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Econometric analysis on BIM contract mode choosing strategy for construction project

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Abstract. BIM technology provides huge progress for construction in theory, but its application on specific project still needs more research in practice. Therefore, this paper conducts econometric analysis on contract modes of different procurement model with BIM technology to make a better strategy for construction. By summarizing the influence factors of the purchase mode selection of the construction project with BIM technology in practice both domestic and international, three econometric models of BIM contract strategy enjoy different advantages and disadvantages for construction planning. And then puts forward the development strategy of the three stages of procurement model for BIM construction project at the national level.

Key words. BIM, procurement model, strategy choosing, construction project.

1. Introduction

BIM technology will rely on various types of information in the whole life period of the construction project, emphasizing the integration and assistance of the various processes of the construction project. The further application of BIM technology can further promote the construction of the project to higher network integration. Combined with the requirements of BIM technology, according to Hall three-dimensional structure model, the integration of construction project procurement mode can be divided into process integration, organization integration and information integration. Therefore, BIM-based construction project procurement model should be able to achieve the construction project throughout the lifecycle of the various stages of the objectives, organization and information integration, creating a more extensive integration, coordinating of construction project system objectives, external resources and internal resources of the information flow network.

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2. Comparison of existing procurement models

There are differences in the contract structure and coordination relationship between the traditional procurement model, the management procurement model and the general contracting procurement model. These models could be more clearly described as below, according to contracts on legal view:

$$\begin{cases} \dot{z}_i = z_{i+1},\ 1 \le i \le n-1 \\ \dot{z}_n = F(Z(t)) \end{cases} \tag{1}$$

Where $Z(t) = \begin{bmatrix} z_1(t) & z_2(t) & \cdots & z_n(t) \end{bmatrix}^T$ is state vector. It is assumed that the scalar function $F(Z(t))$ is satisified the global Lipschitz condition. That is,

$$|F(Z(t))| < \rho_0 + \sum_{i=1}^{n} \rho_i |z_i| \tag{2}$$

$$s(t) = e_n(t) + \int_0^t \sum_{i=1}^{n} c_i e_i(\tau) d\tau \tag{3}$$

Where C describes the contract parties and details for the whole project: in which, MC is the individual third party to managing the project, DB Contractor is the contractor in charge of the whole project implementation, and Subcontractor is the actual construction implementation parties. Different purchasing models all have their own characteristics and advantages and disadvantages [1]. The biggest feature of the traditional procurement model is the separation of each production stage, contracts and responsibilities clear interface, easy to define the rights and obligations of the parties, but the integration is not high, with poor information transmission [2]. The management of purchasing mode is based on the traditional purchasing mode on the introduction of the third party as the project manager, the third party is the link information between the various participants, the third party project management ability and experience decides the success or failure of construction projects. Its integration is higher than the traditional procurement model. The integration of the general contracted procurement model is relatively high, which can realize the integrated management of some stages of construction and production activities. The following will be from the process integration, organizational integration, contract system, information exchange, BIM technology integration and other aspects of comparison [3].

2.1. Traditional purchase model

According to (1), the traditional purchase model of constructing project goes by the construction flow with separate contracts one after another. In strict accordance with the order of design - construction - bidding, the work of each stage is separated from each other, only the last stage of the work is over to carry out the next phase of the work, the project implementation process integration is low [4].The owners and the participants signed a series of independent or related contracts with a rela-

tively mature standard model contract, but the relationship between these contracts always keeps poor correlation with each other. Owners will design and construction work subcontracting to multiple units, the project organization interface, vertical organization for the level of relationship, with strong leadership, horizontal association between the poor, strong inter-organizational, cooperative relationship is poor. The exchange of information between the parties must be carried out by the owners, in 2D written communication, there is a lot of information loss and poor communication problems [5]. For integrated management level is low in this mode, the application of BIM technology remains a big obstacle.

2.2. Management procurement model

According to (2), the management procurement model adopts a "third party" to manage the whole project without the chronological development concern. We use CM as the representative of this "third party" for simplification and comparison. This professional management party not only takes part in communication and coordination among each purchase phases, and also is responsible for coordinating the relationship between the owner, the designer and the contractor. Effective implementation of the various stages of effective work, and promote the design phase and construction phase of communication and exchange. As with traditional procurement, it is a certain correlation of the contract between the organizations, the third party is the link between the owners, designers and contractors. Independent "third party" in the design stage to provide consulting services for the project, in the construction phase to provide management services, so the organization interface less, the use of matrix structure, more efficient. Participants are based on cooperation within the scope of the contract, but there is an independent "third party" in the communication and coordination between the parties, the information transmission more smooth. This model compared with the traditional procurement model, the management of a high degree of integration, and BIM technology can achieve a certain degree of integration [6].

