

# FROM DIGITALIZATION TO SERVITIZATION: UNRAVELING MECHANISMS AND PATHWAYS IN MANUFACTURING FIRM TRANSFORMATION

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**Abstract:** Manufacturing enterprises are the cornerstone of China's national economy, and servitization has emerged as a vital pathway for their transformation, upgrading, and high-quality development. In the context of building a manufacturing powerhouse, leveraging digital technologies to enable servitization transformation has become a key strategic focus. This study adopts a bibliometric approach and utilizes CiteSpace to conduct a visual analysis of both domestic and international literature on digitally enabled servitization transformation in manufacturing enterprises. The objective is to clarify the research scope, trace the evolutionary trajectory, and identify regional distributions within the field. Digital empowerment is identified as a current research hotspot. Through keyword co-occurrence and cluster analyses, the study investigates three core research questions: What is digital servitization? Why does digital empowerment matter for servitization transformation? How does it facilitate upgrading? The findings reveal three primary research themes—theoretical foundations, effectiveness, and pathways of digitally enabled servitization—offering a structured overview of the field's development and contributing to a deeper understanding of its underlying mechanisms. These insights provide valuable guidance for future research and strategic decision-making in manufacturing servitization.

**Keywords:** Servitization transformation of manufacturing enterprises; Digitalization; Bibliometrics; Knowledge mapping

## 1 INTRODUCTION

Manufacturing enterprises constitute the cornerstone of China's national economy, and servitization represents a critical pathway for their transformation, upgrading, and high-quality development. It is also one of the key strategies in China's pursuit of becoming a manufacturing powerhouse. The Made in China 2025 initiative outlines a future development strategy that emphasizes the transition of the manufacturing industry from a production-oriented model to a service-oriented one. Furthermore, the Guiding Opinions on Further Promoting the Development of Service-Oriented Manufacturing, jointly issued by the Ministry of Industry and Information Technology and other relevant departments, underscores the significant role of servitization in the transformation and upgrading of the manufacturing sector. In recent years, amid external economic pressures and with the support of national policies, Chinese manufacturing enterprises have accelerated their transformation and upgrading in areas such as digitalization, intelligence, and servitization. However, research on servitization in manufacturing enterprises and studies on digital technologies have often been conducted in isolation. It is only in recent years that the integration of these two fields has emerged under the concept of digital servitization in manufacturing enterprises. Therefore, more targeted research is needed to gain a deeper understanding of digital servitization, leverage digital technologies to facilitate the servitization transformation of manufacturing enterprises, and thereby promote high-quality economic development in China.

Regarding the phenomenon of servitization in manufacturing enterprises, scholars worldwide have conducted in-depth studies from various perspectives. Existing research has largely focused on the importance of servitization in manufacturing, its influencing factors, and its relationship with firm performance. However, studies on the digital servitization transformation of manufacturing enterprises have recently exhibited exponential growth. In light of this, the present study systematically reviews highly influential and frequently cited domestic and international literature in this field. Through both quantitative and qualitative analyses, it constructs a comprehensive research overview of digital empowerment in the servitization transformation of manufacturing enterprises, thereby laying a foundation for future research.

## 2 DATA SOURCES AND RESEARCH METHODS

### 2.1 Data Sources

#### 2.1.1 Chinese literature data sources

Based on the research theme, this study conducted a literature search in the China National Knowledge Infrastructure (CNKI) database using two sets of keywords related to the concepts of servitization and digitalization in manufacturing enterprises. The first set of keywords pertains to servitization in manufacturing enterprises, including "transformation and upgrading of manufacturing enterprises," "servitization transformation," "service-oriented manufacturing,"

"servitization strategy," "service innovation," and "product-service system (PSS/IPSS)." The selection of these keywords was based on their frequent use in a substantial body of classic literature. This initial search yielded 548 Chinese-language publications. After filtering out conference papers, newspapers, and books, only academic journals and dissertations were retained. A further screening process excluded articles irrelevant to the research topic, such as those merely comparing the manufacturing and service sectors without addressing the servitization transformation of manufacturing enterprises, or those using "service" as a verb in a non-analytical context. Ultimately, 339 articles were selected for quantitative analysis.

The analysis revealed digital servitization as a prominent research topic within this field. Consequently, a second round of data collection was conducted. The second set of keywords focused on the role of digitalization in the servitization transformation and upgrading of manufacturing enterprises. Fundamentally, digitally empowering the servitization transformation of manufacturing enterprises involves leveraging various digital technologies to shift a firm's business model from a product-centric to a service-centric approach, thereby achieving a digital servitization transformation and upgrade. Therefore, the search keywords included "digitalization," "digital servitization," "digital technology," and "data-driven." Again, only academic journal articles and dissertations were retained, excluding conference papers, newspapers, and books. Articles that solely addressed digital transformation or digital services without specifically focusing on the role of digital empowerment in enabling servitization transformation were also removed. This process resulted in the selection of 123 articles for analysis.

Regarding the disciplinary distribution of these data sources, literature in the field of industrial economy accounts for nearly half, followed by trade economy and business economy. This distribution indicates that the servitization of manufacturing enterprises is crucial for promoting national industrial development, particularly high-quality development, facilitating the transition to higher positions in the global value chain, and serving as a key lever for implementing enterprise-level transformation and upgrading, see Figure 1.

