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Research on Environmental Protection Strategy of Urban Construction Subject Based on Evolutionary Game

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Abstract: With the urban renewal and development, the impact of urban construction projects such as old city reconstruction on the surrounding environment has always attracted social attention in the construction process. The strategies of the participants in the project construction in the process of environmental protection need to be further clarified. Taking the government investor and contractor as the construction subject, combined with questionnaire survey and evolutionary game, determines the three-party evolutionary stable game strategy and clarifies the internal mechanism of the evolution trend of the construction subject through simulation. The results show that the investor and contractor have a certain awareness of environmental protection, but they have limited understanding of the relevant policies and regulations issued by the government and believe that the government has little supervision and governance. The optimal evolutionary stability strategy adopted by the construction subject in promoting environmental protection is {Incentive, Effective supervision, Proper protection}, in which the stability conditions are $J_1 > M_1$ and $T_1 > N_1$. Reducing G_1, A, M_1, N_1 and T_1 or increasing J_1 and the construction subject's willingness to take measures can promote the model to stabilize and evolve. The government should establish and improve the incentive system, improve the environmental protection awareness of the construction subject, urge the investor and the contractor to take effective measures to achieve the long-term stability goal of the tripartite subject strategy, and minimize the impact on environmental protection.

Keywords: urban construction project; environment protection; tripartite evolutionary game

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1. Introduction

At present, China is in the middle and high-speed development stage of industrialization and urbanization, and construction has become a pillar industry of the national economy [1]. Malindu Sandanayake et al. pointed out that the environmental pollution problem of construction sites is prominent, and the stakeholders and relevant researchers in the construction industry should firmly work sustainably [2]. The environmental impacts such as noise, dust, safety, drainage pollution and soil erosion caused by urban construction projects cannot be ignored [3]. Wen pointed out that the construction of urban construction projects has a great negative impact, not only in terms of economic losses and casualties, but also in terms of ecological environment damage [4]. Jackson Dullius Piller et al. have studied that in the whole life cycle of urban construction projects, the decision making in the construction stage, including construction technology and technology, are the potential reasons for the impact on the surrounding environment [5].

In order to minimize the environmental impact of urban construction projects, domestic and foreign scholars have conducted some research on the measures and interaction mechanism of the three parties to deal with the surrounding environmental impact caused by urban construction projects. Under the opportunity that the policy objective orientation of the central government has changed from focusing on economic development to paying attention to environmental protection [6], Daniela Lazoroska et al. proposed that under the current limited environment, the government can promote greener technology by deploying effective environmental regulations to reduce the impact on the surrounding environment [7]. He pointed out in the study that government departments can issue incentive policies to reduce environmental impact, such as encouraging banks to give priority to preferential loans to investors who take effective measures for environmental protection [8]. In the application of incentive measures taken by the government, Yang and Cohen have proven the feasibility of incentive policies through examples at home and abroad, which provides a basis for effectively encouraging contractors to take the initiative to implement environmental governance measures [9,10]. For the contractor, the implementation of green construction is the only way to solve the current environmental pollution in the construction industry. Only by adhering to sustainable development can the construction industry be better suitable for social development [11]. Although the government, the investor and the contractor have taken certain measures, at present, the investor and the contractor have limited attention to the surrounding environmental impact and government supervision, and the contractor has speculative psychology, resulting in slow progress in environmental protection and governance, and there are still environmental impact consequences in varying degrees [12].

Due to the complexity of stakeholder relations, social conflicts related to the imbalance of interest distribution [13], and the increase in participants, the current project management method has been unable to meet the actual needs [14]. Game theory provides a new idea for environmental protection of construction projects. When Radwaeissa proposed to study and analyze problems related to urban construction projects, game theory was widely used to solve conflicts. Cooperation has made great contributions to benefit distribution, governance and supervision and risk distribution [15]. However, the precondition of traditional game theory is complete rationality and complete information, and the explanatory power of reality is insufficient. The evolutionary game theory takes the group as the research object, starts from the limited rationality of the subject, understands the dynamic process of group evolution, and explains why the group reaches this state and how to achieve it. The evolutionary game theory is closer to reality [16].

In the decision making of environmental protection behavior of the main body of urban construction projects, the government, investor and contractor are important participants in promoting effective environmental protection. They have the characteristics of interest reconciliation and contradiction. When taking environmental protection decisions, they have the characteristics of game. At the same time, the subject has bounded rationality, and the subject's decision-making behavior has dynamic equilibrium. An evolutionary game means that the optimal decision cannot be made quickly at the beginning, but the strategy can be continuously learned in the process of game, and then the strategy can be adjusted to achieve the improvement of income [17]. Therefore, the three parties of the construction subject need to rationally consider their own behavior strategies under the constraints of the game, realize the overall interest balance and promote the effectiveness of environmental protection. Ke proposed the bounded rationality of the government and developers, and their strategies may change over time. An evolutionary game provides a quantitative method to illustrate the effectiveness of incentives and the changes of participants' strategies [18]. During the research on the ecological environment governance of the Three Gorges Reservoir area, Yang proposed that evolutionary game can calculate the evolutionary stability strategy among stakeholders with scientific and effective methods and make the conclusion more comprehensive, true and objective by continuously improving the indicators of subject coordinated development ability [19]. Ma et al. analyzed Party A's behavior decision through evolutionary game and proposed to implement different incentive policies in order to better achieve the incentive goal [20].

However, the current game research mainly considers the government and contractors, the government, developers and consumers, or investors and contractors as the stakeholders [21,22]. In view of this, this study considers the government, investors and contractors as the construction subjects of urban construction projects and uses the evolutionary game method to put forward the optimal strategy combination of the three parties in promoting the minimization of environmental impact, clarifying the relevant influencing factors to provide practical and theoretical guidance for the excellent development of the surrounding environment of urban construction projects.

