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Applying Business Ecosystem Analysis Methods into Edge Computing Device Business for E-Solutions

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Abstract

In recent years, the importance of E-services incorporating concepts such as IoT (Internet of Things), digital twin, CPS (Cyber-Physical System) and so forth has increased. There, in addition to cloud computing, edge computing on the terminal equipment is becoming essential. For semiconductor companies, this situation might be a business opportunity to transform or transit from the traditional business model to a business model suitable for the edge computing device business. There, it is necessary to form a healthy business ecosystem with various stakeholders. In this article, we briefly illustrate our proposed business ecosystem analysis methods that are (1) business boundary analysis method and (2) business ecosystem stakeholder analysis method. Then we apply them to an actual business case of edge computing device business, in order to confirm effectiveness of them.

1 Introduction

In recent years, the importance of E-services incorporating concepts such as IoT (Internet of Things), digital twin, and CPS (Cyber-Physical Systems) (Stankovic, 2014; Rajkumar, 2010) and so forth has increased. In other words, not only information input by humans, but also huge amount of data could be acquired from sensors on physical devices, and new knowledge is able to be derived by performing big data analysis. Then, based on derived knowledge, new E-services such as automated operation control of equipment under highly flexible contexts or maintenance based on failure sign diagnosis, could be planned and provided. It is necessary to transmit a large amount of data to the cloud site for the process of deriving new knowledge. However, generally, for providing services based on the obtained knowledge once, it could be processed by edge computing on a terminal equipment site. Excellent edge computing technologies would lead to reduction of data traffic, bandwidth cost and improvement of responsiveness, data safety, privacy, and so forth (Shi, 2016).

Therefore, in addition to cloud computing, edge computing on the terminal equipment is becoming essential.

Such changes in the business environment might be a business opportunity for semiconductor companies. Semiconductor companies would transform or transit from their traditional business models to those suitable for the edge computing device business. In such new business model, it would be necessary to build a healthy business ecosystem with various stakeholders.

The concept of business ecosystem regards the business network, which is the relationship among stakeholder companies, as analogy of ecosystem of the natural world. And it is understood that maintaining the health of the business ecosystem is the essential key to coexist and to co-prosper for companies participating in the business ecosystem. Iansiti et al. classified the stakeholder companies that consist the business ecosystem into keystones, landlords/dominators, and niche players, then identified the possible strategies (Iansiti, 2004). However, their study was based on surveys of business cases, therefore it does not include any methods or tools to build healthy business ecosystem. Kubo et al. proposed five frameworks as a method of planning a business ecosystem strategy, and confirmed the validity of the frameworks in a case study of the photovoltaic power generation business (Kubo, 2018). Moreover, Kubo et al. applied these frameworks into agribusiness and planned an ecosystem strategy for agribusiness (Kubo, 2019). However, in these studies, proposed frameworks or methods seem to be implicitly supposed that for creating new business rather than for transformation or transition business model based on current business model. On the other hand, Okada et al. has proposed the method to support transformation or transition of business model, based on system dynamics simulation techniques (Kimata, 2020; Okada, 2020). However, these studies have less considered the business ecosystem yet.

In this article, we briefly illustrate our proposed business ecosystem analysis methods that are (1) business boundary analysis method and (2) business ecosystem stakeholder analysis method. Proposed these two methods could be applied as pre-analysis, before using Kubo's frameworks and/or Okada's simulation method. In section 2 and 3, business boundary analysis method and business ecosystem stakeholder analysis method are briefly discussed respectively. In section 4, we sequentially apply these both methods to an actual business case of edge computing device business, rather than separately such as previous studies (Sekiguchi, 2021a,b) and discuss the applying results, in order to confirm effectiveness of them. In the final session, we summarize the conclusions.

2 Proposal of Business Boundary Analysis Method

In this section, we briefly illustrate our proposal of business boundary analysis method (Sekiguchi, 2021a), based on Fujimoto's theory of product architectural positioning strategy (Fujimoto, 2002).

