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Upgrading models, evolutionary mechanisms and vertical cases of service-oriented manufacturing in SVC leading enterprises: Product-development and service-innovation for industry 4.0

To address Industry 4.0, service-oriented manufacturing unifies the development track of product development and service innovation and constructs a high-quality transformation path based on the service value chain. Therefore, analyzing the specific strategy of service-oriented manufacturing and clarifying its static connotation and dynamic evolution direction have become important topics in academic circles. First, based on the core logic of value creation, the upgrade model and critical contents of service-based manufacturing are studied and summarized using upgrade theory, guided by the evolutionary theory of enterprise deoxyribonucleic acid (DNA). Combining the service value chain (SVC) characteristics of leading enterprises, the influence mechanism of autonomy and otherness on service-oriented manufacturing is clarified. Second, the upgrade model content and upgrade evolution mechanism of service-oriented SVC manufacturing among leading enterprises are summarized. Four upgrade patterns—traditional manufacturing, service-based manufacturing progressive upgrade, and service-based manufacturing breakthrough upgrade I and II—are formed. The Hai Feng Ju Zhen (in Chinese; HFJZ) matrix of the guiding framework of service-oriented manufacturing development is finally formed using the service and manufacturing trends of enterprise revenue-cost. Finally, the complete process of service-oriented manufacturing is identified, presented, and explored using the vertical case of Aviation Industry Corporation of China (AVIC) High Tech. The logical evolutionary framework of resource–capability–advantage–development guides enterprises to construct a spiral development system involving the static upgrading-dynamic evolution of service-oriented manufacturing. We also verify the practicability and regularity of each stage in service-oriented manufacturing through the actual case of AVIC High Tech. We find that enterprises should follow the logic of value creation and use the active introduction of service factors to break the bondage of diminishing production factors. The product development and service innovation of service-oriented manufacturing can double-track and thus should achieve the synergistic construction of the supply chain, value chain, and innovation chain. The upgrade mode of service-oriented manufacturing should be compatible with the state of an enterprise and should not blindly service and lead to the stagnation of development. Scientific research and judgment in terms of a service-oriented manufacturing trajectory and the construction of a development state compatible with service-oriented manufacturing are the keys to the formation of SVC-leading enterprises.

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Introduction

In 2013, Hannover Messe introduced the concept of "Industry 4.0" for the first time, marking the transition from the information age (Industry 3.0) to the intelligence age (Industry 4.0), where information technology promotes industrial change. Compared to the previous stages of industrial development, the disruptive character of Industry 4.0 lies in its convergence and creativity; whether in the steam age ("Industry 1.0"), electrification age ("Industry 2.0"), or information age, their cores rested on a single subject. That is a single revolutionary technology dominated each era (Mishra et al., 2020). Thus, for companies in those times, the identity of "manufacturing" was much stronger. Specifically, learning, mastering, and applying the corresponding steam technology, electrical technology, or information technology made it possible to effectively integrate into the global value system and to make a wide range of profit margins through manufacturing (thus, the traditional industrial phase did not require an act of integration or creative thinking on the part of the subject, but only a step-by-step approach guaranteeing the stability of the manufacturing elements). However, in the Industry 4.0 era, its convergence requires manufacturing companies to master service-oriented functions. Ultimately, an upward spiral pattern of technology for development and development-leading technology is achieved. It is through integration that the core mission of technology for industrial change can be fulfilled. On the other hand, the demand for creativity is forcing manufacturing companies to use service elements as new elements of production to break the spell of diminishing production effectiveness (Serrano-Ruiz et al., 2022). In terms of the law of diminishing marginal productivity of production factors, Industry 4.0 is essentially the beginning of a cycle of declining marginal utility for the industrial system. The traditional steam, electrical, and even information technologies are stifled by the same "Malthusian trap" and "Ricardian rent thinking" as the ancient factors of labor and land. The key to breaking with the established diminishing productivity and marginal decay of production factors is that the new growth of society requires the creation of new factors that are accepted by capital (the marginal productivity of capital) as well as information that is accepted by the market (the marginal utility of consumers). In this logic, services are both a factor of production and a utility of use. Only the creation and integration of the service element into the production system can completely imply the formation of an Industry 4.0 structure (as shown in Fig. 1). In this context, for Industry 4.0, the traditional manufacturing industry needs to realize the dual track of product development (PD) and service innovation (SI) to shape the upgraded model of service-oriented manufacturing (SOM).

In establishing SOM, PD and SI were the original spontaneous activities of a company's autonomous march. However, the convergence and creativity principles of Industry 4.0 enable these primitive and spontaneous activities to shift from centralized control to a decentralized and enhanced control model, culminating in a highly flexible framework for the production of personalized—and digital—products and services. There is, therefore, a propulsive and diffuse link between the context of Industry 4.0 and the practice of the SOM model (Bv and Guddeti, 2021). Industry 4.0 blurs the boundaries among organizations, industries, and elements; on the one hand, as it opens up the activities of companies, new fields of activity and forms of cooperation arise, and collaborative product development and joint service innovation between companies become increasingly intensive. On the other hand, product development within companies is beginning to focus on integrating service elements, and the service innovation process is also concerned with product upgrading amid the demand for increased service effectiveness. The core of this unified framework and logic (the two-track mission linkage of PD-SI and the two-track trend linkage of Industry 4.0 and SOM) is based on the standard concept of "value creation" (Groenroos and Helle, 2010), which is the shift from economies of scale to economies of scope through Industry 4.0, based on homogeneous and scalable costs, to produce heterogeneous and customized industries. The "narrow" nature of these economies of scope can reduce any information barriers between production and marketing, accelerate the interconnection between production and services and feedback on flows, and thus create consumer models and patterns that meet the needs of the new economy. Business models led by relevant new industries become the end product of value creation and value satisfaction. The two-track mission of PD-SI is to create the materialized value of the essential product and the channelized value that carries value transfer. The two-track trend of Industry 4.0-SOM, on the other hand, is the creation of firm-oriented manufacturing value and customer-oriented service value. This evolutionary trend is summarized in Fig. 2.

The concept of the service value chain (SVC) is based on the core of value creation. SVC is the process of transforming input "needs and opportunities" into output "products and services" via the principles of value creation in the traditional value chain (Cohen et al., 2000). In this transformation mechanism, the traditional value chain involves a specific and rigid demand scenario with predefined advanced manufacturing actions and manufacturing process sequences corresponding to market activities. The manufacturing value stream formed by manufacturing subjects and manufacturing elements, based on upstream and downstream relationships, determines the basic operating rules of the traditional value chain. However, with the development of Industry 4.0 scenarios and the dominance of SOM, the variability, and freedom of business models have increased considerably (Song et al., 2016a, 2016b), leading to a flexible demand field and complex and irregular market activities. Rigid manufacturing streams are unable to guide the operation of a value chain, whereby the resulting alternative service value streams have begun to dominate value chain transformation. The soft symmetry of information and the stable adjustment of the established nature that the service value streams emphasize enable traditional value chains to quickly respond to specific changes in demand and, ultimately, to their market. Therefore, SVC is a highly stable, responsive, and efficient main chain based on the service value stream in the traditional value chain. This service-based manufacturing model, formed by SVC, is shown in Fig. 3.

In recent years, developed or advanced manufacturing countries have accelerated the construction and reorganization of SVCs to develop new competitive advantages, further undermining the labor-intensive advantages and land-resource-intensive output of impoverished countries; thus, intensive manufacturing products are no longer suitable for the global market[1]. The competitive disadvantages of basic or homogenous manufacturing are amplified, and the potential to add value is lost in the shift from SVC, eventually creating the vicious trap of incapable product development and disengagement from service innovation. In building SVCs, latecomers often lose their initial momentum and voice due to the captivating nature of their chain and lose their potential role in the hierarchy of governance, as they are unable to sustain high-value expansion activities. Therefore, the leading role of a leading enterprise (LE) is key to maintaining the quality of its country's SVC. Due to the abundance of manufacturing capabilities, an LE has a firm grasp of the market and the ability to integrate traditional value chains; once the idea of service value streams is added, it can quickly promote the construction of SVCs in a particular industry. The essence of an SOM upgrade is to enhance a company's value creation

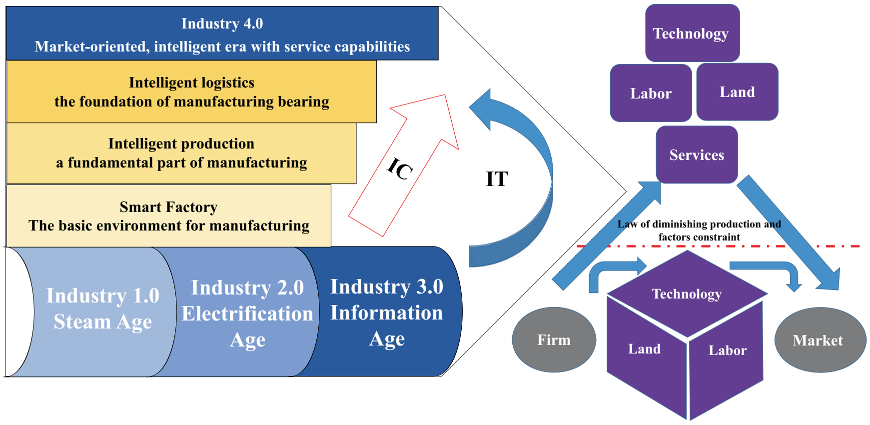

Fig. 1 Principle diagram of the core features of Industry 4.0 and the incorporation of service elements (Figures source: self-made by the author). The driving force of the transformation from Industry 1.0 to 4.0. Among them, the introduction of service elements has the significance of promoting production efficiency.

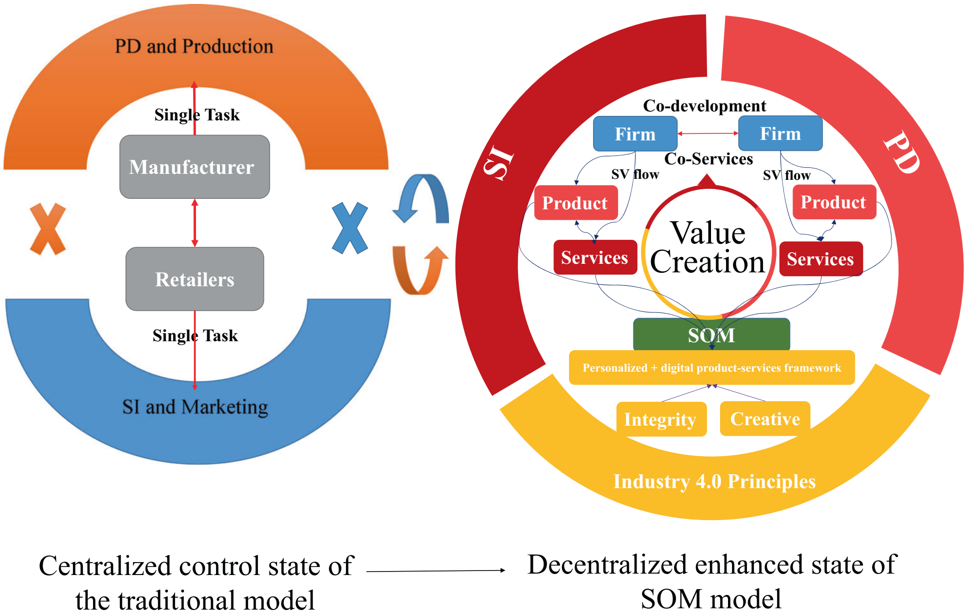

Fig. 2 Evolution of the SOM model under the two-track mission and trends (Figures source: self-made by the author). Service-oriented manufacturing upgrades transform the traditional manufacturing isolation model. The internal operation mechanism of service-oriented manufacturing relies on the connection of service flows.

capability and build its core product technology (PD advantage) and market power (SI market), a goal that is clearly in line with the logic of shaping SVC.

In this context, dissecting the SVC-leading enterprise SOM upgrade model will be of great use in improving the quality of SVC and describing the logic of SOM transformation. By considering the realistic orientation of Industry 4.0 and the core logic of SVC value creation, this study dissects the scientific evolutionary trajectory of leading enterprise SOM from the perspective of PD and SI. In the context of Industry 4.0, the black box of the SOM-enabled SVC mechanism is deciphered (Zhen, 2012). That is, we crack the mechanistic black box of service-oriented manufacturing empowered SVC amid the vast shift toward the era oriented to Industry 4.0. Combining previous service-oriented manufacturing and SVC research, the traditional themes of this research, we provide the following contributions: (1) we define the leading SVC enterprises, enrich the connotation of SVC, and clarify the current strategies and mechanisms of SVC transformation in enterprises; (2) we clarify the broad concept of service-oriented manufacturing and discuss the significance of service and manufacturing integration (Song et al., 2016a, 2016b); and (3) we construct a research framework for service-oriented manufacturing using an effectiveness function or supply chain model to discuss the relationship between service-oriented manufacturing and relevant benefits (Shen et al., 2007).