2. Analysis of Construction Subject

As the main body of urban construction projects, the government, investor and contractor interact and influence the construction and development of the projects. As the maker and promoter of public policies, the government plays a role of supervision and guidance for investors and contractors and has the obligation to control the impact on the surrounding environment [23]; the investor has the right to supervise the contractor and needs to take measures to reduce the impact of the project on the surrounding environment. The contractor needs to deal with the impact on the surrounding environment. As an economic man, the investor and the contractor aim to maximize their own benefits, while the government aims to build an environment-friendly society. The positions and income losses of the three parties are different, which may aggravate the impact on the surrounding environment of urban construction projects. Therefore, coordinating the demand differences of different subjects and dealing with the balance of interests of the construction subjects are conducive to avoiding or reducing the impact of urban construction projects on the surrounding environment. Based on this, this paper determines the government, the investor and the contractor as the construction subject, makes a game analysis on the interest relationship among the three parties, and explores the mechanism of the impact of urban construction projects on the surrounding environment.

The government's regulation, guidance and supervision in the environmental protection work of urban construction projects, including the enhancement of credibility and the additional benefits due to proper protection, directly affect the government's choice of behavior. As the current policies and regulations on the impact of urban construction projects on the surrounding environment are not perfect, the government needs a lot of manpower, material resources and funds if it formulates incentive policies. Therefore, when the overall benefit of the government is positive, the enthusiasm of the government to take measures is high, but the enthusiasm is low anyway.

The investor mainly plays the role of supervising and managing the contractor in the environmental protection process of urban construction projects. When the investor takes effective regulatory measures, it costs more money, but it obtains the benefits of corporate image and the additional benefits of proper protection, which can be recognized by relevant institutions and surrounding residents. Therefore, when choosing strategies, investors choose effective supervision if the income is greater than the expenditure of effective supervision measures. If the overall return is negative, the investor chooses invalid supervision.

As a direct actor in environmental protection of urban construction projects, the contractor's strategy choice directly affects whether environmental protection is effective or not. For the contractor, it can obtain excellent ecological environment and corporate image benefits at that time and ensure the normal life of surrounding residents. However, when the cost of proper protection measures is less than the income, the contractor tends to choose appropriate protection; on the contrary, it is more inclined to improper protection.

3. Questionnaire

3.1. Significance of Questionnaire

Many impacts of urban construction projects on the surrounding environment are increasing with the acceleration of urbanization. Although the investor and the contractor have taken many measures to reduce or avoid the impact of construction on the surrounding environment, the current situation of the construction environment of urban construction projects is still not optimistic, and the surrounding environment is still affected to varying degrees. In order to improve the current situation of the impact of urban construction projects on the surrounding environment and adjust the interests of the main body, it is also necessary to explore the basic cognition and behavior tendency of each construction subject considering the impact of the surrounding environment in urban construction projects.

3.2. Questionnaire Design and Survey Methods

Now the government, investor and contractor are the research objects, and relevant questionnaires are designed respectively. The questionnaire divides the urban construction project into three stages: early stage, preparation and implementation, and explores the basic cognition and behavior tendency of investor and contractor on the impact on the surrounding environment. The questionnaire is mainly released through the "questionnaire star" (https://www.wjx.cn/jq/95012188.aspx, https://www.wjx.cn/jq/95037139.aspx accessed on 1 October 2021); 169 investor questionnaires were recovered and 167 were valid, with an effective rate of 99%; and 152 questionnaires were collected from the contractor, 150 were valid, and the effective rate was 99%. In order to avoid the deviation of the research results as far as possible, the main problems in the questionnaire are analyzed and supported on the basis of statistical analysis, combined with the current situation of urban construction projects, expert inquiry, access to the relevant literature and materials.

3.3. Questionnaire Respondents

The respondents are the main personnel of urban construction projects, including project managers, cost engineers, business personnel, safety officers and so on. The position composition of the respondents is conducive to ensuring the objectivity of the sampling survey results from the subject and object. The professional titles of the respondents include junior engineer, intermediate engineer and senior engineer. The professional title rate of the respondents of both sides is 81% and 76%. Based on the relationship between professional title and work experience, the personnel with professional title have relatively rich work experience to ensure the quality of the questionnaire. The working years of the respondents ranged from several months to 38 years, and the number of urban construction projects involved ranged from 1 to 100. The survey results are of great reference value.

3.4. Results of Questionnaire

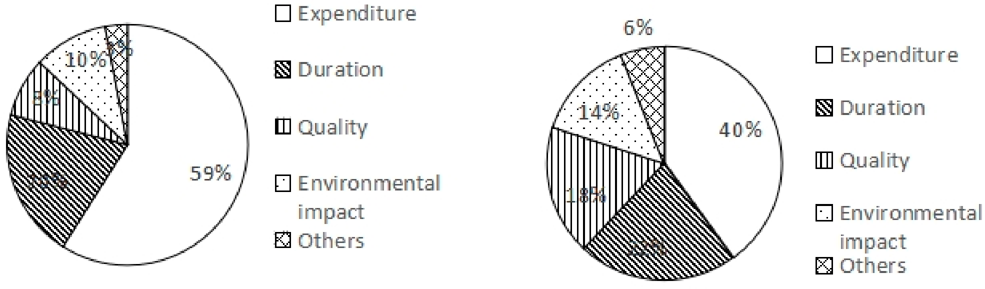
Through the questionnaire survey of the main personnel of urban construction projects, sorting and analyzing the questionnaire, the following conclusions can be obtained:

(1) The investor and the contractor consider it necessary to consider the impact of the urban construction project on the surrounding environment and have also taken relative measures to avoid or reduce the impact on the surrounding environment, mainly by disbursing the cost of environmental protection and treatment measures, repairing the surrounding environment affected during construction and compensating the surrounding people, as shown in Table 1.

Table 1. Ways for both parties to improve the impact of urban construction projects on the surrounding environment.

	Investor/%	Contractor/%
Environmental protection and treatment listed in the bidding document	97	92
It is necessary to repair the surrounding environment affected during construction and compensate the surrounding people	88	81

However, it can be seen from Figure 1 that in the construction stage of the project, when the implementation of environmental protection and treatment measures affects the interests of the investor and the contractor, both parties pay more attention to the expenditure and basically do not pay attention to other items such as construction difficulty and construction technology, which may ignore the surrounding environmental impact, resulting in more serious environmental impact, indicating that it is necessary to reasonably control the expenditure of environmental protection and treatment measures to maintain a safe and good surrounding environment. At the same time, it does not affect its own interests.