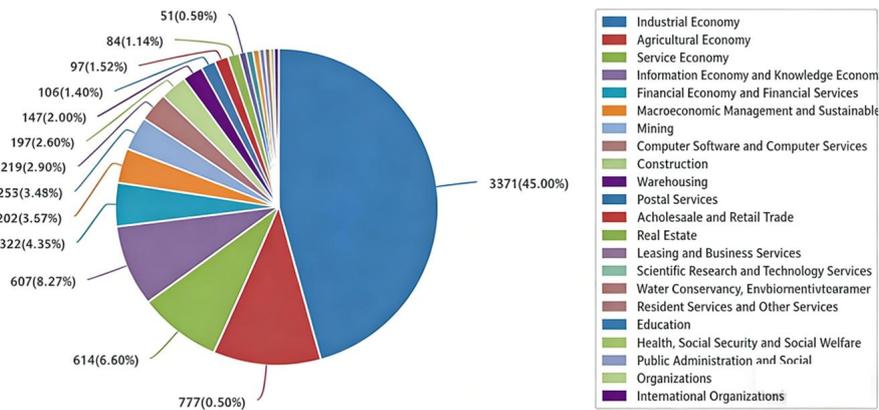
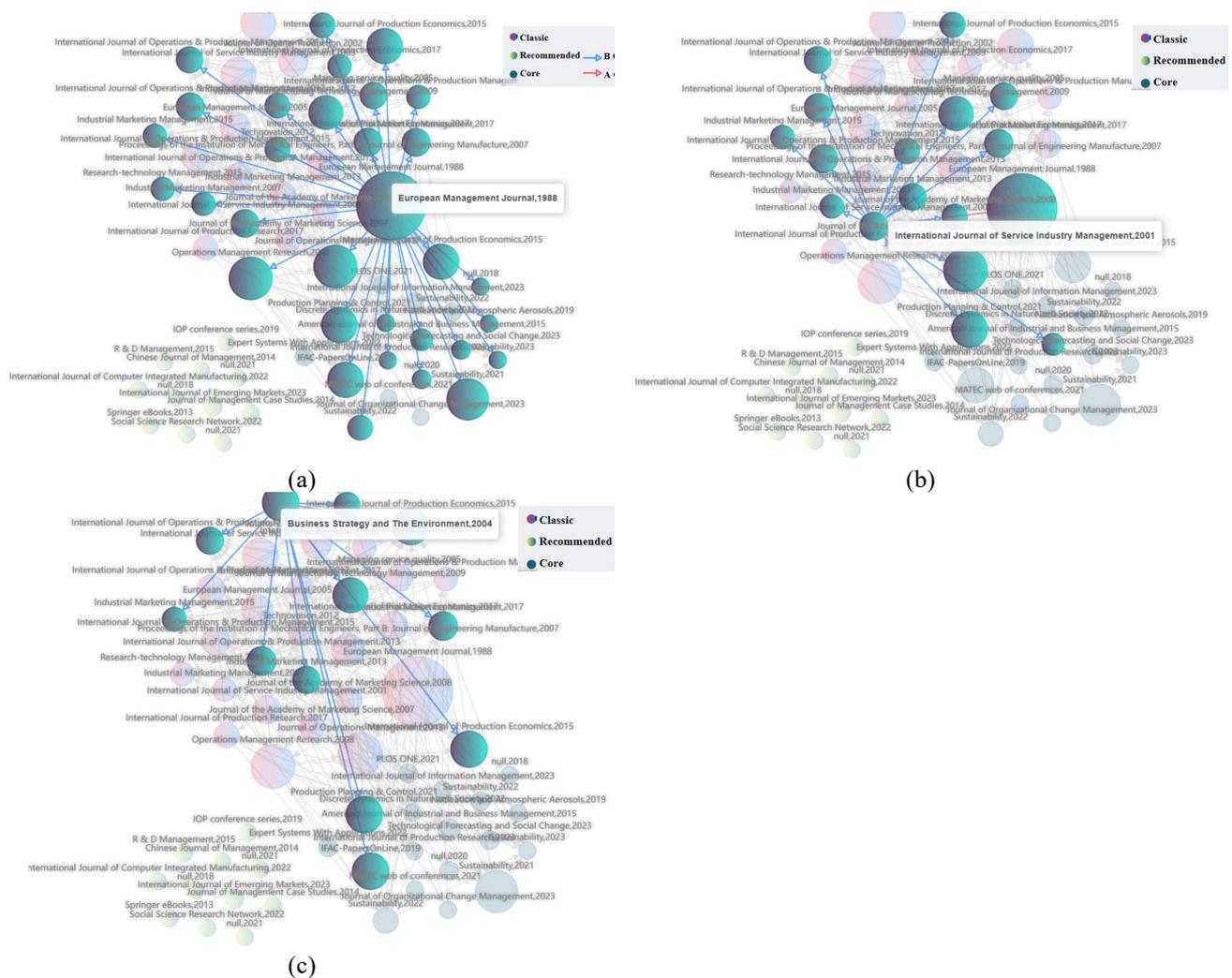


Figure 1 Data Source Distribution

### 2.1.2 English literature data sources

By examining highly cited and review articles related to the research theme within the CNKI database, connections among their references were identified. Utilizing Citexs for a preliminary bibliometric analysis and recommendations of English-language literature, as illustrated in Figure 2, the three earliest and most classic articles on the servitization transformation of manufacturing enterprises were identified. These foundational articles are cited extensively but do not themselves cite earlier works on this specific topic. Scholarly attention to the servitization transformation of manufacturing enterprises can be traced back to 1988, when Vandermerwe and Rada introduced the concept of servitization in manufacturing [1].



