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The Game Model of Cost Risk Management for "Giant Project" under Asymmetry Information

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Abstract

In the construction process of the giant project, because of each participant's asymmetric and incomplete information and their pursuit of maximum interests, etc., the risk of cost control exists in the process of management. This article focuses on the owners facing cost management risk in the construction process of GB. First, it analyzes the behavior of the each project participant, and then constructs the game model among the three main stakeholders including project (engineering) Management Company, the project contractor and the owner in the control of the cost management, for further analysis. Finally, it puts forward relevant strategies for preventing the collusion between project (engineering) management company and the project contractor. The results of the research show that the game model construction of the cost risk management for giant project under the Asymmetry Information, provides not only the quantitative basis for the owner's cost risk control, and also the useful reference for the decision-making of giant project organization and management.

Keywords: *asymmetric information, Giant Project, cost management, game model*

1. Introduction

In China, with the development of the social economy, science and technology, a lot of issues of global significance and great strategic influence props up, such as sustainable development. Because of the China's vast territory, there has been a general trend of projects with large scale recent years, such as the "giant" projects of energy, water conservancy, transportation, national defense construction, ecological environment, ship, high-tech, and so on. It indicates that the difficulty, global participation and influence are increasing in China's major projects construction. It has been proved that the healthy, stable and sustainable development of national economy could only be guaranteed by the successful construction of the giant projects ensures to make contributions to the world economy and human progress.

Giant project is an objective thing in the field of engineering discipline, and belongs to one of the engineering categories. The so-called "giant project" refers to the large engineering projects that can have a significant impact on the regional, national and global economy, and decisive significance to the national defense construction, major science and technology exploration, social stability, environmental protection and major historical events [1]. Therefore giant project is a major one, but the major project might not be a giant one. Giant project mainly has the following features: firstly, the giant project targets the pursuit of the long-term social and economic development, so it might not be always profitable with the government as the main body of investment. Secondly, giant projects usually draws on public funds, and the scale of investment is as large as one billion or tens billions. Thirdly, there are a large number of the participants and pluralistic professional technologies involved [2].

However, in the process of giant project construction, because of each participant's asymmetric and incomplete information and their pursuit of maximum interests, *etc.*, which

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renders the contracts of giant project to be incomplete, unable to be accurately identified the relationship of rights and obligations among three parties. So the whole process of its project management entails various risks: the project (engineering) management company and the project contractor become accomplices privately; the construction company makes false design changes and higher price offer for the visa *etc.*, which gives rise to "three excesses" including the budgetary estimate exceeds the estimate, the budget exceeding the budget estimate, the actual budget exceeding the budget.

The reasons for these risks are not only about the unregulated the construction market currently and the related imperfect regulations, but also about the inconsistent interest in the process of the project contract performed and the moral risk. If these problems are not solved, the giant projects construction could not only cause the investors more loss, and may endanger the quality of the giant project construction and each project participant's long-term interests.

Based on this, how to analyze the giant project subjects using the game theories and how to prevent the risk in the process of cost management have become an important component for the project integration management mode. In the process of the giant project's construction, because each participator has the characteristics of the asymmetric, incomplete information and the pursuit of maximum interests *etc.*, the cost control risk exists in the process of management. This article focuses on the cost management risk, which the giant projects' owners face in construction process. First, it analyzes the project participators' behavior, then constructs the three party game model about the three major stakeholders which are the project (engineering) management company, the project contracting company and the owners, and carrying out analysis, finally putting forward the coping strategies for the prevention of the collusion behavior between project (engineering) management company and the project contracting company. The results of the Research show that, under the asymmetric information, the construction of the game model about giant project cost risk management, it provides the owner with quantitative basis for the cost risk control, but also provides the useful reference for the decision-making of the giant project organization and management [3].

2. The Relationship among the Three Parties Including the Owner, Project (Engineering) Management Company and the Project Contracting Company of Giant Project

Based on the intrinsic feature of giant project like specialty, large-scale and complexity *etc.*, the government, as the main investment body, does not have the ability to complete the giant project management independently. The government usually adopts the entrusted agency model. The government entrusts the giant project management to the professional project management company (engineering) which manages the whole process including the feasibility study, investment and financing, supervision, construction, application *etc.*, and make sure giant project is completed smoothly.

