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The behavioral strategies of multiple stakeholders in environmental nimby conflicts: An evolutionary game theoretical research

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"Chinese-style Nimby" is a thorny issue in China's current public governance. Generally speaking, there is a game relationship between multiple stakeholders in the environmental NIMBY conflicts. Given this, the study constructs the tripartite evolutionary game model of the government, construction enterprises and the surrounding residents, and uses MATLAB to numerically simulate the evolutionary system. The results show: 1) The effect of government negotiations in resolving environmental conflicts is better than environmental compensation, with the increase in the degree of civil resistance, the probability of the government choosing negotiation strategies will increase; 2) Reducing the cost of negotiations in enterprises, or the taxation index when selecting considering public's demands, or improving additional benefits of the corporate, which can effectively improve the positivity of enterprises to consider people's appeals; 3) The higher the compensation and the extra benefits of people's cooperative participation are, the faster the system will evolute to people's cooperative participation. Finally, based on the research findings, this paper provides reference and countermeasures for the construction of multiple co-governance mechanisms of environmental NIMBY conflicts.

KEYWORDS
tripartite evolutionary game, environmental conflict governance, stimulation analysis, behavior strategy, environmental economics

1 Introduction

With the deepening of reform and opening-up, China's urban development has made remarkable achievements. By the end of 2021, the urbanization rate of China's permanent population has reached 64.72% (refer to Kui Feng). Economic development has raised the level of urbanization, but also put forward higher requirements for urban infrastructure, building all kinds of infrastructure including NIMBY facilities has become a realistic choice to ensure urban development. According to the 2020 Annual Report on the Prevention and Control of Environmental Pollution by Solid Waste in China's Large and medium-sized Cities released by the National Bureau of Statistics, in 2019, 196 large and medium-sized cities in China generated 235.602 million tons of domestic garbage and treated 234.872 million tons, with the treatment rate of 99.7% (refer to Ministry of Ecology and Environment of the People's Republic of China). During the period of the "12th Five-Year Plan" (2011–2015) and "13th Five-Year Plan" (2016–2020), the number of China's waste incineration plants increased by 303%, and the incineration treatment volume increased by 577%. Moreover, as of June 1, 2020, China had 455 incineration factories in operation, with a compound annual growth rate of 15.6% over the past 5 years (refer to China Association of Circular Economy).However, the stakeholders in NIMBY problem have different interest demands and value standards, so how to coordinate the interest demands among multiple subjects is the key to solve the NIMBY problem.

The concept of "NIMBY" originated from the word "Not in My Block" proposed by O'Hare in the 1970s, which is used to describe the facilities that can bring overall social interests but have a negative impact on the nearby residents, and public protests caused by the planned location of such facilities (O'hare, 1977; Arif and Sohail, 2020; Zhao et al.,. 2019; Zhao et al., 2022a; Zhao at al., 2022b; Zhenyu and Sohail, 2022). Typically, the NIMBY sentiments are positively related to the distance of the NIMBY facilities, which is frequently tied to concerns about health and safety, the decline in property values, general decline in quality of life, emotional attachments to existing local land uses, and a desire to preserve existing rural aesthetics (Schively, 2007; Van der Horst, 2007; Devine-Wright, 2009, 2011; Yet et al., 2017; Yat et al., 2018; Sohail et al., 2021b; Chai. et al., 2021). The differentiated interests between different subjects and the differentiated value judgment behind them have become an important reason for NIMBY dilemma.

In terms of the urban development history of the world, NIMBY is not an isolated issue (Dmochowska- Dudek and Bednarek-Szczepan´ska, 2018). Similarly, NIMBY is by no means a unique economy and social problem in China. The foreign practice has proved that almost all developed economies will experience a "NIMBY era" after passing through the stage of rapid development. Taking the history of NIMBY in the United States as an example, it has experienced the pre-NIMBY period, the early NIMBY period and the post-NIMBY period (Saha and Mohai, 2005). Since the beginning of the 21st century, especially after 2010, China has witnessed a high incidence of NIMBY incidents, which are mainly reflected in the increasing number of nimby incidents and the more intensive frequency of their outbreaks. Among them, the environmental mass disturbance is one of the typical forms of expression of the NIMBY conflict. Therefore, many studies put NIMBY issues under the research framework of environmental conflict governance. Indeed, interest in environmental governance has led to research at all scales from knowledge-governance (Van der Molen, 2018; Sohail et al., 2019a; Yasara et al., 2019; Sohail et al., 2014a; Sohail et al., 2014b; Sohail et al., 2022a; Sohail et al., 2022b). Being a human being world is making latest technology and at same time it may have impacts on our environment (Sohail et al., 2013; Sohail et al., 2019b; Sohail et al., 2020; Sohail et al., 2021a; Sohail et al., 2021c; Sohail et al., 2021d; Sohail et al., 2022c). to Mining Governance (Bebbington et al., 2019) and focus on issues such as the role of private actors and markets in environmental governance (Vatn et al., 2018), environmental authoritarianism with Chinese characteristics (Kostka and Zhang, 2018), collaborative governance of public health in low- and middle-income countries (Emerson, 2018), polycentric environmental governance (Heikkila et al., 2018), Authoritarianism and Eco-populism (Middeldorp and Le Billon, 2019) and Collaborative Governance (Ide, 2018). Besides, some scholars try to innovate research methods by constructing a practical framework (Bennett and Satterfield, 2018), structural equation modeling and exploratory factor analysis (Jager et al., 2020) and cross-case study (Fisher et al., 2020) to improve the application of technical methods. The literature has widely acknowledged that a cooperative environmental agreement can make a positive impact on reconciliation between rival states (Muhammad et al., 2014; Shahab et al., 2016; Mahfooz et al., 2017; Rasool et al., 2017; Mahfooz et al., 2019; Morrison et al., 2019; Mahfooz et al., 2020; Liu N. et al., 2022; Liu Y. et al., 2022; Lu and Sohil, 2022; Mustafa et al., 2022), which has provided valuable basis for the current domestic NIMBY research.