2.1 Fujimoto's Theory of Product Architectural Positioning Strategy

In Fujimoto's theory of product architectural positioning strategy, product architecture is classified into modular type and integral type. As shown in Fig. 1, according to the relationship among the product function and the product structure that realizes the product function, a product with almost one-to-one relationship (for example, a personal computer) classifies into a modular type architecture, and a product with many-to-others relationship (for example, an automobile) classifies into an integral type architecture.

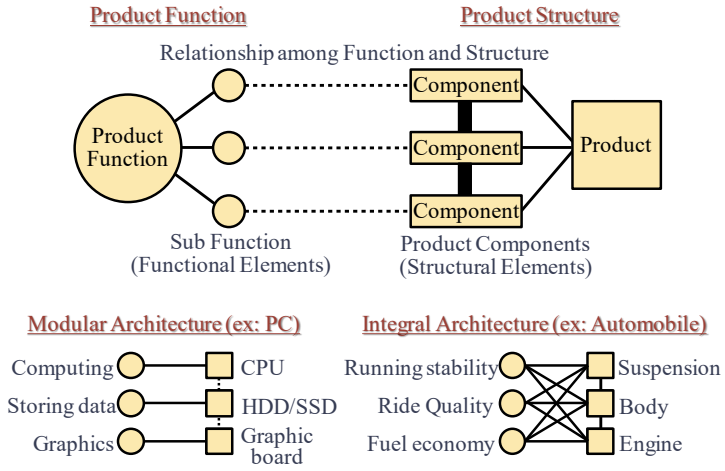

Figure 1: Product architecture types in Fujimoto's theory of product architectural positioning strategy

Furthermore, as shown in Fig. 2, it is classified into four types of product architectural positioning strategies according to the combination of the product architecture type of the customer's product and the architecture type of the own company's product. Fujimoto has pointed out that Japanese companies tend to take Integral-inside-integral-outside strategy however it would be desirable to shift to Integral-inside-modular-outside strategy or Modular-inside-integral-outside strategy.

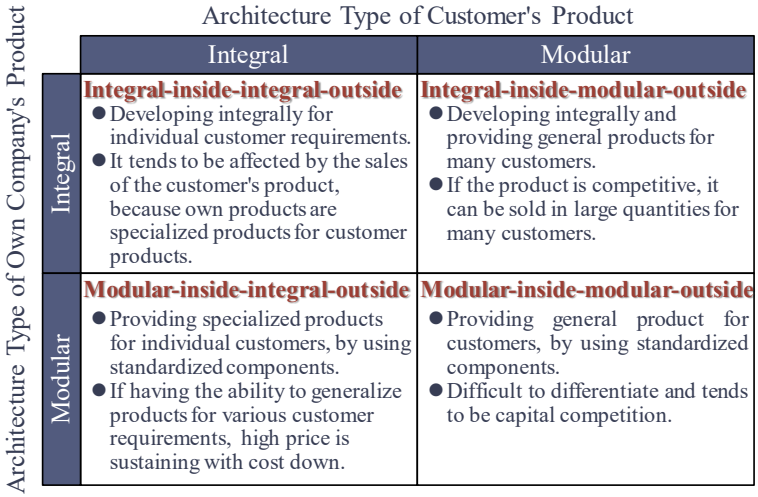

Figure 2: Product architectural positioning strategies

2.2 Understanding the Decline of the Japanese Semiconductor Industry through Product Architectural Positioning Theory

Here, based on Fujimoto's theory of product architectural positioning strategy, we will briefly interpret the decline of the Japanese semiconductor industry in which the first author of this article has worked for about 50 years. In the era when the Japanese semiconductor industry was at its peak, the competitiveness of semiconductor companies was, as shown in Fig. 3, based on integral

design/manufacturing technologies in multi-stages. It had been quite difficult for latecomers to obtain the integral design/manufacturing technology. It works a barrier to entry.

