Research on the Three-Stage Model of Partner Selection of Prefabricated Construction Industry Chain Based on System Design

Teng Yi[1*]

[1]Department of Architecture, College of Planning & Design, National Cheng Kung University (NCKU) Tainan, 701401, Taiwan

Corresponding author: Teng Yi, ytn78083503@126.com

Abstract: In order to improve the effective development of the construction industry chain, the evaluation indicators of the partners are set from the two dimensions of the potential partner enterprises' own strength and whether they can have a positive impact on the entire prefabricated construction industry chain. Based on the system design ideas, this paper obtains a three-stage model of partner selection of prefabricated construction industry chain, combines the actual operation process of the building industry chain to divide the role of the industry chain, and combines BIM technology and IPD mode to build an intelligent model. After getting the partner selection of prefabricated construction industry chain, this paper analyzes the effect of the model to provide a more reliable tool for the subsequent selection of partners in the prefabricated construction industry chain.

Keywords: system design; prefabricated building; industrial chain; cooperative partners. three stages
DOI: https://doi.org/10.14733/cadaps.2023.S15.182-196

1 INTRODUCTION

How to scientifically and rationally evaluate and select partners in the prefabricated construction industry chain is a problem that needs to be solved. One of the core issues of whether the application of prefabricated buildings can achieve the expected results is whether the companies in the prefabricated building industry chain can effectively cooperate with each other. The key to solving this problem lies in the management effect of the cooperative partnership in the prefabricated construction industry chain [13]. The basic prerequisite for obtaining a high-quality industrial chain partnership is to obtain a high-quality partner. Therefore, one of the keys to whether the application of prefabricated buildings can achieve the expected results is how to evaluate and select industrial chain partners in a reasonable and effective manner [7]. Compared with the traditional construction industry chain, the prefabricated construction industry chain puts forward higher requirements for partners. For example, the EPC model is used to select partners based on general project contracting, and partners need to have a high level of information technology application [8].

In the prefabricated construction industry chain environment, the industry competition faced by construction-related enterprises such as general contracting of projects and component parts has risen from between enterprises to between industrial chains, and the interests of enterprises have gradually become in line with the overall interests of the industrial chain. Unanimous. Therefore, when selecting a partner, a general contracting company should not only consider product quality, price, corporate reputation, financial status, and degree of informatization, but also select partners from the perspective of the overall benefits of the prefabricated construction industry chain. Whether the addition of new partner companies can improve the response speed, operational efficiency or reduce operating costs of the entire prefabricated construction industry chain. Ensure that potential partners can meet the basic needs of the owners. The basic needs of the owner are the needs of the general contracting company for its partners, and the partner companies are required to provide the general contracting company with products and services that meet the requirements of quality and cost. In fact, the requirements of general engineering contracting companies for partners are not only the quality and cost of products and services, but also the comprehensive capabilities of the partner companies to provide products and services that meet the requirements, such as the reputation of the partner company, human resources, Financial status and information technology level. When the comprehensive capabilities of the partner companies meet the requirements, the basic needs of the owners can be guaranteed.

Based on the above analysis, this paper obtains the partner selection of prefabricated construction industry chain based on the system design ideas, and analyzes the effect of the model to provide more reliable tools for the subsequent selection of partners in the prefabricated construction industry chain.

2 RELATED WORK

The literature [12] proposed a manufacturing supplier selection system, including 23 criteria and 50 factors. The literature [16] pointed out that the selection of suppliers is a complex system problem with many influencing factors. Moreover, it pointed out the important factors of the product unit price, delivery capacity, product quality, management level and other indicators for supplier selection and judgment, and on this basis, gave the evaluation criteria and importance ranking. The literature [3] proposed eight most important attribute indicators for supplier selection, including product unit price, financial capability, marketing training, production equipment, technical level, delivery capability, product quality, and order efficiency. The literature [11] put forward four indicators of technical level, after-sales service, supply capability, and product quality, and further pointed out that three main dimensions of corporate strategic fit, cost control capability, and risk control capability are used to evaluate suppliers. The literature [15] put forward several evaluation indicators such as supplier's historical performance, business scope, production scheduling ability, and product quality. The literature [18] obtained the weight value of the index system including responsiveness, delivery flexibility, financial health, and R&D capabilities by scoring survey visits and evaluations of multiple procurement staff.

The literature [5] proposed that companies should choose long-term strategic partners or short-term temporary suppliers according to their own conditions and needs to maximize their benefits. Due to the existence of value-added benefits and mutually beneficial benefits of the supplier chain itself, the supplier evaluation system is divided into several categories such as historical performance, production capacity, and product quality system. The literature [19] identified several basic principles of the supplier evaluation system and proposed supplier selection evaluation criteria, and pointed out that the key to supplier management lies in risk control. The literature [6] believed that the core market competitiveness of suppliers is mainly reflected in several aspects such as outstanding business capabilities, scientific management system, and healthy financial level, and established a network of indicators in these aspects to explain them. The literature [1] established a feasible indicator system for supplier performance evaluation, and first classified each indicator according to several dimensions, and finally completed the study using evidence-based reasoning.

