Factors Influencing Establishment and Changes to the System Architecture of Industry-University-Government Alliances

Youngjae Koh

***Abstract*—This paper analyzed the co-opetitors' (suppliers, customers, complementors, and alliance partners) influence on the definition and changes to architecture by examining the development of technological systems in Industry-University-Government alliances (IUG alliance) before industrialization. The approach is combined with the insights from a case study into managing the Next Generation Energy and Social System Demonstration Project in Japan based on the IUC alliance.**

From the analysis this paper finds that the technological architecture types are different depending on the technological development stages, notably, the technological logic in early stage, technological capability, stability and the opinions and knowledge of alliance members in development and refinement stages. This paper also discusses effect of the effectiveness and efficiency for the mass production in the final stage to the type of architecture.

In*dex Terms*—Architecture innovation, changing the type of architecture, influential factors, alliance.

I. Introduction

Technology architecture specifies the design rules around functionality, and how these are organized and connected in a product or system [1]-[3]. However, good architecture can be hard to identify ([4]) at a specific phase and indicate the factors affecting its value. As [2] demonstrated in a case study, setting and changing the technology architecture depends on the technological logic itself and the firm's strategy with respect to outsourced firms. Additionally, as [5] indicated, a single product in development depends on the firm's technology and the customer needs.

Thus, determining and changing the technological architecture, while not a given, is affected not only by technological logic but also co-opetitors' (suppliers, customers, complementors, and alliance partners) capability and opinions. Therefore, the firm's technological direction is affected by participators who must collaborate and compete with [6]. From this background, this paper focuses on determining and changing factors for technology architecture, including technological logic and co-opetitors' influence, such as alliance partners who can potentially change market competition [7], [8].

Previous literature illustrates the potential of architecture as the framework indicating cooperation with others [2]. Reference [9] states that type of architecture depends on the development phase focusing on the phase and the individual firms.

Aside from examining the influence of co-opetitors, this study investigates the development phase and its influence on the definition and changes to architecture by examining the development of technological systems in Industry-University-Government alliances (IUG alliance) before industrialization. The approach is combined with the insights from a case study into managing the Next Generation Energy and Social System Demonstration Project in Japan based on the IUC alliance.

The next section reviews the previous literature to clarify the research questions before presenting the case study and discussion.

II. Previous Literature

A. Technological Determinism

The previous literature related to 'hard technological determinism' or 'a crude form of technological determinism' have been supported that technological development influences society or participants in technology development in only one way, so neither party can change the technology [10], [11]. Previous literatures argued this point by suggesting that technology has its own logic and changes itself [10], [11].

Given such opinions, [9] showed how the firm can fail in terms of market competition, for example problems with implementing incremental innovations. Reference [9] explained that in the early stages of the technological innovation, it is hard to recognize the innovation is accompanied changing architecture. This is because in the early stages, information about the how elements of a product system combine to move with other elements. Therefore, the interactions between components, the type of development of the technology related with the product tends to take an integral[1] type of the architecture.

In this case, firms aiming for innovation must engage in complex coordination with other firms.

However, a refinement of product or systems with the integral architecture improved technological performance,

Manuscript received December 19, 2015; revised March 13, 2016.

Y. Koh is with the Hirao School of Management at Konan University, Hyogo, Japan (e-mail: youngjae0310@gmail.com).

[1]The type of technology forming integral architecture is not well defined in terms of the technical information about how the different elements of a system work together and the interactions between the elements. New technology may offer tremendous improvements in performance, cost, and requirements for other elements to transform promising ideas into a commercial product, though it must adapt to realize this potential [9]. In contrast, modular technology uses components that simply plug into existing architectures without a hitch [9], [12].

doi: 10.18178/joebm.2016.4.5.423

reduced costs, and deepened the technical knowledge with the competition in the industry and it moves to the modular architecture. In the modular architecture stage, the technical information about the interdependency of elements and connection rules between components are well defined and widely known. Through this process, one of the rules components is selected and becomes the standard, or the dominant design [9], [13].

However, as with automobile emissions controls in the 1970s in Japan, technology innovation is controlled not only by technological logic [14], other studies demonstrate the effect of social and political factors [15], [16]. This is called the social construction of technology.

B. Social Construction of Technology

In terms of factors affecting innovation, the social construction of technology framework can serve as a reference. Reference [17] indicated that technological and economic, social, and political factors influence technological innovation. In the early stage of innovation, the determination or changes in technology will be influenced by sociological and political factors due to unstable technology and competition. Thus, after a dominant design emerges, the economic and technological factors begin to exert great influence upon technology development.