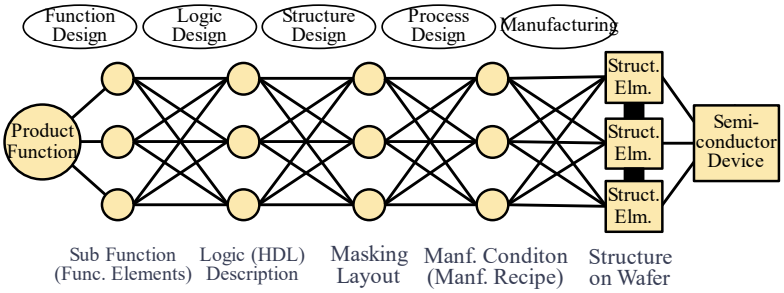

Figure 3: Semiconductor product architecture and integral design capabilities of semiconductor companies

However, semiconductor manufacturing equipment manufacturers, EDA (Electronic Design Automation) tool vendors and so on, have gradually acquired the integral design/manufacturing technologies and have embedded them into their own products, shown in Fig.4. Therefore, it has become possible for latecomers to design and manufacture semiconductor products relatively easily by purchasing semiconductor manufacturing equipment, EDA tools and so on, for latecomers. As a result, the domestic semiconductor companies have lost their competiveness and have declined.

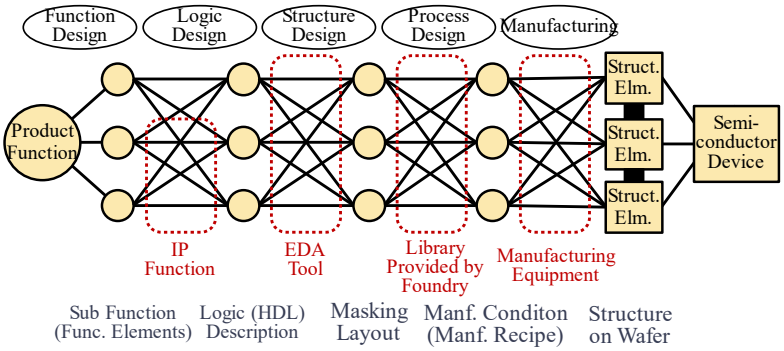

Figure 4: Spilling-out of integral design capabilities from semiconductor companies

In other words, the integral design technologies are the origin of competitiveness, and it is thought that the companies that have grabbed the integral design technology will become more competitive, on the other hand, the companies that have been deprived of it will decline.

2.3 Business Boundary Analysis Method

As shown in the previous section, in order for a company to become more competitive, it is critical how to incorporate the integral design technology. Considering with that, the proposed business boundary analysis method consists of the steps as follows:

Step 1: Identifying integral design technologies on the supply/value chain

Step 2: Evaluating compatibility between integral design characteristics and integral design capabilities owned

In Step 1, we will identify the existing integral design technologies that produce competitiveness on the supply/value chain around the subject company. Figure 5 shows the typical location of the

integral design technologies. In the case of a self-contained type, it has an integral design technology within the company (Fig. 5 (1)), and would be ready to build a new business ecosystem. In the case of supplier collaboration type (Fig. 5 (2)), there is a risk of losing competitiveness if the capability of integral design technology is deprived to the supplier companies as described in Section 2.2. Therefore, it is desirable to take the integral design technology that spans supplier companies into the subject company. In the case of customer collaboration type, the competitiveness of the subject company would be able to strengthen if the integral design technology can be incorporated into the subject company (Fig. 5 (3), from(a) to (b)). In the case of customer & complementary company collaboration type, there is a relatively high opportunity that the customer company's integral design technology can be incorporated into the subject company through technical alliance with complementary companies or internalization through M&A (Fig. 5 (4), from (a) to (b)).

