

Chapter 2

A Game Analysis on Multi-Level Emergency Management for Construction Accident

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Abstract This paper analyzes the framework of multi-level emergency management conducted by government, company and project managers. There exists the fact that sometimes, in the construction market, construction accidents are not reported, and information asymmetry is a main factor that causes ethical risk for emergency management. Using modern information asymmetry theory in economics, this paper studies the dynamic game process of emergency management behaviors with incomplete information when construction accident happens. As the sector entity undertaking project management has more information and is responsible for the accident, moral hazard and adverse selection may happen during emergency management of construction accident. This paper suggests that a system should be established to encourage integrity behaviors and to prevent discreditable behaviors. Effective emergency management system should be able to solve the problem that information about project construction accident is prevented from reporting.

Keywords Construction project • Construction accident • Emergency management • Game theory

2.1 Introduction

The feature, that construction project needs lots of money, requires good cooperation of every profit related participant so as to finish it very well, for example, participation of owner, designer, contractor, government and user. Thus, how to

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coordinate the relationship between each other is an important condition to complete a construction project successfully. As the profit relationship between each other is complicated, most crisis and construction accidents result from bad coordination of relationships between profit related entities, and information can't be passed or communicated as well as misunderstanding between project members.

Game theory research on complicated problems in construction project management is becoming more and more mature. Many scholars do detailed study on client-agent issue during construction project management using game theory and get a lot of achievements. Game theory refers to the methodology that studies decisions made by decision makers when their behaviors are affecting each other and the balance of those decisions. Game theory proves the fact that decision behaviors of people are interacted. When one party is making decisions, he will be affected by other decision makers and will also has an influence on balance problem and making decisions by them. Secondly, such a series of decisions forms a strategy profile, and there exists an equilibrium, which is made up of best strategies of all participants [1]. Game theory was put forward in two papers established in 1928 and 1937 by J.von Neumann, who is a famous mathematician, for the first time. However, the symbol of establishment of game theory is a book called *The Theory of Games and Economic Behavior*, which is written by J.von Neumann and O. Morgenstem together. This book mainly introduces the typical character of economy entities and puts forward some game theory models such as strategy model, normalized model and extended model. It lays a foundation for theory and methodology of game theory. After that, game theory develops very fast and is widely used [2]. For example, Rapoport and Fuller (1998) did a research on the coordination of relationship during game playing between three disoperative parties based on different information structures [3]. Putterman and Skillman (1988) analyzed influence of supervision on how hard people work using different supervision methods and compensation systems [4]. Holmstrom and Milgrom (1987, 1991) studied client-agency issue under multiple tasks, including incentive contract, asset ownership and contract design [5]. Stanley Baiman (2000) studied function of contract information and motivation to the control of quality and cost of product, and he put forward equation deduction of the theory [6]. Abdulaziz (2003) studied the meaning and function of motivation mechanism and motivation contract to project cost control, schedule control and reaching project goals from the perspective of practice [7].

2.2 Working Process of Hydraulic Variable Pitch System

Hydraulic variable pitch system [6] is shown in Fig. 2.1. When the wind turbine generator operates above wind speed, it needs to regulate pitch angle to keep rated power. When output power of generator is higher than rated power, blade angle

will be turned down to reduce wind energy capture. Under the case, the working process of hydraulic system is as follows: when pump is driven by electric motor, hydraulic oil will through the one-way valve (11.1) flow into the system and pressure oil will through electromagnetic ball valve (1), electro-hydraulic proportional directional valve (4), one-way valve (22), electromagnetic ball valve (2) flow into rod cavity (24) to push piston rod right. At the same time, oil will from rod-less cavity (25) through operated check valve (23), electro-hydraulic proportional directional valve (4) flow back pressure pipeline. When power control need to increase pitch angle, electro-hydraulic proportional directional valve will reverse direction and oil will make piston rod move left.

2.3 Multi-Layer Emergency Management Structure

Construction accident is complex, and emergency management is conducted in a complex environment. Project management parties and related companies, government and non-governmental organizations participate in the process and mechanism of construction project emergency management. As a new emergency management, it emphasizes diversification of the subjects. To conduct effective emergency management not only requires a big revolution of ways how administrative department of construction conduct supervision but also need the owner, contractor and supervisor to improve their emergency management abilities and effectively integrate various levels of resources, which will enhance the emergency management ability of construction projects. This is also the basic goal of building a multi-level system of emergency management.

Project level involves the project department of construction company, representatives of the owner, designers in charge from design company, the project supervision department of supervisor company and related personnel from equipment and material suppliers. But the project department of construction company gets the most sufficient information and bear most responsibility in emergency management, so it should play the most important role. Company level refers to companies that relevant project management departments belong to, which mainly consists of construction enterprise, owner, supervisor enterprise and design company, etc. During emergency management, according to the level of construction accident, emergency management for construction project will involve administrative department of construction, county government, and provincial government.