**Figure 2** Citations of Core Papers in Research on Servitization of Manufacturing Enterprises

In addition to selecting classic cited publications, the study also utilized Citexs to identify the most frequently cited, most influential, and high-quality English-language literature from recent years for analysis. These were then supplemented by cross-referencing the bibliographies of the identified sources, ultimately establishing the final research dataset.

**2.2 Research Methods**

This study employs a combination of quantitative and qualitative analyses, utilizing bibliometric analysis, co-word analysis, and content analysis. Quantitative description and analysis are conducted using statistical methods, with CiteSpace employed for bibliometric mapping [1]. Co-word analysis is applied to summarize the core content of the research, visually presenting the hot topics within the field [2]. The log-likelihood ratio (LLR) algorithm is used for cluster analysis, while centrality metrics and clustering outcomes help delineate the key thematic threads in the research area. Finally, content analysis and thematic analysis are employed for descriptive interpretation, and low-frequency term clustering results are used to predict future research directions [3].

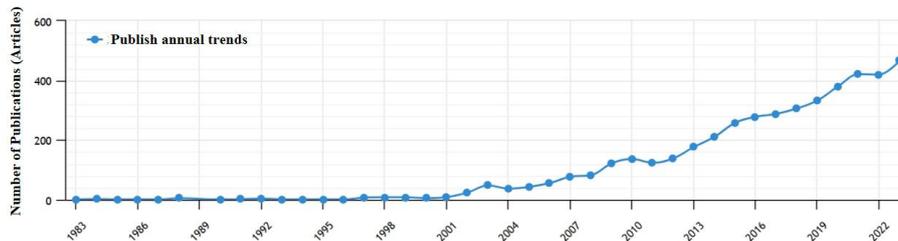
**3 DESCRIPTIVE ANALYSIS**

By combining quantitative and qualitative analyses using CiteSpace, this study conducts a bibliometric investigation and presents descriptive findings from three perspectives: the evolutionary trajectory of research, its geographical distribution, and keyword analysis.

**3.1 Evolutionary Trajectory**

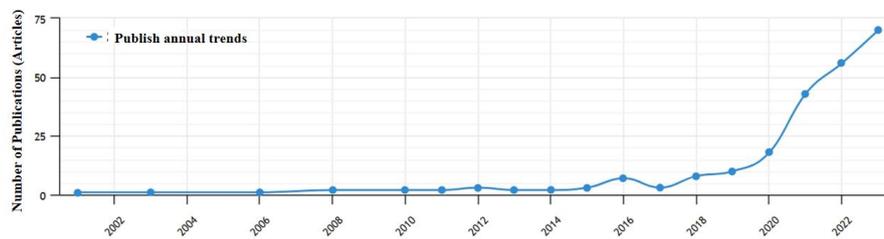
The concept of servitization in manufacturing enterprises was first introduced in 1988. Prior to 2007, the annual number of publications in this field, both domestically and internationally, remained below seven, exhibiting slow growth. This period represents the initial phase of research on manufacturing servitization [2], primarily focused on the conceptualization and classification of servitization in manufacturing. By 2014, scholars began to systematically investigate manufacturing servitization and product-service systems, marking a developmental stage in this line of

inquiry. During this phase, in-depth analyses were conducted on the driving factors, effects, and implications for firm performance concerning the servitization transformation of manufacturing enterprises. Notably, the "service paradox" theory emerged during this time, accompanied by increasingly refined conceptual definitions, see Figure 3.



**Figure 3** Annual Publication Volume of Research on Servitization of Manufacturing Enterprises

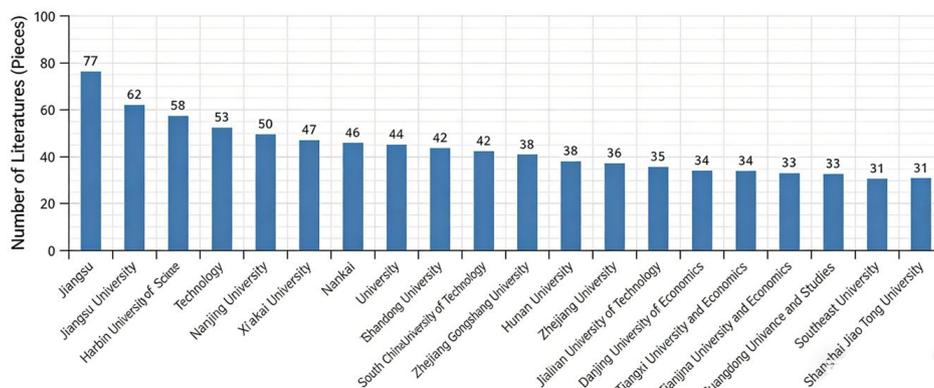
From 2014 onwards, the field entered a phase of research surge, primarily driven by the emphasis placed on advanced manufacturing by major global economies and the consequent enactment of industrial policies. Key examples include the United States' "A National Strategic Plan for Advanced Manufacturing" report in 2012, Germany's "Industry 4.0" initiative launched in 2013, and China's "Made in China 2025" plan issued in 2015. During this period, with the rapid advancement of new technologies such as informatization and digitalization, leveraging digital technologies to facilitate the digital transformation of manufacturing enterprises emerged as a prominent research focus. As illustrated in Figure 4, starting from 2020, the volume of publications related to digital servitization has grown exponentially.