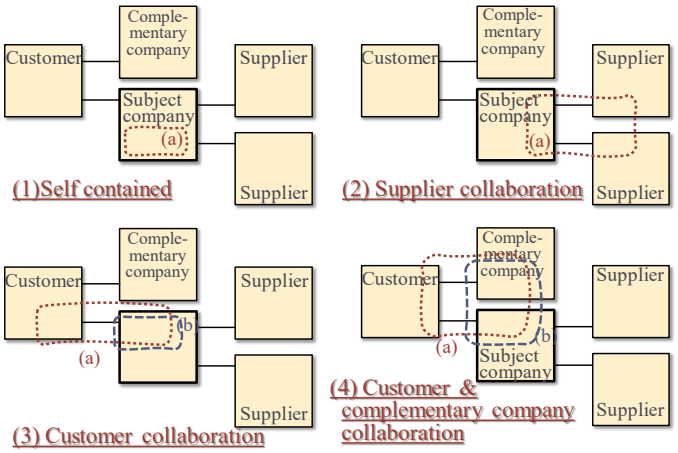

Figure 5: Integral design technologies among companies on supply/value chain

In Step 2, we will evaluate the compatibility between integral design characteristics and integral design capabilities owned. We suppose that there are two types in integral design technologies, such as social integration and physical integration, then the capabilities to resolve them are different as characteristics. Fig. 6 shows the example of weight of social integral design and physical integral design on the hierarchy of product systems. In general, higher level system (system of systems) has characteristics of more social integration than physical integration. Therefore, the compatibility between integral design characteristics and integral design capabilities owned should be evaluated.

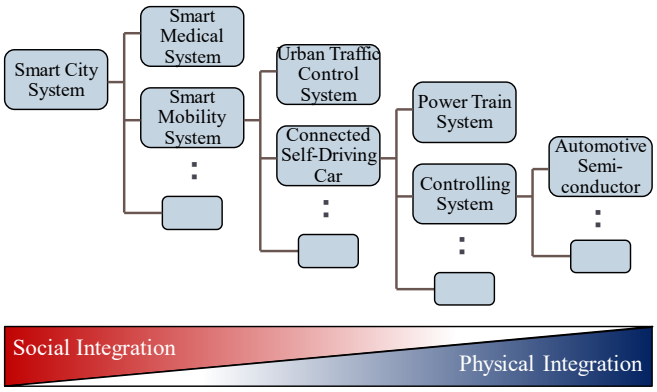

Figure 6: Weight of characteristics of social integration and physical integration on the hierarchy of products

3 Proposal of Business Ecosystem Stakeholders Analysis Method

In this section, we briefly illustrate our proposal of business ecosystem stakeholder analysis method (Sekiguchi, 2021b).

3.1 Stakeholder Analysis of Stakeholder Management in General

According to a systematic literature review (Pedrini, 2019), despite the increasing use of theory, a limited number of studies have discussed ways to develop, execute and measure the results of using this strategic approach with stakeholders. As business model transformation or transition would generally have performed by projects or programs, the theory and process of project stakeholder management (Eskerod, 2015; Mashali, 2020) has been discussed a lot in the field of project management. Stakeholder management process in project management has been defined as a portion of international standard ISO 21500 (Zandhuis, 2013), as follows: (1) Identify stakeholders (located in initiating process group) and (2) Manage stakeholders (located in implementing process group). In "identifying stakeholders" step, individuals, groups and/or organizations those affect project or are affected by project, are identified and documented into stakeholder register. In the subsequent "stakeholder management" step, we will properly understand the needs and expectations of stakeholders and resolve issues.

