

## Article

# Study on Green Building Promotion Incentive Strategy Based on Evolutionary Game between Government and Construction Unit

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**Abstract:** Green buildings are considered to be an effective way to save energy, reduce emissions, and protect the environment. As one of the main bodies of green building construction, the construction unit's willingness to build seriously affects the promotion of green building. Therefore, based on the viewpoints of natural persons and bounded rationality, this study constructs an evolutionary game analysis model, analyzes the impact of local government subsidy policies on the application strategies of construction units, and analyzes the steady-state and selection strategies. The system dynamics model is established using a flow chart, and the simulation results show that, in the long run, increasing the government subsidy and inspection cost cannot improve the application probability of the construction unit. Furthermore, the inspection intensity of the government and the indirect income of the construction unit has a direct influence on the application probability of the construction unit. The results show that the government should adjust the amount of the subsidy reasonably, improve the penalty mechanism, reduce development costs, strengthen publicity, and encourage construction units to actively apply for green buildings, so as to realize the transformation and upgrade of China's construction industry.

**Keywords:** green building; government subsidies; the construction unit; evolutionary game; system dynamics



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## 1. Introduction

Green buildings refer to buildings that reduce negative impacts such as pollution during their entire life cycle and produce positive impacts such as energy saving and environmental protection [1], which is an effective strategy to reduce carbon emissions and construction waste and improve project quality. Due to its huge sustainable development potential, various standards have been introduced around the world to stimulate its development [2]. Compared with the traditional construction model, green building in the construction of water, the dosage of plastering mortar, pouring template, construction, and construction waste energy consumption can be 25%, 55%, 60%, 20%, and more than 70% of the economy, respectively [3]. According to the requirement of "four environmental protections," the sustainable development of the industry and promotion of the progress of a new type of urbanization have important practical significance [4]. However, because China's green building standard system is not perfect, and foreign green building evaluation systems, such as BREEAM and LEED, are not suitable for China's national conditions, the performance of most domestic green buildings in the operation stage cannot be effectively evaluated [5]. In addition, at the current stage, the design capacity for the whole life cycle of green buildings is insufficient and the scale production efficiency is low, which ultimately causes the production cost of green buildings in China to be much higher than that of traditional construction methods [6]. According to the calculation, the total incremental

cost of green building projects in China is approximately 260 yuan/m<sup>2</sup> [7], which restricts the willingness of developers and construction units to build green buildings to a certain extent. At the same time, most buyers of green buildings are less satisfied with their living environment, which reduces their willingness to purchase green buildings to a certain extent [8]. Therefore, the central government and local government, from the national and local levels, respectively, issued land policies, fiscal and taxation policies, and building area of reward policies to support the development of green buildings. Through the analysis of relevant policies, it can be seen that the government is indispensable in the early stage of promoting and applying green buildings. It plays an important leading role, and subsidies are not supported by sufficient scientific evidence. There is also a lack of a corresponding disciplinary mechanism as a guarantee. Only some regions have issued punitive measures. For example, for developers who fail to meet the requirements stipulated in the regulations, Ningxia province will pay a certain percentage of the penalty. They shall not participate in land bidding within two years. Therefore, from the government's point of view, how subsidizing enterprises leads to adopting green buildings and formulating optimal subsidy policies are important issues that need to be solved urgently.

At present, China's green building is in a period of rapid development, and many scholars have studied the government incentive policies for green building: For example, Cen [9], Liu [10], and Sun [11] have determined the fiscal and tax incentive policies of the government in the housing industrialization and put forward the idea of making incentive policies from many angles. Qi [12], Jia [13], and Tang [14] took the interests of the government and developers as the cutting point and used game theory to elaborate the mechanism of government incentive policies. On the other hand, domestic and foreign scholars have combined system dynamics with engineering construction projects and carried out in-depth studies. For example, Marzouk [15] established environmental and economic constraints, USES system dynamics, and an ant colony algorithm to select green building materials. Leon [16] established a project performance prediction model based on system dynamics and proved the model's effectiveness with an example. Ding [17] built a two-stage (design stage and construction stage) SD model for environmental benefit assessment of construction projects and used Vensim software for simulation. The results show that the modified model can effectively evaluate the environmental benefits brought by construction waste reduction. Moradi [18], considering the impact of environment and operation on labor productivity of construction projects, constructed a mixed model based on SLIDES and discrete event simulation (DES), which is close to reality, so it has certain practical significance. Finally, domestic scholars such as Zhong [19], based on the project operation mode and resource matching, built a model combining the integrated earned value method and system dynamics, and the simulation results showed its application value.

The above literature has thoroughly explored the development and application of green buildings in China. At the same time, there are also certain limitations: Most of the literature starts from the perspective of construction units, rarely considering the interaction mechanism between the government and construction units and ignoring the research at the basic level. Part of the literature only carries out theoretical analyses of the government's incentive policy and does not mention the government's punishment mechanism and the enterprise's coping strategy. The evolutionary game, as a theory that can simulate the dynamic process of imperfect rational players before realizing evolutionary stability strategies [20], is very suitable for simulating the strategic choices between the government and construction units in different scenarios. However, although system dynamics, as an important model for realizing evolutionary game theory, has been rather mature in its application in construction projects, few studies have combined evolutionary game theory to simulate the game relationship between the government and construction units in the promotion and application of green buildings. There is also literature that chooses the government and enterprises as the main body and uses evolutionary game theory to analyze their behavior strategies, but the actual effect is not ideal. Because of this, this article embarks from the perspective of corporate rent-seeking, the evolutionary game

theory, and system dynamics (SD). We combine the interests of both sides as the core to set up our country's local government and the construction unit of the evolutionary game analysis model of system dynamics, through Vensim software simulation to demonstrate the evolution of the strategy of the actual situation, explore the government incentive policy impact on the supply side, and provide the basis for the government to formulate reasonable incentive policy.

## 2. The Evolutionary Game Model of Government and Construction Unit

### 2.1. Model Assumptions

#### (a) Game both sides

This paper assumes that the two sides of the game are local governments and construction units, both of which are subjects of bounded rationality. They repeatedly play the game under the condition of asymmetric information and constantly seek the optimal strategy.