Literature [2] puts forward several important strategies in the strategy research of enterprises to enhance market competitiveness, namely resisting new competitors, promoting product replacement and updating, supplier negotiation ability, procurement management ability, etc., to deal with complex problems with the above points. Market competition. Literature [17] believes that the status of supplier management in enterprise management is extremely high, but in theory, enterprises and suppliers are in a competitive relationship. The buyer prevents the seller from forming a market monopoly, and the seller responds by constantly updating products to cater to the market. With the introduction of supply chain thinking. Literature [9] concludes by comparison that under the guidance of supply chain thinking, core enterprises and suppliers cooperate with each other for common development, which can effectively reduce the cost of research on supplier management in the green supply chain of supply enterprises, and both parties can achieve mutual benefit. The effect of symbiosis and common development. Literature [4] pointed out that compared with traditional supply chain management, supply chain partner management requires both parties to strengthen mutual trust and establish a good communication mechanism and benefit-sharing mechanism. Literature [14] believes that supply chain partnership is a solid and win-win partnership established between enterprises and suppliers. Literature [10] believes that the supply and demand parties should sign a cooperation agreement as the boundary, establish a mutually beneficial relationship and an inter-organizational communication and operation mechanism, and establish a common profit index. Professor Ma Shihua defines the supply chain partnership as the supply-manufacturer relationship and the seller-buyer relationship.

3 IMPROVED THREE-STAGE MODEL

Regression analysis method is the most widely used method among various methods of multivariate statistical analysis. It is a mathematical statistical method to deal with the interdependence between multiple variables. In regression analysis, if there are two or more independent variables, it is called multiple regression. In fact, a phenomenon is often connected with multiple factors. Predicting or estimating the dependent variable by the optimal combination of multiple independent variables is more effective and more realistic than using only one independent variable for prediction or estimation.

Therefore, multiple linear regression is more practical than unary linear regression.

(1) The explanatory variable Xi is a deterministic variable, not a random variable, and the explanatory variables are not correlated with each other, that is, there is no multicollinearity.
(2) The random error term has 0 mean and same variance.
(3) There is no serial correlation in the random error term.
(4) There is no correlation between the random error term and the explanatory variable.
(5) The random error term obeys the normal distribution of O mean and homoscedasticity.

The analytical expression of the multiple regression model is:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \cdots + b_k X_k + u$$

Through the observation value $\left(Y_i, X_{1i}, X_{2i}, \cdots, X_{ki}\right), i = 1, 2, ..., n$ of n samples, we have:

$$Y_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + \cdots + b_k X_{ki} + u_i$$

$$\begin{cases} Y_1 = b_0 + b_1 X_{11} + b_2 X_{21} + \cdots + b_k X_{k1} + u_1 \\ Y_2 = b_0 + b_1 X_{12} + b_2 X_{22} + \cdots + b_k X_{k2} + u_2 \\ \cdots\cdots\cdots \\ Y_n = b_0 + b_1 X_{1n} + b_2 X_{2n} + \cdots + b_k X_{kn} + u_n \end{cases} \tag{1}$$

Then, the rectangular form of the multiple regression model is:

$$\begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{pmatrix} = \begin{pmatrix} 1 & X_{11} & X_{21} & \cdots & X_{k1} \\ 1 & X_{12} & X_{22} & \cdots & X_{k2} \\ \vdots & \vdots & \vdots & & \vdots \\ 1 & X_{1n} & X_{2n} & \cdots & X_{kn} \end{pmatrix} \begin{pmatrix} b_0 \\ b_1 \\ b_2 \\ \vdots \\ b_k \end{pmatrix} + \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_n \end{pmatrix} \tag{2}$$

$$Y = XB + U \tag{3}$$

In the multiple linear regression analysis model, Y is an observable random vector, while U is an unobservable random vector, a known matrix, and B is an unknown parameter, and set k>n and rank(X)=n+1. In the classic multiple linear regression analysis, we mainly discuss the estimation and testing of parameter B in the model.

Data Envelopment Analysis (Data Envelopment Analysis) is abbreviated as DEA, which is a new field of cross-study between operations research, management science and mathematical economics. DEA uses a mathematical programming model to evaluate the relative effectiveness (called DEA effectiveness) between departments or units with multiple inputs and multiple outputs (called decision-making units, abbreviated as DMU). Judging whether the DMU is DEA valid according to the data observed for each DMU is essentially judging whether the DMU is on the front surface of the production possible set. The production frontier is an extension of the production function to multi-output situations in economics. The DEA method and model can be used to determine the structure of the production frontier. Therefore, the DEA method can be regarded as a non-parametric statistical estimation method.

DEA evaluates the investment scale and technical effectiveness of its decision-making units (companies or departments of the same type). That is, after investing a certain amount of capital, labor and other resources in various enterprises of the same type, the output benefits (economic benefits and social benefits) are evaluated for relative effectiveness. The establishment of an optimal model for determining the relative productivity of any enterprise is as follows:

$$\begin{aligned} & naxH = h_3 \\ & s.t. \begin{cases} h_j \le 1, j = 1,2,3 \\ u_r \ge 0, r = 1,2, v_i \ge 0, i = 1,2,3 \end{cases} \end{aligned} \tag{4}$$

To introduce the DEA model and clarify the economic meaning of DEA effectiveness, several concepts need to be clarified.

