Research on Value Co-creation in Intelligent Manufacturing

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Abstract: The development of intelligent factories will change the traditional mode of manufacturing operations and enterprise value creation, affecting the overall operational performance of enterprises. This study takes Company A, an industrial computer manufacturer with two affiliated manufactories, as the object since the way it creates value has gradually evolved into an open innovation model, in which consumers are invited to directly participate in the design of products and services and have become an important source of value co-creation. In-depth interview is applied in the collection of primary data. After data collection and process, 16 research findings are provided. By applying the framework of the three-stage theory and strategy of value co-creation, we summarize and analyze the primary data obtained from the interviews. Through the introduction of intelligent manufacturing, process optimization, organizational cooperation and communication pipeline mechanisms in two manufactures, the results show that quality, efficiency, flexibility, and time can all be ensure and improved.

Keywords: Intelligent Manufacturing; Value Co-creation; Internet of Things

1. Introduction

The key to a company's ability to take the lead of its competitors and keep its competitive advantages lies in creating irreplaceable value. Previously, Schumpeterian innovation emphasized creating value through producer-led innovation [1], and Porter (1996) proposed a value chain, which considered a company as a combination of a series of value activities and considers value to be the amount that customers are willing to pay for the products or services provided [2]. With the time being, this value creation model has gradually evolved into an open innovation model, where consumers' participation in the value creation process and collaboration with producers has become an important source of value creation [3]. Since the development of information technology has changed interactive behavior, companies have also invited customers to directly participate in the design of products and services.

The industry pioneers have found that it is necessary for stakeholders such as employees and suppliers to create value for themselves in order for them to actively participate in customer co-creation [4]. Through such strategy, enterprises aim to increase productivity and creativity, reduce costs and employee turnover, and create new business models. Value co-creation is the process in which enterprises and customers discover value together, take joint actions to pursue value, and allocate the created value through reasonable mechanisms [5]. In addition to strategic alliances or cooperative operations, value co-creation also includes collaborative activities between upstream and downstream enterprises in the supply chain. Unlike traditional value creation activities, which only create value independently by enterprises (sellers). Creating value together with customers can be further expanded to include stakeholders or groups. Therefore, enterprises engage in value co-creation with other interest groups and interact to influence the overall value creation in terms of co-design, production, and creation of content and services.

Value co-creation refers to the interaction between different stakeholders, utilizing each other's resources, and creating common interests [6]. The experiential value created involves subjective cognition, varies from person to person, including tangible products, services, and intangible emotions. Value co-creation connects the problems and resources of stakeholders through the mediation of platforms, promoting interaction among stakeholders. The essence of interaction is resource interaction and integration, thereby opening up innovative resources. These new resources not only solve individual problems of stakeholders, but also solve common problems. Since stakeholders need to be able to interact directly with each other, therefore, providing a platform for stakeholders to interact and share experiences is essential. The value co-creation strategy is solve all the issues faced by stakeholders. Through the platform created, stakeholders can develop a network, share resources, solve problems, and finally to create value together.

The process of value co-creation can be divided into three stages: discovering value, value co-creation, and value distribution [7]. Among them, the process of discovering value involves identifying potential customers and assessing their needs. However, potential customers are often difficult to search for, resulting in

increased search costs. In addition, even if a company can find potential customers, understanding their preferences and needs may come at a considerable cost [8]. Based on different stakeholders, we develop interview questions related to value co-creation to explore the value co-creation production models of domestic industrial computer system assembly manufactory and CTOS manufactory.

2. Research Background

Industrial PC (IPC) was first applied in manufacture automation as a controller for CNC (Computer Numerical Controller), which is the control core of machine equipment and provides functions such as monitoring, controlling, or testing of machines or instruments in the manufacturing process. With the continuous enhancement of the functions of personal computers and the continuous decrease of costs, using personal computers for industrial automation upgrading has become a feasible approach. However, personal computers cannot meet the technical and working environment requirements of industrial production. Therefore, relevant businesses have designed industrial computers based on the structure of personal computers. Under the open structure of personal computers and the standardization of software and hardware, coupled with continuous functional upgrades, industrial computer enterprises have developed computers suitable for various professional fields, which are referred to as industrial computers.

