A Study on Governance Structure Selection Model of Construction-Agent System Projects under Uncertainty

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Abstract Construction-Agent System is a newly developed and effective public project delivery method in China. Governance structures affect performance of public projects. According to arrangement of project control rights and residual claims, this paper classifies project structures into two modes in terms of the hierarchy as well as the market. The study suggests that four determinants, including stakeholders, responsibilities and commitments, project objectives and risks, should be taken into consideration when selecting governance structures. A stochastic optimization model is developed to reveal linkage between incentive-constraint mechanisms and governance structures. A numerical example shows that in the high risk state, market governance structure should be selected, while in the low risk state, hierarchy governance structure will be appropriate.
Key words Construction-agent system; Project governance; Governance structure; Stochastic optimization

1 Introduction

Public projects play an important role in improving social welfare and stimulating economic growth for developing countries. For years, management of public projects such as hospitals, museums and schools in China have always been totally implemented by government which takes full responsibility for design, investment, construction and operation. However, due to lack of professional project management capability, government always encountered troubles with controlling project cost and schedule.

In order to solve such problem, a new public project delivery method has been developed in China which called Construction-Agent System derived from Construction Manager (C.M) of America. In Construction-Agent System, a professional project management entity selected by government is responsible for project implementation, including optimum use of available funds, avoidance of delays, changes and disputes, enhancing project design and construction quality, etc. As construction finishes, the project asset ownership will be transferred to government. The entity is called construction agent which is responsible exclusively to the government and acts in the government's interests at every stage of the project.

Construction-Agent System has developed rapidly in China recently. In 2001, six cities including Beijing, Shanghai and Shenzhen began to launch pilot Construction-Agent projects. After three years, the State council of China decided to promote Construction-Agent System nationwide. According to statistics, there have been more than four hundred Construction-Agent projects in China up to 2006.

However, as a newly developed project delivery method, Construction-Agent System has difficulty in designing compensation mechanisms and supervisory schemes, because there exists incomplete and asymmetric information under principal–agent relationship between construction agent and government. Government as principal does not know enough about whether a contract has been satisfied. The solution to this problem is to ensure the provision of appropriate incentives so agents act in the way government wish, thereby government needs to exercise sovereign authority in governing project. Therefore (Yan 2004) argues that Construction-Agent System should be studied by applying project governance theory and responsibilities should be allocated among stakeholders through establishing appropriate Construction-Agent System project governance structure. But in practice, governance structure selection of Construction-Agent System projects lacks theoretical basis, which results in chaos of adopting incentive-constraint mechanisms.

(Yan 2006) points out that performance of Construction-Agent System can not only be improved by using principal-agent theory but also by applying project governance theory. (Lan 2007) presents models of analyzing optimal incentive time coefficient of Construction-Agent System based on government's project revenue maximization. (Yang 2008) demonstrates that government can motivate construction agents through introducing benefit sharing ratio which is inversely proportional to effort cost coefficient.

Project governance has become widely used terms in organizations and gained popularity in both practical application and academic research. (Turner 2001) describes governance structures adopted by successful project-based organizations, and how they use them to manage the interface between projects and their clients. (Winch 2001) presents a conceptual framework for understanding the governance of construction project processes, drawing on transaction cost economics. (Bekker 2007) defines the concept of governance for large capital projects through an international Delphi survey, and introduces a framework for project governance.

Literature review above shows that some researchers have noticed relation between Construction-agent System and project governance, but how to select appropriate governance structure in order to motivate and constrain construction agents effectively still remains unsolved. So this paper aims to find the optimal incentive-constraint mechanism as the way to select the appropriate governance structures of Construction-Agent projects. The paper is organized as follows. In the next section, research methodology is designed. Two types of governance structures are summarized and determinants of selecting governance structures are given in section 3 and section 4. In the following section, governance structure selection model is developed by stochastic optimization. A numerical example is provided in section 6, and finally conclusions are given in section 7.

