Original Research Article

Digital transformation of supply chain of China international engineering enterprises

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Abstract: All along, the competitiveness of Chinese international engineering enterprises has been in the leading position in the international engineering market. However, in recent years, the trend of economic globalization reversal, the re-emergence of protectionist ideology, the international economic and trade rules shuffle and re-establishment, especially the new crown epidemic and regional political tensions, resulting in the global supply chain re-adjustment of the layout, the development of the international engineering industry is experiencing unprecedented impact and challenges. At the same time, the continuous development of digital technology has brought new opportunities and space, the international engineering supply chain is gradually shifting to a digital model, and China's international engineering enterprises are facing competition from many sides. According to the list of the world's 250 largest international contractors in 2024, the study of the relevant business scale and structure of Chinese international engineering enterprises finds that there is a structural imbalance, and the competitiveness needs to be enhanced through digital supply chain empowerment. Through literature research, we found that there are three major problems in the existing supply chain management of enterprises, and then screened out the representative enterprise CHINA COMMUNICATIONS CONSTRUCTION, which is on the top ten list in many business fields, to conduct empirical research on digital supply chain, so as to provide reference and reference for the digital transformation of the supply chain of China's international engineering enterprises supply chain enterprises.

Keywords: International engineering enterprises; Supply chain; Digital transformation
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Land, labor, capital and technology are the four traditional factors of production, and data resources have become the fifth factor of production in the new era.[1] In order to seize the opportunity of the development of digital economy, the state has issued a series of policies. 2015, General Secretary first officially put forward the initiative to jointly promote the construction of "digital China", and the new journey of digital China construction began. The report of the 19th National Congress of the Communist Party of China (CPC) in 2017 explicitly proposed to build a digital China.[2] In 2021, the Outline of the Fourteenth Five-Year Plan put forward "accelerating the development of digitization and building a digital China", emphasizing that accelerating the development of the digital economy is of great significance to seizing the opportunities of the digital era and building a digital China. 2022, the "Fourteenth Five-Year Plan" put forward "accelerating the development of digitization and building a digital China". "The 14th Five-Year Plan for the Development of the Digital Economy" was issued by the State Council, which regarded the digital economy as a new generation of economic formations after the agricultural and industrial economies, and pointed out that the current digital technologies, including 5G, cloud computing, big data, artificial intelligence, etc., will be more broadly and deeply integrated with the real economy, resulting in more new modes of production, new industrial forms, new business models, and new ways of production, new industrial forms, new business models and new economic growth points continue to emerge,

promoting positive steps in the transformation of the industrial economy into a digital economy.

At the same time, in recent years, the epidemic of new coronary pneumonia and regional political tensions have brought about a crisis in the global supply chain, and the world's economic development was once faced with stagnation and retrogression, and so far there are still a variety of unstable and uncertain factors, which continue to increase.[3] The penetration and proliferation of digital technology into various industrial fields naturally brings new opportunities for the transformation and upgrading of enterprise supply chain. Engineering project supply chain management is an important link in the process of project implementation, which is directly related to the quality, cost and schedule of the project and other aspects. In engineering project supply chain management, to ensure the overall systematic, organizational coordination, modular integration and network synchronization of all aspects of project construction and operation, make full use of the huge information network to find external favorable conditions for complementary advantages, and build all the participating subjects into a supply chain network organization to achieve the overall advantage of the cooperation brought about by the goal.[4] To realize this goal, it is far from enough to rely only on the traditional supply chain. Xue Yingcheng pointed out that the promotion of digital supply chain to enhance the competitiveness of the international market includes: reducing the supply chain cost, improving the processing ability of risk management and control, and promoting the green development and innovation of the supply chain.[5] Therefore, the development of digital technology promotes the digital transformation of enterprises, thus empowering the supply chain and transforming the traditional supply chain into a digital supply chain, which is of great significance for further expanding the competitive advantages of China's international engineering enterprises in the international market.