In previous research, scholars have shown more curiosity toward the extended topics of service-oriented manufacturing (Wu et al., 2018). For example, they have explored what kind of leading enterprises can drive the integration of service and manufacturing in service-oriented manufacturing and the specific integration path of enterprises in the evolution process of service and manufacturing (Valilai and Houshmand, 2013). That is, they have sought to answer what service-based manufacturing is, how success in service-based manufacturing is attained, and how corporate success is achieved through service-based manufacturing. These academic gaps remain, attracting the attention of scholars (Giret et al., 2016). With the deepening of service-oriented manufacturing research, scholars have emphasized that

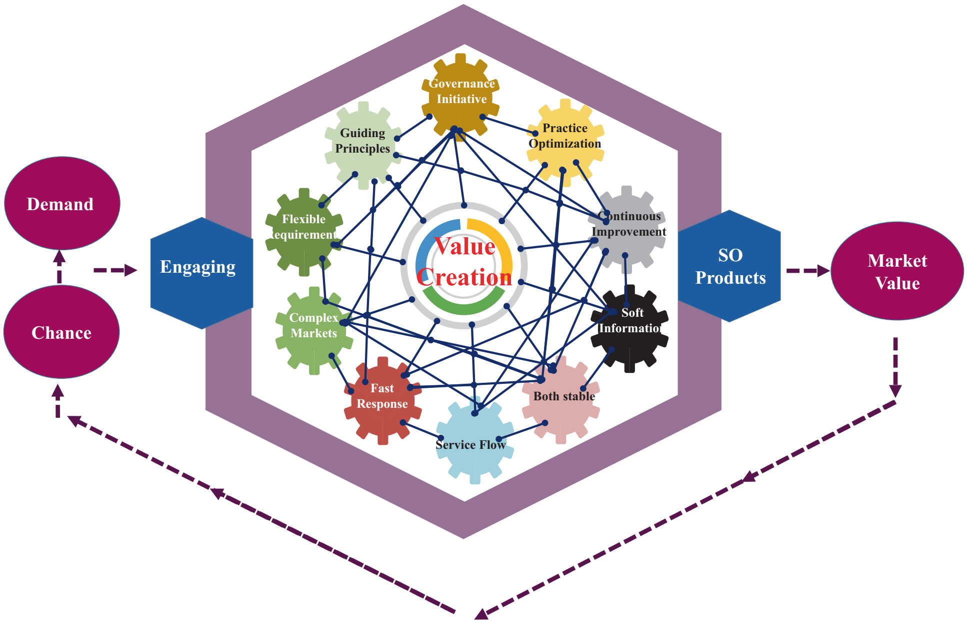

Fig. 3 Mechanism of the SOM model based on service value streams and SVC (Figures source: self-made by the author). The core of the service value chain is value creation. Service manufacturing forms a network of service activities.

the development of service-oriented manufacturing should be reflected in practice. That is, the transformation challenges of service-oriented manufacturing should be resolved through specific business operation activities. Concerning the real activities of enterprises, they can be roughly divided into two kinds of products and services. Therefore, these shape the business principles of enterprises and their integration of the product development and service innovation of both operational elements into the transformation mechanism of service-oriented manufacturing. Such information is important content for future enterprise development.

Accordingly, in this study, we aim to fill the relevant gaps and expand the extant systematic research ideas on service-oriented manufacturing as follows: (1) we clarify the development linkage and transformation ideas of service-oriented manufacturing in leading SVC companies, constructing the connotation, logic and strategy framework of both. (2) We clarify the static and dynamic processes of service-oriented manufacturing and portray the characteristics of enterprise performance in the different stages of service-oriented manufacturing. By connecting multiple perspectives on dynamics and statistics, the construction of the supply chain, value chain, and innovation chain of enterprises can be conducted, which provides specific transformation strategies and logical rules. (3) We construct a logical framework of resource–capability–advantage development and analyze the evolution mechanism of service-oriented manufacturing in different stages; we distinguish the coordination of various operation chains in service-oriented manufacturing. (4) Based on the perspective of the intersection of product development and service innovation, we delineate the specific intersection of service-oriented manufacturing and SVC construction in the business activities of enterprises to clarify how enterprises can maintain the synergistic operation of product development and service innovation to achieve the maximum benefit of service-oriented manufacturing. (5) We define and verify a novel service-oriented manufacturing mechanism using real-existing vertical cases; thus, we determine how companies achieve an SVC leading position via service-based manufacturing activities. Finally, we summarize and compose the rules for the promotion of service-oriented manufacturing in traditional industries, which can help promote the specific practice of service-oriented manufacturing in national strategic transformation.

As we fill the above research gaps, we also engage with the following research contents and directions: (1) How ordinary companies become leading SVC companies through service-based manufacturing activities and how their regular activities are distilled. (2) The static and dynamic contents of service-oriented manufacturing and the specifics of the upgrading process in each stage. (3) The balance of service and product activities in enterprises in their establishment of service-oriented manufacturing and SVC leader status; here, we explore the intersection of enterprise service innovation and product development in each stage. Finally, combining the analytical framework of resource–capability–advantage–development and guided by the operational logic of the value chain, innovation chain, and supply chain, we point out the rationality, effectiveness, and normality of enterprise strategy.

Due to the ambiguity of product development and service innovation activities in service-oriented manufacturing, firm-oriented strategies should be specific. Thus, a systematic approach using qualitative research is chosen in this paper. The qualitative systematic approach in this paper is divided into three parts, one of which is a general qualitative exploration. Evaluating previous studies, the collection of salient concepts is summarized, which our subsequent analytical framework integrates. This lays the foundation for later scientific analysis of research objects. Second, we use qualitative comparison and an inductive approach. Through the progressive induction of phenomenon → connotation → law, our qualitative comparison yields specific content concerning service-oriented manufacturing dynamics and offers an exploration of the upgrading mode and evolutionary mechanism. In this process, we focus on distinguishing the intersection of service innovation and product development activities while comparing and summarizing the method of integrating the two. Third, we perform a case study, exploring qualitative cases to support our analytical framework and the specific content proposed in this study. Our qualitative investigation thus comprises a scientific abstraction, theoretical analysis, and conceptual understanding of the various aspects of service-oriented manufacturing, demonstrating the rationality and normativity of our research framework. Compared to quantitative methods, qualitative research is more suitable for this topic for the following reasons: (1) In terms of the research relationship, the topic of service-oriented manufacturing entails analysis of social phenomena. In addition, in quantitative research, to conduct an objective and impartial study of social phenomena, the researcher must be completely separate from the focal subject to prevent bias. However, in fact, the research questions posed by quantitative research, the theoretical basis for establishing hypotheses, and the methods of the extraction and analysis of social facts have an implicit value orientation. Therefore, qualitative research is not only inevitable but can also reveal the relationships among social phenomena, scenarios, and research; thus, it is the antecedent method for opening and verifying academic topics. Qualitative research can collect information about actual events in real-time in their natural context and provide first-hand research data on the object of study. (2) In terms of our research purpose, our topic requires induction via exemplary and regular research strategies. Qualitative research involves the measurement of social facts to discover social patterns and determine the relationships between them as well as to explain the causes of relevant changes to guide social practice. Qualitative research is more focused on participants' points of view and aims to understand the meaning behind social phenomena. It can therefore reveal the internal dynamics of service-based manufacturing contexts and the dimensions of the human empirical characteristics that quantitative research ignores. Clearly, then, qualitative research methods and their findings are more appropriate for our topic. (3) In terms of our research methodology, the qualitative paradigm of observation–review–induction–survey verification in this study can satisfy the requirements of research rigor, objectivity, and value neutrality. Our findings also meet the need for the authenticity of results. While qualitative research, which mostly obtains first-hand information through observation and research, offers the advantage of observing the relevant causes, attitudes, efforts, and actions that comprise the decision basis of service-oriented manufacturing, it also facilitates the use of the inductive method to assess the information obtained by observation and interview methods. Hence, evidence can be gradually transformed from concrete to abstract in the formation of theories. Theories and results formed in this way emerge from the interconnection of different pieces of evidence, which is a bottom-up process. Therefore, such conclusions are more applicable and more suitable for generalization and application. In summary, we intend to describe the whole process of service-oriented manufacturing through a comprehensive qualitative study and to analyze the logic and laws of these behaviors to expand the realistic operational efficiency of enterprises.

Based on our research topic, we adhere to the following structure:

The first section is a qualitative exploration of research, offering theoretical support via the literature. (1) First, we analyze the evolution theory of corporate DNA. The theoretical basis that supports enterprise service-oriented manufacturing transformation is extracted. Using the theory of enterprise DNA, the relationships among organizational structure innovation, system innovation, technology innovation, and information transformation can be understood. The internal relationship between these factors and service manufacturing upgrading is obtained. Through the orientation of factors, the trend of product and service track construction in service-oriented manufacturing is clarified. (2) Second, we construct the theoretical system of service-oriented manufacturing upgrading through value chains and supply chains. Our analysis of the innovation chain summarizes the core concepts of SVC. The dependence relationship between service manufacturing upgrading and the SVC of leading enterprises is analyzed. By mining static factors, the theoretical basis for the stability of the service-oriented manufacturing static mode is analyzed. (3) Finally, based on cybernetics, the impact of autonomy and otherness on the evolution mechanism of the service-oriented manufacturing mode is studied. Through an exploration of the controlling factors, the theoretical support for the dynamic transformation of service-oriented manufacturing is analyzed.

The second part is our qualitative comparison and research induction. We analyze the upgrade mode (static performance) and evolution state (dynamic performance) of service-oriented manufacturing in leading SVC enterprises. (1) Based on the theoretical exploration mentioned above, the specific content and work of leading SVC enterprises in the service-oriented manufacturing upgrading mode are clarified. We also discuss the external foundation of service-oriented manufacturing brought about by enterprise DNA, the internal architecture of service-oriented manufacturing (product and service track), and the working practice of service-oriented manufacturing. (2) By distinguishing static efforts, we further explore the direction of dynamic evolution. Based on the HFJZ matrix, service-oriented manufacturing is divided into four specific modes and a variety of dynamic evolution possibilities. Hence, we explore the intervention of controlling factors in the direction of evolution to determine the transformation strategy of service-oriented manufacturing.

The third part of this paper is our case verification and analysis. The concrete case of AVIC is used to support our theoretical conclusions. Through this case, the correctness of the theory of the service-oriented manufacturing upgrading mode is verified. (1) Combined with our induction in the second part, we clarify the static model of service-oriented manufacturing upgrading in AVIC High-Tech and analyze its upgrade basis and core architecture. We find that it has responded to the guidance of various theories. Based on the logic of resource–capability–advantage–development, we thus construct a theoretical model of the service-oriented manufacturing upgrading mode for subsequent quantitative research and analysis. (2) Four dynamic upgrading and evolution trends in AVIC High-Tech are identified. The practicability and validity of our theory are evaluated using the HFJZ matrix. We find that the development of AVIC high-tech has typical characteristics. (3) The implications and contributions of AVIC high-tech to service-oriented manufacturing are discussed. In accordance with our theoretical model, the verification value of the case is also articulated.

Literature review

Service-oriented manufacturing is a new business model that has followed the integration of traditional manufacturing into productive services (Quintanilla et al., 2016). Its core lies in that enterprises use traditional physical product activities as the basis to continuously expand their scale of services and use the innovation of service activities to iterate the upgrade of manufacturing mode. Such productive services are not directly involved in the production or transformation of material products but have an indispensable role in manufacturing activities. Therefore, product and service are independent dual tracks for companies at the activity and practice levels. However, there is a significant intersection of their practical applications (Hobo et al., 2006). Service innovation and product development run through the whole process of service-oriented manufacturing in enterprises, and productive service activities exist across all aspects of production and manufacturing, distribution and distribution, and social consumption. Therefore, we analyze the independent operation of each of these from the dual perspective of product development and service innovation to examine the intersection of the two based on the connotations of service-oriented manufacturing (Nagorny et al., 2012). That is, we analyze the initiatives and significance of service and product activities in terms of the establishment of a service-oriented manufacturing model.

Service manufacturing is a professional division of labor based on comparative cost advantages. It can be divested from each production link to adapt to changes in production and marketing methods; it can also function as a new industry to adapt to the increasingly fine social division of labor in the context of modern mass production (Morariu et al., 2013). With strong professionalism, high industrial integration, active innovation factors, flexible operation methods, and sensitive product transformation, the production service industry is an important new industry in the current era of the new industrial revolution. As a new industry and new product in the new era, its successful demonstration often requires the leadership and role of leading enterprises. On the other hand, traditional enterprises engaged in manufacturing development have bottleneck problems; they also need to achieve a leading position through service-oriented manufacturing to retain or break through to become excellent enterprises. Therefore, service-oriented manufacturing is a long-term evolutionary process, i.e., an evolutionary process of static solidification → dynamic adjustment → static restabilization. This static mode of continuous stabilization can be summarized as the upgrade mode of service-oriented manufacturing. The dynamic changes between each static mode can be regarded as the evolutionary process of service-oriented manufacturing. Regarding the stepwise upgrading of service-oriented manufacturing, we analyze the theoretical basis of this upgrading process via upgrading theory and SVC faucet theory. Furthermore, to examine this trend of dynamic and static change, we examine the feedback process of the service-oriented manufacturing evolution mechanism by combining the autonomy and otherness perspectives of cybernetics.

Thus, in this section, we distinguish the logic of service-oriented manufacturing upgrading patterns and evolutionary mechanisms. Guided by the literature, the theoretical bases of relevant content are examined and judged. Accordingly, the intersection of service innovation and product development is summarized to lay the foundation for our definition of the specific model connotations of service-oriented manufacturing in a later section. This aggregation forms the upgrading strategy of service-oriented manufacturing.

Upgrade theory, via the evolutionary theory of corporate DNA. As a micropractice of industrial upgrading, enterprise upgrading is essentially the need for enterprises to match the coordinated development of their industry and society through internal quality, structural, and efficiency adjustments and optimization (Feldman et al., 2016). Thus, the macroscopic vision of industrial upgrading guides the specific details of corporate upgrading. The main upgrading activities of an enterprise include four elements—information transformation, technological innovation, organizational innovation, and institutional innovation (Morgan and Ngwenyama, 2015)—which reflect the guidelines of informatization, innovation, organizational centralization, and institutional efficiency in the industry. From a strategic management perspective, the four elements of a business essentially form a triangular progressive framework of practice-tactical strategy. The practical layer is the use and paving of basic technologies, i.e., information technology transformation activities (Mouzas, 2022). The tactical layer applies innovative technology through the establishment of core technology barriers to maintain the core of competitive market power in the enterprise's long-term and short-term performance objectives (Alam et al., 2022). The strategic layer is the construction of an institutional system to meet the future development goals of the company and to seize market heights (Fischer et al., 2022). Institutional innovation in organizations supersedes the practice–tactical–strategic framework (Min et al., 2022) and serves specific corporate upgrading activities through organizational-level responses.

