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Servitization in Construction and its Transformation Pathway: A Value-Adding Perspective

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ABSTRACT

Against the current social and technological background dominated by services and technology, new opportunities are opening up for the industrial transformation and upgrading of the construction industry. Considering the successful transformation and upgrading of the manufacturing industry through servitization, scholars and practitioners have begun to explore the possibility of servitization in the construction industry. Current practices and theory show that different understandings of servitization in the construction sector exist; however, they are still in their infancy and lack a deep and systematic awareness, which does not benefit the transformation and upgrading of construction through servitization. Therefore, this paper systematically analyzes the motivation, definition, and implications of servitization in construction based on the value-adding nature of servitization and considers the problems confronting the construction industry. To facilitate this development, transformation pathways for servitization in construction are analyzed from multiple angles, including value co-creation, service innovation, and networked operation, which are in line with the new trends in digital construction. In addition, based on the supporting elements of construction, which include finance, human resources, technology, materials, and equipment, this paper examines the impact of servitization on the construction industry's ecology. In short, we expect that this systematic analysis and exposition can provide a holistic view of servitization in construction from the inside out for scholars and practitioners and can help to promote servitization in construction.

1. Introduction

With the world economy shifting from post-industrial to service based [1], service has become increasingly important in all types of economic activities. Since the concept of "servitization" was first introduced in the 1980s [2], the idea of adding the core product's value and then obtaining a competitive advantage through service has been accepted by an increasing number of scholars. Many enterprises are now continually achieving greater competitiveness through servitization. For example, the famous aircraft engine company Rolls-Royce not only sells aircraft engines, but also provides engine management and maintenance. Moreover, the company sells power-by-the-hour aircraft engines. As another example, in addition to selling hardware and personal computers, IBM provides tailored and integrated solutions for customers. In this way, IBM has become the main high-tech services enterprise.

These developments are not accidental; rather, they have emerged in response to the demands of industrial development in the current economic environment. On the one hand, technical progress means that the products provided by enterprises gradually become homogenized. On the other hand, due to material abundance, consumers are no longer content to merely obtain products; they now pay greater attention to the product experience, which has resulted in personal and diverse demands. Studies on the motivation for servitization [3,4] have shown that service is an approach used to differentiate between products. Servitization can also make benefit sharing attractive, and the magnitude of its market is greater than that of the product market. Servitization produces different forms of product service systems (PSSs) that can help enterprises meet complex consumer demands. Due to the function of servitization in improving competition and meeting

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consumer demand, which helps enterprises adapt to the current industry environment, servitization transformation has become a trend in industrial development as a means of adapting to the times.

Affected by the servitization of manufacturing, signs of servitization have appeared in the construction industry. This phenomenon is characterized by service-led projects that provide long-term services based on facility delivery to meet builders' business demands. In this type of project, the contractors' focus shifts from the usual facility delivery to the provision of long-term services related to the facility. This change also extends the traditional project management cycle to the operation and maintenance stage, thereby increasing the complexity of project management. As demonstrated in a series of studies on service-led projects [5], such projects model an integration scheme that ties design, construction, and operations together to meet builders' demands [6]. Servitization in construction is understood as providing long-term operation and maintenance services based on facility delivery. Most service-led projects are large-scale engineering projects characterized by public–private partnerships (PPPs), as long-term services provided by the private sector are needed [7–9]. Since the 2010s, however, many construction companies have started to introduce and utilize the servitization concept without involving PPPs [10,11]. Studies have also pointed out that focusing on operational and maintainable services after facility delivery may draw attention away from problems in the project delivery process [12].

In addition to the above servitization practices, Chinese scholars have highlighted the construction services concept of the "Internet Plus" construction platform [13]. This concept defines construction services as a series of activities relying on tangible resources, such as humans and equipment, which are conducted by all the parties involved in construction to meet clients' specific needs [14]. Following Koskela [15], Liu et al. [16] portrayed construction from a value-stream perspective and divided construction services into design services, material supply services, construction services, and other support services. The concept of construction services put forward by these scholars focuses on servitization of the construction process. This type of servitization makes the specialized division of labor finer and makes it possible for all parties involved in construction to conduct on-demand service transactions on the Internet platform, thus achieving centralization and optimization of the configuration of construction resources.

These service-led project practices and the concept of construction services are based on different understandings of servitization in construction among the industry and academia, indicating an absence of consensus on the meaning of servitization in the construction industry. Whether due to the practice and theory of servitization in construction still being in their infancy or to the lack of a clear definition and systematic understanding (e.g., including motivation, implications, transformation pathway, and influence), it is difficult to provide theoretical support for servitization transformation in the construction industry. Therefore, to help construction enterprises achieve servitization transformation, studies that clarify the concept, implications, and realization path of servitization in construction are required.

This paper proposes a definition of servitization in construction based on an analysis of the motivation for servitization transformation in construction. Taking the value-adding effect of services as the starting point, this paper analyzes the implications of servitization in construction in depth, designs a realization path for servitization in construction, and explores a new form of industry fostered by servitization in construction from many aspects, including finance, human resources, techniques, materials, and equipment. Because digital construction is becoming a new trend, transformation pathways for servitization in the construction industry are discussed in line with the practice of digitalization in construction. In conclusion, we support building a systematic understanding of servitization in construction to promote servitization transformation in construction and related industries. In this way, we contribute to solving the problems confronting the construction industry and to achieving industrial upgrading.

2. Servitization in construction

2.1. The definition of servitization

Servitization—a term that was first coined by Vandermerwe and Rada [2]—is now widely recognized as referring to the shift from selling products to offering "bundles" consisting of goods and services [17]. Because this method generates added value, it has attracted the attention of many scholars. Based on a comprehensive analysis of previous definitions of servitization, Roy et al. [17] described servitization as an innovation of organizational capabilities and processes that aims to better create common value through the shift from selling products to PSSs. This type of value co-creation is characterized by customer participation in the provision of a PSS to better meet the personalized demands of customers, which differs from the traditional way of realizing value creation through product sales.

The PSS concept was first proposed by Goedkoop et al. [18]; it is defined as a system that comprises products, services, participant networks, and support infrastructure. The purpose of this system is to maintain competitiveness, meet consumer demand, and lower environmental impact. Subsequently, many scholars have developed different definitions of PSSs based on this study. Baines et al. [19] synthesized these definitions and summarized a PSS as integrated products and services that provide value during usage. According to this definition, PSSs separate economic benefits from product consumption, which reduces the impact of economic activities on the environment. That is, PSSs emphasize product usage instead of purchases to meet customers' demand, reduce raw material consumption by making use of services to realize "dematerialization," and thus achieve environmental sustainability [20]. From the perspective of meeting customers' demands, a PSS represents a special example of manufacturing servitization. It emphasizes asset performance or utilization rather than ownership and provides usage value for customers by integrating products and services to realize differentiation [19].

The other form of servitization is servitized manufacturing, which was first proposed by Chinese scholars. Sun et al. [21,22] developed an advanced manufacturing model that combines manufacturing and services based on an analysis of the changing trends in the global manufacturing industry. Servitized manufacturing provides PSSs in three different forms: product-oriented PSSs, use-oriented PSSs, and utility-oriented PSSs. In terms of integration, servitized manufacturing includes service-oriented manufacturing [23] and manufacturing-oriented services. The former introduces technical process-level services provided by manufacturing enterprises to the manufacturing process, while the latter occurs when producer service firms provide business process-level services covering the entire life cycle of a product [24,25].