(**a**) (**b**)

Figure 1. Comparison between the impact of environmental protection and control measures and their own interests. (**a**) Investor; (**b**) Contractor.

(2) Through the investor's and contractor's understanding of the government's measures on the impact of urban construction projects on the surrounding environment, the specific data are shown in Figure 2. It can be analyzed that the government's universal education and publicity on environmental protection are insufficient, resulting in the lack of public understanding of it. Moreover, both parties are not satisfied with the government's regulatory and governance measures and believe that the current regulatory and governance efforts are not enough and the effect of improving the environment is not obvious. The government should pay more attention to environmental protection and governance, strengthen publicity or legislation, and jointly build a high-quality urban construction project environment.

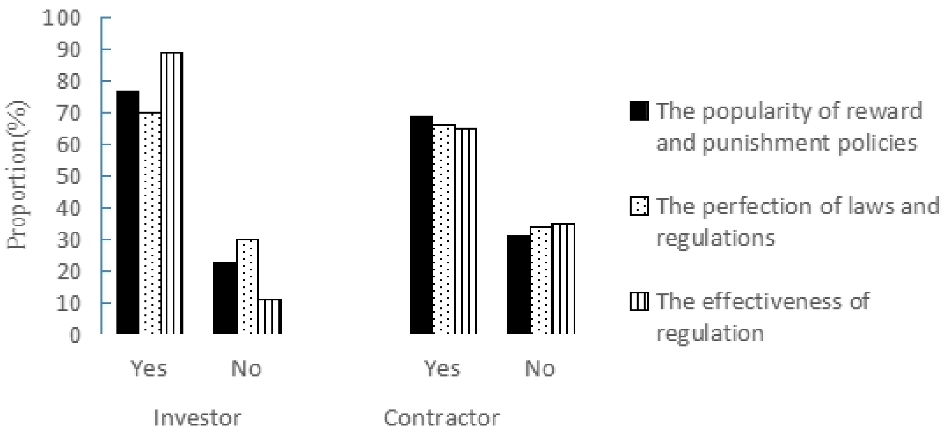


Figure 2. Basic knowledge of investor and contractor on government work.

4. Establishment and Analysis of Game Model

4.1. Game Model Assumptions

Based on the above analysis of the game relationship between the impact of urban construction projects on the surrounding environment, this paper makes the following assumptions:

Hypothesis 1 (H1). *The behavior of the government, the investor and the contractor is limited and rational, and there is no completely rational man, and it is impossible to quickly put forward the optimal strategy initially, but through evolutionary game, we can constantly learn and adjust the strategy to achieve the improvement of income.*

Hypothesis 2 (H2). *In the game system, the government can formulate incentive policies to encourage the investor and contractor to take effective measures to avoid or reduce the impact of urban construction projects on the surrounding environment. The investor can effectively supervise to improve the corporate image, reduce the impact on the environment, and obtain the reward from the government. The contractor shall protect properly, reduce the impact of the urban area on the surrounding environment, reduce the complaints of the surrounding people, improve the corporate image, and obtain the reward from the government.*

Hypothesis 3 (H3). *In the game system, the government, investor and contractor have the power and scheme of their own behavior choice. Each actor has two schemes. The government's strategy is: incentive and no incentive, with probabilities of x and 1-x, respectively. The investor's strategy is: effective supervision and ineffective supervision, and their probabilities are y and 1-y, respectively. The contractor's strategy is: proper protection and improper protection, and the probability is z and 1-z, respectively.*

4.2. Build a Evolutionary Game Model

According to the above assumptions, according to the decisions of the government, the investor and the contractor, there are eight strategy combinations; therefore, the three-party game model can be built, as shown in Figure 3:

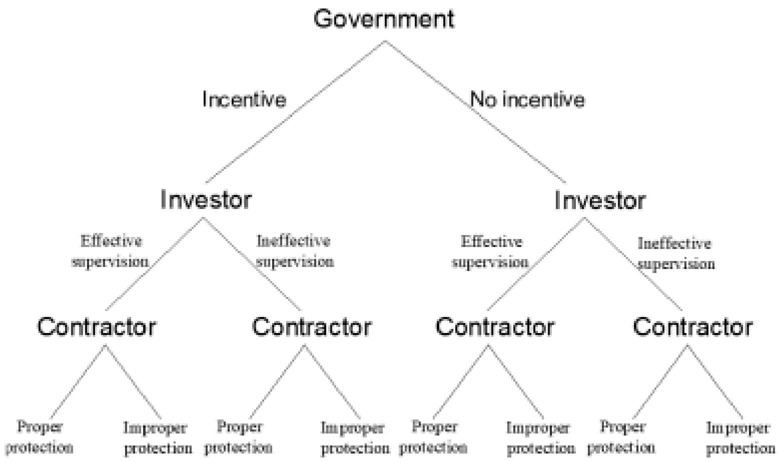


Figure 3. Three-party evolutionary game model.

According to the analysis of the questionnaire survey results of the research group on the cognitive status of the impact of urban construction projects on the surrounding environment in the early stage, the parameters of the tripartite game can be sorted out. The specific parameters and their meanings are shown in Table 2.

Table 2. Game model parameters and their meaning.