(1) Decision-making unit

An economic system or a production process can be regarded as an activity in which a certain number of production factors are input and a certain number of "products" are produced by a unit within a certain range. It is a physical unit that describes the process of converting input to output. DEA efficiency is just the comparison value of a certain decision-making unit with respect to the input-output capacity of the decision-making unit on the production frontier.

(2) Production possibility set

(3) Projection

If the evaluated unit is not valid for DEA, the original input vector and output vector can be adjusted through calculation and solution. After adjustment, it becomes valid for DEA. The adjusted point is the projection of the decision-making unit on the production frontier.

(4) Effectiveness

For any decision-making unit, its 100% efficiency means: ①Under the existing input conditions, any output cannot be increased unless other types of output are reduced at the same time; ②To achieve the existing output, any one All kinds of inputs cannot be reduced unless other kinds of inputs are added at the same time. When a decision-making unit reaches 100% efficiency, the decision-making unit is effective, that is, an effective decision-making unit.

The DEA method mainly has two models: the BCC model and the CCR model. The main difference between the two is that the former describes a variable return to scale model, and the latter describes an immutable scale model. The former not only evaluates comprehensive efficiency, but also separates technical efficiency and scale efficiency from comprehensive efficiency, while the latter does not consider the impact of scale efficiency, that is, technical efficiency is comprehensive efficiency. This paper studies the efficiency in the time series, and the scale of each industry changes, so the BCC model is selected as the efficiency analysis model for this paper.

Four axioms including inefficiency property, ray unlimited property and minimum extrapolation property are introduced, and the concept of Shepherd distance function is introduced to decompose technical efficiency (TE) into pure technical efficiency (PTE) and scale efficiency (SE), namely: TE=PTE*SE. By increasing the constraints on the weight:

Consider the linear programming problem:

$$\begin{cases} \min \theta \\ s.t. \sum_{j=1}^{t} \lambda_j x_j \le \theta x_0 \\ \sum_{j=1}^{t} \lambda_j y_k \ge y_0 \\ I\lambda = 1 \\ \lambda_j \ge 0,\ j = 1, 2, \ldots, \mathrm{t} \end{cases} \tag{5}$$

Since $(X_0, \mathrm{Y}_0) \in T$, (X_0, Y_0) satisfies $\sum_{j=1}^{t} \lambda_j x_j \le \theta x_0$ and $\sum_{j=1}^{t} Y_j \lambda_j \ge Y_0$. It can be seen that linear programming means that in the production possible set T, when the output Y0 remains unchanged, try to reduce the input amount X0 by the same proportion θ . If the input amount X0 cannot be reduced by the same proportion θ , that is, the optimal value $\theta = 1$ of linear programming, in the case of single input and single output, decision-making unit j is both technically effective and scale-effective. Conversely, if the input amount X can be reduced by the same proportion θ, that is, the optimal value $\theta < 1$ of linear programming, in the case of single input and single output, the decision-making unit j_0 is not technically effective or scale-effective.

When evaluating the DEA model, it is necessary to consider the three relationships, namely overall efficiency, pure technical efficiency, and pure scale efficiency. According to DEA's theory, there is a relationship among the three parameters of overall efficiency, pure technical efficiency, and pure scale efficiency, and the pure scale efficiency of DMU can be directly calculated. The calculation formula is $s^* = \frac{\theta^*}{\sigma^*}$, where $\theta*$ is the overall efficiency, $\sigma*$ is the pure technical efficiency, and $s*$ is the pure scale efficiency.

The stochastic frontier method (SFA), also known as the econometric frontier method, gives a function of the production relationship between cost, profit or output, input and environment. The occurrence of random errors is acceptable. The random frontier method usually first estimates a function, and the random error term and inefficiency term constitute the error term of the method. The separation between the random error term and the inefficiency term ensures the validity and consistency of the estimated efficiency, and takes into account the influence of the random error term on individual efficiency.

The main advantage of SFA is to consider the impact of random factors on output. In terms of analyzing technical efficiency, it can only analyze the efficiency between multiple inputs with one output, and the analysis of the many-to-many model in this paper is not suitable. Therefore, this paper selects the DEA model to analyze the efficiency of the high-tech industry in Anhui Province. However, based on the SFA model, the output can be divided into three parts: random factors, technical inefficiency, and production function. In the analysis process of this paper, the external environmental factors and random interference items should be excluded from the value of the input index, so this paper constructs a similar SFA model.

(1) Establish slack variables

In the first-stage DEA model, the slack variables of the input variables of each decision-making unit can be obtained. The slack variable is the difference between the actual input of the investigated object and the input variable under the optimal efficiency. According to the operation of the first stage, the slack variable of the input variable can be obtained:

$$S_{ni} = X_{ni} - X_n\lambda \ge 0, n = 1,2,...,N, i = 1,2,...,I \quad (6)$$

Among them, S_{ni} is the slack variable of the n-th input variable of the i-th input index in the first stage, and X_{ni} is the actual value of the n-th input variable of the i-th input index. $X_n\lambda$ is the optimal input amount of the output vector corresponding to X_{ni} in the effective set.