In summary, servitization emphasizes meeting the personalized needs of customers by integrating products and services, which implies value creation when the needs are met. As the outcome of servitization, PSSs vary according to the mix of products and services provided [26]. In comparison with the servitization of manufacturing, servitized manufacturing not only includes adding value via the integration of products and services, but also advocates the servitization of products' manufacturing processes. That is, manufacturing firms provide professional services to complete production for other enterprises. In this way, manufacturing firms can obtain manufacturing resources with comparative advantages in a wider range, thereby increasing productivity while reducing manufacturing costs [21].

2.2. The status quo of servitization in construction

The idea of servitization has prevailed in the manufacturing industry, and academics and construction practitioners have analyzed whether this model can help resolve the issues confronting the construction industry, such as low construction productivity, weak core competitiveness, and a single revenue stream. In fact, the past two decades have witnessed a great deal of discussion on the implications of servitization in construction.

In the early years of this transition, a shift in the understanding of the construction sector occurred, from construing what the contractor provides to the client as the construction product to the interpretation that contractors also provide a series of construction services in this process [27]. In recent years, emerging and increasing applications of service-led concepts have been seen in the construction sector, such as service-led projects and contracts and service-led relationships. The term "service-led project" was coined to represent an increasingly common type of complex project, in which the life cycle of the project is extended into the operation phase and driven by the users' service requirements [28]. Some scholars call this type of project [29] "service-led contracts." The term "service-led relationship" refers to the adoption of both a service-dominant logic (SDL) and relationship marketing (RM) by project-based firms due to the uniqueness and dynamics of projects [30]. RM encourages firms to increase their profitability by establishing long-term relationships with customers rather than focusing on a single exchange, while SDL shifts the focus of firms from selling products to service exchanges.

Taken together, these concepts reflect a need for the construction sector to shift from product delivery toward satisfying users' needs. As a result, the research emphasis on servitization has also shifted to whole-life considerations and the service dimension of projects. A review of existing studies reveals some ideas on servitization. For example, the idea of offering long-term services based on installed assets is regarded as the driver of service-led projects [8]. Long-term service requirements require a shift in contractors' attention from focusing on delivery and support within a warranty period to longer-term considerations of what may happen in the future. In this case, contractors no longer work as mere builders of facilities but become active participants in the overall maintenance process of a project by acting as maintenance-engineering consultants to clients and as service providers to end customers [31]. Service (instead of merely products) becomes the core denominator when pursuing cooperative client-supplier project relationships [32]. Research agendas indicate that the construction sector has begun to embrace this mode of adding value through long-term service provision based on built assets.

Although the abovementioned studies do not directly refer to servitization in construction, the implications of long-term service provision are consistent with the servitization concept originating from the manufacturing industry [2]. Since construction firms are increasingly compelled to consider the whole-life performance of the buildings they create, academic research has started to explore the implications of servitization within the construction industry. Robinson and Chan [33] pointed out that, with the proliferation of private finance initiatives (PFIs) and PPPs, servitization has begun to matter in the construction sector because design and construction contractors are becoming increasingly involved in the operations and maintenance of built assets. By tracing a construction firm's journey toward servitization, Robinson et al. [10] showed how to enable an organization to create and capture value in new ways by mobilizing new resources across the supply chain, developing new products, and creating new service offerings. In addition, through a case study of another construction firm's pursuit of servitization, Robinson et al. [34] provided fresh insights into how and why emergent technological features, stimulated by new sensor technology, can enable actors within the organization's value chain to act in more servitized ways. These studies suggest that servitization is an effective way to create new value for construction firms and that technology development plays an important role in the transition toward servitization.

Following SDL, the created value is assessed in terms of its value-in-use, in which the service experience of end customers and other relevant stakeholders plays a significant role [35]. To examine the extent to which main contractors and supply chain members improve the service experience through service design, Smyth et al. [36] conducted semi-structured interviews with ten main contractors. They observed that both clients and users realize suboptimal value in their service experience. Fuentes [37] reported that regarding end users as passive actors, rather than as co-creators of value, may affect the project's experiential and financial value outcomes. These studies highlight the importance of end users' service experience during project execution and suggest a shift toward treating end users as co-creators of value.

As the focus shifts toward adding value through service provision in the operations phase of built assets, another line of research has emerged along with the trends of servitized manufacturing; that is, construction activities are conceptualized as construction services for adding value during project delivery [14]. This conceptualization aims to realize resource integration and on-demand allocation through construction service transactions on an Internet platform [16]. Moreover, the construction platform model provides new opportunities for the construction sector to solve the traditional issues confronting this industry, such as information isolation, inefficient collaboration, and inferior construction productivity [13]. Platforms related to construction have been developed in China in recent years, such as the construction e-commerce platform yunzhuwang[†] and the engineering service crowdsourcing platform huameitang[‡].

In summary, there are two lines of research examining the implications of servitization in the construction industry from different perspectives: the perspective of operations servitization and that of production servitization. Most studies are conducted via case studies and provide evidence of the practices of servitization; however, there is still a lack of clear conceptualization of what servitization in construction means and how it can be achieved. Moreover, the conceptualization of servitization should integrate these two perspectives into one.

2.3. The definition of servitization in construction

Given the motivation to transform the construction industry through servitization, SDL must be integrated into construction in order to promote information sharing and active collaboration among professional groups [38]. The transformation process must introduce differentiated service elements into construction to realize diversified competition and allow entity users to participate in the process of service provision, in order to better meet users' demands and help to improve services. In short, services may be effective in helping the construction industry cope with development problems by emphasizing servitization in construction processes, the integration of entity construction and service provision, and the participation of entities' users.

Furthermore, the practice and study of the combination of construction and service show that servitization in construction

[†] yzw.cn.

[‡] huameitang.com.

has two different meanings: providing services related to entity use and maintenance; and offering process-oriented professional services to facilitate building entity delivery. These two meanings correspond to the PSS based on product and service integration and the servitization of the production process, respectively. Research on the servitization of manufacturing indicates that the PSS and producer services are unified by the motivation to add value. The former adds value by meeting customers' personalized demands, whereas the latter does so by improving productivity and reducing waste. Based on the above analysis, we define servitization in construction as adding value by introducing service elements into the process of entity construction and entity use. According to the stage, the manifestation forms of servitization in construction can be divided into construction-oriented services and use-oriented services.

2.3.1. Construction-oriented services

Construction-oriented services are provided during the construction process instead of in the user-centric use stage, with the aim of helping construction enterprises to complete construction-related demands. These services are divided into construction-process services and construction-support services, depending on whether they directly relate to construction activities or not. Construction-process services are services provided by construction enterprises to complete construction activities, and construction-support services are services provided by service enterprises to facilitate the completion of construction activities, including resource-based services (e.g., equipment leasing and material supplying), knowledge-based services (e.g., information services and consulting services), and other support services (e.g., logistics and computing services).

