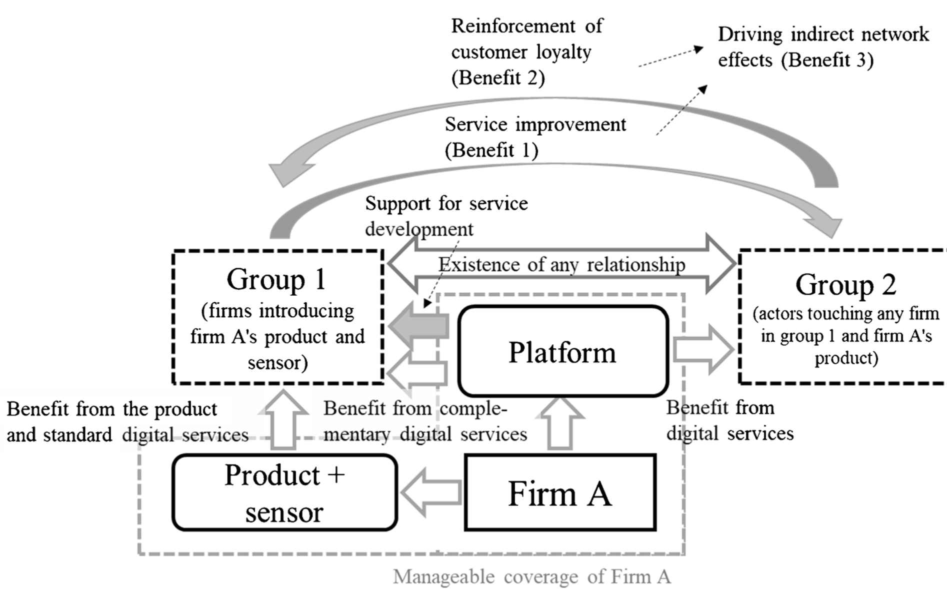


Table 2 Classified patterns of RFID businesses in the Japanese market

Cluster	Case sample	Label	Specification
1	*26*	*Rental management*	*Achieving efficiency or automation in processes of rental goods*
2	*55*	*Goods management in the room (including store, office, storage)*	*Achieving efficiency in goods management by lump scanning*
3	*30*	*Optimization in logistics*	*Achieving efficiency in logistics by lump scanning and automatic scanning*
4	22	Process management	Achieving efficiency in logistics by lump scanning and writing necessary information on the RFID
5	37	Collation management	Mainly collating humans on the list (for example, list of employees) to improve crime prevention. There are relatively many cases connecting existing systems (e.g., attendance management system)
6	56	Others	-
7	*17*	*Position and dynamics management*	*Understanding the positioning of goods in logistics or in the building*
8	14	Bird's-eye view of supply chain	Obtaining a bird's-eye view of the place, amount, or inventory of goods on the supply chain

Italicized spelling indicates the clusters that contained competitive areas for FTEC

servitization (as shown in Figs. 1 c and 2). Initially, we specified a targeted market. Given FTEC's current (at that time) business focus, we considered the apparel, linen supply, and flower industries while designing the ecosystems. We targeted the apparel market because of its large scale and relatively high acceptance of new technologies. Furthermore, we proposed an ecosystem structure, as shown in Fig. 3, which was characterized by the following elements:

Element A: Platform diffusion strategy considering the features of the RFID business The range of platform ecosystems depends on the platform's diffusion range. For RFID-based platforms, this can be determined using the range of diffusion of RFID devices. Therefore, we considered the different ways in which RFID devices could be maximally used by more actors. To achieve this, we decided to facilitate the introduction of RFID tags upstream of the apparel supply chain. Embedding the RFID tag into the label tag of clothing manufactured in apparel factories, is considered as the most cost-effective method. Next, the embedded RFID tag is used throughout the supply chain stages. The downstream actors, such as logistics, warehouses, wholesales, and stores, can use the RFID tags introduced by the upstream actors at no cost.

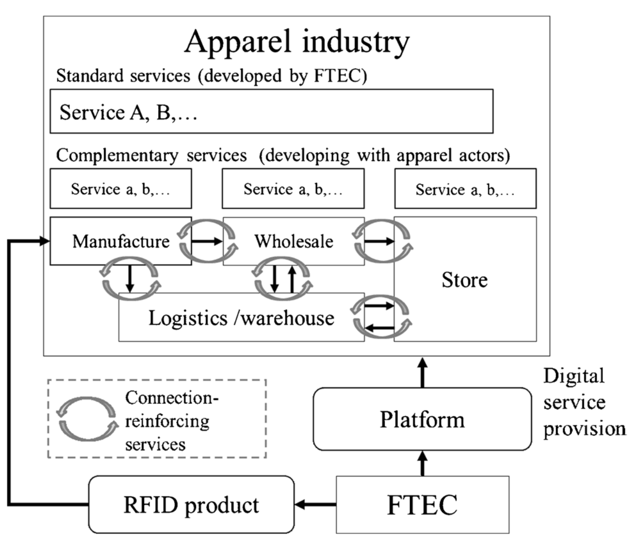


Fig. 3 Ecosystem structure designed in the first cycle of the ADR project

Element B: Prepared standard services and availability of complementary services Corresponding to Fig. 2, we considered two types of digital services, namely, standard and complementary.

Element B-α Standard services are structured by technology and knowledge from FTECs with established RFID services such as rental management, store/stock room goods management, logistical optimization, and position and dynamics management (as highlighted in Table 2). Standard services, such as basic RFID solutions, can be commonly provided to actors belonging to the ecosystem and preinstalled on the platform. However, this does not mean that all services must be used in each business case.

Element B-β Complementary services can be autonomously developed by firms that install the platform developed by FTEC, in accordance with their requirements. The platform owner (FTEC) accepts this to generate innovation in an ecosystem.

Element C: Market expansion strategy based on the indirect network effect mechanism Digital services originally provided to one actor can be transformed to be more valuable services by using an RFID system with related actors.

We call the former "self-completion services" and the latter "connection-reinforcing services." As a mechanism driving the indirect network effect, a connection-reinforcing service is essential for ecosystems to generate virtuous cycles among actors, as shown in Fig. 2. An example of a self-completion service is the inventory management service provided by a warehouse, and an example of a connection-reinforcing service is the service for improving efficiency of incoming and outcoming of products between logistics firms and retail stores. Additionally, if self-completion services are connected among firms, they can become connection-reinforcing services.

Thus, we completed the initial trial of ecosystem design and submitted it to the managers of the FTEC. They evaluated the design and requested for proof that the ecosystem structure would work well, at least at the data level. Therefore, we did not finish the ADR project and moved on to the second cycle of ecosystem design.

Reflection and learning from the first cycle

From the first cycle of the ADR project, we recognized that investigating a firm's past business and the business of its competitors, is an easy way to start platform ecosystem design. This helped the design team in the following aspects: (a) understanding of the competitive areas of the firms is necessary to decide the promising position of the ecosystem, and (b) understanding of the business patterns of the targeted market are useful in understanding the standard business style in the market. This action also contributes to define the standard value propositions of the platform ecosystem and to identify room for complementary value propositions that can be elaborated by or with complementors. Additionally, given the negligible financial cost, firms would not object to this action.

We noticed that the platform diffusion strategy can change depending on the characteristics of the targeted market and how the core technology of the platform has been introduced into the market. To expand RFID usage in the apparel market, we decided to introduce RFID tags upstream of the apparel supply chain. Thus, the platform diffusion strategy should be discussed because the range of platform ecosystems is dependent on the range of diffusion in the core technology of the platform.