(2) Establish a theoretical model of slack variables and environmental variables

The input slack variable is not only affected by internal indicator factors, but also affected by the external environment and random errors. Therefore, this paper establishes the relationship between the slack variable and the environmental variable:

$$S_{ni} = f^n(z_i;\beta_n) + v_{ni} + u_{ni}, n = 1,2,..., \mathrm{N}, \mathrm{i} = 1,2,..., \mathrm{I} \quad (7)$$

Among them, $f^n(z_i;\beta_n)$ is the influence of environmental variables on the input slack variable, β^n is the parameter to be estimated of the environmental variable, and $z_i=\{z_{1i},z_{2i},..,z_{ki}\},i=1,2,...,I$ is the k observable environmental variables. $v_{ni}+u_{ni}$ represents a compound error term, v_{ni} represents a random interference term, and suppose that v_{ni} obeys a random normal distribution. $u_{ni}\geq 0$ represents the inefficiency of reaction management. The two exist independently of each other. The parameters to be estimated in this paper are u_{ni}, β^n, σ^2 and so on.

Then, we use the software Frontier4.1 to perform SFA regression analysis to obtain β^n, σ^2, γ and other parameters, so as to further calculate the expected value of v_{ni} and u_{ni}. The calculation formula is as follows:

$$E\left(u_{ni}/v_{ni}+u_{ni}\right)=\frac{\gamma\sigma}{1+\gamma^2}\left(\frac{f\left(\gamma e_i\right)}{F\left(\gamma e_i\right)}+\gamma e_i\right) \tag{8}$$

$$E\left(v_{ni}/v_{ni}+u_{ni}\right)=S_{ni}-z_i\beta^n-E\left(u_{ni}//v_{ni}+u_{ni}\right) \tag{9}$$

Among them, $e_i=S_{ni}-f^n\left(z_i;\beta^n\right)$ represents the error, γ is the correlation coefficient of the slack variable, and $f\left(\gamma e_i\right)$ and $F\left(\gamma e_i\right)$ are the density function and distribution function of the standard normal distribution of γe.

(3) Adjust input variables

The estimated value of each parameter of the regression model calculated from the above steps and the adjustment of the input variable value are mainly for adjusting each decision-making unit to the same environmental condition. The formula is as follows:

$$X_{ni}^A=X_{ni}+\left[Max\left\{z_i,\hat{\beta}^n\right\}-z_i,\hat{\beta}^n\right]+\left[Max\left\{E\left(\hat{v}_{ni}/\hat{v}_{ni}+\hat{u}_{ni}\right)\right\}-EE\left(\hat{v}_{ni}/\hat{v}_{ni}+\hat{u}_{ni}\right)\right] \tag{10}$$

X_{ni}^A is the value of the n-th input variable of the i-th input index after adjustment, that is, the value of the input variable under the same environment.

1. The first stage: the traditional DEA model

The traditional DEA model mainly uses the BCC model with variable returns to scale for analysis, which is consistent with the principle of the basic DEA model introduced above. The basic principle is to select relevant data and use the input-output-oriented DEA. Perform efficiency calculations to obtain the relative technical efficiency value of the decision-making unit

2. The second stage: build a similar SFA model

The value of technical inefficiency in the first stage is caused by three factors: random factors, environmental factors, and management inefficiency. Then the slack variables and these three factors are analyzed, and the input items are adjusted. The purpose of adjustment is to adjust

The influence of the three factors that affect the difference value is eliminated, and the interference of these three factors on the input and output items is eliminated, so that the adjusted decision-making unit is in the same external environment and the same luck component.

3. The third stage: the adjusted DEA model

The adjusted input term and the original output term or the adjusted output term and the original input term are used to estimate the efficiency of DEA, which is still substituted into the variable reward model of the first stage, and the efficiency of each DMU is measured, and the technology obtained Efficiency is the efficiency value without environmental factors and random interference.

The high-tech industry production function is a typical multi-input and multi-output production function. Therefore, it is very difficult to calculate by simple linear function or empirical calculation. The method of parameter estimation is not only for the problem of multi-input and multi-output. Simplify the processing of complex issues, and at the same time process different data units, making data processing more flexible. There are various types of indicators for the input and output of high-tech industries, such as manpower indicators and sales. Income indicators, patent indicators, etc., are difficult to unify data units. Therefore, the DEA model has absolute advantages in parameter estimation. In the efficiency evaluation of the DEA model, the data results show the relative efficiency between the indicators rather than the absolute efficiency. Therefore, even if the efficiency is 1, it does not mean that there is no room for improvement.

In addition, the efficiency level of high-tech industries is affected by many factors. For example, the economic environment, social environment, and natural environment of each decision-making unit will have different impacts on the performance evaluation of high-tech industries. Therefore, three Stage DEA is to measure the efficiency of DMU by converting data into the same economic environment through a certain method.

4 RESEARCH ON PARTNER SELECTION OF PREFABRICATED CONSTRUCTION INDUSTRY CHAIN BASED ON SYSTEM DESIGN

This article believes that the construction supply chain can be understood as a functional network chain structure that transforms construction materials or services into intermediate products and final buildings through the mutual cooperation and collaborative work of different upstream and downstream companies, and delivers them to the final customer or owner. Among them, related companies such as designers, general contractors, subcontractors, and suppliers begin to control logistics, information flow, and capital flow from the project conceptual design or material procurement stage. Because building materials and intermediate products increase their value in the supply chain due to processes such as processing, packaging, and transportation, the construction supply chain is also a value chain that can bring more economic benefits and added value to enterprises. The schematic diagram of the construction supply chain structure is shown in Figure 1.