2 Research Methodologies

(Renz 2007) suggests that an exploratory approach is the best method to study project governance, which combines deductive-inductive approach. Therefore case studies are deemed the most appropriate for exploring regular pattern of governance structures. (Bekker 2007) also points out that it is necessary to verify effectiveness of specific governance structures by case study results. Consequently, existing research about Construction-Agent System project governance mainly adopts case study method. So it is possible for this study to take advantage of related research results in section 3 and section 4. Moreover, this paper elaborates characteristics of two types of project governance structures which are very common in practice, in order to reveal their relation to specific incentive and constrain mechanism. Government can select appropriate governance structures for Construction-Agent System according to optimal incentive and constrain mechanism.

So in this paper, the establishment of quantitative linkage between governance structures and incentive-constraint mechanisms is the key to realize research goals mentioned above. In Construction-Agent System, government aims to achieve desired project deliverables at lowest possible cost, while construction agents intend to get benefits as much as possible, both of which have an effect on designing incentive-constraint mechanisms. Government's payoff and construction agent's benefits may be influenced by uncertainties, i.e. cost overruns, schedule delay and poor quality. As a result, it is necessary to take uncertainties into account when analyzing principal-agent relationships. The study applies stochastic optimization method to find optimal incentive-constraint mechanisms through Monte-Carlo simulation.

3 Governance Structures of Construction-agent System Projects

Project governance structure is a framework of defining stakeholders' responsibilities and commitments which determines who should take part in project management during project life cycle. In other words, it should define how resources and risks are distributed among stakeholders. Governance structure of Construction-Agent System project is an organized structure established as authoritative within the institution, comprising responsibility and commitment allocation between government and construction agent, in order to measure project outcomes, benefits and value against both the plan and measurable expectations. Therefore how to design and select governance structure is a key to this study.

According to Lindkvist's research (2004), governance structures can be classified into two basic modes, the hierarchy and the market, relying on authority and prices respectively. Although (Miller 2005) questions the idea of having a common governance structure for public projects, and the author argues that a specific governance structure must adapt to the particular project and its context, it is still necessary to summarize general governance structures for Construction-Agent System. This paper adopts taxonomy suggested by Lindkvist which is sensible in the context of Chinese public projects. The specific governance structures and corresponding basic organizing properties are elaborated below.

3.1 Hierarchy governance structure

In hierarchy governance structure, government as principal appoints non-profit organizations as construction agents, such as government branches responsible for public project construction

management. In the mode, construction agents are selected by authority while not by competitive bidding based on market. Due to common interests existing between government and construction agents, project control rights are not transferred to agents, thereby agents have not residual claims accordingly who need not to assume risk. That is to say, construction agents should not be responsible for project risk, i.e. cost overrun, at the same time, have no rights to share project overflow benefit such as cost savings. The only benefit of construction agents is project management fees paid by governance.

Hierarchy governance structure is very common in Construction-Agent System of Shenzhen in China. The construction agent is named as Department of Public Works, responsible for construction of all public projects except for water treatment and transport projects. As of the end of August 2008, Shenzhen Department of Public Works has completed more than 150 Construction-Agent projects.

3.2 Market governance structure

Market governance structure represents match between project control rights and residual claims. Government selects construction agents through competitive bidding from private sector, such as project management companies. Since construction agents aim to make profit from agency activities, government ought to transfer project control rights partly or fully to construction agents, in order to take advantage of private sector's project management skills and experiences, and construction agents must have project residual claims, which means construction agents should not only be responsible for project risk of loss, but also have rights to share project benefit simultaneously.

Construction-Agent System in Beijing of China completely adopts market governance structure. When government investment accounts for more than 60% of total investment, public projects should apply Construction-Agent System. Up to 2008, there have been about 65 Construction-Agent System projects in Beijing, including 11 Olympic Projects.

4 Determinants of Selecting Governance Structures

According to previous research, this paper summarizes four determinants of selecting governance structures shown in the table below.