#### (b) Behavioral strategy is to take the probability

We supposed that there are only two strategies for local governments and construction units in the construction industry transformation and upgrade context. The government subsidies for green building can be an extension of its functions and can also be seen as an investment behavior under the market economy. The ultimate aim is to realize the benign development of the economy and the environment. The strategy is divided into "incentive" and "no incentive," respectively, corresponding to the probability of  $x$  ( $0 \leq x \leq 1$  or less or less) and  $1 - x$ . For the construction unit, the application of green building will lead to higher incremental costs and harm their interests. Under government subsidies, the construction unit will obtain the corresponding construction market. Its strategies can be divided into "apply" and "don't apply," and their probabilities are  $y$  ( $0 \leq y \leq 1$ ) and  $1 - y$ , respectively. The game strategy combination of the two parties is shown in detail in Table 1.

**Table 1.** Strategy selection combination of the game parties.

	Game Both Sides	The Construction Unit	
		Application of $y$	$1 - y$ Is Not Applied
The government	Incentive $x$	(Stimulation, application)	(Incentive, not applied)
	$1 - x$ is not energized	(Disincentivize, apply)	(No incentive, no application)

#### (c) Assumptions and explanations of profit and loss parameter values as shown in Table 2.

**Table 2.** Setting and explanation of profit and loss parameter values of the game parties.

Game Subject	Parameter Setting and Interpretation (Unit: 10,000 yuan)
The construction unit	$a_1$ : The direct economic benefits of the construction unit when choosing traditional cast-in-place buildings $a_2$ : The direct economic benefits when the construction unit chooses the green building $a_3$ : Cost of the construction unit when choosing a green building (such as technology investment, transportation cost, etc.) $a_4$ : Indirect benefits brought by the construction unit when choosing a green building (such as enterprise image, brand value, green building market benefits, etc.) $a_5$ : A fine imposed on a construction unit for failing to implement government incentive policies
The government	$b_1$ : When the construction unit chooses the traditional cast-in-place building, the government's revenue $b_2$ : When the construction unit chooses the traditional cast-in-place building, the government pays the management cost $b_3$ : The cost paid by the government when choosing incentive strategies (policy publicity, policy research, etc.) $b_4$ : When the construction unit chooses a green building and meets the subsidy standard, the subsidy amount of the government $b_5$ : The benefits of the government (economic growth, resource conservation, environmental protection, government credibility, etc.) when the construction unit chooses green buildings

Note: The above parameters are all greater than 0.

2.2. Model

According to the above assumptions, the known government strategy is “incentivize” green buildings and “do not incentivize” green buildings. The construction unit’s strategy is to apply green buildings and not green buildings. The game payment matrix of both sides can be represented in Table 3.

**Table 3.** Game payment matrix between the government and the construction unit.

Game Both Sides		The Construction Unit	
		Application of y	1 - y Is Not Applied
The government	Incentive x	$[-b_3 - b_4 + b_5, A + b_4]$	$[B - b_3 + a_5, a_1 - a_5]$
	1 - x is not energized	$[b_5, A]$	$[B, a_1]$

Note:  $A = A_2 - A_3 + A_4$ , that is, the net income of the enterprise from adopting green buildings:  $B = B_1 - B_2$ , that is, the government’s net income when the construction unit adopts traditional buildings.

For the government, the expected and average earnings of the prefabricated construction units with and without incentives are as follows:

$$U_{1Y} = y(-b_3 - b_4 + b_5) + (1 - y)(b_1 - b_2 - b_3 + a_5) \tag{1}$$

$$U_{1N} = yb_5 + (1 - y)(b_1 - b_2) \tag{2}$$

$$U_1 = xU_{1Y} + (1 - x)U_{1N} \tag{3}$$

For the construction unit, the expected revenue and average revenue of green buildings with or without application are, respectively,

$$U_{2Y} = X(a_2 - a_3 + a_4 + b_4) + (1 - x)(a_2 - a_3 + a_4) \tag{4}$$

$$U_{2N} = x(a_1 - a_5) + (1 - x)a_1 \tag{5}$$

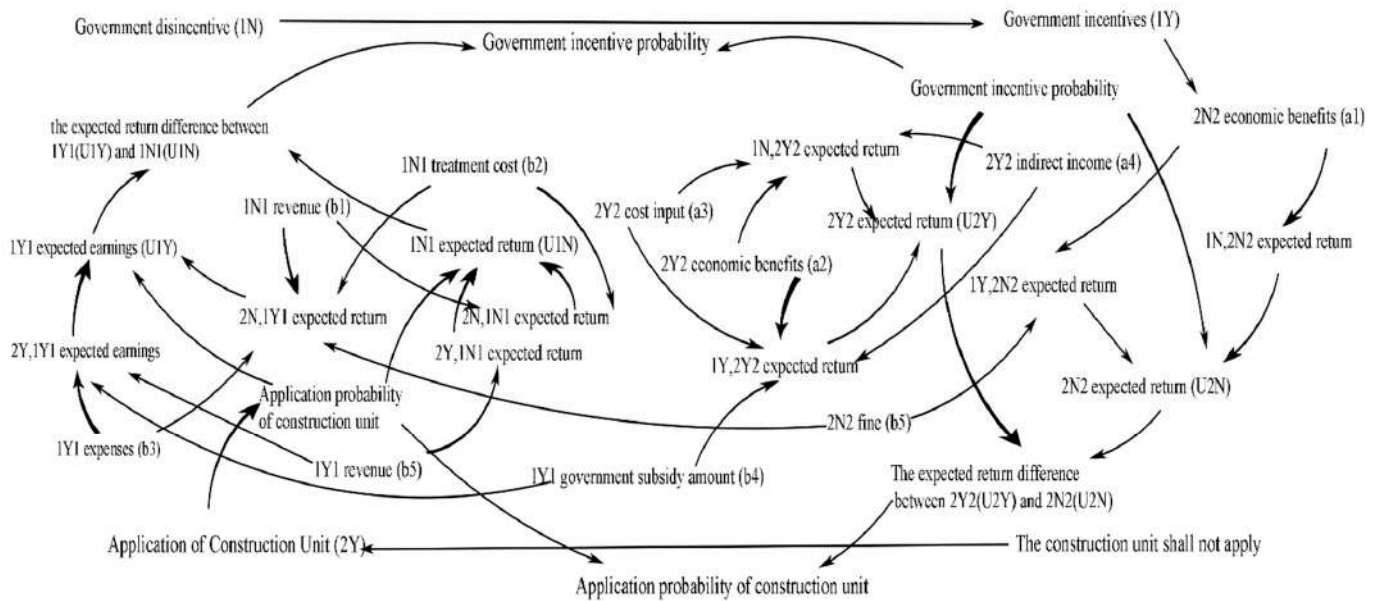
$$U_2 = yU_{2Y} + (1 - y)U_{2N} \tag{6}$$

According to the replication dynamic equation formula of the evolutionary game, the dynamic replication equation of the government strategy and the construction unit strategy can be obtained as follows:

$$F(x) = \frac{dx}{dt} = x(U_{1Y} - U_1) = x(1 - x)[-y(a_5 + b_4) + (a_5 - b_3)] \tag{7}$$

$$F(y) = \frac{dy}{dt} = y(U_{2Y} - U_2) = y(1 - y)[x(a_5 + b_4) + (A - a_1)] \tag{8}$$

SD model of the evolutionary game between government and construction unit shown in Figure 1.