3.2 Stakeholder Analysis Method for Business Ecosystem

In general, the stakeholder companies that compose a business ecosystem make decision by themselves to participate in specific business ecosystem. And also it is free to leave the business ecosystem and to move into another business ecosystem. In other words, in addition to the general and conventional stakeholder management or stakeholder analysis (as shown Fig. 7 (A)) which identifies stakeholders, clarifies their interests and seeks the optimal solution based on them, new concepts are desired to analyze the stakeholders for planning the business ecosystem. That is a concept (shown in Fig. 7 (B)), as first identifying the possible frames for mutual complementary (win-win) relationships with stakeholders in the business ecosystem, then clarifying what is the value of participation from the viewpoints of stakeholders. And, considering what the subject company should do for stakeholders in order to facilitate their participation in the business ecosystem.

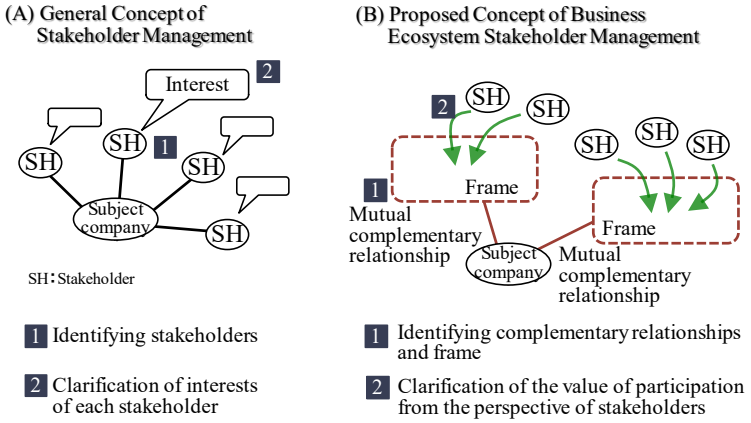

Figure 7: General concept and proposed concept of business ecosystem stakeholder analysis

We extracted mutual complementary relationship patterns among with stakeholders and organize them, in order to identify complementary relationships and frames from a wide range in business ecosystem stakeholder analysis. Such organized patterns and their utilization is called pattern language or design patterns, and has been studied in various domains such as architecture (Alexander, 1977), software (Gamma, 1995) and so forth. Here, based on both extensive surveys of business cases and practical experience of authors of this article, we have extracted and organized the stakeholder complementary relationships into nine types of patterns. Below is an overview of the nine patterns.

(1) Basic supply chain (not only materials but also including manufacturing equipment, etc.)
(2) Quantitative complementation of in-house capacity (production capacity)
(3) Quantitative complementation of in-house ability (sales capacity)
(4) Synergistic effects with complementary products/service providers
(5) Building access channels to new markets
(6) Fostering and strengthening relationships with providers of scarce resources/capabilities
(7) Utilization of business infrastructure/platform services
(8) Creation of a business opportunity (permission of business)
(9) Financing

Some of the nine patterns of stakeholder complementary relationships are shown in Fig 8 by using CVCA (Customer Value Chain Analysis) (Donaldson, 2004) notation. It explicitly describes the flow of products/services, money (here, as '$' symbol) and information (here, as '!' symbol).