Furthermore, [16] showed the mechanism by which sociological and political factors affect technological innovation by demonstrating that interpretative flexibility and closure (rhetorical closure and closure by definition of the problem). Earlier means to evaluate technology have been determined objectively, and vary by interpretations of different social groups. The latter method demonstrates the correctness of a group's opinion with socially embedded phrases indicating that the conflict has been resolved. The sociological point of view suggests factors that potentially lead to technology innovation, however, the question remains related to whether to the technological architecture innovation. In other words, content of the technology innovation is still a black box from the early stage to the final stage which is thinking about mass production. Therefore, the purpose of this paper is to clarify this question.

As [12] illustrated, knowledge accumulation related to technology both encourages incremental technological innovation and architectural innovation, as long as it influences a firm's success or failure. As reference [17] analyzed it related to technological determinism. On the other hands as reference [16] analyzed the social construction of technology also affects to direction of the innovation. From this point of view, this paper refers the framework of technological determinism and social construction of innovation on each stage of innovation.

The next section explains the research method and the process of technological architecture change in the Next Generation Energy and Social System Demonstration Project in Japan based on an IUC alliance.

III. Case Analysis

The analysis uses interview data from Yokohama city, Kitakyushu city and JX Nippon Oil and Energy (hereafter, JX).

A. Tests on a Smart Grid System in Japan

In Japan, the smart-grid system demonstration tests are called the Next-Generation Energy and Social Systems Demonstration Project and have been performed in Yokohama, Kansai Science City, Toyota, and Kitakyushu cities. In Japan smart-grid demonstration test the funding is comprised of government subsidies, which amounts to two third of the total, with the remainder provided by each participant.

This project started with the aim of reaching the target CO_2 reductions outlined in the Kyoto Protocol and it was implanted between April 2010 and March 2015.

This study examines tests in ordinary houses, commercial facilities including buildings (Building Energy Management System, hereafter, BEMS), schools, public facilities, electric vehicles (EV), and community energy management systems (CEMS). The project includes at least 25 participants in Yokohama and at least 34 in Kitakyushu as of 2012.

This paper analyzes one participating firm, JX, which assisted in developing Home Energy Management Systems (HEMS) in Yokohama and transportation in Kitakyushu cities.

B. Organization Promoting Demonstration Tests in Yokohama city

The Next-Generation Energy and Social Systems Demonstration Project Promotion Council is organized in Yokohama. Table I outlines the organizational structures, which were established in 2010 when the city was selected as a demonstration areas for the project.

TABLE I: YOKOHAMA SMART CITY PROJECT PROMOTION COUNCIL

Promotion Council	
Chair: General manager, Yokohama City Members: Related firms	
Promotion Committee	General manager in Yokohama; representatives of working groups; and related firms
WG	**HEMS, BEMS, CEMS, EV**
WG Leader	Toshiba
Participating Firms	Panasonic and other firms

Source: Interview data material (Yokohama City, 2013) from July 12, 2013 and Japan Smart City Portal (http:// jscp.nepc.or.jp)[18].
*WG: Working Group, the set of firms working on the same theme.

The Yokohama Smart City Project (YSCP) Promotion Council shown was established to promote the Next-Generation Energy and Social Systems Demonstration Project. The council contains four working groups (WGs): HEMS, CEMS, BEMS, and transportation. Due to space limitations in the paper, Table I shows only the name of the project (ex. EV) and the each projects not to mention about participated firms and organizations.

C. Purpose of JX in the Project and the Early Stage Architecture Formation in Yokohama City

JX participated in the Next-Generation Energy and Social Systems Demonstration Project because of the movement to decentralize energy. In association with the demonstration project, the firm aimed to solve problems associated with the mass introduction of solar power and promoting the solar and fuel cell businesses. Thus, the project requires a technological structure as well as the capacity to introduce renewable energy sources, such as solar power, and more specifically a hierarchical system to introduce components. As such, CEMS host system was established to bring together HEMS, BEMS, and EV under the one structure to create an entire regional energy management system. It organized connecting each system with the CEMS that placed at the top of the structure. Toshiba Co, Mitsui Fudosan Residential Co., Ltd (hereafter, MFR), and JX were responsible for developing individual HEMS systems in Yokohama city.

In this way, the early stage of the Next-Generation Energy and Social System architecture adopted a modular structure in terms of technological logic.

Having said this, it should be noted that the operation of this system, at this early stage, is in fact a coordinated by the participants themselves with the integral type. The individual members (WGs) meet on a weekly basis to make any necessary adjustments to the project. This means there would be the stage the technological architecture and the operational coordination architecture are different.

This means the technology architecture is modular type though, the operational coordination type is still integral one at the early stage of the system development.

D. Architecture Formation for HEMS in Yokohama City

The program in Yokohama City's household sector is broadly divided into two parts: demonstration tests mainly using an Electricity Demand and Response (DR) method, and the other involved with installing HEMS. JX participated in both.