Table 1 Determinants of Selecting Governance Structures

Determinants	Reason of being considered	Researchers who suggest this
stakeholders	the base of governance structures	Renz,Turner,Yan
responsibilities, commitments	the base of incentive and constraint	Renz,Miller,Turner
project objectives	direct project governance	Renz
project risks	influence complexity of structures	Bekker,Young,Turner,Winch

First, governance structures intrinsically are relationship frameworks consisting of control bodies and executive boards who participate in Construction-Agent System. So it is necessary to identify stakeholders relating to governance. Although there exist several stakeholders in public projects, for example, government, construction agents, contractors, providers and customers, the study suggests that emphasis should be laid on the analysis of relationships between government and construction agents, because principal-agent relationships of both parties determine activities of other stakeholders.

Second, governance performance can be guaranteed by reasonable allocation of responsibilities and commitments among stakeholders which determines how to design specific incentive-constraint mechanisms. If construction agents take the responsibility of assuming risks, incentive scheme should be established accordingly.

Third, project objectives play an important role in directing project governance. In Construction-Agent System, government usually sets three objectives for public projects, namely, investment, schedule, quality. It is essential to ensure realization of project objectives to the greatest extent when designing and selecting governance structures.

Fourth, risks have significant influence on project objectives and stakeholders' relationships. How to decrease risk of loss is a key mission of governance structure selection. Although many external and internal risks come up during project implement, effect of all risks can be measured by influence of three types of overall risks, namely, cost overrun, schedule delay, poor quality. For this reason, the study mainly analyzes relation of these three risks and governance structures.

5 Governance Structure Selection Model

5.1 The basic scheme

Governance structure selection for Construction-Agent System primarily takes payoff of government and benefit of construction agents into consideration. In Construction-Agent System, government's payoff, denoted as P_g, consists of three parts. First part is project actual investment, denoted as I_a, which is paid by government according to final cost when checking and accepting the completed construction project. Second part is construction agent fee (F_{ca}) paid by government to construction agents for coverage of the latter's project management cost. F_{ca} usually can be calculated by I_a with a coefficient f which ranges from 0.8% to 2.0% according to practice experience. Third part are contingency fees (written as C_f) which have relation to incentive-constraint mechanisms. C_f can be calculated as follows.

$$C_f=a_I(I_p-I_a)+a_s(S_p-S_a)I_p/S_p+a_qQ_B \quad (1)$$

where a_I , a_s , $a_q \in [0,1]$, called decision variables, are incentive and constraint ratios of cost, schedule and quality respectively. For the simplicity, the study does not distinguish incentive ratios from constrain ratios. I_p and S_p are planned project investment and construction period. The term $a_I(I_p-I_a)$ in equation (1) is cost incentive and constraint faced by a construction agent. When I_p is greater than I_a, there are project cost savings which can be shared by the construction agent based on the parameter a_I. On the contrary, cost overrun appears, the construction agent ought to compensate damage for government. The second term of equation (2) is schedule incentive and constraint, where S_a is actual project construction period, I_p/S_p is unit time cost. The third term is quality incentive and constraint, where Q_B can be determined in three states: high quality, with probability of p_h, $Q_B=Q_H$(benefit from high quality); normal quality, with probability of p_n, $Q_B=0$; low quality, with probability of p_l, $Q_B=Q_L$(loss from low quality). Considering influence of risks, I_a , S_a and Q_B should be stochastic variables, which are functions of other factors, such as project characteristics, construction agent effort level, construction agent market maturity, etc.

5.2 The model setup

In order to realize project objectives at reasonable costs, and at the same time to effectively motivate and constrain construction agents, government should solve:

$$\begin{aligned} &\text{Min } E\,[(1+f)I_a+a_I(I_p-I_a)+a_s(S_p-S_a)I_p/S_p+a_qQ_B] \\ &\text{s.t. } E\,[fI_a+a_I(I_p-I_a)+a_s(S_p-S_a)I_p/S_p+a_qQ_B]\geq B \\ &\quad E\,[a_I(I_p-I_a)+a_s(S_p-S_a)I_p/S_p]\leq E(a_qQ_B) \\ &\quad a_I, a_s, a_q \in [0,1] \end{aligned} \quad (2)$$

Objective function above aims to minimize government's average payoff P_g, where E is expectation operator. First constraint condition is construction agent participation constraint, which demands agent's expectation benefit should not be less than B (the lowest acceptable benefit).Second constraint condition aims to prevent the construction agent from conspiring with other stakeholders, such as contractors, to make fraud cost savings or ahead of schedule at the risk of reducing quality. After finding optimal solutions a^*_I , a^*_s , a^*_q, governance structure selection criteria for Construction-Agent System can be established as: if a^*_I, a^*_s, a^*_q all equal to or close to zero, select hierarchy governance structure; if anyone of a^*_I , a^*_s , a^*_q significantly greater than zero, select market governance structure.