**Figure 1.** SD model of the evolutionary game between government and construction unit. Note: The “1” in the figure represents the government; “2” denotes the construction unit; “Y” indicates that the construction unit should use or be encouraged by the government; “N” indicates that the construction unit should not use or be encouraged by the government; for example, “2Y, 1N1 Revenue Value” shows the revenue value of the government when the installation unit should be built with assembly type and the government does not encourage it.

### 3. Stability Analysis of Evolutionary Game Model

#### 3.1. Stability Analysis of Evolutionary Game Model

According to Formula (7), we outline the following:

If  $y = a_5 - \frac{b_3}{a_5} + b_4$  then  $F(x) = 0$ . Whatever  $y$  is, the government is in a stable state.

If  $y \neq a_5 - \frac{b_3}{a_5} + b_4$ , then  $F(x) = 0$ , then  $x = 0$  and  $x = 1$  are the two stable points of the government strategy replication dynamic equation. Deriving  $F(x)$  can be obtained as follows:

$$\frac{\partial F(x)}{\partial x} = (1 - 2x)[-y(a_5 + b_4) + a_5 - b_3] \tag{9}$$

According to the literature lemma [21] and the theorem, the evolutionary stability strategy can only be satisfied when  $\frac{\partial F(x)}{\partial x} < 0$ . Therefore, different situations of  $a_5 - b_3$  are discussed.

When  $a_5 - b_3 < 0$  there is always  $y > a_5 - \frac{b_3}{a_5} + b_4$  then  $x = 0$  is an evolutionary stability strategy, and the government will choose the “non-incentive” strategy as a bounded rational economic man.

When  $a_5 - b_3 > 0$  is used, the penalty imposed on the construction unit for failing to implement the government incentive policy is greater than the cost paid by the government when choosing the incentive strategy, which can be divided into two situations:

When  $y > a_5 - \frac{b_3}{a_5} + b_4$ , then  $\frac{\partial F(x)}{\partial x} \Big|_{x=0} < 0$ ,  $\frac{\partial F(x)}{\partial x} \Big|_{x=1} > 0$ , then  $x = 0$  is an evolutionary stabilization strategy

When  $y < a_5 - \frac{b_3}{a_5} + b_4$ , then  $\frac{\partial F(x)}{\partial x} \Big|_{x=0} < 0$ ,  $\frac{\partial F(x)}{\partial x} \Big|_{x=1} > 0$ , then  $x = 1$  is an evolutionary stabilization strategy.

#### 3.2. Stability Analysis of the Unilateral Strategy of the Construction Unit

According to Formula (8), we outline the following:

If  $x = a_1 - A/a_5 + b_4$ , then  $F(y) = 0$ , and the construction unit has a stable state no matter what value  $x$  takes.

If  $x \neq a_1 - A/a_5 + b_4$ , let  $F(y) = 0$ , then  $y = 0$  and  $y = 1$  are two stable points of the dynamic Equation of the strategy replication of the construction unit, and the formula  $F(y)$  can be obtained by differentiating:

$$\frac{\partial F(x)}{\partial y} = (1 - 2y)[x(a_5 + b_4) + (A - a_1)] \quad (10)$$

Only when  $\frac{\partial F(y)}{\partial y} < 0$  can the evolutionary stability strategy be satisfied. So, we need to talk about the different cases of  $A_1$  minus  $A$ .

① When  $a_1 - a < 0$ , there is always  $x > a_1 - a/a_5 + b_4$ , then  $y = 1$  is an evolutionary stability strategy, and the construction unit, a finite rational economic man, will choose the "application" strategy.

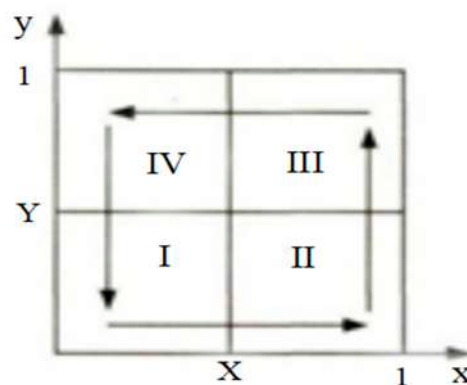
② When  $a_1 - a > a_5 + b_4 > 0$ , then there is  $a_1 - a/a_5 + b_4 > 1$ . At this time, there is always  $x < a_1 - a/a_5 + b_4$ , then  $x = 0$  is an evolutionary stability strategy. As a finite rational economic man, the construction unit will choose the "no application" strategy.

③ When  $a_5 + b_4 > a_1 - A > 0$ , it can be divided into two cases:

When  $a_1 - A/a_5 + b_4, \frac{\partial F(y)}{\partial y} \Big|_{y=0} > 0, \frac{\partial F(y)}{\partial y} \Big|_{y=1} < 0$ . At this point,  $y = 1$  is an evolutionary stabilization strategy.

When  $a_1 - A/a_5 + b_4, \frac{\partial F(y)}{\partial y} \Big|_{y=0} > 0, \frac{\partial F(y)}{\partial y} \Big|_{y=1} < 0$ . At this point,  $y = 0$  is an evolutionarily stable strategy.

Based on the above analysis, the game evolution trend of the strategies of the government and the construction unit is shown in Figure 2.