Parameters	Description
G_1	The governance and supervision costs paid by the government for maintaining the surrounding environment of the project when taking incentive measures
K_1	The credibility of the government's incentive measures has been improved
K_2	Additional credibility of the government due to proper contractor protection
G_2	When the government does not take incentive measures, it needs to control and supervise the surrounding environment of the project
A	Total incentive fees paid by the government
α	Proportion of investor in total government incentives
$1-\alpha$	Proportion of the contractor in total government incentives
P_1	Income of the investor during normal operation of the project

Table 2. *Cont.*

Parameters	Description
M_1	Operating cost and cost of environmental protection and treatment measures to be paid by the investor during effective supervision
J_1	Corporate image benefits brought by the investor during effective supervision
J_2	Corporate image benefits brought to the investor due to proper environmental protection
M_2	Ineffective if the investor does not actively supervise or the supervision is superficial cost of supervision
F_1	Penalty imposed by the government on the investor when the supervision is not active or superficial, resulting in the impact on the surrounding environment
P_2	Revenue of the contractor during the normal operation of the project
N_1	Cost of environmental protection and treatment measures required by the contractor at that time
T_1	Loss of corporate image caused by improper contractor protection
N_2	Cost of environmental protection and treatment measures required by the contractor at that time
F_2	Cost of environmental protection and treatment measures required by the contractor at that time due to improper protection. When the surrounding environment is affected, the government's fine is to the contractor
R	Residents' compensation and environmental restoration costs after the surrounding environment is affected
β	The proportion of residents' compensation and environmental remediation costs to be paid after the ineffective supervision of the investor causes the impact on the surrounding environment
1-β	Proportion of residents' compensation and environmental repair expenses to be paid after the impact on the surrounding environment caused by improper protection of the contractor
S	Slowdown loss of the contractor when it is required to stop work for rectification due to improper protection

According to the relevant parameters assumed by the model, the income matrix of the three-party construction entities under eight strategy combinations is obtained, and the results are shown in Table 3.

Table 3. Build the main income matrix.

Strategic Combinations	Government	Investor	Contractor
(Incentive, Effective supervision, Proper protection)	$K_1 + K_2 - G_1 - A$	$P_1 + \alpha A + J_1 + J_2 - M_1$	$P_2 + (1 - \alpha) A - N_1$
(Incentive, Effective supervision, Improper protection)	$K_1 - G_1 - A + F_2 - K_2$	$P_1 + \alpha A + J_1 - M_1 - J_2$	$P_2 + (1 - \alpha) A - N_2 - R - F_2 - S - T_1$
(Incentive, Ineffective supervision, Proper protection)	$K_1 + K_2 - G_1 - A$	$P_1 + \alpha A - M_2$	$P_2 + (1 - \alpha) A - N_1$
(Incentive, Ineffective supervision, Improper protection)	$K_1 - A - G_1 + F_1 + F_2 - K_2$	$P_1 + \alpha A - J_2 - M_2 - \beta R - F_1$	$P_2 + (1 - \alpha) A - T_1 - N_2 - (1 - \beta) R - S - F_2$
(No incentive, Effective supervision, Proper protection)	$- G_2$	$P_1 + J_1 + J_2 - M_1$	$P_2 - N_1$
(No incentive, Effective supervision, Improper protection)	$-K_2 - G_2 + F_2$	$P_1 + J_1 - M_1 - J_2$	$P_2 - N_2 - R - F_2 - S - T_1$
(No incentive, Ineffective supervision, Proper protection)	$- G_2$	$P_1 - M_2$	$P_2 - N_1$
(No incentive, Ineffective supervision, Improper protection)	$-K_2 - G_2 + F_1 + F_2$	$P_1 - J_2 - M_2 - \beta R - F_1$	$P_2 - T_1 - N_2 - (1 - \beta) R - S - F_2$

4.3. Replication Dynamic Equation of the Game Model

(1) For the government, the expected returns of the government's "Incentive" and "No incentive" strategies are shown in E_{g0} and E_{g1}:

$$E_{g0}=yzF_1-yF_1+z(2K_2-F_1-F_2)+(K_1-K_2-G_1-A+F_1+F_2) \quad (1)$$

$$E_{g1}=yzF_1-yF_1+z(K_2-F_1-F_2)+(-K_2-G_2+F_1+F_2) \quad (2)$$

(2) For the investor, the expected returns of the investor's "Effective supervision" and "Ineffective supervision" strategies are shown in E_{i0} and E_{i1}:

$$E_{i0}=x\alpha A+2zJ_2+(P_1+J_1-M_1-J_2) \quad (3)$$

$$E_{i1}=x\alpha A+zJ_2+zF_1+z\beta R+(P_1-M_2-F_1-J_2-\beta R) \quad (4)$$

(3) For the contractor, the expected returns of the contractor's "Proper protection" and "Improper protection" strategies are shown in Ec_0 and Ec_1:

$$E_{c0}=x(1-\alpha)A+(P_2-N_1) \quad (5)$$

$$E_{c1}=x(1-\alpha)A-y\beta B+[P_2-N_2-F_2-S-T_1-(1-\beta)R] \quad (6)$$

According to the expected returns of the three parties under different decisions, the following replication dynamic equation can be obtained:

(1) For the government, the replication dynamics formula is:

$$F(x)=\frac{dx}{dt}=x(1-x)(E_{g0}-E_{g1})=x(1-x)(zK_2+K_1-G_1+G_2-A) \quad (7)$$

(2) For the investor, the replication dynamics formula is:

$$F(y)=\frac{dy}{dt}=y(1-y)(E_{i0}-E_{i1})=y(1-y)(zJ_2-zF_1-z\beta R+J_1-M_1+M_2+\beta R+F_1) \quad (8)$$

(3) For the contractor, the replication dynamics formula is:

$$F(z)=\frac{dz}{dt}=z(1-z)(E_{c0}-E_{c1})=z(1-z)[-y\beta R+T_1-N_1+N_2+F_2+S+(1-\beta)R] \quad (9)$$

5. Solution of Game Model and Analysis of System Evolution and Stability

The three-dimensional dynamic system is obtained by combining the replicated dynamic equations of the government, the investor and the contractor. The stable equilibrium state is analyzed by making it equal to 0 according to the relevant properties of the Jacobian matrix. The results are as follows:

$$F(x)=\frac{dx}{dt}=x(1-x)(E_{g0}-E_{g1})=x(1-x)(zK_2+K_1-G_1+G_2-A)=0 \quad (10)$$

$$F(y)=\frac{dy}{dt}=y(1-y)(E_{i0}-E_{i1})=y(1-y)(zJ_2-zF_1-z\beta R+J_1-M_1+M_2+\beta R+F_1)=0 \quad (11)$$

$$F(z)=\frac{dz}{dt}=z(1-z)(E_{c0}-E_{c1})=z(1-z)[-y\beta R+T_1-N_1+N_2+F_2+S+(1-\beta)R]=0 \quad (12)$$

