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Research Article

Model Analysis and Simulation of Equipment-Manufacturing Value Chain Integration Process

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The servitization of construction enterprises based on value chain integration means that construction enterprises use prefabricated buildings and combine advantageous resources to integrate preconstruction feasibility analysis, investment and financing services, design, etc., and postconstruction decoration, operation and maintenance, and waste disposal. This article takes the equipment-manufacturing industry as the research object, and based on the analysis of the service-based value chain integration process, it puts forward research hypotheses, constructs research models, and conducts data simulation research to explore how the equipment-manufacturing industry can realize the logic of industrial value through service reintegration and optimization reveal the changing laws and key influencing factors of the equipment-manufacturing industry's value-added capabilities during this process. The results show that the industrial connection density, service element embedding methods, and knowledge absorption capacity have a significant impact on the value-added ability of the equipment-manufacturing industry during the integration process. The increase in industrial connection density promotes the enhancement of value-added capabilities, and it is significant at the initial stage and then weakened. Both the input-side and output-side service element embedding can affect the value-added ability, but the effects of the two are different. The improvement of knowledge absorptive capacity can promote the occurrence of service innovation, thereby enhancing the value-added capacity of the equipment-manufacturing industry.

1. Introduction

In the production and circulation process, around the core enterprise, all upstream and downstream enterprises that provide products or services to end customers constitute a chain or the network structure closely connects a series of enterprise nodes such as suppliers, manufacturers, distributors, retailers, and customers, and realizes the process of transforming raw materials into products and delivering them to the end customers [1]. The supply chain is centered on the core enterprise, based on the integration and control of the information flow, logistics, and capital flow within the chain to ensure the orderly, efficient, and high-quality supply coordination of all links in the supply chain. The value chain theory is derived from Michael Porter's theory of competitive advantage. It can be indicated by a value chain [2]. It

can be seen that the value chain theory takes a more detailed view of enterprise nodes as a collection of multiple activities. These activities are interrelated and interact to form a dynamic process of creating value [3]. Compared with the research ideas of supply chain theory aiming at reducing costs, value chain theory focuses more on how to create value added, which is the key to a company's core competitive advantage. The early value chain theory was confined to the inside of a single enterprise, and some scholars later extended it to the outside of the enterprise.

Supply chain management focuses on a single core enterprise. Through the management and control of the entire chain of information flow, integrity, and capital flow, the customer will set the product at the appropriate amount, quality, and appropriate timing to the appropriate location. The management of the supply chain requires the

cooperative operation of each member node in a single chain to flexibly respond to the complex and changeable market environment, as shown in Figure 1. However, the supply chain theory is limited to a single chain centered on manufacturing companies in terms of the scope of member control and the integration of accessory resources [4]. Although the member nodes in the chain are closely connected, they are excessively dependent on each other. When some important nodes supply interruption occurs, a chain reaction will affect all downstream nodes. In addition, because the scope of management is limited to a single chain, different supply chains are independent, and the distribution of accessory resources is uneven, and there is no efficient way to transfer accessory resources between chains [5]. Since the European and American countries rely on servicing to achieve industrial upgrading in the 1990s, the important role of servicing in industrial development has become increasingly prominent [6]. The global economy has shown a trend of transforming from an industrial economy to a service economy [7], and service and manufacturing have emerged. With obvious integration and mutual enhancement, servicing is generally regarded as an effective way to achieve industrial upgrading [8, 9]. As a pillar industry of the national economy, the rapid expansion of the equipment-manufacturing industry through the low-end embedding of the global value chain has not brought about qualitative changes and continuous enhancement of competitiveness, but it is limited by the increase in labor wage costs and developed countries. With technological blockade and other factors, the equipment-manufacturing industry is facing multiple dilemmas of locked high-end upgrades in the value chain, fierce competition in the low-end market, and rising production costs [10]. Therefore, drawing on the experience of industrial upgrading in developed countries, reintegrating and optimizing the logic of industrial value through service-oriented reintegration, and improving the value-added capability of the industry are an important way for the equipment-manufacturing industry to achieve industrial upgrading. Research on servitization mostly focuses on the following aspects:

(1) *The Service Mechanism and Evolution Path.* Servitization is a major change strategy adopted by product-centric companies [11], and companies obtain and consolidate their competitive advantages by integrating services rather than simply adding them [12]. Based on this, scholars have analyzed the evolutionary law and path of servicing from multiple perspectives such as value chain extension, product servicing, and servicing strategy upgrades [13–17].

(2) *The Factors Affecting Servitization.* Based on different objects and perspectives, scholars have conducted a lot of research on the factors affecting service. For example, it takes the equipment-manufacturing industry as the research object, and through empirical analysis, it is concluded that the servicing process is mainly affected by two factors: environment and organization [18]; he proposes that the relative productivity and innovation ability of the service

industry serve the manufacturing industry from the perspective of globalization. Industrialization output has an obvious driving effect, and factors such as the added value rate of the manufacturing industry and the intensity of input servitization have a certain inhibitory effect on servitization [19]. From the perspective of service innovation, they empirically analyzed the promotion and mechanism of human capital investment and good customer relationships on service innovation [20].