**Figure 2.** Phase diagram of game evolution between government and construction unit.

### 3.3. Analysis of the Evolvement Stability of Mixed Strategy of Government and Construction Unit

According to the analysis in Sections 2.1 and 2.2, there are three evolvable stabilization strategies for the government and the construction unit under different initial conditions. According to the current intelligent development of the green building, the intelligent construction unit application benefits brought by the green building are far less than the benefits of choosing the traditional way to build. Therefore, through punishment lines, the government will avoid two extremes in the increase or decrease in the emergence of the above three kinds of situations in the real condition to realize the possibility of the A-line. Therefore, this section mainly discusses  $a_5 - b_3 > 0$  and  $a_5 + b_4 > a_1 - A > 0$ , both the government and the construction unit, under the condition of the stability of the mixed strategy.

#### (1) System analysis

According to the above two-dimensional dynamic system equation (5) and Equations (1)–(3), it can be known that, when  $(F(x), F(y)) = (0,0)$ , four equilibrium points of the system can be

obtained, which are  $x_1 = (0,0)$ ,  $x_2 = (0,1)$ ,  $x_3 = (1,0)$ , and  $x_4 = (1,1)$ . Let  $x = a_1 - A/a_5 + b_4$  and  $y = a_5 - b_3/a_5 + b_4$ . If  $x$  and  $y$  satisfy  $0 \leq x \leq 1$  and  $0 \leq y \leq 1$ , respectively, there is a fifth equilibrium point, that is,  $x_5 = (x,y)$ .  $x_1, x_2, x_3$ , and  $x_4$  correspond to the pure strategy Nash equilibrium, and  $x_5$  corresponds to the mixed strategy Nash equilibrium. The five equilibrium points of Nash can be:  $(0,0), (0,1), (1,0), (1,1), (x,y)$ . According to the view put forward by Friedman, the stability of equilibrium points of an evolutionary system can be obtained by analyzing the local stability of the Jacobi matrix obtained by this system [22], which can be expressed as

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} \end{bmatrix} = \begin{bmatrix} (1 - 2x)[-y(a_5 + b_4) + (a_5 - b_3)] & -x(1 - x)(a_5 + b_4) \\ y(1 - y)(a_5 + b_4) & (1 - 2y)[x(a_5 + b_4) + (a_2 + a_4 - a_1 - a_3)] \end{bmatrix} \tag{11}$$

According to the Jacobian matrix local stability method, when the equilibrium point satisfies the determinant  $\det(J) > 0$  and trace  $\text{tr}(J) < 0$ , it indicates that the system is in a local asymptotic stability state in the dynamic evolution process, and this point is regarded as the system local evolution stability strategy (ESS). According to the determinant and trace method in the matrix, the stability analysis of the above five equilibrium points is carried out, and the results are shown in Table 4.

Table 4. Evolution stability strategy of the system (S).

Equilibrium Point	det (J)	Symbol	tr (J)	Symbol	Result
(0,0)	$L \times M$	-	$L + M$	Uncertain	saddle point
(0,1)	$-(L - M) \times N$	-	$-(L - M) \times N$	Uncertain	saddle point
(1,0)	$-L \times (M + N)$	-	$-L + M + N$	Uncertain	saddle point
(1,1)	$-(N - L) \times (N + M)$	-	$-L - M$	Uncertain	saddle point
(x,y)	$xy(1 - x)(1 - y) \times N_2$	-	0	0	centre

According to the above analysis, when  $x = a_1 - A/a_5 + b_4$ ,  $y = a_5 - b_3/a_5 + b_4$ , the point  $(x,y)$  corresponding to the characteristics of the root is purely imaginary, according to the literature and theorem: The evolution of the point  $(x,y)$  is stable equilibrium, but not asymptotically stable, the system evolution trajectory is around the center of the ring rail line, closed trajectory rings did not pass the center, and there is no limit cycle.

### 3.4. Model Simulation Analysis

The model’s initial value is assumed as follows: Simulation start time (INITIAL TIME) = 0, end time (FINAL TIME) = 5.0, step length (TIME STEP) = 0.0078125, unit: month. The external variables take the estimated value of a green building project of Honghuiyuan in Shenyang as the initial value = 3,  $A = 1.8$ ,  $a_4 = 0.7$ ,  $a_5 = 1.2$ ,  $B = 2$ ,  $b_3 = 0.7$ ,  $b_4 = 1$ ,  $b_5 = 1.1$  (unit: million yuan). The following discusses the change in the government subsidy probability and the construction unit application probability under different initial values.

#### (1) Initial simulation analysis

At this stage, both sides of the game adopt Nash equilibria  $x_1 = (0,0)$ ,  $x_2 = (0,1)$ ,  $x_3 = (1,0)$ ,  $x_4 = (1,1)$ ,  $x_5 = (6/11, 5/22)$ , use V e n—sim D S S 5.6a software for data processing, and input initial values for the simulation.

When both sides of the game adopt the  $x_1$  strategy, it can be understood that when the government chooses the “non-incentive” strategy, as a rational natural person, the construction unit will “not apply” green building and maintain the status quo for its own interests. When the game changes to the A2, A3) strategy, all of the construction units choose “apply” green building and choose “no incentive” government policy (all

of the construction units choose “no” green building, the government chooses “incentive strategy”). That is to say, even if the construction unit (the government) was previously in a disadvantageous position, in the absence of choice before the new strategy, it learns to always be in a stable state. When the two sides of the game adopt four strategies, it can be understood that when the government chooses to supplement the “incentive” strategy, the construction unit takes into account its interests at the same time. The best strategy is to “apply” green buildings and the initial value of both sides of the game is the evolution process of the equilibrium state can be shown in Figure 3.

