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PRIMARY RESEARCH

Vertical integration for smart manufacturing-The dynamic capability perspective

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Abstract
Industry 4.0 or smart manufacturing uses digitalization to change manufacturing methods. However, there is little empirical research into the benefits of smart manufacturing, though some studies point out that latecomers will lose competitiveness. This research uses a case study to explore how an aerospace company implemented smart manufacturing in practice. The company uses emerging technology to build up the smart manufacturing process and vertical integration. In its vertical integration, the company uses sensors to collect the manufacturing data for analysis. The results can be displayed on a mobile system immediately for managers and operators controlling the manufacturing process and productivity. The company faced challenges in launching its vertical integration in smart manufacturing, including operators' Information Communication Technology (ICT) skills and knowledge, linking the ICT systems of new and old facilities, and big data analysis capabilities.

I. INTRODUCTION

The German government proposed Industry 4.0 in 2011 [1] setting the direction of German R&D and investment in manufacturing in the coming years [2, 3]. Industry 4.0 emphasizes the impact of digital technology on the future of the manufacturing industry [4, 5, 6] which will integrate ICT in the production system and increase the degree of horizontal and vertical integration.

In the future, digital technology will be brought into production and manufacturing process, and move the industry towards manufacturing [7, 8]. Incorporating new communication technologies will transform the production value system [9], and the production process is moving towards smart development [10]. Therefore, Industry 4.0 is not only a manufacturing revolution, but it also changes the business models, innovation models, industry chains, and value chains [11, 6].

According to an industry survey conducted in Germany in 2015, 18% of the industry's owners have heard the concept of Industry 4.0. Among them, 33% believe that the core of Industry 4.0 is ICT and networking, and 25% cannot apply the Industry 4.0 concept according to specific description [10]. Even now, there are still many unknowns for the implementation and impact of Industry 4.0 [10, 12]. Most studies are based on theory and applications are still under development [13].

[14] used the dynamic capabilities perspective to describe the business response to the rapid changes in the external environment. They point out that past events, experiences, and processing models, as well as the resources and knowledge organizations possess will affect the accumulation of capabilities and knowledge. Dynamic capabilities can be divided into three distinct activities [15] perceptions, values, and transformations. Companies respond to external environmental changes and competition by applying internal processes and resources to adjust their objectives [15].

Facing the trend of smart manufacturing development, how enterprises can coordinate and integrate their value chains is very important in terms of competitiveness and future development. By developing information systems, companies can use ICT to collect data. However, the systems between departments and enterprises are not ex-

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actly the same. When integrating value chains, the cross-departmental links and data as decision-making information are still in the development stage. Companies need to understand their own core technological capabilities and the dynamics of the external environment to determine what capabilities they will continue to develop. To enable companies to establish smart manufacturing capabilities, it is important to explore company practices around value chain integration, and the strategic factors of integration. Therefore, this study has two research questions:

1. What factors influence companies' decisions on actions for vertical integration?
2. What does the value gain from value chain integration? What resources should companies invest in, and what capabilities should they establish?

This study uses dynamic capabilities to explore the opportunities for value chain integration, the factors that influence decision making, and the relationship between resources and capabilities that require investment.

The dynamic capabilities framework describes companies in the process of developing smart manufacturing. It is worth examining practical applications in firms for information, and providing this information for business transformation or government resource allocation to enhance capabilities in response to changes in the environment.

The structure of this paper is as follows. The second part discusses the origins of Industry 4.0 and the literature on value chain integration and dynamic capabilities. The third part focuses on firms' integration of manufacturing value networks, and the fourth part addresses the implementation and conclusion of smart manufacturing development.

II. LITERATURE REVIEW

A. *Industry 4.0 and Value*

Advances in science and technology led to a significant increase in industrial productivity. Since the first industrial revolution, the manufacturing industry's development underwent several changes. The new technologies were applied to the manufacturing industry to increase output and improve quality.

Industry 4.0 was first presented at the Hannover Messe in Germany in 2011. Conceptually, it uses innovative network technology to link information from inside and outside of the factory, generating new values and building new business models [8]. Industry 4.0 is a milestone for manufacturing transformation. In 2013, the German government incorporated Industry 4.0 into the "High-Tech Strategy 2020 Action Plan" and will invest 200 million Euros to upgrade the computerization, digitization, and intelligence of the manufacturing industry [16, 17]. The goal is to make Germany a model of global smart manufacturing.