(3) *Service-Oriented Performance.* Scholars generally believe that servicing can improve the performance of enterprises or industries to varying degrees [21–23].

This article takes the equipment-manufacturing industry as the research object, and based on the analysis of the service-based value chain integration process, it puts forward research hypotheses, constructs research models, and conducts data simulation research to explore how the equipment-manufacturing industry can realize the logic of industrial value through service reintegration and optimization reveal the changing laws and key influencing factors of the equipment-manufacturing industry's value-added capabilities during this process. The results show that the industry connection density, the embedding method of the service element, and the knowledge absorption capability have a significant impact on the added value capability of the equipment-manufacturing industry during the integration process. An increase in industry connection density promotes the improvement of value. Functions are added and are important in the early stages, and then weakened. Embedding both the input and output service elements may affect the added value capability, but the two effects vary. Capacity enhancement of absorbance knowledge facilitates the development of service innovation and thereby enhances the value-added capacity of the equipment-manufacturing industry. This means that each branch in the multilevel hierarchy must maintain a certain inventory level at all times, and the more the branch is in the upstream of the accessory chain, the more it needs to maintain a higher inventory level. For this reason, there will be a large number of long-term inventory levels in the accessory supply chain. The idle resources not only increase the burden of inventory management but also greatly increase the cost of inventory storage. In addition, because the after-sales market demand is not static, there is a backlog of inventory in most outlets, but some outlets may be still out-of-stock which has occurred.

2. Construction of a Multivalue Chain Collaboration System for Manufacturing Accessories

2.1. Analysis of Traditional Accessory Chain Collaboration System. The core goal of the traditional accessory chain collaboration system is how to construct an appropriate after-sales accessory network structure to meet the supply requirements of after-sales accessories at all levels of the
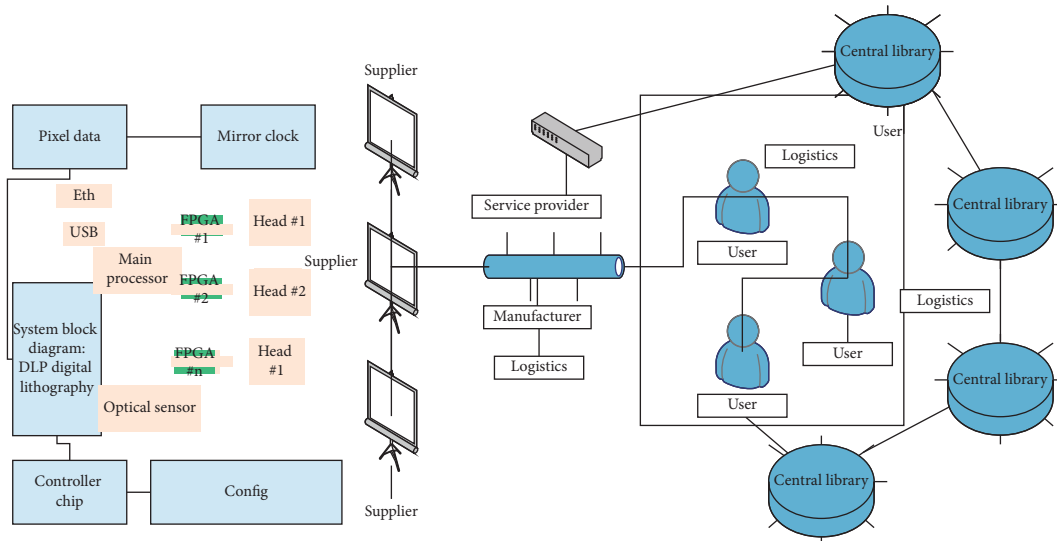
FIGURE 1: Traditional value chain collaboration.

supply chain as much as possible. At present, most auto companies and parts companies adopt a multilevel approach to planning after-sales parts networks. As shown in Figure 2, these manufacturing companies set up parts center libraries in several central areas across the country to radiate second-level outlets across the country. They establish secondary parts warehouses in various provinces, cities, and regions to radiate various after-sales terminal outlets in the area. The entire multilevel supply network is based on manufacturing companies, with primary and secondary central libraries as branches, distributors, service stations, etc. The terminal outlets are a multilayer tree structure of leaves. This multilevel planning makes the child nodes in the accessory chain very dependent on the parent node. In addition, in the entire accessory network, the node with a smaller depth tends to occupy a more important position.

