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Game Analysis of Behavior Choice on Construction of the Social Emergency Rescue System Between Government and Enterprises

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ABSTRACT The behavior choice between the social emergency rescue rules makers (government and its important participant enterprises) has a great influence on the social emergency rescue activities. So this paper makes an in-depth analysis on the behavior choice between government and enterprises in the social emergency rescue activities. We analyses the actions and motivations between government and enterprises through constructing the static and dynamic game model between government and enterprises in the emergency management technology innovation. Finally, the corresponding suggestions are proposed.

INDEX TERMS Behavior choice, construction, game analysis, social emergency rescue system.

I. INTRODUCTION

At present, with the deepening of economic globalization and international cooperation, the emergencies are becoming more frequent, complex and international, which results in greater loss and wider scope of influence. It poses a serious challenge for the government to strengthen its emergency management capacity. Therefore, it is rather important to strengthen the in-depth cooperation between the government and its important forces. The social emergency rescue enterprises could improve the technical innovation ability of emergency management, and promote social emergency rescue ability through the technical innovation and upgrading of emergency management, in the hope of effectively responding to emergencies.

In recent years, with the frequent occurrence of emergencies, the social demand for using advanced emergency management technology to improve the capacity and efficiency of social emergency rescue has increased dramatically. Many emergency management experts and scholars at home and abroad pay attention to the innovation of social emergency rescue technology. In foreign countries, the United States, Japan, Australia and other major developed countries have attached great importance to the theoretical and practical research of social emergency rescue technology innovation for many years, especially the research on emergency early warning, emergency decision-making and emergency rescue system construction [1], [2]. Yotsukura *et al.* presented a framework that links simulations have been developed independently and a prototype system connects two disaster and rescue systems with different features [3]. James LW had developed an evaluation process of these systems for the American government [4]. Japanese scholars put forward the evaluation model of emergency management capacity of Japanese big cities [5]. Australian scholars deeply studied the evaluation system of emergency management capacity and pointed out that emergency response and disaster reduction measures are the core elements of the evaluation system [6]. Son *et al.* summarized and synthesized the literature that examined resilience in the context of emergency management [7]. Liu *et al.* presented an effective quantification method to assess the dynamic value of social media data [8]. In China, there are many researches on the technology innovation of emergency management. Qing and Zhao established the comprehensive ability evaluation system of urban emergency management [9], [10]. Song *et al.* scientifically constructed the scientific and technological support system of emergency management [11], [12]. Zhong *et al.* preliminarily determined the constituent elements of the scientific and technological support system of emergency management [13]. Huang et al carried out in-depth research on the construction of the scientific and technological support system of emergency management in Hubei Province [14]. Lu proposed that Guangdong

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should promote the scientific and technological innovation of emergency management to strengthen the construction of the scientific and technological support system. Tang proposed a collaborative emergency linkage model applying to China's actual situation. Chi developed "dynamic game network technology" based on the characteristics of emergency management [15]. Yao analyzed the game process between an emergency and the crisis managers in emergency management [16]. Based on the research on social emergency rescue technology at home and abroad, the quantitative research on the innovation was very popular. Many researchers used mathematical models to study the law and evolution process. Game theory has been applied in emergency management system [17]–[24]. Unfortunately, using the game theory approach is still insufficient and the research results are few.

Therefore, this paper uses the game theory to carry out the research on the behavior selection of government and enterprise in the construction of social emergency rescue system. Furthermore, we discusses how the two sides can promote the "competition and cooperation game" in the construction of social emergency rescue system, in order to provide the theoretical basis for the government to formulate the construction policy of social emergency rescue system.

The organization of this paper is as follows: we give the introduction of the relevant works in Section 1. In section 2, the static game analysis of behavior choice between government and enterprise is investigated. Section 3 performs the dynamic equilibrium analysis of government and enterprise behavior choice. In Section 4, conclusions and suggestions are given.