**Figure 4** Annual Publication Volume on Digital Empowerment in Servitization of Manufacturing Enterprises

### 3.2 Geographical Distribution

An analysis of the distribution of research institutions reveals a distinct geographical pattern, with primary concentrations in regions such as Shanghai, Jiangsu, Zhejiang, Xi'an, and Harbin. The Yangtze River Delta region, encompassing Shanghai, Jiangsu, and Zhejiang, serves as a crucial manufacturing hub. These areas actively promote Industry 4.0 initiatives, place greater emphasis on carbon emission reduction, and prioritize accelerating the servitization level of manufacturing enterprises, thereby driving the transformation and upgrading of manufacturing firms in surrounding urban clusters. In contrast, Xi'an and Harbin represent key centers for manufacturing equipment development and heavy industry in China. Accelerating the servitization transformation and upgrading of manufacturing enterprises in these regions is conducive to strengthening China's real economy and fostering high-quality development, see Figure 5.



**Figure 5** Geographical Distribution of Research Institutions

### 3.3 Keyword Analysis

#### 3.1.1 Keyword co-occurrence analysis

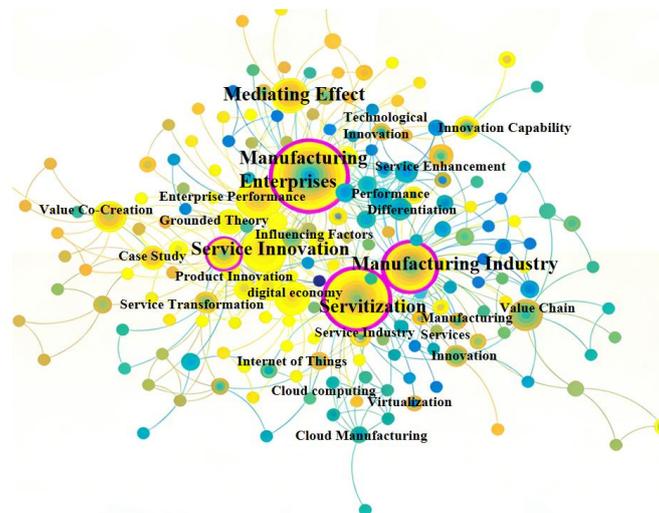
The 339 records on manufacturing enterprise servitization retrieved from CNKI were imported into CiteSpace to conduct a keyword co-occurrence analysis of the literature published between 2000 and 2023. As shown in Figure 6, the co-occurrence analysis extracted 274 keyword nodes, forming 497 connections. Table 1 presents the frequency and centrality of keywords calculated by CiteSpace, listing the top 10 keywords by frequency. These are, respectively: "servitization," "manufacturing industry," "manufacturing enterprises," "firm performance," "digitalization," "service innovation," "technological innovation," and "case study." The high frequency of these terms indicates significant scholarly attention, suggesting a relatively concentrated focus within the domestic research field.

The color gradient in the figure corresponds to the chronology of the keywords; a warmer, more yellow hue signifies a current research hotspot. For instance, the keywords "servitization," "manufacturing industry," and "manufacturing enterprises" exhibit a color transition from blue to yellow from the inner to the outer layers of their nodes, and they also demonstrate the highest centrality. This indicates that research on these three aspects has been ongoing since the year 2000 and continues to be relevant today. The keywords displaying the most intense yellow coloration are "digitalization," "digital economy," and "digital technology," with colors shifting from orange-yellow to golden yellow. This suggests that these are emerging research directions that have gained traction in recent years and represent a burgeoning and highly active area of study.

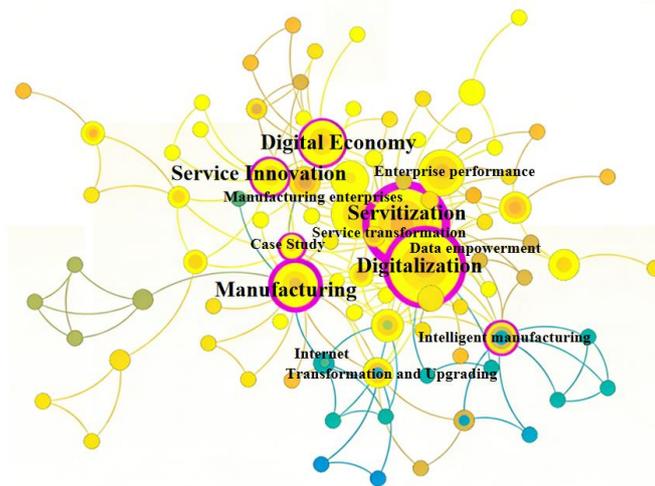
Subsequently, the literature from the second CNKI search, focusing specifically on digital empowerment in the servitization transformation of manufacturing enterprises, was imported into CiteSpace. As illustrated in Figure 7, this co-occurrence analysis extracted 123 keyword nodes, forming 211 connections. Prominent keywords in this dataset include: "servitization," "digitalization," "digital economy," "intelligent manufacturing," "digital technology," and "data empowerment." Apart from keywords like "intelligent manufacturing" and "internet," which have been subjects of extensive research since approximately 2010, most of the other popular keywords linking digitalization with manufacturing servitization are relatively recent and currently active areas of inquiry. The subsequent thematic analysis will provide a synthesized review focusing on the aspects of "business models," "firm performance," and "influencing factors."