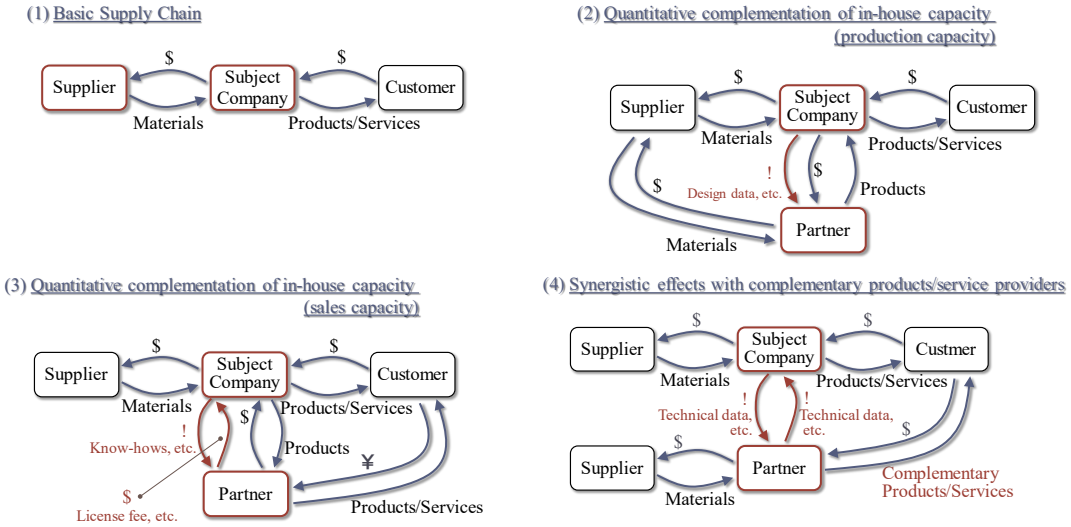

Figure 8: Patterns of stakeholder complementary relationships (some portions)

Considering with previous discussions, we have proposed the business ecosystem stakeholder analysis method which consists of the three steps as follows:

Step 0: Analyzing business boundaries by using our method proposed in section 2, if needed
Step 1: Identifying possible stakeholder complementary relationships
Step 2: Clarifying the values for stakeholders to participate into the business ecosystem
Step 3: Planning promotion measure/actions for stakeholders' participation

In step 1, we will identify the possible stakeholder complementary relationships and frames by employing patterns of stakeholder complementary relationships. Nine patterns could make us easily

identify relationships with stakeholders that have not been aware yet. Also, by classifying known stakeholders into the patterns, any mutual complementary relationships that are insufficient considerations, could be revealed.

In step 2, we will clarify the values for stakeholders to participate into the business ecosystem. Each type of stakeholder complementary relationship patterns abstractly shows the values or expectations of collaborative partner companies, however we would have to further materialize and clarify them while assuming a specific business model. If possible, it is desirable to proceed while involving potential stakeholder candidates. In this step, it would be considered that the conventional stakeholder analysis method also could be utilized.

In step 3, promotion measures/actions, which could be conducted by subject company, for facilitating stakeholders' participation will be planned in detail.

4 Applying Proposed Methods into an Actual Business Case

In this section, we apply proposed business ecosystem analysis methods, that are business boundary analysis method and business ecosystem stakeholder analysis method, into the actual business case of Japanese semiconductor company R. In recent years, the importance of E-services incorporating concepts such as IoT, digital twin, CPS and so forth has increased. There, in addition to cloud computing, edge computing on the terminal equipment is becoming essential. Such changes in the business environment might be a business opportunity for semiconductor companies. Semiconductor companies would transform or transit from their traditional business models to those suitable for the edge computing device business. In such new business model, it is necessary to build a healthy business ecosystem with various stakeholders.

As step 1 of business boundary analysis method, we identify integral design technologies. Not limited to PCs, digital tablets and/or smartphones, advanced digital technologies are beginning to be embedded into any products such as manufacturing equipment, medical equipment, automobiles, home appliances and so forth. In such a digitized equipment, the state of the equipment itself and the environment is observed by sensors on the equipment, and if needed, communicate with the cloud site, and digital processing is performed to control the actuators on the equipment. There, analog semiconductor technology for observation, power semiconductor technology for driving actuators are required. And of course digital semiconductor technology is essential. Therefore, the importance of integral design technology of all three semiconductor technologies is rapidly increasing. This is a Fig.5 (4): Customer & complementary company collaboration type. We are able to analyze that company R which has strength for digital semiconductors, should grab the integral design technology in collaborate with the companies specialized at analog semiconductors and power semiconductors. Next, in step 2 of business boundary analysis method, integral design technology for digital, analog, and power semiconductors, is typical physical integration rather than social integration. It would be analyzed that this characteristic is well compatible to company R's integral design capability. Actually, company R has made several M&As in order to strengthen the analog and power semiconductor technologies, since 2017.