By solving the equilibrium point of the evolutionary game system, the following ten pure strategy equilibrium points are obtained: E1(0, 0, 0), E2(0, 0, 1), E3(1, 0, 0), E4(0, 1, 0), E5(1, 1, 0), E6(0, 1, 1), E7(1, 0, 1), E8(1, 1, 1),

$$E_9=\left(0,\frac{N_1-N_2-T_1-F_2-S-(1-\beta)R}{\beta R},\frac{M_1-M_2-\beta R-F_1}{J_2-F_1-\beta R}\right),$$

$$E_{10}=\left(1,\frac{N_1-N_2-T_1-F_2-S-(1-\beta)R}{\beta R},\frac{M_1-M_2-\beta R-F_1}{J_2-F_1-\beta R}\right).$$

Because the asymptotic stability solution of multigroup evolutionary game system must be a strict Nash equilibrium solution, this study only considers the equilibrium points E_1~E_8. Secondly, the asymptotic stability of the equilibrium point is judged according to Lyapunov stability theory. The equilibrium point with all eigenvalues having negative real part meets the condition of evolutionary stability strategy. The simplified Jacobian matrix is as follows (13).

Bring the equilibrium point into the Jacobian matrix and calculate the eigenvalue to judge the asymptotic stability of the equilibrium point. The corresponding eigenvalues are shown in Table 4. It can be seen that for the equilibrium point E1, two of its eigenvalues are bigger than 0($\lambda_2 > 0$ and $\lambda_3 > 0$), which does not satisfy the Lyapunov stability condition; therefore, E_1 is an unstable point. Similarly, E_2, E_3, E_6 and E_7 are unstable points. Only the stability of equilibrium points E_4, E_5 and E_8 need to be discussed. In order to further analyze the evolution steady state and determine the short-term target strategy, set the parameters that do not appear in the main strategy corresponding to E_4, E_5 and E_8 to 0, and then simplified Table 5 can be obtained.

$$D_{et}(J) = \begin{bmatrix} \frac{dF(x)}{dx} & \frac{dF(x)}{dy} & \frac{dF(x)}{dz} \\ \frac{dF(y)}{dx} & \frac{dF(y)}{dy} & \frac{dF(y)}{dz} \\ \frac{dF(z)}{dx} & \frac{dF(z)}{dy} & \frac{dF(z)}{dz} \end{bmatrix} = \begin{bmatrix} (1\text{-}2x)(zK_2+K_1-G_1+G_2-A) & 0 & x(1-x)K_2 \\ 0 & (1-2y)(zJ_2-zF_1-z\beta R+J_1-M_1+M_2+\beta R+F_1) & y(1-y)(J_2-F_1-\beta R) \\ 0 & z(1-z)(-\beta R) & (1-2z)[-y\beta R+T_1-N_1+N_2+F_2+S+(1-\beta)R] \end{bmatrix} \quad (13)$$

Table 4. Equilibrium point Jacoby matrix feature value table.

Equilibrium Point	Eigenvalues			
	λ_1	λ_2	λ_3	Symbol
E1(0, 0, 0)	K1 − G1 + G2 − A	J1 − M1 + M2 + βR + F1	T1 − N1 + N2 + F2 + S + (1 − β) R	(unknown, +, +)
E2(0, 0, 1)	K1 + K2 − G1 + G2 − A	J2 + J1 + M2 − M1	− [T1 − N1 + N2 + F2 + S + (1 − β) R]	(+, +, −)
E3(1, 0, 0)	−(K1 − G1 + G2 − A)	J1 − M1 + M2 + βR + F1	T1 − N1 + N2 + F2 + S + (1 − β) R	(unknown, +, +)
E4(0, 1, 0)	K1 − G1 + G2 − A	−(J1 − M1 + M2 + βR + F1)	−2βR + T1 − N1 + N2 + F2 + S + R	(unknown, −, unknown)
E5(1, 1, 0)	−(K1 − G1 + G2 − A)	−(J1 − M1 + M2 + βR + F1)	−2βR + T1 − N1 + N2 + F2 + S + R	(unknown, −, unknown)
E6(0, 1, 1)	K1 + K2 − G1 + G2 − A	−(J2 + J1 + M2 − M1)	−(−2βR + T1 − N1 + N2 + F2 + S + R)	(+, −, unknown)
E7(1, 0, 1)	−(K1 + K2 − G1 + G2 − A)	J2 + J1 + M2 − M1	−[T1 − N1 + N2 + F2 + S + (1 − β) R]	(−, +, −)
E8(1, 1, 1)	−(K1 + K2 − G1 + G2 − A)	−(J2 + J1 + M2 − M1)	−(−2βR + T1 − N1 + N2 + F2 + S + R)	(−, −, unknown)

Table 5. The equilibrium point Jacoby matrix feature value simplifies the table.

Equilibrium Point	Eigenvalues			
	λ_1	λ_2	λ_3	Symbol
$E_4(0, 1, 0)$	G_2	$-(J_1 - M_1)$	$-2\beta R + N_2 + F_2 + S + R$	(+, unknown, unknown)
$E_5(1, 1, 0)$	$-(K_1 - G_1 - A)$	$-(J_1 - M_1)$	$-2\beta R + N_2 + F_2 + S + R$	(unknown, unknown, unknown)
$E_8(1, 1, 1)$	$-(K_1 + K_2 - G_1 - A)$	$-(J_2 + J_1 - M_1)$	$-(T_1 - N_1)$	(−, unknown, unknown)

It can be seen from Table 5 that the eigenvalues of E_4 are not all less than 0 ($\lambda_1 > 0$), which does not satisfy the Lyapunov stability condition; therefore, E_4 is an unstable point. Equilibrium points E_5 and E_8 strategically reflect the government's active supervision and guidance on the development of urban construction projects, and the investor's active response and management of the surrounding environmental impact caused by the construction projects, which is consistent with the conclusion that the investor has a full understanding of the surrounding environmental impact caused by urban construction projects and is aware of its own responsibilities and obligations in the preliminary investigation of the research group.