**Table 1** High-Frequency Keywords in Literature on Servitization of Manufacturing Enterprises

Rank	Frequency	Centrality	Year	Keyword
1	47	0.4	2006	Servitization
2	43	0.32	2000	Manufacturing Industry
3	35	0.26	2006	Manufacturing Enterprises
4	21	0.1	2008	Firm Performance
5	15	0.03	2021	Digitalization
6	13	0.16	2000	Service Innovation
7	11	0.05	2016	Technological Innovation
8	10	0.07	2012	Case Study
9	9	0.03	2016	Mediating Effect
10	8	0.04	2018	Digital Economy



**Figure 6** Keyword Co-occurrence Network Map of Literature on Servitization of Manufacturing Enterprises



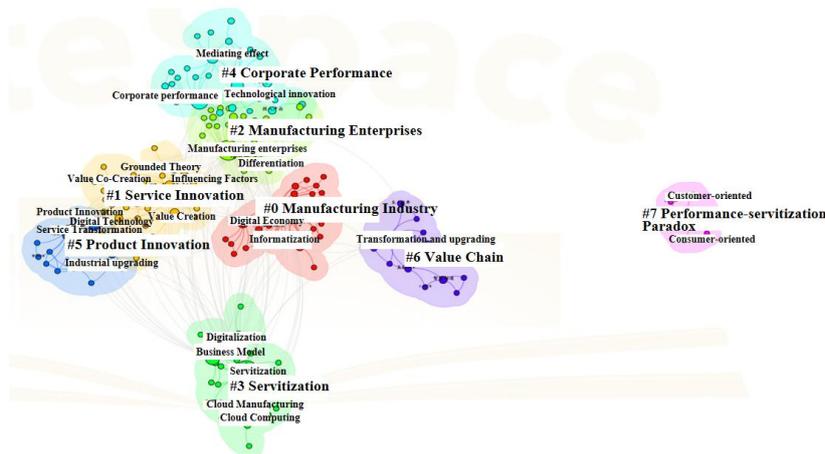
**Figure 7** Keyword Co-occurrence Network Map of Literature on Digital Empowerment in Servitization Transformation of Manufacturing Enterprises

**3.1.2 Keyword cluster analysis**

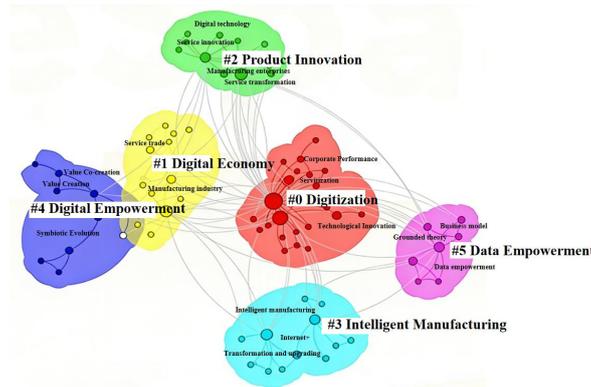
Keyword clustering maps illustrate the distribution of research areas by grouping keywords based on their similarity. Clusters are ranked according to the number of keywords they contain; a smaller serial number indicates a larger cluster. CiteSpace provides two metrics for evaluating clustering quality: the modularity Q value and the mean silhouette S value. A Q value higher than 0.3 signifies a significant cluster structure, while S values above 0.5 and 0.7 indicate reasonable and highly credible clustering, respectively [4].

The cluster analysis conducted on the research concerning manufacturing enterprise servitization is presented in Figure 8. The clustering yielded a Q value of 0.6586 and an S value of 0.8961, indicating a significant and highly credible clustering structure. The resulting hot topics in research related to the servitization transformation of manufacturing enterprises include: manufacturing industry, service innovation, servitization, firm performance, product innovation, value chain, and the performance-servitization paradox.

Building on this, a cluster analysis was performed specifically on the literature regarding digital empowerment in manufacturing enterprise servitization, as shown in Figure 9. This clustering produced a Q value of 0.5873 and an S value of 0.8958, also indicating a significant and highly credible clustering structure. The prominent hot topics in current research on digitally empowering the servitization transformation of manufacturing enterprises include: digitalization, product innovation, intelligent manufacturing, digital empowerment, digital economy, and data empowerment.



**Figure 8** Keyword Clustering Map of Literature on Servitization of Manufacturing Enterprises



**Figure 9** Keyword Clustering Map of Literature on Digital Empowerment in Servitization Transformation of Manufacturing Enterprises

Based on the analysis of the evolutionary trajectory, geographical distribution, keyword co-occurrence, and cluster analysis, this study identifies three key findings. First, research on manufacturing enterprise servitization rests on a substantial theoretical foundation, with scholarly inquiry dating back to the 20th century. Currently, digital servitization has emerged as a prominent research hotspot, and while studies on digital servitization have begun to explore its implementation processes, this area remains in its nascent stage. Second, research activity is more pronounced in economically developed regions such as the Yangtze River Delta, as well as in traditional industrial bases known for manufacturing. Third, the primary research themes converge on the conceptualization and classification of manufacturing/manufacturing enterprise servitization, the factors influencing manufacturing enterprise servitization, and the impacts of adopting servitization on manufacturing firm performance, value chains, and enterprise as well as product innovation. Within the context of digitalization as a current hotspot, the main research themes specifically focus on digital empowerment and data-enabled servitization in manufacturing. Building on these findings, the following sections will elaborate on the predominant research themes concerning digitally empowered servitization transformation in manufacturing enterprises.

## 4 THEMATIC ANALYSIS

Based on the descriptive analysis and cluster analysis results presented above, current research can be categorized into three main themes, structured around the fundamental questions of "what it is," "why it matters," and "how it works." The first theme concerns the theoretical research on digital servitization in manufacturing enterprises, encompassing related concepts, influencing factors, and relationship analysis. The second theme focuses on the effectiveness of digital empowerment in driving the servitization transformation of manufacturing enterprises, including the role of digital-driven capabilities in servitization transformation and research on how digitalization facilitates innovation in servitization business models within manufacturing firms. The third theme investigates the pathways through which digital empowerment enables the servitization transformation and upgrading of manufacturing enterprises.