Multi-level emergency management is helpful to fully understand emergency management for construction accident and to effectively organize and reasonably solve all contradictions and problems during emergency management for construction accident. It is also helpful to adjust the working pattern while construction accident is changing constantly in order to keep up with development of society better.

2.4 Dynamic Game Analysis on Emergency Management Behaviors With Incomplete Information

When construction accident happens, it will bring influence on both project, enterprises and government, what's worse, they even need bear legal responsibility. As project management units have more information and they must bear legal responsibility if any accident happens, ethic risk and adverse selection exist during emergency management for construction accident.

2.4.1 Participant

The two participants in dynamic game are “construction administration department” and “project manager” during emergency management for construction accident. The “construction administration department” generally refers to the entity sector that need to make administrative decisions and conduct supervision behaviors when construction accident happens; The “project managers” refers to relevant participants who are involved in project construction, including owner, construction company, supervision company, design company and subcontractors. And “project manager’s emergency behaviors” refers to measures and behaviors taken by the owner or construction company to conduct emergency management for construction accident.

2.4.2 Strategy Space

The strategy space of “construction administration department” consists of administrative action plans, that of “project manager” strategy is emergency management measures taken by project participants in a certain condition of emergency. Assuming that there are n kinds of possible emergency actions of “project manager”, “project managers’ emergency behaviors” chooses action i with probability of p_i and changes from emergency situation i to j with probability of p_{ij} . The “construction administration department” will choose to undertake relevant plans according to different emergency situation j and its dynamic changes of situation.

2.4.3 Variable Definition

During the process of emergency management for construction accident, assuming that there is a dynamic game between emergency behaviors of “construction

administration department” and “project manager”, variables are defined as follow:

CM (Cost of Monitoring)—the cost that construction administration department spends on monitoring whether project manager is hiding accident information;

CH (Chastisement)—the punishment on project manager by construction administration department for hiding construction information;

D (Damage)—damage utility for hiding information;

ΔR —difference of the benefit to project manager between different degrees of hiding information;

π —probability that construction administration department checks whether construction entities are hiding some information;

η —probability that project manager hides true accident information.

Among the variables mentioned before, CM, CH, D, $\Delta R \geq 0$, $0 \leq \pi, \eta \leq 1$. Assuming that:

1. $f : \Theta \rightarrow \Omega$ is already known, and it is relatively stable within a limited duration of construction accident situation. Θ refers to collection of the information that is reported by project manager and can be seen by construction administration department, Ω refers to collection of all information about emergency management situation of project manager. The information that can represent emergency management of project manager consists of emergency rescue plans, emergency rescue organizations, qualification of the general contractor and all kinds of risk management situations.
2. Project managers who hide accident information, besides construction administration department and owner, can be the contractor, supervision company, design company, consulting company and insurance company, etc., including construction workers, management and technical personnel and so on.

According to the theory, these parties have their own utility curves which are different from each other, which represents different interests when they are hiding accident information. But for the sake of simplicity, it assumes that the interests of construction administration department and other profit related parties are the same. It will monitor the behavior of hiding accident information of construction project as the interest representative of construction workers, insurance companies and other profit related parties.

3. $D \geq CM$, $CH \geq \Delta R$, according to the rational man hypothesis, it is known that construction administration department is not rational if the cost is larger than the loss brought to construction market because of untruthful information; And if the marginal benefit because of hiding information is bigger than possible punishment, the punishment by construction administration department is not trustful.

2.5 One Stage Game Theory

During emergency management in a sudden accident, the construction administration department's strategic is to choose to always “monitor” the whole process of construction accident that actually happens during project construction or completely “not to monitor”, here M (Monitoring) represents choosing to monitor and NM (No Monitoring) refers to choosing not to monitor; The strategies in the situation of construction accident is to hide information (using F as False) or timely, accurately report information (using R as Real); Among them, (NM, R) represents cooperative behaviors. Obviously, The construction administration department doesn't have pure strategy Nash equilibrium on whether monitoring or not in the situation of construction emergency, but mixed strategy Nash equilibrium can be found.