II. THE STATIC GAME ANALYSIS OF BEHAVIOR CHOICE BETWEEN GOVERNMENT AND ENTERPRISE

In order to analyze and study the behavior choice of government and enterprise in the construction of social emergency rescue system, this paper puts forward the following assumptions for the establishment of game model of both parties:

Hypothesis 1: There is only one government and one enterprise in the construction of social emergency rescue system, excluding other scientific research units and social organizations in colleges and universities, aiming at maximizing respective profit.

Hypothesis 2: There are two kinds of action strategies of the government in the construction of social emergency rescue system: active support and negative support. There are only two kinds of action strategies of enterprises in this system: implementation of construction behavior and non-implementation of construction behavior.

Hypothesis 3: Two sides of the game have equal status. Both sides can freely choose the action plan according to the maximum of their own profit. Both sides of the game have equal information in each action step.

Hypothesis 4: Government revenue mainly comes from this enterprise. The economic income R of the enterprise depends on the output Q, that is $R = R(Q)$. The enterprise has the reputation cost which does not implement the construction behavior. The government has the political cost which passively supports, or even does not, the enterprise to implement the construction behavior.

Based on the above assumptions, the static game model of behavior selection of government and enterprise in the construction of social emergency rescue system is shown in TABLE 1.

TABLE 1. Static game model between government and enterprise.

		Government	
		Active support	Negative support
Enterprise	Not implemented	R_2-h-F, T_2-H+F-C	R_2-h, T_2-H
	Implementation	R_1, T_1-C	R_1, T_1

In the static game model, the income of enterprises is realized through the production of emergency rescue technical products or emergency management technical products. We use Q_1 to produce the technical product output when the enterprise implements the construction behavior. And the corresponding enterprise profit is R_1. Q_2 is the technical product output when the enterprise does not implement the construction behavior. And the corresponding enterprise profit is R_2. The implementation of the construction behavior involves a lot of financial and human resources. Meanwhile, the technical products produced by technological innovation have unstable functions, which results in high prices and small market rate at the initial stage, that is, low output and low profits. Therefore, $Q_2 > Q_1$, $R_2 > R_1$. If the enterprise does not carry out the construction behavior, the outdated technology and low rescue rate of technical products providing the social rescue professionals will cause that the crisis event emergency management ability is low. This will result in the loss of property or even life of the society and people and cause the loss of corporate social image, which will be condemned by people. The loss of social image is called reputation cost, which is called h. In this situation, if the enterprise does not conduct construction, the actual revenue is R_2-h.

For the government, the direct income comes from the tax T of the enterprise, which is a function of the output Q of the technological products of the enterprise, that is, $T = T(Q)$. Because that $Q_2 > Q_1$, $R_2 > R_1$, the government gets more tax when the enterprise does not implement the construction behavior which is $T_2 > T_1$. Considering the social responsibility and social impact, the government will urge the enterprises to implement construction behavior, improve emergency technology and enhance the technical content of rescue products. One effective way is to punish the enterprises that do not implement construction behavior. In this way the government will get income F. If the government actively supports enterprises to implement construction behavior, this will generate resource cost, which is support cost C. In addition, if the government passively supports the enterprises to carry out construction, this will result in the outdated technology of rescue products and the low rescue efficiency. As a result, the safety of the society and people is not guaranteed, which will arouse condemnation from the public and affect the official career and other losses. We call it the political cost, and record it as H. See TABLE 1 for the specific income matrix.

Government and enterprise are one-off static games. Based on this, we analyze the behavior choice between government and enterprise, and draw the following conclusions:

(1) When $f<C$, the government revenue from punishing the enterprises does not implement the construction behavior (i.e. implementing the negative support strategy) which is not equal to the government's support cost of actively supporting the enterprises to implement the construction behavior. The best choice of the government's behavior is negative support.

(2) when R_2-h-F>R_1, the benefit of enterprises for not implementing construction behavior is always greater than the benefit of implementing construction behavior. In this case, no matter what behavior of the government takes, the optimal strategy of the enterprise is not to implement the construction behavior.

(3) According to the analysis of Eqs. (1) and (2), when $F > C$ and R_2-h -F <R_1, there will be two Nash equilibrium in the game. The government and the enterprise are in a state of confrontation: when the government actively supports the enterprises, the enterprise chooses to implement the construction behavior; when the government passively supports the enterprises, the enterprise chooses not to implement the construction behavior.