### 4.1 Theoretical Research

#### 4.1.1 Conceptual definitions of servitization: domestic and international perspectives

Within this research hotspot, scholars primarily explore the concepts, models, and influencing factors of digital servitization in manufacturing enterprises. The concept of digital servitization in manufacturing enterprises builds upon the foundation of manufacturing servitization. The term "servitization" in manufacturing was first introduced by Vandermerwe and Rada in 1988, referring to a model where manufacturers transition from offering purely products to providing "products + services," bundling products with services to meet customer needs for product utility rather than ownership [5]. Servitization is considered a strategic alternative to product innovation and standardization, a means of countering commoditization, and a method for establishing unique, loyal customer relationships [6]. The academic community holds varying definitions regarding the integration of manufacturing and service industries. Some studies note that the United States refers to this integration as service-oriented manufacturing or manufacturing servitization, while European countries interpret it as building product-service systems [7]. Other research explains this integration as the development of producer services.

Domestic scholarly research on manufacturing enterprise servitization can be traced back to the late 20th century. Guo Yuejin posited that servitization-oriented operations in manufacturing enterprises encompass two scenarios: marketing innovation for tangible products aimed at creating service advantages, and the extension of business activities into the service sector [8]. Dai Keqing pointed out that, influenced by macro-environmental factors such as information technology, sustainable development, and business model transformation, manufacturing servitization not only refers to manufacturers expanding their activities along the value chain but also represents an emerging trend toward systematic development, evolving from service modularization to the construction of integrated ecosystems under the influence of networking, platformization, and systematization [9].

#### 4.1.2 Influencing factors of servitization

The factors influencing the servitization of manufacturing enterprises are diverse. Huang Qunhui and Huo Jingdong explored macro-level factors affecting manufacturing servitization, finding that economic freedom and the proportion of imports and exports in the manufacturing sector significantly promote servitization. Conversely, factors such as the manufacturing value-added rate and the intensity of service input in manufacturing can, to some extent, inhibit it [10]. Lu Zhiping and Zhao Zijuan et al. conducted a more nuanced study, examining the respective impacts of customer orientation and market orientation on servitization. They found that customer orientation has a significant positive effect on the servitization level of manufacturing enterprises, with service innovation playing a mediating role in this relationship [11]. Numerous scholars have investigated the impact of "customization" on manufacturing servitization. Sousa and Silveira discovered that the intensity of product customization strategy (strategic market priority, product, process) is positively correlated with servitization (basic services/advanced services) [12]. Qi et al. demonstrated that enhanced product innovation capability can promote higher levels of servitization, with mass customization capability indirectly improving servitization levels through product innovation capability. Their study also found that lean and agile practices indirectly influence servitization via product innovation capability [13].

#### **4.1.3 Digitalization and manufacturing enterprise servitization**

Digital servitization is a technological transformation process wherein enterprises leverage big data technologies to shift their core structure from production-centric to service-centric models. This transformation involves developing entirely new services or enhancing existing ones through the application of digital technologies, thereby reshaping products, processes, services, and strategies [14]. Jiao Yong and Coreynen suggest that the dimensions of digitally enabling enterprise servitization transformation are primarily reflected in the shift from factor-driven to data-driven approaches, from product-centric to consumer-centric models, and from competition to reciprocal coexistence [15,16]. Favoretto et al. qualitatively analyzed how digitalization promotes servitization transformation by altering firm motivations, strategies, service offerings, and organizational structures [17]. Relevant empirical studies include that of Zhao Chenyu, who constructed enterprise digitalization indicators using text mining and elucidated how the combined effects of digital technology application, internet business models, intelligent manufacturing, and informatization collectively drive enterprise servitization transformation [18].

## **4.2 The Effects of Digital Empowerment on Manufacturing Enterprise Servitization Transformation**

### **4.2.1 The role of data-driven digital capabilities in manufacturing enterprise servitization transformation**

To undergo servitization transformation, an enterprise must first be able to effectively acquire product and customer data in near real-time. The data collection capabilities of digital technologies are instrumental in understanding customer service opportunities. Supported by digital collection capabilities, enterprises can optimize product-support services (SSP) without temporal or spatial constraints. They can monitor product operational status, rapidly identify faults, and ensure timely installation, inspection, repair, and maintenance services.

Digital development brings data analytics capabilities to enterprise servitization transformation, enabling companies to identify potential service opportunities, continuously learn from new information, predict and provide early warnings of product operational faults, conduct timely analysis and product maintenance, and simultaneously analyze customer needs to optimize products and deliver services, thereby facilitating the personalized development of enterprise servitization transformation.

Digital application capabilities leverage various digital technologies to reduce service costs, streamline service processes, and enhance service quality. Concurrently, research into technologies such as intelligent manufacturing and digital twins can augment interactive experiences. Remote monitoring technologies enable the detection and maintenance of product faults, potentially breaking the "service paradox."

### **4.2.2 Digitalization driving innovation in servitization business models for manufacturing enterprises**

The application of the Internet of Things (IoT) integrates digital services with physical goods, endowing traditional products with sensor-based digital services and offering customers new value propositions. Beyond the utility of existing physical goods or services, these services are enhanced by internet technologies to deliver added value. In this business model, if customers wish to access additional IoT services, they must first purchase the primary physical good or service, essentially paying a fee to enjoy supplementary business services.