The practical benefits of Industry 4.0 include making manufacturing tasks flexible, reducing lead times, and enabling small batch production. In addition, data analysis can help firms provide high-quality services, increase productivity [18], and save manufacturing costs [19, 20]. [21] argues that promoting Industry 4.0 can increase production efficiency in production processes by 30%. According to [19], Industry 4.0 will reduce manufacturing and processing costs by 15 to 25%, and increase productivity significantly, which would also lead to revenue growth.

In response to the development of Industry 4.0, the manufacturing industry will face several challenges [22]:

1. Integration with new information technology.
2. Ability to process large amounts of data.
3. Self-regulating capabilities among decentralized systems.
4. Information security issues arising from connected systems.

B. *Horizontal and Vertical Integration in Industry 4.0*

Industry 4.0 can be seen as a move toward flexibility and automation in the manufacturing industry. It can be replicated modularly and spread among manufacturing firms. It is also a smart plan for the next generation of smart manufacturing operations [23]. The data collected during the production process and systems during manufacturing are stored in the cloud. This improves data accessibility, and companies can respond or make adjustments more quickly. These systems make the production system more flexible, virtualization, decentralization, real-time capabilities [24] and improve the quality of production by reducing human operations [19]. Applying ICT helps the manufacturing system focus on establishing the value network. Value chain integration will provide better quality output, save time and costs, and increase manufacturing companies' competitiveness [25].

[26] argue for three keys to promoting Smart Factories in Industry 4.0: horizontal integration of value networks, vertical integration and networked systems, and peer-to-peer integration of the entire value chain [27]. Horizontal integration is overall cooperation between the enterprise and related enterprises. Competitive and cooperative relationships establish an ecosystem in which information, finance, and material can move continuously in cooperation [27].

From the perspective of the overall system, integration includes the interconnection of value elements such as equipment, people, organizations, processes, and products. The

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composition of value networks links and creates value between the elements. Due to the interactive links of the value elements, companies can generate breakthroughs and innovations from their interactions. This will create opportunities to develop new business models [27]. Vertical integration is the integration of relevant value elements such as people, equipment, and products within a manufacturing line or factory. In addition to the interaction of value elements, vertical integration also includes integrating tasks such as marketing, sales, services, and procurement [28]. A smart manufacturing system can link the activities in the manufacturing value chain with CPS [27]. The vertical integration allows visualization of the manufacturing process and make to react to customers' request more quickly [29].

C. Dynamic Capability Theory

[14] propose the dynamic capabilities approach based on resource-based theory. They mention that firms' competitive advantages of enterprises depend on management, organizational processes, and the availability of assets [14]. The dynamic capabilities framework emphasizes two aspects. First, the company must be able to constantly innovate to cope with the changing external environment. Therefore, it is inevitable that for an innovation response, time and speed are important. Second, it emphasizes that strategic management plays a key role in adapting, integrating, and reconfiguring internal and external organizational skills and resources, and having the ability to respond to changing circumstances. The scholars' view of dynamic capabilities suggests that it is organization's ability to establish, extend, and modify its resource base with purpose [30]. [31, 32] proposes dynamic capabilities in three parts in the study; namely, sensing, seizing, and transforming. Sensing is the focus on customer needs and then identifying, developing, co-developing, and evaluating technical opportunities [32]. Organizations need to be able to identify and understand changes in the external environment. Furthermore, the organization uses change to form competitive strategies and implements them. There are three actions involved in sensing. Environmental scanning refers to the exploration of opportunities and markets from internal and external sources (e.g., customers, suppliers) to detect potential opportunities. Second, the organization learns and evaluates potential opportunities by forecasting performance or gaining access to information and identifying specific areas for further action [33, 32]. Third, firms must determine their strategic actions [34].

Seizing ability confirms the value. Organizations identify opportunities, the market's needs, and the value proposition. This is a key action that links organizational strategy and value. This helps the company to determine the value of its actions and determine the action plan that has market potential [32].

Transformation includes adjustment and redeployment [31]. The dynamics of transition are important for adjustment because it helps firms reconfigure existing resources to align with the new strategy. Transformation helps firms build or acquire new resources to fill current gaps in its resources.

III. RESEARCH METHODS

This study explores the value of manufacturing network integration in the manufacturing industry. Since smart manufacturing in practice is still in its infancy, this study uses case study methods to collect and analyze data. In case studies, researchers collect data from a multifaceted perspective to effectively obtain practical knowledge [35]. The case study method helps to provide a deeper understanding of the knowledge of specific phenomena. This type of research can develop the views and practices that affect the application of a company's dynamic capabilities and an applied perspective.