We also realized that the firm perceive a large degree of uncertainty and risk in implementing an ecosystem strategy. In this ADR project, although we proposed an ecosystem structure based on information from the actual business activities of the FTEC and its competitors, more proof was required by the managers. Therefore, employees who suggest introducing an ecosystem-based structured business need to present ample proof to remove any concerns that the top management might have regarding the project.

Second cycle of the ecosystem design

FTEC managers requested further validation of the proposed ecosystem structure. Given that we had already collected most of the capturable data from FTEC and its competitors, we needed to conduct further investigations to obtain additional evidence. Hence, we conducted a questionnaire survey involving apparel firms (and apparel-related logistics firms) to extract information regarding the considered ecosystem structure. The questionnaire was designed by us, while printing, distribution, and collection of the survey data were conducted by Teikoku Databank, Ltd., a credit-checking firm in Japan. Based on the sales amounts of firms, we selected the top 4500 apparel firms and top 500 apparel-related logistics firms from the Teikoku Databank's list of firms. The survey period was from January 7 to January 21, 2019. A total of 701 responses were received from the apparel firms and 115 from apparel-related logistics firms. The number of confirmed valid responses were 622 and 43, respectively. In the questionnaire, we included the following question items: types of products/services (apparel firms: types of clothes; logistics firms: types of logistics services), business areas (apparel firms: apparel-related business areas including retail, wholesale, manufacturing, etc.; logistics firms: logistics-related business areas such as shipping, storage, packing), business connections (apparel firms: business partners' apparel-related business areas; logistics firms: business partners' logistics-related business areas), significant problems in apparel-related business (items related to potentially available RFID-based services), present situation and willingness to introduce RFID solutions to resolve these problems, maximum investable rate to resolve these problems, problems with RFID introduction, and RFID installability (whether the specification of the apparel label tag can be decided by the firm). The item regarding the maximum investable rate was to be responded to in a free-writing style, and the others were multiple choice questions. The details of the questionnaire are provided in the Appendix Table 7.

Here, we only summarize the questionnaire results relevant to this study. Table 3 summarizes the results of the following items: the needs to resolve problems related to potential RFID services, which were separated into problems related to self-completion and connection-reinforcing services. The results show that some items were moderately or highly selected by respondents (italicized in the table). Such items can be considered as candidates for developing more promising standard services provided on the platform ecosystem. On the whole, 68% of apparel firms and 72% of apparel-related logistics firms showed a willingness to introduce RFID. Among the respondents, 51% (approximately the same rate was seen across apparel and apparel-related logistics firms) responded that they had considered introducing the RFID system, while only 6% of apparel firms and

Table 3 Need for resolution of problems related to potential RFID services

Type	Problem	Percentage in apparel firms	Percentage in apparel-related logistics firms
Related to self-completion services	*Improving efficiency of inventory management*	*66%*	*63%*
	Improving efficiency of stocktaking	*54%*	*56%*
	Product place management (in stockroom or warehouse)	17%	42%
	Product place management (in apparel store)	10%	-
	Product place management (in the logistics vehicle)	–	2%
	Improving efficiency at the checkout counter	24%	–
	Efficient use of customer information	36%	44%
	Employment management	20%	42%
	Improving connections among business systems	25%	53%
	Prevention of loss, theft, or outflow of goods	15%	28%
Related to connection-reinforcing services	Optimization of logistics	33%	53%
	Improving movement efficiency in the incoming and outcoming of products	*40%*	*72%*
	Product place management (on supply chain)	5%	14%
	Labor shortage	*36%*	*86%*
	Improving connections to online sales system	43%	30%
	Efficient use of sales information	44%	44%
	Improvement of service quality	33%	72%
	Improving customer relations	*44%*	*67%*
	Improving cooperation with business partners	19%	42%
	New customer acquisition	*51%*	*58%*

Items satisfying the average percentage value, which is 50%, across apparel and apparel-related logistics are regarded as high needs and shown in italics

14% of apparel-related logistics firms had introduced RFID. The most common barrier they faced in introducing RFID was the "lack of cost-effectiveness of the RFID solution" (60% of apparel firms and 64% of apparel-related logistics firms agreed existence of this problem).

Utilizing the survey results, we modified the standard services on the ecosystem as to be improving efficiency of inventory management, stocktaking, and incoming and outcoming of products. Although labor shortage, improvement in customer relationships, and new customer acquisition were also confirmed as high needs, we consider that these can be improved using the three aforementioned standard services. Thus, we modified the standard ecosystem services and acquired proof of their validity. The survey results also indicated that the problem of the "lack of cost-effectiveness of RFID solutions" must be resolved in the ecosystem design stage. Accordingly, we considered the following two approaches: reduction of cost or improvement of effectiveness. However, the latter approach requires additional investment for R&D activities and entails high uncertainty in the proposition. Therefore, we focused on the former approach and proposed a new pricing scheme that focuses on the specific features of this ecosystem structure and the following additional element:

Element D: New pricing scheme This element involved discounting the RFID system fee for upstream firms that introduced the RFID tag and charged a digital service fee to downstream firms without introducing an RFID tag. This emerged from the element A of the platform diffusion strategy in the proposed ecosystem structure. RFID tags will be embedded into the clothing label tags in apparel factories. These tags can be potentially used throughout the supply chain, once the goods leave the factories.

As we were required to prove the validity of the proposed ecosystem structure in the evaluation stage of the first cycle, we need to test the effectiveness of this pricing scheme. To this end, we used an agent-based simulation method that can be used in complex systems. Previous studies have used this method to test the effectiveness of certain situations or specific strategies related to platform ecosystems (e.g., Inoue et al., 2019, 2020). The simulation system was uniquely created by us in R and calibrated using questionnaire data. This system simulates the adoption of RFID in the apparel industry. In the simulation experiment, results from a conventional RFID business situation (pattern A) and the proposed ecosystem structure are compared using with a new pricing scheme (pattern B). In pattern A, only agents, which can determine the specification of the apparel label tag, install the RFID system and use

RFID-based services. In pattern B, agents receive products embedded with the RIFD label tag from the upstream of the supply chain and can also use RFID-based services by paying the cost. Hereby, the installation cost of the RFID system in pattern B was set to be smaller than that in pattern A. Agents representing the apparel and apparel-related logistics firms has the opportunity to participate in the ecosystem (namely, installation RFID system and/or starting use of RFID-based service) by the following two ways: being randomly pushed by FTEC or contacting FTEC themselves. We also set that the possibility of occurrence of the latter behavior will increase as the size of the agents in the ecosystem increases. This is because higher adoption of the RFID system would increase its chances of being adopted other firms influenced by imitation behavior. The decision of participation in the ecosystem was based on the cost-effectiveness of the RFID service, and the judgment criteria was set to be different for each agent based from the data of questionnaire. In the simulation experiment, we considered the following three evaluation indicators: (a) the number of agents adopting the RFID system or services (as an indicator of market share); (b) the total sales of the platform owner agent (as an indicator of the benefit to FTEC); and (c) the total surplus of agents, excluding the platform owner agent (as an indicator of incentives for outside actors participating in the ecosystem). Further details of the simulation procedure are shown in the Appendix (see Fig. 8 and related explanations).

Figure 4 shows the simulation results. The values of all evaluation indicators in pattern B were larger than those in pattern A: 1.73 times on indicator (a), 1.10 times on indicator (b), and 1.30 times on indicator (c) (see the values of y-axis in the results shown in Fig. 4). These results indicate that the proposed ecosystem structure, using the new pricing scheme, provides a larger market share and generates lock-in effects for the actors in the ecosystem. The benefits of the platform owner could also increase to some extent. Hence, the simulation results illustrate the effectiveness of the proposed ecosystem structure.