The test in Yokohama by JX has been performed using firm house of JX 16 dwellings and Tokyo gas 24 dwellings.

The DR demonstration test was implemented from 2012, mainly confirmed and it confirmed the electricity consumption peak cutting.

The demonstration of HEMS was achieved by the Mansion Energy Management System (hereafter, MEMS), it approaches low-carbon through advanced energy saving control and demand response control system. The main firms participating in the test were Toshiba Co, MFR, JX.

The contents of the business that each firm are responsible as follow.

1) MEM equipment and server development: Toshiba Co.
2) Building a technology demonstration filed: JX
3) Construction of demonstration filed: MFR
4) Verification of the validity by simulation with real data: Toshiba Co., MFR, JX.

The system development on the Next-Generation Energy and Social Systems Demonstration Project started in fiscal year of 2011, the verification for checking the connection with CEMS promoted in fiscal year of 2012. Additionally, as the Table II indicates each firm has responsibility to develop and adjust individual system on 2013.

This means the technology architecture in the stage of the system development and refinement, the type of its architecture as a whole system is modular one. Some of participators are invited because of their capability to develop special component or the system, though it is efficient to clarify the scope of responsibility and to leave it to each firm. The interviewer of the JX placed themselves as the firm who combine several devices and provide service as effectively.

TABLE II: THE ROLE OF THE FIRMS AND PERFORMANCE OF HEMS IN YOKOHAMA CITY

	2011	2012	2013
Toshiba Co.	A)Development MEMS equipment & Server	A)Development MEMS equipment & Server B)Verification validity by simulation (checking operation of each device to the DR command from the CEMS	A)Development MEMS equipment & Server B)Demonstration of efficacy by dwelling data
JX	A)Development of equipment that connect to the CEMS	A)Verification validity by simulation	A)Implementing the verification of energy saving effect with MEMS by collecting data from HEMS
MFR	A)Introducing the data collaboration enabled system connected with CEMS	A)Verification validity by simulation	A)Implementing the verification of energy saving effect by MEMS by collecting data from HEMS

(Source) The interview to the JX (2015/03.

However, as the JX interviewer said the process to make the connecting interface with CEMS and to make the operation each devices to the DR command from CEMS is as similar to make coordination in the integral system.

This is because the infrastructure of the information system to connect with CEMS needs the information sharing, though the system was developed as the type of modular system it needs frequent meeting and takes time to know each device and making a whole system[2].

Until the technology of the system becomes stable the coordination architecture is shaped as integral one. This operational coordination type is keeping even if the participator did not want to open their capability and technology for fear of outflow of information.

In addition to that, the operational coordination type on the period of the development and refinement stage still integral, even the architecture as a technological system is modular type. For making stable and connecting the each component it is necessary to share information about each component functions and specification frequently as a whole system.

On the last stage to development, firms checked the each device whether running as they expected. As the interviewer of JX said after the system connection become stable their meeting was implied rarely with vendor and Toshiba Co. when compare with in the early stage of the development that time they have the meeting once or twice in every week.

This means not only each component's technological

[2]The interview to the JX on Mar. 2015.

logic but also stabilization as the system affect operational coordination architecture. In this process as the system becomes technically stable, meetings for connecting among WG are reduced.

E. Architecture Formation for Transportation in Kitakyushu City

The program in Kitakyushu city is called Kitakyushu SC (Smart city) project. In that project JX carried out demonstration experiment as one of the transportation WG member as bellow Table III indicated.

TABLE III: THE ROLE OF THE FIRMS AND PERFORMANCE OF THE TRANSPORTATION AREA IN KITAKYUSHU CITY

	2011	2012	2013
NEC	The development and the production of Battery and Charger Integration System (BCIS)	Connecting to the CEMS. strength of the operation of service, the repair equipment and the function of energy management	
JX	The test facility for carrying out a verification test of BCIS	Quantitative evaluation of peak cut effect by the BCIS	To construct of management structure and the evaluation of the peak cut effect by the BCIS
Tokyo Institute of Technology	Procurement of equipment for the research and the analysis for the BCIS of spillover effects	Response and the investigating of leveling possibilities and evaluation of the regional power to the rapid charge receptor peak in EV models	Estimation of spread range with the spread scale analysis of rapid charge Rapid charging service analysis using the BCIS and other measure data

(Sources) Interview to the JX (2015/03)

As the Table III shows NEC, JX and Tokyo Institute of Technology have each responsibility to demonstrate project. Among them JX has the role to demonstrate their system with the BCIS that is developed by NEC on 2011 and they evaluated its effect on 2012 for checking the possibility of stability verification, spread of technology.