1. Business scale and structure of China's international engineering enterprises

The Engineering News Record (hereinafter referred to as ENR) has published "World's 250 Largest International Contractors" list for many consecutive years, counting the turnover of international projects completed by each country in the previous year. A total of 81 Chinese mainland enterprises have been shortlisted in the "World's 250 Largest International Contractors" in 2023, which is the same number as last year, and continues to maintain the first ranking in the list. According to the total international turnover of the listed enterprises in each country, the total international turnover of the listed enterprises in China in 2024 amounted to US$122.97 billion, an increase of 4.3% year-on-year, accounting for 24.6% of the total international turnover of the world's 250 largest international contractors, a decrease of 2.9 percentage points compared with that of the previous year. The overall business scale maintained stable development.[6]

The ENR list divides the international engineering industry into nine business sectors, namely housing construction, manufacturing and processing, power engineering, water conservancy engineering, water supply and drainage and sewage treatment, petrochemicals, transportation and construction, industrial construction, and communications engineering. 2024's list shows that Chinese companies have been ranked in the top 10 in all specialized business sectors except communications engineering.[6] In terms of the proportion of business fields of Chinese international engineering contractors (as shown in Figure 1), among the total business turnover of Chinese international engineering enterprises in the past year, housing construction accounted for 28.51%, transportation construction accounted for 21.88%, petrochemical construction accounted for 19.52%, and electric power engineering accounted for 14.4%, accounting for 84.31% in total, which is the most dominant business field of China's outbound contracting. At the same time, these fields are also China's traditional areas

of strength, as Chinese international engineering enterprises are heavily involved in infrastructure construction in developing countries in Asia, Africa and Latin America. However, these fields have low entry barriers, high costs and low profits, and belong to the low-end and middle-end markets in the international engineering market, facing competitive challenges from India, Turkey and other countries.[7] That is, China's international engineering enterprises have not yet entered the high-end market such as communication engineering field, industrial construction, water supply and drainage and sewage treatment, etc., there are problems that the proportion of low-end market share is too high and the business structure is unbalanced, and there is an urgent need to empower the supply chain management through digital technology means, reduce the cost of management, and focus on vigorously developing the business of the high-end market on the basis of ensuring the existing advantages.

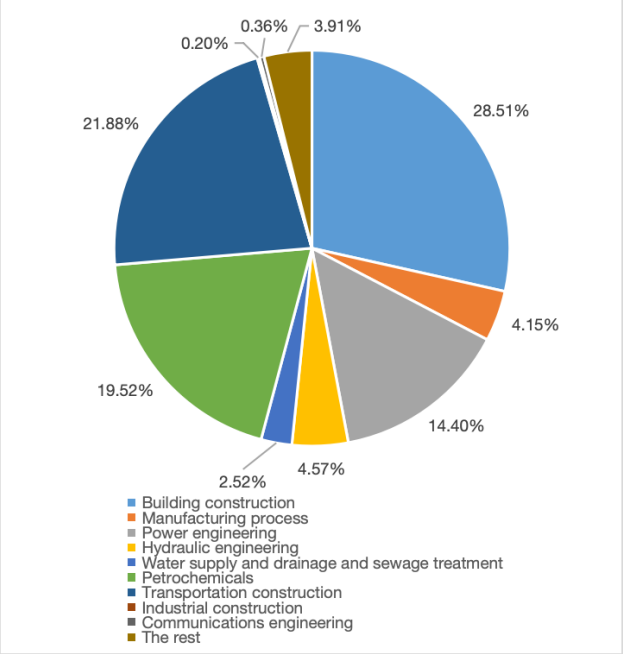

Figure 1. Proportion of China's international engineering contractors' total turnover by professional field in 2023.

2. Difference between traditional supply chain and digital supply chain

Zhang Wei pointed out that the trend of the global supply chain to be digitally driven will drive the international "new infrastructure" market to continue to grow and expand. The current use of digital technology has improved the level of intelligence, resulting in a qualitative improvement in production efficiency and supply and demand response speed. It also reduces the reliance on traditional manual labor, which will have a profound impact on the global supply chain.[10] The difference between digital supply chains compared to traditional supply chains is reflected in a number of dimensions as shown in Table 1.

Table 1. Differences between traditional and digital supply chains.

	traditional supply chains	Digital Supply Chain
Organizational structure	Flat, linear, product-focused organizational structure	A new supply chain network ecosystem that builds a business core based on customer needs and connects internally and externally
Collaborative models	In the case of multiple operations, each operation is primarily sequential, with one completed before the next.	Digitalized supply chain information systems and network platforms enable simultaneous design, production and delivery operations, significantly enhancing the ability of supply chain parties to collaborate.

