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GAME THEORY-BASED BEHAVIORAL DECISION ON IT PROJECTS RISK

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Abstract. *The subjective behavior of software projects (software developers, users and other stakeholders) is conducted from the perspective of stakeholders to find out the potential risks in information technology (IT) project. Based on the asymmetric information theory and conflict theory as the basic research methods, this paper aims at analyzing the relationships among IT projects actors in the game by using game theory. Then IT project risks in the process are identified which can provide valuable information for the decision-makers and help decision-makers understand the development course of events. The results showed that the developers will take advantage of information to damage the interests in hiding technical information of agents and users under the asymmetric information in a balanced outcome of the game. Therefore, the users need to introduce third-party supervision and take amount of penalty to assess the qualifications of the project.*
Keywords: Asymmetric information, Software project actors, Game analysis, Stability analysis

1. **Introduction.** With the continuous enhancement of people's risk awareness, risk management is increasingly required. Discussions on the issue are in full swing in the theorists. Currently, identifying the risk factors has two main focus areas. First, defining the risk from the type of resource, such as personnel, finance, technology, time, information, and knowledge. Foreign scholars Sandra explored the factors of information technology (IT) projects risk management through knowledge management techniques and other objects. The companies of Brazilian technology were as examples for research and feasibility studies. The view that the knowledge management techniques and other objective risk factors should be integrated to IT project management activities in the software industry is very significant [1]. Lopez and Salmeron discussed the impact of IT project risk caused by the technology and a new system and provided the decision support for the IT project risk managers [2]. Second, scholars discussed the issues related to the field of risk management systems and risk assessment from multiple perspectives. The basis of these studies is to identify risk factors for the problem. Lazaros and Prodromos investigated the relationship between personnel quality and process quality within the scope of IT projects [3]. Vahid and Abdi proposed a quantitative assessment framework to quantify the uncertainty cost of the project on how to impact the IT project risk based on Bayesian network [4]. Pan and Xiong established a software project risk assessment model about the analysis of needs and predicted the software project risk level from the perspective of requirements analysis [5].

It is worth noting that the existing literature is often more concerned about the objective risk factors and focuses on the point of management. However, the root of project risks is generated by the project actors which dominate the trend of project development. In the field of the risk of IT project, the studies on the behavior of the main project risks are few. The research on IT project risk is still in its infancy. Currently, Walsh and Schneider applied the theory of behavior and agency to analyzing the main factors of the project according to the motivation and behavior of decision makers [6]. Domestic scholars have tried to apply the theory of actors risk to the field of engineering project risk. Xiang and Kong established a behavioral theory of game model based on the establishment of asymmetric information and provided a solution to regulate the behavior of the main project [7]. He emphasized the importance of the project participants and believed that the success of the project depended on the project stakeholders subjectivity, which is very significant in the field of engineering [8]. This paper attempts to take advantage of conflict analysis model to avoid the risk of IT projects involved in the decision-making body based on the asymmetric information. The features is that the information asymmetry theory and game theory are introduced to the project risk management. By extracting the risk caused by the stakeholders' behaviors of software projects provides the better solutions for the stakeholders in the software projects.

The rest of the paper is organized as follows. Section 2 gives a brief introduction of the theory of game analysis model; Section 3 illustrates modeling of software project actors and analysis; Section 4 gives the conclusion and suggestions for our future study.

2. **Construction and Analysis of Game Model.** Game theory generally includes participants, actions, information, strategies, payment functions, as well as the results of the six balanced constituents [9]. Conflict analysis is a kind of decision analysis method which is developed on the basis of game theory. Conflict analysis can predict and assess the conflict for decision-makers to make a comprehensive ex-ante and ex-post analysis and help decision-makers make a correct judgment of the merits of the decisions. In reality, the game is among software developers, users and third-party supervisor, and this tripartition is dynamic. Tripartition will adjust their behavior following their own interests to maximize rationality in the multi-stage of game. In this paper, the tripartite revenue function is added to the model which is an effective way to improve the conflict analysis.

