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The Success of Smart Factory Adoption: Firm's Dynamic Capability Perspective

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Abstract

This research explores how the success of smart factory adoption is influenced by firm's dynamic capability. This research describes the underlying processes on how organizations manipulate or adapt organizational elements harmoniously to implement smart factory successfully. Although understanding of these processes is essential to many researchers and practitioners in the field, the information system research literature contains very few examples of this type. The research is conducted in the following sequence: first, the concept of dynamic capability is presented followed by research methodology; and then the analyses of case data are presented followed by discussions and future directions. The results of this research show that the firms with higher dynamic capability adopted smart factory more easily through alignment of various organizational elements.

Keywords : Dynamic Capability, Smart Factory and Innovation Adoption

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1. Introduction

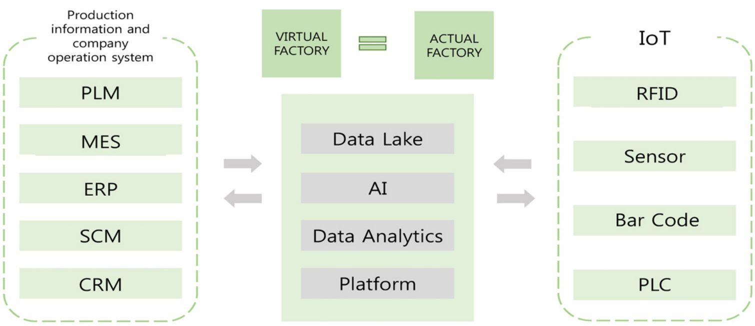
Many nations have tried to diffuse smart factory to modernize their manufacturing industry. However, the diffusion rate is slower than expected. According to a report on government-supported smart factory initiative using four levels of smart factory assessment model - Foundation, Middle1, Middle2 and Advanced, 79% of the firms are in Foundation stage with MES and ERP implementation completed [KSFF, 2017]. None of the firms are in Advanced stage with enterprise-wide integration of the physical and virtual world. The percentages of Middle1 (having real time monitoring of factory operation) and Middle2 (having optimized factory operation) stages are 19.2 and 1.7 respectively.

In a fully connected smart factory (i.e. Advanced stage), networked machines (with sensors), manufacturing information systems (PLM, MES) and enterprise systems (ERP, SCM, CRM) are fully integared to the data platform to stream data into a data lake. The collected data in the lake are analyzed by data analytics tools and AI; and shared across value chain to achive adpatability and optimization in production according to market demand [Porter, 2015].Thus, the ultimate goal of the smart factory is not to automate the manufacturing process but to gain new forms of competitive advantages through building manufacturing flexibility according to market demand.

To implement the vision of a fully connected smart factory across enterprise and external customers and suppliers, top management support and organizational-level efforts are required. The fully connected smart factory which is also called as Industry 4.0, is more than improving manufacturing process using digital technologies. It is about reshaping business strategies, capabilities and business models to create new value in the market.

Previous research on the smart factory diffusion focuseson a readiness level of the manufacturing process as a reason for the slower diffusion rate [Cho and Shin, 2019]. They further developed the readiness assessment model that assesses the manufacturing process in terms of order management, design management, material management, production management, quality management and facility management.

Unlike the previous research, this research takes the position that in the highly dynamic environment, firm's innovation adoption is influenced by the firm's dynamic capability [Lin et al., 2016; Lin et al, 2020]. Dynamic capability is defined as an ability to adapt to the



〈Figure 1〉 Platform based CPPS (Cyber Production Physical Systems) [Readhat, 2021] changing business environment and thus to achieve competitive advantages [Teece, 2018; Helfat and Martin, 2015; Teece et al. 2016; Sirmon et al., 2007; Eisenhardt and Martin, 2000; Teece et al., 1997]. Drawing upon seminal works on Strategy and Structure [Chandler, 1962 Child, 1972], dynamic capability focuses on the relationships between environments, strategy, capability and business performance. An organization with dynamic capability is characterized to have strategic agility and reconfigured capabilities to be adaptive to market changes and therefore, to have high performance in the marketplace.

This research explores how success of smart factory adoption is influenced by firm's dynamic capability. This research describes the underlying processes on how organizations manipulate or adapt organizational elementsin coordinated manners to implement smart factory successfully. Although understanding of these processes is essential to many researchers and practitioners in the field, the information system research literature contains very few examples of this type.

In the next sections, first, existing literature related to concept of dynamic capability is discussed. Second, research methodology and analyses of case data are presented. Finally, discussions and future directions are presented.