Through analysis, both E_5 and E_8 have the possibility to realize the stability of evolutionary game, and the specific stability conditions are shown in Table 6.

Table 6. Equilibrium point stability conditions of the Jacoby matrix.

Equilibrium Point	Stability Condition		
	λ_1	λ_2	λ_3
$E_5(1, 1, 0)$	$K_1 - G_1 - A>0$	$J_1 - M_1 > 0$	$0.5 < \beta \leq 1$, and R is much greater than other parameters
$E_8(1, 1, 1)$	—	$J_1 - M_1 > 0$	$T_1 - N_1 > 0$

However, by substituting the stability conditions of E_5 and E_8 into income matrix Table 3, the analysis shows that when R is much greater than other parameters, under E_5 strategy, the contractor is in a state of loss, which does not conform to the actual development law of urban construction projects. On the contrary, the contractor chooses appropriate strategies to protect urban construction projects and reduces the impact on the surrounding environment. The corresponding strategy is E_8.

At the same time, after substituting the E_8 stability condition into the income matrix, there is no situation contrary to the reality, which also confirms the feasibility and stability of the strategy. Therefore, the final evolutionary stability strategy is E_8, and the evolutionary steady state of {Incentive, Effective supervision, Proper protection} is the target steady state of environmental impact protection and treatment of urban construction projects in the short term.

When $J_1 - M_1 > 0$ and $T_1 - N_1 > 0$, the three parties are stable, both the investor and the contractor should realize the condition that the benefits obtained by taking environmental protection measures are greater than the losses. Therefore, the government should establish and improve relevant systems, affirm the contributions made by the investor and the contractor in environmental protection, and set restrictions on advanced units of environmental protection in relevant bids, protecting and guiding the sustainable interests of investors and contractors, so as to promote the long-term stability of the three main strategies and minimize the impact on environmental protection.

6. Matlab Simulation Analysis

In order to intuitively show the influence of an influencing factor on the behavior selection and stability of the government, the investor and the contractor in the urban construction project on the surrounding environmental protection, combined with the above stability conditions, this paper assigns the relevant parameters of the tripartite game and carries out Matlab numerical simulation. Initially, assuming that the willingness of the government, the investor and the contractor to choose different strategies is 50%, and the relevant parameters in the tripartite game payment matrix are set as: $K_1 = 1000$, $K_2 = 400$, $G_1 = 300$, $G_2 = 100$, $A = 400$, $M_1 = 600$, $M_2 = 100$, $J_1 = 600$, $J_2 = 200$, $F_1 = 300$, $N_1 = 700$, $N_2 = 400$, $S = 200$, $T_1 = 200$, $F_2 = 300$, $R = 1000$, $\beta = 0.6$. The dynamic evolution of specific strategy selection is as follows.

6.1. Impact of Government Behavior on Evolution Results

Assign values of 300, 600 and 900 to G_1, respectively, and the dynamic equations evolve 50 times over time. Analyze the impact of G_1 change on the model evolution path. The simulation results are shown in Figure 4.

It can be seen from Figure 4 that as G_1 increases, the evolution speed of the game model slows down, and when G_1 is 900, the government's willingness to take incentive measures first decreases, then increases, and finally tends to be stable, indicating that when G_1 is too large, the stability strategy may be {No incentive, Effective supervision, Proper protection}, and the stability strategy is contrary to the given conditions. Therefore, reasonably determine the governance and supervision costs paid by the government for maintaining the surrounding environment of the project when taking incentive measures, so as to ensure that the government takes incentive measures without affecting the evolution efficiency.

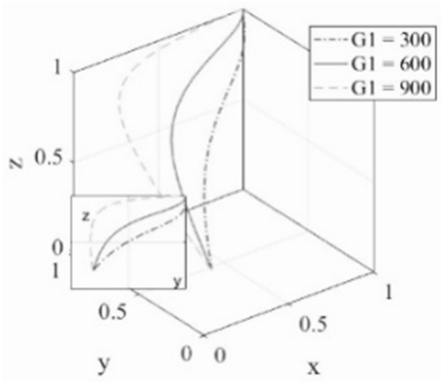


Figure 4. Model evolution trajectories of different G_1.

Similarly, assign A as 400, 800 and 1200, copy the dynamic equations to evolve 50 times over time, and analyze the impact of a change on the model evolution path. The simulation results are shown in Figure 5.

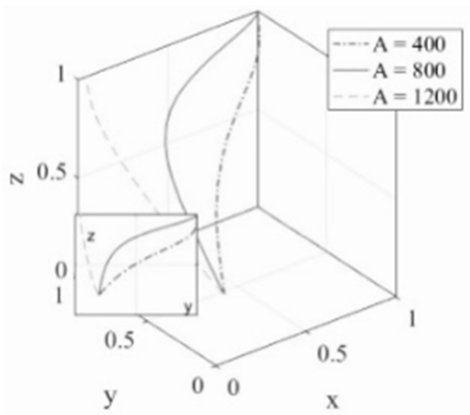


Figure 5. Model evolution trajectories of different A.

As can be seen from Figure 5, in a certain range, during the evolution of the game model to the equilibrium point, A is negatively correlated with the evolution speed of the game model and causes the willingness of investors and contractors to take effective measures to increase. When A is too large, for example, A is 1200, and the evolution of the game model is stable, the incentive willingness of the government is 0, and no incentive measures will be taken. Therefore, when determining the incentive cost for investors and contractors, the government should reasonably control the cost, so as to ensure that investors and contractors have a high willingness to take effective measures and improve the evolution efficiency.