2.3.2. Use-oriented services

Use-oriented services refer to integrated solutions of building entities and services provided by stakeholders to meet the need for physical space to live, work, or entertain. The services attached to the building entity aim to facilitate entity use and improve user experience; they include basic operation and maintenance services such as maintenance and repair, energy management, emergency management, change or relocation management, and security [39], as well as extended services for particular groups, such as healthcare services for older people. Moreover, depending on whether or not the users own the building entities, use-oriented services can be classified into two categories: user-dominant services and owner-dominant services. The term "user-dominant" means that the use-oriented services are directly delivered to the users who own the building entities, while "owner-dominant" indicates that use-oriented services are delivered to satisfy the users' needs, but the building entities belong to the owners instead of the users.

In general, servitization in construction aims to improve the competitiveness of construction enterprises and better meet owners' demands for building entity construction and customers' demands for entity usage. At the enterprise level, servitization in construction is an effective means to realize differentiation in the construction process, build entity-related services, improve construction efficiency, quickly respond to market demand, and promote competitiveness. At the industry level, servitization in construction is a new pathway to realize the deep integration of construction and services, and is instrumental in transforming the industry from a low value-adding sector to a high value-adding sector.

The basic definition of servitization in construction is insufficient for practitioners to determine how to realize servitization transformation at the industry and enterprise levels. By referring to studies on the servitization of manufacturing, scholars from the construction community are paying a great deal of attention to the changes and benefits brought about by servitization [4], the challenges confronting this industry [40], and transformation paths [41]. Considering that servitization in construction is still in its infancy, there are few cases available for analyzing its challenges. Our purpose is to clarify the implications and extension of this new concept and to provide path suggestions for practitioners to realize servitization in construction. Thus, the subsequent sections analyze and discuss the changes implied by servitization in construction, the possible transformation pathways, and the extended influence of servitization on industry ecosystems.

3. The implications of servitization in construction

Servitization in construction implies a change, the core of which is the transition from project implementation with building entities at the center to service provision with customer demands at the center. This shift essentially changes the traditional methods of adding value through construction. Construction enterprises' business model and their synergistic relationships among enterprises in the industry will change accordingly. As shown in Fig. 1, there are three aspects to the transformations brought about by servitization in construction: adding value, the business model, and the operational model.

3.1. Adding value

From different perspectives, value can be divided into the customers' perceived use value and the exchange value during selling [42]. Under the commodity-dominant logic, value is considered to be the exchange value, as value is delivered through commodity transactions. Under the SDL, value is determined by its use and is co-created by service providers and service beneficiaries in their interactions [43]. In the construction industry, all types of enterprises conduct businesses around building entities, making building entities the carriers of value creation, delivery, and capture. As seen from the entire life cycle of building entities (Fig. 2), adding value in the construction industry mainly occurs in two stages: the construction stage and the use stage. The construction stage includes value-adding activities for creating building entities, such as planning, design, and construction. The use stage incorporates value-adding activities that ensure the building entity's normal functions, such as asset management and renovation.

In regard to building entities, the value-adding activities in every stage of construction primarily involve implementing the functional conversion from input to output. For example, design completes the transformation from the owner's vision of the building entity to a design plan, and construction represents a completed transformation from materials to a building entity. From the perspective of conversion, the value-adding activities of construction are limited to particular stages, resulting in the separation of each stage of construction. This not only compresses

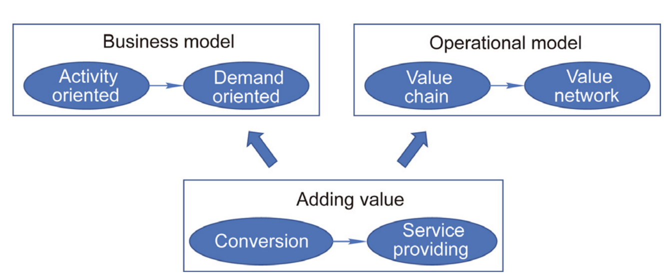

Fig. 1. Changes implied by servitization in construction.

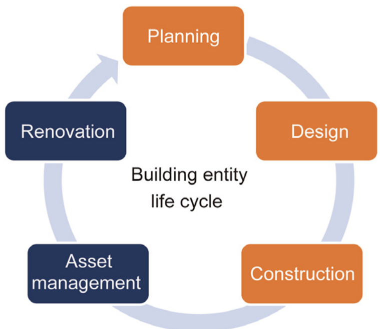

Fig. 2. Entire life cycle of a building entity[†].

the space for adding value, but also weakens the collaborative efficiency among stages.

In contrast, from the perspective of servitization, the adding value of all stages in construction focuses on the customers' demand, and value is co-created through supply-and-demand interactions between the construction participants and the customers (Fig. 3). In this context, "customers" include not only end users, but also owners, contractors, design units, and other stakeholders who have diverse needs in the construction process. The construction participants, also referred to as the suppliers, who encounter different "customers," must not only complete functional conversion activities in a construction stage of the building entities, but also provide support services related to the conversion activities in other stages before and after the construction stage. The "customers," also referred to as the demanders, must participate in the process of value creation instead of selecting products or services passively, in order to better meet customized demands.

Based on the above analysis, value-adding transformation from the perspective of servitization in construction can be summarized as follows:

Transformation 1. From the perspective of servitization in construction, the traditional method of adding value based on conversion activities has shifted to service provision centered on customers' needs at all levels, including both functional and support services that cover the entire life cycle of the building entity.

3.2. The business model

The business model represents an enterprise's strategic selection and core logic when creating and capturing value in a value network. Strategic selection determines what value enterprises provide for which customers, while value creation and capture determine the process of delivering value to customers and the way enterprises maintain operations. The core logic then clarifies the causality hypothesis behind value delivery and ensures the internal consistency of strategic selection. Therefore, in terms of composition, the business model is a value system that comprises strategic selection, value creation, value capture, and value networks. Since servitization changes construction enterprises' value-adding methods, it is bound to bring changes to value creation and capture, and thereby change the entire system of adding value.

Traditionally, consulting, design, construction, and similar enterprises participate in construction projects by signing a contract with the owners or contractors and being remunerated for completing construction tasks for the owners or contractors, such as management, design, or construction. As seen from the business model logic, construction enterprises create value for owners or contractors by completing conversion activities with their resources (i.e., human resources and equipment). At the same time, owners or contractors fulfill contractual obligations such as payments so that enterprises obtain value. In the traditional business model of construction enterprises, value is exchanged through activities.

Against the background of servitization, the value-adding method of construction enterprises involves providing services that are centered on fulfilling personalized demands. Because personalized demands typically cover several stages of the entire life cycle of building entities, construction enterprises must extend beyond their original scope of activities and achieve participation in the entire life cycle of building entities. Then, construction enterprises can create value for owners—not only in the stage of entity construction, but also in the stage of entity use. In short, the business model of construction enterprises becomes a means of value creation oriented to meeting demands (Fig. 4). In contrast, the business model of construction enterprises in the servitization model can be summarized as follows:

Transformation 2. Against the background of servitization in construction, construction enterprises' business model is transformed from activity-dominant value exchange to demand-dominant value exchange.

3.3. The operational model

In the manufacturing field, production operations are the process in which enterprises put every element through a series of transformations and finally produce tangible products and intangible services. Due to the complexity of building entities and the fine division of labor in construction, the construction of buildings must be jointly completed by several enterprises. Therefore, construction operation is the process of delivering building entities that are completed through the interactions among participants. The relationship between the participants—that is, considering whether the participants benefit the construction process and whether this process can be coordinated efficiently—is the key element influencing construction and operation efficiencies.