2. Literature Review

2.1 Resources and Capabilities

Capability is defined as "an ability to perform coordinated tasks utilizing organizational resources [p. 999, Helfat and Peteraf, 2003]." The capabilities are ranged from less complicated to highly complicated capabilities [Brown and Eisenhardt, 1999; Siggelkow, 2002]. An organization is considered to be a collection of resources and capabilities. An organizational capability is built by putting various organizational resources together such as human resources, business processes, IT and recently the data. Capabilities can be formed through bundling of the existing resources or reassembling of the existing resource bundles. Reassembling include hiring and educating new resources; as well as divesting less valuable resources [Uhlenbrcuk et al., 2003; Sanchez, 1995]. New capabilities are also developed by coordinating existing capabilities; or acquiring new capabilities [Hitt et al., 1998].

To have sustainable competitive advantage, firms focus on the resources and capabilities that are rare, durable, valuable and inimitable [Shillings, 2019]. A set of integrated and coordinated abilities that the firm have distinctively in the market is called core competency. An example of the core competency is semiconductor design capability. The core competencies could be from functionalcapabilities such as R&D as well as cross-functional capabilities such as new product development capabilities combiningoperations and R&D capabilities [Grant, 1996].

2.2 Organization Structure

The environment and technology influence organizational structure that is defined as "the formal allocation of work roles and the administrative mechanisms to control and integrate the work activities [Child, 1972, p.2]." Organizational structure is also defined as the framework of the relations on tasks, operating process, systems and people working together to achieve a common goal [Minterzberg, 1972]. The organizational design and managerial practices influence organization's performance.

According to Kretschmer and Khashabi [2020], technology adoption by the organization changes firm's operation and processes at different levels, which in turn results in changes in organizational structure. "Many new functions and tasks from the digital era are now essential for successful market performance [Kretschmer and Khashabi, 2020, p.90]." These taskscan be grouped together into team; and decision rights can be assigned to the team. Some administrative tasks (or functions) could be eliminated.

For example, AI creates new tasks that were not necessary before such as bias checking and prediction. This in turn relates to administrative activities to control. In addition, firms realize the output of the prediction machine enables firms to perform preventive maintenance. This in turn makes the firm realize new tasks/processes/functions as well as unnecessary processes. AI also makes the firm realize the lack of coordination among existing tasks to perform the preventive maintenance and thus, the need for the coordination among functional units to manage i) the performance of product life cycle as well as ii) capturing feedback to improve products/services and the process [Porter, 2015].

Integration of functional units involves leadership and process re-design for order processing, product development and supply chain. Firms need to determine which activities and resources across firm's boundaries need to be bundled to create firm's capability to create value. It is desirable to bundle interdependent tasks together not only across intra organizational boundaries but also across inter-organizational boundaries [Stamas, 2014].

2.3 Characteristics of Dynamic Capability

The dynamic capability is often described in association with high resource fluidity [Doz, and Kosonen, 2008]. High resource fluidity represents an organization's ability to reconfigure operating processes and various resource allocationsin order to facilitate organizational transformation [Doz, and Kosonen, 2008].

Successful redeployment of appropriate resources and implementation of new processes and systems require competencies embedded in business routines (i.e. organizational processes) and organizational structure to conceive, choose, implement such change [Peppard and Ward, 2004; Rockart, 2004]. Competencies are also described as organizational characteristics to permit organization to recognize, select, implement strategies [Barney, 1997]. Competencies are determined by 1) firm's technical infrastructure and 2) organizational ability to "deploy appropriate resources as well as implement and operate new processes and systems [p. 182, Peppard and Ward, 2004]."

A set of routines comprising the dynamic capability are: sensing changes in the environment by perceiving incoming information (perception], filtering and analyzing perceived information (processing), making decisions based on the analysis result (responding), and reconfiguring organizational resources (aligning) [Seo and La Paz, 2008]. Dynamic capability relies on analyzing existing knowledge and identifying new knowledge by which the firm adjusts and reconfigures their resources to address a dynamically changing environment [Wang and Ahmed, 2007; Eisenhardt and Martin, 2000; Sull, 1999a, 1999b]. In the work of Lin et al. [2016], the components of the dynamic capability associated with the adoption of management innovation include: sensing capability, absorptive capacity, integrative capability, and relational capability. Managers' capacity to sense and seize opportunities also influence organizational innovation [Helfat and Martin, 2015].

Dynamic capability is associated with learning through experience and knowledge articulation [Hung et al., 2009; Zollo and Winter, 2002]. Experiential knowledgeobtained from experiences allows better recognition on needs for change. Knowledge articulation improves causal links between action-performance, which results in adaptive changes to the operating routines [Zollo and Winter, 2002; Gavettia and Levinthal, 2000].

3. Research Methods

After literature review on the smart factory adoption, it was determined that no existing theories are relevant to accomplish the research objective. Thus "ground theory building" methodology is used for this study [Glaser et al., 1999; Yin, 1984; Eisenhardt, 1989]. This methodologybuilds theory grounded in the data inductively which is different from traditional deductive theory building where an existing theoretical framework is chosen, then data is collected to show how the theory can be applied to the phenomenon under study.