6.2. Impact of Investor Behavior on Evolution Results

Assign M_1 as 600, 800 and 1000, copy the dynamic equations to evolve 50 times over time, and analyze the impact of M_1 change on the evolution path of the game model. The simulation results are shown in Figure 6.

It can be seen from Figure 6 that increasing M_1 within a certain range slows down the evolution speed of the game model. When M_1 is too large, for example, M_1 is 1000 and the game model is stable, the stability strategy is {Incentive, Ineffective supervision, Proper protection}. At this time, the investor does not take effective supervision measures, which is inconsistent with the hypothesis, and it shows that the incentive measures taken by the government have not received ideal feedback. Therefore, when determining M_1, the investor shall appropriately reduce its value to improve the evolution effect of the model.

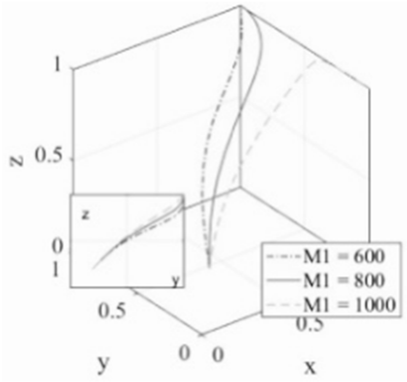


Figure 6. Model evolution trajectories of different M_1.

Similarly, assign J_1 as 600, 900 and 1200, copy the dynamic equations to evolve 50 times over time, and analyze the impact of a change on the model evolution path. The simulation results are shown in Figure 7.

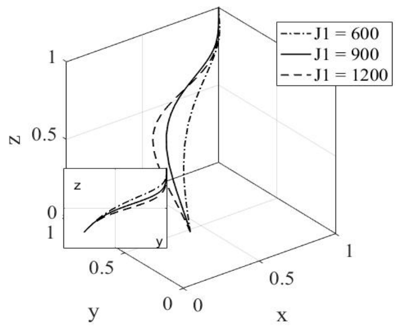


Figure 7. Model evolution trajectories of different J1.

It can be seen from Figure 7 that increasing J_1 within a certain range accelerates the evolution speed of the game model. When it is too large such as 1200, the evolutionary game rate is less than the evolutionary game rate of 900, indicating that increasing the value of it continuously cannot promote the tripartite equilibrium. Therefore, for investor, the continuous improvement of corporate image benefits may have a negative impact on the environmental protection of urban construction projects, and the value of J_1 should be reasonably controlled.

6.3. Impact of Contractor Behavior on Evolution Results

Assign N_1 as 700, 800 and 900, copy the dynamic equations to evolve 50 times over time, and analyze the impact of N_1 change on the evolution path of the game model. The simulation results are shown in Figure 8.

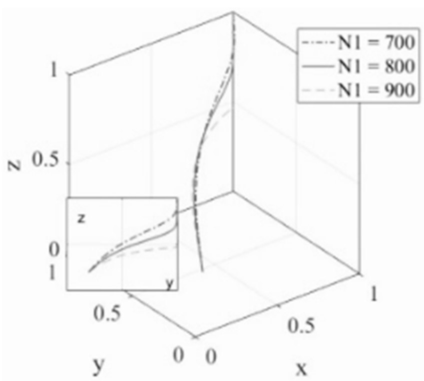


Figure 8. Model evolution trajectories of different N_1.

It can be seen from Figure 8 that in a certain range, reducing N_1 can accelerate the evolution of the game model, reduce the willingness of investors to take effective measures and increase the willingness of the government to take incentive measures. When N_1 is too large, for example, N_1 is 900 and the game evolution model is stable, the contractor's willingness to protect properly is low, less than 0.5. Therefore, when determining N_1, the contractor should control the willingness of the government and investors to take effective measures, and appropriately reduce N_1 to improve the model evolution effect.

Similarly, assign T_1 as 600, 900 and 1200, copy the dynamic equations to evolve 50 times over time, and analyze the impact of a change on the model evolution path. The simulation results are shown in Figure 9.

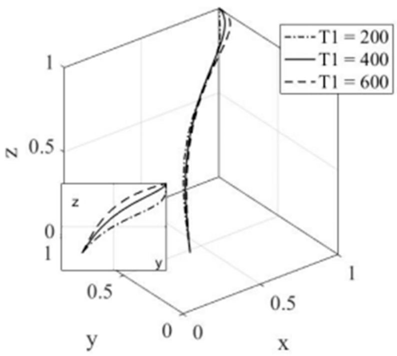


Figure 9. Model evolution trajectories of different T_1.

As can be seen from Figure 9, within a certain range, increasing T_1 can accelerate the evolution speed of the game model. With the increase in the loss of the contractor's corporate image effect, the probability of the contractor's proper protection also increases; when it is too large, the evolution rate of the game model is negatively correlated with its value. Excessive loss cannot promote the rate of tripartite evolution to the equilibrium point. Therefore, the contractor should reasonably control its own corporate image loss and avoid the negative impact caused by excessive loss.

6.4. The Impact of Each Subject's Will on the Evolution Results

The values of x are 0.2, 0.4, 0.6 and 0.8 to explore the impact of the change of willingness of each subject on the evolution path of the game model. Similarly, the assignment y is 0.2, 0.4, 0.6 and 0.8, and Z is 0.2, 0.4, 0.6 and 0.8. The simulation results are shown in Figure 10.