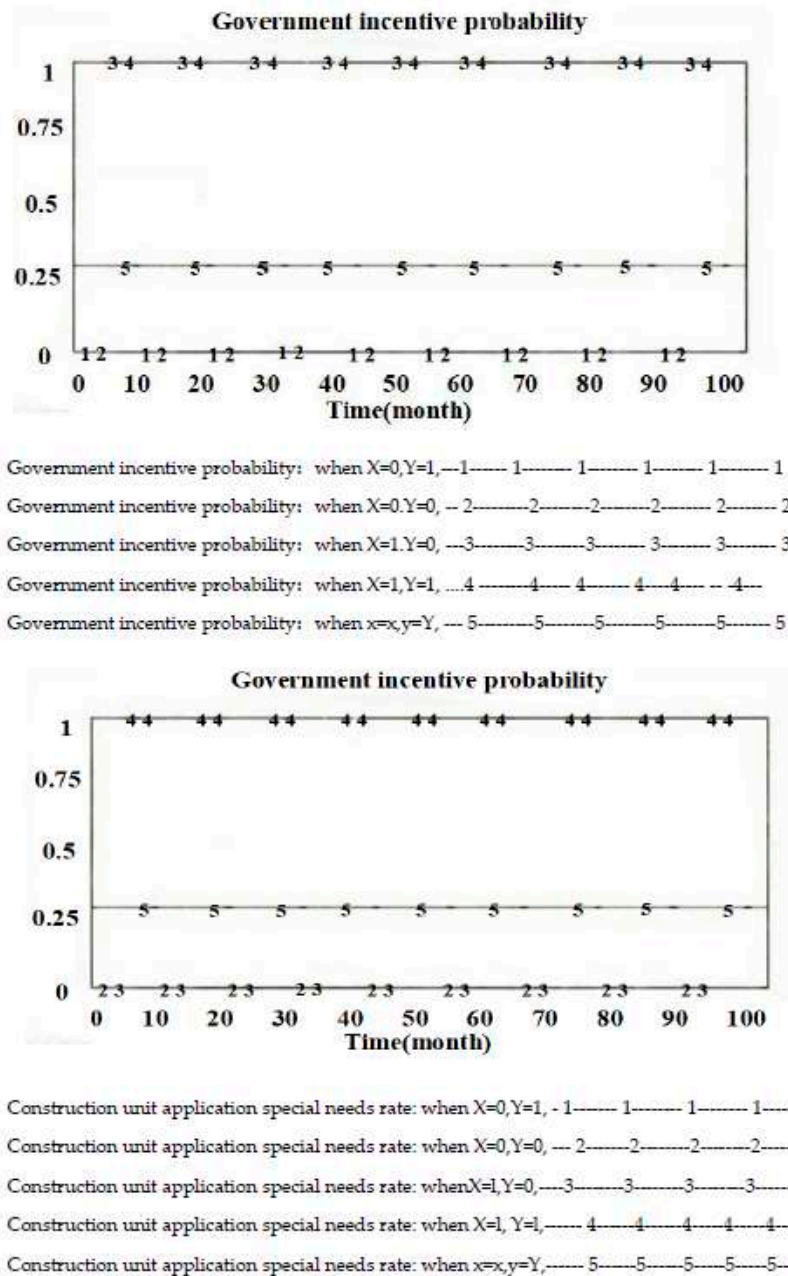
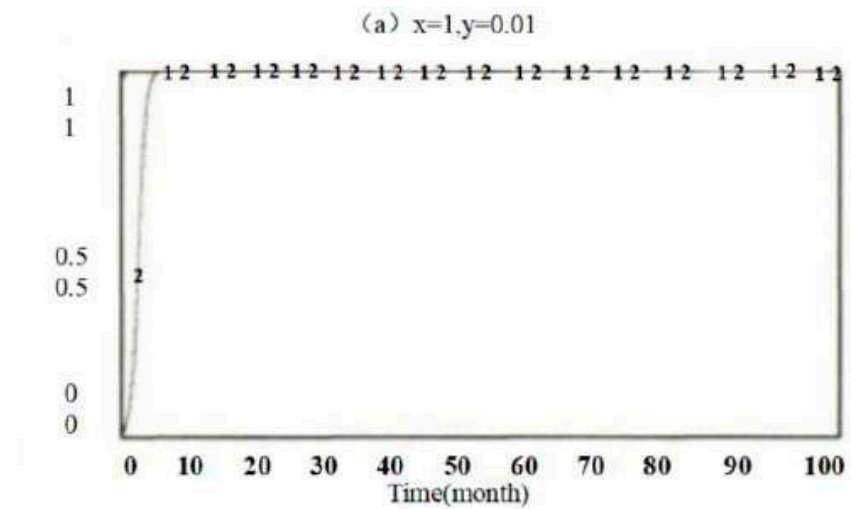


Figure 3. The initial value of both sides of the game is the evolution process of the equilibrium state.

The following is the analysis of the final stable state of the system when the individual adopts the new strategy. We assume that  $x = L$  and  $y = 0.01$ , that is, when the government adopts incentive policies, only 1% of the construction units choose to apply green buildings, and the evolution process of the game between the two parties is not shown in Figure 4a. However, it can be seen from Figure 4a that when the government chooses strong incentive

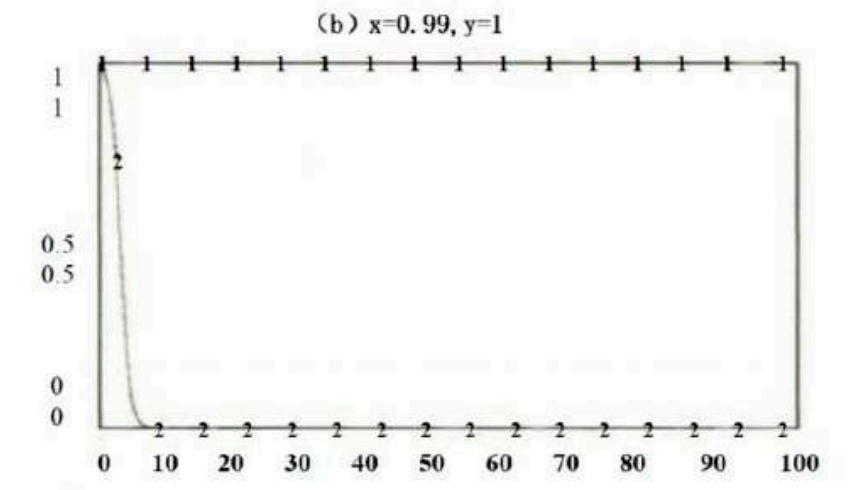


policies, although only 1% of the construction units choose to apply green buildings at the beginning, due to the government’s active incentive policies, the construction units quickly adopt the application strategy out of their best interest. At this time, the system reaches the equilibrium state A4. Suppose  $x = 0.99$  and  $y = 1$ ; that is, 99% of the government adopts subsidy measures, and all the construction units choose to apply green buildings. The evolution process of the game between the two sides is shown in Figure 4b. Figure 4b shows that when the construction unit of the application strategy is adopted, the green building has formed scale, despite the majority (99%) of local governments choosing an incentive strategy. However, as a result of the construction unit employing the conscious choice application strategy under the condition of a market economy, the local government’s strong incentive policy does not play a big role, thus gradually reducing subsidies, propaganda, and so on, and the system reaches equilibrium  $x_2$ , green building in the era of “subsidy”.