Through the interpretation of NIMBY discourse, it can be found that there are different opinions on the NIMBY phenomenon at present. Davies used a case study of the Millennium Stadium in Cardiff and the City of Manchester Stadium to illustrate that sports stadia can actually enhance the value of the residential property and contribute indirectly to property value through the creation of pride, confidence and enhanced image of an area (Davies, 2005). As discussed by Terwel et al., the viability of onshore CO2 storage projects may be jeopardized by the presence of NIMBY sentiments in the population. In their research, they argued that the trust in the government affected how respondents judged the societal risks and benefits associated with CO2 storage (Terwel et al., 2013). Krause et al. utilized survey data collected from 1,001 residents of the coal-intensive United States state of Indiana and examined how the closeness of a hypothetical CCS facility to individuals' communities influences their acceptance of it (Krause et al., 2014). Based on the comparative studies in Shanghai and Hong Kong, Linlin Sun et al. considered that public participation has a positive impact on public acceptance of NIMBY facilities during the planning stage timely, and late public participation will increase public discontent and further decrease the possibility of the public to accept NIMBY facilities (Sun et al., 2016). Meishu Wang et al. believe that the closer is the houses and the ground wastewater treatment plants (WWTPs), the severer were the inhibition effects, indicating the relationship between environmental quality and property price (Wang and Gong, 2018). Avdan et al. used two online survey experiments to test these arguments as followed. Firstly, the personal proximity of terrorist attacks is positively related to the perceived threat of terrorist attacks. Secondly, the physical proximity of terrorist attacks is positively related to the perceived threat of terrorist attacks (Avdan and Webb, 2019). Based on a case study of the dwellings in Tallahassee, FL, Jackson et al. highlighted how funding constraints and NIMBYism (Not in My Backyard-ism) stymied stakeholder efforts to achieve equity and affordability at the dwellings, which resulted in the inability to achieve project aims of developing housing that serves the homeless population (Jackson et al., 2020). Qing Yang et al. innovatively proposed ontology reasoning technology to construct a municipal solid waste (MSW) risk response model and discussed a NIMBY crisis case study to verify the reasoning results of the inference system. Meanwhile, the results showed that rule reasoning of transformation can effectively improve intelligent decision-making regarding MSW risk response (Yang et al., 2020). Jie Yu et al. assumed that the local government's intervention in rumors to a certain extent is conducive to promoting the new media to publicize facts about the pollution NIMBY facilities and to restrain the local people's choice of resistance strategies. It also found that the local government's punishment for the new media spreading rumors should be kept above a certain level to restrain the new media from spreading rumors (Yu et al., 2021).

Reviewing the existing literature on NIMBYism, although present studies have covered many aspects of NIMBY conflicts, such as influential factors (Li et al., 2019; Zheng and Liu 2018; Jerolmack and Walker 2018; Sæpo´rsdo´ttir and O´ lafsdo´ttir 2020; Xu and Lin 2020), generation mechanism (Liu et al., 2018; Whittemore and BenDor, 2019), and governance countermeasure (Zhang et al., 2018). Yet, there is still a relative paucity of research that has applied evolutionary game to reveal the game relationships and influence mechanism among multiple stakeholders in the environmental NIMBY conflicts. More specifically, there is a lack of horizontal comparison of the effectiveness across the multiple stakeholders in the management of NIMBY conflicts under different evolutionary contexts. Consequently, this study focuses on the game relationship of stakeholders, as well as the behavioral strategies adopted in the in environmental NIMBY conflicts. In addition, what are the influencing factors of these behavioral strategies and what are the interaction mechanisms? In other words, this study explores the key factors influencing the behavior choice of multiple stakeholders in nimby environmental conflict governance, and how to control these factors to make the game system evolve towards the established goal, namely, the evolutionary stability strategy.

Inspired by previous work, the study aims to establish a tripartite evolutionary game model of the government, construction enterprises and the surrounding residents, and considers the influence parameters such as the degree of government compensation, the corporate taxation index and the degree of civil resistance. Then, the article focuses on the evolutionary stability of game tripartite strategies under the three cases, concluding (government's negotiation strategy, enterprise considering people's requests, people's cooperative participation) as a stable equilibrium point of the tripartite evolutionary game in the environmental conflict governance (Yen et al., 2021; Jian et al., 2021; Jiang at al, 2021; Kamonja et al., 2014; Lan et al., 2022; Li et al., 2022a; Li et al., 2022b). Based on numerical analysis, we conduct further simulation experiments to study the main factors influencing the evolution of participant behavior strategies. Finally, we put forward some policy recommendations for optimizing the management of environmental NIMBY conflicts. In the remainder of this paper, we first offer detailed but non-technical remarks on the specification of evolutionary game models, and then introduce evolutionary models focused on the problem of multi-cooperation and co-governance of NIMBY conflicts (Sect. 2). Second, we analyze the stability of each equilibrium point and determine the evolutionary stability strategy (ESS) in different situations of environmental NIMBY (Sect. 3). Third, we discuss the influence of related parameters on the evolutionary path via numerical simulation, such as the degree of government compensation, the corporate taxation index and the degree of civil resistance (Sect. 4). We close with relevant concluding remarks and corresponding policy recommendations and then summarize the conclusions and limitations of this manuscript (Sect. 5).

2 Model assumptions and construction

We constructed an evolutionary model focused on the problem of multi-cooperation and co-governance of NIMBY conflicts, which involves the three stakeholders of local government (G), construction enterprises (C) and surrounding public (P). These stakeholders have bounded rationality and possess the ability to learn and evolve.