The solidification and stability of this upgrading framework are thus guided by the evolutionary theory of corporate DNA proposed by Richard R. Nelson and Winter (1982). Corporate DNA evolution states that upgrading a company is a spontaneous growth activity of the organization. In line with biological evolution, the upgrading of firms follows three core mechanisms given by 'nature' (the market): diversity, heritability, and natural selectivity (Nelson et al., 2002). Diversity comes from the differentiation of organizational structures. The different directions of innovation in organizational structures and the different stable substances that link the framework of upgrading in enterprises ultimately determine the heterogeneous changes in the upgrading of all enterprises (Li, 2020), resulting in a wide variety of enterprise forms. Heritability, as the core pattern that brands a company's core, essentially represents the strategic layer of thinking in the framework of corporate upgrading. The institutional system is the stable substance that runs through the development of the enterprise and is a central element in the achievement of its most long-term goals (Voss, 1991). No matter how a company develops, upgrades and leaps forward, it depends on the adaptive innovation of its institutional structure. Natural selectivity corresponds to an upgraded framework at the practice-tactical level. A market that leads technology change empowers companies to master their possibilities of information technology infrastructure and guides them in how to meet the needs of the market and make natural choices through scientific, and technological innovation.

In summary, industrial upgrading determines the specific practices of corporate upgrading. With the quest for market adaptation at its core, the evolutionary theory of DNA also clearly differentiates the specific layers of enterprise upgrading (Child et al., 2012). Through the scientific extraction of DNA evolution, the theory of enterprise upgrading has gradually generalized the genetic code of an enterprise, i.e., an enterprise is an active social organism with its own genetic code (Ryva et al., 1991). Combining the four "nucleotide molecules" of a company will thus ultimately guide the different paths and directions of upgrading. Among these, innovation in organizational structure corresponds to the diversity gene, institutional innovation corresponds to the heritability gene, and technological innovation and information transformation are the natural selective genes for enterprise upgrading. This is shown in detail in Fig. 4.

In the context of SOM, manufacturing companies are actually developing at the practical level to meet the demands of Industry 4.0 (Brouthers and Brouthers, 2010). In this new market environment, the "natural market" emphasizes the universality and applicability of information technology. This dictates that manufacturing companies bear the brunt of improvements to their information construction base when meeting the preconditions for upgrading their businesses through transformation (Su and Levina, 2011). Furthermore, due to the squeeze of homogeneous products, technological innovation, as a progressive alternative to the "natural market", has led to tactical upgrading in companies. Thus, while retaining the "hereditary attributes" of the physical system of manufacturing companies, they have begun to expand their service elements, service sectors, and service systems, gradually upgrading themselves into a new system of intertwined service and manufacturing. Finally, to maintain competitive differentiation, lead the transformation of their industry, and upgrade all their levels, manufacturing companies are shaping new organizational structures through

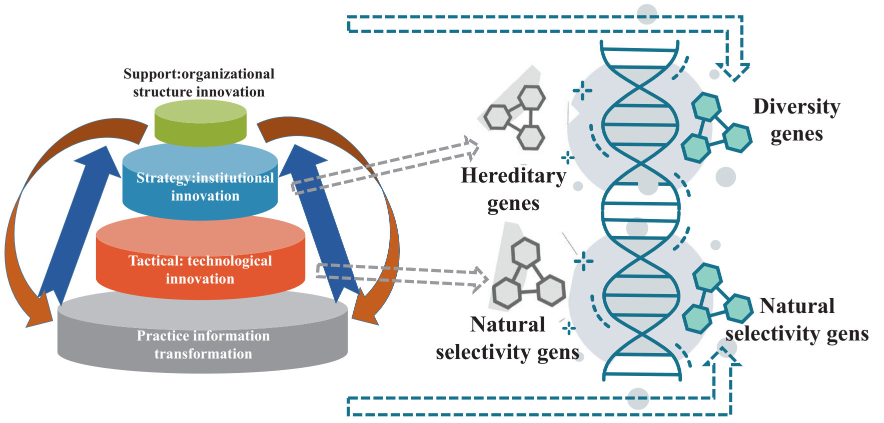

Fig. 4 Pyramid framework for enterprise upgrading and the corresponding extracted evolutionary genes (Figures source: self-made by the author). The key elements of the development of service-oriented manufacturing under the theory of corporate DNA.

the development of "diversity genes" (Josephson et al., 2016). These processes, combined with the definitions of enterprise upgrading model mechanisms given by various schools of thought, can be summarized into six significant upgrading models. Hence, we regroup these upgrading model mechanisms based on the PD and SI perspectives under our Industry 4.0-oriented premise, as shown in Table 1.

Specifically, we combine the two-track perspectives of PD and SI to dissect the self/other-dominant driven model of SOM enterprise upgrading. We also clarify the value-adding mechanism of SOM enterprises, supported by the theory of enterprise evolution.

SVC leading enterprise SOM upgrade. Contrary to traditional value chains, SVCs do not provide compensatory advantages to latecomers in the development process (Xi et al., 2013). Latecomers also find it difficult to obtain efficient ways to add value from SVC dependencies. Conversely, latecomers often inhibit functional upgrading due to competitive barriers and the distracting environment of 'others-dominance' (Wang, 2018). Therefore, for the establishment of a national service-oriented manufacturing environment and the development of a national service value chain (NSVC), an LE should take the lead, relying on favorable resources in its domestic market (Aliy, 2000) to form a domestic LE-led service value distribution system, thereby optimizing the service capabilities of NSVC local enterprises. Regarding international SVCs, an LE is an object of study that allows better analysis of the future highs and lows of SOM to reveal SVC value creation logic.

Most scholars believe that an SVC-leading enterprise is a local enterprise with a high ability to lead the development of SVC (Heintzman, 2005). An SVC-leading enterprise leads its industry in technological breakthroughs and market expansion through new product development and the design of a service system that meets market needs (Gibbons and Hazy, 2017). Therefore, the core of an SVC leader's SOM upgrade entails the following: (1) realizing product chain innovation, i.e., forming interoperability between the supply chain and the innovation chain and the innovating technology and ideas in the industry's original upstream and downstream supply chains; (2) realizing chain innovation in services, i.e., forming an interconnection between the value chain and the innovation chain and the innovating models and systems for the markets and consumer groups that the industry is oriented to. Under this logic, the key to upgrading and stabilizing the SOM model is the formation of a multi-dimensional unification of the supply chain, the innovation chain, and the value chain.

The supply chain (SC) is the essential feature of SOM (Ellram et al., 2010); however, it is always anchored in "manufacturing behavior" and "production activity". Supply relationships and their valuable feedback for the supply chain define the internal relationships of SOM, opening up the points of connection and interaction among the elements (Field and Meile, 2008). It can only be based on a supply chain where the "service" element is present and is added to all supply relationships and value transfers—for example, a novel integrated structure is formed between upstream raw materials and midstream producers, overlaid by the idea of SI. There are principles of differentiation, customization, and specialization between the two relevant parties in terms of bargaining, pricing, and delivery (Garrett et al., 2022). In contrast to that the previous fixed business model, this new upstream and downstream relationship is essentially one in which the supplier of raw materials sees the producer as an "active and special consumer". This approach allows upstream manufacturers to be more attentive to the interests of their midstream customer base, resulting in gentler and more stable business activities between these two parties.

The value chain (VC) is the core objective of SOM (Delgado and Mills, 2020). The previous diagram shows how SOM is a new business model that relies on SVC to unfold. The essence of SVC, like the value chain, is value creation. Therefore, the transfer and increase in value are where SOM leads from beginning to end. However, at the base of the value chain are all the key activities that add value, suffused with services. As in traditional value chains, the subject is often concerned only with the delivery of the project and ignores day-to-day fragmented needs and feedback; the focus is only on project management, ignoring the integrated planning of the construction theme. The phenomenon of "blind men—trying to size up an elephant, each mistaking the part he touches for the whole animal—take part in the whole" due to a local perspective due to "silos" can lead to a variety of lower quality results. The key to breaking through this bottleneck of low-level value creation is a holistic, systematic, and humanistic approach to service delivery.

The innovation chain (IC) is an important driver of SOM (Viswanath, 2013). In other words, product development entails explicit innovation at the physical level, while service innovation involves implicit change at the thinking level; SOM is not a simple "1 + 1" superposition of products and services but requires a synergy of innovations from both sides. The relationships among the connection of subjects, the transfer of elements, and the flow of information formed by such fit structures the innovation chain. Therefore, the dual-track integration of SOM requires the opening of the innovation chain.

Table 1 Correspondence and mechanism of SOM enterprise upgrading model from PD and SI perspectives.

Patterns	Correspondence ladders and strategies	Humphrey and Schmitz (2002)		Liu and Zhang (2007)	Kaplinsky et al. (2003)	Liu (2017)	Generalization
		Activity boundaries	Upgrade dynamics	Dominant	Sources of advantage	Balanced products and services	Track Perspectives
Pattern upgrades	Information Transformation and Implantation	Unchanged	Socially driven	Self-dominant	Compulsive advantage, failure to acquire a sample upgrade advantage will disqualify you from competition	Equally driven, laying the foundation for integration	Product/ technology track
Product upgrades	Technological Innovation	Change	Buyer driven	Others-dominant	Upgrading product value per unit through innovation	Product » Service, single-track status	Product/ technology track
Process upgrades		Change	Buyer driven	Others-dominant	Gaining product value at scale by restructuring manufacturing processes	Product > Service, single-track status	Product/ technology track
Functional upgrades	Service Innovation	Change	Buyer driven	Others-dominant	Gaining a participation advantage in the service chain	Service > Innovation, two-track status	Service Track
Model upgrades	Institutional Innovation	Unchanged	Producer driven	Self-dominant	Gain management advantage with a highly matched institutional structure, the internal value increase	Equally driven, laying the foundations of the model	Service Track
Interchain upgrades	Organization optimization	Unchanged	Industry driven	Self-dominant	Transfer of established functions in the service chain to create added value in the organizational structure	Equally driven by high quality, forming a SOM model	Service Track

Feedback from self and other dominance on the evolutionary mechanisms in the SOM model. In cybernetics, there is a stress on the control-oriented difference between Self and Other-dominance (Xin et al., 2022). Self-dominance is expressed as freedom from control, self-creation, and subjective motivation (Chen, 2021). In contrast, the Other-dominant perspective sees passive motivation and postmotivational leadership as the keys to organizing the cognitive environment. The evolution of a model is often a struggle for control (Rodríguez-Prieto et al., 2021). The changes in control that precede stability determine the direction and internal twists and turns of a model's evolution.

In terms of SOM, the critical evolutionary leap is the acquisition of service-oriented functions by manufacturing entities, which shape service-oriented prototypes and integrate secondary and tertiary industries (Yang, 2015). The success and speed of this leap depend on the struggle for control between Self-dominance and Other-dominance. When Self-dominance dominates, the manufacturing subject seeks to counter the game of control. The manufacturing subject follows a positive evolution, and the service elements are accommodated. When Other-dominance dominates, the manufacturing subject encounters counter-control. The manufacturing subject thus tends to become locked into an industrial quagmire (Korkeamki et al., 2021), continuing to maintain the fundamental state of manufacturing activity.

Self-dominance is a core feature of the subject's activity. In terms of competence, manufacturing entities that seek autonomy, even if they do not participate in the transformation of services, will gain manufacturing advantages through product development and thus maintain a favorable position in their industrial competition. In the long term, the self-directed manufacturing entity seeks to achieve SI by superposing service values (Yacoub et al., 2020), ultimately forming a service spectrum, meeting heterogeneous user needs, and optimizing supplier bargaining relationships. Once a robust service-oriented identity is established, the subject will seek wider profit margins across its service and manufacturing activities.

Other dominance is a core characteristic of subject stability. In terms of capabilities, manufacturing subjects amid Other-dominance generally do not engage in service transformation or develop product businesses. Their robustness of operations may enable them to grasp the advantages of scale and intensity. However, as such dominance is often not maintained over time, the subject's stability amid Other-dominance is one with nonequilibrium, i.e., stable in the short term, and the probability of losing dominance in the long term is also stable (Peng et al., 2021). In terms of development, even though Other-dominant manufacturing actors are involved in PD and SI, this reactive innovation lags both society and industry (Starzyńska et al., 2021). It is thus more a reluctant transformation, forced by obsolescence. This transition causes it to fail to become an LE of SOM and drives its inability to participate in the high-quality, competitive activities of SVC.

Literature review and research framework. We propose that the evolution of the SOM upgrade model is based on an LE that drives the construction of the SVC via the two core elements of PD and SI in the context of Industry 4.0. The acquisition of the initial corporate evolutionary gene occurs through information technology transformation, technological innovation, institutional innovation, and organizational innovation. This combination of evolutionary genes results in an evolutionary pattern of sample upgrading, product upgrading, process upgrading, functional upgrading, model upgrading, and interchain upgrading. In their adjustment and evolution of each model, SOM enterprises achieve the cross-unification of their supply chain, value chain, and innovation chain; that is, they finally complete the realistic practice of PD and SI. However, due to the difference in control amid Self-dominance or Other-dominance, manufacturing agents often exhibit heterogeneity in their evolutionary dynamics that ultimately determine the 'intrinsic content' of service manufacturing in the various SOM models.

Throughout the extant research, academics have not analyzed the evolution and mechanism of the SVC-leading enterprise SOM upgrade model. First, we identify that the core challenges are the need to build a complete system of an SVC-leading enterprise SOM to showcase the specific content and core initiatives of SOM. Second, it is necessary to clarify the scientific performance of PD and SI two-track tasks via the perspectives of Self- and Other-dominance and to summarize the main breakthrough patterns among SOM enterprises. Third, we corroborate this exploration mechanism with real-life examples, where we examine and demonstrate the sequence of PD and SI evolution in the context of Industry 4.0.