Next, we should play the Nash equilibrium probability distribution.

The probability of enterprises not implementing construction behavior is X, the probability of implementing construction behavior is (1-X); the probability of government active support is Y, and the probability of negative support is (1-Y). The expected revenue of enterprises without construction behavior and implementation of construction behavior strategy is u_i^y, u_i^n. The expected revenue of government active support and negative support strategy is u_g^y, u_g^n.

When the Nash equilibrium of mixed strategy is achieved, the expected return of the government's choice of active support and passive support strategy should be equal. The enterprise chooses its own behavior strategy combination, that is:

$$u_g^y = u_g^n \tag{1}$$

where

$$u_g^y = X(T_2 - H + F - C) + (1 - X)(T_1 - C) \tag{2}$$

and

$$u_g^n = X(T_2 - H) + (1 - X)T_1 \tag{3}$$

Based on Eq. (1) (2) (3), we can obtain X=C/F.

When the government chooses its own behavior strategy combination, the expected returns of enterprises choose to implement construction behavior strategies which are equal, namely:

$$u_i^y = u_i^n \tag{4}$$

where

$$u_i^y = (R_2 - h - F) + (1 - Y)(R_2 - h) \tag{5}$$

and

$$u_i^n = YR_1 + (1 - Y)R_1 \tag{6}$$

According to (4) (5) (6), we can get Y =$R2$-$R1$-h/F.

Based on the above analysis, we can get the mixed strategy solution of the game.

When $Y \in (R_2 - R_1 - h/F, 1]$, the best behavior choice of the enterprise is to implement the construction behavior.

When $Y \in [0, R_2 - R_1 - h/F)$, the best choice of enterprise behavior is not to implement construction behavior.

When $X \in (C/F, 1)$, the best choice of the government behavior is active support.

When $X \in (0, C/F)$, the best choice of the government behavior is negative support.

When $Y = Y^* = R_2 - R_1 - h/F, X = X^* = C/F$, the government and the enterprise reach the game equilibrium.

In the above mixed game, the Nash equilibrium depends on the expected earnings R_2 and R_1, the reputation cost h, the penalty F and the support cost C of the government. However, the enterprises do not implement the construction behavior.

III. THE DYNAMIC EQUILIBRIUM ANALYSIS OF GOVERNMENT AND ENTERPRISE BEHAVIOR CHOICE

The above model analysis is only a static game analysis. Next, let's take two steps. Firstly, we will dynamically analyze the behavior choice of the government and enterprises in the construction of social emergency rescue system. Secondly, we will discuss how the variation of relevant factors causes the game equilibrium to change, which will impact the behavior choice of both the government and enterprises. By doing these, we could scientifically grasp the interaction between government and enterprise and provide decision-making basis for the government to relevant policies. Thus, the construction of emergency rescue system of the enterprises is accelerated.

We use the coordinate chart to study how the changes of relevant factors affect the behavior choice of both the government and the enterprise. First, the analytical formula (2) is transformed into$u_g^y = (T_1 - C) + X(T_2 - Y_1 - H + F)$, which is represented by a straight line AB on the coordinate diagram. Line AB describes the relationship between the revenue of the government's active support and the probability of the enterprise without implementing the construction behavior. Point A indicates the revenue of the government's active support when the probability of the enterprise without implementing the construction behavior is 0 (i.e. implementing the construction behavior), which is recorded as $T_1 - C$.

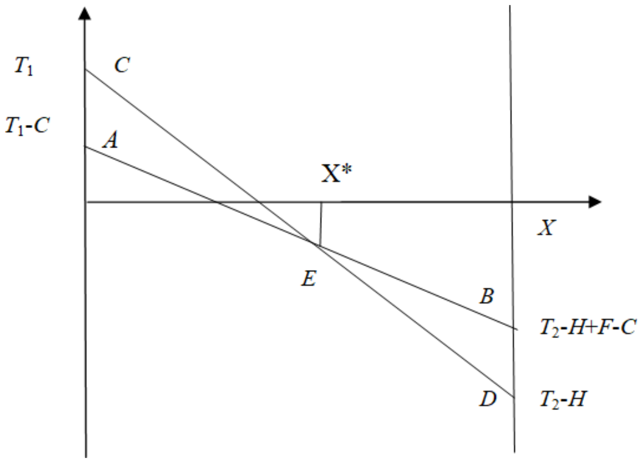

FIGURE 1. **The schematic diagram of enterprise behavior selection probability in government strategy space $X*$ is the probability that the enterprise will not implement the construction behavior strategy optimally.**