In the construction process of the giant project, the usual practice is this: government sets up a legal company as owners; according to the requirements of the contract, the owner selects project (engineering) management company, which is responsible for the whole management process of the giant project; the project (engineering) management company signs a contract with the owner on the giant project management and accepts the supervision of the owner; the construction company makes the giant project constructed according to the contract and accept the supervision of the project (engineering) management company; the service unit will complete and operate project, so as to realize the separation of the functions

of government investment, investment management, project management, project construction and project operation.

There are more subjects of the giant project, including a variety of domestic and international government organizations, people's organizations, financial institutions, project owner, contractor, and supplier *etc.*, In these subjects, the relationship of the three parties which are the owners, the project (engineering) management company and the project contractor is more prominent and important. There relationship can be shown in Figure 1. (Note: the double arrow represents the relationship of the contract; the single arrow represents the supervisory relationship) [4].

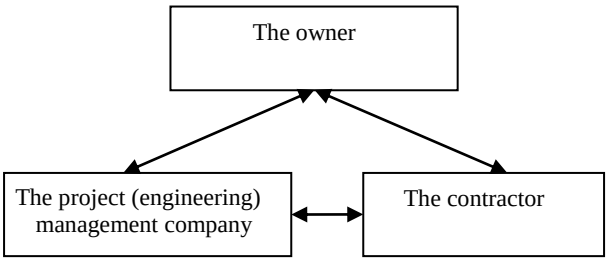

Figure 1. The Relationship of the Owners, the Project (Engineering) Management Company and the Project Contractor

3. The Framework of the Game Model for the Giant Project's Cost Risk Management

Game theory is also known as "countermeasure theory" or "competition game theory", and is the standard analysis tool of economics. It refers to individuals or organizations, makes selections and implements it according to their behaviors or strategy and obtains the corresponding results or yield profits respectively in face of certain environmental conditions and constraints of certain rules, relying on the available information [5].

Game theory has existed since ancient times, Sun Zi is not only a military works, but also a first game theory books in ancient China. Initially, game theory is mainly applied to research the victory or defeat of the chess, bridge and gambling, and the game situation is known on the experience level, not on the theory level. Hungarian mathematician, von Neumann founded the modern game theory in the 1920s, announcing the birth of the game theory formally. In 1944, Von Neumann collaborated with the economist, Oskar Morgenstern on the book of the theory of games and economic behavior and published it, while promoted the two persons game to the N persons game and applied the game theory system in the economic field, establishing its foundation of discipline and theoretical system.

Presently, Game theory has wide applications in biology, economics, international relations, computer science, political science, military strategy, and many other disciplines. In real life, we can use the game theory to explain almost all the problems. The fundamental principle of game theory is: about the no cooperative and perfect competitive game, just as the two men playing chess, one person wins one means that another person will lose one, in which the net profit is zero. We transform the chess into the game. If we know the set of participants (two parties), the set of strategy (all moves) and profit (the wining chess and the losing chess), whether or not and how to find a theoretical "solutions" or "balance". It is also the specific strategies which are the most "reasonable" and "optimal" for the two participators. Using the criterion for the traditional determinism "Maximum and minimum", namely, each side of the game all hypothesize that all strategies from the other side have the

fundamental aim to make the loss of the opposite side the most, and thus optimize their own countermeasures. Using a certain linear calculation, we are able to find a "minimal and maximal solutions" for every two-person zero-sum game and could finally make each other reach the maximum profit and balance [6].

In giant project management, as the bidding company, the owner commission the contractor to exercise the power of the project construction, and commission the project (engineering) management company as the agent carrying out the right for the whole process management of the project. However, once the project (engineering) management company as an exercising power of supervision independently enters into collusion with the contractor, it will bring the investment risks for the owners and bring the economic loss for the country.

Game theory researches on the decision-making, which is made when the behaviors of the decision group is interacted directly, and the research on the problem of the decision-making balanced. It offers a general mathematical method, which is used to analyze the situation of two or more participants involved and the decision affecting the welfare between the participants. It formed the foundation for applying the game theory to analyze the cost risks management of the giant project. The risk for the giant project's cost management is problem-oriented, with game theory as the guide of methodology, the cost management of giant project as the "normative ", and game theory as the "positive".