2.1 Model assumptions

At first, we tried to make a clear explanation of the relationship between the two parties in the game, the relevant hypothesis and parameters are stipulated as follow:

Hypothesis 1. For the siting of NIMBY facilities, there have two behavioral strategy options for each of the three stakeholders, namely: the local government (G) adopts compensation strategies A and negotiation strategies E, the strategy space is $STE = \{A, E\}$, the probability of adopting the two strategies is x

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and $(1 - x)$, respectively; the construction enterprise (C) adopts the strategies of considering the public appeals F and the strategies of ignoring the public appeals H, the strategy space is $STE = \{F, H\}$, the probability of adopting the two strategies is y and $(1 - y)$, respectively; the surrounding public (P) adopts the strategies of cooperative participation J and the strategies of resistance K, the strategy space is $STE = \{J, K\}$, the probability of adopting the two strategies is z and $(1 - z)$, respectively. Notably, $x, y, z \in [0, 1]$ are all functions of time t.

Hypothesis 2. The construction of NIMBY facilities will produce negative externalities (E_c) and the overall social benefits (ε) for the enterprise. When the government adopts a compensation strategy, the total cost of compensation paid by the enterprise to the surrounding residents is α, and the government also has a certain proportion of compensation to the residents (σ), thereby the actual amount of compensation is $\sigma\alpha$. There are no compensation costs that need to pay by the government or enterprise due to residents' resistance. In addition, the strength and cost of the residents' resistance is η and β_1, respectively. Thus, the total cost of resistance borne by the resident is $\eta\beta1$. Meanwhile, residents' resistance will bring the social risk costs (γ_1) to the government, thereby $\eta\gamma_1$ means the total risk cost paid by the government. For another, the government needs to pay for the costs of negotiation (δ_1) while the compensational strategy fails, and the residents will get the benefits (ξ_1) when they cooperate with the government. However, once the residents adopt a resistant strategy, the cost of resistance borne by the resident is β_2 and the total cost is $\eta\beta_2$. Additionally, in this case, the residents will obtain an extra benefit of resistance ξ_2, and the entire risk costs taken by the government are $\eta\gamma_2$ $(\gamma_2 > \gamma_1)$.

Hypothesis 3. The construction cost of NIMBY facilities for the enterprise is θ, and the economic benefits for the enterprise and residents after the facilities completion are κ_1 and φ_1, respectively. On the one hand, when the enterprise considers the public appeals and they reach cooperation, the additional benefits obtained by the enterprise and citizens are ν and ω (such as the stimulus benefits from the government). However, in the circumstances, once the cooperation fails and the surrounding residents adopt a resistant strategy, the cost of resistance borne by the resident is λ_1 and the total cost is $\eta\lambda_1$, but the residents will obtain an extra income of resistance φ_2 and the corporate reputation loss cost is $\eta\vartheta_1$. On the other hand, when the enterprise adopts a strategy that does not consider public appeals, but they still reach the cooperation, the company can obtain additional benefits κ_2, while the residents will lose the benefits φ_3. Similarly, the total cost of resistance for surrounding residents is $\eta\lambda_2$ and can receive an extra income φ_4 when they perform a resistant strategy, but the corporate reputation loss cost is $\eta\vartheta_2$.

TABLE 1 The benefits matrix of three stakeholders in the game models.

(G)	(C)	(P)	
		J	K
A	F	$(\varepsilon - \tau - \sigma\alpha + \psi_1\pi, \tau - \theta + \kappa_1 - \mu - \psi_1\pi + \nu, \varphi_1 - E_c + \sigma\alpha + \mu + \omega)$	$(\varepsilon - \tau - \eta\gamma_1 + \psi_1\pi, \tau - \theta + \kappa_1 - \mu - \psi_1\pi - \eta\vartheta_1, \varphi_1 - E_c - \eta\beta_1 + \mu - \eta\lambda_1 + \varphi_2)$
	H	$(\varepsilon - \tau - \sigma\alpha + \psi_2\pi, \tau - \theta + \kappa_1 - \mu - \psi_2\pi + \kappa_2, \varphi_1 - E_c + \sigma\alpha + \mu - \varphi_3)$	$(\varepsilon - \tau - \eta\gamma_1 + \psi_2\pi, \tau - \theta + \kappa_1 - \mu - \psi_2\pi - \eta\vartheta_2, \varphi_1 - E_c - \eta\beta_1 + \mu - \eta\lambda_2 - \varphi_3 + \varphi_4)$
E	F	$(\varepsilon - \tau - \delta_1 + \psi_1\pi, \tau - \theta + \kappa_1 - \delta_2 - \psi_1\pi + \nu, \varphi_1 - E_c + \xi_1 + \omega)$	$(\varepsilon - \tau - \delta_1 - \eta\gamma_2 + \psi_1\pi, \tau - \theta + \kappa_1 - \delta_2 - \psi_1\pi - \eta\vartheta_1, \varphi_1 - E_c + \xi_1 + \xi_2 - \eta\beta_2 - \eta\lambda_1 + \varphi_2)$
	H	$(\varepsilon - \tau - \delta_1 + \psi_2\pi, \tau - \theta + \kappa_1 - \delta_2 - \psi_2\pi + \kappa_2, \varphi_1 - E_c + \xi_1 - \varphi_3)$	$(\varepsilon - \tau - \delta_1 - \eta\gamma_2 + \psi_2\pi, \tau - \theta + \kappa_1 - \delta_2 - \psi_2\pi - \eta\vartheta_2, \varphi_1 - E_c + \xi_1 + \xi_2 - \eta\beta_2 - \eta\lambda_2 - \varphi_3 + \varphi_4)$

Hypothesis 4. Due to the public characteristic and the inevitable negative externalities of the NIMBY facilities, the government needs to pay the financial subsidies τ to the enterprise. Besides, when the government adopts a compensation strategy, the enterprise also needs to make compensation (μ) to the surrounding residents. While the government adopts a negotiation strategy, the negotiation cost for the enterprise is δ_2. In addition, the government will collect taxes (π) from the enterprise. When the enterprise considers public appeals, their taxation intensity is ψ_1, and the total taxes the enterprise needs to pay are $\psi_1\pi$. On the contrary, when the enterprise does not consider the public appeals, their taxation intensity is ψ_2 and the total taxes required to pay are $\psi_2\pi$.