If a supply interruption occurs at this node, it will affect the entire branch supply system headed by this node. In addition, the multilevel nature of the parts supply chain forces each node at each level to set up its own parts inventory, but due to the "bullwhip effect," the inauthenticity of after-sales parts demand information will flow upstream along the supply chain. The phenomenon of step-by-step amplification occurs. When the information reaches the top part central library, the demand information it obtains will have a huge deviation from the customer demand information in the actual after-sales market. For this reason, there will be a large number of long-term inventory levels in the accessory supply chain. The idle resources not only increase the burden of inventory management but also greatly increase the cost of inventory storage. In addition, because the after-sales market demand is not static, there is a backlog of inventory in most outlets.

2.2. Construction of Accessory Multivalue Chain Collaboration System.
There are many shortcomings in the traditional parts chain collaboration system. The main reason is that this kind of collaboration system cannot effectively integrate and allocate the parts resources in the supply chain, and the resources cannot be transferred quickly, and the inventory backlog and supply interruption cannot be avoided. However, looking at the essence from the surface, the essence of the problem is that there is still a lack of an effective collaboration system and coordination mechanism to rationally integrate and utilize the accessory resources between the various levels of outlets, the accessory resources between the homogeneous industry chains, and the heterogeneity.

Regarding accessory resources in the industry chain, when planning parts supply chains, manufacturing companies only focus on the vertical multilevel network structure of the supply chain, while ignoring the possible collaboration relationships between peer-level outlets. In addition, the accessory chains in different industrial chains have their own governance, and there are double barriers to information and modes between chains, making each accessory chain unable to obtain external chain resources, let alone releasing its own huge backlog of accessory resources to external chains to convert them for value. The key to effectively solving the problem of resource integration and distribution of multiple accessory chains is to build a resource coordination organizer in a multichain environment, that is, an information hub that gathers accessory information resources at all levels of the multiple accessory chains, as shown in Figure 3.

The multichain collaborative cloud service platform stands at the top of the multiparts value chain as the dominant player. By pooling multichain information resources to break the information barriers between the original chain and the chain, the originally divided accessory chain collaboration system is tightly closed. The difference from the traditional accessory chain collaboration system is that the entry degree of each node in the accessory multi-value chain collaboration system has increased, which means that the relationship that was originally strongly dependent on the parent node is broken, and it also means that the
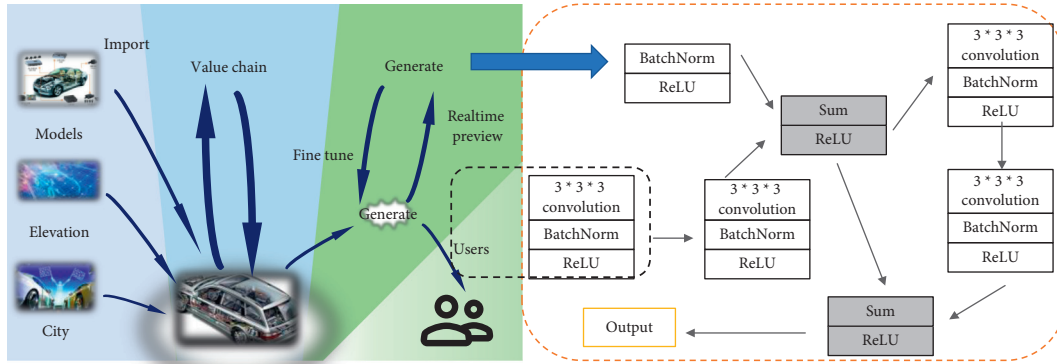
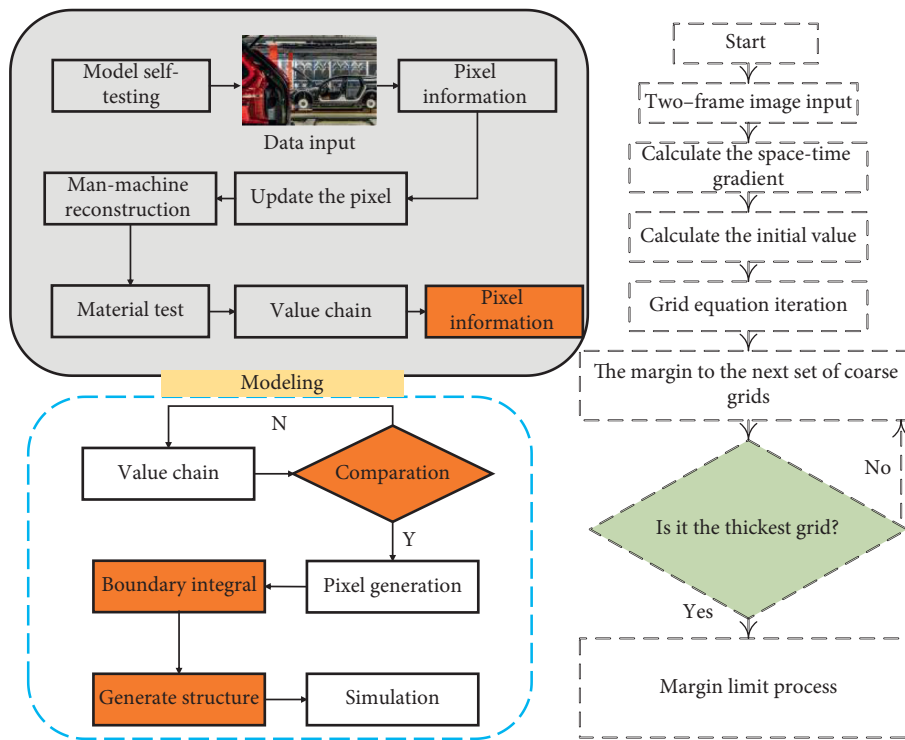FIGURE 2: Collaboration of traditional accessory chains.

