

Research on Value Stream Analysis of Prefabricated Building Based on SVN

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Abstract—With the adjustment of the national industrial structure, the transformation of the production mode of the construction industry and the advocacy of the concept of green and energy-saving building, prefabricated building will become the next trend of the construction industry. However, prefabricated building has not been popularized in China's construction industry, which may attribute to the participating parties have not realized the value-added effect that brought by the application of prefabricated building. Therefore, it is necessary to analyze the value gained by all parties in the application of prefabricated building from a global and systematic perspective. Based on the theory of Value and Stakeholders Value Network (SVN) methods, this paper may build a network with value – information – coordination of the stakeholders in a prefabricated building project, and make a comprehensive evaluation on the value acquisition ability and the uncertain risks of key stakeholders in a prefabricated building projects, which may provide a new perspective for the implementation and decision-making of prefabricated building projects.

1 INTRODUCTION

With the population growth and economic development, the construction industry has developed rapidly. However, the energy-intensive construction poses several environmental problems, like energy shortage, climate deterioration and air pollution. Therefore, as a more cleaner construction method, the prefabricated building has found favor in both industry and commerce.

Values are regarded as subjectively desirable outcome of project stakeholders. Although the potential value of prefabricated building may appear self-evident, the construction industry has been slow to accept it for many reasons. The most significant one is that in spite of the evidence, stakeholders lack both an appreciation of and quantifiable evidence for the value added by prefabricated building. Although the perceived value should be a clear motivator for organizations in the construction industry to adopt new technologies, the justification for owners' investment, which merely considers tangible values without incorporating intangible ones. This is important because contractors, especially mid-sized ones, will hesitate to adopt prefabricated building. Therefore, this paper aims at quantifying the value stream of prefabricated building application by analyzing the value exchange and transmission of its stakeholders, so as to promote the application of prefabricated building in the construction industry.

Prefabricated building is the best embodiment of the

concept of sustainable development and green construction in the industrialization of architecture. The idea of industrial engineering is applied to manufacture the prefabricated components used in construction in the factory in advance, and then transport them to the construction site for assembly. The adoption of fabricated technology is an innovation of construction technology, which helps to improve the continuity and productivity of working process, reduce construction waste, optimize construction cycle, improve construction quality and reduce maintenance cost in the later period of construction. Compared with the traditional cast-in-place construction method, the construction cycle of prefabricated buildings is reduced by at least 25%, the carbon emission and construction waste are reduced by 34% and 74% respectively, the cost saving is up to 58%, and the labor demand is reduced by 30%. It's apparently that promoting the development of prefabricated buildings can not only improve the quality of products, but also conform to the concept of green, circular and sustainable development.

In order to promote the development of prefab buildings, the government has also issued relevant documents. The Evaluation Standards for Prefabricated Buildings, which were formally implemented on February 1, 2018, explicitly proposed to vigorously develop prefab buildings and increase the proportion of prefab buildings in the newly built building area. The government of Henan province has also formulated corresponding supporting policies and subsidies for prefabricated buildings. It is estimated that prefabricated

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buildings will account for more than 25 percent of the newly built floor space in Henan province by 2020. However, due to China's low level of building industrialization, and prefabricated building projects need to be carried out in a cooperative environment, the key to improve the application of prefabricated building is to achieve a win-win situation among multiple parties.

However, different stakeholders have different feelings about the value of prefabricated building projects. The research on the value of prefabricated buildings at home and abroad mostly adopts qualitative or statistical methods to explain the benefits of prefabricated buildings to all parties. Based on game theory, Qi Baoku et al. analyzed the game relations among the government, the owner and the prefabricated component factory in the promotion of prefabricated construction, providing theoretical support for the value analysis of stakeholders. Cong Weiyi evaluated the developer's choice and application of passive residential development strategy under the incentive policy through the value analysis between the government and the developer group. The advantage of prefabricated building is that it can save construction cost and time limit through multi-party cooperation. However, the value relationship of the project is various, so it is necessary to analyze the value stream of prefabricated building project from the overall perspective of the system and discuss the value acquisition ability of all parties.