The IPD model is an integrated engineering project transaction model based on lean construction, full life cycle and integrated theme to maximize project benefits. It emphasizes the rational and maximum utilization of refined production and engineering resources, and reduces engineering costs to increase project value. Compared with the traditional "transactional" contract, the whole life cycle thinking makes the IPD model focus on the entire implementation process of the project, not just the construction results. Integration is the integration of teamwork in construction projects. By using the IPD exclusive contract to sign a multi-party cooperation agreement, all parties risk sharing and benefit sharing, maximizing the mutual use of information resources, so that the goals of all parties in the team tend to be consistent, and the project goals and collaborative management are jointly achieved, as shown in Figure 2.

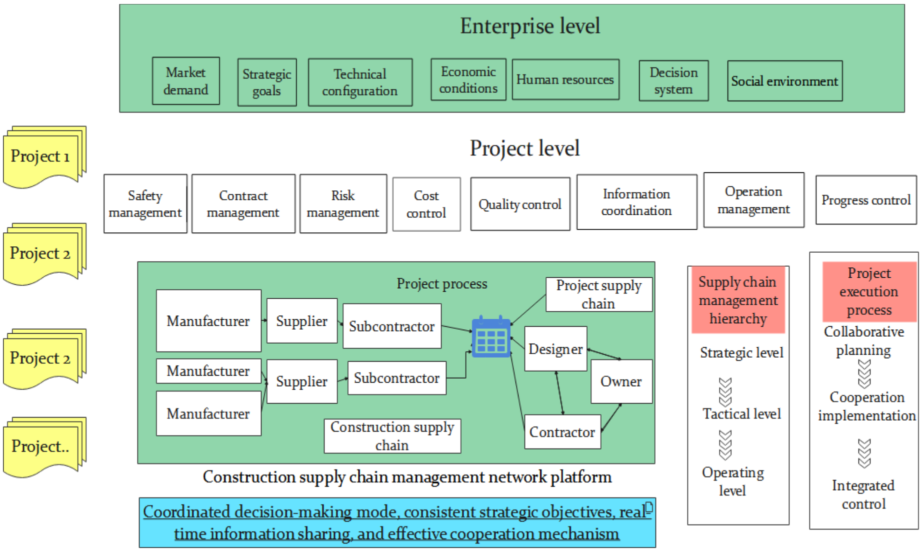

Figure 1: Schematic diagram of the prefabricated construction supply chain structure.

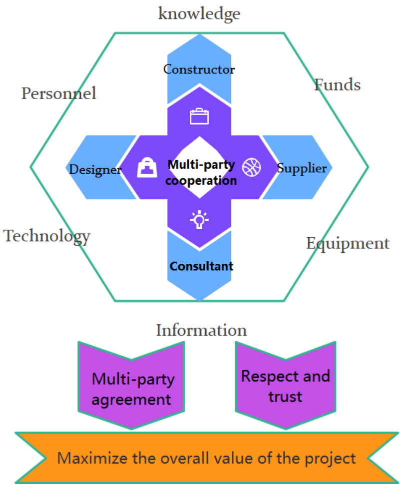

Figure 2: Conceptual diagram of IPD mode.

The construction of engineering projects has the characteristics of comprehensiveness, complexity, system, and huge communication and coordination workload. From the perspective of the participants, the construction supply chain is based on the project. In order to respond to the needs of the owner in a timely manner, the participants use BIM to share and interact with each other, carry out close cooperation and establish a project-based multi-party cooperation organization. From the perspective of information flow, the content of information exchange between participants in the construction supply chain is divided into cost, schedule, quality, and safety information according to project management objectives. BIM can integrate multiple information sources into an information comprehensive database, and provide the technical, economic, and management information needed in the operation of the construction supply chain.

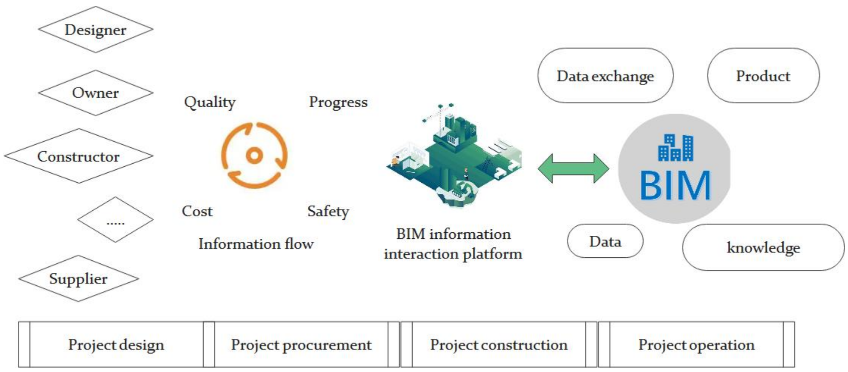

Figure 3: Conceptual model of the combination of construction supply chain and BIM.

At present, there is little research on the supply chain cooperation relationship in the AEC industry. Based on the development of supply chain theory, the E-R entity relationship model is used to describe the non-hierarchical supply chain network structure of the ACE industry, which reflects the contractual relationship and information exchange between supply chain participants in the network, as shown in Figure 4.