Based on the results of the data analysis and simulation experiments, we modified the ecosystem structure, as shown in Fig. 5. Accordingly, we completed the second trial of ecosystem design and resubmitted it to the managers of FTEC. They evaluated it and highlighted the inconsistency between supposed firms in the proposed ecosystem structure and characteristics of certain apparel firms that FTEC wants to capture into the ecosystem. In detail, this ecosystem structure might not cover some large apparel firms, specifically the specialty store retailers of private label apparels (SPA). These firms manage most areas of their supply chain and might remain separate from the ecosystem because they have a distinctive business network. Although these firms can benefit from RFID-based digital services, they cannot benefit from the indirect network effect of the proposed ecosystem structure. Given that FTEC aims to become an RFID platform leader in the apparel industry, it could not afford to overlook the SPAs because such firms cover a non-negligible market share of the apparel industry. Thus, we moved on to the third cycle of ecosystem design.

Reflection and learning from the second cycle

The second cycle of the ADR project implies that the ecosystem structure can create an opportunity to renew the pricing of platform-related products. Platform-pricing among actor groups is a basic mechanism of platform diffusion (Evans, 2003; Hagiu & Wright, 2015; Rochet & Tirole, 2003, 2006). The proposed ecosystem structure creates a large imbalance in expenses incurred by upper and lower actors installing RFID in the apparel supply chain. This helps reconsider the pricing scheme of the RFID business, a change that was difficult to foresee before the ADR project. Thus, consideration of the ecosystem structure allows firms to reconsider their business models.

Second, we recognized that the ecosystem structure was based only on past business cases and might be insufficient in satisfying the firm's expectations. In the section "Reflection and learning from the first cycle," we have described

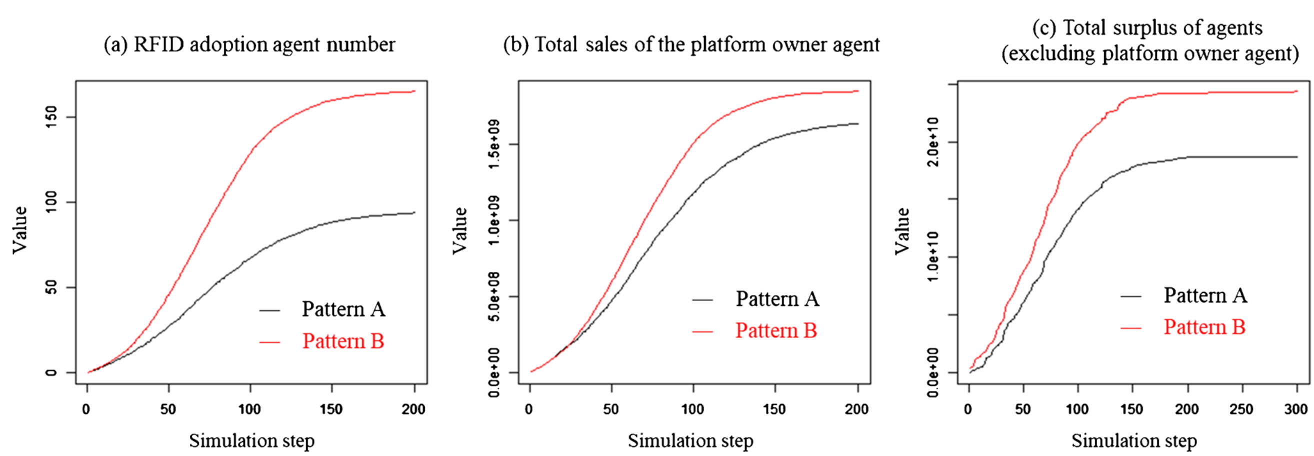


Fig. 4 Simulation results

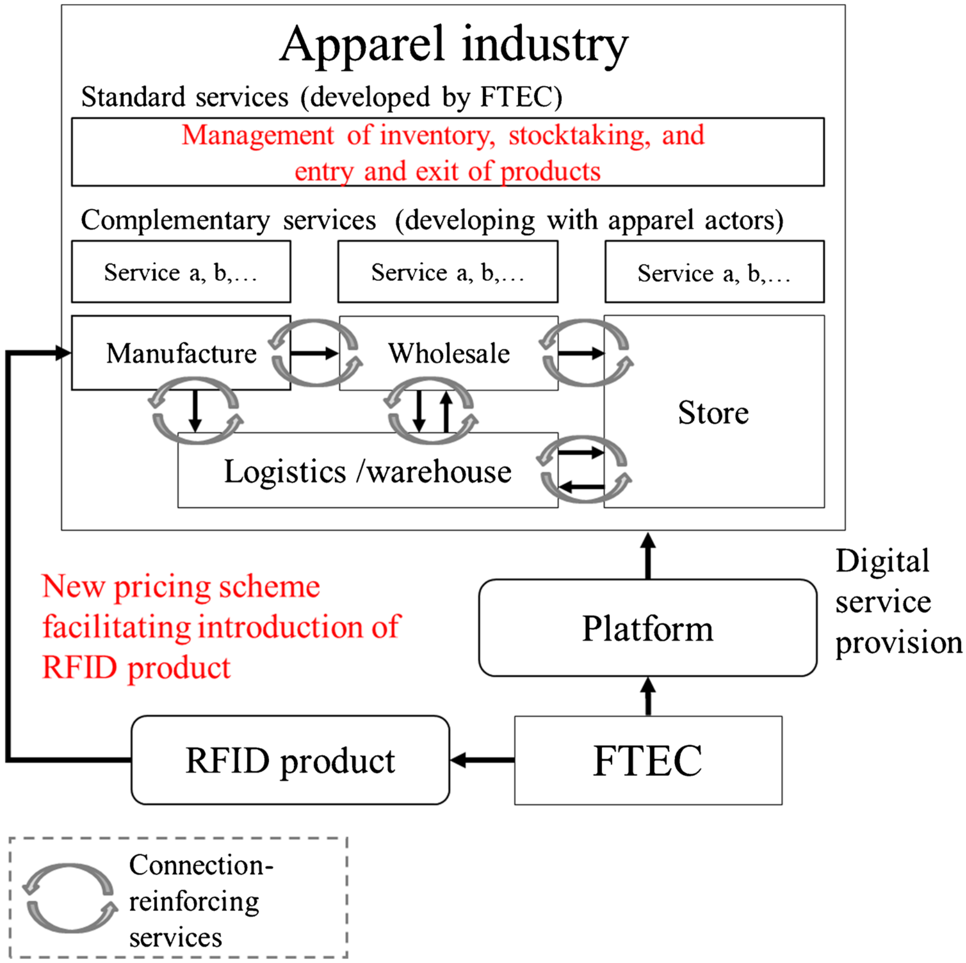


Fig. 5 Ecosystem structure designed in the second cycle of the ADR project. Red parts have been the modified from the previous version

this method to be effective for starting with the design of the ecosystem. However, past data and information may be inadequate for designing the ecosystem desired by firms' managers and executives. Thus, we realized that the ecosystem design may need to be modified considering the future perspectives of firms.

Third cycle of ecosystem design

In the second cycle of ecosystem design, we improved the ecosystem structure and demonstrated its effectiveness through simulations. However, given FTEC's strategic purpose, we must reconsider the ecosystem structure. We realized that this limitation arose from the B2B2B structure because the majority of the customers of large apparel firms, including SPAs, are individual consumers. Therefore, we reconsidered the design that allows the addition of an element to fulfill the B2B2C pattern:

Element G: Using both B2B2B and B2B2C business models We added the actor groups of apparel consumers to the ecosystem structure. This allowed the provision of digital services to apparel consumers, based on RFID systems, and the formation of a two-sided market between apparel firms and consumers. Through this modification, SPA firms can receive benefits as complementors in the platform ecosystems.