In the sample selection of samples, this study chose a company that entered the international aerospace value chain. The data were collected through face-to-face interviews, and internal and external secondary data. The interviewed participants consisted of six senior managers from the R&D and information departments, as well as industry partners. The interviews used semi-structured questionnaires that address three dynamic activities, and the research and analysis followed case study principles [36].

The interviews were recorded and provided to the interviewees for confirmation to avoid misunderstanding [37]. The research results are based on the dynamic capability framework and interview records.

IV. CASE NETWORK INTEGRATION STUDY

A. Background Information

The case of this study is a Taiwanese aerospace company that entered the international aircraft manufacturing supply chain. The company mainly produces large-scale components for civil aircraft. Production is based on customer demand to provide small-scale, diverse production. To manage production, the company implemented Enterprise Resource Planning (ERP). Since Industry 4.0 is an important trend in manufacturing transformation, the case company gradually established a smart manufacturing system starting in 2015. The system introduced significant new technol-

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ogy into the inner manufacturing process including sensors, cloud, and big data. Their goal was to enable flexibility in the production line for small-batch production [18] to meet the need for customization products [12] and lean production [23].

B. The Enterprise Value Network Integration Dynamic Capability Analysis

1) Sensing: To speed up industrial transformation in Taiwan, the government launched the "Five Plus Two Innovation Industry Plan" in 2016, which is the core of driving the next stage of Taiwan's industrial growth [38]. The plan refers to the five major innovation industries and together with new agriculture and the circular economy. The aviation aerospace industry employs advanced technologies that require continuous innovation.

The aerospace industry's manufacturing system is global with a complex supply chain. The higher the level of system integration is, the higher the value added is [39]. The aircraft manufacturing cooperation system is based on the aircraft's component requirements. There are different supply chain systems and types of cooperation. At present, the main aerospace manufacturing cluster is still dominated by Europe and the United States, but the manufacturing value chain is moving to Asia and Southeast Asia. In order to enhance the competitiveness of the domestic aerospace industry, and in response to the development of smart manufacturing, the domestic industry organized the Taiwan Aerospace Industry A-team 4.0 to target the international supply chain.

The company uses smart technology to conduct simulations before production due to the high cost of materials in the aerospace industry. The system can monitor the simulations in real time, and report on errors for correction. Compared with the past, when quality was checked after manufacturing the finished product, these smart technologies reduce costs greatly.

2) Seizing: In terms of promoting Industry 4.0, companies need to choose the technology in which they will invest and confirm the benefits of the investment [40]. The case company believes that if Industry 4.0 is fully automated, it may be a misunderstanding, in that it is not the essence of Industry 4.0. The company chose to use ICT and other technologies to assist manufacturing.

Industry 4.0 focuses on digitization in manufacturing [18], which should combine ICT and operations technology in the production system. It is an entity-virtual-entity integration. The case company believes that if it implements smart manufacturing, network integration is an important value for the enterprise. Value network integration will benefit the firm through cost savings, improved efficiency in the production systems, and higher international industry competitiveness. In addition, domestic industries can also increase the value added of technological capabilities and products, and cultivate industrial talent. Regarding the mastery of value, the industry believes that applying information systems will allow the company to collect six important elements of the manufacturing process: materials, machines, manufacturing methods, metrology, maintenance and modeling, and information technology applications. Sensors collect the data, and then integrate it with cloud computing and big data, which could then be expanded to cover the supply chain and customers. The relationships among customers, the company, and the supply chain form an ecosystem, which is in line with research by [41] because it enables device diagnosis and data sharing through CPS technology. Since the collection process is not fragmented, it provides continuous feedback to the manufacturing system and improves the production process [19], which in turn enables the establishment of a self-adjusting and flexible smart ecosystem [42].

According to the data collection, storage, and application in the case company, Figure 1 summarizes the information structure following [12] system architecture. The system includes the manufacturing layer, cloud system layer, and service layer.

Sensors collect manufacturing device data in the manufacturing layer. The data are then stored in the cloud system for further analysis. The service layer is a convenient and user-friendly interface that supports dynamic monitoring, troubleshooting, process planning, and decision making.

3) Transforming: Vertical integration of Industry 4.0 means integrating several subsystems within the plant [17]. When the case company conducted system integration, the first step was to connect to the existing ERP systems. The company's IT system connects the existing system and routine processes based on the on requirements of the production process and machine.