2.3. General contracting procurement model

According to (3), the general contracting procurement model liberates owner from the complex construction process, while the general contractor could manage highly integrated complementation with other parties. The main work of design and construction is basically done by the same contractor, can realize the conditional edge design, construction side, the project implementation process integration is higher. The owners are only one contract party on behalf, which means, DB contractors and owners have the design capability of the contract alone, or design and construction side to combine the identity of contract with the owners, shared responsibility and obligation in the process of design and construction. DB contractor as the project leader shall be responsible for the unified management of the various stages of the construction process and the parties involved in the project. The subcontractor may be present in the project, but the owner will only negotiate with

the DB contractor. The owner shall exchange information with the DB contractor, the design and construction shall be completed by the same DB contractor, and the information exchange shall be smooth. It is highly integrated with BIM technology, strong adaptability, but difficult [7]. By comparison, three main types of procurement for construction projects each have their own characteristics, overall, the General Contracting mode of high integration and information transfer smoothly, but not essentially changing patterns of production process, there are still some loss of information [8].

3. Owner's choice based on BIM construction project procurement mode

The direct economic benefits of BIM technology are reflected in the integrated management of construction projects, improve the construction efficiency and realize the win-win situation of the participants, and the realization of economic efficiency is dependent on BIM technology of information processing and management ability. Therefore, the choice of BIM-based construction project procurement model should for the full application of BIM provide support for organizational integration, information integration, goal management, contracts and so on [9].

3.1. Influencing Factors of Owner's Choice by the purchase mode of the construction project based on BIM

Any construction project procurement model has its own characteristics and limitations, the uniqueness of the construction projects and the degree of understanding of the participants on the BIM determines the procurement model used for each project is not the same. Owners in the choice of BIM-based construction project procurement model, it should be combined with the characteristics of the project itself and the characteristics of the participants, taking full account of the construction project procurement model and BIM integration and BIM technology in construction project implementation risks. Therefore, the influencing factors of BIM-based construction project procurement model can be summarized as the attributes of BIM construction project, BIM technology application depth and breadth, project management objectives, BIM technology implementation environment and BIM implementation risk factors. Then, these five key factors are explained separately in detail on the following part:

3.1.1. Application of BIM's construction project attributes The attributes of the project mainly consider the complexity of the construction project, construction scale and investment type. It is one of the most important advantages of BIM technology to build a multi - dimension and multi - dimensional information model, which can help the project management to understand the design of the project, as well as the problems such as fault, leakage, collision and shortage. When the construction project based on BIM is not complex, and the scale is small, the traditional purchasing mode can be considered to reduce the investment risk; If the owner has

a higher time limit for the project, and the requirements of the implementation of the fast path, can consider the management of procurement models, such as CM procurement model; When the design of the project is more complex or the scale of construction is large, can consider application the fit of procurement model and BIM, such as DB procurement mode [10].

3.1.2. Depth and breadth of BIM application A single application of BIM technology in construction project or a phase of the project application, could be green energy analysis, collision check, according to the characteristics of the construction project itself to choose the appropriate procurement model. BIM technology is not particularly high in the single function of BIM or when it is applied at a certain stage. Each participant can solve the application problem of BIM in construction project through mutual coordination, which is precisely the current BIM in the traditional procurement model of the application does not appear "acclimatized" the main reason. The application of BIM technology in the design and construction stage can consider the DB purchasing mode with high integration degree. The project operation phase of BIM application requires the project manager to provide the BIM model of the whole process stage of the construction project. It can consider the EPC procurement mode or the DB procurement mode. The application of the BIM technology should be dominated by the owner, which is convenient for the operation of the BIM application and management. Of course, the application of BIM in the whole life cycle of construction project, and IPD procurement model is the most appropriate. But given the domestic construction engineering areas of the management capacity, cooperation and contract model text and other issues, IPD procurement model are not be recommended for using in the primary stage of the application of BIM [11].

3.1.3. Construction project management objectives based on BIM The main objectives of project management include project cost, duration, quality and information model requirements. The cost control of the BIM project should consider not only the cost factors of the construction project itself, but also the purchase cost concerning the BIM application, such as software cost, personnel training cost, BIM expert consultation and hiring costs, which may greatly influence the economic benefit of the whole project. Management procurement model and general contracting procurement model could achieve the integration of several stages of construction projects to a certain extent. It is conducive to the realization of BIM application goals, which will help shorten the duration and improve efficiency

3.1.4. Environmental factors for BIM implementation BIM implementation of environmental factors mainly refer to: the government level of law, technical support, BIM software maturity, BIM standards, benefits of BIM implementation benefits, the construction enterprises to understand the concept of BIM and fitness and market competition. With government support given full play to BIM advantage, the introduction of national standards can effectively prompted the owner to select higher integration of procurement models, to improve economic efficiency.