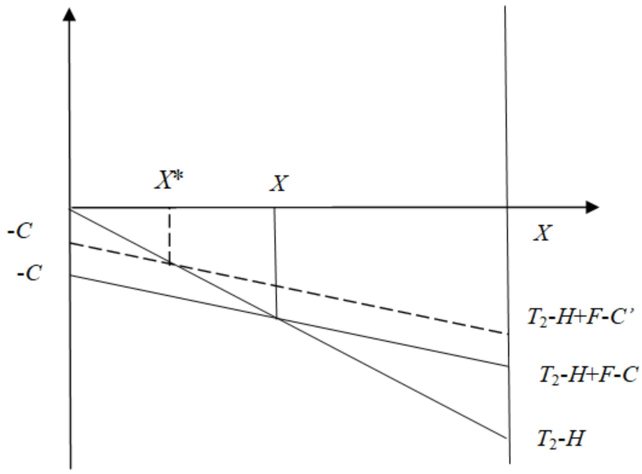

FIGURE 2. **The equilibrium diagram of reducing government support cost C. $X*$ is the probability that the enterprise will not implement the construction behavior strategy optimally.**

Point B indicates the revenue of the government's active support when the enterprise does not implement the construction behavior, which is recorded as $T_2 - H + F - C$. Similarly, we simplify formula (3) with $u_g^n = T_1 = X(T_2 - T_1 - H)$, which is represented by straight line CD on the coordinate graph. The straight-line CD describes the relationship between the revenue of government's negative support and the probability of enterprises not implementing the construction behavior. Point C indicates the revenue of government's negative support when enterprises implement the construction behavior, which is recorded as T_1. Point D indicates the revenue of government's negative support when enterprises do not implement the construction behavior, which is recorded as T_2-H. The intersection of the two income lines AB and CD at point E indicates that there is no difference between the expected income of the government's active support or passive support. This means that the government has reached the optimal equilibrium state. The corresponding $X*$ here is the probability that the enterprise will not implement the construction behavior strategy optimally, which is recorded as C/F. See FIGURE 1 for details.

According to the coordinate FIGURE 1, we can intuitively understand the equilibrium process of the behavior game and find out which factors affect the behavior choice equilibrium between the government and the enterprise in the construction of the social emergency rescue system. Based on the above analysis, we know that reducing the government's support cost C, reducing the government's revenue T_2, increasing the government's penalty income F and increasing the government's political cost H will urge enterprises to reduce the probability of not implementing the construction strategy. As a result, enterprises will improve the technique and advancement of the emergency rescue technology products, which will enhance the efficiency of emergency rescue and ensure the safety of public life and property.

Next, we will carry out a detailed analysis of four factors affecting the equilibrium process: reducing the government's support cost C, reducing the government's revenue T_2, increasing the government's punishment revenue F for the enterprises that do not implement the construction behavior, and increasing the government's political cost H. (for the convenience of analysis, we set $T_1 = 0$. Of course, this simplification will not affect the conclusion). (1) Reduce the resource cost C of the government's active support for enterprises to implement the construction behavior. If the government's support cost C is reduced, the revenue curve AB of the government's active support for enterprises to implement the construction behavior will shift upward (see FIGURE 1-2), and the equilibrium point X will shift to the left, which indicates if the support cost is reduced, the government's active support revenue will increase. In this case, the government will take active support strategy. At the same time, if the government adopts the strategy of active support, the income of enterprises for not implementing the construction behavior will be reduced. Therefore the probability of enterprises' not implementing the construction behavior will be reduced, and then the government will relax the active support. Through the continuous dynamic game between the two sides, the new equilibrium point $X*$ will finally be reached. As is shown in FIGURE 2, $X* < X$ shows that the cost reduction of active support in implementing construction behavior will ultimately reduce the probability of enterprises' not implementing construction behavior, promote the implementation of enterprise behavior, and enhance the advanced technology of emergency rescue technology products.