Traditional stakeholder analysis like Freeman's stakeholders strategic model (Hub - And - Spoke, H&S)^[1], only considers the relationship between stakeholders and the core organization. While, the research on global network can only analyze the structural characteristics of the network with unique exchange relationship between subjects and single relationship type (such as only economic relationship or social relationship)^[2]. Therefore, it is necessary to multidisciplinary system method to explore the value of prefabricated construction project network. Based on value stream model of SVN, this paper may build a value network of stakeholders in prefabricated building projects. By comparing the SVN with traditional project model, this paper may make an evaluation on the value exchange and transmission of the key stakeholders in prefabricated building projects, and promote the application of prefabricated construction drive path and strategy.

In the current literature, an increasing number of scholars are now using quantitative methods to extend the research focus from an individual stakeholders to an overarching network theory that includes multiple stakeholders. However, most researchers have only considered a single type of relationship within a network and are thus unable to capture multiple types of relationships in the same network in order to accurately evaluate the perceived values of stakeholders.

Therefore, based on value stream model of SVN, this paper may build a value network of stakeholders in prefabricated building projects. By comparing the SVN with traditional project model, this paper may make an evaluation on the value exchange and transmission of the key stakeholders in prefabricated building projects, and promote the application of prefabricated construction

drive path and strategy.

2 THEORETICAL FRAMEWORK

The analysis method of SVN was proposed by Cameron^[3], a scholar from Massachusetts institute of technology^[4]. Feng^[5] defined SVN as a multi-relationship network composed of core organizations and their stakeholders, including the exchange of tangible and intangible values between core organizations and stakeholders as well as between stakeholders^[6]. Based on the stakeholder theory, social exchange theory and system engineering theory, SVN takes the economic relationship and social relationships in the same network framework for research. And it makes a reference to the concept and principles of microeconomics, mainly is the "utility", to analyze the non-economic social exchange. Different from social exchange theory and social network analysis, the new contribution of SVN method is to analyze the complex multiple value exchanges, multi-type relationships and indirect relationships among stakeholders. Based on this theory, this paper makes the following assumptions about SVN network formed in the process of prefabricated construction projects:

(1) Relationship type: in social exchange theory, social relationship and economic relationship are two basic types of relationship. As social exchange is an extension of economic exchange^[3], both the contractual and cooperative relationships among stakeholders in prefabricated construction projects can be compared and analyzed by the subjective utility evaluation method.

(2) Exchange mode: in social exchange theory, "restricted exchange" and "general exchange" are defined as two basic exchange models. As the application of prefabricated building requires a lot of indirect cooperation, the SVN model takes "general exchange" as the focus of value path search and analysis.

(3) Strategic analysis: the value acquisition ability of stakeholders is determined by the strength of the exchange relationship and the structure position. The benefit degree of stakeholders in the prefabricated building application can be measured by the statistical indicators in the network, and based on this, the strategic analysis of different stakeholders can be conducted.

3 RESEARCH DESIGN

3.1 Definition and identification of stakeholders

Stakeholders are groups or individuals who have specific interests in the operation or success of a project. They can be divided into internal and external types. According to the definition and classification of stakeholders by project management, this paper defines the stakeholders of prefabricated construction projects into two categories: those who directly participate in prefabricated construction projects or those who influence or are affected by the implementation of projects. The other is the unit that benefits or takes risks in an assembled project.

3.2 Modeling

In this paper, subjective utility is used to comprehensively evaluate the value stream of the two dimensions of "need for resources" and "importance for sources", and the mean values of each dimension are calculated with a five-scale scale. According to the Feng scoring method [4], the scale value of "need for resources" was calculated by the exponential method, while the scale value of "need for sources" was calculated by the linear method. The maximum value of the two-dimension evaluation is 0.98, and the minimum value is 0.11. In order to make the "need for resources" score between 0.11 and 0.98, the index value calculated by the five-scale index method is about 1.7. To simplify the calculation, the value stream score is the product of the multiplication of two dimensions. Delphi method was adopted for the quantitative evaluation of value streams. Corresponding expert questionnaires were designed for the value needs of 7 types of stakeholders, and the value streams were scored to establish a quantitative model.