From the interview with JX, it is appeared that until the stability of the system is ensured meetings had been at least once a week in the early stage of the development stage among WG members. However, after the system becomes stable the frequency of meeting is reduced. This means the type of technology architecture is modular in the early, development and refinement stages, but operational coordination type is integral one.

After, the system becomes stable and on the stage of considering mass production in final stage, meetings are rarely implemented in the WGs.

IV. CONCLUSION AND CONTRIBUTION

This paper exemplifies the co-opetetors effect to the determination and factors changing of architecture with technological system in each development stage.

From the analysis of the JX case in Yokohama city and Kitakyushu city on Next-Generation Energy and Social Systems Demonstration Project, find that factors influence to the technology architecture is technological logic in early stage, the stability of technology, opinions of alliance members in development and refinement stages. In addition to those factors this paper finds that the effectiveness and efficiency of the technology in the final stage for thinking mass production would be affect to the type of technology architecture.

On the previous literature of the technology determinism [10], [11] and the social construction of technology [13], [16], [17] indicated technology architecture is affected by the technological, economical, sociological and political reason. However, the case of JX implicated the possibility that the system is modular or integral as a whole system is affected not only depends on the technology stability, but also by participators opinions and knowledge about connecting systems.

Moreover, it shows the possibility that the technology architecture and the operational coordination types are not the same because of participators knowledge gap to the whole system of technology.

REFERENCES

[1] K. Ulrich, "The role of product architecture in the manufacturing firm," *Research Policy*, vol. 24, pp. 419-440, 1995.

[2] C. Baldwin and K. Clark, *Design Rules: The Power of Modulity*, Cambridge, MA: MIT Press, 2000.

[3] T. Fujimoto, A. Takeishi, and Y. Aoshima, *Business Architecture*, Tokyo: Yuhikaku, 2001.

[4] D. Wyatt, D. Wynn, J. Jarret, and P. Clarkson, "Supporting product architecture design using computational design synthesis with network structure constraints," *Research in Engineering Design*, vol. 23, pp. 17-52, 2012.

[5] M. Yasumoto, "The development approach on the cell-phone development," *Business Architecture*, Tokyo: Yuhikaku, 2001, pp. 172-194.

[6] A. Afuan, "How much do your co-opetitors' capabilities matter in the face of technological change?" *Strategic Management Journal*, vol. 21, pp. 387-404, 2000.

[7] J. Galaskiewicz and A. Zaheer, "Networks of competitive advantage," *Research in the Sociology of Organizations*, vol. 16, pp. 237-261, 1999.

[8] A. Yassine and L. Wissmann "The implications of product architecture on the firm," *Systems Engineering*, vol. 10, no. 2, pp. 118-137, 2007.

[9] K. Kusunoki and H. Chesbrough, "The dynamic shift of product architecture," *Business Architecture*, Tokyo: Yuhikaku, ch. 13, pp. 263-285, 2001.

[10] D. MacKenzie and J. Wajcman, "Introductory essay: The social shaping of technology," *The Social Shaping of Technology*, Berkshire, UK: Open University Press, pp. 3-27.

[11] R. Williams and D. Edge, "The social shaping of technology," *Research Policy*, vol. 25, pp. 865-899.

[12] R. Henderson and K. Clark, "Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms," *Administrative Science Quarterly*, vol. 35, pp. 9-30, 1990.

[13] P. Anderson and M. Tushman, "Technological discontinuities and dominant design: A cyclical model of technological change," *Administrative Science Quarterly*, vol. 35, pp. 604-633.

[14] Y. Zhu, A. Takeishi, and S. Yonekura, "The timing of technology innovation: The case of automobile emission control in the 1970s," *Organizational Science*, vol. 40, no. 3, pp. 78-92, 2007.

[15] G. Dosi, "Technological paradigms and technological trajectories," *Research Policy*, pp. 147-162, 1982.

[16] T. Pinch and W. Bijker, "The social construction of facts and artifacts: Or how the sociology of science and the sociology of technology might benefit each other," *The Social Construction of Technological Systems*, Cambridge, MA: MIT Press, pp. 17-50, 1987.

[17] M. Tushman and L. Rosenkopf, "Organizational determinants of technological change: Toward a sociology of technological revolution," *Research in Organization Behavior*, Greenwich, Conn.: JAI Press, 14, pp. 311-347.
[18] Japan Smart City Portal. [Online]. Available: http://jscp.nepc.or.jp/article/jscp/20140421/393940/print.shtml

Youngjae Koh is currently an associated professor at the Hirao School of Management at Konan University, Hyogo, Japan. She graduated from Korea University. She received her M.A. and Ph.D. in business administration from Hitotsubashi University in Tokyo, Japan, where she also worked as a junior fellow. She received the Takamiya award from the Organizational Science Conference (Soshiki Gakkai) in 2008 for best paper.