After literature review on smart factory and dynamic capability, interviews were arranged with people including business manager and smart factory/IS managers in Korea who had intensive experience of smart factory projects. Before conducting the interviews, a semi-structured interview protocol was prepared to guide the interviews. Since we focus on the dynamic capability of manufacturing firms with smart factory projects, we categorized components of dynamic capability into sensing, seizing, coordinating and reconfiguring. Based on this definition and focus, we limited interviewees to people who are in charge of smart factory projects. One of researchers involved in this research took the role of facilitator and moderated discussions based on the questions prepared.

Three interviews were conducted in Korea (see 〈Table 1〉). The companies interviewed are described in Appendix. The location of the interviews was selected by the participants. Usually the interview was performed in a meeting room at the company of the participants. With some participants, follow-up was conducted through e-mailto request clarifications and to offer participants the opportunity to provide feedback. Interviews were transcribed in Korean and translated into English.

〈Table 1〉 Overview of company and interviewees

Location	Group	Company	Position
Korea	1	COV	Strategy/IS/Smart Factory Manager
	2	JIN	Smart Factory Manager
	3	VEL	Business manager

Interviews were guided by a facilitator with open-ended questions for approximately one hour each. According to the interview protocol, the interviews were proceeded from explaining the research objectives and interview objectives to the interviewees. Even though the goal of the interview was to discover the dynamic capability of manufacturing firms with smart factory projects, we lead the interview to talk about challenges and issues raised during the smart factory project life cycle phases for structuring the discussion. The lifecycle phases include pre-implementation, implementation and post implementation phases. Then, we tried to investigate the firm's capability needed to manage those specific problems of a smart factory project. Therefore, the following items were discussed during the interview:

- Distinctive activities and issues occurred throughout smart factory project life cycle phases
- Action required to manage the activities and issues

Data analysis was performed using the constant comparative method of grounded theory [Glaser et al., 1999]. Furthermore, research findings were reviewed by interviewees to confirm. Data analysis is presented in the following section.

4. Data Analysis & Research Findings

Using the constant comparative method, data analysis went through several overlapping phases of reading the collected data, discovering repeated ideas and concepts, coding the ideas and concepts and modifying the names of the codes to better represent conceptual ideas. The coding categories can be modifiedto generate concepts [Glaser et al., 1999; Holliday, 2007; Pettigrew, 1990]. These categories are basis for new theory.

First, the interviews were put in writing. Basic units of text (words, phrases or sentences) were extracted from the transcript; and categorized them into four codes – 'phase', 'challenges/issues', 'actions taken' and 'dynamic capability (i.e. sensing/processing, responding and reconfiguration)' required to re-

〈Table 2〉 Coding Categories

Phase	Challenges/Issues	Action Taken	Dynamic Capability Required
Pre-Implementation	Sensing changes in manufacturing environment (COV, JIN, VEL)	Applying for government fund	Sensing/Processing/Responding
	Not being able to resolve political issues inside company (VEL)	No action	Responding (make decision based on analysis)
	Having difficulty of setting expectations among stakeholders about the project (JIN, VEL)	No action (JIN)	Responding
Implementation	Having difficulty of reaching consensus between PM and Factory (JIN)	Planning, Education	Reconfiguration
	Employee not wanting to enter data into system (COV)	Education	Reconfiguration
	Employee not following the process in ERP system (COV)	Education	Reconfiguration
	Lack of PM with experience (VEL)	No action	Reconfiguration
	Lack of consultants with experience (VEL)	No action	Reconfiguration
	Directors in the factory not following PM (VEL)	No action	Reconfiguration
	Lack of agreement between headquarter and factory (VEL)	No action	Reconfiguration

solve the challenges (see ⟨Table 2⟩). The initial codes for dynamic capability required - sensing/processing, responding and reconfiguration were derived from a review of the literature. In order to reach desirable between-coder-reliability, the following process was employed: coding individually, checking the agreement among codes, and a discussion on differences about the coding scheme to resolve the differences. Table 2 shows coding categories used in the analysis.

In the second column of ⟨Table 2⟩, the identified challenges of the smart factory projects are presented. This study found that firms overcome those challenges based on dynamic capabilities (shown in the last column of see ⟨Table 2⟩).

JIN and COV do not seem to have problems in sensing and responding capabilities. Both companies are vendors of well-known global firms. Their relationships with the global firms allow them to sense changes occurring in current business environment. VEL lacked responding capability and made mistakes in selecting the consulting firm due to firm's internal political issues.

> Due to political issues, the consulting firm with the lack of experience was selected. The lack of competency of both PM and consultant are major causes of the failure (Interview with VEL)

Two of three firms noted that the most challenging task is aligning Project Manager (PM) and manufacturing departments during the reconfiguration process.