Table 1. (*Continued*)

	traditional supply chains	Digital Supply Chain
Management tools	Adoption of traditional software such as MES, ERP, PLM/PDM, SCM, WMS, etc. and lack of connectivity	Business development is mainly based on digital platforms, cloud-based SaaS services, mobile applications and Internet platforms
technical application	Dependent on information systems integration and software applications and development	Digital supply chain-related systems, platforms and tools mainly adopt lightweight microservice architecture and low-code development, and widely apply new technologies such as cloud computing, Internet of Things, big data, artificial intelligence, blockchain, 3D printing and so on in business execution
Decision-making mechanisms	Reliance on managers' experience in the field	Combined with the experience of managers, intelligent analysis of large amounts of data to maximize the realization of efficient and accurate decision-making
implementation capacity	Reliance on manual labor, aided by machines and systems	More digitized and intelligent machines and systems, faster and more efficient execution, less reliance on manual labor

3. Problems faced by supply chain management of Chinese international engineering enterprises

3.1. Inadequate supply chain digital infrastructure capacity

Supply chain management systems and related software are mainly of the following types: enterprise resource planning (ERP) software for integrating the business, processes and data of various departments of an enterprise; supply chain management software (SCM) to help an enterprise plan, coordinate and manage the whole process of activities in the entire supply chain, from inventory to purchasing to logistics; and customer relationship software (CRM) for managing customer information, sales processes, marketing and other activities; product lifecycle management software (PLM) for the management of product lifecycle, including design, production, distribution, service and end-of-life of all aspects of information; product data management software (PDM) for the management of various types of data and documents in the process of product design and manufacturing; for the monitoring and management of real-time production data, equipment status and other information in the manufacturing process, manufacturing execution system (MES) and so on. At present, China's application of supply chain management systems and related software has a low penetration rate, and the infrastructure capacity required for the digitization of the international engineering supply chain is insufficient for higher requirements.[3]

3.2. Information silos exist in supply chain management

An important feature of engineering and construction products is location uniqueness, and the locations of the engineering and construction projects undertaken by enterprises are not fixed, especially in the case of international engineering projects, which are not only at irregular locations, but are even far apart, often transnational and transcontinental. Therefore, although the core suppliers and service providers of international engineering enterprises generally do not change frequently, the overall network of their supply chain must have a high degree of flexibility and adaptability in order to make timely adjustments according to the real-time demand of customers, possible changes in construction locations and other uncertainties. Adjustments include the amount and destination of input resources, while also reserving resources for possible new projects.[8] In addition,

the occurrence of various disruptive events can exacerbate the complexity of the uncertainty environment and severely impact the performance of the engineering supply chain. These disruptive events include production interruptions or facility disruptions due to public health emergencies, earthquakes, fires, floods, etc., disruptions to transportation routes caused by extreme weather, etc.[9] For international engineering construction projects, possible disruptions also include war, international economic and trade friction, cultural differences, and so on. In the face of many possible disruptions, engineering construction projects must improve the stability of the supply chain network in the face of the risk of disruption, by maintaining the structure and function of the supply chain to ensure the normal operation of the supply of materials. For example, it can strengthen the cooperation between nodes through resource information sharing, improve the flexibility of the supply chain by equipping backup suppliers and transportation systems, and increase the redundancy of the supply chain by holding buffer stocks and safety stocks to mitigate disruptions. Compared with domestic projects, international projects have large investment amount, long construction period, and also involve import and export of machinery and equipment, construction materials, international logistics, personnel expatriation and other factors, which makes supply chain management extremely difficult. Therefore, the supply chain should have strong linkage with each other, so as to turn the "chain" into "network", realize dynamic optimization configuration, and improve the speed and quality of response to demand.

However, at present, China's international engineering enterprises have not yet fully realized the business integration and centralized control of resources within the supply chain, and there is the phenomenon of information silo in supply chain management. The so-called information silo phenomenon refers to the computer application system function is not related to mutual assistance, information is not shared and interchangeable, resulting in information and business processes and applications are disconnected from each other. For example, multiple departments do not share a set of information systems, each information system has its own information center, database, operating system, application software, etc., and do not interoperate with each other, each in its own way. China's international engineering enterprise project types, regional span, supply chain distribution at the same time the low degree of centralization, resulting in high control risk, management level, information technology silo phenomenon prevails. The consequence of this phenomenon is that the enterprise's massive data resources have not been fully utilized, and the enterprise supply chain is always a "chain" and can not be aggregated into a "network".

