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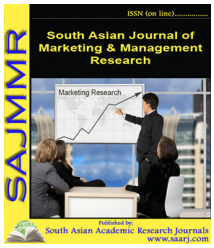

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SELF-MANUFACTURING OR OUTSOURCING DECISIONS IN PREFABRICATED CONSTRUCTION: A MARKET EQUILIBRIUM SUPPLY CHAIN MODEL

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ABSTRACT

Prefabricated construction is a more environmentally friendly option than conventional on-site building. The prefabricated building method, however, still faces many difficulties. Self-manufacturing or outsourcing choices, for example, are critical to the prefabricated building industry's industrial structure and organization, as well as the company's production and operation decision-making. The prefabricated building supply chain in this study is made up of one upstream component manufacturer and two downstream contractors. The big contractor may self-manufacture or outsource the precast component, while the small and medium-sized business (SME) contractor can only purchase components from the component maker. Under various choices, such as component self-manufacturing or outsourcing, a complete game model (Cournot-Stackelberg model) was developed. The equilibrium solutions of production, price, and profit may be obtained by solving the profit functions of various firms in the prefabricated building supply chain. The optimum choice on production and operation, as well as the profit boundary conditions, are indicated by these equilibrium solutions. The profit levels of businesses in the supply chain are evaluated through a dynamic simulation in the changing process of prefabricated construction market size under various behavioral choices once important factors are assumed. The following are the findings: profit levels of all supply chain enterprises and the entire supply chain increase as market size increases, downstream contractors and the entire supply chain have a higher profit level under the component self-manufacturing decision, but upstream component suppliers have a higher profit level under the component self-manufacturing decision. Managerial implications are proposed from the perspectives of extensive publicity, mandatory implementation, strengthening industrial chain integration, and intensifying component factory guidance to promote the development of prefabricated construction, based on the results of the game-theoretic analysis and numerical simulation. Finally, the major issues that should be researched more in the future are given.

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KEYWORDS: *Market Equilibrium, Outsourcing Decision, Prefabricated Construction, Supply Chain, Self-Manufacturing Decision,*

1. INTRODUCTION

The building sector has a major effect on the environment, society, and economy. Traditional cast-in-situ building techniques have long been chastised for their low productivity, lack of cost and safety management, lengthy construction time, substantial resource consumption, and enormous waste generation. As a result, sustainable building is critical for attaining global sustainability goals and producing a healthy built environment. Prefabricated building techniques have gained global recognition as a sustainable alternative to conventional construction methods. Manufacturing structural components at factories, transporting structural components to construction sites, and assembling structural components to make a building are the three major stages in the prefabrication process. Prefabricated construction techniques have showed tremendous promise in terms of improving building quality, decreasing construction time, boosting resource usage efficiency, minimizing construction waste, improving health and safety performance, and expanding economies of scale. Prefabricated steel buildings, for example, may save 81 percent in embodied energy and 51 percent in material mass, according to Aye. According to the project utilizing semi-prefabrication technique decreased greenhouse gas emissions by approximately 1.1 tons per 100 m2 when compared to the project using conventional construction methods. Due to the use of prefabricated construction methods, Vance, the largest residential real estate developer in Mainland China, reported that the construction of the Vance Xinlicheng Project in Shanghai reduced energy consumption by 70%, raw material consumption by 50%, construction waste by 40%, and on-site labor by at least 50%.

As a result, promoting prefabricated building is a realistic need for transitioning from the conventional resource/labor-intensive construction mode to a green built environment and long-term growth. In different nations, prefabrication methods have been gradually used in the building sector. Precast concrete solutions, for example, account for 20–25 percent of the building sector in the European Union, and the proportion is much greater in northern European nations, where it accounts for 40–50 percent. Despite the many benefits of off-site building and the widespread popularity of prefabricated construction throughout the globe, prefabricated construction adoption in China remains low. According to the "Deep study report on China prefabricated construction industry investment planning," prefabricated buildings accounted for just 2–3 percent of newly constructed structures in China in 2015 .In the 1960s, prefabricated buildings were first brought to China. However, it has just begun to develop since 2012, as a result of governmental support for the transformation and upgrading of China's conventional construction sector, as well as the Chinese government's promotion of the construction industrialization plan [1].

In the field of prefabricated building, a number of academics have looked at supply chain management. Existing efforts have primarily focused on four aspects: organizational form, information integration and supply chain optimization, building component production and management decision support, and knowledge sharing, all of which have unquestionably contributed to the prefabricated construction industry's better development. Existing research, on the other hand, focuses on identifying specific barriers to prefabrication construction growth, which is insufficient for integrated supply chain management and system thinking. As a result, it is necessary to consider how to promote prefabricated construction from a whole-system perspective, which includes implementing supply chain management to realize the integration

and collaboration of the prefabricated construction industry's main members in the supply chain, resources, and information [2].