Exploring the upgrade model and evolution of SVC leading enterprise SOM

This is based on enterprise upgrading theory and the guidance of the leading enterprises' service-oriented manufacturing upgrading model. This section summarizes the upgrade model and evolutionary content of service-oriented manufacturing. We incorporate the information transformation, technological innovation, institutional innovation, and organizational structure innovation of the enterprise upgrading theory into our foundational system of service-oriented manufacturing. Through the respective coupling of the value chain, innovation chain, and supply chain, the logic of value creation is used as a guide to lead the collection of enterprise product development and service innovation.

SVC leading enterprise SOM upgrade model analysis. The mechanism of the SOM upgrade breakthrough and market demand expansion, coupled with PD and SI, is shown in Fig. 5.

The transformation of information technology, the technological innovation base, and institutional and organizational innovations described earlier lay the external foundation for SOM upgrade. Mechanistically, the transformation of Industry 3.0 to Industry 4.0 reflects a change in the logic of the world's new deep revolution of information technology. The application and recatalysis of information technology have gained significant weight in the development of manufacturing industries, and the deepening use of information technology has led to important changes in the paradigm of industrial innovation (Ofb et al., 2021). The product competition in low-level manufacturing is gradually changing into group, cluster, chain, and ecological competition. This integration represents both an increase in the number of operational elements (a shift from a single manufacturing mindset to a cutting-edge composite development mindset) and an increase in the number of application modes. Among these, group and cluster competition suggest innovative connotations for organizational structures, and chain and ecological competition suggest directions of improvement for institutional structures (Mr et al., 2020). In addition to those of endogenous dynamics (competitive pressure) and environmental drivers (Industry 4.0 orientation), market demand puts forward construction demands on the external upgrade base of SOM. The rapid feedback of market information resources drives the construction mechanism of information transformation, while product information dominates the kernel of technological innovation. While Marx emphasized that there can be no production without need, the pinnacle of natural science is the discovery, creation, and satisfaction of new needs that arise from society itself. Market-induced model information is thus the fulcrum for transforming traditional industrial systems. The new SOM paradigm is characterized by two major features, namely, knowledge and technology intensity and active industrial innovation, which dictate that SOM must follow the direction of cutting-edge technology and major technological change and innovation. The transfer of pattern information accelerates the forward deployment of SOM. A new institutional support structure is therefore being built at multiple levels, including the incubation of cutting-edge technologies, diversified investment, early market cultivation, and the creation of industrial ecology to promote the development of future service manufacturing via "technology generating demand and demand-leading industry". Finally, the organizational structure is the field of practice for the above activities and is internally led by feedback from SOM upgrade demands. Hence, the "self-upgrading" of the upgrading model is dominated, as seen in Fig. 1.

The core architecture of SOM is a fusion of PD and SI (Sholihah et al., 2020). The largest difference between SOM and isolated service and manufacturing industries is the embedding of SVC. The value creation logic formed by SVC unifies the service, information, and knowledge flow in the traditional service industry and the product, resource, and technology flow in the traditional manufacturing industry. For the isolated service and manufacturing industries, the value-adding process they carry is only supported by the tandem of the value chain and therefore presents itself as a competition for the "value cake" after the service—the product. The services sector is superseding the manufacturing voice through modular channels, compressing the manufacturing value space. The manufacturing industry hopes to use iterative product innovation to consolidate its position in the material stream of the value chain. However, the manufacturing and service providers do not think about each other, let alone make profits and create value together. In summary, the logic of traditional value chains is that of an interchain of feedback from multiple subjects competing for benefits after adding value. The "value relationship" in a value chain is, in fact, a process of value reduction and extraction (Chaston, 1994), i.e., the retransmission of the benefits derived from the exploitation of the chain by the actors in the chain. SVC, however, is quite different, emphasizing the integration and unification of services and manufacturing, the merging of service flows (and the information and knowledge flow they contain) and product flows (and the resource and technology flow they contain) in a logic of sharing and cocreation (Wolfgang et al., 2014). As Fig. 3 illustrates, SVC forms good relationships between service-manufacturing systems through governance initiatives. Under the guiding logic of value cocreation, companies can optimize their practices to meet the flexible needs of complex markets. Continuous improvements and rapid responses meet the multidimensional needs of advanced markets, ultimately achieving the stability of service and product flows. Therefore, the service subject and the manufacturing subject embedded in SVC create new benefits. Through the collaborative efforts of both parties, these benefits are cascaded and

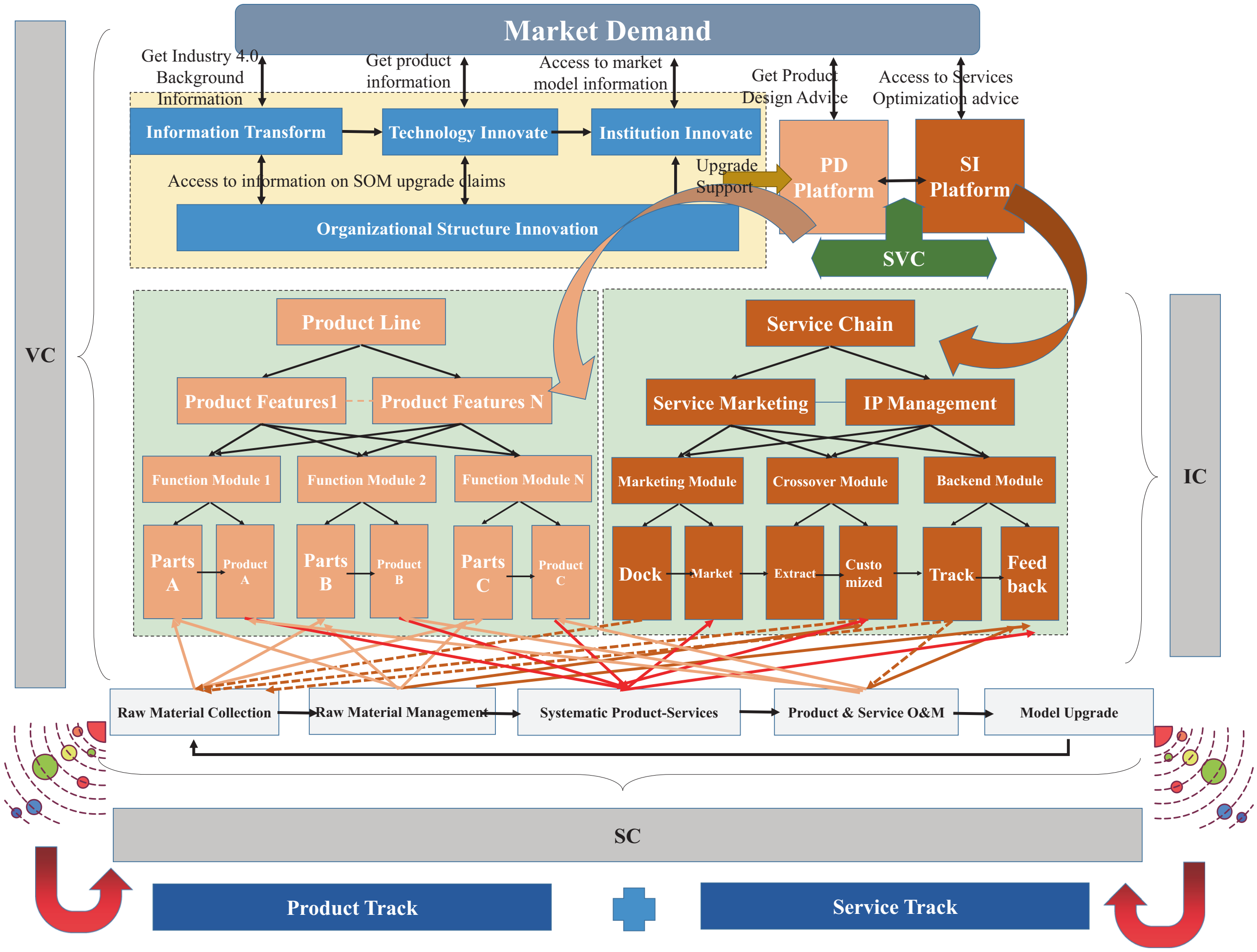

Fig. 5 SOM upgrade mode (Figures source: self-made by the author). The service-oriented manufacturing upgrade model includes three core sectors: infrastructure construction, product development, and service innovation. The interweaving forms an integrated supply of service-oriented manufacturing products.

continuously passed on, i.e., are part of the process of value increment and synergy. The main bodies in the chain are constantly attaching new value-added points under the combination of SVC, continuously improving the SOM conditions and enhancing the integration of upstream and downstream resources of SVC. Thus, the SOM upgrade model in which PD and SI are coupled under the SVC mechanism achieves a rapid leap in value. This is why the isolated development model of manufacturing and services is being eliminated from the market, i.e., the value gain cannot be fed back into the service architecture or product architecture alone, and thus the future of the market is the modular upgrading of the dual architecture.

Within the PD and SI platforms, the respective upgrade models are based on the product line and service chain processes to achieve improvements, such as links. In terms of product architecture, the core of this upgrade is the innovation capability that is based on the acquisition, transformation, and integration of internal and external resources. In the SOM model, the vertical optimization of manufacturing activities is forming modular innovation advantages with product platforms, creating sustainable innovation capabilities to meet future markets (Franco et al., 2009). Horizontal optimization is the innovative overlay of functions and modules. Through hierarchical and logically guided module structure relationships, the modules' product performance, cost, and practicality are guided to continuously improve their efficacy. In terms of service architecture, the core of the upgrade is the high-end extension of the advantages developed in marketing and knowledge activities, expanding the competitive resilience of manufacturing companies toward service activities. The vertical optimization of service activities entails the enhancement of the added value of productive service activities. Relying on the guidance of productive service activities leads to the separation of the noncore business of a manufacturing entity, which in turn enhances the core business capabilities of its manufacturing industry and enables the upgrading of the industrial structure. The horizontal optimization of service activities reflects the close connections between the front-end, middle-end, and back-end segments of service activities. Through the intersection of marketing and knowledge activities, traditional multilevel sales are transformed into a radial system led by a service platform. With the help of intelligent tools, the differentiated requirements of different business formats and segments are met. This extends the reach of the traditional sales terminal. As a result, the modular upgrade of the two structures and two tracks of service and manufacturing drive the effectiveness of the service-based manufacturing model upgrades.

In upgrading the SOM model, its ultimate outward manifestation is the optimization of specific production activities. This practice is also the convergent presentation of SOM (Benedettini et al., 2017). Specifically, this involves the following: (1) The raw material collection stage, where the docking, customization, and tracking aspects of the service activities improve the quality of the raw material collection chain. The upgrading of raw material collection activities drives the quality of the basic components, which indirectly results in high-quality products. This logic can be summarized as integrating services into the product drive. (2) The raw material management phase involves the optimization of raw material management and supports the improvement of components, responding to service activities such as customization strategies, production element tracking, and feedback. This logic can be summarized as the effectiveness of service-manufacturing convergence. (3) The systematic product-service production stage ultimately leads to the output of service products, production services, etc., which are the main outcomes of the service manufacturing upgrade. (4) Product and service O&M involves the internal optimization of a service's back end and the continuous output of product quality. This logic can be summarized as a service-to-product improvement. (5) Model upgrading is a self-cyclical process of the collation of SOM model practice activities. Through the internal collation of cyclical service production activities, the cycle improves the quality of the output of services and products. The final response is a steady evolution of the SOM upgrade model.

Due to the previously explored theoretical basis, the value chain and the supply chain merge to continuously improve the product track. The juxtaposition of the innovation chain with the supply chain results in the continuous optimization of the service track. Since the nature of the track determines the dynamic evolution of products and services, below, we look at the dynamic characteristics of the PD and SI tracks to determine the evolutionary implications of the SOM model.

Evolutionary mechanism of the SVC leading enterprise SOM upgrade model. Based on our previous analysis, the evolution of the SVC-leading enterprise SOM upgrade model involves a dynamic presentation of the mutual integration and development of the product track and the service track. Product tracking refers to how the product development process in enterprises, based on the standard model of the same industry support, combined with their SOM upgrade basis, promotes the product along with a certain target for improvement and development. For an LE, becoming a leader is exactly how the product track runs from low to high. Technology catch-up theory emphasizes the role of structured innovation, whose orbital goals facilitate companies to leapfrog the product development level. Dual innovation theory adds that the core of the product trajectory results from the alternating effects of incremental and breakthrough innovation, both of which present different dominant forces in different cycles of product development. The combined forces of the two innovation forces determine the direction of the product trajectory. At the heart of both the technological catch-up and the dual innovation, perspectives are the intervention of Self-dominance or Other-dominance in a firm. In terms of the service track, this refers to the process of corporate services, based on the dynamic changes in the market, which meet the incremental demands of mainstream users for services behind existing products. For an LE, the improvement in behavior, the innovation of service paradigms, and the stacking of added value represent the operation of the service trajectory from low to high. In line with this product trajectory, the direction and dynamics of the service trajectory are also determined by Self-dominance or Other-dominance interventions. This is illustrated in Fig. 6.

As seen in Fig. 6, the evolution of the SOM escalation model forms a base state and three evolutionary states, guided by Self-dominance or Other-dominance.