To validate this modification, additional questionnaire surveys were conducted involving apparel consumers. The survey aimed to identify promising digital services, based on RFID systems, to provide to consumers. It was also used to assess whether introducing these services could benefit apparel firms. Given that we did not have information to identify appropriate RFID-based services to provide to consumers, we conducted the surveys in two steps. In the first survey, we collected freely written answers from apparel consumers. In this survey, consumers described their problems (including complaints) with apparel shops. We individually confirmed all answers and categorized them based on their patterns of meaning. Next, we discussed the results with FTEC practitioners and identified the available RFID-based services to solve these problems. In the second survey, we structured the questionnaire items based on the results of the first survey. Regarding the identified problems that could be resolved by potential RFID-based services, the respondents were asked, "Q1: Do you agree that this is a significant problem?'

and "Q2: Do you think that resolving the problem can help increase your purchase intention at the shop?" The responses to the former question were scored presented using a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*); the latter was included the responses, "will not change" or "will increase."

The respondents were drawn from Cross Marketing Inc., one of the largest internet research companies in Japan. We requested 1,000 respondents for the first survey and 2,000 for the second survey. The respondents were screened to fulfill the following two criteria: "visiting the apparel shop one or more times a month" and "paying more than 50,000 JPY (about 450 USD at that time) for apparel products each year." The first survey was conducted from October 7, 2019, to October 9, 2019, and the second from January 28, 2020, to January 31, 2020. The survey period was short because we closed the survey as soon as we received the expected number of responses. In the second survey, 1674 valid responses were obtained after removing contradictory answers.

Based on the results of the first survey, we identified the following 13 consumer problems that could be solved by providing RFID digital services: (1) unnecessary face-to-face services; (2) stockout; (3) low assortment; (4) absence of clerks; (5) inappropriate recommendations; (6) difficulty in using the fitting room; (7) difficulty in finding target products: (8) insufficient face-to-face services; (9) difficulty obtaining product information: (10) lack of clerks' merchandise knowledge; (11) requirements for untouched products: (12) difficulty in comparing products at home or at another store; and (13) long waiting times at the checkout counter. We further discussed and identified how these problems can be solved using RFID technology (see Table 8 in the Appendix). From the 13 identified problems and corresponding potential RFID digital services, the items of the second survey were designed. To analyze the expected service provision patterns, we applied exploratory factor analysis (promax rotation method) to acquire data regarding the answers for Q1. This is because the provision of all digital services corresponding to the 13 problems is not realistic, and the summarized services can contribute to cost reduction for platform owners. To identify the appropriate number of factors, we used a scree plot to confirm the point of inflection in the eigenvalues of the factors (Yong & Pearce, 2013).

Table 4 presents the results of the factor analysis and mean values of the questionnaire results for each problem. Accordingly, we extracted two latent factors from the data and defined Factor 1 as "problems occurring when consumers want detailed product information for careful consideration before purchasing" and Factor 2 as "problems occurring when a consumer expects efficiency in the process of purchasing a product." Considering the mean value of the questionnaire results (both Q1 and Q2), the values of Factor 2, on average, were higher than those of Factor 1. Therefore, considering Factor 2, we defined the standard digital services for resolving consumers' problems related to stockout and relatively small assortments in shops. The factor analysis results suggest that this service should be provided so that consumers can use it without the help of clerks. The results also show that services related to Factor 1 imply an improvement in service quality and efficient provision of product information. However, based on the results of the questionnaire, such digital services would be considered as the second priority. Thus, the effectiveness of the added element in the ecosystem structure was confirmed, and detailed consumer-oriented digital services were identified.

Based on the analysis of apparel consumers, we modified the ecosystem structure as shown in Fig. 6. We submitted this structure to FTEC managers and obtained their approval. The managers then presented them to the executives and secured authorization for investment. Thus, the initial purpose of the joint research project was achieved.

Table 4 Exploratory factor analysis of problems in apparel shops and questionnaire results

	Factor 1	Factor 2	Significance of the problem	Contribution to increase in purchase
Lack of clerks' knowledge	**0.67**	−0.08	2.90	0.38
Difficulty in comparing products	**0.66**	−0.06	2.88	0.39
Unnecessary face-to-face service	**0.65**	−0.44	2.31	0.32
Difficulty in obtaining product information	**0.62**	0.00	3.00	0.45
Difficulty finding target products	**0.57**	0.10	3.03	0.42
Long waiting times at checkout counters	**0.55**	−0.07	2.78	0.37
Absence of clerks	**0.54**	0.17	3.03	0.33
Inappropriate recommendations	**0.52**	0.18	3.09	0.36
Requirement for untouched products	**0.50**	0.04	3.00	0.44
Difficulty in using the fitting room	**0.49**	0.20	3.05	0.43
Stockout	−0.03	**0.70**	3.84	0.60
Insufficient face-to-face service	−0.12	**0.65**	3.89	0.50
Low assortment	0.25	**0.47**	3.34	0.52

Note: Bold numbers means that bolded items belongs the factor in each

Reflections and learning from the third cycle

The third cycle of the ADR project revealed the significance of incorporating consumers as actor groups in the designed ecosystem structure. If the considered ecosystem structure supports B2B2B business models, customers may not fit into it. Incorporating consumers into an ecosystem structure can help resolve this problem. Although there may be exceptions in some markets, consumers prefer autonomy in purchasing goods. Therefore, if we consider the relationship between firms and consumers on the platform, it can potentially generate an indirect network effect. Accordingly, the firms will be motivated to cultivate new values based on the platform to acquire more consumers. Thus, we realized the significance of adding consumers to the design of ecosystem structures.

Formalization of learning

After working on the joint research project for 29 months, we presented the platform ecosystem structure based on the RFID-based platform for FTEC. By summarizing the learnings of the joint research project, we formulated the processes that intrapreneurs can follow to the design platform ecosystem structures, as shown in Table 5.

As a supplement, the statistical methods and techniques of information science used in our ADR project have proven valuable; however, intrapreneurs are not necessarily required to use them. The purpose of our data analysis was twofold: to test the validity of the designed ecosystem structure and to provide evidence to firm executives on the promise that the proposition holds. Therefore, if these two objectives are satisfied, other methods can be applied. For example, if the executives prefer proposition of results of more simple data analysis, descriptive statistics might be an appropriate method. If the executives think customers' opinion is more important, implementation of in-depth interviews for supposed customers in the ecosystem, would be appropriate.

Discussion and conclusions

The recent evolution of IoT, sensors, data sciences, and other related areas has created opportunities for firms to expand their work to platform-related businesses (Paschou et al.,