FIGURE 3: Accessory multivalue chain collaboration system.

accessory resource vertical flow has been transformed into multichain vertical and horizontal bidirectional flow. The child node no longer relies too much on its parent node, which means that when the parent node has a supply interruption, its impact on the child node is not as good as before, and the multichain vertical and horizontal bidirectional liquidity of the accessory resource makes the inventory backlog of the node's accessories. It becomes possible to transfer resources to the out-of-stock node, thereby simultaneously solving the dual problem of inventory backlog and out-of-stock.

In addition, due to the collection of multichain information resources, the original "dead resources" in each accessory chain are converted into "living capital." Based on multichain business collaboration, each node in the

accessory multivalue chain can be created while reducing inventory costs. Values ultimately realize the cost reduction and appreciation of the entire accessory multichain. However, it is not enough to just collect information resources of multichain accessories. How to configure accessory resources based on the information resources is the key to the problem. For this reason, the following chapters will build on the multivalue chain collaboration system of accessories.

3. Analysis of Value Chain Integration Model

3.1. Value Chain Cross-Chain Business Collaboration Model. The accessory multivalue chain cross-chain business synergy is the synergy of heterogeneous chain accessory business

between multiple homogeneous industrial chain companies at all levels. Through a series of cross-chain accessory value activities, different chains in the vicinity of each value link different industrial chains. The spare parts resources are effectively integrated to realize the sharing and complementation of advantageous resources among multiple homogeneous industrial chains. The automotive network parts in a single industry chain are managed in a multilevel hierarchical manner, from the central warehouse of manufacturing enterprise parts, to parts of the warehouse, the transit warehouse, and terminal parts in different parts. Dealer and service provider warehouse multilevel hierarchical models have multiple types of homogeneous nodes at each level of the value chain. The business radiation range of these nodes is divided by region and provides supply of after accessories. Therefore, in the case of multiple industrial chains, there are multiple homogeneous nodes of different industrial chains in the same area. These nodes are separated from each other in the traditional accessory collaboration model, but they are effective in a multivalue chain environment. Business collaboration allows for more efficient integration and reorganization of a variety of things. Excellent accessory resource in the area is among multiple industrial chains.

The inventory cost of a company in the period $T(t)$ is the cumulative cost of inventory per unit time in the subperiod $T(tv)$. Then, there is the inventory cost $Cs(t)$ of the company in the period $T(t)$:

$$Cs(t) = \sum s(t)Q. \tag{1}$$

If there are p cycles in the company at time T, the inventory cost of the company at time T is $Cs(T)$:

$$Cs(t) = \sum Cs(q). \tag{2}$$

The out-of-stock cost of an enterprise in the period $T(t)$ is the cumulative cost of out-of-stock per unit time in the subperiod t, and the out-of-stock cost $Cr(t)$ of an enterprise in the period $T(t)$ is

$$\left\{ \begin{array}{l} Cr(t) = \sum os(t) \\ \sum Cr_i = 1 \end{array} \right\} \underset{\overleftarrow{i=t}}{\longrightarrow} (C_{r1}, C_{r2}, \ldots). \tag{3}$$

The cross-chain business collaboration cost of a company in the cycle $T(t)$ is the sum of the cross-chain business costs in the cross-chain collaboration business set $B_{rc}(t)$ in the subcycle T, and the cross-chain business collaboration cost $C_{kc}(t)$ is

$$\left\{ \begin{array}{l} C_{kc}(t) = \sum bcc(t) \\ C_{kc}(T) = \sum Ckc_i \end{array} \right\} \underset{\overleftarrow{i=t}}{\longrightarrow} (C_{kc1}, C_{kc2}, \ldots). \tag{4}$$