Digitalization fosters the innovation of shared business models within manufacturing servitization. This model allows customers to pay for limited-time use or access to a product, enabling simultaneous use by different users and thereby improving asset utilization. In this scenario, physical ownership of the product remains with the supplier, and the user base undergoes transformation. As Alfian, Rhee, and Yoon observed, compared to traditional leasing models, shared business models result in more frequent ownership changes and shorter usage cycles [19]. For example, the emergence of car-sharing services, facilitated by mobile applications and digital tracking technologies, enables precise usage and payment without the need for reservations.

Digitalization fosters solution-oriented business models. With the assistance of IoT technologies, suppliers can provide integrated solutions tailored to customer needs. In B2B contexts, this involves supporting clients' core operations, enhancing efficiency, and expanding business capabilities [20]. Suppliers guarantee customers continuous and uninterrupted access to products that deliver specific utilities. By employing IoT technologies, suppliers gain access to real-time information regarding product status, enabling them to provide maintenance and other support services more effectively [21].

### 4.3 Pathway Research

In terms of pathway research, Coreynen et al. conducted a multi-case study to investigate how digitalization facilitates servitization. Through an analysis of four small and medium-sized manufacturing enterprises, they identified three distinct servitization pathways enabled by specific digitalization choices: industrial servitization, commercial servitization, and value servitization. From a dynamic resource-based perspective, the study discussed the obstacles, dynamic resource allocation, and competitive advantages unique to each pathway. It ultimately provided managerial insights on successfully achieving higher levels of service through the development of digital assets, as well as the skills required for deeper integration into customer processes [17]. Dong Hua and Sui Xiaoning, drawing upon the DIKW (Data-Information-Knowledge-Wisdom) framework, conceptualized digitalization as a driving force behind servitization. They proposed a four-stage, three-dimensional model for the transformation and upgrading of manufacturing enterprises, clarifying the dominant pathways for servitization transformation [22].

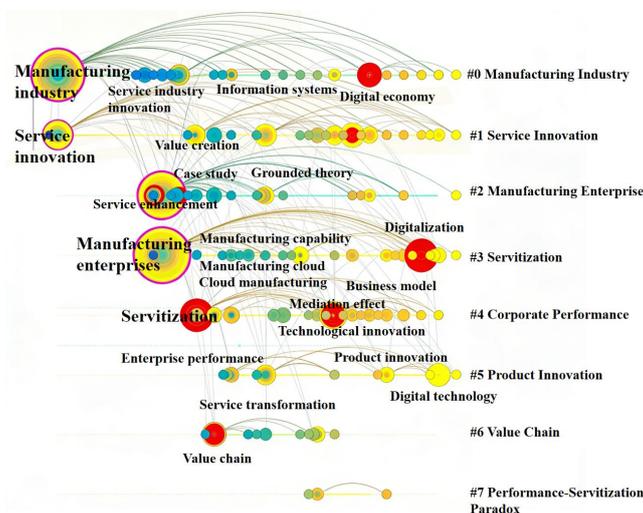
Jiang Junfeng and Shang Yanying conceptualized manufacturing servitization as a dynamic process characterized by "data empowerment—enhancement of industrial digitalization capabilities, product data utilization capabilities, and customer value interaction capabilities—the combined effects of industrial servitization, customer servitization, and value servitization" [23]. Shang Yanying, Jiang Junfeng, and Wang Xiulai, focusing on the pathways of digitalization-enabled servitization transformation in manufacturing enterprises, took the adaptive alignment between dynamic capabilities and market environment as the core driving force. They constructed a theoretical framework wherein internal mechanisms capture the invariability of data empowerment driving manufacturing servitization, while external mechanisms capture the variability shaped by contextual factors. This framework elucidates how the interaction of internal and external mechanisms influences manufacturing enterprise servitization [24]. Zhang Zhengang et al. proposed that digitally enabled servitization follows a three-stage pathway: "digitalization of production factors—formation of digital service capabilities—creation of digital service value" [25].

Pan Rongrong, Luo Jianqiang, and Yang Zichao elaborated on the application scenarios where digital technologies empower servitization transformation. They analyzed the "double-edged sword" effect of empowerment, where it simultaneously holds potential and entails risks, and subsequently offered countermeasures and suggestions [26]. Liu Chao et al. investigated the impact and mechanism of digital development on the servitization transformation of sporting goods manufacturing enterprises. Their findings identified two significant pathways through which digital development promotes this transformation: enhancing innovation capabilities and optimizing human capital structure [27].

## 5 RESEARCH SUMMARY AND FUTURE PROSPECTS

The keyword timezone map reveals the distribution of research hotspots in different years, illustrating the evolutionary path of themes within the research field and how research hotspots shift over time. By combining the keyword burst detection map with a review of the existing literature, this study summarizes the current state of research and proposes directions for future inquiry.

The results from the keyword timezone map (Figure 10) and keyword burst detection map (Figure 11) indicate that the integration of servitization and digital technologies represents an emerging and highly active research direction. Research trends related to specific digital technologies, such as "cloud computing," "industrial internet," and "cloud manufacturing," are also intensifying. Furthermore, "digital technology" and "technological innovation" are identified as promising avenues for future research. The investigation into the impact of digitally enabled servitization transformation on the performance of manufacturing enterprises remains an ongoing area of study, with continuous deepening and refinement. The following section will elaborate on the specific research breakthroughs anticipated within these major research directions.