3.3 Method of Value Path Searching

Based on SVN quantitative model, relevant procedures based on DSM technology and adjacency matrix and accessibility matrix algorithm in graph theory are adopted to obtain all value paths and scores between any two stakeholders. These "restricted exchanges" can reflect the key measures that drive the adoption of prefab buildings by searching for the highest-scoring value paths that owners pass on to different stakeholders. The "general exchange" in the high value path is the driving path for prefabricated building applications. In view of the owner's core role in prefabricated construction projects, SVN path search includes all value loops with the owner as the start and end point, and stakeholder nodes and value streams in each path are only passed once.

According to the multi-attribute value theory, Cameron et al. [3] proposed that the value path score is equal to the product of all value stream scores, and this method ensures that the value length is inversely proportional to the value division.

In projects using prefabricated construction, the longer the value path, the more difficult it is for the owner to push the relevant units to participate in prefabricated construction management, which is consistent with the actual situation

3.4 Analytical Method

The value acquisition ability of the stakeholders in prefabricated construction projects can be evaluated by two indexes that the WSO (weighted stakeholder occurrence) and the SO (stakeholder occurrence). The WSO index not only considers the value path score but also considers the number of value paths. While, the SO index only considers the number of value paths. The calculation formula of the two indexes is as follows:

$$WSO_k = \frac{\sum U_{ck}}{\sum U_c} \tag{1}$$

$$SO_k = \frac{\sum N_k}{\sum N} \tag{2}$$

Where k denotes a stakeholder in the use of prefabricated building, $\sum U_{ck}$ denotes the sum of all value paths' scores of the stakeholder, $\sum U_c$ denotes the sum of all value paths' scores which begin and end with the owner, $\sum N_k$ denotes the total number of value paths of stakeholder k, and $\sum N$ denotes the total number of value paths which begin and end with the owner.

Based on the above formula, the "weighted stakeholder proportionality coefficient" PWSO and the "stakeholder proportionality coefficient" PSO can be obtained through standardization. The formula is as follows:

$$PWSO_k = \frac{WSO_k}{\sum WSO_k} \tag{3}$$

$$PSO_k = \frac{SO_k}{\sum SO_k} \tag{4}$$

The quantitative evaluation of the value stream adopts the Delphi survey method, and the corresponding expert questionnaires are designed according to the value needs of seven stakeholders, and the value streams are scored to establish a quantitative model.

4 SVN MODEL OF PREFABRICATED CONSTRUCTION PROJECT

This paper takes EPC general contract management model as an example to analyze SVN value stream in assembled project.

4.1 Stakeholder and value stream determination of prefabricated construction projects

The government, owners, contractors and prefabricated component suppliers are important stakeholders in the project. Since owners play a decisive role in the construction process, the core organization in the SVN model of prefabricated construction projects is defined as owners. According to the characteristics of the EPC mode and the method for determining stakeholders, eventually determine its stakeholders, respectively are government(G), owner(O), construction contractor (C), design organization(D), subcontractors (SC), factory for prefabrication(FP) and cost consultation(CC), responsibilities of supervision are included in the owner side, which will not be listed here.

Stakeholders feature template is the best way to determine the value demand, through literature analysis of prefabricated construction projects in the role, objectives and specific needs of each stakeholder is defined, then respectively from various stakeholders choose 1-2 experts interview, finally identified with 7 types of stakeholders node 67 value stream network. The "knowledge or information" value stream was the largest, accounting for 38% of the total, and the importance of knowledge and information transfer in prefab

construction projects. Besides, there were 53 intangible value streams, or 79 percent of the total, which illustrates the importance of intangible value in prefab construction projects and verifies the limitations and shortcomings of the value quantification method that only measures tangible value.