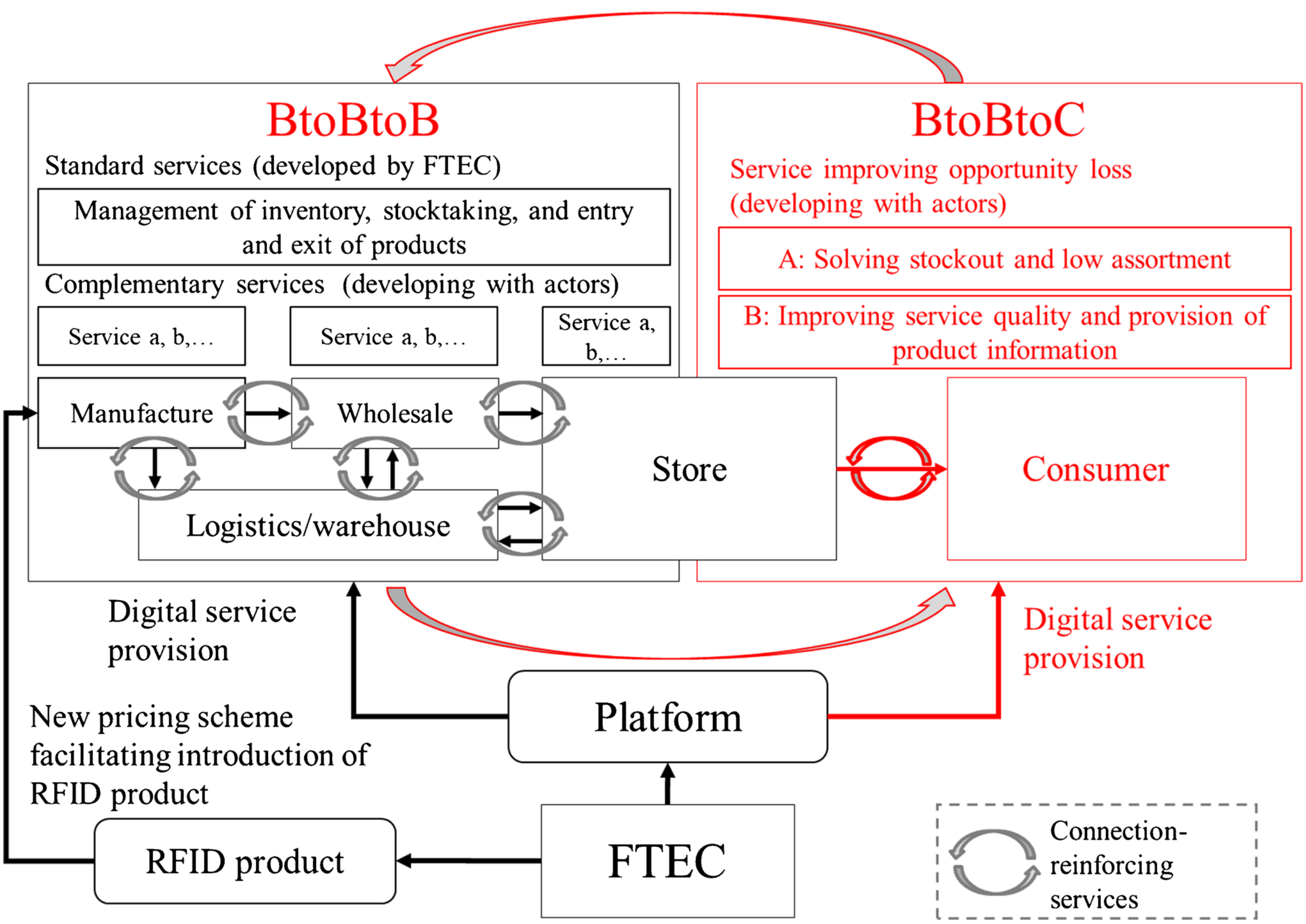


Fig. 6 Ecosystem structure designed in the third cycle of the ADR project. Red parts indicate modified parts from the previous version

Table 5 Processes for designing a platform ecosystem structure by intrapreneurs

Processes	Description
Step 0: Designing an initial ecosystem structure using platform ecosystem concepts and concepts (or theories) related to the target market	Referring to the concepts of platform ecosystems and concepts (or theories) related to the target market, product, and technology, the intrapreneurs can design an initial ecosystem structure. Here, the following five points should be especially considered: • Designing mechanisms that drive the indirect network effect among the actors in an ecosystem • Considering actors who can act as complementors • Designing structures in which complementors can generate innovation based on platform technologies • Understanding how values appreciated by the actors in the ecosystem, can be generated • Understanding specific prerequisites and/or restrictions to achieve the aforementioned points
Step 1: Analysis of past business cases	For the technology planned to be used as the core of the platform, intrapreneurs analyze business cases of their firm and (potential) competitors. By understanding and categorizing these cases, they can identify the promising business patterns that can be set as the standard value proposition of the platform ecosystem
Step 2: Making the ecosystem structure into concrete shape	The intrapreneurs combine the results of Steps 0 and 1 to modify the initial ecosystem structure to be more made into concrete shape. During the modification, the following points should be discussed: • **Determination of actor groups incorporated into the ecosystem.** The intrapreneurs have to determine at least two actor groups that will be included in the ecosystem. The prerequisite of "at least two" is drawn from the structural precondition of platform ecosystems. These actor groups can be defined based on the results of Step 1, which are as follows: (A) customers purchasing products related to the platform, and (B) customers of actors positioned in the actor group (A). If these two groups cannot cover the future targeted customers of the platform firm, more actor groups may be considered • **Determination of value propositions on the platform ecosystem.** This can be defined by referring to successful business cases analyzed in Step 1. However, if the designed ecosystem supposes new actor groups that were not included in the successful cases, intrapreneurs propose any candidates for value propositions (appropriate products or services) which will cover them and confirm their validity in Step 3 • **Determination of the platform diffusion strategy.** Intrapreneurs should discuss a systematic platform diffusion strategy. The appropriate strategy may differ depending on the characteristics of the target market and the way in which the platform core is introduced into the market. The top priority should be to find a way for more actors to utilize the core technologies of the platform • **Configuration of a new pricing scheme supporting the platform diffusion strategy.** If the design of the ecosystem structure changes the business model related to the platform technology, intrapreneurs might find an opportunity to modify the pricing scheme of the platform technology. A new pricing scheme could be introduced to support the diffusion of the platform
Step 3: Verification of the validity of the ecosystem structure	Even if the proposed ecosystem structure is based on successful cases and established concepts (or theories), managers and executives might feel a large degree of uncertainty and risk in implementation. Therefore, intrapreneurs need to provide ample proof to eliminate any such concerns. In this study, we have illustrated some ways to do this. They include data acquisition through a questionnaire, statistical analysis, and simulation. Depending on the preference of the managers and executives or the culture of the firm, the proper way to propose evidence for future success of the ecosystem may differ
Step 4: Elaboration of the ecosystem structure	After Step 3, intrapreneurs may find the need to modify the ecosystem structure. In some cases, returning to Step 1 or 2 may be warranted. Any discrepancy between the business strategy assumed in the designed ecosystem structure and companywide business strategy, must be cleared
Step 5: Proposition of the designed ecosystem business	After intrapreneurs design the elaborate ecosystem structure and provide sufficient proof of its validity, they present it to the managers and executives of the firm

2020). To start platform ecosystem businesses in non-platform firms, intrapreneurs could play an important role. Some previous studies on electronic markets have investigated the initial stages of digital platforms and platform ecosystems (e.g., Fürstenau et al., 2019; Otto & Jarke, 2019). However, no study has specifically focused on intrapreneurs and their challenges in building platform businesses for existing organizations. Their challenges are related to the following two difficulties: designing the structure of platform ecosystem-styled businesses under organizational restrictions and proposing persuasive and acceptable plans to firms' decision makers. Our study addresses this gap by proposing design processes that can used by intrapreneurs designing platform ecosystems. Using an ADR project with FTEC, we interpreted the learnings and implications of the project. Furthermore, we provided the processes intrapreneurs can use while designing a platform ecosystem structure in established non-platform firms. In this section, we first consider the applicability of the proposed process to other cases. Next, we describe the theoretical implications of the studies on the design of platform ecosystems, and their practical implications for intrapreneurs that try to design platform ecosystems in their firms. Finally, the limitations and related future research are discussed.

Applicability of the proposed processes

Given that the proposed processes are based on a single case study, a discussion of their applicability to other cases is necessary. We consider that applicability increases as the situation and context of the cases become increasingly similar to those of the ADR project in this study. Conversely, larger different situations and contexts make it difficult to apply these processes. Here, we describe two supposed patterns where findings will be difficult to implement.