In recent years, the demand for automation equipment and the Internet of Things (IoT) products has grown rapidly. With the development of intelligent systems and the IoT technology, industrial computers and embedded motherboards have gradually become one of the basic structure in the IoT from traditional niche markets [9]. The IoT will dominate the changes in the entire technology industry in the next 10-15 years, further changing human lifestyles and industrial competition, leading to a more complex operation of the entire industrial computer ecosystem compared to the past. However, due to the continuous expansion of industrial computer application fields, applications such as aerospace, communication, smart grids, and the IoT, have been developed, which have become the overall growth engine in the domestic intelligent control industry in the future. Among them, robot automation equipment and IoT products have a wide range of applications, and demand is growing rapidly.

This study focuses on the production model of value co-creation in the domestic industrial computer industry. In the case company, in-depth interview is applied to assist in the collection of primary data. By applying the framework of the three-stage theory and strategy of value co-creation, namely the question structure during in-depth interviews, we summarize and analyze the primary data obtained from the interviews. Based on data analysis, the value co-creation model of its two manufactures is provided.

3. Case Study

3.1 Introduction of Company A

Company A is an industrial computer manufacturer with two affiliated manufactories: system assembly (SA) and Configure to order service (CTOS). It provides integrated network technology, computer platforms, and customized products and solutions to customers, has become a highly influential multinational company in industries such as the IoT, automation, embedded computing, providing customers with value oriented and diverse customized services, and holds a leading position in the market. Before analyzing the value co-creation mode of the CTOS and SA in the context of intelligent manufacturing, it is necessary to first explain the differences in order taking, operational characteristics, organizational scale, and customer attributes between the affiliated manufactories.

The SA adopts a planned order taking production mode, with a relatively large quantity. In addition to producing standard products of its own brand, there are also customized products; The CTOS is similar to that of the SA, but it mainly focuses on customized assembly, and the production is more flexible, so the quantity is not as large and has less economies of scale. The customized products of the SA and CTOS will not compete with each other, as the customization of the SA only targets certain types, and it still has some fixed solutions; CTOS, on the other hand, can all be customized according to the customer orders, and its customers usually only have scattered orders with limited application volume.

The main difference between the SA and CTOS comes from the different customer order receiving modes. The former is a planned order receiving production, with a large order size and mainly standard products, which has economies of scale; the latter mainly provides customized orders for services, so most of them are bulk orders. In addition, in terms of manufactory scale: the SA is a complete factory area, while CTOS is just a simple factory area, mainly engaged in large-scale assembly, which is relatively thin in organization. The production line operators are the main force, with some engineering personnel, relatively simple technology, and supply chain management. So, basically it's a small system factory.

The SA also has a function of assisting CTOS in the production of some customized products, which can also achieve the effect of capacity adjustment between the two factories. Especially in times of recession, the production capacity of the system factory may be partially idle, which can help CTOS assemble customized products and learn from the production logic of CTOS. At that time, the SA was also involved in the customized project because CTOS had some internal problems that prevented delivery to customers, and the output value of the SA was also relatively low. Therefore, the company decided to move some CTOS products to the SA for assembly, and let the SA know how CTOS customization is done, so that both parties can communicate with each other. The operational situation will still vary depending on the prosperity of the industry.

In good times, there is no problem with the SA's full capacity, but once the economic situation deteriorates, the utilization rate of production capacity decreases. However, as CTOS cultivates small customers, the orders are relatively scattered, and the collection of these scattered orders is also considerable. The system factory can pull orders from CTOS to fill my production capacity gap and adjust production capacity.

In terms of customer loyalty, CTOS are higher than SA since CTOS must quickly adapt to the special specifications proposed by customers, resulting in short delivery times and high production flexibility. The SA take orders that combine raw materials into a system. It is more like taking a semi-finished or finished product, doing modification and assembly operations. Therefore, the delivery time of CTOS is usually very short. Generally, the SA takes about eight to ten weeks from material preparation to production while whe customers of CTOS require a 3 to 5 days delivery time, there is a need for high flexibility and a shorter delivery time.

3.2 Discovering the Value

Research findings 1: Industry 4.0 and the IoT have brought huge output and business opportunities to the industrial computer industry.

The trend of Industry 4.0 and the IoT has indeed brought huge output value and business opportunities to the industrial computer industry. In recent years, governments around the world have adopted advanced technology to solve various problems in order to promote sustainable development of cities. At the same time, they have also used this technology to shape smart city and enhance its competitiveness. As early as 2018, Company A decided to collaborate with IBM in order to support the infrastructure of smart city development. Computers and sensors are applied in transportation plans, providing real-time billboards for buses, equipment for MRT, and terminal sensors for e-tags on highways.