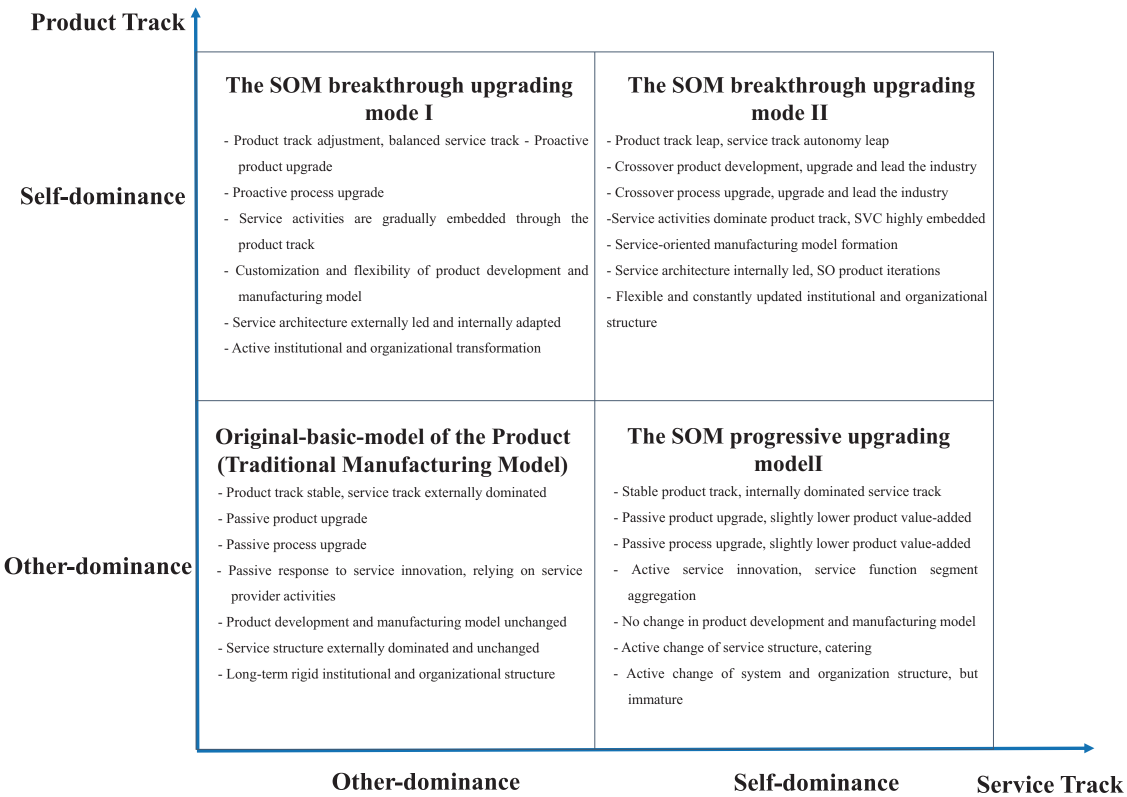

Fig. 6 Evolution content of service-oriented manufacturing upgrade model (Figures source: self-made by the author). Service-oriented manufacturing has formed three modes: progressive upgrade and breakthrough upgrade. Each mode is heterogeneous due to the difference in the initiative of the product track and the service track.

The base state is the original and basic model of the product, the so-called traditional manufacturing model. Traditional manufacturing is the starting point for SOM upgrades. From an evolutionary perspective, the initial state is the essence of an SVC-leading enterprise. In this model, the manufacturing body has a solid production line, supply line, and manufacturing chain, creating a stable product track. However, due to the localized nature of manufacturing, most of its sales and service activities are passed on to intermediaries or sellers via outsourcing. This service track is thus in Other-dominance. As the market evolves and society develops, some manufacturing entities will be eliminated, but the visionary LE will follow the market changes and upgrade its products and processes. However, the lack of a SOM vision and the limitations of a rigid institutional and organizational structure make this upgrade a reactive innovation. From an endogenous perspective, the stagnation of the starting point of the traditional manufacturing model is essentially the result of the role of product Other-dominance and service Other-dominance. The manufacturing subject passively accepts market changes and makes stressful product developments. The passive feedback on product development amid Other-dominance produces limited development. At the same time, the manufacturing entity is passively dependent on the activities of external service providers, while profits and channels are "dominated by others", locking the company in a primitive state.

Of the three evolutionary states, the one with the smoothest evolutionary trend and the softest degree of evolution is the progressive upgrading model. The SOM progressive upgrading model involves the penetration of traditional manufacturing into the service sector. In this process, the product development side of an LE has not changed fundamentally, and the manufacturing characteristics and physical nature remain. However, the Self-dominance of the SI is presented, and the LE's service structure is changed. To maintain a self-controlled service track, subjects often establish their own service, sales, and guarantee channels, and thus service function segments are gradually aggregated. However, the high cost of building services and the lack of significant improvement in product development capabilities result in lower value-added products and lower revenue generation and profitability per unit of manufacturing cost. In general, this evolutionary trend is slow and steady. This is because there is no reversal in the general pattern or state of manufacturing activities in the companies. These companies develop a gradual upgrading process of manufacturing + services.

SOM breakthrough upgrading mode I reveal a more intense evolutionary state. In this process, the increased autonomy of product track thinking has led the LE to focus on the importance of product development in the market. Proactive thinking has led to corporate products, which are beginning to be deployed ahead of the market. This proactive product upgrade and process upgrade enables the product track to begin to accelerate. Furthermore, to guarantee the development of products, an active institutional and organizational structure has replaced the rigid model of traditional manufacturing. As a result of the difficulties in selling over-the-top products, companies have also started to nurture their own service tracks to keep their service-product track relatively balanced. Service activities are embedded in the product track through SVC, but the dominant SI mindset of others has led to relatively limited enhancement of the service track. The overly bespoke and flexible nature of this service model, coupled with the ponderous cost of product development, often puts pressure on this model of SOM upgrade.

SOM breakthrough upgrading mode II is the most intense state of all evolutionary trends. This activity is characterized by a high degree of innovation and a significant leap in product trajectories, influenced by Self-dominance. Here, the service track is also clearly developing in a self-dominant role. The leapfrogging of products and processes brought about by the dual-track activities are thoroughly compatible with the market and lead the industry. Through the deployment of service activities, service products, and product services have taken over the entire market, and the distinctive attributes of the LE have begun to emerge. At the same time, institutional and organizational structures remain in a state of flux due to the active promotion of Self-dominance. On the other hand, the dynamism of SVC has increased significantly as a result of the increased 'service' character of the SOM and the dominance of the service architecture over the manufacturing model.

Based on each evolutionary model's revenue and cost trends, we illustrate the respective evolutionary results in Fig. 7[2]. The academic community has summarized this as the HFJZ matrix. As shown in Fig. 7, the traditional manufacturing model has

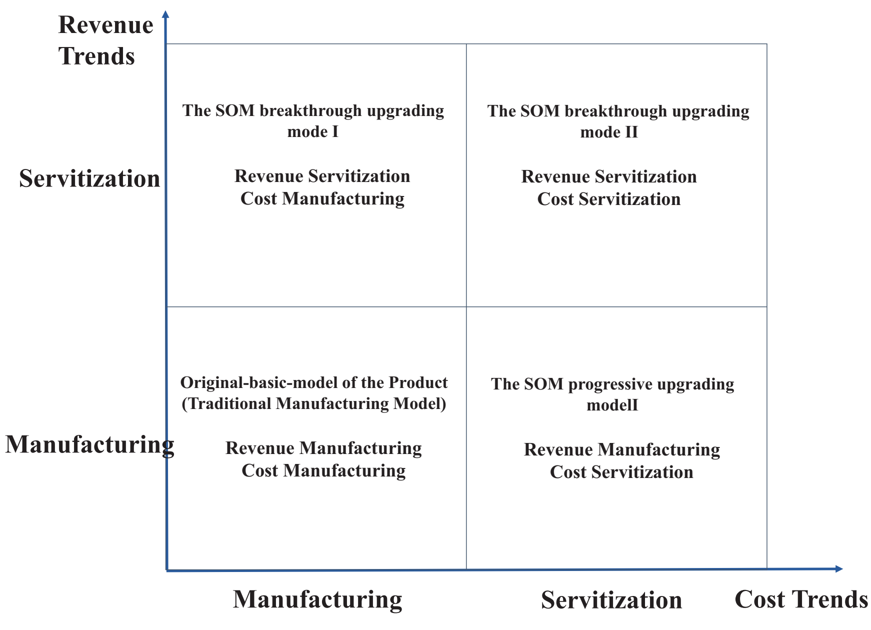

Fig. 7 Evolutionary results of the SOM upgrade model (Figures source: self-made by the author). Along with the difference in upgrade mode, service-oriented manufacturing shows changes in revenue and cost.

revenues and costs conferred by the manufacturing activity, and the profits from this model are very limited. Traditional manufacturing has been reduced to the extreme; on the revenue side, it is a price fight where the low price wins, which is not the ideal revenue situation. In the SOM progressive upgrading model, revenues are still earned from manufacturing products, but costs move to a high level of service. Some companies in this model believe that SOM transformation is only about customization, resulting in infinite increases in their costs, which are of all kinds. However, as this is a service manufacturing convergence on the cost side, not the revenue side, the end result is increased costs with no improvement in revenue. In the breakthrough upgrading model I, some enterprises have developed SOM for the better. That is, the cost side still must have a low-cost advantage. In contrast, the revenue side is able to set prices according to the affordability of customers and achieve the servitization of revenue. This flexible handling enables initial profitability via SOM. In breakthrough upgrading Model II, costs appear to have increased due to servitization, but there are two trends within this model. One uses service-oriented management and expansion to develop a competitive advantage. A broader market claim is captured through a top-down position in the market. In the balance of revenue servitization−cost servitization = SOM gain, this trend amplifies revenue and reduces the SI cost of industrial upgrading. The second uses the trend of servitization and the SVC chain to form a high-quality development path, reducing the energy consumption and costs of manufacturing and service activities. Here, companies use the economies of scale of productive services to reduce costs and ultimately escalate profits in the service-based manufacturing revenue balance.

In summary, the creation of an SVC-leading enterprise follows this trend. The first component is revenue enhancement, i.e., the servitization of revenue. Selling to the right customer at the right time at the correct value allows businesses to expand revenues without increasing costs, increasing profits. The second is cost reduction, a cycle of improvement from cost-manufacturing to cost-servicing. Standardization, mass production, lean manufacturing, TPS, and a host of other experiences accumulated over the years in the manufacturing industry are all sufficient to bring costs under control.

Furthermore, optimization costs are reduced through economies of scale in servitization, and new product standards and lean manufacturing are created. As the cycle repeats, cost control is continually achieved. These two components form the basis for SOM's understanding of revenue as a dynamic balance between service and product tracking.

Case study

Research methodology. This paper uses a longitudinal case study to analyze the upgrade model and evolutionary mechanism of the SVC leading enterprise SOM for the following reasons: (1) to provide a scientific analysis of how and why a SOM was upgraded; and (2) to reveal the dynamic process of SOM the evolution of a vertical case.

Subjects of study. Based on typicality, illumination, and completeness principles, we take AVIC Hi-Tech (AVIC), a well-known and listed Chinese company, as the subject of our research.

(1) *The typicality of SOM*: AVIC, as the domestic LE in new materials and equipment manufacturing, has nearly 40 years of manufacturing history that span the development of China's manufacturing industry. In terms of manufacturing categories, AVIC and its predecessor (Nantong Machine Tools) and subsidiaries cover cutting-edge manufacturing, such as new materials for aviation and technology development for high-end intelligent equipment, as well as R&D and manufacturing of products related to primary manufacturing fields, such as aviation, rail transportation, automotive, medical devices and equipment manufacturing. Moreover, AVIC has formed a complete product service system in its long-term development, forming a complete service organization of sales and technical services, real estate development, innovation, and entrepreneurial investment.

(2) *Case inspiration*: AVIC has gone through various development, acquisition, and redevelopment stages and has changed from a laggard to a leader in terms of product services. Moreover, it is an SVC-leading enterprise that has moved through several service manufacturing upgrading models and evolutionary cycles.

(3) *Evolutionary integrity*: The complete evolution of AVIC spans the various types of SOM models illustrated in Fig. 6. Therefore, an analysis of PD and SI regarding AVIC facilitates analysis of the dynamic trends and critical initiatives of SOM. The path to the scientific development of SOM enterprises is thus summarized, laying the foundation for latecomers to become SVC-leading enterprises.

Data collection. AVIC is a listed company, and its official website is open and interactive; this provides a reasonable basis for compiling the following data in this study: (1) The content of AVIC's PD and SI was compiled via official website reports, executive statements, and WeChat publicity platform content, whereby the interview questions were extracted. (1) We obtained first-hand data through interview conversations and expert consultations with AVIC's senior and middle leaders. (3) The results of these interviews were grouped and coded from the PD and SI perspectives while taking into account the Self-dominance and Other-dominance of the service track and the product track. The theoretical analysis model was collated through the coding structure and the design of these constructs. All the primary data sources and classifications are shown in Table 2.

During data collection, we first used text analysis software, UCINET, to collect information on service-oriented manufacturing enterprises. Through social semantic network analysis, we found that a large number of service-oriented manufacturing keywords pointed to "AVIC" enterprises. Therefore, we preliminarily set this as the research object of our case analysis. Second, we held two expert meetings in March 2022 and June 2022. The March 2022 conference was held online. We invited members of the expert service manufacturing committee, personnel from the Ministry of Industry and Information Technology, etc., to select suitable service manufacturing demonstration enterprises. This meeting was held at AVIC in June 2022. AVIC has been recognized as a service manufacturing model in China. We invited 2 academicians from the Chinese Academy of Sciences, 3 provincial and ministerial leaders, and more than 20 university professors. All the participants acknowledged the service-oriented manufacturing model of AVIC, ensuring the objectivity and validity of our research while strengthening the research value of the case.

In this study, the acquisition of all qualitative data followed the principle of calibration sampling. In the design of case information quality control standards, we set standards that met the specific content of service manufacturing product development and service innovation. The design of the targeted basic conditions thus includes (1) distinct service-oriented manufacturing activity attributes; (2) flexible production or service activities; and (3) work in accordance with the provisions

Table 2 Information on data.