3.1.5. Risk factors for BIM implementation Choosing a BIM-based construction project procurement model, the owner should also consider the risk of BIM's integration with the various procurement models when considering the risks of the BIM technology itself. These risks may come from technology, human resources, capital, industry standards, etc. Whether the participants in the construction project are willing to take the above risks is also one of the considerations for the owners to choose the procurement model for construction projects.

3.2. The owner's selection strategy of the construction project procurement mode based on BIM

After the combination of the above five factors, the owners in the choice of BIM-based construction project procurement model, according to the following recommendations: During the selection on project procurement model, firstly the basic properties of the project should be considered. If a large public investment projects belong to the government, and the local government for the use of BIM technology support for large, DB purchasing mode could be a good choice, for BIM could play a sufficient role in the project life cycle. BIM technology in a certain stage of the construction project, or a single application of the function of BIM, according to the characteristics of construction projects, project objectives management requirements and the owner of the project management capacity to select the appropriate procurement model, for BIM Less consideration. If the application of BIM technology in the design and construction stage, and its application of more in-depth, it is recommended with the integration of higher DB procurement model. As lacking of CM procurement model in the domestic application of less, and there is no corresponding demonstration text, it is not recommended to use CM procurement model. According to the technical difficulty of the project and the strength of the BIM, the owner can choose the purchasing models. At present, the application of BIM technology in our country is mainly focused on the design units and consulting units, which can choose the DB purchasing mode and the EPC purchasing mode, give full play to the advantage of the design unit. If the owner of the BIM based construction projects lack of practice, can enter into a strategic cooperation agreement with the BIM consulting unit, BIM consulting unit for the owners to provide BIM consulting services, as the T2 terminal project of Xiantao National Airport, Shenyang. In accordance with the relevant provisions of the law, and all aspects of construction projects basically go through the bidding process, owners partners is not determined in advance the future units. Therefore, before choosing the appropriate procurement model, the owner should choose the appropriate purchasing mode according to the industry reputation of potential partners, previous experience of cooperation, project management strength, the ability of BIM technology application and other factors. To sum up, for the application of BIM technology construction projects, in the procurement model selection, the owners consider the project attributes, project characteristics, BIM technology, the characteristics of potential partners and other factors. Only the balance of the factors can choose a suitable for a specific BIM-based construction projects procurement model.

4. Research on the Strategy of National Development BIM - based Construction Project Procurement Model

BIM technology in the domestic application development is still in its infancy, and the lag of the BIM standard and the localization of software development, hinder the development of BIM technology in china. However, with the development of BIM technology and its application in depth, the existing construction project procurement model diversity cannot meet the requirements of BIM technology. Many scholars at home and abroad believe that IPD procurement model can give full play to the function and advantages of BIM. The application of BIM in IPD procurement model, in its basic framework, it can achieve the construction project life cycle of BIM applications. The implementation of IPD purchasing mode is the key to success in the construction project implementation of the early establishment of a highly collaborative project team to achieve project early intervention, the parties involved in the risk sharing, benefit sharing and lean construction etc. At present, however, the construction market is in the buyer's market. The antagonistic relationship between the various participants of the construction project, poor cooperation and exchanges between the parties, so it is difficult to realize the cooperation among the participants, the risk share, the benefit sharing and other requirements. Therefore, the development of China's construction project procurement model based on BIM must be phased. The contract structure of IPD procurement model promulgated by AIA Association has reference significance for our country. The biggest characteristics of IPD purchase mode is the sharing of risk quintal and benefit, and it is built on the basis of mutual trust between the participants. While the domestic construction market is in the buyer's market, the interests of the owners, designers and contractors in the opposite relationship. The mutual trust between the parties needs long-term cooperation and running in, therefore, the implementation of IPD procurement model should be carried out in stages. AIA Association of the three IPD procurement model for China to promote the development of IPD provides a good reference.

4.1. The first stage: the transition from the traditional purchasing mode to the IPD purchasing mode

In this procurement model, the owners, designers and contractors to set up a cooperative team, the cooperation team throughout the project design and construction of the whole process. The team was established by the owner and the contractor and the design of the corresponding design contract and construction contract, and the relationship between the contractor and the contractor is established through the IPD cooperation agreement. IPD cooperation agreement in detail the provisions of the design and contractor in the construction of the entire project in the process of the relationship between the rights and obligations, and the application of the depth and breadth of BIM, the parties to build BIM model content and the use of the model permissions. Take the traditional contractual relationship of IPAD given by AIA Association as an example. The specific operation is: first of all, the owners and designers according to B195 and A295 signed a design contract.