The framework for applying giant project on the research of the giant project's cost risk management is: when the cost risk of the owners occurs, the owner plays the leading role for decision-making of the cost risk and should take the corresponding measures to deal with the risk. We apply the game theory on the cost management of the giant project. It evolved into the rational players (the participant) selecting strategies themselves for the sake of maximizing their interests (make the project cost be most beneficial to themselves) and make the strategy achieve a balance (the final result of the project cost management). This includes the necessary factors constituting game theory, the factors are: participants (each project participant), action (each party carrying out the work for cost management), information, strategy (the strategy for maximizing benefit have been taken and will be taken), payment, results and equilibrium [7].

4. The Construction and Analysis of the Game Model for Giant Project about the Three Parties' Cost Risk Management under Incomplete Information

From the perspective of information economics, information asymmetry induces opportunistic behavior. Namely, the problems of adverse selection and moral risk are the main reason that causes the confused order of China's construction market and the nonstandard behavior of the market participants and thus result in the loss of credit in the construction market [8].

4.1. The Classification of the Information Asymmetry in the Project Construction Process

Information asymmetry is the distribution of knowledge or probability about certain events distributed asymmetrically among the corresponding economic persons. The asymmetric theory is the important content of microeconomics which can be used to handle the impacts and the resulting market operation efficiency in the information market brought by related information being distributed differently to transaction parties. The asymmetric distribution of information is suitable in any main market body, the construction market being no exception.

The information asymmetry is mainly divided into the following categories in the project construction process.

4.1.1. The Information Asymmetry Between the Owner and the Contractor: The information asymmetry between the owner and the contractor mainly has the following two processes. In the bidding process, the contractor may deliberately hide their private information, and provide false information to the owner, thereby obtaining the advantageous position in the contract, which easily cause the problem of adverse selection. In the construction process, namely after both sides signing a contract, if the building unit doesn't implement the effective supervision of behaviors of the contractor, the real behavior information can't be obtained from the owner. If the relevant incentive and restraint mechanism is not perfect, the contractor may use their own advantages of information resources and take the behavior benefiting them. Thus the interest of the owner will be damaged, thereby resulting in the risk of moral hazard.

4.1.2. The information asymmetry between the owner and the supervisor: The information asymmetry between the owner and the supervisor also mainly exists in the process of bidding and construction process. In the bidding process, the problem of adverse selection is easily to be caused. In the construction process, due to the supervision mechanism, the power of the owner's supervision is empty. As a result, the supervisor probably hurt the interest of the contractor by using the advantage of their own information resources, thereby generating the problem of moral risk [9].

4.1.3. The Information Asymmetry Between the Owner (The Contractor) and the Supplier: If the materials and equipment are provided by the owner agreed in the contract, the problems of adverse selection and moral hazard also exist because of the asymmetric information between the owner and the materials (equipment) supplier. If the contract agrees that the owner only provide the equipment and the contractor is responsible for the procurement of materials, the problems of adverse selection and moral hazard also exist brought by the asymmetric information between the owner and the equipment supplier and between the contractor and the materials supplier.

4.1.4. The Information Asymmetry Between the Supervisor and the Contractor: The information between the supervisor and the contractor is also asymmetric from the angle of information economics. In the construction market, the supervisor as the agent of the owner, the relationship between the supervisor and the contractor is supervising and being supervised. In general, the supervisor is familiar with the construction of the building products, but they don't know enough such information as to management, technology, capacity, the degree of subjective effort, and the contractor whether to choose the action in conformity with the owner's goal. Consequently, the problem of the information asymmetry exists between both sides because of incomplete information [10].

In the construction process of giant project, the owner, the main body and the contractor, the constructors have less information in the cost control. While the project (engineering) management company, as the agent, grasp more information relative to the owners, due to the comprehensive regulation for the project. In the process of the giant project construction, the information model is shown in Figure 2.

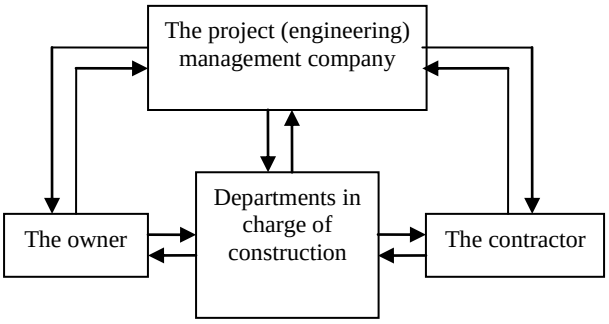

Figure 2. The Information Model in the Process of the Giant Project Construction

Under the condition of asymmetry information among the three parties, in terms of the risk in the cost management of the giant project, how to use the game theory to analyze and solve the problems, how to find optimal solutions for the abstract mathematics problem as the reality induced, so as to provides possibility for guiding practice in theory? The following will use the game theory, and project (engineering) Management Company, project contractors and owners which are the three main stakeholders are seen as each side of the game to be gamed among the three parties [11].