3.2. Cross-Chain Collaboration Value-Added Value of Accessory-Demanding Enterprises.

Parts demanding companies would have suffered a loss of $Cr(t)$ due to shortages in the subperiod T. However, due to the timely cross-chain coordination replenishment in this cycle, this loss was made up, so the parts demanding companies. The value-added value of cross-chain collaboration in subcycle T is the value created through cross-chain collaboration minus the cost loss of cross-chain collaboration, namely,

$$V_{dx}(t) = C_r(t) - C_{kc}(t) = \sum os(t) - \sum bcc(t). \tag{5}$$

If there are p cycles in the parts demanding company in time T, then the cross-chain collaborative value-added value $V_{dx}(t)$ of the company in time T is

$$V_{dx}(T) = \sum V_{dx}(t) - \sum bcc(t). \tag{6}$$

Cross-chain coordination of accessories promotes the formation of supply and demand transactions between companies in different chains that do not originally have business relationships, and supply and demand transactions will undoubtedly create value added. If the accessory-provider company supplies accessories to the accessories demanding company through cross-chain collaboration in the subcycle T, the value return is V_s; then, in the cycle $T(t)$, the total value of the synergistic value-added return obtained by the enterprise's cross-chain business-related enterprise set is

$$V^c_{s(\beta) \longrightarrow \alpha}(t) = \sum V^c_s(t). \tag{7}$$

The cross-chain coordination of parts not only solves the shortage problem of parts demanding enterprises but also provides a solution for the inventory backlog nodes in the multichain environment to effectively release the inventory pressure. Companies that may have caused huge inventory costs due to inventory backlogs through out-of-stock companies in different chains release inventories to alleviate the phenomenon of inventory backlog. Therefore, the value-added value of warehousing in the subcycle of the accessory-provider company is the cost of inventory backlog released through cross-chain coordination, namely,

$$V^c_{ss(\beta) \longrightarrow \alpha}(t) = cs \times nkc. \tag{8}$$

Part multichain collaboration is not only a collaboration between multiple supply chains but also a win-win situation between multiple value chains. The optimization strategy of multichain collaboration needs to stand on a double viewpoint of supply chain and value chain to supply chain for various parts, including Coordination cost reduction, game value improvement, cooperation of different value chains. On the basis of the above-mentioned cross-chain and hyperchain business collaboration models, this section builds an accessory multivalue chain business collaboration optimization model from the perspective of cost scaling and value appreciation in the process of multichain collaboration.

3.3. Value Chain Collaborative Optimization Strategy.

The collaborative scheduling model of accessory multivalue chain business is shown in Figure 4. In the figure, the company receives the SR needs of subsequent affiliated companies in the period $T(t)$, and meets them when the inventory is sufficient. As the inventory level continues to

decrease to the order point level R, the company begins to predict the next demand based on the current demand and formulate a procurement plan for the former company to gather PR for purchase. At this time, the inventory replenishment has entered the order lead time. During this time, because there is still demand for subsequent enterprises, the inventory will continue to decrease. At this time, if the enterprise gathers SR, there is a sudden demand increasing, as shown in the subperiod T, or if the company's collection of PR occurs out-of-stock to extend the order lead time, as shown in the subperiod, both will cause the shortage of inventory and cause the supply shortage to the lower-level enterprises. It will cause out-of-stock costs for the company, and for the company's successor CM, SR will also be unable to meet the needs of the successor company's SR due to supply outages. It can be seen that supply interruption in a certain value link of the vertical supply chain will be affected by multiple subsequent links. Therefore, we should try to avoid stock-outs in each link in the vertical supply chain. During the stock-out subcycle, cross-chain and cross-chain business-coordinated supply of parts can be carried out to avoid supply interruptions. In the cycle $T(t+1)$, the coordinated supply mode of cross-chain and superchain business of accessories can effectively avoid the occurrence of shortages.

The cross-chain and superchain collaborative supply source of an enterprise needs to be selected from the set of business-related companies cvarea and svarea. The selection process mainly considers the current market supply and demand status of the supply source and the geographic location of the supply source. Among them, the market supply and demand status of the supply source affects the market supply, and demand balance inappropriate selection will cause shortage of supply sources, so the process of cross-chain and superchain replenishment is only to transfer risks to other chains, not to solve the problem, or even backfire. A better source is to solve the problem. The problem of shortage of CM can reduce stock backlog of various chain sources, reduce the cost of various chain stocks, and bring value added across the value chain. Suppliers affect lead time and stitching of the replenishment costs of cross-chains and ultrachains. When the geographical location chooses more appropriate suppliers, the problem of shortage can be solved more quickly and at lower cost. Therefore, how to select a supply source that is beneficial to both the accessory demander and the accessory supplier from the many supply sources in the accessory multivalue chain, so as to construct a cross-chain business-related enterprise set cvarea and the svarea set of hyperchain business-related enterprises, must be considered in the coordinated optimization of accessory multivalue chains. For this reason, the collaborative optimization game strategy (COGS) of accessory multichain collaborative selection is designed to achieve the CHN internal accessory requirements.