The company uses ICT in its machine equipment and production process management. The company launched vertical integration to set up sensors on the machines to record the overall equipment application rate, production progress, staff workload, and productivity. The sensor tracking collects production data for further analysis. The results then provide information for line managers to adjust the online operator's task. All members on a production line can check the completion time and required manufacturing process time on the screen and mobile devices. The oper-

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ators can follow the information and prepare materials for the next batch of production. The staff can obtain the information about the production materials required according to job authority.

The personnel are no longer simply watching the operation of the machines, but think about the time to maintain the machines. Furthermore, they can use the data analysis to propose improvement plans for production process. The system also allows employees to manage their own work.

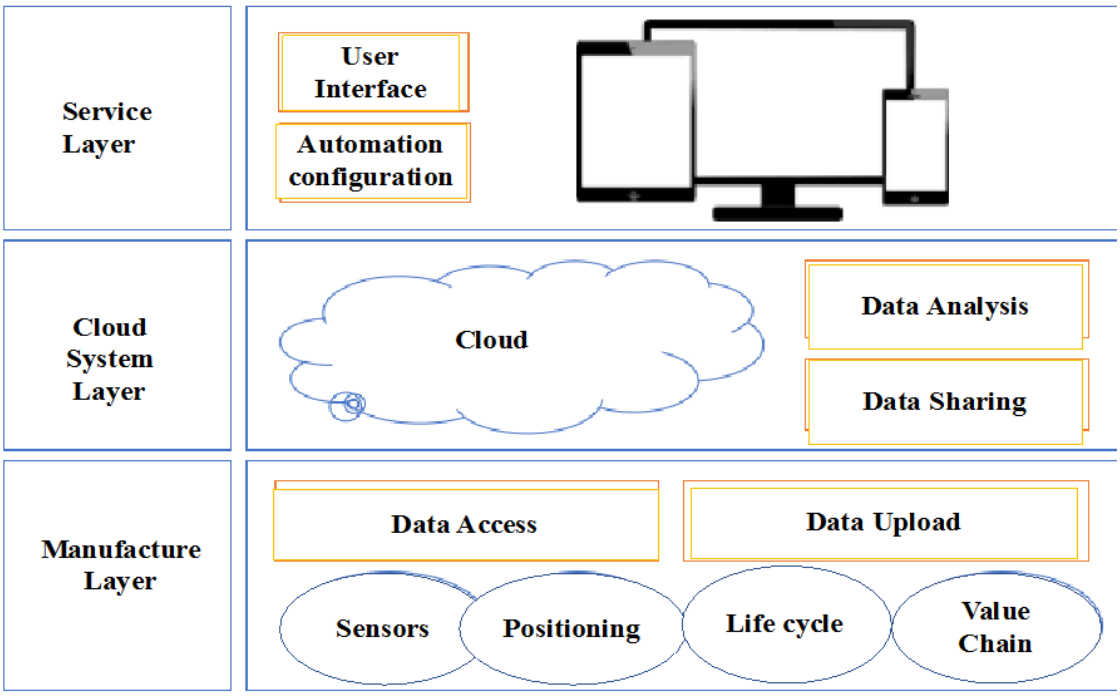

Fig. 1. The integration system structure of case company

The case company uses sensors to collect real-time production data and store data in the cloud for analysis. They can monitor production schedules and anomalies on the screen or on smart handheld devices from anywhere. They can also instantly respond to problems on the production line and help operators to make flexible adjustments. [43] mention that strengthening the cooperation between people and machines will improve production quality by reducing human errors. [26] point out that Industry 4.0 helps companies closely link the production process planning and real production processes, and provides immediate feedback. By linking new technologies and manufacturing systems, firms can respond immediately to complex changes in the manufacturing systems [8].

In addition, by collecting and analyzing the data, companies can control the effective working hours of each machine. The management team can expand the depth of production management, shorten invalid working hours, and increase utilization. The information is connected with the production value chain.

Therefore, the company now procures internal production equipment equipped with sensors. Even so, more than half of the existing machinery does not have this capability. The existing machine equipment comes from various brands and still functions well.

The challenge is to allow the old and new machines to have the same communication language. The challenges of constructing CPS in enterprises must cross the boundaries between system hierarchies and organizations, allowing digital integration and continuous interaction [12].