Traditional construction organizes projects to facilitate building entity delivery. According to different project purchase models, there may be different contractual relationships between project members. However, due to the unitary nature of building entities, the relationship between project members typically has temporality and ends with the completion of the project. As shown in the upper part of Fig. 5, project members include owners, design parties, construction parties, and suppliers. There are different temporal contractual relationships between adjacent members along the value chain, corresponding to different construction tasks, such as planning, design, entity delivery, and material supply. Furthermore, the separateness of each stage of construction (particularly the separation between design and construction) results in project stakeholders focusing only on their own function and benefits. The lack of mutual proactive cooperation among the project members seriously affects the efficiency and performance of construction operations. When launching a supply chain, lean construction, and other management ideas, project members do not change their focus and only collaborate passively in response to external incentives or management constraints. This model cannot maximize system efficiency.

In contrast, under the servitization logic, meeting customers' demands becomes the enterprise's focus, and the method of project organization centered on building entity delivery is unsuitable. Driven by customers' demands, the original project participants become service providers, and their scope of activities expands from a single stage to every stage during the building entity's entire life cycle. To better meet the diverse needs deriving from

[†] https://hydronic-flow-control.com/en/page/our-services–building-life-cycle.

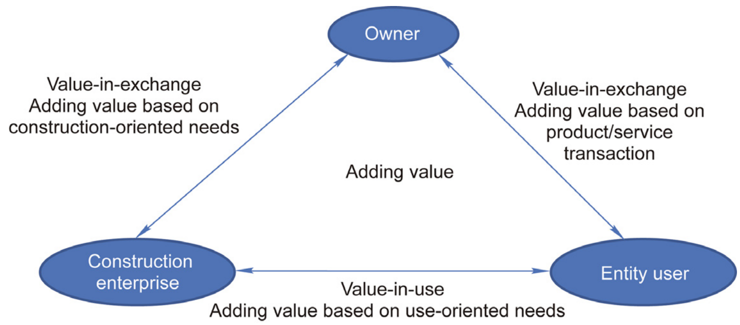

Fig. 3. Need-oriented value creation under servitization in construction.

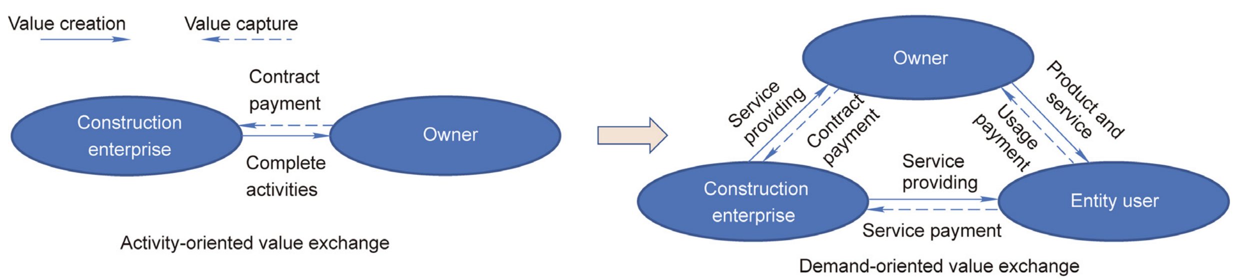

Fig. 4. Business model change under servitization in construction.

construction-oriented and use-oriented demands, the participants must actively cooperate with the stakeholders at every stage. As shown at the bottom of Fig. 5, every participant can be connected to every other participant through these two types of demands, rather than through the single-stage connection in the value chain. For example, in prefabricated construction, the main contractor acts as a system integrator between the design party and supplier in order to coordinate the design and production of prefabs. Although the unitary nature of the building entities still exists, because the life cycle of building entities is long, every participant must form a long-term cooperative relationship. This relationship is reflected not only in current service programs, but also in other new service programs.

By comparing the construction operation model before and after servitization transformation (Fig. 5), this operational model transformation can be summarized as follows:

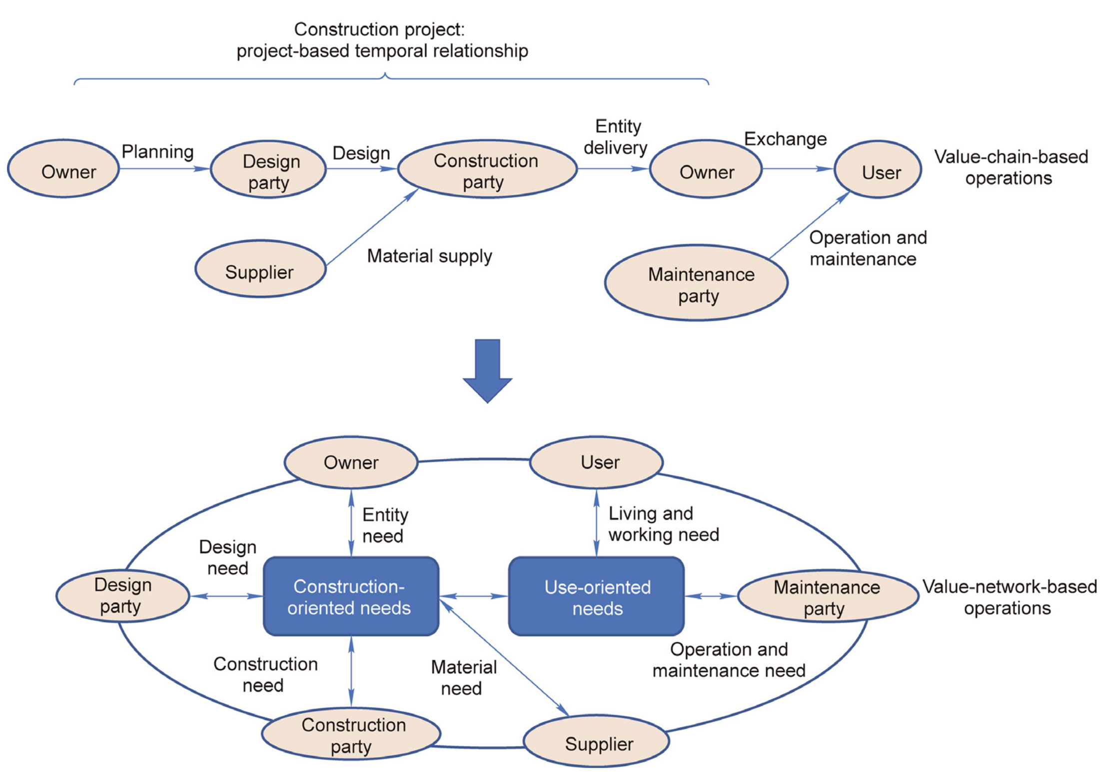

Fig. 5. Operational model transformation under servitization in construction.

Transformation 3. Servitization in construction transforms a value-chain-based operation model with fragmented construction stages and temporary organizational relationships into a value-network-based operation model with participation in the entire process and a long-term cooperative relationship.