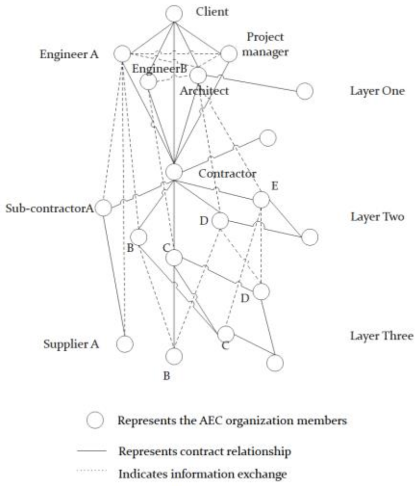

Figure 4: Supply chain network structure of the prefabricated construction industry.

Due to the complexity of the construction supply chain system, this paper combines B1M technology and supply chain management theory to analyze the contractual relationship and information interaction between the participants in the supply chain from the perspective of product-process model and organizational model, as shown in Figure 5 and Figure 6.

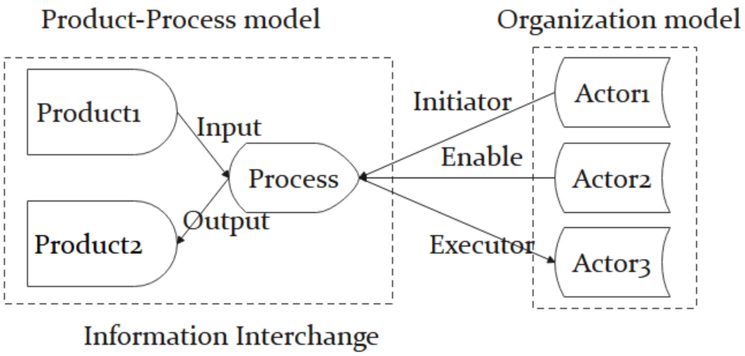

Figure 5: Conceptual model A.

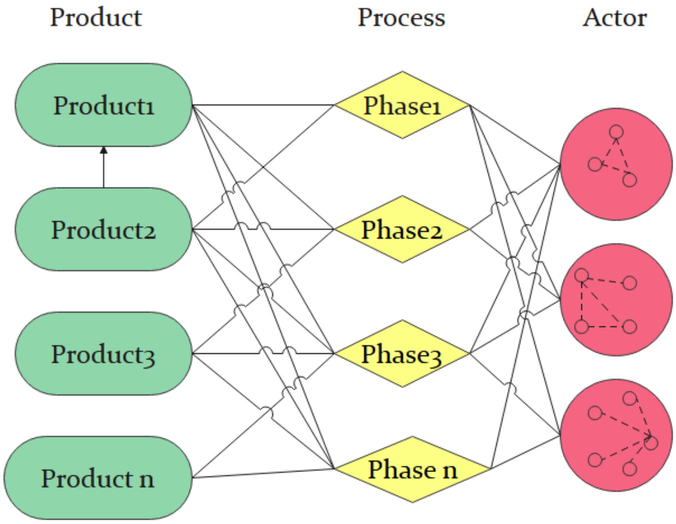

Figure 6: Conceptual model B.

The IPD contract is a kind of "relational" contract, which focuses more on the process, not just the result of the construction product, and is a powerful guarantee for the normal operation of the organizational relationship. Moreover, the IPD model contract embodies the restriction and cooperation relationship between the parties, and is a written document with legal effect. The organization has formulated a series of standard contract texts, which are suitable for the development of different types of cooperation under the IPD model, as shown in Figure 7.

Based on the management idea of the IPD model, the various participants in the construction supply chain take the project and contract relationship as the basis, and take the IPD project management team as the core and BIM technology as the cooperative management platform. Moreover, in compliance with the implementation principles of the IPD model, all parties use BIM technology for team collaboration such as timely model sharing, communication and exchange, and engineering task assignment. At the same time, all parties establish a cooperative network organization for the entire life cycle of the project to achieve collaborative work between the participants, as shown in Figure 8.

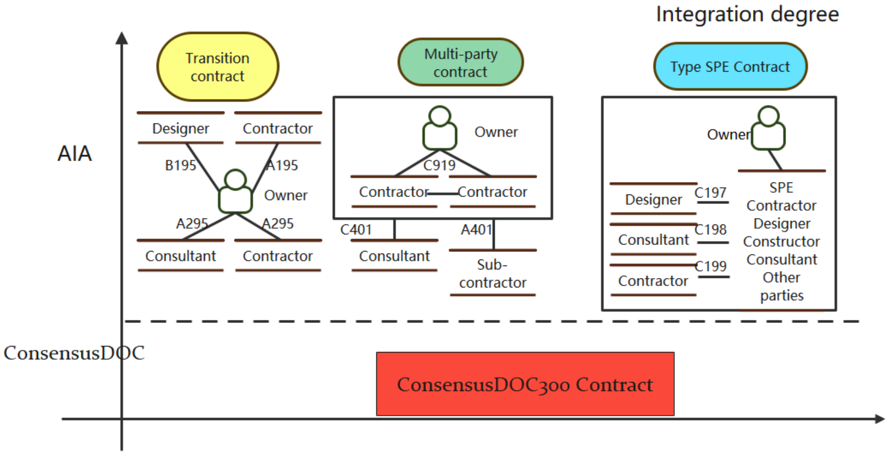

Figure 7: Standard contract text division under the IPD model.