The first difficult pattern would be cases in which the top management team did not feel the necessity for business model innovation. In our case, the top management team understood the significance of improving current business models and implementing a platform ecosystem concept, at the start of the project. Therefore, we were only required to present an effective and acceptable proposition of a platform ecosystem structure. Given that ecosystem business models present larger uncertainties than simpler business models, if the situation and context are largely different, executives might not accept doing business using ecosystem concepts. This is especially true if they do not understand their significance. In such cases, intrapreneurs may need to add other processes to persuade the top management team.

The second difficult pattern would be the cases in which the firms need high investment or deep exploration to develop platforms based on the firm's core technologies. In our project, the FTEC had already completed the development of a series of RFID-related and digital platform system technologies. Therefore, the degree of potential investment and exploration did not seem to be too high until the realization of the platform ecosystem. If the situation and context were different, especially if the firm and/or its belonging industry were far from digital technologies, actions toward digital transformation may be necessary before considering the application of the proposed processes. In such cases, intrapreneurs would need to introduce additional processes in the development of digital-related businesses.

Theoretical implications

This study provides new avenues for research on the initial design and development of platform ecosystems. Although a few previous studies have focused on the design process in the initial stage of building platform ecosystems, their results and implications are fragmented (Shi et al., 2021). Additionally, because these studies have focused on situations in which entrepreneurs or alliances introduce platform businesses, they cannot cover the situations of intrapreneurs. Using an ADR project, this study showed the necessary processes and content for intrapreneurs to design platform ecosystem structures (Table 5). Here, for comparison with entrepreneurs, we refer to Shi et al. (2021). They proposed four significant capabilities for the development of a platform ecosystem. This proposition overlaps with our ADR project in the following two respects: innovation leverage (identifying one's own innovation assets, developing a platform utilizing the identified assets, and designing the platform as shared assets for complementors' generation of more innovations) and market exploration (exploring the demand in the market for the designed platform and innovations generated on the platform). Our ADR project required these capabilities in the design processes. Therefore, we considered that these capabilities would be similar between intrapreneurs and entrepreneurs.

However, we observed the following two differences between the case of entrepreneurs and our case: (a) the directions of innovation leverage and market exploration must be aligned with the strategy of the firms, even when the design processes are underway; and (b) an evidence-rich proof demonstrating the potential of the platform ecosystems reduces perceived uncertainty and clarifies the legitimacy of the proposition. These differences are obviously related to the different natures of entrepreneurs and intrapreneurs (Brenk et al., 2019; Camelo-Ordaz et al., 2012; Davis, 1999). Therefore, intrapreneurs need the following additional capabilities to successfully develop platform ecosystems: flexibility in securing the consistency of the proposition within their firm and ability to acquire appropriate knowledge, and information legitimize the proposition. Given that these two capabilities have not been mentioned by previous studies focusing on entrepreneurs or alliances, this study adds to the literature on the initial design and development of platform ecosystems by identifying relevant aspects for intrapreneurs.

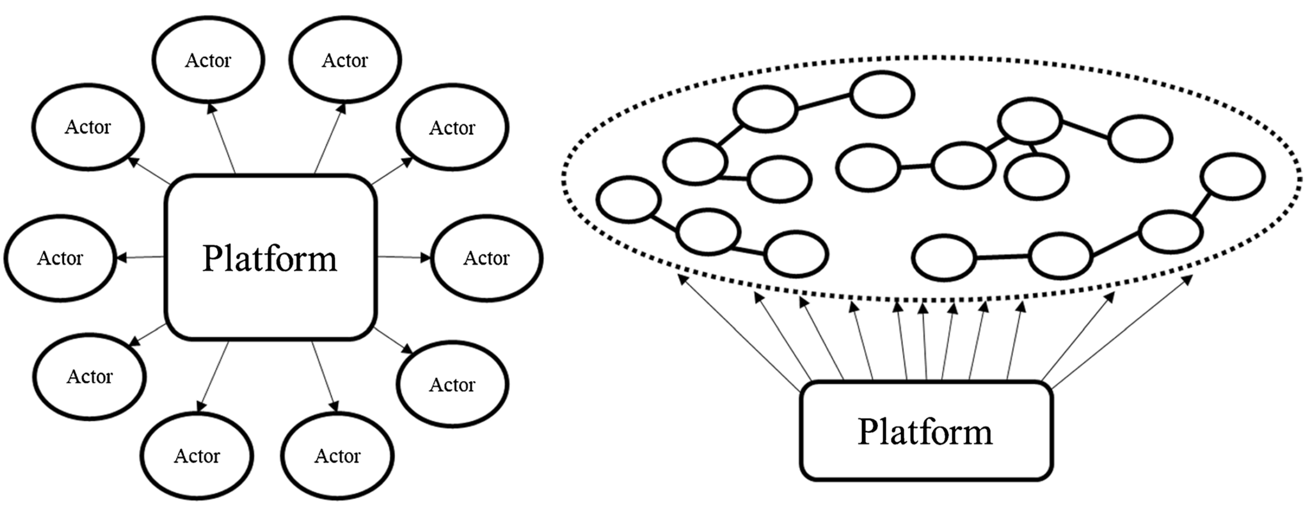
Another issue for discussion is that the developed structure of the platform ecosystem had a style that was different from that of conventional platform ecosystems. Figure 7 portrays this difference. The traditional form of the platform ecosystem is the center of markets and industries. A typical example is the video game platform ecosystem (Inoue & Tsujimoto, 2018a). However, the ecosystem structure designed in this study complements the conventional market structure. Similar to a traditional platform ecosystem, the proposed ecosystem also formed a hub-and-spoke structure but utilized the established business networks in a complementary way. We attribute this to the nature of intrapreneurs. Given that business proposals by intrapreneurs should follow the firms' resources and environment (Camelo-Ordaz et al., 2012), the design of the platform ecosystem could necessarily become a style that supports the existing businesses and networks of belonging firms. This was also observed in the ADR project. Thus, this study implies that the structure of platform ecosystems could essentially differ between entrepreneurs and intrapreneurs, and expand the aspect of platform ecosystem research in terms of the relationship between the nature of the designer of the ecosystem and the resultant structure.

Practical implications

This study proposes the necessary processes for designing the structure of platform ecosystems for intrapreneurs in established non-platform firms. While these processes can be helpful for practitioners, our ADR project also implied that the consideration of platform ecosystem businesses themselves would be helpful in improving the businesses of the firms. As demonstrated, through the consideration of platform ecosystems, firms could have opportunities to re-identify the value of their businesses, elaborate on new value propositions, and reconsider existing pricing schemes. Thus, this study provides a summary of the benefits of forming platform ecosystems and the design processes for intrapreneurs, and also highlights the benefits of considering new types of platform ecosystem businesses for established firms.

Limitations and future research

This study has several limitations. First, the ADR project in this study covered only the ecosystem structure design. Therefore, we cannot report any insights from after this stage (from the start of the platform business to its success). Future studies could investigate the differences derived from the restrictions and characteristics of intrapreneurs in the next stages of implementing platform business, and compare them with entrepreneurs. Second, we only focused on RFID-related platform ecosystems. However, there are other ways to implement digital servitization using IoT technologies. Future studies could focus on the design of digital servitization platform ecosystems based on other IoT-related technologies. Third, our study includes only one firm. Therefore, the results of this study may be influenced by the culture of the firm and the country in which it is located. Future studies could further investigate intrapreneurs' design for platform ecosystems by representing different countries, industries, sectors, and company cultures.



(a) Conventional platform ecosystem: It exists as the center of markets/industries or creates new markets/industries.

(b) Platform ecosystems observed in our ADR project: These exist complementarily with existing markets and business networks and support them

Fig. 7 Differences between conventional and observed platform ecosystems

Appendix

Table 6 shows the components of RFID businesses in Japanese market. This was based on the analysis results of RFID business cases of FTEC and its competitors, which included 56 firms.