Data sources	Coding	Data classification	Data size
Primary data	FIR1	Semi-structured interview results	18.3 h of audio/approx. 226,000 words
	FIR2	Informal interview results	Approx. 137,000 words
	FIR3	Formalized interview results	Approx. 65,000 words
	FIR4	Expert program and Consultation results	Approx. 72,000 words
Secondary data	SEC1	Formal and Informal Statements by AVIC Board Leaders and President in Public	Video 2.5 h/approx. 18,000 words
	SEC2	AVIC internal executive emails and statements	Audio 3.8 h/approx. 29,000 words
	SEC3	AVIC's authoritative official reports (1978-2022)	Approx. 51,000 words
	SEC4	AVIC and predecessor annual reports (1993–2022)	17 reports
	SEC5	AVIC's official integrated media platforms (WeChat, Weibo, etc.)	Approx. 28,000 words
	SEC6	Paper records of AVIC's internal press, networking meetings, and other materials	Approx. 46,000 words

of the Identification Rules of China Service Manufacturing enterprises. After controlling for the samples, we coded our case information using the root method and then verified our coding via survey sampling to demonstrate that the information met the sample selection standard, guaranteeing our sampling quality.

AVIC SOM upgrade mode scenario. Combining Fig. 5 with the case's facts, we summarize the performance and coding of the elements and supplement these with empirical examples.

SOM upgrade basis. As a sizeable state-controlled enterprise, AVIC's abundant capital reserves have enabled it to take the lead in completing its information transformation. In 1956, AVIC's predecessor, Nantong Machine Tools, was established. In 1993, Nantong Machine Tools was officially launched. As one of the first machine tool companies in China, AVIC represents the nation's traditional manufacturing industry. Its resource-intensive advantage allows it to hold nearly 10% of China's primary manufacturing industry, and it has rapidly expanded its foreign trade in machine tools since China acceded to the WTO. Since 2010, AVIC has been promoting the intelligent transformation of the manufacturing chain in the context of information technology reform as follows: (1) In terms of technical architecture, the transformation from information technology (IT) to digital technology (DT) is achieved. The information transformation is based on the traditional architecture + desktop side. AVIC has introduced a complete technical information support system and a technology cluster for machine tool manufacturing using technologies such as cloud network segments. (2) Among the demand characteristics, machine tools, aerospace compound materials, intelligent equipment, and other products are used to achieve any change, from facing deterministic demand to uncertain demand. With the help of enterprise resource planning (ERP) and customer relationship management (CRM), AVIC meets its scale-oriented deterministic demand. Furthermore, intelligent customer platforms are used with the aid of digital technology to customize and differentiate product requirements and meet uncertainty in its customer market. (3) In terms of its core requirements, AVIC establishes information stations to shift from improving efficiency to supporting innovation, which enables it to support business innovation, management innovation, and organizational innovation in the face of uncertain demands.

With its information technology transformation, AVIC is gradually building an open technology innovation platform. In the past, AVIC was more oriented toward internal resource optimization, resulting in a closed technology system. Today, AVIC is thinking about transforming service manufacturing to build an open technology system based on global optimization and achieve data integration with its suppliers, their suppliers, its agents, and its customers. Via this participation of multiple parties, AVIC's technological innovation is optimized in the same direction: on the service side. Hence, AVIC not only provides hardware + software + solutions but also, more importantly, a set of consumer-focused operation solutions, where the technical demands made by customers become an essential basis guiding service innovation. AVIC further optimizes existing technologies to achieve rapid growth in technical specifications on the product side.

In terms of its institutional innovation and organizational restructuring, AVIC has performed even better. On the one hand, changes in AVIC's structure were inevitable due to its military-industrial properties. The military is the end user of the military industry's products, and today's establishment system changes will directly impact future military equipment procurement needs. Moreover, reform is bound to co-occur with user demand changes, and the supply side—the military industry/defense industry drives such changes. Since the adoption of the Decision of the Central Committee of the Communist Party of China on Several Major Issues of Comprehensively Deepening Reform at the Third Plenary Session of the 18th Central Committee in 2013, the reform of state-owned enterprises has entered a new phase, with a substantial increase in the top-level design, depth of reform, areas involved and their quantity, and the implementation of pilot reform measures, resulting in the upgrading and overall deepening of the reform of state-owned enterprises. In AVIC, such reform has formed a "$1 + N$" top-level framework system, involving the implementation of its four actions, ten actions, "double hundred actions," and other pilot reforms. Specific examples of such actions include revising the business performance assessment standards to guide AVICs' high-quality development and stimulate internal vitality; focusing on the development of the primary industry; divesting the "three supply and one industry" to streamline the organization and strengthen the technological breakthroughs in the primary industry while avoiding any duplication of investment and waste of resources; moving from "managing assets" to "managing capital" while promoting the internal vitality of the enterprise through equity incentives and other means; and, finally, improving the level of asset-backed securities of central military enterprises through measures such as the restructuring of research institutes and mixed ownership reform. AVIC has therefore expanded its corporate structure and organizational volume through the internal restructuring of research institutes and matching asset structure with organizational structure, with core assets leading the SOM infrastructure.

The core architecture of the SOM. As a leading SVC company, AVIC has implemented a convergence framework between PD and SI. At the product development end, the company is in the prepreg stage, a critical link in the composite material industry chain with obvious advantages in terms of positioning. Prepregs are made from reinforcing materials impregnated with resin and are an essential intermediate substrate for the preparation of composite materials; they are irreplaceable in the production and development of composite materials. Around this core function, AVIC has implemented prepreg materials into its functional modules of Machine

Tools–Smart Manufacturing using its manufacturing platforms (Airwise Equipment and Nantong Machine Tools). Through the linkage and synergy of the functional modules of several subsidiaries, domestic resin and T300 grade carbon fiber prepreg are formed. Furthermore, through vertical cooperation and internal operations, the company has made composite parts (prepreg and honeycomb) into full-size large wall panels, automated assembly products for aircraft wall panels, etc. AVIC thus leads the entire spectrum of basic–high-end manufacturing at the service innovation end. In turn, a complete customer base and service marketing system have been built. At the same time, through the merger and acquisition of several subsidiaries, the systematic management of capital and intellectual property has been developed. For example, AVIC's machine tool manufacturing technology is constantly being adapted by drawing on the individual input of external customers, which has been consolidated into a permanent innovation that is applied to its products. This complete docking–marketing–information extraction–concept customization–tracking–application–feedback upgrade path thus forms the basis of AVIC's services. Finally, AVIC fulfills more than 50% of the effective orders for carbon fibers worldwide through its product–service fusion. The company's technology accumulation in the vital process of prepreg preparation and perfect resin system reserves, and military aviation's prepreg need to participate in the preresearch stage of military aircraft research and development to confirm the completion of technical indicators further strengthen the company's leading position in this field; thus, its first-mover advantage is obvious. In addition, the company's main downstream customers are concentrated in its controlling shareholder, the Aviation Industry Group, a professional development, and production unit for military aircraft in China. Covering all critical models in China's military aviation field, the company relies on the Group's significant downstream channel advantages. Hence, it has a solid leading position in the field of military aviation prepreg.

Theoretical model construction. Based on the previous analysis and the coding of our cases, we compiled our coding results. These are shown in Table 3.

Building on Table 3, we have developed a logical evolutionary framework of resource–capability–superiority–development from a strategic management perspective. AVIC's SOM upgrade model shows that the core requirement for companies to achieve the SVC faucet goal is the multidimensional integration of their supply chain, value chain, and innovation chain and that their integration must follow this logic. In conjunction with our previous overview of the SOM upgrade model, we specify the mechanistic model of the SOM upgrade in Fig. 8.

Subsequent scholars can use the findings in Fig. 8 in empirical analysis. In conjunction with Fig. 8, the logical framework of resource–capacity–advantage development better reveals the case mechanism. Leaving aside the dynamic perspective, the SOM enterprise is represented within each evolutionary stage, as shown in Fig. 8. Figure 8 can therefore be further summarized as a static upgrade process for a SOM enterprise.

At the resource end, SOM enterprises should combine the background of Industry 4.0 and rely on the industrial internet and digital intelligence technology. They should begin by building on their established manufacturing foundation, breaking the traditional manufacturing shackles to extend and penetrate their service field, and then promote the integration of manufacturing and services to achieve SOM transformation. Technological, institutional, and organizational innovations require a sound public service system with the following resources: (1) SOM major research and development program—to break the static bottleneck of the SOM upgrading model, on the one hand, a company needs to systematically launch scientific and technological research, use critical technologies and information platforms, and set up joint research institutions with key enterprises and universities. On the other hand, it must strengthen the support of essential critical standard technologies and research and distinguish the technologies that restrict the development of its SOM, forming a list of standard technology catalogs. This development of the innovation background drives the overall atmosphere of resource sharing. (2) Precise policy toolkit—i.e., strengthen policy guidance and support, formulate comprehensive policies to promote the development of SOM, and increase support in terms of financial resources and other aspects. Here, the government appropriately relaxes market access, breaks down barriers to the expansion of manufacturing enterprises into the service sector, and supports the service business of manufacturing enterprises at the same price as the general industry in terms of preferential policies and resource use. (3) SOM enterprises receive adequate resources from the service industry, i.e., comprehensive and professional services such as strategic research, planning, enterprise diagnosis, and solutions for manufacturing enterprises via resources, intermediary service agency development, and business model innovation. Manufacturing companies thus draw on relatively favorable information technology to form industry-wide service transformation solutions by addressing fundamental issues such as talent development, basic R&D, joint standards development, intellectual property protection, and service value measurement.

At the competence end, the effective combination of SVC is used to expand the SOM enterprise division of the labor system. The company expands the two-way access to SOM through the convergence of PD and SI, reducing information silos and encouraging manufacturing enterprises to work with upstream and downstream enterprises and third-party service enterprises to achieve risk sharing and information sharing in multiple scenarios and channels. Throughout the life cycle, it works with industry associations, research institutions, and industrial parks to facilitate new industry alliances across regions, industries, and fields, giving full play to the demonstrative role of leading enterprises. Finally, it forms a new pattern of SOM development for SMEs from point to point. Based on the excellence of SOM's capabilities, a national brand image of manufacturing can be formed with the ultimate goal of enhancing the competitiveness and capabilities of basic manufacturing.

On the advantage end, SOM gradually demonstrates the model's superiority by integrating products and services. A product–service system spans the entire product lifecycle, forming a comprehensive, whole-chain system-based service and providing customers with product service packages comprising integrated products and services. Based on SOM experiences, industry understandings, and technical potentials, pain points and difficulties in the market can be resolved. By establishing the industry base, connecting and improving the supply chain, and exporting business models and other enabling services, the quality of market SOM output increases, culminating in the upgrade of multidimensional indicators, such as profit and performance.

Finally, as its resources, capabilities, and strengths continue to be strengthened, the SOM entity builds sufficient strength to begin upgrading from static to dynamic, and thus it eventually repeats the accumulation of resources, capabilities, and strengths in each stage of the model's performance. By accumulating quantitative changes, qualitative leaps can be achieved, ultimately allowing it to reach the target development state of SOM breakthrough evolution.

Table 3 AVIC SOM upgrade mode codes.

Concepts	Coding results	Subject line	Examples of evidence (typical citation)
Upgrading basics	Information transformation	Introduction of Industry 4.0 production lines, acquisition of information companies	It is a professional high-tech company that integrates R&D, production, sales, and service of composite materials (SEC3). The company's development direction is "high-quality" CNC machining centers (SEC4). It uses technologies such as big data and cloud computing and algorithms such as artificial intelligence and blockchain to empower the entire production and operation process and strengthen the deep integration of business and cutting-edge technology (SEC5).
	Technological innovation-PD	Diversification of product range and modules	Innovative products in high-performance resin and prepreg technology, new structures for high-performance composites, resin-based composite manufacturing technology, metal-based and ceramic-based (including C/C) composite molding technology, material characterization and testing technology, and advanced non-destructive testing technology (FIR3). It has a complete R&D and production system (SEC6).
	Technological innovation-SI	Service architecture optimization, customer group optimization	The company has accumulated technology in the vital process of prepreg preparation and perfect resin system reserves. The prepreg for military and aviation needs to be involved in the research and development and the completion of technical index confirmation at the pre-research stage of military aircraft (FIR1). The industry-wide restructuring effectively contributes to enhancing technical and service capabilities and optimizes resource allocation and asset structure (FIR4).
	Institutional innovation	Restructuring and improving the institutional framework	It is proposed to promote the improvement of the modern enterprise system, improve the corporate governance structure, promote the conversion of the operating mechanism of enterprises, amplify the functions of state-owned capital and achieve value-added of state-owned capital (FIR2). Under the system, research institutes and university institutions focus on the urgent need for high-end manufacturing, essential frontier innovation, and critical core technology research. Some production tasks are delegated to the industry, allowing enterprises to develop (SEC1).
	Organizational innovation	Team building, management ladder development	The "three-tier structure and two levels of operation" reform and construction of the central business organization system. "three-tier structure and two levels of operation" means that the parent company and the subsidiaries are granted full operating rights. At the same time, the grandchildren, i.e., the third tier, have no or no full operating rights at all (SEC2). The management team has many years of experience in the industry, with extensive experience in research and development and production, and can make sound decisions on the development of the company's operations and the effective implementation of the company's strategy (SEC6).
PD	Product functions	New product breakthroughs, technological paradigm shifts	Domestic enterprises already have the technology and batch production capacity of T300-grade and T700-grade carbon fibers for aviation; T800-grade carbon fibers have completed engineering trial production. (SEC1). In the various types of aircraft types under study, most composite materials have been designed to use more than 20% of their structural weight (SEC5).
	Functional modules	System framework, functional boards, and clusters	In terms of manufacturing technology, advanced technologies such as digital manufacturing, automated assembly, advanced manufacturing processes, and complex parts manufacturing are represented, showing trends in automation, information technology, and intelligence (FIR2). Future technology directions focus on critical technologies for production lines of 10,000 or even 100,000-piece composite parts and environmental friendliness and recycling of composite parts (FIR4).