After consideration of business boundary analysis method, as step 1 of business ecosystem stakeholder analysis method, we identified possible stakeholder complementary relationships for company R. The result is shown in Table 1. R-car consortium and R-IN Consortium are the consortiums which have been led by company R from before. From this analyzing result, it has been revealed that there are insufficient considerations for several patterns of possible stakeholder complementary relationships, even though company R has made the consortiums to collaborate stakeholders.

Table 1: Possible stakeholder complementary relationships

Patterns of stakeholder complementary relationship	Mapping of corresponding stakeholders in a business case	
(1) Basic supply chain	Material suppliers, Manufacturing equipment venders, etc.	
(2) Quantitative complementation of in-house capacity (production capacity)	Foundries	
(3) Quantitative complementation of in-house capacity (sales capability)	**R-CAR Consortium** (E) Engineering/Manufacturing Firms (F) System Integrators (G) Consulting Firms	**R-IN Consortium** (N) Contract Based Developers (O) System Integrators/Consulting Firms
(4) Synergistic effects with complementary products/service providers	**R-CAR Consortium** Providers of (A) Middleware/Application (B) OS (C) Development Environment/Tool (D) LSI	**R-IN Consortium** Providers of (H) Board/Development Kit (I) Development Environment (J) OS (K) Protocol (L) Middleware (M) Application Software
(5) Building access channels to new markets	(Highly important but insufficient consideration)	
(6) Fostering and strengthening relationships with providers of scarce resources/ capabilities	(Highly important but insufficient consideration)	
(7) Utilization of business infrastructure/ platform services	(Relatively important but insufficient consideration)	
(8) Creation of a business opportunity (permission of business)	(Important in some domains such as autonomous driving technology, but insufficient consideration)	
(9) Financing	Financial companies (especially financing for M&A)	

Furthermore, the first author of this article has conducted step2 and step 3 of business ecosystem stakeholder analysis, however it is impossible to disclose the result of analysis because it is an analysis of current strategy in actual company. Therefore, a series of interview and/or questionnaire surveys to confirm the effectiveness of our proposed method and the result of the analysis, has been conducted. In interview and/or questionnaire surveys, several experts of various roles in semiconductor business had answered. The portion of interview surveys results is shown in Table 2.

From those results, we can see many experts evaluated that the proposed methods are effective to understand and organize the stakeholders' relationships from a bird's-eye view. Also they evaluated the advantages that the nine patterns could make clear the lack of considerations about relationships among stakeholders. Not only from the strategic headquarters, sales department, software department, etc. of subject company, but also from the managers of stakeholder companies, the evaluations are generally well. In addition, as comments, we have obtained important suggestions as follows: (1) the complexity of reality; (2) the asymmetry of information among stakeholders and subject company; (3) the necessity of guidelines for analysis and indicators for monitoring; and (4) the necessity of department for stakeholder management. Those would be future studies.