Table 7 summarizes the questionnaire items from the survey of apparel and apparel-related logistics firms. The purpose of the questionnaire was practical, not academic. Therefore, we did not intentionally adopt a questionnaire design typical for academic purposes, for example, setting items for the implementation of a structural equation modeling approach.

Table 6 Components of RFID businesses in Japanese market

Objective	Data type	RFID's technological benefit
• Inventory management • Process management • Rental management • Entrance and exit management • Collation management • Place management • Logistics optimization • Asset management • Operation management • Use management • Employment management • Count management • Improvement of efficiency on checkout counter • Amusement • Identifying target • Connection to website • History management • Presenting information • Waste disposal management • Temperature/humidity management • Observing temperature • Fraud prevention • Introduction of product information	• Existence • Place/position • Count • History • Category • Charge amount • Progress • Information • Temperature • Combination of temperature and humidity • Weight • Personal identification • Time	• Automatic scanning • Distant scanning • Lump scanning • System connection • Re-writability • Memory capacity • Tolerance for dirt • Uniqueness • Environmental monitoring • Endurance for shock
• Reduction of time • Reduction of risk • Grasp of position • Data analysis • Simplification of process • Attendance management • Detection of disposal timing • Quality management • System connection • Authenticity judgment • Time management • Individual management • Improving enjoyment • Storing data • Presenting information • Process management • Improving the value of existing services	• Inventory management • Position management • Collation management • Process management • Security • Customer management • Connection with POS • Fusion between digital and analogue • Identification of target • Improvement of efficiency on checkout counter • Connection with website • Presenting information • Freshness management • Detection of existence • Acquiring personal identifiable information • Measurement of conditions • Introduction of products	• Planning and design (in) • Planning and design (within) • Planning and design (out) • Production (in) • Production (within) • Production (out) • Logistics (in) • Logistics (within) • Logistics (out) • Customer channel (in) • Customer channel (within) • Customer channel (out) • End customer (in) • End customer (within) • End customer (out)

Table 8 shows the RFID-based solutions for the problems proposed by consumers when they visit apparel stores. This is based on the analysis results of questionnaire surveys for approximately 2700 consumers.

Figure 8 shows the simulation procedures for the agent-based simulation system developed by the authors. The simulation included the following two parts: the agents' parameter-setting stage and main simulation stage. We designed the simulation system to allow us to flexibly improve it and test various pricing schemes, considering its use in the practical situation of FTEC's businesses. In this study, we show the output at a fixed price as the simplest experimental case. In "pattern A," we set the price

Table 7 Summary of questionnaire items on the survey involving apparel and apparel-related logistics firms

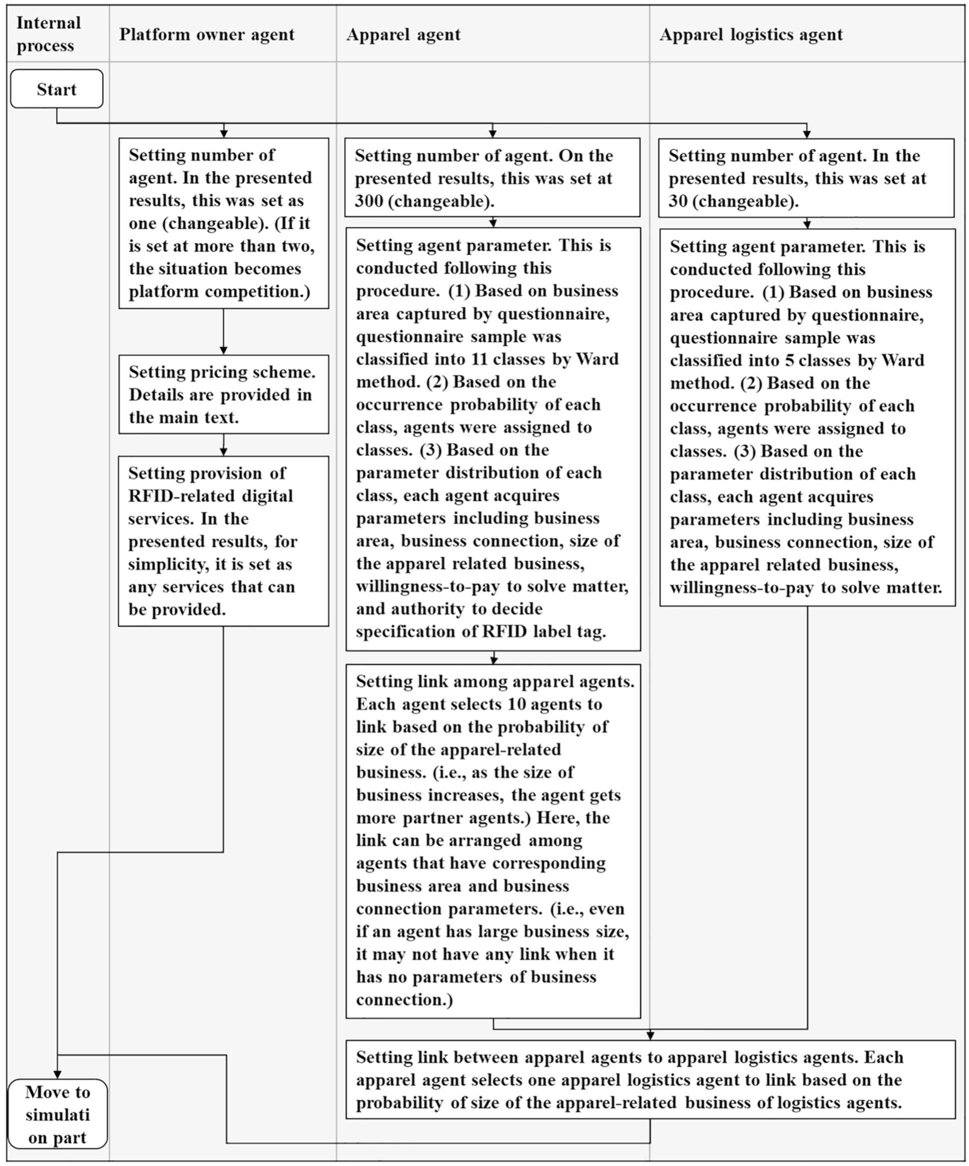
Question	Style	Items
1. Handling products	Multiple choices	[Apparel firms] 1. General apparel goods; 2. Men's apparel goods; 3. Women's apparel goods; 4. Uniform; 5. Innerwear, underwear, lingerie; 6. Baby/children's clothing; 7. Kimono (Japanese traditional clothing); 8. Sportswear; 9. Shoes [Logistics firms] 1. Daily necessities, miscellaneous goods; 2. Clothing, apparel supplies; 3. Medical, nursing care products; 4. Foods, Agricultural products; 5. Industrial products
2. Business area and business connection	Multiple choices	[Apparel firms] (Selecting about implementation in-house, implementation of group companies, and implementation of business partners in each.) 1. Retail (mass retailer); 2. Retail (department store); 3. Retail (specialty stores/direct sales stores); 4. Wholesale; 5. Logistics (transportation); 6. Logistics (warehouse); 7. Manufacturing; 8. Product planning and design; 9. Mail order/E-commerce/Internet sales; 10. Apparel rental; 11. Apparel-related consulting; 12. Apparel-related IT system construction [Logistics firms] (Selecting in-house implementation) 1. Shipping; 2. Storage; 3. Cargo handling; 4. Packaging; 5. Distribution processing
3. Significant problems in apparel-related business (these are potentially resolved by RFID solutions)	Multiple choices	1. Improving efficiency of inventory management; 2. Improving efficiency of stocktaking; 3. Product place management (in stockroom or warehouse); 4. Efficient use of customer information; 5. Employment management; 6. Improving connections among business systems; 7. Prevention of loss, theft, or outflow of goods; 8. Optimization of logistics; 9. Improving movement efficiency of the incoming and outcoming of products; 10. Product place management (on supply chain); 11. Labor shortage; 12. Improving connections to online sales system; 13. Efficient use of sales information; 14. Improvement of service quality; 15. Improving customer relations; 16. Improving cooperation with business partners; 17. New customer acquisition [Items for only apparel firms] 18. Product place management (in apparel store); 19. Improving efficiency at checkout counter [Items for only logistics firms] 20. Product place management (in logistics vehicle)
4. Present situation and willingness to introduce RFID solutions to resolve problems	Multiple choices	For each item shown in Question 3, select the present situation regarding the introduction of RFID solutions and future willingness for introduction of RFID solutions
5. Maximum investable rate to resolve these problems	Free writing	(No item because this question was free writing.)
6. Any problems in RFID introduction	Multiple choices	1. Insufficient effectiveness of RFID solution; 2. Lack of cost-effectiveness in RFID solution; 3. Lack of clarity regarding RFID installation; 4. RFID does not fit in our operation; 5. Any technical issues; 6. We could not decide to introduce it by ourselves (factors caused by other companies); 7. We have never considered introducing it
7. RFID installability (about the authority for specification of the apparel label tag)	Multiple choices	[Apparel firms] 1. Our firm has the authority; 2. A firm in our group has the authority; 3. A business partner has the authority; 4. Others/we do not have information [Logistics firms] N/A (Logistics firms do not have the authority for specification of the apparel label tag in general.)