Table 3 (continued)

Concepts	Coding results	Subject line	Examples of evidence (typical citation)
	Components and products	Patent applications, product output	Civil aviation aircraft braking device and friction material localization development (FIR3). The Company applied for 57 accepted patents during the reporting period, and 22 patents have been granted. The Company has a batch production capacity of resin, prepreg, and honeycomb for aviation composite materials (SEC5).
SI	Service marketing	Service model, service level	Accelerate the construction of the production park, continuously improve the production management model and continue to expand production capacity (SEC1). Strengthened synergies among stakeholders to focus on value creation, business success, and shareholder returns with a synergistic and innovative development strategy (SEC2).
	Intellectual property management	Knowledge building and management	It realizes the conversion of old and new dynamics with investment in high-quality, high-tech projects to create irreplaceable core competencies (FIR1). It has a long history in the localized development of brakes and friction materials for civil aviation aircraft. It is the first recipient of the Component Manufacturer Approval Certificate (FIR4) among domestic civil aviation aircraft brake manufacturers. Its product service, engineering, and industrialization projects have been included in the national Torch Program and the New Product Promotion Program of the National Defence Science and Industry Commission and Beijing Municipality many times (SEC5).
Product and service integration	Systematic products-services	Inclusive, diverse output	Built into a comprehensive large-scale state-controlled listed enterprise for the research and development and production of new aviation materials and the research and development and manufacturing of high-end intelligent equipment (SEC1). Business covers new aviation materials, high-end intelligent equipment, rail transportation, automobiles, medical devices, equipment manufacturing, real estate, innovation, and entrepreneurial investment, etc. (SEC4)
	Model upgrading	Gridded and scaled up	After years of development, AVIC's products have a perfect market service network, covering the whole country and are sold to Japan, the European Union, and other countries and regions (SEC1). AVIC to build a high-tech enterprise group with synergistic development in the two significant military and civil affairs fields and mutual promotion of industry and finance. To give full play to the advantages of the listed company in terms of institutional mechanism, corporate governance, financing, and investment, and to promote the transformation and industrialization of high-tech achievements in strategic emerging industries such as new aviation materials and high-end intelligent equipment manufacturing (SEC6).
	Corporate performance	Improvement in key economic indicators	Ensure the completion of production delivery tasks and annual operation targets, achieving annual sales revenue of RMB2.9 billion and a total profit of RMB400 million (SEC1). Improve internal management and production efficiency through management tools such as AOS, ERP, and the technical transformation of intelligent production lines to ensure the completion of research and production tasks and balanced delivery. Finally, achieve the targets to improve the total asset turnover ratio, return on net assets, funds tied up in production costs, and accounts receivable funds (SEC3).

Evolution of the AVIC SOM. This paper has outlined the complete evolution of AVIC SOM based on the case discussions. Due to its long history and continuous progress, AVIC encapsulates the primary stages of traditional manufacturing and the three evolutionary models of SOM. Its specific evolutionary process is shown in Fig. 9.

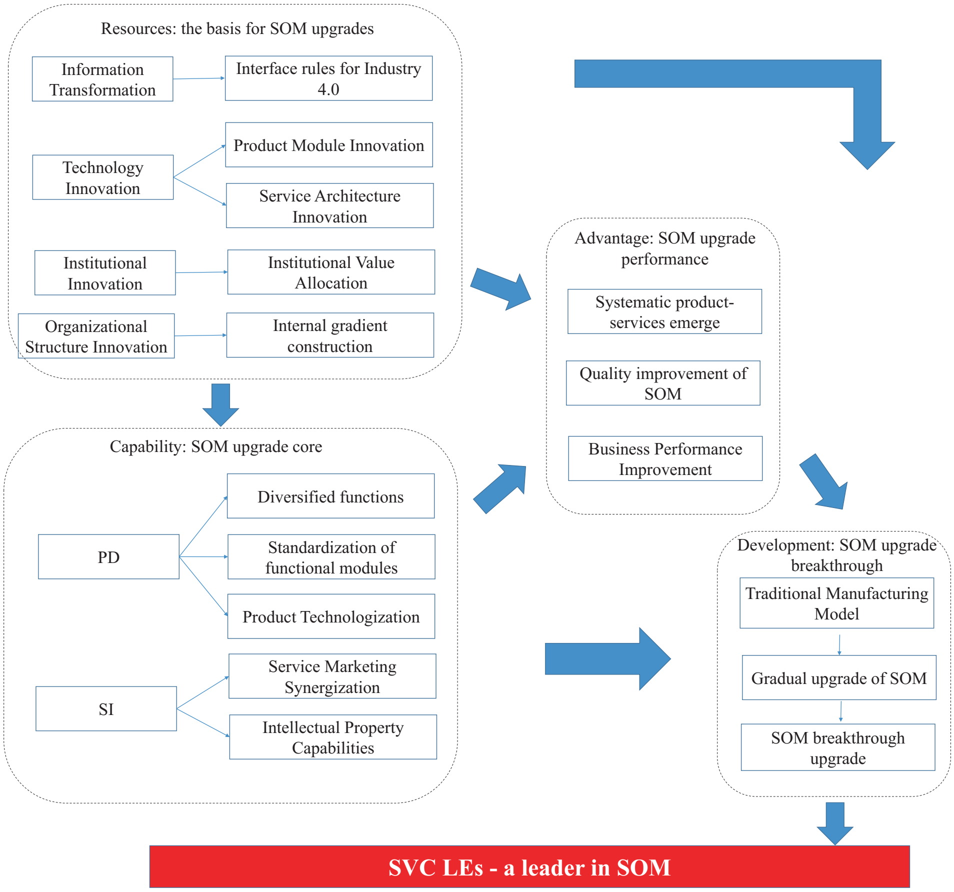

Fig. 8 Mechanistic model of the SOM upgrading model (Figures source: self-made by the author). Under the action of the service value chain, the resources of service-oriented manufacturing promote the aggregation of capabilities and work together with the ability elements to form the advantages of the service-oriented manufacturing model. Finally, promote the high-quality development of the model.

(1) *Traditional manufacturing (1956–1989)*: AVIC's predecessor, Nantong Machine Tool, was established in 1956 as one of the first machine tool companies to have absolute industrial leadership and a voice in China's heavy industry construction strategy. Over nearly 30 years of development, AVIC has become a large backbone enterprise in the Ministry of Machinery Industry, the first of the machine tool export base enterprises in China. Moreover, in 1989, Nantong Machine Tool became the new centerpiece of the capital market as the second listed company in the machine tool industry in China.

AVIC went through a problematic product development cycle in the Traditional Manufacturing stage. Initially, due to capital constraints, a lack of technology, and the institutional constraints of the planned economy, AVIC was only able to produce loose parts for machine tools independently. The product platform and the complete production chain had not been formed. The organizational structure was ancient, resulting in AVIC's participation in only a few simple links in the supply chain, with low bargaining power for its products. Following China's reforms and opening up, which introduced some foreign investment and advanced technology, AVIC seized the opportunity to become one of the first Chinese machine tool enterprises to export to foreign markets. It thus formed the framework of its VMC and VMCL product platforms, which can manufacture, produce and repair all kinds of machine tools that were compatible with a single product type. Its main products included ten categories, thirteen series, and more than seventy variations. These included a rocker universal milling machine, CNC milling machine, vertical milling machine, CNC lathe, vertical machining center, horizontal machining center, and gantry machining center. Its large manufacturing scale and production capacity made it the leading traditional manufacturing industry in China. When upgrading in the manufacturing phase, AVIC continued to develop its product tracks. It took advantage of the scale effect to establish functional modules and aggregation systems for its complementary products, resulting in a significant increase in production efficiency. In addition, the streamlining of personnel and the organization's restructuring ensured that AVIC remained flexible and could better position itself in changing times. Relaxations and changes in the institutional context also provided the impetus for AVIC's development. However, in this stage, AVIC did not develop any service-oriented activities. The target audience for the marketing and sales departments remained secondary companies or distributors; there was no direct targeting of market customer groups. In addition, the feedback capability for operation and maintenance was poor, and some of the machines purchased by customers would not even be returned to the factory for a warranty repair. Overall, AVIC's product track development in this stage was excellent, but its service track construction was unimpressive.

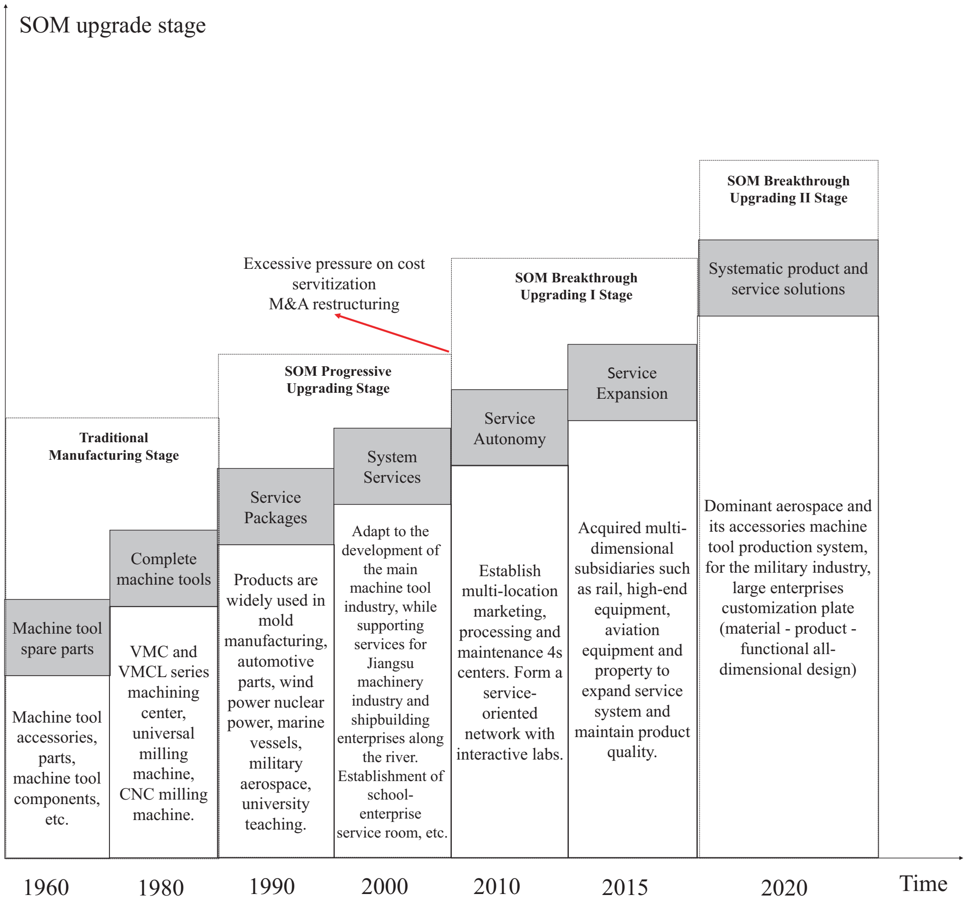

Fig. 9 AVIC SOM evolution process (Figures source: self-made by the author). In the 60 years of development, AVIC has experienced seven product/service changes, spanning all modes of service-oriented manufacturing. Eventually, it became a leading enterprise.

(2) *SOM progressive upgrading (1990–2009)*: With AVIC's manufacturing upgrades, its product development capabilities were significantly enhanced, culminating in its qualification for market launch in 1989. The rapid entry of financial capital offered AVIC access to more comprehensive market information, and the service track entered an accelerated phase of development. In the 1990s, AVIC built a series of marketing platforms around its core machine tool products and introduced service packages for machine tools through partnerships with the government, companies, and universities, combining machine tool products and service innovation to enter the 'soft product' market. After 2000, with its accession to the WTO and expansion into the foreign trade market, AVIC began to expand its marketing and knowledge management, designing integrated support services around large units, including customized machine tools, customized adaptations, and complete solutions model designs. In the process, however, the rapid escalation of AVIC's service track was divorced from the effective renewal of its product track. Its product side did not change but instead exacerbated the serviceable change in costs (Fig. 7). In addition, due to a decline in technological competitiveness, many homogeneous latecomers entered the market; AVIC's earnings from manufacturing could not cover its costs of service, and the company's profitability began to decline; thus, it entered a restructuring phase in 2010.

(3) *SOM Breakthrough Upgrading I (2010–2020)*: With the restructuring of AVIC and the rapid importation of state-owned assets, AVIC began to enter the Breakthrough Upgrading I stage. First, AVIC started the construction of the autonomy of its product track, the iteration of its traditional machine tool products, the formation of an intelligent machine tool manufacturing chain for 4.0, and the generation of new intelligent machine tool products. Second, AVIC entered the high-end manufacturing market through mergers and acquisitions and by introducing novel product chains, such as carbon fiber (as shown in Fig. 10). The broadening of the market for high-end products significantly increased the company's manufacturing earnings. Then, AVIC established a sales network under its control and entered the service industry to support the stable sales of high-end products through a superimposed balance of service tracks. In this stage, AVIC achieved massive profitability through revenue servitization and cost manufacturing (reduction), and the enterprise's SOM entered a breakthrough development, allowing it to become a leading demonstration of China's manufacturing transformation.