Table 2: Result of interview surveys

	Reviewers	Reviews for Effectiveness of Proposed Method	Comments
A	(Former) General Manager of Strategy Headquarters	Recently, there are many business issues that cannot be addressed by the activities of a single company, and the number of corporate collaborations has increased significantly. So, it is meaningful to systematize from an academic point of view.	I would like you to propose which complementary relationship pattern should be applied as a corporate behavior, and what are the guidelines and indicators for making that judgment.
B	(Former) Senior Manager of Sales Department	Efforts so far have focused on some of the complementary relationships, and it has not been possible to look at stakeholders in these patterns. I think it is necessary from now on.	We have to establish a department to think about these things. I realized that we needed someone to control the point of stakeholder relationship.
C	General Manager of Software Department	I've never seen such a framework. The current efforts are unintentional. It is necessary to take a bird's-eye view and then break down. We can understand the points to be discussed by applying this method.	
D	(Former) Business Executives	Geopolitical risk is the number one issue in business, behind the environment, human rights, and the SDGs. Recommendations for building a future ecosystem that goes beyond risk are valuable.	Although various studies are being conducted by industry, academia and government, I think that we have not yet been able to propose specific measures more than general caution. If it is a proposal for building an ecosystem in the future that goes beyond risk, I would like you to lead everyone.
E	Semiconductor Engineer (Highest Professional Level)	As organised, easy to understand. I've never seen anything systematic like this before. By applying this method, it became clear that we have not strategically involved the stakeholders. We can see which piece is missing. Candidates are also easy to find.	Regarding the supplier part, the structure is becoming more complicated, so please organize it in more detail. I think it would be interesting to include a competitor.
F	Semiconductor Engineer (Highest Professional Level)	Reality shows a complex aspect. Applying this method reveals the problems of traditional strategies. Even if you are actually considering it, it is meaningful to organize and show it as a framework. Tacit knowledge does not make progress.	
G	Business Exective of Stakeholder Company	Until now, I think that I have rarely considered a strategy based on the idea of complementary relationships between stakeholders. In particular, I realized that it is effective to promote the idea of co-creation in the development of new products and new technologies in order to realize innovative businesses.	The environment surrounding the semiconductor business is complicatedly intertwined, and it can be said that we have to dig into further by using CVCA (Customer Value Chain Analysis).
H	(Former) President of Stakeholder Company	Thinking with nine patterns is easy to think because it covers the whole.	When conducting such an analysis, I'm concerned about the asymmetry of information (that is, there is a lot of information that is not disclosed). Therefore, it is doubtful whether the target area can be created well. It would be interesting to include more customer issues.
I	Senior Manager of Stakeholder Company	I think each company individually understands the patterns of complementary relationships when considering the relationship between its own company and its stakeholders.	I would like to know what kind of criteria should be used in order to determine and execute for effective complementary relationships.

5 Conclusions

E-services with various physical equipment are becoming more important. In such E-services, not only cloud computing but also edge computing would be essential. Those changes might be a business opportunity for semiconductor company to transform or transit their business model into suitable one

for edge computing device business. There, it is necessary to form a healthy business ecosystem with various stakeholders.

In this article, firstly we briefly illustrated our proposed business ecosystem analysis methods that are (1) business boundary analysis method and (2) business ecosystem stakeholder analysis method. Business boundary analysis method consists of two steps as follows: Step 1: Identifying integral design technologies on the supply/value chain; and Step 2: Evaluating compatibility between integral design characteristics and integral design capabilities owned. Also, business ecosystem stakeholder analysis method consists of three steps as follows: Step 1: Identifying possible stakeholder complementary relationships; Step 2: Clarifying the values for stakeholders to participate to the business ecosystem; and Step 3: Planning promotion measures/actions for stakeholders' participation.

In this article, next, we sequentially applied our proposed business ecosystem analysis methods to an actual business case (Japanese semiconductor company R) of edge computing device business, in order to confirm effectiveness of these methods. However, it is impossible to disclose the result of analysis because it is an analysis of current strategy in actual company. Therefore, a series of interview and/or questionnaire surveys to confirm the effectiveness of our proposed method and the result of the analysis, has been conducted. In interview surveys, several experts of various roles in semiconductor business had answered. From the results, we can see many experts evaluated that the proposed methods are effective to understand and organize the stakeholders' relationships from a bird's-eye view. Not only from the strategic headquarters, sales department, software department, etc. of subject company, but also from the managers of stakeholder companies, the evaluations are generally well. Therefore, we would be able to conclude that our proposed business ecosystem analysis methods are effective to analyze the stakeholders in order to build the new business model with the healthy business ecosystem.

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