The basic model of game analysis can be expressed by the formula $C = \{N, E, F, P, UI\}$. Among them: N: Participants, $N = \{1, 2, \ldots, N\}$ is at least two or more; E: The current set of all possible situations under the circumstances; F: Revenue function, it was used to represent the income after participants choosing strategy; P: The set of different actors' order of preference for each situation on the set of feasible situation; UI: The unilateral improved set of each conflict participant ordered according to their preference.

2.1. **Basic assumptions.** Supposing the entire software project activities are mainly tripartite stakeholders, namely software developers, users and third-party supervision, and it is not related to software agents and other stakeholders.

Hypothesis 1: Developers, users and supervisor, tripartition of game are rational economic man, maximizing the benefits as their guidelines.

Hypothesis 2: In this paper, we study the phase for the project implementation stage; after software developers and users reaching an agreement, developers design software according to users' requirements.

Hypothesis 3: Supervisor introduced is delegated by the users, such as universities and qualification enterprise. Supervisor is responsible for acceptance of software developed by the project developer. If they find the developer has occult behaviors, they will make punishment to developers for occult technical information. Then, supervisor will get the punishment.

Hypothesis 4: After supervision party regulating, the users have a right to choose whether to accept the software developed by the software developers conforming to users' requirements.

Hypothesis 5: The order of three parties in the game is that supervision takes action first, followed by the developers and finally the users take action.

Hypothesis 6: Analyzing the various factors of the occurrence probability caused by strategy based on the probability calculation of the strategy in the game.

2.2. **Construct model.** According to the actual situation of the implementation of the software project in the performance phase, the players, the policy sets, viable situations, revenue functions, and stability analyses of the model are in these situations as follows.

(1) Players. Suppose there are three players: software developers (D), software project users (U), and the supervisor (S).

(2) Player's strategy. The policy sets of software project developers and users are as Table 1.

Table 1. Policy set of tripartite game

Game party	Policy set
Developers	{ Occult Technical Information } { Frankly Technical Information }
Users	{ Accept } { Refuse }
Supervisor	{ Supervise } { Not supervise }

Notes: Technical information includes: implanting software with "back door", paying to upgrade software, bundling with malicious software plug-ins and other types of information technology.

In the process of tripartite game, each player can choose their own strategies based on other participants' strategies selected in the program. After all program participants have selected, every set is an end. Theoretically, it has $2^6 = 64$ kinds of conflicts ending, but we need to exclude the situation that does not meet the actual bureau.

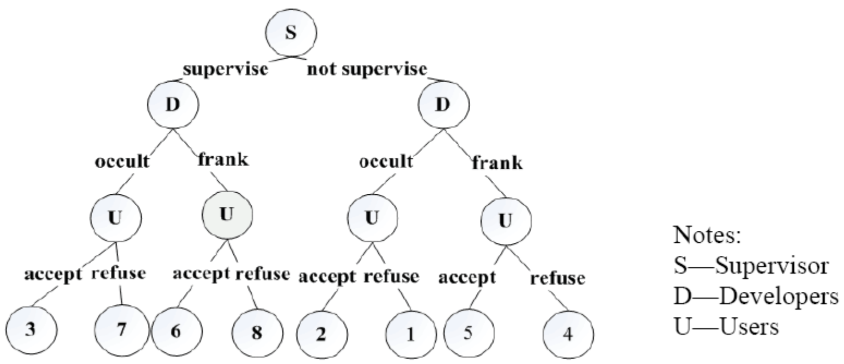

Figure 1. Policy of tripartite game tree

2.3. **Related revenue function.** We suppose parameters are defined as follows: while users accept, Q_1, Q_2, Q_3 respectively represent the benefits of software developers, users, and supervisor if occult technical behavior did not occur. R_1 is the additional benefit when software developers meet the basic needs of users, but occult technology behaviors occur. C_1 and C_2, respectively, represent occur developers and users' inputs while occult behavior does not occur. Otherwise, when users decline, users need to provide with compensation. q_1 represents revenue of software developers if users did not accept. α_i represents the degree of energy regulators in the regulatory process consumed, but energy consumed by a regulator increases when occult behaviors act. Z_1 represents developers penalty value produced by regulators because punish developers' software has occult technology. This article assumes that punishment for developers of owns to regulators gain.