> Building consensus as well as division of responsibility between PM and manufacturing department were challenging. Therefore, it is recommended for the firms with plan for smart factory: to perform planning, design, and feasibility study with the highest priority. In this way, probable problems can be identified in advance to prevent extra costs and to complete the project on time [Extra cost and delay actually occurred] and the consensus for the project objective is built between PM and manufacturing departments.
> (Interview with JIN)

> Although top management in headquarter has strong commitment in smart factory project, a lack of PM's leadership hinders obtaining cooperation from manufacturing division in foreign subsidiary. This caused constant complain from both director and production manager of the foreign subsidiary on standardization issues. (Interview with VEL)

All three firms expressed the importance of change management including employee education for the process change.

> Lack of understanding of the employees, engineers and management about new system and new process made the test period longer. (Interview with JIN)
>
> Resistance from the employees are the most difficult problem to deal with. At first, the employees did not want to enter data into system. The employees did not want to follow the process implemented in the ERP system. The education for the employees is done outside and inside of the company. (Interview with COV)
>
> Educating the use MES and ERP systems to the employees in foreign subsidiary was difficult due to communication problems.

(Interview with VEL)

This study shows that the success of smart factory project is dependent on firm's dynamic capability, especially reconfiguring capability. The firms having less difficulty of aligning human resources and processes according to changes required by smart factory projects had succeeded smart factory projects. This is congruent with the study of Zahra et al. [2006], which asserts that the firms with higher dynamic capability has less difficulty of reconfiguring resources and routines.

5. Discussions and Conclusions

The study results indicate that the companies with higher dynamic capability made the process of organizational changes such as smart factory easier. Through alignment (i.e. resource reconfiguration) such as employee education, the companies with higher dynamic capability have higher chances to implement the smart factory successfully. This supports the assertion of Doz, and Kosonen [2008]: the firms with high resource fluidity (i.e. alignment of process changes and various resource allocations) make business transformation faster and easier. As indicated in the interview results, the resistance from employees and management could be managed not only by education but also by goal sharing. The alignment such as goal sharing and the consensus building requires the executive level commitment, which indicates importance of the governance of IT for smart factory success.

What this practically means that smart factory is enterprise-wide innovation, requiring organizational level efforts and top management attention. Difficiency of these efforts hinders adoption and progress of the smart factory. When firms' effort and government policy are shortsighted and neglect complexity of enterprise-wide innovation, smart factory diffusion is slower. Smart factory is not anisolated project within a factory floor but a project requiring dynamic capability of a firm

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〈Appendix〉 Company Description

Cov (Smart factory level 3)

Cov is a manufacturing/research service company for automotive parts. It's excellency in standardization is recognized by the Ministry of SMEs and Startups. Smart Factory was imitated to meet the quality requirement by foreign buyers. At that time, Cov also needed to reduce unit cost and improve productivity. They completed 1st phase (MES, ERP and PLM) and 2nd phaseof the smart factory (SPC-Statistical Process Control, QMS- quality management system and CMS-Cyber Manufacturing). During 2020, they plan to implement MIS which is 3rd phase.

According to the interviewees who is a manager of planning/ smart factory/ IT, MES[1] which improves visibility from raw material to products, is the most important for the smart factory initiative. Only after data gathering and analyses over the manufacturingprocess, prediction and prevention are possible.

After smart factory, Cov cut employees by half and received order from BMW [2020], Hyundai [2019], and Volkswagen. [2014].

Jin (Smart factory level 4)

Founded in 1978, Jin is a leading manufacturer in car industry and has been key supplier to car makers in world-wide. Jin is also the first vendor of Hyundai Automobile. It adopted smart factory via government initiative calledProject to Build Demonstration Factories with support from the Ministry of SMEs and Startups in 2017. The project intended to build a role model of the smart factory. By executing the project, Jin has achieved quality and productivity improvement through factory automation. Smart factory adoptionreplaces dangerous task by robots, thus results in reducing industrial hazard and relocating employees to other tasks. Smart factory also allows the firm to monitor of before process and in process products; to identify malfunction in temperature and time; and thus to ensure quality. The results are remarkable with 20.5% increase in productivity and 50% increase in defect rate [Lee, 2019].

Velo

Clothing manufacturer for motorcycle. Velo implemented MES and ERP for inventory, HR and facility management as well as for manufacturing efficiency. Headquarter is in Seoul. Factory is in China and Vietnam. They overrun budget by 40%. They planned to complete the project within 10 months, from May, 2018 to March, 2019. They could not finish the project and finally suspend the project in Feb, 2020.

1) MES records and tracks the process of transformation of raw material to finished products. MES can identify and track error occurred during the process. Using theMES datam firms can analyze the cause of the error and improve the quality of the process and products. MES permits manufacturing optimization to maximize quality and productivity.

Author Profile

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