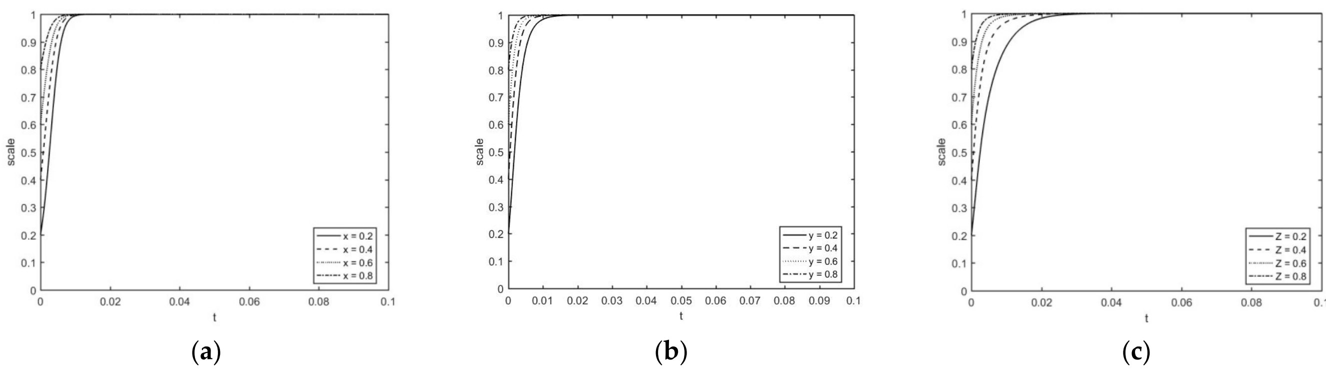


Figure 10. The influence of the will of each subject on the evolutionary result. (**a**) about x; (**b**) about y; (**c**) about z.

As can be seen from Figure 10:

(1) As the willingness of each subject changes from low willingness to high willingness, the time for the game model to tend to the stable strategy also shortens, and the higher the willingness, the faster the evolution speed.

(2) The order of the improvement effect of the evolution speed caused by increasing the subject's willingness is: the contractor is the most willing to protect properly, the investor is the second most willing to supervise effectively, and the government is the least willing to take incentive measures.
(3) Each subject evolves in the same direction and finally reaches the ideal evolution equilibrium point $E_8(1, 1, 1)$.

6.5. Analysis of Evolutionary Game Simulation Results

According to the evolutionary game analysis of the government, investors and contractors, the main factors affecting the evolution effect are K_1, K_2, G_1, G_2, A, M_1, M_2, J_1, J_2, F_1, N_1, N_2, S, T_1, F_2, R, β, and the impact of various parameters on the behavior of the main body within a certain range in Table 7. The evolution result E_8 [1, 1, 1] is the most effective short-term stability strategy for the environmental protection of the main body of urban construction projects. E_8 [1, 1, 1] the necessary conditions for the establishment of the evolutionary stability strategy are $J_1 > M_1$ and $T_1 > N_1$, in which the government takes incentive measures to deal with the impact of the surrounding environment. Under the encouragement of the government, the investor chooses effective supervision when the corporate image benefit obtained from effective supervision is greater than the operation cost and environmental protection and governance measures cost that need to be paid during effective supervision; under the encouragement of the government, the contractor protects properly when the benefit value of corporate image obtained by proper protection is greater than the cost of environmental protection and treatment measures required by the contractor at that time. In other words, when $J_1 > M_1$ and $T_1 > N_1$, the realization of {Incentive, Effective supervision, Proper protection} evolutionary stability strategy can be guaranteed.

Table 7. The influence of each parameter on the subject's behavior.

Probability of Subject Taking Action	Parameters	
	Positive Influence	Negative Influence
x	M_1, N_1, J_1, T_1	A, G_1
y	A, G_1, N_1, T_1	M_1, J_1
z	A, G1, M1, J_1	N_1, T_1

7. Conclusions

This paper studies the optimal environmental protection strategy of urban construction project construction subject through limited questionnaire and evolutionary game method. The main conclusions are as follows:

(1) The investor and contractor believe it is necessary to pay attention to the impact of urban construction projects on the surrounding environment, and more than 80% believe that the surrounding environment can be improved from two aspects: listing the cost of environmental protection and treatment measures and repair compensation. However, when environmental protection measures involve the interests of enterprises, both parties give priority to protecting the income of enterprises and may ignore the surrounding environment. From the analysis of the basic cognition of the investor and the contractor on the government's work, it is found that both parties lack the cognition of the government's environmental protection work and believe that their supervision and governance efforts are small, and the effect of improving the environment is not significant.
(2) The three parties have a game stability strategy. When the government, the investor and the contractor carry out urban construction and environmental protection, the optimal behavior strategy is {Incentive, Effective supervision, Proper protection}, in which the stability conditions are $J_1 > M_1$ and $T_1 > N_1$.

(3) Through the simulation, it is considered that reducing the supervision and governance costs when the government adopts incentives and the incentive costs for investors and contractors, reducing the cost of effective supervision measures for investors, reducing the cost of proper protection measures for contractors and increasing the willingness of each construction subject to take measures promote the model to stabilize and evolve the strategy. At the same time, within a certain range, with the increase in corporate image benefits of investor's effective supervision, the probability of investor's effective supervision increases; when the corporate image loss caused by improper contractor protection increases, the probability of proper contractor protection decreases.
(4) In order to promote the main body of urban construction projects to better and more stably promote environmental protection, the three parties need to make efforts from the following aspects: improve the incentive policy and establish an appropriate reward and punishment mechanism. Only when the government formulates a reasonable reward and punishment system for environmental protection can it effectively promote investors and contractors to take positive measures, strengthen technology, policy and management innovation, and achieve the goal of sustainable development. Strengthen responsibility implementation, supervision and assessment to ensure the main strategy selection. Formulate binding provisions to restrict the strategic choice of the three parties, take the form of economic punishment for urban construction projects with serious impact on the surrounding environment, and give material and reputation rewards to urban construction projects with excellent surrounding environment to ensure the strategic choice of the three parties. Improve the environmental protection awareness of the main body of urban construction projects, and strengthen the main body's prevention, control and governance capacity. Protecting the environment is everyone's responsibility, and environmental governance is a long-term and complex project that requires the participation of all subjects, using multiple platforms for environmental protection publicity, improving enterprise consciousness and jointly building a harmonious and beautiful home.

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Institutional Review Board Statement: All subjects gave their informed consent for inclusion before they participated in the study.

Informed Consent Statement: To obtain informed consent from the participants, we provided a complete explanation of the objectives and procedure of this research. All questions from the participants were answered. The participants were assured that their responses would be confidential and anonymous.

Data Availability Statement: Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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