Before proposing an optimization game strategy for accessory multichain collaborative selection, it is worth explaining that there is an obvious difference between the accessory multivalue chain collaborative optimization problem solved in this article and the general optimization problem, that is, the problem studied in this article. It is a cooperative game problem among multistakeholders. Obviously, each node in the accessory multivalue chain environment can be regarded as an independent stakeholder. These independent stakeholders can only consider self-interested cooperative strategies. They do not care about whether these self-interested strategies will harm the interests of other nodes, let alone whether these self-interested strategies will affect the overall value added of the accessory multivalue chain. In other words, there will be no problems in the coordinated optimization of accessory multivalue chains. Any company is willing to increase the value added of the entire multichain accessory chain at the expense of its own interests, even if the benefits it sacrifices are minimal. To illustrate this point, the accessory multivalue chain collaborative optimization problem proposed in this paper cannot solve the optimal strategy by only using heuristic algorithms to maximize the objective function and solve the general combinatorial optimization problem. The strategy with the optimal function is most likely an infeasible strategy.

4. Cloud Platform-Based Accessory Multivalue Chain Collaboration System Architecture and Simulation

The accessory multivalue chain involves the business synergy of accessories between multiple types of homogeneous or nonhomogeneous industrial chains, and each industrial chain involves accessory suppliers, vehicle manufacturers, accessory central libraries, regional accessory libraries, distributors, and service providers. For many enterprise nodes such as 4S stores and logistics providers, the business activities of different companies in each chain and between different chains are different. For the vertical supply coordination and horizontal allocation coordination of the accessory business in the same industry chain, it also covers the horizontal cross-chain collaboration and vertical hyperlink collaboration of the accessory business, and the corporate collaboration relationship presents a crisscross and intricate network form. In order to effectively integrate the information resources and accessory resources of each industry chain, and build business synergy in the accessory multivalue chain on this basis, cloud service technology is essential. As shown in Figure 5, the cloud service platform not only supports business synergy among enterprise groups in the upper, middle, and downstream links of multiple industrial chains, but also provides cross-chain and ultrachain business synergy between different industrial chains.

The cloud service platform based on the model needs to support cross-chain and ultrachain coordination of accessory business between different levels of enterprises in multiple industrial chains, facing complex and diverse business collaboration rules, complex and huge multichain data information resources, and ever-changing chain business collaboration needs, how to build a good information processing mechanism to effectively use multichain information resources, how to design a reasonable multichain
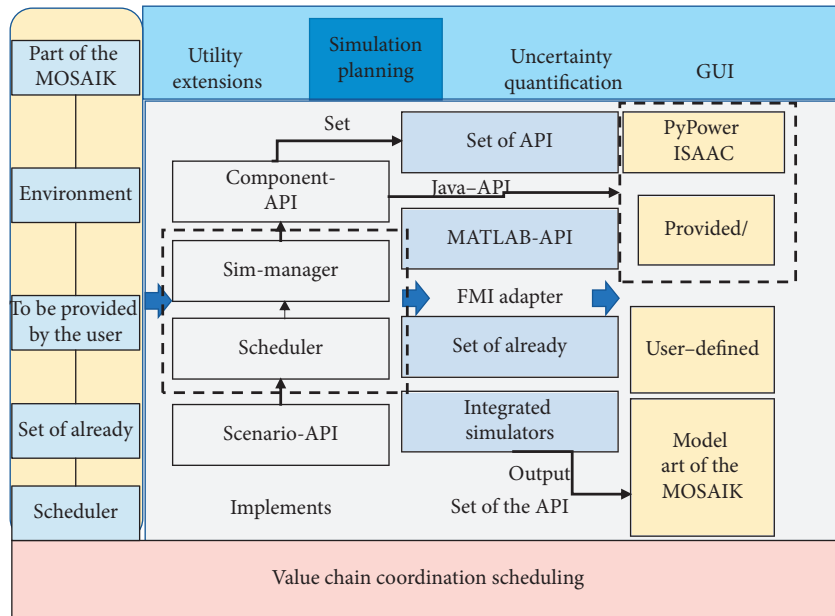
FIGURE 4: Cooperative scheduling model of parts multivalue business.
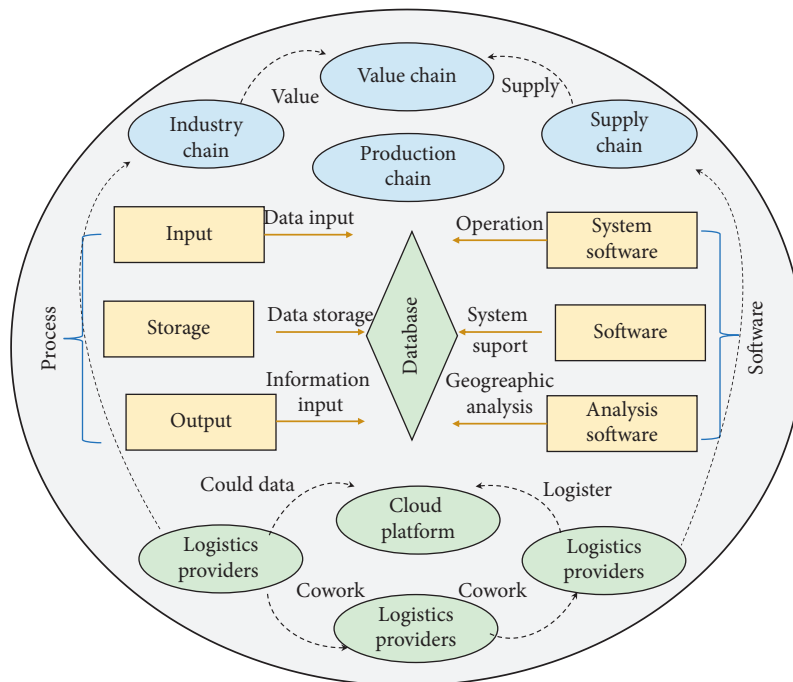