The probability of tripartite participation distributes as follows. The probability of software developers with occult behavior is P_1 and probability of frankly technical information behavior is $(1 - P_1)$. Probability of users successfully accepting software is

Table 2. Returns matrix of tripartite game (software developers, users, supervisor)

Game situation	Revenue function	Probability
0	$(0,0,0)$	0
1	$(q_1,-q_1,0)$	$P_1(1-P_2)(1-P_3)$
2	$(Q_1+R_1-C_1,Q_2-R_1-C_2,0)$	$P_1P_2(1-P_3)$
3	$(Q_1+R_1-C_1-Z_1,Q_2-R_1-C_2,$ $\alpha_i(Q_2-C_2)+Z_1)$	$P_1P_2P_3$
4	$(q_1,-q_1,0)$	$(1-P_1)(1-P_2)(1-P_3)$
5	$(Q_1-C_1,Q_2-C_2,0)$	$(1-P_1)P_2(1-P_3)$
6	$(Q_1-C_1,Q_2-C_2,\alpha_i(Q_2-C_2))$	$(1-P_1)P_2P_3$
7	$(q_1,-\{q_1+\alpha_i(Q_2-C_2)\},\alpha_i(Q_2-C_2))$	$P_1(1-P_2)P_3$
8	$(q_1,-\{q_1+\alpha_i(Q_2-C_2)\},\alpha_i(Q_2-C_2))$	$(1-P_1)(1-P_2)P_3$

Notes: In the revenue function, the first matrix represents profit of software developers, the second matrix represents the users' income, and third parties matrix is on behalf of earnings supervision.

P_2 and rejection probability is $(1-P_2)$. Regulatory probability of supervisor is P_3 and non-regulatory probability is $(1-P_3)$. Table 2 is the game's payoff matrix in each of the inner situation.

According to the reverse induction we can solve the game equilibrium solution, the results are as follows:

(1) Software developers' gain equilibrium:

$$\begin{aligned}U_1 = {} & P_1P_2(1-P_3)(Q_1+R_1-C_1)+P_1P_2P_3(Q_1+R_1-C_1-Z_1)\\ & +(1-P_1)P_2(1-P_3)(Q_1-C_1)+(1-P_1)P_2P_3(Q_1-C_1)+P_1(1-P_2)(1-P_3)q_1\\ & +(1-P_1)(1-P_2)(1-P_3)q_1+P_1(1-P_2)P_3q_1+(1-P_1)(1-P_2)P_3q_1\end{aligned}$$

Then we make derivation of the above function, and the first derivative is equal to zero, as follows.

$$\begin{aligned}dU_1/dP_1 = {} & P_2(1-P_3)(Q_1+R_1-C_1)+P_2P_3(Q_1+R_1-C_1-Z_1)\\ & -P_2(1-P_3)(Q_1-C_1)-P_2P_3(Q_1-C_1)+(1-P_2)(1-P_3)q_1\\ & -(1-P_2)(1-P_3)q_1+(1-P_2)P_3q_1-(1-P_2)P_3q_1=0\end{aligned}$$

We get the conclusion. $P_3^*=R_1/Z_1$.

(2) Users' gain equilibrium: In order to simplify the calculation, so

$$\begin{aligned}U_2 = {} & P_1P_2(1-P_3)(Q_2-R_1-C_2)+P_1P_2P_3(Q_2-R_1-C_2)\\ & +(1-P_1)P_2(1-P_3)(Q_2-C_2)+(1-P_1)P_2P_3(Q_2-C_2)\\ & +P_1(1-P_2)(1-P_3)(-q_1)+(1-P_1)(1-P_2)(1-P_3)(-q_1)\\ & -P_1(1-P_2)P_3(q_1+q_2)-(1-P_1)(1-P_2)P_3(q_1+q_2)\end{aligned}$$

Then we make derivation of the above function, and the first derivative is equal to zero, as follows.

$$\begin{aligned}dU_2/dP_2 = {} & P_1(1-P_3)(Q_2-R_1-C_2)+P_1P_3(Q_2-R_1-C_2)\\ & +(1-P_1)(1-P_3)(Q_2-C_2)+(1-P_1)P_3(Q_2-C_2)\\ & +P_1(1-P_3)q_1+(1-P_1)(1-P_3)q_1+P_1P_3(q_1+q_2)\\ & +(1-P_1)P_3(q_1+q_2)=0\end{aligned}$$

We get the conclusion. $P_1^*=(Q_2-C_2+q_1+P_3q_2)/R_1$.