Research findings 2: Intelligent manufacturing plays a role as a backend service in the smart city development.

Research finding 3: Participating in the smart city development helps businesses accumulate experience and technology.

Company A provides equipment for the development of smart cities with higher efficiency, lower cost, and faster production. Through participation, the case company has also gained important experience and technology in the field of the IoT, including product development and organizational operations. Intelligent manufacturing or automated production plays a backend role in the planning of smart cities. The organizational structure has also been adjusted with the development trend of the industry, which has laid a good foundation for the development of the company's operational strategies in the future. With the development of the IoT, it will build a complete product line that meet various needs, including smart cities, smart factories, smart healthcare, smart logistics, etc in the next 10 to 15 years.

Research findings 4: Intelligent manufacturing can ensure the four major values of quality, efficiency, flexibility and time from the upstream supply chain to the end users.

The benefits brought by intelligent production to SA and CTOS mainly lie in quality, efficiency, flexibility and time, among which quality is the foundation of manufacturing activities. The issues that customers are concerned most about come from quality, price, delivery time, etc. However, customers in the industrial computer industry value quality more than price. The value of Company A is co-created by CTOS, SA, product department, business department, as well as external supply chain and customers. Quality is the foundation of all manufacturing, automation and intelligence can improve the efficiency and effectiveness of production quality control. For example, the intelligence of production equipment can provide early warning, identify equipment problems, and avoid poor quality production. The benefits of automation are complete from manufacturing to the supply chain, and further to the back-end users.

Research findings 5: KPIs for value co-creation should have different priorities and importance for different participants.

The four KPIs of Company A in production management are cost, time, flexibility, and quality. If delivery time is pursued, it is usually difficult to balance both quality and cost. As a result, the priority level of the four major KPIs varies. The assembly manufactory prioritizes quality and cost while the other considers delivery time and flexibility. However, after introducing intelligent manufacturing, both manufactories can achieve KPI improvement. In the early stage, improving delivery time and flexibility is the key for CTOS, when the goal is reached, intelligent manufacturing is introduced to the second stage. With good delivery time and flexibility control, other cost and quality KPIs can also be improved.

Research finding 6: When defining problems in cooperation, both parties must consider differences in organizational attributes in order to maximize overall value.

Due to the different product attributes and target customers, therefore, it is not product oriented but project oriented when defining problems; Moreover, due to the different scales of the two factories, the SA has a more complete organizational structure and abundant resources, so it can assist CTOS in achieving process optimization under cost control. If there is a cooperation on a certain product, a more common approach is capacity coordination, aimed at increasing the overall order flexibility, reducing costs and risks, maintaining quality, and solving the problem of human resource allocation caused by economic fluctuations.

Research finding 7: In order to achieve value co-creation, it is necessary to define cooperation model based on different organizational structures.

SA and CTOS hold regular meetings for communication and discussions. Before engaging in value co-creation, both parties will design a model for departmental collaboration. The cooperation logic is that

the SA directly supports CTOS, so two manufactories with different organizational units will have corresponding cooperation models. This must be defined first in order to solve organizational problems.

Research findings 8: Value co-creation must address human nature issues, which can be coordinated by managers in the short term but shall be well designed from the perspective of organizational systems in the long run.

When cooperating, both parties need to face issues with the human nature of organizational members. From both short-term and long-term perspectives, Company A addresses this issue: One is to promote the overall benefits of value co-creation through senior managers of the company, coordinating the issues arising from cooperation between the two manufactories; the other is to conduct organizational communication and personnel rotation, seeking common ground in differences and carrying out value co-creation.

The key to successful cooperation between the two lies in the attitude of the managers towards the cooperation. Whether it is the senior management of the group or the top executives of the two manufactories, it is necessary to establish a consensus on value co-creation. The most fundamental aspect of cooperation and co-creation is to solve the problem of human nature. In the short term, it must be coordinated by the senior management of the company, bringing in the directors of the two manufactories to coordinate and cooperate together. This collaborative business is a bonus for CTOS and the entire group, as outsourcing may cost more money. The long-term solution is that both sides must communicate, including at the organizational level. Therefore, from the top management to the workers, regular rotation is necessary, so that employees no longer only view cooperation from their own perspective, in order to truly reduce barriers.