(2) Increase the government's penalty income F from the enterprises that do not implement the construction behavior. If we increase the penalty income F given by the government to the enterprises that do not implement the construction behavior, the income curve AB of the government actively supporting the enterprises to implement the construction behavior rotates counterclockwise around the left end (see FIGURE 3). In this situation, the government will take the initiative to support the enterprises to implement the

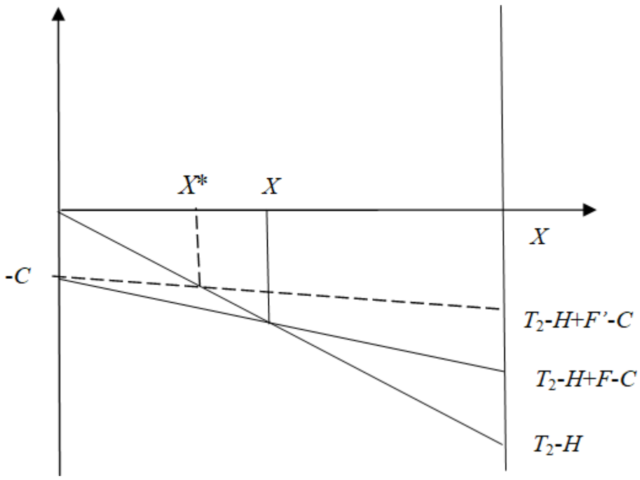

FIGURE 3. **The equilibrium diagram when the government gives penalty income f to enterprises that do not implement technological innovation $X*$ is the probability that the enterprise will not implement the construction behavior strategy optimally.**

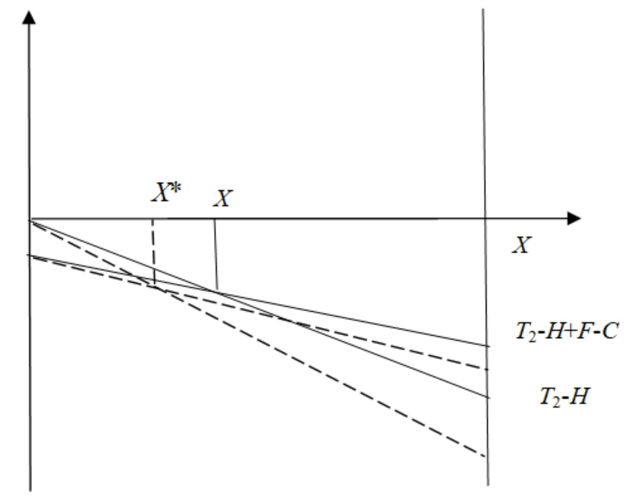

FIGURE 4. **The equilibrium diagram when T_2 is reduced or H is increased $X*$ is the probability that the enterprise will not implement the construction behavior strategy optimally.**

construction behavior. If the government adopts the active support strategy, the enterprise will reduce the probability of not implementing the construction behavior due to the decrease of revenue. After repeating games between the two sides, the enterprise will finally reach a new equilibrium point X∗. It can be seen from FIGURE 3 that X∗ <X indicates that increasing government punishment policies could urge enterprises to implement construction behavior.

(3) Reduce the government's revenue T_2 when the enterprise does not implement the construction behavior. With the decrease of T_2, the revenue curve AB (the government's active support construction behavior) and CD (the government's passive support construction behavior) rotate counter clockwise around the end point (as shown in FIGURE 4). The new point X∗ at the intersection of two new lines is the probability of the enterprise's optimal non implementation of the construction behavior strategy. From FIGURE 4, X∗ <X indicates that the reduction of the government's revenue T_2 from the enterprise can reduce the probability of enterprises without implementing construction behavior and promote the implementation of construction behavior.