More, $P_3^*=R_1/Z_1$ and $q_2=\alpha_i(Q_2-C_2)$ will be the introduction of the above equations, and then we can get this result: $P_1^*=\{(1+\alpha_iR_1)(Q_2-C_2)+q_1Z_1\}/Z_1R_1$.

2.4. **Stability analysis of conflict model.** Combining these above contents to do stability analysis, we achieve a balance end from all possible outcomes. Specific steps are as follows. For players D, if we consider result q, reasonable stable result (r) does not exist unilateral improvements, namely no UI. Called for D, r is the most stable situation [10].

The stability of software project developers' set is $(2, 3, 1, 0)$, and the stability of software project users' set is $(6, 5, 3, 1, 0)$. Thus, situation 3 is the global stability. According to the above approach, we make all the outcome with stability analysis. The results are shown in Table 3.

Table 3. Stability analysis

Software developer (D)	Priority sequence of software developers (D)								
Stability of the players	r	r			r		r		r
Preference ordering	2	3	5	6	1	4	7	8	0
Unilateral Improvements			2	3		1		7	
Users (U)	Priority sequence of software project user (U)								
Stability of the players	r	r	r			r			r
Preference ordering	6	5	3	2	4	1	8	7	0
Unilateral Improvements				5	5 6		6	3	

3. Results Analysis.

3.1. **Countermeasure and suggestion.** Through the income equilibrium results, we can get that the probability of software developers information occult technology is $P_1^* = \{(1 + \alpha_i R_1)(Q_2 - C_2) + q_1 Z_1\}/Z_1 R_1$.

P_1 is inversely proportional to Z_1 and R_1, and has a definite proportional relationship with $Q_2 - C_2$. That is to say, if software developers gain the greater income through occurring occult technology behavior, the greater probability the users will choose the risk of rejection. Otherwise, the income gained by the users in the case of acceptance is more. At the same time, the probability of occult technology behaviors will be bigger. If we want to reduce the probability of software developers' information occult technology in the stage of the software project performance, we require these following aspects.

(1) Reducing the benefits of software developers got by occult technology behaviors, can reduce earnings of regulators.

(2) Introduce the third-party supervision and increase the amount of penalty to software developers' occult technology behavior, once found and punished without leniency.

(3) Reducing the net benefits of users gained by the software project, while can cause software developers reduce the probability of occult technology behavior.

From what has been discussed above, the probability of users to accept the software exploited by software developers will be inversely proportional to the additional revenue R_1. When supervisor' revenue increases, it indicates that punishment function is increasing. With the degree of occult technology information behavior occurred by software developers substantially increasing, the probability of user' acceptance will be reduced. Therefore, while introducing the third-party supervision, developing the contract needs to mark the occult technology behaviors of software developers occurred. Therefore, the introduction of third-party supervision, while developing the contract to be marked once software developers stealth technology behavior occurs, will severely punish and prevent bad moral hazard behavior of software developers. Software developers will be severely punished, which can reduce bad moral hazard behavior of software developers.

3.2. **Numerical simulation of mathematica.** To illustrate the connotation of establishing the game model, and further demonstrate the scientific nature of the theorem, we make numerical simulation through the mathematica software. The following trends are hypothetical argument, which only describe the general trend, not carefully described digital units.

(1) In the complete information, according to equilibrium formula $P_3^* = R_1/Z_1$, the probability of the third party supervision regulation is related to R_1 and Z_1; at the same time, R_1's growth is interrelated with Z_1's. Users can only set the giving to the third party supervision after estimating R_1, so Z_1 is not fixed. We suppose that when penalty amount is in a certain state and the unit is 1000, the greater occult income developers obtained, the greater the probability that the users go to a third-party supervision, as shown in Figure 2.