FIGURE 5: Value chain collaboration based on cloud platform.

collaboration strategy to effectively support multichain business collaboration, and how to establish a feasible process scheduling model to effectively ensure the quality of multichain collaboration are key issues to be considered for cloud platforms. For this reason, this chapter proposes a cloud platform-based accessory multivalue chain business collaboration system architecture, as shown in Figure 6.

To support business collaboration of multivalue chains of accessory, cloud platform is a combination of information resources that support business collaboration of accessories from multiple industry chains and prioritize various industries and a variety of multichain collaboration models covering the need to form business data sets. Business links include parts procurement, inventory management, parts sales, parts after sales, and Stix distribution. This includes business links that support cross-chains and ultrachain adjustment of parts between different industrial chains. The integrated data resources need to be further classified, processed, and analyzed to improve the quality of multichain data resources and more effectively play the value of data
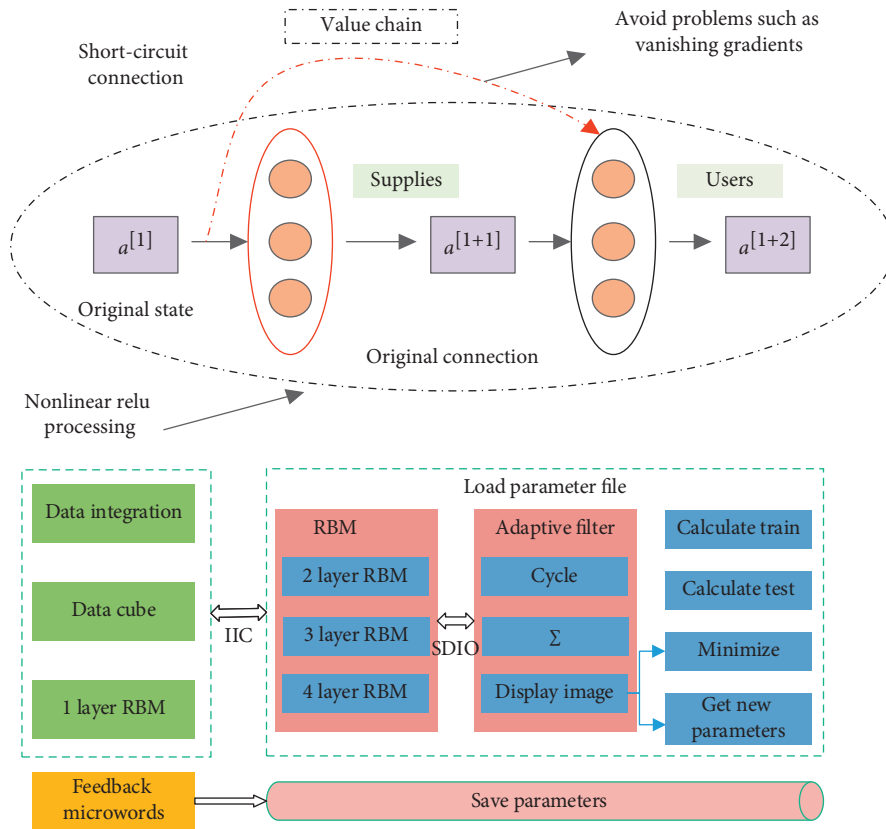
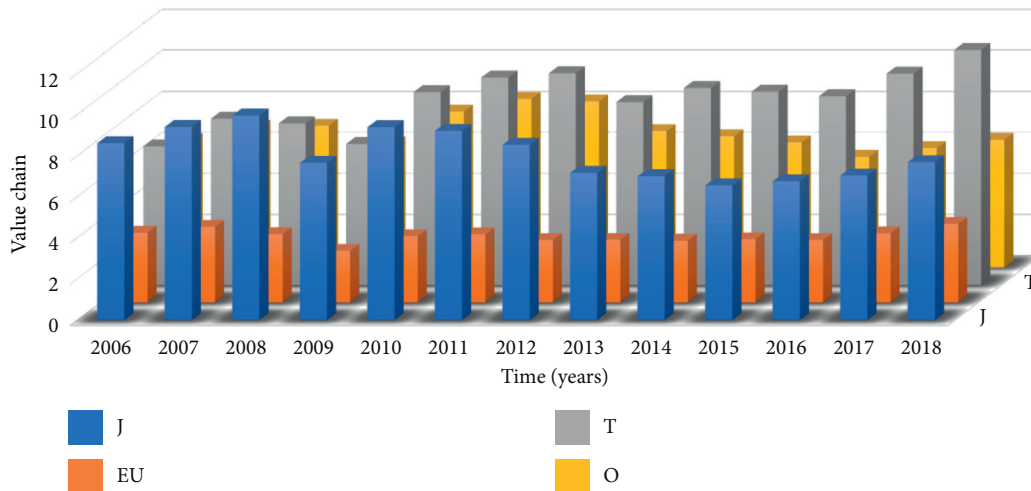Figure 6: Value chain collaboration architecture.