Research findings 9: A value co-creation platform may not necessarily be an actual information platform, but the communication mechanism between the two parties is a value chain platform.

When the two collaborate to promote intelligent production related projects, there is no need for a platform to shared information. In addition to the internal ERP system of the group, there is also a need for regular communication mechanism.

There is a need for platforms and resources so that both parties can use interchangeably since customer needs are not the same. Once the communication mechanism is established, both manufactories can share information.

Research findings 10: The third party can also be taken as a value co-creation platform.

In order to promote intelligent production, an intelligent leadership team is formed. This unit is independent, and serves for all the intelligent projects. Because of the cooperation between the two manufactories, successful experience can be replicated and disseminated through intelligent leadership team, which can also be seen as a value co-creation platform.

3.3 Co-creating the Value

Research findings 11: By collaborating with outsourcing manufactories and adjusting internal production capacity, high production flexibility, organizational stability, and the utilization of the production line can be maintained.

When two manufactories collaborate to create value, the capacity adjustment is the most common outcome carried out in capacity utilization due to unstable economic conditions. When the SA receives fewer orders, orders for CTOS can be handed over in order to maintain utilization of the equipment. When the utilization of the production line of SA is high, the CTOS can maintain a cooperative relationship with the outsourcing manufactories based on its own capacity utilization status to ensure production flexibity.

In terms of capacity utilization, although the SA production is based on the market expectations and plans, its operating conditions may still vary due to the prosperity of the industry. At good times, the production capacity of the SA can reach full capacity, but once the economic situation deteriorates, the utilization rate of production capacity will decrease. However, since customer size of CTOS is small, so the orders are relatively scattered, only when these scattered orders are aggregated, the quantity can reach a high level. The SA can pull orders from CTOS to fill capacity gap and adjust production capacity. If production cannot achieve economies of scale, it will have a significant impact on the operation of the entire business. So, both parties shall complement each other by helping the other party meet customer requirements.

Based on the current business model, CTOS can make most of the business on its own, and the rest can be outsourced to ensure production flexibility. Company A does not need to hire very many employees to serve the needs of customers. Once there is a capacity gap in the SA, CTOS can be brought back from the original outsourcing to meet the production capacity needs within the group first. Therefore, the cooperative relationship between CTOS, SA and outsourcing factory can help Company A adjust production capacity and better meet customer order requirements.

Research findings 12: Through value co-creation, it helps to improve the efficiency of technology transfer in intelligent production.

The value co-creation model of the two also exists in the case of technology transfer. Due to the abundant resources and manpower of the SA, when introducing advanced intelligent manufacturing technology, the case company first provides seed instructor training and technology introduction to the core technical personnel of the CTOS through the SA, and then transfers the machine equipment and technology to the CTOS. The implementation effect is good, and the internal communication efficiency of the two factories is also faster than that of the CTOS directly importing from abroad. The SA can also learn new intelligent production technologies.

Research findings 13: The utilization of resources for value co-creation must conform to the spirit of altruism in order to achieve maximum value.

Not only between the CTOS and the SA, but also when the various units of the case company collaborate to promote intelligent production related plans, the principle of resource allocation or application must comply with the spirit of altruism in order to achieve the maximization of group value. Under this principle and objective, some units may not necessarily be directly affiliated with two manufactories, but rather directly serve all manufactories, such as the Joint Inspection Center responsible for incoming goods quality control (which can be seen as a shared resource among all units). Therefore, CTOS and SA will not directly face suppliers, but will pass through the Joint Inspection Center. The center is the IE department of the system factory. Starting from 2018, in order to jointly create value for both parties, the center became a shared source for both manufactories.

Research findings 14: Intelligent production platforms can be divided into two types: information systems and organizations.

From the perspective of information systems, the case company's platform for intelligent production integrates internal and external partners, including suppliers and customers' ERP systems. For some important customers, some permissions can even be opened to allow them to directly control the quality and delivery time. This platform is not connected to important external partners' platforms, only some of which are compatible with each other's data for transportation. The information in the platform can be divided into three categories: quality, delivery time, and price. The first two categories can be seen on the intelligent production platform, whether it is the company's suppliers or customers. This intelligent platform, similar to an ERP platform, that integrates external partners. However, for some key customers, the company can also open some permissions and allow them to come to the company's backend to directly see the quality and delivery time. When the company and IBM collaborate to build a smart city, although it has its own platform, we have our own platform, and the two parties can only share information. After all, they are mainly software based, and we are mainly hardware based, with different attributes.