(2) Under the complete information, according to the equilibrium formula, $P_1^* = \{(1 + \alpha_i R_1)(Q_2 - C_2) + q_1 Z_1\}/Z_1 R_1$, the probability of software developers' information hiding technology is related to $Q_2 - C_2$ and Z_1. Then, reducing the income by the user got through project activities can reduce the probability of the developers' information occult technology behaviors. Finally, improving the penalty amount can reduce the probability of the developers' information occult technology behaviors. We assume the value of $R_1 = 10$, $Q_2 - C_2 = 20$, $\alpha_i = 0.5$, $q_1 = 8$, as shown in Figure 3.

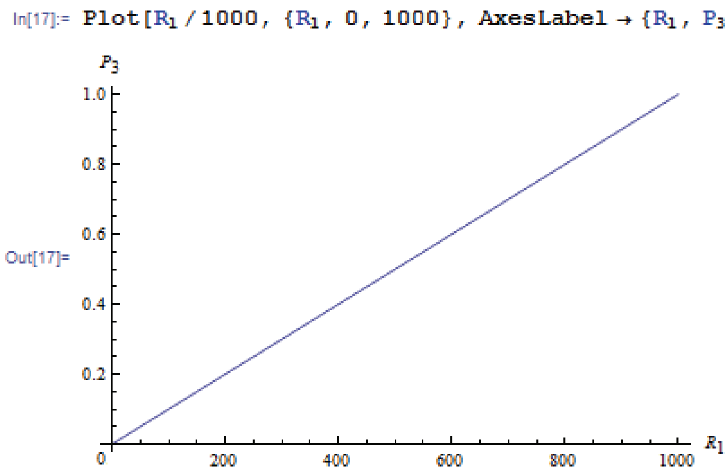

Figure 2. Relationships between software developers' proceeds by occult information and probabilities of third-party supervision's regulation

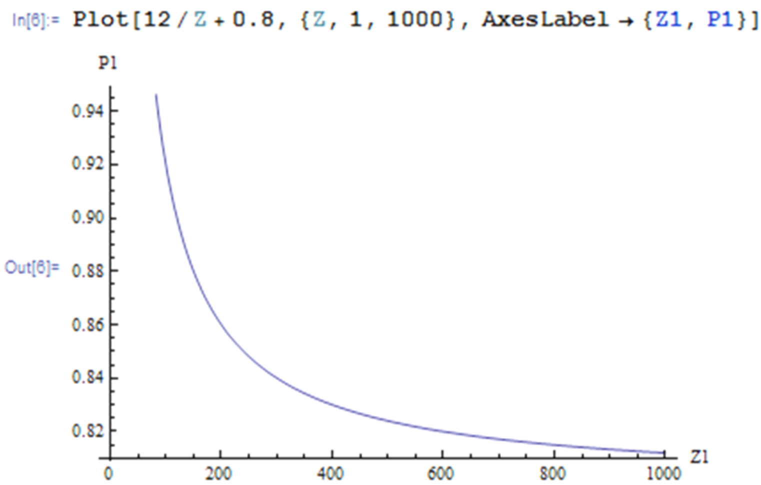

Figure 3. Relationships between penalty amount and probabilities of information occult technology of software developers

4. **Conclusions.** The above analysis showed that IT project developers will conceal technical information. In fact, software developers have intangible technical information. Most users do not understand the real profitability of IT projects and cause the blindness promotion. And most users do not grasp the full and true software technology information. There exists serious asymmetry information between software developers and software users. Currently, the whole process of IT projects generally follows the above tripartite equilibrium in the game. In this article, the conclusions and the reality of the conflict are fully fit.

Therefore, it is recommended when users and developers attempt to sign a contract, users should introduce the third-party supervision to assess the qualifications of the project. According to the past experience to measure the ability of project returns, users are necessary to understand the relevant laws and regulations in order to protect their own benefits. The IT project users and IT project developers must develop a good agreement in advance. It can effectively prevent IT project developers from hiding the core technology of information software to circumvent user needs. Once the users found that IT project developers choose occult strategy, they should timely feed back and increase the amount of penalty to software developers' occult technology behavior, once found and punished without leniency.

If necessary, users should take legal means to safeguard their own interests. This paper established the game model of IT projects between actors to discover the project risks, not just fitting the reality of a common phenomenon in the software industry, but providing the best solutions for actors. Based on asymmetric information studying the main IT projects involved in the game model analysis is a new perspective in the field of IT project risk.

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