Figure 7: Cosimulation results of various companies.

resources. Subsequently, based on the accessory multivalue chain business synergy model and technical methods, business synergy among multichain enterprises is realized. The system architecture is mainly divided into the following levels:

(1) *Multichain Data Resource Integration Layer*. This layer gathers multiple industry chain accessory business information resources and is the hub of multichain information resource interaction.

Information resources need to be formed based on the multichain business collaboration model multitype data sets to provide real-time information support for cross-chain business collaboration between multiple industry chains, ultrachain business collaboration, and business collaboration within each industry chain.

(2) *Multichain Data Processing and Analysis Layer*. Multichain information resources are the integration of
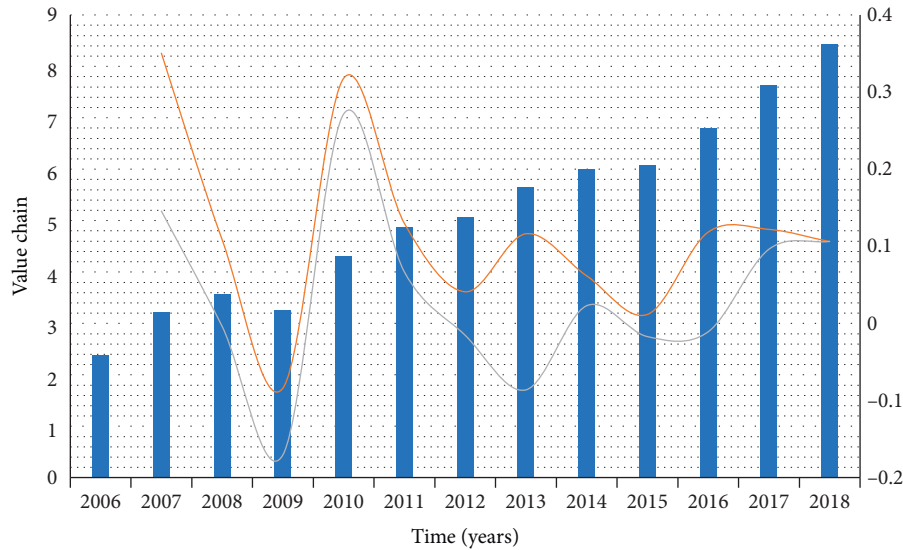
FIGURE 8: Value chain collaborative simulation results.

data resources in multiple industry chains. Due to the coverage of multiple industry chains, multiple collaboration modes, and multiple types of business processes, integrated data resources generally exist large, high-dimensional, and other characteristics, and before applying data resources for multichain business collaboration, certain data resources need to be processed to improve the quality of data utilization.

It can be seen from Figures 7 and 8 that whether it is for the multichain collaborative demand side (out-of-stock nodes) or the multichain collaborative supplier (supplier node), it can gain value every time it performs multichain collaboration. The positive-sum game in this coordination process is the key to promoting the coordination between the supply and demand sides. In addition, it can be seen that in a multichain localized interruption environment, because there are fewer backlog nodes in the system, the supply nodes tend to obtain the multichain collaborative value-added value of the out-of-stock nodes, while the system is in the multichain local backlog environment. There are many backlog nodes, so the supply nodes are more inclined to release their own inventory to obtain the added value of inventory.

5. Conclusion

This article takes the equipment-manufacturing industry as the research object, and based on the analysis of the service-based value chain integration process, it puts forward research hypotheses, constructs research models, and conducts data simulation research to explore how the equipment-manufacturing industry can realize the logic of industrial value through service reintegration and optimization reveal the changing laws and key influencing factors of the equipment-manufacturing industry's value-added capabilities during this process. The results show that the density of industrial connections, the way of embedding service elements, and the ability to absorb knowledge in the integration process have a

significant impact on the value-added ability of the equipment-manufacturing industry. The increase in industrial connection density promotes the enhancement of value-added capabilities, and it is significant at the initial stage and then weakened. Both the input-side and output-side service element embedding can affect the value-added ability, but the effects of the two are different. The improvement of knowledge absorptive capacity can promote the occurrence of service innovation, thereby enhancing the value-added capacity of the equipment-manufacturing industry.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

Acknowledgments

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