From the perspective of relationship type, the number of "restricted exchange" (direct exchange) between owners and other stakeholders is 41, while the rest is only the direct value stream of other stakeholders. The latter is the key to form "general exchange" between owners and other stakeholders, which enhances the value acquisition ability of all parties. In addition, it can be seen from the figure that both the input and output of stakeholders contain multiple types of value streams, and value type conversion generally occurs from input to output. The application of prefabricated buildings is not only the transmission of a single stream of value, but generally requires the transformation from capital to products or services to knowledge or information. Therefore, SVN model is conducive to enhancing the systematic understanding of the value of prefabricated building projects among stakeholders.

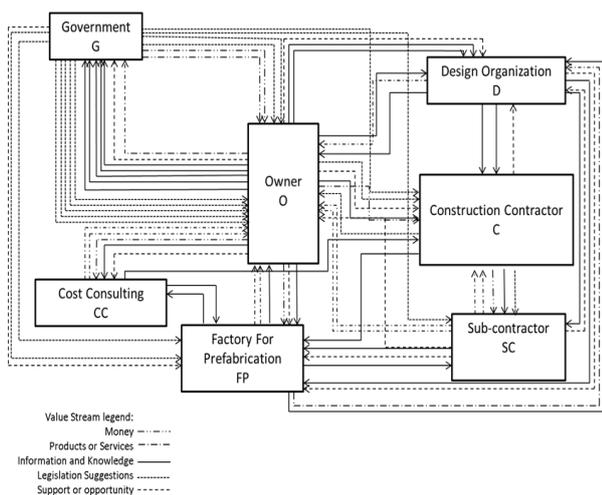


Figure 1. The qualitative model of SVN in prefabricated projects

4.2 Analysis of Stakeholder Value Acquisition Capability

Traditional stakeholder theory, such as the H&S model, only examines stakeholder parties with a single exercise of core organizations. However, the SVN model can examine the direct or indirect exchanges between stakeholders at the same time. The value acquisition capability of key stakeholders was scored quantitatively by the interviewed experts, as shown in Fig. 2. Due to the value paths of SVN and H&S are different, PWSO_SVN, PWSO_H&S, PSO_SVN and PSO_H&S are adopted for comparative analysis.

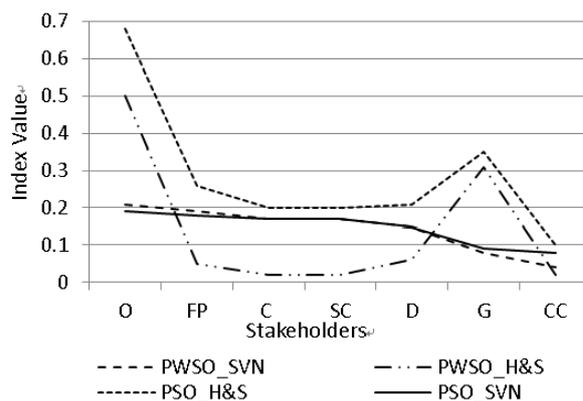


Figure 2. Comparison of PWSO and PSO between SVN and H&S models

As can be seen from Fig. 2, the trend of PWSO and PSO is roughly positively correlated, with the change range and trend being basically the same, indicating that the structure position of stakeholders can largely reflect the value acquisition ability of stakeholders. Moreover, the node location in the figure has a strong control advantage over the network. For example, the owner and the government located in the node location can gain more benefits through the control over the network. In addition, through comparison, it is found that in the SVN model, except for the owner, the prefabricated component factory is the biggest beneficiary, followed by the general contractor and subcontractor. However, in the H&S model, besides the owner, the government is the biggest beneficiary, followed by the prefabricated component factory and the design unit. This change reflects the positive effect of indirect exchange on the value acquisition ability of stakeholders, that is, all parties can obtain greater value benefits through indirect exchange with other organizations.

5 CONCLUSIONS

This paper, by establishing the value network of stakeholders in the application of prefabricated buildings, is conducive to enhancing the systematic and quantitative understanding of the value of prefabricated buildings among the participants, and provides a new perspective for the development of prefabricated buildings in China.

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