4.2. Qualitative Description

In the construction process of giant project, the owners will generally entrust the comprehensive management of the developed projects to a project (engineering) management company. So that whether it plays the role of the whole process supervision control fully has become the key of determining cost to be high or low.

Among the relationship of the owner, project (engineering) Management Company and the contractor, the owner is direct or indirect beneficiaries of the giant project construction, project (engineering) Management Company is the agent of the giant project construction management, and the contractor is the implementer of the project, and the three all have their interests [12].

In some cases, the larger interests in common exist between the project (engineering) management company and the contractor, so it is easy to form a conspiracy. The contractor will take the rent-seeking behavior for the sake of the economic interest according to a certain probability. It is possible to make the project (engineering) management company deviate from just and fair position, defending the contractor's interests to a certain degree, meanwhile, obtaining the benefit, in order to form the relationship of income and payment between the two sides, the owners' economic interest is damaged ultimately. In this process, the contractor must be recognized by the project (engineering) management company firstly, and sustain certain loss in order to get this extra income. However, if the costs exceeded economic benefits due to the contractor, the contractor would not to take the rent seeking action and only consider the payment due to the normal construction.

In this process, if the owners prove that the collusion behavior between the project (engineering) management company and the contractor is true, the owners will adopt the corresponding measures for punishment. The punishment about the project (engineering) management company is that the owner will expropriate their income from the collusion and deduct M times more than the income which is from the contractor's excessive revenue in agent fee due to the contractor. The punishment about the contractor is that the owner

recovers the payment due to the contractor and in addition fines the contractor the N times more than the income from the rent-seeking gain as punishment [13].

4.3. The Cost Management Game Model for the Owners, the Project (Engineering) Management Company and the Contractor

For constructing the cost management game model for the owners, the project (engineering) management company and the contractor, we make the following hypothesis:

(1) In the process of the game for the owners, the project (engineering) management company and the contractor, the relationship is cooperative game between the project (engineering) management company and the contractor, while the relationship is non-cooperative game between the owners and the project (engineering) management company and between the owners and the contractor.

(2) The probability of the contractor making the rent-seeking from the project (engineering) management company is P, and the owners supervising the collusive behavior with the certain probability of X. The probability of the owners supervising the collusive behavior successfully is y.

(3) The contractor's rent-seeking is successful, and the project (engineering) management company agrees to be collusive and give the amount of S to the contractor as income. The changes, the claims and other matters happen during the contractor's construction, which are paid for with the H standard.

(4) In the process of the rent-seeking, the corresponding costs which are paid by the contractor is C, including the costs paid to the project (engineering) management company by the contractor in collusion or the costs paid by C to the project (engineering) management company from the contractor's excess income, and the C2 for the fine is taken by the owner when the collusion is found.

(5) The cost of the owner supervising is W. In the following cases, the earnings for the owner, the project (engineering) management company and the contractor are as follows [14]:

The first case, the collusive behavior which exists between the project (engineering) management company and the contractor are:

Firstly, the owner's supervision is successful, and the corresponding measures are taken as punishment. The punishment for the project (engineering) management company is to confiscate income from the collusion and deduct the amount of mC1 from the agent fee, recover the payment due to the contractor, and fine n times more than the collusive income. So the three parties' benefit are (m+1) C1+ (S-H) -W, -mC1, -n (S-H) -C respectively.

Secondly, the owner's supervision is not successful, but the collusive behavior still occurs. The benefit of the owner, the project (engineering) management company and the contractor are - (S-H) -W, C1, S-H-C respectively.

Thirdly, the owner do not supervise, and the three parties' benefit are - (S-H), C1, S-H-C respectively.

The second case, the collusive behaviors which don't exist between the project (engineering) management company and the contractor are:

Firstly, the owner supervise, but doesn't find the collusive behavior, and then the benefit of the owners, the project (engineering) management company and the contractor are-W, 0, 0 respectively.

Secondly, the project (engineering) management company and the contractor are not in collusion, and the owner doesn't supervise, the benefits are 0 respectively.