2.2 Model construction

According to the above assumptions, the game matrix of each subject of the NIMBY under different strategy combinations is shown in Table 1.

3 Evolution game model analysis

3.1 Analysis on the evolutionary stability strategy point of the local government

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

U_{g1} is the average income of local governments adopting compensation strategies in the game, U_{g2} is the average income of adopting negotiation strategies, $\overline{U_g}$ is the overall average income. U_{g1} and U_{g2} can be expressed as

$$U_{g1} = yz(\varepsilon - \tau - \sigma\alpha + \psi_1\pi) + y(1-z)(\varepsilon - \tau - \eta\gamma_1 + \psi_1\pi) + (1-y)z(\varepsilon - \tau - \sigma\alpha + \psi_2\pi) + +(1-y)(1-z)(\varepsilon - \tau - \eta\gamma_1 + \psi_2\pi) \tag{1}$$

$$U_{g2} = yz(\varepsilon - \tau - \delta_1 + \psi_1\pi) + y(1-z)(\varepsilon - \tau - \delta_1 - \eta\gamma_2 + \psi_1\pi) + (1-y)z(\varepsilon - \tau - \delta_1 + \psi_2\pi) + (1-y)(1-z)(\varepsilon - \tau - \delta_1 - \eta\gamma_2 + \psi_2\pi) \tag{2}$$

Combining 1) and (2), we get

$$\overline{U_g} = xU_{g1} + (1-x)U_{g2} \tag{3}$$

When 1) and 3) are combined, the replicator dynamics equation of local government strategy selection can be written as

$$F(x) = \frac{dx}{dt} = x\left(U_{g1} - \overline{U_g}\right) = x(1-x)\left[z(\delta_1 - \sigma\alpha) + (1-z)\left((\delta_1 + \eta\gamma_2 - \eta\gamma_1)\right)\right]. \tag{4}$$

Then, the first derivative of the replicator dynamics equation can be calculated as follow:

$$dF(x)/dx = (1-2x)\left[z(\delta_1 - \sigma\alpha) + (1-z)(\delta_1 + \eta\gamma_2 - \eta\gamma_1)\right]. \tag{5}$$

Let $G(z) = z(\delta_1 - \sigma\alpha) + (1-z)(\delta_1 + \eta\gamma_2 - \eta\gamma_1)$. According to the stability theorem of replicator dynamics equations and the principle of evolutionary stability strategy, when $F(x) = 0$ in formula (4) and $dF(x)/dx < 0$ in formula (5), the probability of local government strategy selection reaches the evolutionary stability point. Since $\partial G(z)/\partial z = -\sigma\alpha - \eta\gamma_2 + \eta\gamma_1 < 0$, so $G(z)$ is a subtractive function about z. When $z = (\delta_1 + \eta\gamma_2 - \eta\gamma_1)/(\sigma\alpha + \eta\gamma_2 - \eta\gamma_1) = z^*$, $G(z) = 0$, then $F(x) \equiv 0$ and $dF(x)/dx \equiv 0$, so all the x is the evolutionarily stable strategy point, which means the local government chooses to compensate or negotiate all is its optimal strategy choice. When $z < z^*$, $G(z) > 0$, obtaining $dF(x)/dx|_{x=1} < 0$, then $x = 1$ is an evolutionarily stable strategy point of the local government. On the contrary, when $z > z^*$, then $x = 0$ is an evolutionarily stable strategy point. The dynamic phase diagram of stability evolution replication for the local government's strategy selection is shown in Figure 1A.

Based on Figure 1A, V_{A_1} is the volume of A_1, which presents the probability of the local government choosing the compensation strategy. Similarly, V_{A_2} refers to the probability of adopting the negation strategy. V_{A_1} and V_{A_2} can be calculated as

$$V_{A_1} = \int_0^1\int_0^1 \frac{\delta_1 + \eta\gamma_2 - \eta\gamma_1}{\sigma\alpha + \eta\gamma_2 - \eta\gamma_1} dydx = \frac{\delta_1 + \eta\gamma_2 - \eta\gamma_1}{\sigma\alpha + \eta\gamma_2 - \eta\gamma_1}, V_{A_2} = 1 - V_{A_1} \tag{6}$$

We can derive the following propositions from (6).

Proposition 1. The probability that the local government chooses to negotiate is positively correlated with the proportion of compensation and total compensation costs and is reversely associated with the negotiation cost, the strength of the residents' resistance, and the entire risk costs taken by the government.

According to Proposition 1, in selecting strategies for local governments, the government prefers to choose the negotiation strategy if the proportion of compensation and the total costs of compensation are too high. On the contrary, the government will adopt a compensation strategy once have the higher costs of the negotiation, the greater residents' resistance, and the more raised risk costs needed to afford by the government.

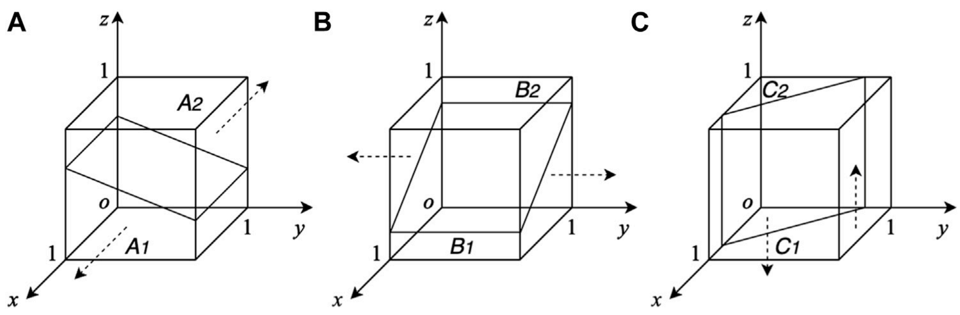

FIGURE 1
(A) The phase diagram of government strategy evolution. **(B)** The phase diagram of the strategic evolution of the enterprise. **(C)** Resident strategy evolution phase diagram.