If π is given, expected benefits for project managers to choose to hide real information about the accident ($\eta = 1$) and timely, accurately report information ($\eta = 0$) are:

$$U_{b1}(\pi, 1) = -C_H \cdot \pi + \Delta R \cdot (1 - \pi) = \Delta R - (C_H + \Delta R) \cdot \pi \quad (2.1)$$

$$U_{b1}(\pi, 0) = 0 \cdot \pi + 0 \cdot (1 - \pi) = 0 \quad (2.2)$$

Make $U_{b1}(\pi, 1) = U_{b1}(\pi, 0)$, then $\pi^* = \Delta R / (\Delta R + C_H)$, namely, project manager need to estimate the probability π that construction administration department may conduct monitoring, if $\pi < \Delta R / (\Delta R + C_H)$, project manager will choose to hide information; if $\pi > \Delta R / (\Delta R + C_H)$, project managers will choose to timely, accurately report information; if $\pi = \Delta R / (\Delta R + C_H)$, project manager will choose to hide or timely, accurately report real information randomly. Further, $\partial(\pi^*) / \partial(\Delta R) > 0$, which means that if the difference of the benefit to project manager between different degrees of hiding information is bigger, it is more possible for construction project subjects to hide information, then construction administration department should pay more efforts on monitoring them.

If η is given, expected benefits for construction administration department to choose to conduct monitoring ($\pi = 1$) and find no problems ($\pi = 0$) are:

$$U_{m1}(1, \eta) = (-C_M + C_H) \cdot \eta + (-C_M) \cdot (1 - \eta) = \eta \cdot C_H - C_M \quad (2.3)$$

$$U_{m1}(0, \eta) = -D \cdot \eta + 0 \cdot (1 - \eta) = -D \cdot \eta \quad (2.4)$$

Make $U_{m1}(1, \eta) = U_{m1}(0, \eta)$, then $\eta^* = C_M / (C_H + D)$. If $\eta > C_M / (C_H + D)$ then construction administration department will choose to conduct monitoring; on the contrary, the best decision for construction administration department is not to conduct monitoring temporarily or to choose randomly. Further, $\partial(\eta^*) / \partial(C_M) > 0$ means that if the cost of monitoring for construction administration department is bigger, it is more possible for construction project subjects to hide information.

It can be seen that the effectiveness of mechanism of information disclosure, which is about construction accident for projects depends on the four factors: the

benefit to project management entities by hiding information, the punishment from construction administration department for hiding information, capacity and responsibility of supervisor. If the construction administration department is antagonistic to hiding information behavior more strongly, the capacity of supervisor is stronger. If law defines more responsibilities for construction administration department, the motivation for construction project subjects to hide information in the situation of emergency is smaller, which means that it is more possible for them to provide reliable information. Conversely, if it can bring obvious benefit to the construction project subjects by hiding information, and the construction administration department disregard the behavior and the responsibility of supervisor is very small, then it is quite possible for construction project subjects to hide information.

2.6 Conclusion

In repeated game with limited times, the equilibrium of every stage is the equilibrium result of one stage game, which means that mixed strategy equilibrium of one stage game will appear. However, with the assumption that all participants obey in repeated game with limited times, the equilibrium result will be got eventually, but the premise is that probability of project managers to be rational is big enough. Then, the assumption of repeated game with limited times can provide behavior rules for establishing the mechanism of monitoring construction accident.

In the situation of emergency, malicious behaviors are very common and serious between project subjects, companies as well as enterprises and the government. And we should also pay more efforts on monitoring the evaluation of construction project contracts and build an public environment of being proud of keeping one's words and being ashamed of being dishonest. During key procedures such as construction market access, bidding evaluation and registration review of all kinds of personnel who are qualified, we should set up evaluation index of enterprise credit and individual credit and intensify the economic punishment on enterprises and individuals for being dishonest, as well as gradually establishing and developing the system that encourages credible behaviors and prevent discreditable behaviors.

References

1. Xie S (2003) Economy game theory [M]. Fudan University Press, Shanghai, pp 17–18
2. Zhang W (1996) Game theory and information economy [M]. Shanghai Sanlian Book Store, Shanghai Renming Press, Shanghai, pp 76–82
3. Rapoport A, Fuller MA (1998) Coordination in noncooperative three-person games under different information structures. Kluwer Academic Publishers, Dordrecht

4. Putterman L, Skillman G (1988) The incentive effects of monitoring under alternative compensation scheme. *Int J Ind Econ.* 6:109–119
5. Holmstrom B, Milgrom P (1991) Multi-task principal-agent analyses: incentive contracts. Asset ownership and job design. *J Law Econ Organ* 7:24–52
6. Stanley B (2000) Information, contracting, and quality costs. *Manag Sci* 46(6):776–789
7. Bubshait AA (2003) Incentive disincentive contracts and its effects on industrial projects. *Int J Project Manag* 21:128–131

Measuring Technology and Mechatronics Automation in
Electrical Engineering

Hou, Z. (Ed.)

2012, XIV, 526 p., Hardcover

ISBN: 978-1-4614-2184-9