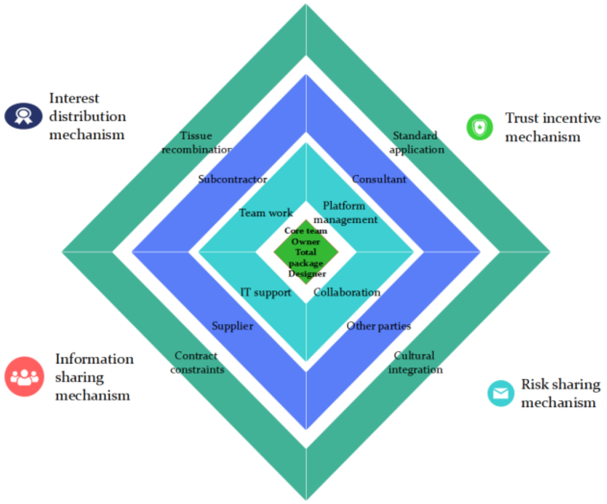

Figure 8: The collaborative work mode of construction project team members.

After constructing the model, this paper verifies the effect of the three-stage model through data research. Starting from the actual situation, this paper obtains a large amount of data through the Internet, and uses the model to process the data to verify the effect of the industry chain information processing and the evaluation of the effect of partner selection of the three-stage model of this paper. At the same time, this paper evaluates the effectiveness of the system constructed in this paper, and the final results are shown in Table 1.

Num ber	*Information processing*	*Partner selection*	*System reliability*	*Num ber*	*Information processing*	*Partner selection*	*System reliability*

1	*75.1*	*85.0*	*65.1*	*21*	*87.5*	*82.0*	*65.5*
2	*74.3*	*77.4*	*68.9*	*22*	*82.9*	*89.2*	*76.2*
3	*71.8*	*63.2*	*87.2*	*23*	*86.3*	*81.3*	*76.6*
4	*80.8*	*89.7*	*72.6*	*24*	*60.9*	*72.5*	*93.1*
5	*85.0*	*75.6*	*87.2*	*25*	*59.3*	*71.2*	*89.8*
6	*79.0*	*74.6*	*69.7*	*26*	*68.6*	*68.5*	*88.9*
7	*79.2*	*72.0*	*76.4*	*27*	*74.7*	*77.0*	*69.4*
8	*64.7*	*86.7*	*76.0*	*28*	*80.1*	*66.7*	*67.5*
9	*61.2*	*83.0*	*81.8*	*29*	*60.6*	*76.1*	*92.4*
10	*63.4*	*78.3*	*68.4*	*30*	*62.0*	*63.2*	*77.5*
11	*60.1*	*65.9*	*71.6*	*31*	*80.5*	*77.0*	*78.7*
12	*81.3*	*83.5*	*90.8*	*32*	*72.3*	*64.9*	*84.6*
13	*82.5*	*77.1*	*68.0*	*33*	*67.8*	*66.7*	*76.4*
14	*81.7*	*78.3*	*88.8*	*34*	*69.8*	*65.5*	*71.6*
15	*62.7*	*72.1*	*85.0*	*35*	*61.4*	*84.7*	*67.6*
16	*81.2*	*66.8*	*87.5*	*36*	*84.4*	*66.4*	*68.1*
17	*63.9*	*75.9*	*75.4*	*37*	*80.0*	*85.8*	*93.7*
18	*66.4*	*74.7*	*71.4*	*38*	*79.2*	*78.2*	*85.4*
19	*65.0*	*86.4*	*85.0*	*39*	*64.8*	*70.3*	*80.3*
20	*64.4*	*88.1*	*93.8*	*40*	*78.2*	*90.2*	*72.6*

Table 1: Statistical table of the test results of the three-stage model.

From the above experimental analysis, the three-stage model performs very well in terms of the effect of industrial chain information processing and the evaluation of the effect of partner selection. It is also verified that the three-stage model of partner selection of the prefabricated construction industry chain based on system design can help construction companies choose the right partner, and has a positive effect on the development of the entire prefabricated construction industry chain.

5 CONCLUSION

At present, experts and scholars do not have much research on the selection of prefabricated building partners, and most of them are concentrated in the field of traditional buildings. When studying real estate supply chain partners, an evaluation and selection model is constructed based on the learning and adaptability of intelligent computer algorithms, which can effectively improve the operational stability of the prefabricated construction industry chain. When conducting research on partner selection in construction supply chain, constructing a three-stage evaluation selection model based on data envelopment analysis is an important way to improve the partner selection mode of the prefabricated construction industry chain. On the whole, although traditional methods are effective in selecting partners, they also have some limitations such as complex calculations and strong subjectivity. As the prefabricated construction industry is a cross-industry, cross-enterprise, multi-level gray system, and the relationship between the various elements in the system is intricate, this paper obtains a three-stage model for partner selection in the prefabricated building industry chain based on the system design philosophy. Moreover, this paper analyzes the effect of this model to provide a more reliable tool for the subsequent selection of partners in the prefabricated construction industry chain.