4. The transformation pathway of servitization in construction

The introduction of servitization into construction will thus upgrade and rebuild the construction industry in many aspects, such as adding value, creating new business models, and establishing new operational models. The analysis in the previous section on the implications of servitization in the construction industry highlighted the core elements of the transformations in all aspects; however, the problem of how to achieve the three abovementioned transformations still exists, particularly in terms of the extensive industrial transformation that is occurring as a result of emerging digital technology. For example, intelligent manufacturing [44], wisdom medical systems [45], blockchain finance [46], and climate-smart agriculture [47] are all new forms of industry that emerged after digital technology was introduced into traditional industries. It is imperative to analyze the achieved method of servitization in construction in depth with respect to the digital revolution. This analysis should start with the digital revolution of construction to explore specific value-adding methods, business model innovation, and operational models of servitization.

At present, the development and popularization of digital technology greatly support the revolution of the traditional construction industry, spawning the concept of digital construction [48,49]. In addition, Industry 4.0, which originated in manufacturing, has been introduced into the construction industry, and scholars have coined the term Construction 4.0 [50]. Regardless of whether the term Industry 4.0 or Construction 4.0 is used, the core idea is to use digital technology to reinvent construction. This idea includes changing construction activities, stakeholders' collaborative styles, and building entity uses and aims to improve the efficiency and benefits of construction in order to meet increasingly diversified user demand.

In regard to the impacts of digitization on the servitization of manufacturing, digital transformation can drive manufacturing servitization by providing complex and novel services [51,52]. The main route involves the integration of different business dimensions, such as digital technology and after-sale [53], production [54], and the supply chain [55]. On the other hand, the adoption of technologies such as the Internet of Things (IoT) and artificial intelligence (AI) can enhance or completely change the nature of service delivery, and new service-oriented business models will emerge. Applications of different digital technologies, such as big data and cloud computing, also change the way to create value through servitization [56,57]. In other words, digitization innovates the business model by adding new services or improving existing services, and then changes the method of value creation with digital technology.

In construction, the digital revolution involves the adoption of digital ecosystems based on building information modeling (BIM) and the common data environment (CDE) to complete building entity delivery and related business. The adopted digital technologies mainly include video and laser scanning, AI, cloud computing, big data and data analysis, blockchain, augmented reality (AR) and virtual reality (VR), and the IoT [58,59]. Through the functions of these various technologies, the application of digital technologies can provide cognitive and control support for building entity construction and use from many aspects, including building entity modeling and simulation, data collection and conversion, information analysis and sharing, and changing the way activities are completed and the interactions between participants in the life cycle of building entities. As shown in Fig. 6, we develop the following implementation framework by referring to the impact of digital technology on manufacturing servitization and combining it with an implications analysis of servitization in construction.

4.1. Adding value based on value co-creation

As the core idea of the SDL, value co-creation proposes that customers are always co-creators of value, because products or services have value only when they are used or experienced by customers [60]. In other words, value co-creation is the process by which products or service providers indirectly interact with customers to create value; thus, it emphasizes the interaction between the provider and the customer [61]. In the digital age, the usage of digital technology is changing the interactions between providers and customers. More specifically, digital intelligence, connectivity, and analytical capabilities is merging the providers' and customers' value-creation activities into a process, thereby facilitating the interaction between the two parties in terms of resources, processes, and outcomes. Enterprises co-create value by increasing the breadth and depth of interactions in such joint processes [62].

Under the influence of value co-creation, the value creation of servitization in construction should be done through a process of

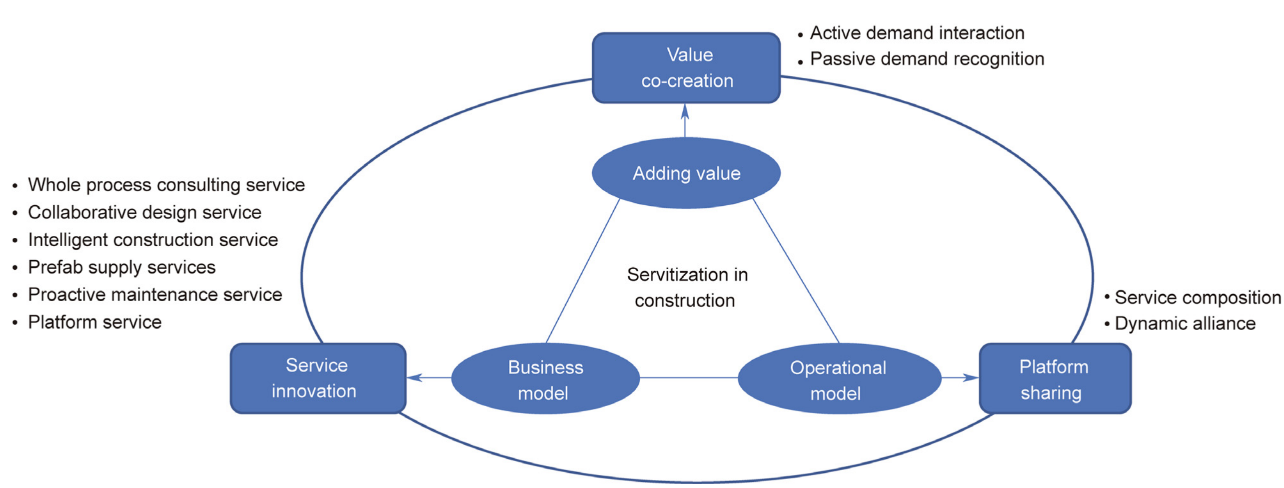

Fig. 6. The transformation pathway of servitization in construction.

interaction between building entity users and owners. Digital technology provides the possibility for in-depth interaction. With BIM technology, building entity design has changed from a traditional two-dimensional drawing design to a three-dimensional model design, and building entities can be modeled as visualized digital objects [63]. With AR/VR technology, building entities can be shown to users in a "visible and felt" manner. It is helpful for users to offer suggestions for product design according to their own needs [64]. For example, design groups and stakeholders have conducted visible communication of medical facility design in a VR environment [65]. In short, BIM and AR/VR involve entity users in design and construction [66], allowing them to provide their own requirements to ensure that the final building entities fit their specifications. This greatly improves the value of building entities.

In addition to users' active interaction, the IoT, big data, AI, and other technologies can help building entity operators to collect their users' potential demands from the process of entity usage, and then perfect the design to attract potential users and meet their demands [67]. Capturing the behavioral data of users by means of deployed smart sensors and smart equipment in building entities and identifying user satisfaction with the different functions of the building entities through AI and big data can provide a reference for updating building entities. For example, the occupancy information of high-rise buildings can be extracted through a simple and low-cost IoT sensor; then, information about how human activities affect the energy usage of the building can be analyzed. Finally, the analysis results can be useful for the design of energy-conservation measures to reduce the energy consumption of buildings [68–70]. Moreover, intelligent equipment is usually supplied with interactive capabilities that enable the equipment to respond to user requests in real time. In this way, operators can proactively collect information on user dissatisfaction, which can serve as the basis for subsequent improvements to building entities [71].

Overall, value co-creation between the owners and users of building entities is the process by which users give feedback on entity construction and operation through active and passive methods. This process can help owners and operators better meet user demands and thereby create greater value.