V. DISCUSSION

This study uses the perspective of dynamic capabilities to discuss the direction of value network integration, the generated value, and capabilities in smart manufacturing. [44] states that disruptive innovations in ICT will change the path of manufacturing development in the next decade. Data collection and application will be the key to implementing Industry 4.0. Data analysis can create new opportunities and value for the industry. This study finds that an Aerospace manufacturing company implemented the concept of Industry 4.0 at their manufacturing site to develop opportunities in the global value chain. By integrating ICT and production technology, production data is continuously

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collected. The data analysis findings support decision making and reduce manufacturing process errors, thereby increasing competitiveness in the value chain. Participation in an international value chain is an important enabler that drives companies to demonstrate quality and capability. In addition, the government's industrial policy provides another impetus combined with industrial organizations (A team). Improving competitiveness is a common goal and drives companies to conduct in-depth value network integration.

There are two values for the company: the first is between the enterprise itself and the international value chain and the second is between the enterprise and Taiwanese industry. In the former case, the focus is on the positioning the company in the international market and having the value chain recognize the technological capability. Therefore, the value of quality and effectiveness is particularly emphasized. For the domestic industry value chain, the case company plays a leading role. The company emphasizes the improvement of technical capabilities, production quality, and talent cultivation.

To implement the integration, the company integrates existing input resources and links to new ICT technologies to manufacturing, and develops a suitable integrated system. Firms use emerging technologies for vertical integration and gain advantages in a competitive environment [17]. Vertical integration within the enterprise is achieved enterprise information systems, including collecting manufacturing processes data with sensors and continuously storing the data in cloud systems. Data analysis provides a dynamic visualization of the data on mobile devices or screens, so that management and operators can control the productivity of the production lines and utilization anytime, anywhere. Furthermore, the system can also evaluate the overall productivity and utilization of human resources.

This study finds that the aerospace company used ICT to connect the old machinery to new equipment, and integrated the collected data on the same platform. This strategy allows the equipment to operate under a common architecture, systematically collect data, and analyze it. However, with the continuous accumulation of large amounts of data, companies still need professional analysis. The data analysis results provide feedback to manufacturing, thereby creating a virtuous circle of smart manufacturing [42].

In smart production environments, the task requirements of production operators will change. Production line operators are no longer responsible for low-level jobs, which information systems and automated production will replace. Instead, they need to perform tasks that demand tacit knowledge that is difficult to replace by automation [45]. Personnel must conduct production planning and make decisions based on the results of statistical analysis, and so need more knowledge and skills for a smart manufacturing environment.

A. Suggestions for Practice

The results of this study lead to the following practical recommendations. First, it provides information about the process and trends in smart manufacturing development, and describes international development and application cases through industry analysis. This will help firms gain knowledge and sense the customer needs. Second, the development of Industry 4.0 does not mean that a large investment in new equipment is required. The case study shows that companies should think about its existing investments and consider technical requirements and competitive advantages [46]. Companies should focus on smart production application and then gradually implement it, rather than synchronizing all operational process simultaneously. Companies should establish a plan at the beginning and promote innovation based on demand.

VI. CONCLUSION

This study uses dynamic capabilities theory to discuss the vertical integration of a manufacturing company facing smart manufacturing. Prior to implementing vertical integration, the positioning of international value chains, industry trends, and government policy help enterprises review their internal and external environment. The case company confirmed that vertical integration enhanced their global competitiveness.

This will create value for the domestic aviation industry, not only in stabilizing its position in the international value chain, but also in improving domestic industrial technology capabilities. Furthermore, the implementation improved production efficiency and industrial talent cultivation.

The process of implementing integration in the company involved linking systems and organizations. The company adopted gradual measures to integrate the network. Using the existing system coupled with the application of emerging technologies, companies can gain valuable information about their activities. Managers and operators could quickly find the information and make decisions through the devices. Vertical network integration is easier to implement than horizontal network integration is. Horizontal integration works across organizations and requires more complex system capabilities and talent. Value network integration enhanced the company's competitiveness, though

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it is still developing its vertical integration. This integration involves industrial technology capabilities, information infrastructure, and talent capabilities. Therefore, using the value chain to integrate and combine with the global value chain will contribute to the value network implementation. The results of this study can be used as a reference for value network integration practices in smart manufacturing.

Due to the limitations of this study, follow-up researchers can use this study as a basis and provide more abundant results and findings. First, this study chose the aerospace industry as an example; however, this industry has few companies in the global industrial value chain and that actively apply the ICT. Therefore, the vertical integration approach can only indicate its present state. Future research investigating other industries can more specifically show the effectiveness of smart manufacturing implementation in manufacturing companies and clarify the impact of integration on industrial applications.

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