Table 8 Problems in apparel shops and candidates of RFID digital services for consumers

Content of problem	Example of considered RFID-based digital service
1. Unnecessary face-to-face service	As other RFID service examples shown in this table, most face-to-face services might be replaced by RFID services
2. Stockout	(a) RFID can be used to provide management service for product places. First, this service confirms to consumers whether there is a stockout. (b) When there is a stockout, by connecting to logistics and inventory management system based on RFID, the consumer can directly order for home delivery
3. Low assortment	Consumer can obtain information about similar products by scanning their RFID and ordering them, if required. In other cases, the problem may be solved by digital services described in the cell for Problem 2
4. Absence of clerk	Consumers can call clerks by scanning the RFID
5. Inappropriate recommendation	Based on analysis of purchase data, related products can be recommended when a consumer scans an RFID
6. Difficulty in using the fitting room	Scanning RFID products can connect consumer the fitting room reservation system
7. Difficulty in finding target products	This can be resolved by digital services described in the cell for Problem 2
8. Insufficient face-to-face service	This can be resolved by digital services described in the cell for Problem 4
9. Difficulty in getting product information	A consumer can get product information by scanning RFID
10. Clerks' lack of merchandise knowledge	Digital services described in the cell for Problem 9 can help resolve this problem
11. Ordering untouched products	A consumer can order new (untouched) products by scanning RFID
12. Difficulty in comparing products that are at home or at another store	(a) A consumer can get information about clothes by scanning RFID. (b) The consumer can compare clothes virtually among shops (or maker/brands) affiliated to the platform
13. Long waiting at checkout counter	Self-checkout system can resolve this problem

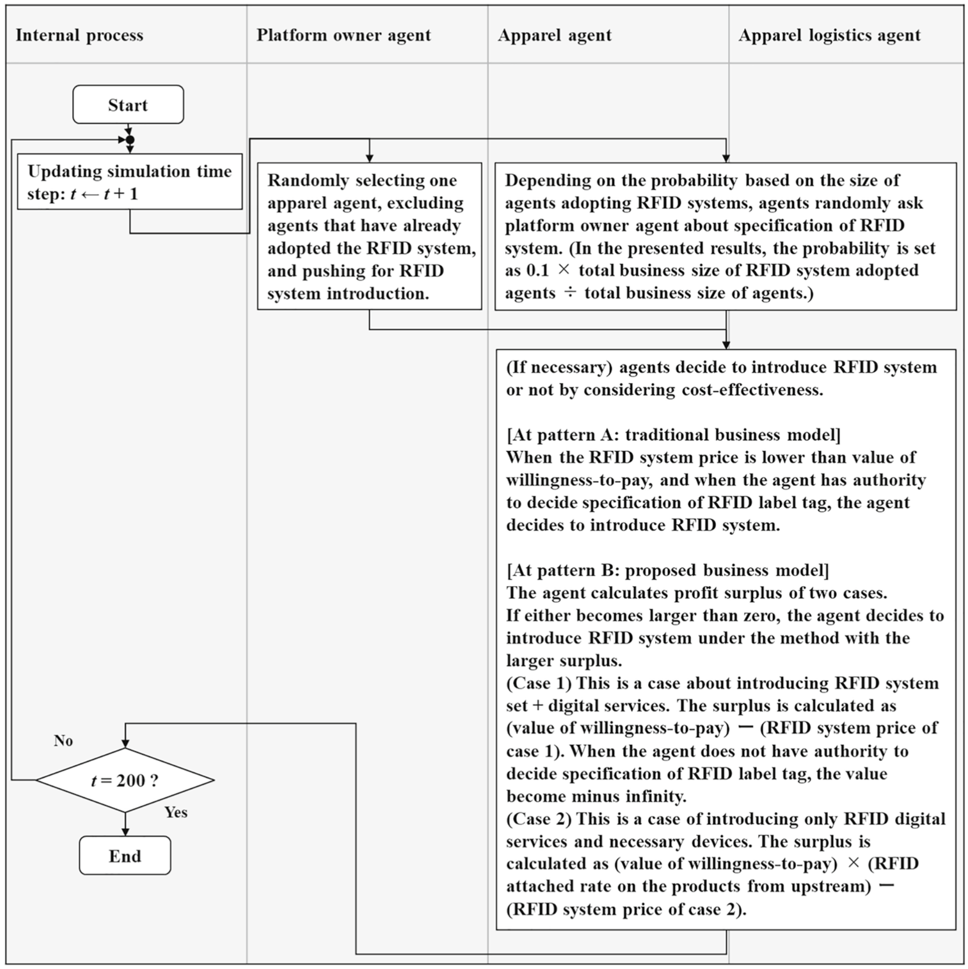
of the RFID-based platform system at 17.5 million JPY (about 160,000 USD at that time). In accordance with the actual situation, in this pattern, agents, which cannot determine the specification of the apparel label tag, cannot introduce the RFID system. In "pattern B," we set the price of the RFID-based platform system at 15.0 million JPY (about 135,000 USD at that time). In this pattern, the agents, which cannot decide the specification of the apparel label tag, can use the RFID digital services by paying 5.0 million JPY (about 45,000 USD at that time) if they received products embedded with the RIFD label tag from the upstream of the supply chain. In the experiment, we considered the following three evaluation indicators: (a) number of agents adopting the RFID system or services; (b) the total sales of the platform owner agent; and (c) total surplus of agents excluding the platform owner agent. The surplus is calculated as the willingness-to-pay (= maximum investable rate of the agent to resolve problems for RFID × sales proportion of the agent-related apparel business) minus the price of the RFID system or services. The experiment was repeated 50 times, and the mean values of each indicator were calculated.

Fig. 8 Structure of an agent-based simulation



(a) Agent parameter setting stage

Fig. 8 (continued)



(b) Main simulation stage.

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Data Availability The data are not publicly available due to restrictions. However, the data are available from the authors upon reasonable request and with the permission of Fujitsu Frontech Ltd. (FTEC).

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