**Figure 10** Keyword Timezone Map of Research Literature



Figure 11 Top 9 Keywords with the Strongest Citation Bursts

First, the integration of servitization and digital technologies represents the most prominent contemporary research direction, exhibiting a rapid growth trend. However, studies in this area are currently dispersed across various disciplines, including engineering, business, marketing, computer science, decision science, social science, economics, energy, and environmental science, without forming a systematic research field. Therefore, future research could benefit from cross-disciplinary integration and collaboration.

Second, a review of relevant domestic and international studies reveals that scholars have generated rich findings concerning the concepts, influencing factors, effects of digital empowerment on manufacturing enterprise servitization, and the associated pathways. Research has clearly established the positive role of digitalization in the servitization transformation of manufacturing enterprises and has preliminarily explored, from multiple perspectives, the mechanisms through which digital empowerment facilitates this transformation. However, investigations into the specific pathways of digitally enabled servitization transformation in manufacturing enterprises remain largely theoretical, lacking in-depth, systematic inquiry and empirical validation. Consequently, future research should pursue more systematic and empirically grounded studies on the pathways of digital empowerment for servitization transformation in manufacturing enterprises.

Third, the machinery and industrial equipment sector has received the most attention in empirical research, as it is considered one of the most promising areas for exploring and leveraging the benefits of digital servitization. The automotive industry has also garnered significant interest from researchers. In contrast, literature on other industrial sectors is considerably scarce. Within the empirical studies covered in this review, the machinery and industrial equipment sector emerges as the most frequent research subject. Other sectors, such as publishing, leather manufacturing, and food retail, are each addressed in only one or two studies. Research tends to analyze single or, at most, two industries in case studies. Hence, broader cross-industry comparisons represent a valuable direction for future investigation.

Fourth, research on digitalization has predominantly focused on the impact of digital technologies on the servitization transformation of manufacturing enterprises, often concentrating on a single, specific digital technology [28]. Technologies such as the industrial internet, big data analytics, and cloud computing are frequently emphasized in discussions of digitalization's role. Future studies could explore the functions of a wider array of digital technologies in servitization, as well as the combined application of multiple technologies.

Finally, the relationship between manufacturing enterprise servitization transformation and firm performance has been a persistent research topic. The advent of digitalization offers the potential to resolve the "service paradox." Current research on firm performance in this context primarily addresses the role of digital technologies, particularly in the development of intermediate and advanced services. Future research could investigate the impact on firm performance by examining the different business models and pathways through which digitalization enables servitization transformation and innovation.

## 6 CONCLUSION

This study centers on the digital-enabled servitization transformation of manufacturing enterprises. By adopting bibliometric methods combined with CiteSpace and Citexs tools, it systematically sorts out and conducts a visual analysis of domestic and international literature in this field, clarifying its research scope, evolutionary trajectory, regional distribution and core research hotspots. Through keyword and thematic analyses, existing research is divided into three major themes: theoretical foundation, enabling effects and implementation paths, with an in-depth analysis of the internal mechanisms of digital empowerment in the servitization transformation of manufacturing enterprises.

The study finds that servitization has become a crucial strategic choice for the transformation and upgrading of the manufacturing industry, and the integration of digitalization and servitization is an inevitable trend of industrial development. Since the concept of manufacturing servitization was first proposed in 1988, research in this field has gone through the initial and developmental stages; research on digital empowerment has seen an explosive growth since 2020 and become a core research hotspot. Domestic research institutions are mainly concentrated in the

manufacturing-developed Yangtze River Delta region and traditional industrial bases such as Xi'an and Harbin, which is highly consistent with the characteristics of regional industrial development.

Theoretical research has formed a complete system regarding the conceptual definition of manufacturing servitization, its influencing factors and the internal correlation between digitalization and servitization integration. Digital technologies effectively promote the servitization transformation of manufacturing enterprises by fostering data-driven capabilities and driving the innovation of servitization business models, and also have the potential to resolve the "service paradox". The digital-enabled path models proposed by scholars from multiple perspectives provide diversified theoretical references for corporate practice.

At the same time, this study also identifies obvious deficiencies in current research: research is scattered across multiple disciplines with insufficient interdisciplinary integration and collaboration; research on the implementation paths of digital servitization is mostly theoretical exploration with a lack of empirical verification; research objects are highly concentrated in the equipment manufacturing, automotive and other industries, with the absence of cross-industry analysis leading to insufficient generalizability of conclusions; research on digital technologies focuses on single technologies, lacking discussions on the combined application and synergy mechanism of multiple technologies.

This study constructs a knowledge map of the digital-enabled servitization transformation of manufacturing enterprises, sorts out the evolutionary trajectory and core themes of the field, makes up for the research gap in systematic combing, and lays a theoretical foundation for subsequent research. Meanwhile, it clarifies the positive role and implementation mechanisms of digital empowerment, which can provide decision-making references for manufacturing enterprises in their digital and servitization transformation, and also offer policy insights for the government to formulate industrial support policies and promote the high-quality development of the manufacturing industry.

In general, digital-enabled servitization is an inevitable path for the transformation and upgrading of manufacturing enterprises in the digital era, and research and practice in this field are still in a stage of rapid development. With the innovative application of digital technologies such as the industrial internet and digital twins, the connotation and extension of digital servitization will be continuously enriched. Future research should focus on interdisciplinary integration, empirical verification of paths, cross-industry comparison and the synergy effect of multiple digital technologies, deepen the understanding of the internal mechanisms of the transformation, and provide more scientific and practical theoretical support and practical guidance for the high-quality development of the manufacturing industry and the construction of a manufacturing power.

## COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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