The contract specifies that the designer has the obligation to assist the owner to list the potential contractor in order to complete the project. Secondly, select the potential contractor before bidding, and determine the highest price in the bidding process. The price is directly filled in the contract terms of A195 and A295. In the detailed design phase, the designer reviews the design document with the owner and the contractor. In addition, the architect is responsible for the integration and coordination of the model data provided by contractors, design consultants and subcontractors. Major decisions need to be approved by the owners, major decisions include: project planning, progress, price, etc., but these are content should be coordination and communication with the designer and contractor. The traditional procurement model to over IPD model, is based on the concept of IPD to improve the traditional procurement model, The risk allocation is similar to that of traditional purchasing mode, and the respective risk liability is stated in the agreement or contract. And in this procurement model is used to ensure the highest price pricing model. As for the contractor, the only risk is the actual construction cost exceeds the guaranteed maximum price, and the owner assumes the major risk. For larger construction projects, the owner can transfer some of the risk by purchasing insurance. At this stage, the main responsibilities of the relevant departments in China is to launch the BIM application contract and traditional contract cooperation text structure based on the IPD agreement as soon as possible, and gradually establish the concept of Ideological and collaborative work between owners and contractors, design, lay the foundation for the promotion of the two stage of the IPD purchasing mode.

4.2. The second stage: IPD procurement model under multi party cooperation agreement

The owners, designers and contractors or more parties to participate in the signing of a multi-party agreement, the formation of multi collaborative work environment, to achieve the goal of the contractor and even more participants to participate in the early. IPD procurement model under the multi-party agreement can really achieve the "risk of public use," the concept of IPD. The main management of the project under this mode of procurement is done by the project management team, which is composed of a representative of each participant. The implementation team of the project is also composed of representatives of the parties to complete the project management and supervision. In this collaborative model, will create a high quality of the owners, and seek the interests of all parties to maximize. Take the contract of the IPD multi-party agreement given by the AIA Association as an example. In the IPD model under the multi-party agreement, according to C191, the owner, the designer, the contractor or other major project participants sign a multi-party agreement to complete the design, construction and operation of the project. The multi-party agreement provides a framework for the cooperation of the parties, in which the parties have completed the objectives of the project. The interests of non-owners are compensated by the "Cost-of-the-Work" model. The compensation model is goal oriented, and provides a collaborative incentive mechanism in the design and construction stage of construction projects. In the aspect

of risk management, according to the C191 multilateral agreement, the agreement of multi participant shall establish a risk matrix according to the actual situation of the project and protocol requirements, risk allocation by risk matrix, but risk matrix does not constitute a part of the contract documents. In addition, C191 also maintains the tradition of "liability immunity" in the AIA contract text, and C191 rules: except the situation of one party intentional act or breach of contract specific obligations listed, each party should give up on the other side of the responsibility. In addition, through the principle of mutual compensation, the risk will be further allocated to the participants. "Mutual compensation principle" refers to the parties involved in the C191 contract should be compensated due to for one's own negligence or omission caused to another party due to claims, damages, losses and personal injury or property loss. The key to the success of the IPD procurement model under the multi-party agreement is the drafting of multi-party agreement, AIA Association in addition to the standard form of multi-party agreement, but also released a lot of attachments to supplement multi-party agreement.

4.3. The third stage: IPD procurement model under single objective entity

The IPD procurement model under a single objective entity is still based on the contract text presented by the AIA Association. According to Article 8 of C195, the owners, design companies and construction management companies jointly set up a limited liability company (LLC Liability Company, LLC), LLC company management by the members of the management committee. Each of the owners, design firms and construction companies may appoint at least one representative as a member of the management committee, but the members of the committee must be odd, and the owner's representative is at least one more than any other non-owner's representative, and on behalf of the owners selected a person as the chairman of the management Committee. The decision of the management committee must be unanimously approved, but can be excluded by a majority vote of the matters stated in the agreement. In addition, the LLC Company set up a project management team, responsible for the overall planning, design and construction activities. The project management team is authorized by the project decision maker. The project management team may include non LLC members, but they can only serve as project consultants. The regular meeting of the Group at least once a week, and all decisions shall be adopted by consensus. If agreement cannot be reached, then entered the dispute adjudication procedure.

5. Conclusion

The change of the construction project procurement mode is reflected by the change of the structure of the construction contract. This change of the contract structure is reflected by the change of the structure and content of the contract text. In different development stages of the construction project procurement model based on BIM, there should be corresponding construction project contract text.

According to the development strategy of the national level based on BIM, this paper puts forward suggestions on the model choice and also development of BIM based construction contract text. In the future, more empirical study with survey data could be carried out to achieve further investigation on BIM application study.

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