4.2. Business model changes based on service innovation

Related studies of servitization in construction show that digital technology will bring about new forms of company cooperation, new products and services, new customer relationships, and new employee relationships, which will then affect companies' business activities and processes, change value-creation and delivery methods, and form a new business model [72].

In regard to the integrated solutions provided by servitization, digitization can be divided into the different degrees of remote monitoring, control, optimization, and autonomy. Thus, digitization results in five different business models—namely, product-oriented service providers, industrialists, customized integrated-solution providers, result providers, and platform providers—which are produced by combining the degree of customization in an integrated solution (standardization, modularity, and customization) and the pricing logic (product-oriented, contract-oriented, usability-oriented, and output-oriented) [73].

In contrast, the influence of digitization on servitization in construction is mainly reflected in the content and mode of service provision. More specifically, consulting, design, construction, and supervision are the main services provided by participants in the construction process of building entities. Digital technologies will revolutionize the content or provision methods of these services and result in the innovation of service offerings, such as whole-process consulting services, collaborative design services, intelligent construction services, prefeb supply services, predictive maintenance services, and platform services.

4.2.1. Whole-process consulting services

In contrast to traditional consulting services, which provide a single service for decision planning, design, construction, and other stages, the support of digital technology allows consulting firms to provide consultation services covering the entire life cycle of building entities. On the one hand, BIM and CDE technology can effectively dissolve information barriers at all stages of construction, promote the communication and transmission of information across the entire life cycle of building entities, and provide data and information support for consulting services during the full life cycle. For example, due to the complexity, variability, and uncertainty of large-scale hydropower projects, exploiting collaboration platforms based on BIM technology is beneficial for project participants and stakeholders, as it allows them share risks, information, and resources, as well as participate in project management [74]. On the other hand, the efficient storage of information provides conditions for knowledge mining based on big data and AI, helps consulting enterprises accumulate experience and form knowledge based on past services [75,76], and then offers multifold whole-cycle engineering consulting services. For example, natural language-processing methods can be used to extract concepts and relationships from contract documents [77], or text data-mining technology can be used to find and classify useful knowledge from post-project evaluation [78].

4.2.2. Collaborative design services

With the wide usage of BIM technology, design based on models has gradually become the main design method. The standardization and modularization characteristics of the model enable the design to be decomposed into several design tasks, which are then completed by different professional designers. With the support of cloud computing and VR technology, professional designers in different geographical locations can manipulate the same design model simultaneously (e.g., view or edit it) to avoid design errors caused by different versions of the design model [79–82]. The decomposability of design tasks also offers the possibility of using crowdsourcing; that is, by releasing professional design tasks through an Internet platform, professional designers with qualifications, reputation, and willingness can complete design tasks through competition or team cooperation, making it possible to effectively utilize the wisdom of the crowd to obtain satisfactory design solutions [83,84]. The cooperativeness of design services is also reflected in the use of online platforms based on BIM technology to enable end users, professionals, and policy-makers to comment on architectural designs and extract information to generate more effective designs [85]. Ideally, professional designers can participate in subsequent design-related tasks to provide knowledge of the building structure, such as interior design and renovations.

4.2.3. Intelligent construction services

Recently, a range of Internet-enabled physical equipment, such as robots, sensors, and actuators, has been used to provide automatic and safe smart applications. This type of equipment is the basis for providing smart construction services. During the construction process of building entities, traditional construction methods based on material conversion can be subverted by the use of additive manufacturing to automatically print physical components and products [86–88]. Robots can replace manual work, improve construction efficiency, and avoid construction accidents [89–91]. Construction equipment with sensors can effectively resolve the uncertainties brought about by dynamic changes in the environment, thereby facilitating environment-aware component assembly and construction [45,46,92]. These intelligent applications all require real-time monitoring and control, and edge computing technology provides the possibility of meeting such real-time requirements [93].

4.2.4. Prefab supply services

Prefabricated construction refers to the practice of producing building components in a factory, transporting the entire or mid-process building components to construction sites, and assembling these components to create a building entity [94]. Although this concept is not new, prefabricated construction is attracting a fresh wave of interest and investment due to its significant benefits, which include faster and safer manufacturing, better quality control, and lower environmental impacts [95]. In general, prefabricated construction involves four stages: design, production, transportation, and installation. The wide adoption of prefabricated construction methods will create demand for the design, production, and transportation of components. In most cases, design and production services are provided together by the manufacturers. General contractors are responsible for onsite assembly, while acting as system integrators to manage the integrated supply chain covering these four stages.

4.2.5. Predictive maintenance services

Empowered by digital technology, facility managers can predict the state of a building entity's functional components and the user's comfort using acquired data during the use of the building entity, and then provide corresponding maintenance services or comfort-improvement services. Based on predictions of functional components' situation in the future, facility managers can conduct maintenance before breakdowns occur. For example, the state of heating, ventilation, and air conditioning (HVAC) systems can be monitored in real time through the IoT. Relying on the acquired state information, machine learning algorithms are used to predict the future state of HVAC systems; then, appropriate maintenance plans are formulated [96]. Furthermore, the building environment has an important effect on user comfort. Facility managers can evaluate and predict users' comfort level using built environment data and user behavior data, and then adopt control strategies to change the built environment. For example, wearable sensors or infrared thermal imaging can be used to identify users' thermal comfort adjustment behavior, making it possible to build personal comfort models and predict users' thermal comfort. On this basis, facility managers can then develop HVAC system control strategies to adjust the building environment [97–100].

4.2.6. Platform services

Given the demand for information sharing in all stages of building entities' life cycle, enterprises can provide information integration and sharing services based on Internet platforms for project participants. For example, to achieve lean prefabricated construction, cloud computing and IoT technology can be used to build a service platform, provide all types of information for prefabrication, transportation, and assembly, and finally enable all participating enterprises to easily share information without technical know-how or a technical team [101]. Furthermore, to realize an effective connection between service demand and supply, platform enterprises can provide transaction services based on Internet platforms to improve the allocation efficiency of service resources. For example, based on the cloud computing paradigm, the single European electronic market has integrated the service-oriented architecture (SOA) framework and the BIM model to build an e-commerce platform for the construction industry and to trade HVAC services and collision-detection services [102,103].

4.3. Networked operations based on platform sharing

Value-network-based operational models are typical networked operations. In networked manufacturing, the feature of networked operations is overcoming the limitation of geographical dispersion by using Internet technology to support collaboration among participating enterprises over a building entity's entire life cycle and to provide products and services that the market demands at faster speeds, better quality, and lower cost [104]. The purpose of servitization in construction is to provide integrated solutions to meet personalized demand. Given varying demands, integrated solutions composed of different construction services are needed, and alliances among the service providers involved in these integrated solutions will therefore continually change. In this case, the key to the networked operations that are required by servitization in construction is to enable collaboration among the participants of dynamic alliances in order for solutions to be delivered efficiently and efficiently. This task involves two aspects: alliance member selection and collaborative relationship management. By successfully addressing the challenges of building entities' immobility and the geographical dispersion of construction service providers, a platform model based on digital technology will help to achieve this type of networked operation.