(4) *SOM Breakthrough Upgrading II (2020–)*: This phase has seen a whole new development of AVIC due to its upgrade of PD and SI, combined with its SOM upgrade base's renewal in Industry 4.0. The supporting resources of the enterprise have become broader and broader, forming a complete SVC via the interweaving of its supply chain, innovation chain, and value chain. AVIC has mastered the ability to extract new materials and resources for high-end manufacturing, to offer new top products, and to dominate

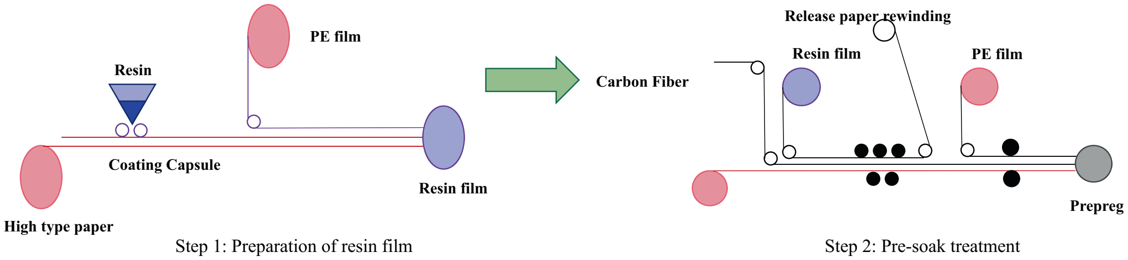

Fig. 10 Self-dominated upgrade of the AVIC product track (Figures source: self-made by the author). AVIC has formed an innovative and advantageous carbon fiber preparation mode. The advantages of production are realized through the optimization of the PE film.

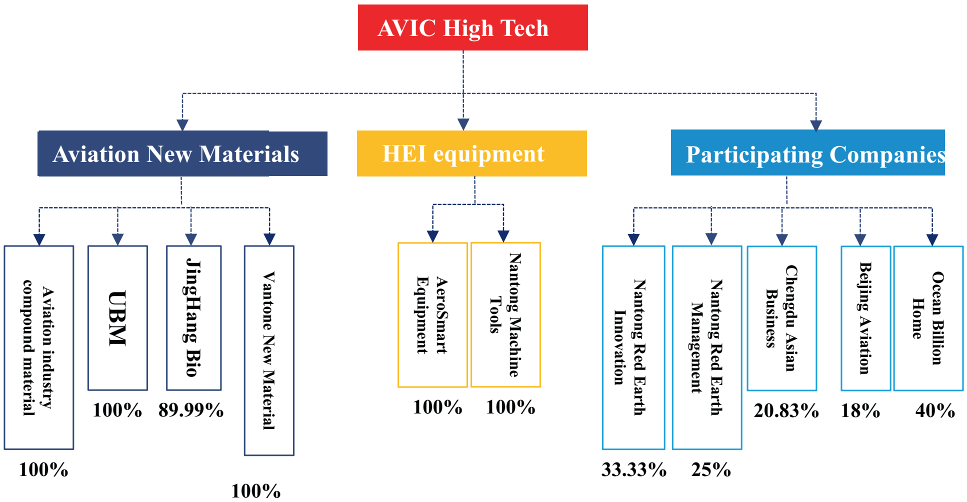

Fig. 11 AVIC complete SVC enterprise network (Figures source: self-made by the author). Through the development of a service-oriented manufacturing model, AVIC has spanned multiple industries and formed a development framework with comprehensive strength.

the controllable and adjustable ability of service channels; hence, finally, it has formed a substantial soft power of service. AVIC's SVC industrial network is shown in Fig. 11.

However, the autonomous extension of AVIC's service track in this phase has exacerbated its cost pressures. The simultaneous juxtaposition of revenue and cost servitization reduces profit margins from SOM Breakthrough Upgrading I. Based on its annual report, AVIC's net profit has decreased at an average annual scale of 3%, compressing its profit margin. However, in the long run, the increased autonomy of AVIC High Tech's services gives it a better voice in its competitive market. With the enhancement of its service capacity, AVIC has transformed this from a service production activity to a production service activity. The supply capacity and quality of the supply of its services have been significantly improved, providing access to capital and new technological elements and allowing AVIC to become an active leader in Industry 4.0. With the stabilization of its service supply, AVIC will continue to optimize cost space, improve the quality and efficiency of its service supply, reduce consumption, and further grasp the leading position in the SVC.

Contribution refinement. Based on the real-life case of AVIC High Tech, this study has corroborated the specific upgrading process of service-oriented manufacturing, unifying and coordinating the strategies of product development and service innovation in specific activities. The service targets in this study include responsible governmental industrial sector agencies, traditional manufacturing companies, model companies with leading positions, and service-oriented companies seeking to form manufacturing activities. For each of these service recipients, the study provides the following respective contributions:

(1) *Government industrial sector*: Both service and product activities depend on the information platform in Industry 4.0. Therefore, government departments should vigorously promote infrastructure construction concerning the hardware foundation of service-oriented manufacturing, i.e., the deep integration of manufacturing and service industries and the comprehensive utilization of factor resources across industries. Efforts should be made to break through existing institutional and mechanical barriers, change traditional thinking patterns, and increase policy support and guidance for the integrated development of the manufacturing and service industries; manufacturing enterprises should improve their level of the industrial division of labor and collaboration while promoting the optimal integration of factor resources into different business sectors.
(2) *Traditional manufacturing enterprises*: Service and product tracks need to be integrated to achieve the advancements of the service-oriented manufacturing model. Based on the case of AVIC High Tech and the process of service-oriented manufacturing evolution discussed in this paper, manufacturing enterprises should design innovation and model upgrades to cultivate, create and guide consumer demand. Through a scientific service and product tracking, they should predict and explore market demand to develop new products based on digital intelligence drives, creating a closed-loop model of the whole chain of "design–production–consumption–design" to promote the precise matching of enterprise production

capacity and market demand while driving consumption upgrading. The operation of the four stages of service-oriented manufacturing should impel thinking guidance under the HFJZ matrix. Enterprises should foster the development of new industrial design industries and new models, which encourage industrial design enterprises to give full play to their design advantages and vertically incubate their own product brands. They should avoid the negative transformation path of the high service cost and low-cost value.

(3) *Leading enterprises*: Our results highlight the role of the service-based manufacturing upgrade model. The key to becoming a leading enterprise via SVC is the deep application of modern technology in both management and model. The coordination of the innovation chain, value chain, and supply chain is driven by technological progress, market opening, and institutional innovation. In the crossover of the product track and service track, the original industrial boundary is broken through technology penetration, industry linkage, chain extension, and internal reorganization. These eventually promote industrial cross-fertilization and breed new business models. The dynamic process of mutual support, efficient synergy, integration, and interaction between service and manufacturing is thus a process of intermingling multiple value chains.

(4) *Service companies that expand their manufacturing activities*: We have proposed a progression model of service innovation that circumvents the trend of industrial hollowing out. The phenomenon of a service industry's detachment from the real economy still exists, and one of the more prominent examples is the internal circulation of funds in the financial service industry, where some funds are detached from the real economy. The HFJZ and service-oriented manufacturing evolution mechanism proposed in this paper highlight the construction strategy of service enterprises when integrating manufacturing activities to accelerate the construction of an industrial system with the synergistic development of the real economy, science and technology innovations, modern finances, and human resources.

This paper thus completely explains the meaning and mechanism of service-oriented manufacturing and describes the upgrading characteristics and evolutionary direction in each stage. Through our use of case summary and induction, the research system of service-oriented manufacturing has been enriched. At the theoretical level, this study focuses on the practice of SOM at the product-service level. Through the intersection of product and service activities, the specific practice strategy of service-oriented manufacturing is clarified. On the application side, through the design framework of resource–capability–advantage development, the specific practices of enterprises are revealed, and the transformation path ordinary enterprises can follow in service-oriented manufacturing to become leading enterprises is designed and formed. Our global study of service-oriented manufacturing is further enriched by the focal Chinese cases. Compared with similar case studies, we are the first to use a review case study the unity of our review, framework construction, and case study. Similar to other research, we have applied a combination of qualitative and objective analysis. First, we use "soft" methods, such as expert surveys and Delphi, to narrow the scope of case collection. Second, using objective methods such as social semantic networks and grounded theory, we determined our specific case of AVIC. Then, based on the theoretical guidance and logical framework we obtained, this case was analyzed, and the dynamic and static evolution process at each stage was considered. Finally, the reasonableness and correctness of our theory and framework were demonstrated by a case study. In addition, we have promoted a particular research system in this paper. In contrast to similar studies, (1) we have used longitudinal cases to achieve static and dynamic analysis in our research. Thus, the service and product track change course of service manufacturing have been better described. The key strategies to control the service-oriented manufacturing model are extracted from our conclusions. (2) We have used cases to prove the scientificity of and support our theory. The "demonstration" of our qualitative research is thus realized. Through the comprehensive application of cases, our research, and our literature review, a new direction of qualitative research has been integrated. (3) At the content and contribution level, the HFJZ matrix and other theories are proposed. These effectively support the development idea of service manufacturing. Expanding the depth for subsequent research, our variable–model relationship also contributes to better applications of the quantitative method.

Conclusion

Research findings. The upgrade of the AVIC SOM is a dynamic evolutionary process based on the continuous optimization of PD and SI to achieve a shift from Other-dominance to Self-dominance. Based on the foundation of the SOM upgrade for Industry 4.0, traditional manufacturing enterprises use the innovation of product track and service track to realize the unification of their supply chain, value chain, and innovation chain and the formation, consolidation, and extension of SVC concerning the logic of value creation. Through SVC, the traditional manufacturing industry has been transformed into two types of SOM: progressive upgrading and breakthrough upgrading. The differences within these upgrading models concern product and service autonomy, in addition to the controllability of products and services, SOM, and traditional manufacturing under the HFJZ matrix's architecture. This includes the following four states: Traditional Manufacturing Model of Revenue Manufacturing–Cost Manufacturing State; Progressive Upgrading Model of Revenue Manufacturing–Cost Servicing State; Breakthrough Upgrading Model I of Revenue Servicing–Cost Manufacturing State; and Breakthrough Upgrading Model II stage of Revenue Servicing–Cost Servitization State. Different upgrade models determine the development spaces and profit levels of companies. An inappropriate upgrade evolution trend may lead a company to fall into the trap of SOM. Enterprises must use the platform period of resource–capability–advantage construction to maintain and extend their SOM upgrade breakthroughs. Through the accumulation of quantitative and qualitative changes, enterprises will be driven to upgrade and cyclically make breakthroughs, creating a stable and positive SOM model. In this regard, we propose the following countermeasures:

(1) Actively address Industry 4.0 using the transformation opportunity of SOM to break through the decreasing bondage of production factors. Services are an essential factor in the production and operational resources in this era. Services are a crucial way to promote the effectiveness of enterprises. At some level, services carry the future, the transformation of products. In contrast to developed countries, China's experience demonstrates that Chinese manufacturing is transforming itself into Chinese services. Transformation into SOM is a sure way to expand the profit space for traditional manufacturing and reshape competitive advantage.

(2) Follow the logic of value creation and realize the parallel development of PD and SI via the creative and convergent principles of Industry 4.0. The core logic of SVC is used to

change the traditional "exploitation mindset" of the value chain and to guide SVC participants to create value together, promoting a change in the manufacturing services ecosystem for the better. SOM does not concern "demanufacturing" but amplifying the roles of services and modern internet technology in manufacturing. The integration of services into the technical or product advantages of manufacturing, the addition of service elements to inputs and outputs, and the implementation of a "product + service" production model will add value to all aspects of SVC and create more economic momentum.

(3) Scientific cognition of the SOM upgrading model, using the product track and service track to integrate the value chain, innovation chain, and supply chain to achieve systematic product–service production. The first step is to grasp the empowerment offered by the era of Industry 4.0, i.e., combining the power of innovation to optimize the organizational structure and institutional framework and give an enterprise a modern dynamic. Second, companies should pay attention to the effective development of products and the pioneering innovation of services, design a modular platform interweaving functions and form a flexible component–product production mechanism. The horizontal mechanism of service marketing and intellectual property management enables efficient management of the whole service process of docking and feedback. Finally, based on the intersection of product lines and service chains, a qualitative upgrading of raw materials, product and service generation, and product and service operation and maintenance is carried out in all aspects. Through continuous renewal, managers lead the reoptimization of the SOM upgrade model.

(4) Rational perception of SOM track control should not be blindly integrated at the wrong time. Any enterprise's profits, costs, and incomes vary significantly when the product track and service track are intertwined in the model. Enterprises should scientifically establish their SOM upgrade mode and path rather than blindly depleting resources, which results in inefficient SOM output. The new form of production brought about by SOM has impacted traditional production organization relations. As the development and design of new products and technologies require the collaboration of experts from many different fields, the cost of internalizing R&D activities is higher than that of outsourcing services. However, as knowledge-based services often need to be closely linked to a company's production organization processes and constantly revised, this, in turn, may lead to a significant increase in the cost of outsourcing services, resulting in uneconomical costs. Companies should therefore adapt to the new model of development in their ever-integrating industry and master their control of the scientific product-services track.

Research gaps and outlook. This study uses AVIC as a case study, which may entail limitations. Subsequent studies can expand the industry perspective by selecting LEs in different manufacturing categories to dissect and validate their transformations. In addition, the logical framework of resource–capacity–advantage–development formed in this paper could be subsequently validated using empirical research, as this could clarify the specific effects of pathway relationships in SOM.

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Notes

1 Just like the value chain concept mentioned by Michael Porter in terms of competitive advantage, the traditional value chain met the business needs and established enterprise advantages in the 20th century, realizing the value-added process in society.

2 This matrix is defined as the HFJZ matrix, created by Zhao Haifeng, the author of this paper. In important academic forums such as the Service-Oriented Manufacturing Conference, it was named H(ai)F(eng)J(u)Z(hen) in recognition of the contributions of these scholars.

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Author contributions

HL: Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work. HZ: Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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The authors declare no competing interests.

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Additional information

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