Government incentive probability: when  $X=1, Y=0.01, 1-1-1-1-1-1-1-1-1-1$

Construction unit application special needs rate: when  $X=1, Y=0.01, -2--2--2--2--2--2--2--2$



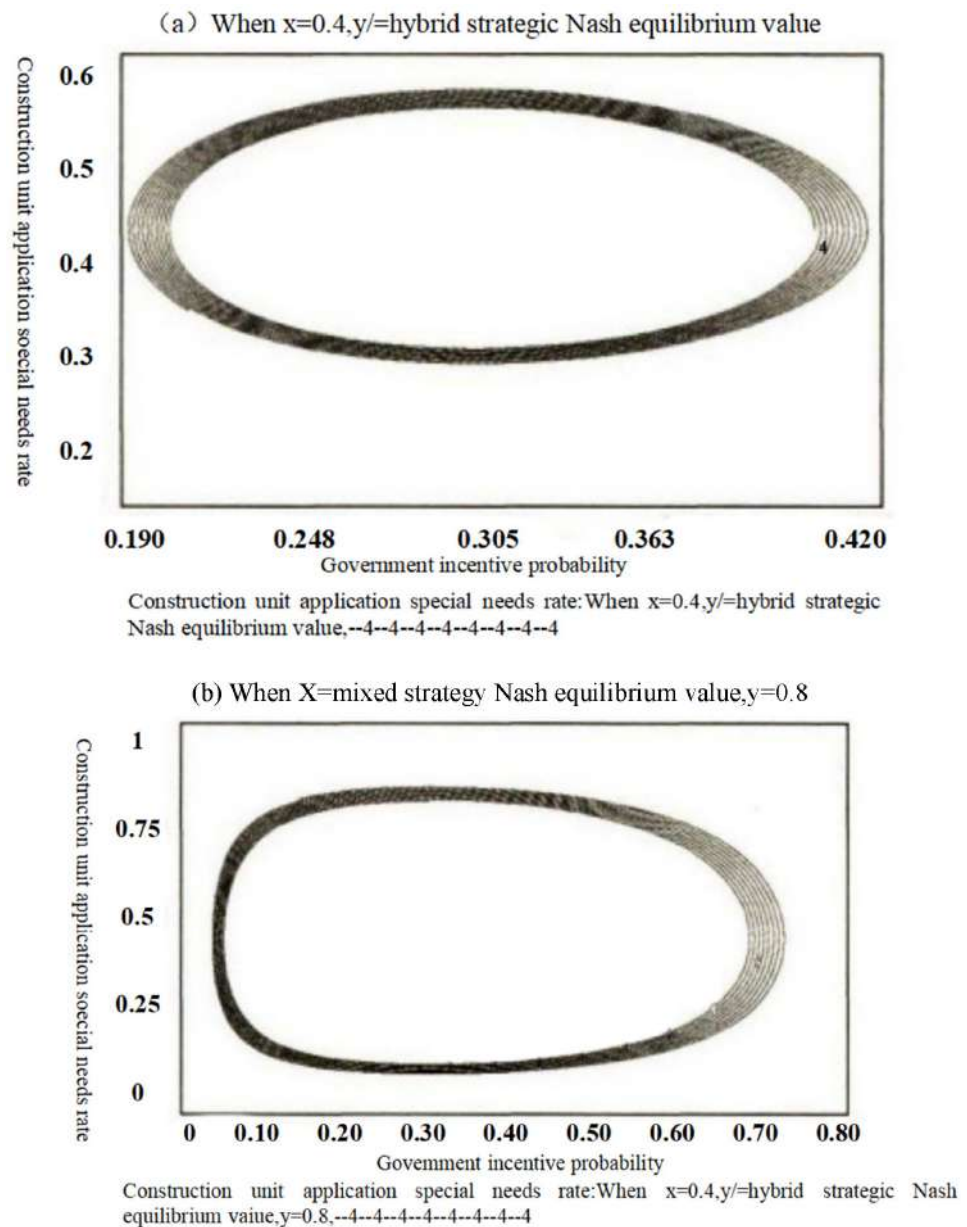
Construction unit application special needs rate: when  $X=0.99, Y=1, 1-1-1-1-1-1-1-1-1-1$

Government incentive probability: when  $X=0.99, Y=1, -2--2--2--2--2--2--2--2$

**Figure 4.** Evolution process of game between two parties when  $x = 1, y = 0.01$ , and  $x = 0.99, y = 1$ .

**(2) One side of the game adopts the initial hybrid strategy Nash equilibrium**

When one side of the game adopts a mixed-strategy Nash equilibrium value and the other side randomly chooses to apply (excitation) probability, assuming that  $A5 = (0.4, y/)$  and  $A6 = (x', 0.8)$ , the evolution results are shown in Figure 5. The analysis of Figure 5 shows that when the game takes at least one party with a mixed strategy Nash equilibrium value, the other party will adjust their strategy according to each other; with the increase in game time and the number of games, the game strategy shows great changes, the evolution shows instability, and the game behavior is not easy to control.