This article investigates the prefabricated building industry's organization from a market equilibrium standpoint in the prefabricated construction supply chain. Following the investigation and survey conducted by Sustainability of into prefabricated construction in China, it was discovered that establishing a precast component enterprise necessitates a plot of land, a factory building, advanced production lines imported from abroad, and other factors, all of which necessitate a significant investment. However, due of the unpredictability of market demand and a lack of technological management expertise, most precast component businesses are not effectively managed. This study attempts to address the following research questions using a combination of literature review and field inquiry in the area of prefabricated construction:

Should structural components be precast by creating a self-owned plant or provided by upstream independent component manufacturers for big building enterprises. How can small and medium-sized construction businesses (SMEs) engage in the prefabricated building sector, given that they lack independent component manufacturing capacity. What effect does the choice to self-manufacture or outsource have on the whole supply chain, various businesses, and the prefabricated building industry.

To address the aforementioned questions, this paper examines the prefabricated construction supply chain, which consists of one upstream component manufacturing enterprise and two downstream construction contractors, and develops a comprehensive game model that integrates the Cournot and Stackelberg models (Cournot-Stackelberg model) from the standpoint of market equilibrium. The market equilibrium findings for component self-manufacturing vs. component outsourcing are given. The paper goes on to examine how it affects the organizational structure of prefabricated building by maximizing the profitability of upstream and downstream businesses in the supply chain.

2. DISCUSSION

The remainder of the paper is laid out as follows. Gives an outline of the relevant background. The modeling assumptions and research methods, as well as the complete game model and numerical analysis, are presented in. The findings of the comparative study of the game model and the numerical simulation are discussed in. The management implications for supporting the growth of the prefabrication construction sector are discussed in. Finally, brings the study to a close and proposes research possibilities for the future.SCM may be defined in three ways: as a management philosophy, a collection of activities for putting that philosophy into practice, and a set of management procedures. First, the supply chain is seen as a whole rather than a collection of disparate pieces as a management philosophy, emphasizing the synchronization and convergence of intrafirm and interfere operational and strategic capabilities. Second, various activities, such as mutually sharing information among supply chain members, sharing risks and rewards, cooperation, integration of processes from sourcing to manufacturing and distribution across the supply chain, and building and maintaining long-term relationships, are required to successfully implement the SCM philosophy. The aforementioned actions are part of a coordinated effort known as supply chain management (SCM) amongst supply chain partners to dynamically react to end customer requirements. Third, SCM is defined as the process of coordinating connections, information, and material flow across organizational boundaries. Through coordinated control of the flow of physical products and related information from source to consumption, SCM may provide improved customer service and economic value [3].

The SCM theory was developed in the manufacturing sector and has since been extensively applied to a variety of other industries, including construction, mining, transportation and storage, and property and business services, to increase efficiency and reduce costs. Because the construction sector is extremely fragmented, with major negative consequences such as poor productivity, cost and time overruns, conflicts and disputes, and the resultant claims and lengthy litigations, SCM is seen as a possible solution. The construction supply chain is part of project-based construction management, which differs from the manufacturing industry's process-based production management. Successful SCM techniques have been extensively used in construction project management, according to previous study [10].

The SCM approach is more appropriate in the prefabricated construction management sector than conventional construction management, which is confined to the secondary-level supply chain between the raw material supplier and the contractors. One of the most important features of prefabricated building techniques is industrialization. Prefabricated construction has a more complex supply chain structure than traditional building, for example, component design, prefabrication, and installation may all be combined. Self-development has benefited the component manufacturing industry the most, as it has generated many possibilities, set the groundwork for adopting supply chain management, made adequate use of labor specialization, and formed industrial alliances. However, the component manufacturing company is the weakest market player in the current prefabricated construction supply chain due to a variety of constraints, including a lack of professional technician and management personnel, a large upfront investment for the automated production line, and insufficient production and management experience. As a result, rather than increasing production capacity blindly, component manufacturing businesses should adjust their firm size and growth rate to the prefabricated building industry's development stage and needs [4].

Shifting from "conventional and on-site building" to "innovative and industrialized housing" poses significant difficulties. More measures and government assistance are therefore required to promote prefabrication adoption and better support the prefabricated building industry's growth.