Proposition 2. The willingness of the public to choose cooperative participation will significantly increase the probability that the government adopts a negotiation strategy.

According to Proposition 2, the more intense willingness of the public to choose cooperative participation, the higher the acceptance rate they have for the NIMBY decision-making. Consequently, the resistant effects derived from the public are more weakening, thereby facilitating the government adopting the negotiation strategies. On the contrary, the government is more inclined to choose compensation strategies.

Proofs for Proposition 1 and Proposition 2 are in the supplementary material.

3.2 Analysis on the evolutionary stability strategy point of the local government

U_{c1} is the average income of the construction enterprises with consideration of the public appeals in the game, U_{c2} is the average income without consideration of the public appeals, $\overline{U_c}$ is the overall average income. U_{c1}, U_{c2}, and $\overline{U_c}$ can be expressed as

$$\begin{aligned} U_{c1} = & xz(\tau - \theta + \kappa_1 - \mu - \psi_1\pi + \nu) + x(1-z)(\tau - \theta + \kappa_1 - \mu \\ & - \psi_1\pi - \eta\vartheta_1) + (1-x)z(\tau - \theta + \kappa_1 - \delta_2 - \psi_1\pi + \nu) \\ & + (1-x)(1-z)(\tau - \theta + \kappa_1 - \delta_2 - \psi_1\pi - \eta\vartheta_1) \end{aligned} \quad (7)$$

$$\begin{aligned} U_{c2} = & xz(\tau - \theta + \kappa_1 - \mu - \psi_2\pi + \kappa_2) + x(1-z)(\tau - \theta + \kappa_1 - \mu \\ & - \psi_2\pi - \eta\vartheta_2) + (1-x)z(\tau - \theta + \kappa_1 - \delta_2 - \psi_2\pi + \kappa_2) \\ & + (1-x)(1-z)(\tau - \theta + \kappa_1 - \delta_2 - \psi_2\pi - \eta\vartheta_2) \end{aligned} \quad (8)$$

$$\overline{U_c} = yU_{c1} + (1-y)U_{c2}. \quad (9)$$

According to (7), 8) and (9), the replicator dynamics equation of the construction enterprises strategy selection can be written as

$$\begin{aligned} F(y) = \frac{dy}{dt} & = y\left(U_{c1} - \overline{U_c}\right) \\ & = y(1-y)[z(\nu + \eta\vartheta_1 - \eta\vartheta_2 - \kappa_2) + \psi_2\pi - \psi_1\pi + \eta\vartheta_2 \\ & \quad - \eta\vartheta_1]. \end{aligned} \quad (10)$$

Then, the first derivative of the replicator dynamics equation can be calculated as follow:ik

$$\begin{aligned} \frac{dF(y)}{dy} = & (1-2y)[z(\nu + \eta\vartheta_1 - \eta\vartheta_2 - \kappa_2) + \psi_2\pi - \psi_1\pi + \eta\vartheta_2 \\ & - \eta\vartheta_1]. \end{aligned} \quad (11)$$

Let $C(z) = z(\nu + \eta\vartheta_1 - \eta\vartheta_2 - \kappa_2) + \psi_2\pi - \psi_1\pi + \eta\vartheta_2 - \eta\vartheta_1$, according to the stability theorem of replicator dynamics equations and the principle of evolutionary stability strategy, when $F(y) = 0$ in formula (10) and $dF(y)/dy < 0$ in formula (11), the probability of the construction enterprises strategy selection reaches the evolutionary stability point. $C(z)$ is a subtractive function about z, so when $z = (\psi_2\pi - \psi_1\pi + \eta\vartheta_2 - \eta\vartheta_1)/(\eta\vartheta_2 - \eta\vartheta_1 + \kappa_2 - \nu) = z^{**}$, obtaining $C(z) = 0$, then $F(y) \equiv 0$ and $dF(y)/dy \equiv 0$, so all the y is the evolutionarily stable strategy point, which means the construction enterprises choose to consider or do not consider the public appeals all is its optimal strategy choice. When $z < z^{**}$, $G(z) < 0$, obtaining $dF(y)/dy|_{y=0} < 0$, then $y = 1$ is an evolutionarily stable strategy point of the construction enterprises. On the contrary, when $z > z^{**}$, then $y = 0$ is an evolutionarily stable strategy point. The dynamic phase diagram of stability evolution replication for construction enterprise's strategy selection is shown in Figure 1B.

Based on Figure 1B, the cross-section is over the point $(0, 0, z^{**})$, V_{B_1} is the volume of B_1, which presents the probability of the construction enterprises choosing the strategy with consideration of public appeals. Similarly, V_{B_2} refers to the probability of strategy without consideration of public appeals. V_{B_1} and V_{B_2} can be calculated as

$$V_{B_1} = \int_0^1\int_0^1 \frac{\psi_2\pi - \psi_1\pi + \eta\vartheta_2 - \eta\vartheta_1}{\eta\vartheta_2 - \eta\vartheta_1 + \kappa_2} dydx = \frac{\psi_2\pi - \psi_1\pi + \eta\vartheta_2 - \eta\vartheta_1}{\eta\vartheta_2 - \eta\vartheta_1 + \kappa_2 - \nu}, \quad (12)$$

$$V_{B_2} = 1 - V_{B_1} = 1 - \frac{\psi_2\pi - \psi_1\pi + \eta\vartheta_2 - \eta\vartheta_1}{\eta\vartheta_2 - \eta\vartheta_1 + \kappa_2 - \nu}. \quad (13)$$

As a result of 12 and 13, we can derive the following propositions.