6 A Numerical Example

Here a numerical example is presented to illustrate the governance structure selection model. The government attempts to build a hospital by the means of Construction-Agent System. The parameters of the model are given as in Table 2.

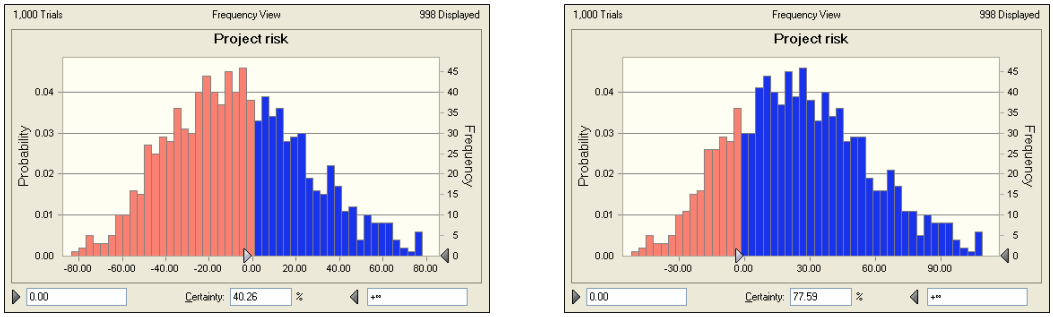
Table 2 Input Parameters Used in the Numerical Example

variables	I_a (million yuan)	S_a (month)	Q_B (million yuan)	f (I_p B S_p) (million yuan, million yuan, month)
Probability distribution or value	Triangular (150, 180, 200)	Triangular (16, 18, 24)	Q_L= -20, p_l=0.4 Q_B=0, p_n=0.4 Q_H=40, p_h=0.2	f=1.2% (165 1.5 20)^{H} (180 1.5 22)^{L}

The labels H and L denote two risk states, the former is high risk state, where government has high criteria for investment and construction period; the latter is low risk state, where government has low criteria for investment and construction. Substituting parameters into equation (2), through exercising

Monte-Carlo simulation by setting maximum number of trials to run to 1000 in Crystal Ball stochastic optimization software, optimal solution can be achieved as follows (see details in Figure 1).

In the high risk state, where $P[I_p\text{-}I_a+(S_p\text{-}S_a)I_p/S_p+Q_B\geq 0]=40.26\%$, all incentive and constraint ratios are significantly great than zero. In this case, market governance structure should be selected, and value of objective function is 178.51. In the low risk state, where $P[I_p\text{-}I_a+(S_p\text{-}S_a)I_p/S_p+Q_B\geq 0]=77.59\%$, all incentive and constraint ratios equal to zero approximatively. In this case, hierarchy governance structure should be selected, and value of objective function is 179.18.



High risk state
Optimal solution
a^*_1=0.13, a^*_s=0.16, a^*_q=0.37

Low risk state
Optimal solution
a^*_1=0.00, a^*_s=0.00, a^*_q=0.02

Figure 1 Optimal Solutions under Two Risk States

7 Conclusions

Construction-Agent System is an effective public project delivery method in China. According to arrangement of project control rights and residual claims, governance structures of Construction-Agent System can be classified into two types: the hierarchy, the market. The study suggests four determinants of selecting governance structures should be considered, namely, stakeholders, responsibilities and commitments, project objectives and risks. A stochastic optimization model is developed to select governance structures through finding optimal incentive-constraint mechanisms. A numerical example shows that when in the high risk state, market governance structure should be selected, when in the low risk state, it is appropriate to select hierarchy governance structure.

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