First and foremost, greater government measures in support of prefabricated building are required. On the one hand, prefabricated building must be promoted in order to satisfy market demand in the construction industry. Every year, Chinese central and local governments fund and build a significant number of public housing units to meet the housing requirements of low-income households. To guarantee a particular market size, mandatory regulations may be established to use the prefabricated construction technique in public buildings, government structures, and inexpensive housings. Prefabricated building, on the other hand, may help to enhance the circular economy. Construction component manufacturing that is standardized and industrialized may help to minimize waste of building materials, water, and land, as well as enhance resource recycling. Mechanized assembly construction may significantly decrease labor demand, speed up building, minimize wet activities, and accomplish environmentally friendly construction [5]. Second, it is essential to improve the direction for component manufacturing companies in terms of technical innovation, operation, management, and investment, as well as to collaboratively promote prefabricated building. The process of prefabrication is very complicated [6].

Various prefabricated components have different structures and functions. As a result, coordination and cooperation are critical throughout the prefabricated building process. On the one hand, not only should hardware equipment be imported from developed nations and regions, but component makers should also resort to sophisticated technology and management expertise.

Establishing standards and clarifying investment needs for precast component manufacturers is critical, taking into account the present state of growth and the size of the prefabricated building sector in China. Component standardization and building information modeling (BIM) technology, on the other hand, are excellent techniques for achieving architectural design, manufacturing, and construction synergies. Component standardization, for example, may be used to connect the many parts in the prefabricated building supply chain, thus improving technical cooperation. BIM technology may help to enhance information exchange and transmission across various topics and processes, as well as address issues like geographical constraints, standard discrepancies, and communication hurdles, and boost the coordination of the whole prefabricated building process [10].

Third, for the overall growth of the prefabricated sector, the integration of industrial chains must be enhanced. Market study, land resource development, project design, material supply, component manufacturing and transportation, component integration and assembly, commodity circulation, and property administration are all part of the prefabricated industrial chain. There are numerous embedded dynamic chains for a particular procedure. Product design, staff training, material supply, component production, product design amendment, product testing, and component parts transportation, for example, are all part of the embedded chain in the component production process. As a result, establishing an integrated industrial chain between product design, production, and construction firms can improve mutual complementation of technology, resources, and information while also achieving risk sharing [7].

Fourth, more education and motivation are needed to improve public awareness and understanding of the advantages of prefabricated construction. The successful transition away from centuries-old construction methods necessitates a shift in culture and public perception [8]. More public awareness, for example, through the use of multimedia such as newspapers, televisions, and radios, as well as in various forms such as press conferences, expos, and advertising videos, will inform the public about the benefits of prefabricated construction, such as higher construction quality, improved safety, and a better living environment, and thus stimulate potential market demand for prefabricated construction [9].

3. CONCLUSION

A prefabricated construction supply chain with one upstream component manufacturer and two downstream contractors is examined in this study. The large contractor can self-manufacture or outsource precast components, whereas the small contractor can only buy them. components from the manufacturer of the components comprehensive game model component self-manufacturing or component self-manufacturing model) is established under two decision scenarios, component self-manufacturing or component self-manufacturing model). outsourcing. The output, price, and profit equilibrium solutions are calculated by solving Profit functions in the prefabricated construction supply chain that indicate the best choice on the profit boundary conditions, production, and operation Profit levels are calculated using dynamic simulations that vary market sizes. Prefabricated construction is subject to a variety of decisions. The findings of this research show that: The profit levels of the entire supply chain, as well as all of the businesses that make up it, are rising in tandem with the growth of the economy.

Downstream contractors have a higher profit level under the component because of the market size, and downstream contractors have a higher profit level under the component because of the market size. Self-manufacturing decision than component outsourcing choice, while on the contrary, self-manufacturing decision Upstream component suppliers profit more as a result of the component outsourcing decision. In the market competition, the SME contractor is at a

disadvantage, the equilibrium the output of the small contractor is reduced as a result of the large contractor's outsourcing decision, and when the market is small, there are many risks; however, a higher profit level can be expected. With the expansion of the market Managerial implications, according to the previous analysis are presented from the perspectives of widespread public awareness, mandatory implementation, and strengthening In order to promote the integration of the industrial chain and the intensification of component factory guidance, prefabricated construction is being developed. This paper focused on the prefabricated supply chain's short-term supply chain equilibrium problem. The construction market is still in its early stages. The limited number of people in this stage is one of its most distinguishing features market dominated by big corporations, a market infrastructure that is inadequate, and a lack of support Industries. As the industry's demand grows and the market's size expands, more and more companies are entering the market. Prefabricated construction will include more businesses from various areas of the supply chain. It has the potential to alter the industrial structure and organizational style significantly. Consequently, it isIt is essential to develop a more realistic model based on the current constructed scenario. Market for building Furthermore, choices on component self-manufacturing or outsourcing will be made. For the big contractor, this results in various transaction costs, which will be investigated further in the future.

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