Proposition 3. The probability that construction enterprises choose to consider public demands is positively correlated with tax revenue and the taxation index of local governments when enterprises do not consider public demands. On the contrary, it is negatively correlated with enterprise extra income, the degree of civil resistance and local government's taxation index when enterprises consider public demands.

According to Proposition 3, on the one hand, the government can increase the tax collection of the construction enterprises to guide the enterprises to adopt the strategy considering public appeals. On the other hand, the increase of the extra benefits that the construction enterprises obtain when they ignore the public appeals will significantly increase their willingness to choose the strategy of disregarding public appeals. Meanwhile, the reduction in the intensity of the surrounding public's resistance will enhance the willingness of the construction enterprises to adopt the strategy considering public appeals. Hence, the government can set up a reasonable reward and punishment mechanism to reduce the expectations of residents who are seeking increasing extra benefits in the NIMBY conflicts by resistant participation. Moreover, the mechanism could also enhance the willingness of the enterprises to consider the public appeals in the construction and production, thereby promoting the cooperation between the public and enterprise.

Proposition 4. During the evolution process, there has decreased probability of the construction enterprises choosing the strategy considering the public appeals with the increase in the probability of the surrounding public choosing cooperative participation.

Collectively, Proposition 4 shows that the enterprises' strategy to consider public appeals is negatively related to the public's probability for cooperative participation. With the increase of the probability that the residents choose cooperative participation, companies may engage in speculative behavior that does not consider the public appeals due to no reputation loss-costs. On the contrary, companies tend to adopt a stabilizing strategy that considers public appeals. To avoid the occurrence of enterprise speculation, on the one hand, the public should selectively adjust their participation strategies, and on the other hand, enterprises should promote cooperation with minimal investment.

In the supplementary material, proofs for Proposition 3 and Proposition 4 are provided.

3.3 Analysis on the evolutionary stability strategy point of the local government

U_{p1} are the average benefits of the surrounding public with cooperative participation in the game, U_{p2} are the average benefits of the public's strategy with resistant participation, $\overline{U_p}$ are the overall average benefits. U_{p1} and U_{p2} can be expressed as

$$U_{p1} = xy(\varphi_1 - E_c + \sigma\alpha + \mu + \omega) + x(1-y)(\varphi_1 - E_c + \sigma\alpha + \mu - \varphi_3) + (1-x)y(\varphi_1 - E_c + \xi_1 + \omega) + (1-x)(1-y)(\varphi_1 - E_c + \xi_1 - \varphi_3) \quad (14)$$

$$U_{p2} = xy(\varphi_1 - E_c - \eta\beta_1 + \mu - \eta\lambda_1 + \varphi_2) + x(1-y)(\varphi_1 - E_c - \eta\beta_1 + \mu - \eta\lambda_2 - \varphi_3 + \varphi_4) + (1-x)y(\varphi_1 - E_c + \xi_1 + \xi_2 - \eta\beta_2 - \eta\lambda_1 + \varphi_2) + (1-x)(1-y)(\varphi_1 - E_c + \xi_1 + \xi_2 - \eta\beta_2 - \eta\lambda_2 - \varphi_3 + \varphi_4) \quad (15)$$

From 14 and 15, we can derive the following expression for $\overline{U_p}$.

$$\overline{U_p} = zU_{p1} + (1-z)U_{p2} \quad (16)$$

Similarly, the replicator dynamics equation and its derivative of the surrounding public strategy selection can be written as

$$F(z) = \frac{dz}{dt} = z\left(U_{p1} - \overline{U_p}\right) = z(1-z)[x(\sigma\alpha + \eta\beta_1 - \eta\beta_2 + \xi_2) + y(\omega + \eta\lambda_1 - \varphi_2 - \eta\lambda_2 + \varphi_4) + \eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4] \quad (17)$$

$$\frac{dF(z)}{dz} = (1-2z)\,[x(\sigma\alpha + \eta\beta_1 - \eta\beta_2 + \xi_2) + y(\omega + \eta\lambda_1 - \varphi_2 - \eta\lambda_2 + \varphi_4) + \eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4] \quad (18)$$

Also, let $P(y) = x(\sigma\alpha + \eta\beta_1 - \eta\beta_2 + \xi_2) + y(\omega + \eta\lambda_1 - \varphi_2 - \eta\lambda_2 + \varphi_4) + \eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4$. According to the stability theorem of replicator dynamics equations and the principle of evolutionary stability strategy, when $F(z) = 0$ in formula (17) and $dF(z)/dz < 0$ in formula (18), the probability of the surrounding public strategy selection reaches the evolutionary stability point. Since $P(y)$ is an increasing function about y, so when $y = (\xi_2 - \eta\beta_2 - \eta\lambda_2 + \varphi_4 - x(\sigma\alpha + \eta\beta_1 - \eta\beta_2 + \xi_2))/(\omega + \eta\lambda_1 - \varphi_2 - \eta\lambda_2 + \varphi_4) = y^*$, obtaining $P(y) = 0$, then $F(z) \equiv 0$ and $dF(z)/dz \equiv 0$, so all the z is the evolutionarily stable strategy point, which means the surrounding public chooses the cooperative or resistant participation all is their optimal strategy choice. When $y < y^*$, $P(y) < 0$, obtaining $dF(z)/dz|_{z=0} < 0$, then $z = 0$ is an evolutionarily stable strategy point of the construction enterprises. On the contrary, when $y > y^*$, then $z = 1$ is an evolutionarily stable strategy point. The dynamic phase diagram of stability evolution replication for the surrounding public's strategy selection is shown in Figure 1C.