On the premise of the hypothesis above, between the owners, the project (engineering) management company and the contractor, the game model of their benefit are as shown in figure 3.

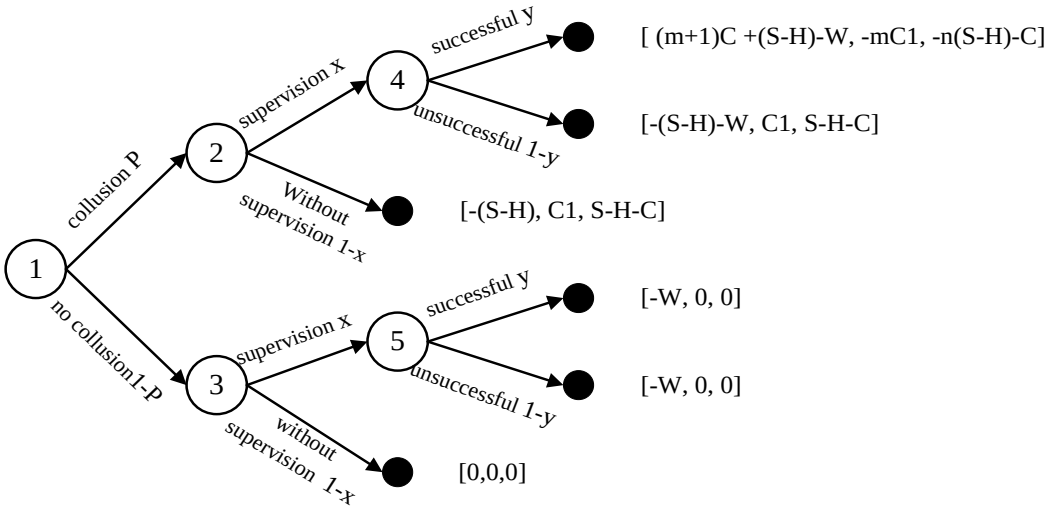

Figure 3. The Game Model of their Benefit between the Owner, the Project (Engineering) Management Company and the Contractor

4.4. Solving the Game Model

(1)Given P the probability about the collusion between the project (engineering) management company and the contractor, whether the owner supervises or not, the returns which the owner expected correspondingly are:

$$G1 = P\{[(m + 1)C1 + n(S - H) - W]y + (1 - y)[-(S - H) - W]\} + (1 - P)[(-W)y - W(1 - y)];$$

$$G2 = P[-(S - H)] + 0(1 - P)$$

When the owner's expected gains have no difference in carrying out supervision or not, in the owner's equilibrium of the game model, it will have the optimum probability of the collusion between the project (engineering) management company and the contractor, the optimum probability is:

$$\text{Let } G1 = G2 \text{, draw } Z = \frac{W}{y[(m + 1)C1 + (n + 1)(S - H)]}$$

(2) Given x as the probability of the owner's supervision. The project (engineering) management company is involved in the conspiracy or in normal work, so the respective expected benefits are:

$$G3 = x[-mC1y + (1 - y)C1] + (1 + x)C1;$$

$$G4 = 0$$

When the expected income of the project (engineering) management company involving in the conspiracy or the normal work has no difference, we will draw the best probability of the owner's supervision.

$$\text{Let } G3 = G4 \text{, draw } X1 = \frac{1}{y(m + 1)!}$$

(3)Given x as the probability of the owner's supervision. The probability of the contractor's rent-seeking or not is

$$G5 = x\{y[-n(S - H) - C] + (1 - y)(S - H - C)\} + (1 - x)(S - H - C);$$

$$G6 = 0$$

When the expected income of the contractor's rent-seeking or not has no difference, we will draw the best probability of the owner's supervision.

$$\text{Let } G5 = G6 \text{, draw } X2 = \frac{S - H - C}{yn(S - H)} \frac{S - H - C}{yn(S - H)}$$

Thus, the Nash equilibrium solution for the game mixed strategy is:

$$\{Z^*, X1^*\} = \{\frac{W}{y[(m+1)C1 + (n+1)(S - H)]}, \frac{1}{y(m+1)}\} \quad (1)$$

$$\{Z^*, X2^*\} = \{\frac{W}{y[(m+1)C1 + (n+1)(S - H)]}, \frac{S - H - C}{yn(S - H)}\} \quad (2)$$

4.5. Analysis of the Game Model

(1) In the game model between the owner, the project (engineering) management company and the contractor, according to the Nash equilibrium solution for the game mixed strategy, the project (engineering) management company and the contractor will be in collusion with the probability of P* and obtain the extra income. If the collusive probability is P>P*, the best choice of the owner is to supervise them; If the collusive probability is P>P*, the owner could not strengthen the supervision.