Teng Yi, https://orcid.org/0009-0009-8754-6543

REFERENCES

[1] Basole, R. C.; Srinivasan, A.; Park, H.; Patel, S.: ecoxight: Discovery, exploration, and analysis of business ecosystems using interactive visualization, ACM Transactions on Management Information Systems (TMIS), 9(2), 2018, 1-26. https://doi.org/10.1145/3185047

[2] Daradkeh, M.: Critical success factors of enterprise data analytics and visualization ecosystem: an interview study, International Journal of Information Technology Project Management (IJITPM), 10(3), 2019, 34-55. https://doi.org/10.4018/IJITPM.2019070103

[3] Fadeyi, M. O.: The role of building information modeling (BIM) in delivering the sustainable building value, International Journal of Sustainable Built Environment, 6(2), 2017, 711-722. https://doi.org/10.1016/j.ijsbe.2017.08.003

[4] Fei, T.; Jiangfeng, C.; Qinglin, Q.; Zhang, M.; Zhang, H.; Fangyuan, S.: Digital twin-driven product design, manufacturing and service with big data, The International Journal of Advanced Manufacturing Technology, 94(9-12), 2018, 3563-3576. https://doi.org/10.1007/s00170-017-0233-1

[5] Jayakrishnan, M.; Mohamad, A. K.; Abdullah, A.: Journey of an Enterprise Architecture Development Approach in Malaysian Transportation Industry, Int. J. Eng. Adv. Technol, 8(4), 2019, 765-774.

[6] Kasemsap, K.: Knowledge discovery and data visualization: theories and perspectives, International Journal of Organizational and Collective Intelligence (IJOCI), 7(3), 2017, 56-69. https://doi.org/10.4018/IJOCI.2017070105

[7] Kim, Y. C.; Hong, W. H.; Park, J. W.; Cha, G. W.: An estimation framework for building information modeling (BIM)-based demolition waste by type, Waste Management & Research, 35(12), 2017, 1285-1295.https://doi.org/10.1177/0734242X17736381

[8] Kocakaya, M. N.: Building information management (BIM), a new approach to project management, Journal of sustainable construction materials and technologies, 4(1), 2019, 323-332. https://doi.org/10.29187/jscmt.2019.36

[9] Kuo, Y. H.; Kusiak, A.: From data to big data in production research: the past and future trends, International Journal of Production Research, 57(15-16), 2019, 4828-4853. https://doi.org/10.1080/00207543.2018.1443230

[10] Li, D.; Tang, H.; Wang, S.; Liu, C.: A big data enabled load-balancing control for smart manufacturing of Industry 4.0, Cluster Computing, 20(2), 2017, 1855-1864. https://doi.org/10.1007/s10586-017-0852-1

[11] Mandičák, T.; Mesároš, P.; Tkáč, M.: Impact of management decisions based on managerial competencies and skills developed trough BIM technology on performance of construction enterprises, Pollack Periodica, 13(3), 2018, 131-140. https://doi.org/10.1556/606.2018.13.3.13

[12] Okakpu, A.; Ghaffarian Hoseini, A.; Tookey, J.; Haar, J.; Ghaffarianhoseini, A.; Rehman, A.: A proposed framework to investigate effective BIM adoption for refurbishment of building projects, Architectural Science Review, 61(6), 2018, 467-479. https://doi.org/10.1080/00038628.2018.1522585

[13] Qin, X.; Shi, Y.; Lyu, K.; Mo, Y.: Using a TAM-TOE model to explore factors of Building Information Modelling (BIM) adoption in the construction industry, Journal of Civil Engineering and Management, 26(3), 2020, 259-277. https://doi.org/10.3846/jcem.2020.12176

[14] Shaw, S.; Rowland, Z.; Machova, V.: Internet of Things Smart Devices, Sustainable Industrial Big Data, and Artificial Intelligence-based Decision-Making Algorithms in Cyber-Physical

System-based Manufacturing, Economics, Management and Financial Markets, 16(2), 2021, 106-116. https://doi.org/10.22381/emfm16220217

[15] Ustinovichius, L.; Popov, V.; Cepurnaite, J.; Vilutienė, T.; Samofalov, M.; & Miedziałowski, C.: BIM-based process management model for building design and refurbishment, Archives of Civil and Mechanical Engineering, 18(4), 2018, 1136-1149. https://doi.org/10.1016/j.acme.2018.02.004

[16] Ustinovičius, L.; Puzinas, A.; Starynina, J.; Vaišnoras, M.; Černiavskaja, O.; Kontrimovičius, R.: Challenges of BIM technology application in project planning, Engineering Management in Production and Services, 10(2), 2018, 15-28. https://doi.org/10.2478/emj-2018-0008

[17] Wang, X.; Dong, Y.; Chen, M.; Su, F.; Ling, L.: Research on Real-time Temperature Control Method for Multi-Visualization of Hot Runner System Based on Internet of Things, Journal of Applied Science and Engineering, 22(4), 2019, 683-690.

[18] Wei, T.; Chen, Y.: Green building design based on BIM and value engineering, Journal of Ambient Intelligence and Humanized Computing, 11(9), 2020, 3699-3706. https://doi.org/10.1007/s12652-019-01556-z

[19] Xu, T.; Song, G.; Yang, Y.; Ge, P. X.; Tang, L. X.: Visualization and simulation of steel metallurgy processes, International Journal of Minerals, Metallurgy and Materials, 28(8), 2021, 1387-1396. https://doi.org/10.1007/s12613-021-2283-5