3.3. Low level of synergy among supply chain stakeholders

Supply chain management meets customers' personalized product needs through modular integration. Using modular integrated supply chain, different modules are given to specialized suppliers to be in charge of specialization and to meet the needs of multiple specialized areas such as transaction, logistics, and capital flow, so that mass customization can be achieved through specialized division of labor coupled with highly efficient synergy. The integration of engineering supply chain management is manifested in the modular integration of construction projects carried out in different regions and at the same time to form a total solution.[8] However, for international engineering projects, it is difficult to realize efficient collaboration upstream and downstream of the supply chain. From the viewpoint of the external environment, the international engineering industry has a complex construction environment, diverse boundary conditions, numerous factors affecting the execution of the construction plan, and variable project construction organization and planning schemes, resulting in parallel design, construction and procurement activities without clear node boundaries. At the same time, language

differences, protectionist ideology and other reasons make the lack of information interaction between upstream and downstream enterprises, forming a vicious circle; from the internal environment, the lack of uniform business and data standards between industries, coupled with the varying capabilities of the information technology architecture design of individual enterprises, making the system architecture shows diversity and differentiation, difficult to docking, and not able to support the closed-loop management of the supply chain.

4. Digital transformation empowers China's international engineering supply chain management

Despite being plagued by both regional political tensions and low competition from other countries, China communications construction still managed to rank among the top ten in many business areas in this list. One of the important factors is to promote the digital transformation of the enterprise through digital technology, integrate the modern concept of supply chain collaboration, continue to improve the level of supply chain management, and reduce the cost of enterprise operation and management.

By linking the industrial chain and upstream and downstream supply chains, China communications construction has realized global resource sharing, linked internal and external systems, realized centralized procurement management, established unified standards to complete the synergy between business and finance, and helped to build a world-class supply chain with "innovation, synergy, safety, green and wisdom". In 2014, China communications construction successively put on-line the material procurement system and equipment procurement system, including the electronic bidding and trading platform certified by the Development and Reform Commission, and the system is positioned as a carrier for the operation of the procurement management system.[11] To date, the platform construction has been perfected. The external part of the system architecture is the control platform, including the main functions such as large screen display, statistical analysis, early warning monitoring and decision-making support; the internal part of the system is firstly the purchasing platform, where the preparation of purchasing plan, the production of purchasing program, purchasing source searching and the management of suppliers are accomplished. After completion, it enters the supply platform, where contract signing, project acceptance, project settlement and invoice management are carried out, and then all business data are pushed to the financial cloud for financial fulfillment. In addition, there is a supply chain finance platform, etc., which realizes the efficient synergy between industry and finance.

As of August 2024, China communications construction has established seven platforms, including procurement sub-platform, supply sub-platform, control sub-platform, cloud e-commerce platform, commerce business sub-platform, resource sharing platform, and open platform, and conducted AI pilots in supplier profiling and bid evaluation assistance. The results include deepening full-level penetration, deep integration of industry and finance in all scenarios, strengthening internal and external synergy and sharing, and improving the compliance management system. Examples have proved that the digital supply chain can promote enterprise management reform, lead innovation, promote digital transformation, and help comprehensively drive the closed-loop management of the entire enterprise supply chain.

5. Conclusion and outlook

Digital supply chain is an important development trend in international engineering management. Although some head enterprises have realized the significance of digital transformation, and have achieved certain results in the transformation. However, most enterprises are still in the transition stage of digital transformation, and

there are many problems that need to be solved, making the digital transformation of China's international engineering supply chain face greater challenges. This paper analyzes the business scale and structure of China's international engineering enterprises, and finds that although China's international engineering enterprises rank first in the world in terms of total turnover, they have not actually entered the high-end market, and are facing the situation of high cost, low profit and many competitors. In order to enhance the market competitiveness of Chinese international engineering enterprises, three major problems in the supply chain of Chinese international engineering enterprises are analyzed through literature research: insufficient supply chain digital infrastructure capacity, information silo phenomenon in supply chain management and low level of supply chain related parties' collaboration. Then, china communications construction, which is one of the top ten companies in many business fields, is taken as the object of empirical research to prove the important role of digital supply chain in the efficient collaboration of business and finance and the reduction of management costs, so as to provide reference for the further promotion of supply chain digitalization transformation of China's international engineering enterprises.

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