From an organizational perspective, the intelligent team of the case company also plays a platform role, reporting directly to the company headquarters and not exclusively belonging to the CTOS or the SA. Its task is to promote intelligent production, with one in Qingdao and one in Kunshan, and there are cooperative relationships with external research and academic institutions. The unit is divided into three groups, one responsible for cases related to MES (Manufacturing Execution System) systems; another person is responsible for hardware automation; the last group is responsible for testing automation.

3.4 Distributing the Value

Research findings 15: The benefits of the value distribution stage can be divided into tangible and intangible benefits.

In promoting intelligent production related plans, the production capacity cooperation between the SA and CTOS can provide the SA with OEM fees paid by CTOS. For SA, it is possible to receive fees for producing products for the CTOS. This can also improve the production line utilization and reduce idle production capacity. The benefits obtained by CTOS factories lie in the savings in outsourcing costs. The internal outsourcing fees charged by SA are lower than those of external cooperating outsourcing factories. The assurance of customer delivery time and quality, and the assistance of system factories to optimize production processes and increase their output value.

In addition to capacity cooperation, SA and CTOS factories must also allocate value based on the principles of altruism and sharing in their respective project outcomes. The company headquarters will require each factory to develop many projects, and everyone is responsible for being able to replicate them to other factories, so that everyone will not care who has invested more resources in the development. The factory that develops first will gain benefits, but the resources invested must be balanced with the benefits, and the cooperation is mutually beneficial, not one-way. Only in this way can the cooperation of sharing project results continue.

Research finding 16: Value allocation should consider the sharing of costs and expenses between both parties involved in the cooperation.

The distribution of benefits that affect value co-creation should also consider the allocation of costs and expenses. Taking the IE department shared by CTOS and the SA as an example, 70% of the department's expenses come from the SA, while 30% come from the CTOS. Because both manufactories share the costs of the department, IE has a responsibility, obligation, and clear role positioning for their participation in value co-creation. If both manufactories set up IE departments separately, it will cause excessive organizational expansion.

4. Conclusion

From upstream supply chain to end users, the value co-creation system of the case company can be divided into three phases: value discovering, value creation and value distribution. With the promotion of intelligent manufacturing, the four major values of quality, efficiency, flexibility, and time are ensured and improved.

Value co-creation mainly involves collaboration with co-creators to solve overall and individual problems. When inviting specific objects to become co-creation partners, it is necessary to think about the problems faced by the other party in order to find the key reasons to persuade them to join. Especially let the other party know clearly that participating in this collaborative

activity can solve their current problems and provide complementary resources to increase their competitive advantage. In the value discovery stage, the KPIs for value co-creation have different priorities and importance for different participants. Therefore, when defining problems in cooperation, it is necessary to consider the differences in organizational attributes, and at the same time, necessary organizational changes and definition of cooperation models must be carried out to achieve the maximization of overall value. In addition, value co-creation must address human issues, which can be coordinated by managers in the short term and designed from the perspective of organizational systems in the long term. Therefore, in the first stage before value co-creation, Company A sahll define cooperation models based on their respective organizational structures.

In the value creation stage, through value co-creation, it helps to improve the efficiency of technology transfer in intelligent production; In addition, by establishing cooperative relationships with outsourcing factories and adjusting internal production capacity, better production flexibility, organizational stability, and production line utilization is maintained. Regarding the resource utilization of value co-creation, Company A adheres to the spirit of altruism in order to achieve maximum value.

In the value allocation stage, the benefits can be divided into the tangible and the intangible. For the SA, it can obtain the outsourcing fees from the CTOS' as well as improve the production line utilization. The benefits obtained by CTOS lie in the savings of OEM costs, the assurance of customer delivery time and quality, and the assistance of the system factory to optimize production processes and increase its output value. In addition to capacity cooperation, the SA and CTOS must also allocate value based on the principles of altruism and share their respective project outcomes. Finally, the allocation of value should also consider the sharing of costs and expenses between both parties involved in the cooperation. In addition, when conducting value co-creation, it is necessary to establish a platform mechanism. Apart from the actual information platform, communication mechanism, and third-party organizations shall all be considered as value linkage platforms.

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