With digitalization having arrived in the construction sector, the use of digital twin models in construction will gradually gain popularity [105]. The core of digital twins lies in establishing mirror computer models of products, processes, or services by utilizing real-time data collected from sensors to conduct simulation decisions and optimization [106]. With the support of these digital twins, all types of construction services can be modeled as computable forms that are stored on the Internet platform and can be acquired through service transactions. Based on this setup, stakeholders can obtain customized solutions by combining different construction services through a platform search and transactions to achieve their personalized task goals. The final service composition solution determines which service providers participate in goal achievement and their collaborative relationship; however, whether participants can achieve ideal synergy is still decided by management.

Subject to the contractual transaction relationship, information that emerges in the service delivery process among the alliance members must be stored on the platform and shared among the members. This requirement dissolves the information barriers in traditional project management and lays a solid information foundation for collaboration between members. For example, inspection information on building quality can be uploaded to the collaboration platform based on BIM and indoor positioning technology to improve the collaboration efficiency among participants involved in quality management [107]. Collaborative safety-monitoring platforms are used to collect, analyze, and disseminate safety information among different stakeholders, which helps reduce the negative impact of safety information asymmetry and inefficient communication on the effectiveness of safety supervision [108]. Moreover, such platforms can improve the collaboration between participants by implementing contracts that require benefit sharing and risk sharing, such as by designing cost-sharing contracts to encourage alliance members to share knowledge [109]. An incentive-sharing contract can be used to promote equipment sharing among contractors in order to ensure project construction efficiency [110]. Moreover, the platform can make joint service recommendations that allocate more bundled demands to service providers with a high level of collaboration performance in order to cultivate active collaboration among service providers.

5. Derivative industrial formation under servitization in construction

For value creation, the construction industry requires not only design units, contractors, subcontractors, operators, and other construction enterprises that complete value-adding activities, but also material suppliers, financial enterprises, labor companies, technology research, and development enterprises to support value-adding activities by providing finance, human resources, technology, materials, equipment, and other resources. To simplify this description, we refer to two types of enterprises: value-adding core enterprises (referred to herein as core enterprises) and value-adding supporting enterprises (or supporting enterprises). These two types of enterprises and the value exchange between them constitute the value-creation system of the construction industry. Along with the external macro environment (e.g., politics, economy, society, technology, environment, and law), they form the ecology of the construction industry.

As noted earlier, servitization transformation in construction takes personalized demand as its starting point to seek opportunities for adding value. To meet personalized demand, core enterprises must change their business models and adopt new operational ways to implement them. The supporters of core enterprises must also make changes to adapt to the servitization requirements of the core enterprises and to develop new businesses related to servitization in construction (Fig. 7). More specifically, the demands of construction enterprises, such as financing demands, real-estate finances, and financial insurance, will launch new financial services for engineering projects, referred to herein as "engineering financial services". Innovation in construction services will require a large and highly skilled labor force, and the skill improvement of idle labor and standardized management will promote human resources. In the digital age, servitization is bound to produce a great deal of data, and the demand for data management and the analytical ability required by construction enterprises are likely to form a big data market. Specialized intelligent equipment providers will emerge to meet the growing demand for intelligent sensing equipment in smart buildings, homes for the elderly, and other intelligent building entities. Several aspects of these challenges and requirements are expounded in detail below.

5.1. Engineering financial services

As part of the external environment of the construction industry, financial services aim to generate capital for construction. With the servitization transformation of construction, the industry's demand for financial services will be transformed from simple capital demand to a more sophisticated demand for comprehensive services. Financial services should be deeply embedded in the construction system to fulfill financial demands during all—or at least the critical—stages of the construction process. Moreover, construction involves many types of enterprises, including material suppliers, contractors, and facility operators, each of which will develop a different model of engineering financial services. Based on current practice in the industry, the engineering financial market includes equipment financing services, real-estate financial services, aged housing financial services, and other models. The details are as follows.

5.1.1. Equipment financing services

Caterpillar Inc., a construction machinery manufacturer, provides short-term and long-term rental services through rental systems containing more than 1500 online stores worldwide, and expects to establish an entire industrial ecological chain that covers products, technologies, and services. Statistics show that rental business development does not reduce product sales but rather increases sales and profits. In addition, during the economic crisis, Caterpillar proactively provided equipment financing services for small and medium-sized enterprises with tight cash flow to help them improve performance and income. In this way, its customers experience the value of Caterpillar's services, which enhances customer loyalty and is helpful in establishing long-term relationships with customers.

5.1.2. Real-estate financial services

At present, some enterprises are cooperating with third-party platforms to launch Internet and real-estate financial products,

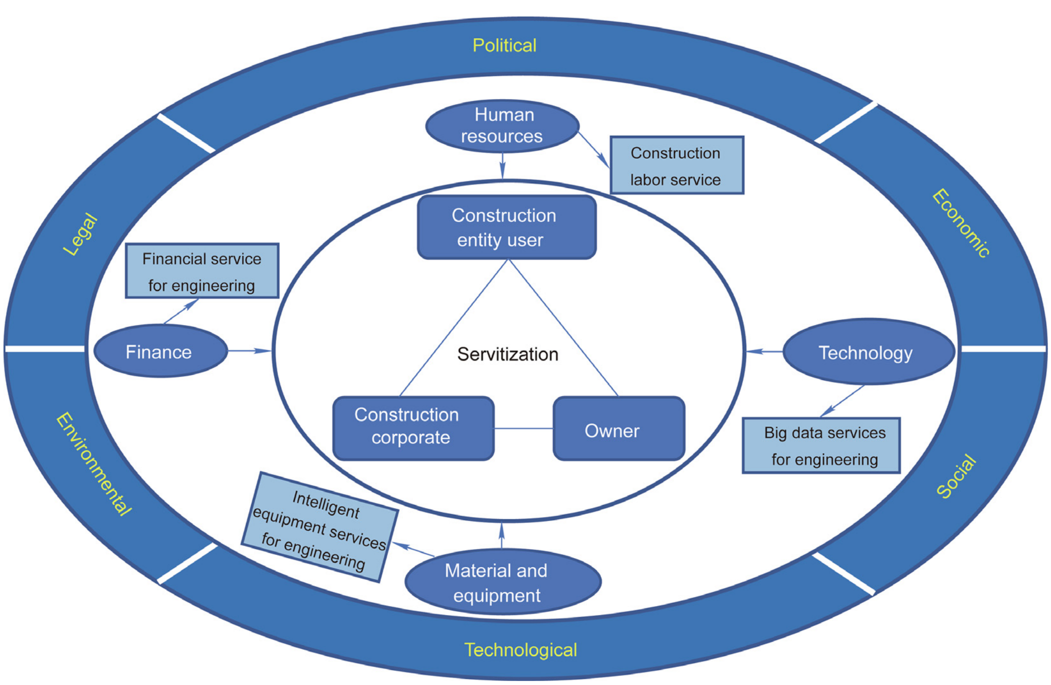

Fig. 7. New industries under servitization in construction.

which serve individual investors and provide funding solutions for small and medium-sized real-estate enterprises. On this basis, the financing enterprises can further establish real-estate financial platforms on the Internet and bring socially idle funds, institutional funds, and real-estate projects into effective contact by designing different products. It is notable that, when most enterprises provide engineering financial services that depend on third-party platforms, problems such as insufficient operational capacity and high asset cost easily occur. Therefore, if conditions permit, enterprises can build their own platforms and offer related financial services.