Based on Figure 1C, V_{C_1} is the volume of C_1, which means the probability of the surrounding public choosing the cooperative participation strategy. Similarly, V_{C_2} refers to the probability of adopting the resistant participation strategy. V_{C_1} and V_{C_2} can be calculated as

$$V_{C_2} = \int_0^1 \int_0^{\frac{-\eta\beta_2+\xi_2-\eta\lambda_2+\varphi_4}{\sigma\alpha+\eta\beta_1-\eta\beta_2+\xi_2}} \frac{-\eta\beta_2+\xi_2-\eta\lambda_2+\varphi_4-x(\sigma\alpha+\eta\beta_1-\eta\beta_2+\xi_2)}{\omega+\eta\lambda_1-\varphi_2-\eta\lambda_2+\varphi_4} dxdz$$
$$= \frac{(\eta\beta_2-\xi_2+\eta\lambda_2-\varphi_4)^2}{2(\omega+\eta\lambda_1-\varphi_2-\eta\lambda_2+\varphi_4)(\sigma\alpha+\eta\beta_1-\eta\beta_2+\xi_2)} \tag{19}$$

$$V_{C_1} = 1 - V_{C_2}$$
$$= 1 - \frac{(\eta\beta_2-\xi_2+\eta\lambda_2-\varphi_4)^2}{2(\omega+\eta\lambda_1-\varphi_2-\eta\lambda_2+\varphi_4)(\sigma\alpha+\eta\beta_1-\eta\beta_2+\xi_2)} \tag{20}$$

According to 19 and 20, we can get the following propositions.

Proposition 5. The probability that the surrounding public chooses the cooperative participation strategy is positively correlated with the extra cooperation-derived benefits that the public obtains when the construction enterprises consider the public appeals. In addition, it is also positively associated with the proportion and amount of compensation by the local government and the total cost taken by residents to opposite the enterprise's strategy. Meanwhile, the probability of the public's cooperative participation is reversely linked with the extra benefits and the intensity of the public's resistance. Besides, it is also negatively connected with the residents' resistance-derived benefits when the local government adopts a negotiation strategy, as well as the total cost taken by residents to opposite the government's strategy.

In summary, Proposition 5 shows that the probability of whether the public adopts a cooperative participation strategy in the game for NIMBY conflicts is affected by several factors. Briefly, the public is more likely to choose a cooperative participation strategy when they obtain more cooperative benefits and compensation, as well as the higher resistance costs. In other words, higher external compensation can promote public cooperation and participation.

Proposition 6. During the evolution process, the surrounding residents have an extended probability of choosing cooperative participation strategies with the increase of the probability that local governments adopt compensation strategies and the construction companies choose strategies to consider public appeals.

In conclusion, Proposition 6 shows that as the local government adopts compensation strategies and the construction enterprises choose the strategies considering the public appeals, the surrounding public is more willing to prefer cooperative participation as a stable strategy. On the contrary, the surrounding residents are more inclined to choose a resistant participation strategy.

The detailed proof procedures for Proposition 5 and Proposition 6 are in the supplementary material.

3.4 Analysis on the evolutionary stability strategy point of the local government

Let $F(x) = F(y) = F(z) = 0$, the partial equilibrium point can be obtained as $E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(0,1,1)$, $E_5(1,0,0)$, $E_6(1,0,1)$, $E_7(1,1,0)$ and $E_8(1,1,1)$. The Jacobian matrix of the three-party evolutionary game model is

$$J = \begin{bmatrix} J_1 & J_2 & J_3 \\ J_4 & J_5 & J_6 \\ J_7 & J_8 & J_9 \end{bmatrix} = \begin{bmatrix} \partial F(x)/\partial x & \partial F(x)/\partial y & \partial F(x)/\partial z \\ \partial F(y)/\partial x & \partial F(y)/\partial y & \partial F(y)/\partial z \\ \partial F(z)/\partial x & \partial F(z))/\partial y & \partial F(z))/\partial z \end{bmatrix} \tag{21}$$

with

$$J_1 = (1-2x)G(z), J_2 = 0, J_3 = x(1-x)(-\sigma\alpha-\eta\gamma_2+\eta\gamma_1),$$
$$J_4 = 0, J_5 = (1-2y)C(z), J_5 = (1-2y)C(z), J_6 = y(1-y)$$
$$(\nu+\eta\vartheta_1-\eta\vartheta_2-\kappa_2), \quad J_7 = z(1-z)(\sigma\alpha+\eta\beta_1-\eta\beta_2+\xi_2),$$
$$J_8 = z(1-z)(\omega+\eta\lambda_1-\varphi_2-\eta\lambda_2+\varphi_4), J_9 = (1-2z)P(y)$$

According to the method proposed by Friedman, the evolutionary stability strategy (ESS) of the differential equation can be obtained by analyzing the local stability of the Jacobi matrix of the system. According to the evolutionary game theory, the equilibrium point that meets all the eigenvalues of the Jacobi matrix with non-timing is the evolutionary stable point (ESS) of the system. We bring each equilibrium point $E_i(i=1,\cdots,8)$ into the Jacobi matrix (21), and the eigenvalues of the Jacobi matrix can be obtained, as shown in Table 2.

In the present study, we focus on how to effectively increase the probability that construction companies adopt the strategies considering public appeals and cooperative participation by the surrounding public when the local government performs a negotiation strategy in the game for NIMBY conflicts. Therefore, the equilibrium point $E_4(0,1,1)$ is the principal one we focus on. If the $E_4(0,1,1)$ is the ESS of the model, it needs to meet the equilibrium conditions simultaneously:

$$\begin{cases} \delta_1 - \sigma\alpha < 0, \\ -(\nu-\kappa_2+\psi_2\pi-\psi_1\pi) < 0, \\ -(\omega+\eta\lambda_1-\varphi_2+\eta\beta_2-\xi_2) < 0 \end{cases} \tag{22}$$

Simplify the above conditions to get $\delta_1 - \sigma\alpha < 0$, $\nu - \kappa_2 + \psi_2\pi - \psi_1\pi > 0$ and $\omega + \eta\lambda_1 - \varphi_2 + \eta\beta_2 - \xi_2 > 0$. When the surrounding residents choose the strategy with cooperative participation in the game, the benefits of local governments adopting the negotiation strategy are greater than the benefits

TABLE 2 The eigenvalues of Jacobian matrix.