(4) Increase the political cost H of government. With the increase of government' political cost H, the two revenue curves AB and CD of the government rotate counterclockwise around the endpoint respectively. The new intersection point X∗ is the optimal behavior point of the enterprise, X∗ <X, indicating that increasing the government' political cost can indeed reduce the probability of the enterprise not implementing the construction behavior and promote the enterprise to implement the construction behavior (see FIGURE 4).

IV. CONCLUSION AND SUGGESTIONS

Based on the above dynamic equilibrium analysis of the behavior choice between the government and enterprises in the construction of social emergency rescue system, we can draw a conclusion that reducing the government's support cost C, reducing the government's income T_2, increasing the government's penalty income F and increasing the government's political cost H will contribute to urging enterprises to implement the construction behavior and enhancing the advanced technology of the emergency rescue technology products. To achieve these, we offer the following advices for the government in order to formulate support policies to promote the implementation of construction behavior of enterprises and improve the function of emergency rescue technology products.

(1) Formulate scientific and effective support policies, standardize the implementation of support policies and minimize the cost of resources actively supported from the government.

According to the social demand for emergency rescue technology and the social security expected by people, we should formulate scientific and effective support policies for the implementation of the construction behavior of the enterprise through full investigation and demonstration. These support policies include a series of preferential policies for finance, tax, talents, funds, projects and land, so as to avoid increasing the cost for the lack of scientific guidance. At the same time, we should standardize the system, ensure the implementation of supporting policies and reduce the implementation cost. Through improving the scientific nature of supporting policies, reducing the cost of formulation and standardizing the implementation behavior, we hope to reduce the resource cost of the government's active support for enterprises to implement the construction behavior, and urge enterprises to implement the construction behavior.

(2) Increase the penalty income F from the enterprises that do not implement the construction behavior and reward the enterprises that implement the construction behavior.

Firstly, it the enterprises do not implement the construction behavior and improve the performance of emergency rescue technical products, they should be punished more.

These punishments include the collection of backward production capacity tax, the implementation of technical elimination, forced production suspension and rectification, etc., in order to increase the cost of enterprises that do not implement the construction behavior, indirectly reducing the profits of enterprises, and urging enterprises to adopt technological innovation for development. Secondly, the enterprises that implement the construction behavior should be given each various incentives, including material incentives such as priority of government's procurement, government's provision of various low interest loans or technical transformation funds, as well as measures to improve the reputation of enterprises: media praise and awarding product quality marks. All these measures will contribute to promote enterprises to accelerate the construction behavior.

(3) Reduce the governmen's revenue from enterprises not implementing the construction behavior T_2.

The enterprise can use a large number of resources to produce more emergency rescue technical products without implementing the construction behavior. After years of mature sales experience, the enterprise has a high market share of technical products and a high sales rate of technical products, which brings a lot of profits for the enterprise smore tax T_2 for the government. Therefore, the government and the enterprise are not willing to promote the construction behavior considering their own short-term interests. That is to say, the interest alliance formed by the government and the enterprise hinders the implementation of the construction behavior of the enterprise. Therefore we should break the close interest relationship between the government and the enterprise, reduce the proportion of the local tax. In order to promote the enterprise to accelerate the construction behavior, the government should do the introspection to reduce the revenue brought by the government's failure. Thus, the advanced and efficient emergency rescue technology products will be produced to meet the needs of the public and enhance the social responsibility of the government and enterprises.

(4) Introduce restraint mechanism to increase government political cost H and enterprise reputation cost h.

We should give full play to the role of restraining organizations, the public, non-governmental organizations and news media. These measures will be conducive to establish a scientific restraining mechanism, standardize the construction behavior and enhance the social responsibility of the government and enterprises. Through all-round constraints of the public, non-governmental organizations, news media and other organizations, the reputation cost of enterprises will improve construction behavior, reduce insufficient product function of the emergency rescue technology, even guarantee the safety of public life. As a result, the enterprises will consciously perform social responsibility and promote the construction behavior. On the one hand, the supervision of the public and social organizations by the media will make the government face more direct constraints. On the other hand, these measures increase the political cost of the government and urge the government to perform its duties in accordance with the law, meanwhile, actively support enterprises to implement the construction behavior.

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