(2)For the project (engineering) management company and the contractor, the best probability of their collusion is Z* which depends on the several variables that are W, y, m, Cl, N, S, H. Among the variables, C1, S, H are not controlled by the owner in the process of the owner supervising the collusion behavior, and considered as the invariants. Apparently, for the project (engineering) management company and the contractor, the best collusive probability P is directly proportional to the cost of the owner's supervision W and is inversely proportional to y, m and N. Therefore, only through improving efficiency of the supervision and lowering the cost of supervision W, and meanwhile improving the intensity that are M and N for punishing the project (engineering) management company and the contractor, could the owner achieve the aim for reducing P.

(3)For the owner, the best probability of the supervision that is selected depends on the value orientation of the project (engineering) management company or the contractor and the tendency to maximize their interests in the collusion of both sides. During their collusion, if the owner put the project (engineering) management company in the first place, the best probability of supervision is X1*.If X> X1*, the project (engineering) management company will represent the owner to carry out the rights, conversely, the project (engineering) management company would prefer to be in collusion with the contractor. During the collusion, if the owner put the contractor in the first place, the best probability of supervision is X2*. If X> X2*, the contractor would not have the rent-seeking; conversely, the contractor would prefer to have the rent-seeking from the project (engineering) management company [15].

5. The Conclusion

It is proved that the requirements of the large-scale capital invested on giant project must be matched with the corresponding cost management system which is perfect. The effective cost management for the giant project not only relates to the economic benefits of the giant project, but also greatly improves the efficiency of utilizing the state-owned capital. From the game model between the owner, the project (engineering) management company and the contractor, it could be seen that the direct cause of the giant project's cost management risk is

the collusion between the project (engineering) management company and the contractor. In order to effectively avoid the collusive behavior between the project (engineering) management company and the contractor, the owner should take the following measures.

(1) Lower the cost of supervision, and improve the efficiency of supervision

The best probability of the collusion between the project (engineering) management company and the contractor is directly proportional to the cost of the owner's supervision. As the owner of the giant project's cost management, the most effective treatment which would reduce the collusive probability is to reduce supervisory cost and improve the supervisory efficiency.

(2) Define the duty and the right of the three parties, making the incentive mechanism

When the owner signs the contract, the owner should make clear the duty and the right of the three parties. The project (engineering) management company has the duties of supervising and managing the giant project, and the contractor should have the duties of the giant project's construction. Establishing the system for investigating the responsibility, the project (engineering) management company has the responsibility for a total investment of the giant project. If the project exceeds the investment, the project (engineering) management company would undertake financial responsibility. At the same time, the employer should establish an effective incentive mechanism and express it in the contract clauses, so as to fully arouse the enthusiasm of the project (engineering) management company and the contractor to enhance the intrinsic motivation of the lawful performance. If the project (engineering) management company and the contractor have the good performance for the contract, the owner should give them the reasonable reward, making the project (engineering) management company supervise the contractor justly as representing the owner's interests and the contractor has the lawful performance for the contract.

(3) Increase the intensity of the punishment

Increasing the intensity of the punishment will greatly increase the cost of the collusion between the project (engineering) management company and the contractor. The owner expresses the provision of punishment in the contract in a clear way, so as to be effective against the collusive behavior and reduce the probability of the collusive behavior.

(4) Establish the admittance system of the market.

Establishing the admittance system of the market will improve the threshold of the project (engineering) management company. Let the ability of capital, credit rating and management experience other conditions include in the qualification documents for choosing the project (engineering) management company, so as to effectively exclude the project (engineering) management company of the capital inadequacy, the low credit rating, the bad experience of the project organization and the unreasonable professional structure from the construction market.

In short, the construction of the giant project is a huge and complex systemic engineering. The schedule of the giant project is long and the uncertain factors are more, so it's the prevention and control of the cost risk are particularly important. For the giant project, we should continue to explore the scientific cost management method and the risk evaluation mechanism for restricting the cost risk in the controllable range, to obtain the good economic, social and environmental benefit.

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