5.1.3. Aged housing financial services

Some real-estate enterprises are integrating full-cycle and high-guarantee health insurance systems into the health housing industry to provide exclusive insurance and pension financial planning for all-age customers. For older populations, this service model solves the demand for investment finance and insurance services. With these services, enterprises can expand their service businesses and propose financial insurance products that best meet the demographic demand by analyzing, sifting through, and blending feedback data from selling pension products. Furthermore, they can combine health insurance data with health services and explore sustainable development modes in which pension commercial insurance and pension services closely cooperate and support each other.

5.2. Construction labor services

At present, there are 54.37 million construction workers in China, most of whom are migrant workers with a weak position in labor relations. In disputes, their rights and interests are difficult to guarantee due to a lack of effective records such as work information. In such cases, it is expected that the demand for protecting construction workers' rights and interests will increase. Comprehensive management of workers' information is a promising way to address this problem.

In November 2018, the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD) began using a national service information platform for construction worker management. This platform has played a positive role in the management of dishonest enterprise behavior in regard to defaulting on workers' wages. However, building workers have strong mobility in China, and their identities as farmers and as workers are constantly shifting back and forth; therefore, many challenges are encountered in ensuring the consistency and refinement of building workers' information systems. Since the construction platform can collect all types of information about construction workers, including building product information, work status information, and work evaluation information, some scholars have developed a blockchain for recording building workers' information, which is jointly established by construction workers and enterprises. In addition, workers' construction quality records and wage distribution can be automatically obtained through smart contracts, forming a trackable management model with clear responsibilities and sanctions.

5.3. Big data services for engineering

The extensive application of various digital technologies in the servitization transformation of construction will generate a large amount of engineering data, including data not only from construction and engineering entities, but also from enterprise operations and management activities. Data analysis provides value-adding services to the stakeholders of building entities, and big data from engineering projects provides a basis for applying big data analysis methods. This fact will be manifested in big-data-driven engineering decisions, including industry governance, enterprise management, and construction management. Although engineering big data has many benefits, small and medium-sized enterprises cannot realize the entire process of big data application on their own. Doing so is also a challenge for large enterprises. Because engineering big data applications involve data collection, data storage, data analysis, and other processes, data collection must deploy sensor networks of intelligent sensing equipment, data storage requires the purchase of a dedicated storage server, and data analysis requires professional and technical talent. For small and medium-sized enterprises, investing in engineering big data applications will occupy the capital for the enterprises' core businesses. Purchasing big data solutions provided by third-party enterprises will allow small and medium-sized enterprises to focus on their core competitiveness instead. It is expected that the demand for big data applications will give rise to professional engineering big data services that aim to provide engineering-application-related services or integrated solutions for construction enterprises.

From the application process of big data, professional enterprises can provide engineering IoT services and engineering big data analysis services for engineering big data collection and storage. Engineering IoT services aim to help construction enterprises build sensor networks for data collection, including the installation of sensor equipment, the deployment of data transmission networks, and data storage management. For example, IoT networks have been deployed in the cement industry to support mobile batching plants [111]; they have also been deployed in the concrete industry [112]. Xu et al. [101] put forward the view that IoT platforms based on cloud computing make it possible for small and medium-sized enterprises to use IoT technology economically and flexibly. The analysis services of engineering big data provide technology and professional knowledge that allow construction enterprises to achieve various management goals, such as resource and waste optimization, facility management, and energy management and analysis [113]. In addition, professional enterprises can offer solutions for integrating engineering big data to achieve specific management goals. In this way, they can be responsible not only for data collection, but also for data analysis and support management decisions. A typical example is an onsite management scheme based on video monitoring [114], which, through closed-circuit television installed at various locations on the construction site, offers a visual analysis of video surveillance to evaluate onsite safety and give early warning of potential dangers.

5.4. Intelligent equipment services for engineering

In recent years, building entity users have paid increasing attention to the intelligent functions of building entities, which are in demand for smart buildings. A synthetic analysis of the various definitions of smart buildings indicates that a smart building is an integrated building system that can obtain and utilize information and knowledge about the environment and users by means of intelligent equipment. This improves the adaptability of interactions between the building and its users to meet many requirements, such as energy efficiency, long building life, and occupant comfort and satisfaction [115]. It is notable that intelligent equipment, comprised of information awareness and collection tools, is the basis of constructing smart building systems, and its demand is bound to increase greatly with the increasing interest in smart buildings. This growing interest is reflected not only in the number of smart buildings, but also in the requirements for new intelligent equipment and technologies.

Existing research indicates that the focus of academia and industry for smart buildings is on energy efficiency and health protection. In particular, health protection focuses on health monitoring and timely response in elderly living environments. These aspects can support the development of different types of engineering intelligent equipment services—mainly residential and building environment-related intelligent equipment services [71,116]. In this context, residential intelligent equipment includes sensors for air temperature, carbon dioxide (CO_2), humidity, thermal fluid, and particulate matter. With constant changes in people's requirements for living or working environments, the information to be acquired is also continually changing, and new sensing devices must be developed accordingly. Moreover, the emergence of new sensor equipment will stimulate demand. These needs complement each other and mutually promote development.

6. Conclusions

Servitization provides opportunities for transforming the construction industry, and scholars and practitioners are actively exploring the possibility of servitization in construction. Nevertheless, there is still a lack of in-depth and systematic knowledge of servitization in this industry. This paper comprehensively analyzes the motivation, meaning, implications, and realization pathways of servitization in construction, as well as its impacts on other industries. It also systematically establishes a cognitive framework of servitization in construction with reference to problems confronting the construction industry.

The following aspects can be concluded from the comprehensive analysis. First, the value-adding method and business model changes due to servitization in construction are starting points for construction enterprises to pave the way for servitization transformation, and changing the operational model lays the foundation for transforming the method of construction management. Second, many aspects, such as value co-creation, service innovation, and networked operations can be path references for construction enterprises to realize servitization transformation. Third, servitization in construction generates new forms of industry that provide novel ideas for the development of construction-supporting enterprises. These new forms of industry will also improve the quality of construction. This mutually supportive dynamic is conducive to achieving a "win–win" cooperation ecosystem in the construction industry.

This paper aimed to provide theoretical support for practitioners in the construction industry to realize servitization transformation by building a systematic understanding of servitization in construction. This paper is a starting point for researching servitization in construction; however, many theoretical and practical problems remain and require scholarly attention. In theory, servitization in construction will spur a revolution in construction management to address unclear management problems. Scholars must consider the problems hindering servitization in construction and explore corresponding solutions. In practice, servitization transformation involves changing the organizational structure. Therefore, the foremost question facing enterprises is: what organizational structure should be adopted by traditional construction enterprises to promote the servitization transformation? In addition, current policies and regulations remain mismatched with new business or operational models under servitization in construction. For example, conducting a construction service transaction through a platform has not yet been legalized. Therefore, the question of how to overcome this limitation to promote servitization in construction is important. In addition to the abovementioned problems, scholars must explore other possible problems in this field. We hope that this paper will attract the attention of scholars in the field of construction management to servitization in construction and will inspire new ideas and research efforts to realize servitization in the construction sector.

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Compliance with ethics guidelines

Dian Liu, Hongwei Wang, Botao Zhong, and Lieyun Ding declare that they have no conflict of interest or financial conflicts to disclose.

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