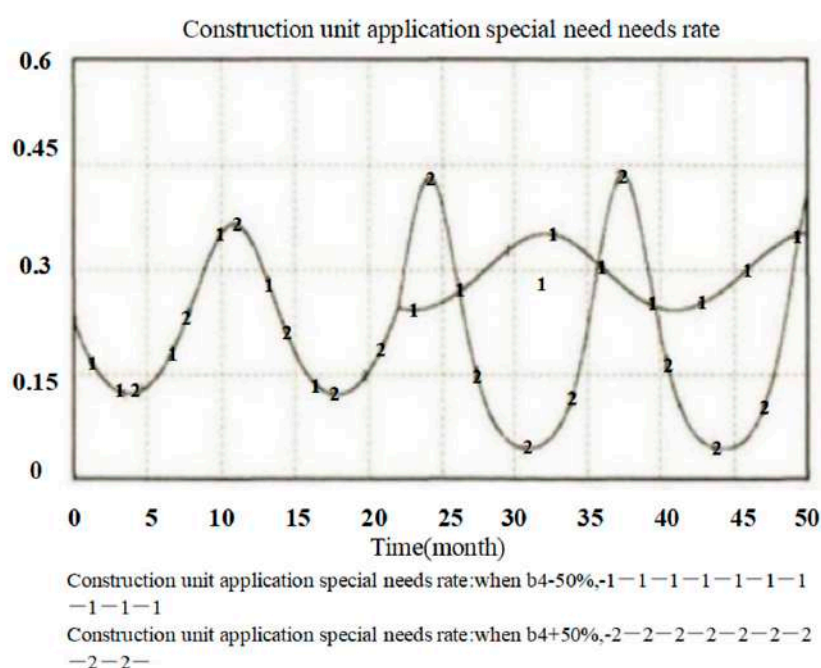


**Figure 5.** The evolutionary process when a game party adopts the Nash equilibrium value of a mixed strategy.

**(3) The impact of the subsidy on the model**

When  $x = 0.4, y/ =$  hybrid strategic Nash equilibrium value, the influence of the government subsidy amount on the application of green building by construction units is studied. In the first case, when  $TIME = 22$  (at this  $TIME$ , the probability that the construction unit adopts the prefabricated type is increasing), the amount of subsidy to the construction

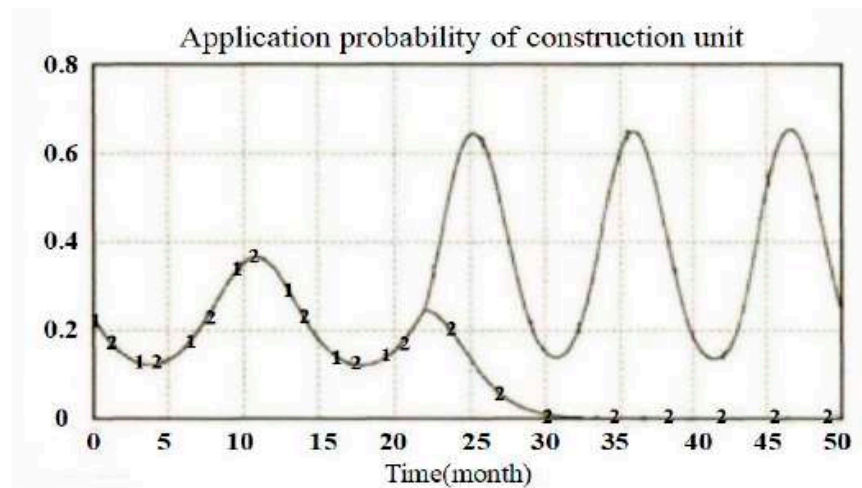
unit was increased. At this TIME, the initial value of the subsidy amount is increased from 6 to 1.5. In the second case, when TIME = 22, the amount of subsidy granted to the construction unit is reduced, and the initial value of the subsidy amount is reduced from 1 to 0.5. The simulation results of the two are shown in Figure 6. It can be seen from Figure 6 that the increase in local government subsidies to construction units within a cycle can improve the probability of construction units applying green buildings. However, construction units will re-learn new strategies after experiencing the high subsidy policies of the government, and the probability of application will rebound to a large extent. In addition, the government's behavior of increasing subsidies cannot reduce the game equilibrium point of construction units. From a cycle point of view, the behavior of reducing subsidies cannot improve the application probability of construction units, and there will be a stage rebound. However, on the whole, it reduces the equilibrium point of the game of construction units so that it is relatively stable. Therefore, an appropriate reduction in subsidies is a relatively sound decision.



**Figure 6.** The influence of a change in B4 on the application probability of construction unit.

#### (4) The influence of punishment intensity on the model

When  $x = 0.4$ ,  $y =$  hybrid strategic Nash equilibrium value, the influence of government punishment on the application of green building by construction units is studied. In the first case, when TIME = 22, the punishment to the construction unit will intensify, and the fine's initial value will be increased from 1.2 to 1.68. In the second case, when TIME = 22, the punishment to the construction unit is reduced from the initial value of the subsidy, from 1.2 to 0.72. At this point, the simulation results are shown in Figure 7. It can be seen from Figure 7 that, within a cycle, local governments increase the punishment amount for construction units that fail to implement incentive policies, which can increase the probability of applying green buildings (both the valley value and peak value increase) but cannot reduce the game equilibrium point of construction units. However, what is certain is that the probability of the construction unit applying green building will decrease with the reduction of government punishment. Therefore, in the long run, the government should strengthen supervision and improve the supervision and punishment system while making incentive policies.



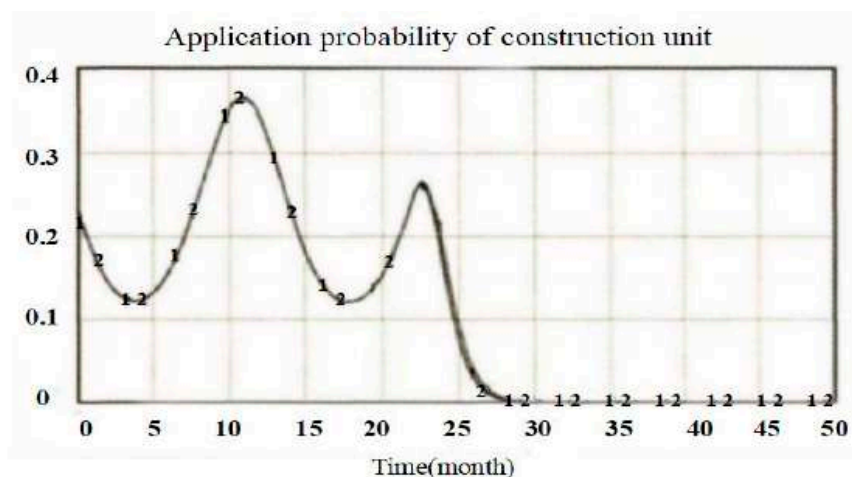
Construction unit application special needs rate: when  $85 + 40\%$ , -- 1-- 1-- 1-- 1-- 1--1--1

Construction unit application special needs rate: when  $a5 - 40\%$ , -- 2-- 2--2--2--2--2-- 2--2

Figure 7. The influence of the government penalty amount on the application probability of construction units.

(5) The government checks the influence of cost and indirect income of construction units on the model

When  $x = 0.4$ ,  $y/ =$  hybrid strategy Nash equilibrium value, we analyze the impact of government inspection costs on the application probability of construction units, assuming that when TIME (TIME) = 22, the initial value of inspection strength 63 increases from 0.7 to 0.91 and 1.05, respectively, and these simulation results are shown in Figure 8. It can be seen from Figure 8 that the local government increases the inspection cost at TIME (TIME) = 22, and the construction unit gradually reduces the application probability of green buildings. This is because the inspection cost of the government is transferred to the construction unit, which indirectly increases the construction cost of the construction unit, reduces the profit space, and reduces the enthusiasm for development.

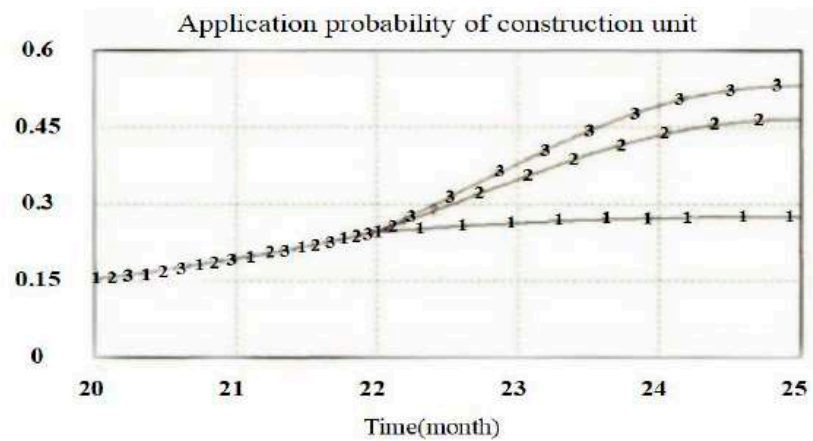


Construction unit application special needs rate: when  $b3 + 50\%$

Construction unit application special needs rate: when  $b3 + 30\%$

Figure 8. Influence of government inspection cost on the application rate of construction units.

When TIME (TIME) = 22, the construction unit's initial indirect income value A4 increases from 0.7 to 0.91 and 1.05 and decreases from 0.7 to 0.49. The simulation results are shown in Figure 9. It can be seen from Figure 9 that the indirect benefit of the construction unit developing green buildings is proportional to the probability of applying green buildings.



Construction unit application special needs rate: when  $a_4 - 30\%$ , 1-1-1-1-1-1-1

Construction unit application special needs rate: when  $a_4 + 30\%$ , -2--2--2--2--2--2--2

Construction unit application special needs rate: when  $a_4 + 50\%$ , -3--3--3--3--3--3--3

Figure 9. The influence of indirect income  $\sim$  on the application probability of the construction unit.

#### 4. Discussion and Recommendations Based on Simulation Results

The above analysis shows that government incentive policies can directly change the choice of construction units, and the amount of the government subsidy, penalties, inspection costs, and development costs of construction units all have a significant impact on the application of green buildings by construction units. Based on the results of the above factors, this study puts forward the following suggestions for the government's incentive behavior:

- We will reasonably adjust the number of subsidies through the simulation analysis of the influence of the change in government subsidy on the application strategy of construction units. It can be seen that a blind increase in the financial subsidy by the government will not encourage construction units to choose the application strategy but will reduce the enthusiasm of construction units to apply and hinder the development of construction industrialization. On the other hand, excessive financial subsidies will also pressure the government and restrict the development of other activities. In addition, the government's appropriate reduction of financial subsidies can stimulate the construction units to choose the application strategy regarding market competition, but the high volatility is not conducive to the government's control. Therefore, the government should measure the subsidy amount scientifically and adjust the subsidy strategy in time according to the market changes to ensure the interests of construction units and realize the functions of the government.
- Improve the punishment mechanism. Through changes in the government punishment line  $a_5$  simulation analysis on the impact of the construction unit application strategy, increasing the intensity of punishment for the construction unit can improve the utilization ratio of the construction unit, but contributed to the construction unit's instability in the process of evolution and volatility. Therefore, the government should consider tax policy, land policy, fiscal policy, and approval link angles such as the workforce, taken together, to form a dynamic effective punishment mechanism.
- Reduce development costs. Through the simulation analysis of the influence of the change in government inspection cost on the application strategy of the construction

unit, it can be seen that the increase in the development cost or government inspection costs will directly or indirectly affect the probability of the construction unit applying green building. This is because improving regulatory efficiency and reducing regulatory costs, on the one hand, can strengthen the level of the self-discipline of enterprises; on the other hand, it is also an extension of government functions. In addition, reducing the incremental cost of development using large-scale production and technological upgrading is also an important means of accelerating green building.

- d. Step up publicity. Through the simulation analysis of the influence of the change in the indirect income of the construction unit on the application strategy of the construction unit, it can be seen that with the increase in the indirect income of the construction unit, the probability of the application of green building will also increase. Therefore, from the perspective of construction units, they should pay attention to improving their brand and image. From the two aspects of the government and the construction unit, strategies such as increasing the construction of pilot cities and pilot projects, constantly expanding the market, forming a good public opinion environment, and improving consumers' cognition of green building are suggested.

## 5. Conclusions

Although green buildings have strong sustainable development potential, most construction units are reluctant to adopt green buildings. In order to solve this problem, this study selects the construction unit and the government as the main body and explores and quantifies the evolutionary game analysis of the green building construction stage. In this paper, the construction of a system dynamics flow chart is established through the establishment of an evolutionary game model. From the data simulation analysis, it can be determined that the amount of government subsidy, the intensity of punishment, and the cost of the inspection will have an impact on the application of green building by the construction unit, which will further affect the promotion and application of green building in China. Because of the positive and negative effects of these three government behaviors on the application strategies of construction units, this paper puts forward the corresponding suggestions and countermeasures.

By analyzing the previous literature and analyzing the activity characteristics of green buildings, the system dynamics theory was analyzed to formulate an incentive for green building policy. The evolutionary game analysis method, based on the view of finite rationality, overcomes the limitation of the hypothesis of complete rationality in traditional game theory and provides a possibility for solving practical problems. The method combining evolutionary game theory and system dynamics is applied to the government to formulate incentive green building policies for the first time, providing new ideas for evolutionary game theory. Furthermore, targeted policy suggestions are obtained from the simulation results, which are helpful for the government to realize the full implementation of green buildings, stimulate the environmental protection concept of construction units, and realize the sustainable development of China's construction industry.

Although the objectives of this study were achieved, some limitations were still present. The strategy analysis between the government-consumer and the construction unit-consumer is not mentioned in the paper, which will be the direction of future research.

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