Equilibrium Point	Eigenvalues k_1	Eigenvalues k_2	Eigenvalues k_3
$E_1\,(0,0,0)$	$\delta_1 + \eta\gamma_2 - \eta\gamma_1$	$\psi_2\pi - \psi_1\pi + +\eta\vartheta_2 - \eta\vartheta_1$	$\eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4$
$E_2\,(0,0,1)$	$\delta_1 - \sigma\alpha$	$\nu - \kappa_2 + \psi_2\pi - \psi_1\pi$	$-(\eta\beta_2 - \xi_2 + +\eta\lambda_2 - \varphi_4)$
$E_3\,(0,1,0)$	$\delta_1 + \eta\gamma_2 - \eta\gamma_1$	$-(\psi_2\pi - \psi_1\pi + +\eta\vartheta_2 - \eta\vartheta_1)$	$\omega + \eta\lambda_1 - \varphi_2 + +\eta\beta_2 - \xi_2$
$E_4\,(0,1,1)$	$\delta_1 - \sigma\alpha$	$-(\nu - \kappa_2 + \psi_2\pi - \psi_1\pi)$	$-(\omega + \eta\lambda_1 - \varphi_2 + \eta\beta_2 - \xi_2)$
$E_5\,(1,0,0)$	$-(\delta_1 + \eta\gamma_2 - \eta\gamma_1)$	$\psi_2\pi - \psi_1\pi + +\eta\vartheta_2 - \eta\vartheta_1$	$\sigma\alpha + \eta\beta_1 + \eta\lambda_2 - \varphi_4$
$E_6\,(1,0,1)$	$-(\delta_1 - \sigma\alpha)$	$\nu - \kappa_2 + \psi_2\pi - \psi_1\pi$	$-(\sigma\alpha + \eta\beta_1 + +\eta\lambda_2 - \varphi_4)$
$E_7\,(1,1,0)$	$-(\delta_1 + \eta\gamma_2 - \eta\gamma_1)$	$-(\psi_2\pi - \psi_1\pi + \eta\vartheta_2 - \eta\vartheta_1)$	$\sigma\alpha + \eta\beta_1 + \omega + +\eta\lambda_1 - \varphi_2$
$E_8\,(1,1,1)$	$-(\delta_1 - \sigma\alpha)$	$-(\nu - \kappa_2 + \psi_2\pi - -\psi_1\pi)$	$-(\sigma\alpha + \eta\beta_1 + \omega + +\eta\lambda_1 - \varphi_2) + \eta\lambda_1 - \varphi_2)$

TABLE 3 The local stability of equilibrium point.

E	Case 1[1]		Case 2[2]		Case 3[3]	
	(k_1, k_2, k_3)	*Stability*	(k_1, k_2, k_3)	*Stability*	(k_1, k_2, k_3)	*Stability*
E_1	$(+,+,-)$	*Unstable*	$(+,+,+)$	*Saddle Point*	$(+,+,+)$	*Saddle Point*
E_2	$(-,+,+)$	*Unstable*	$(-,+,-)$	*Unstable*	$(-,+,-)$	*Unstable*
E_3	$(+,-,+)$	*Unstable*	$(+,-,+)$	*Unstable*	$(+,-,+)$	*Unstable*
E_4	$(-,-,-)$	*ESS*	$(-,-,-)$	*ESS*	$(-,-,-)$	*ESS*
E_5	$(-,+,-)$	*Unstable*	$(-,+,+)$	*Unstable*	$(-,+,+)$	*Unstable*
E_6	$(+,+,+)$	*Saddle Point*	$(+,+,-)$	*Unstable*	$(+,-,-)$	*Unstable*
E_7	$(-,-,+)$	*Unstable*	$(-,-,+)$	*Unstable*	$(-,-,-)$	*ESS*
E_8	$(+,-,-)$	*Unstable*	$(+,-,-)$	*Unstable*	$(+,-,+)$	*Unstable*

[1] $\eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4 < 0,\ \sigma\alpha + \eta\beta_1 + \eta\lambda_2 - \varphi_4 < 0,\ \sigma\alpha + \eta\beta_1 + \omega + \ \eta\lambda_1 - \varphi_2 > 0.$

[2] $\eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4 > 0,\ \sigma\alpha + \eta\beta_1 + \eta\lambda_2 - \varphi_4 > 0,\ \sigma\alpha + \eta\beta_1 + \omega + \ \eta\lambda_1 - \varphi_2 > 0.$

[3] $\eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4 > 0,\ \sigma\alpha + \eta\beta_1 + \eta\lambda_2 - \varphi_4 > 0,\ \sigma\alpha + \eta\beta_1 + \omega + \ \eta\lambda_1 - \varphi_2 < 0.$

of choosing compensation strategies, the benefits of construction companies choosing the strategies considering the public appeals are greater than the benefits of ignoring the public appeals strategies. Whereas the local government adopts the negotiation strategies, the benefits of the surrounding public choosing the cooperative participation strategies are greater than the benefits of resistant participation strategies.

Next, we try to analyze the stability of each equilibrium point in three cases, as shown in Table 3.

Case 1. When $\eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4 < 0$, $\sigma\alpha + \eta\beta_1 + \eta\lambda_2 - \varphi_4 < 0$, $\sigma\alpha + \eta\beta_1 + \omega + \ \eta\lambda_1 - \varphi_2 > 0$, based on the Table 3, $E_4\,(0,1,1)$ is the only stable equilibrium point of the model.

Accordingly, when the construction enterprises ignore the public appeals, the benefits of the surrounding residents choosing the cooperative participation strategy are less than the benefits of choosing the resistant participation. Meanwhile, when the local government adopts the compensation strategies and the construction enterprises choose the strategies considering the public appeals, the benefits of the surrounding residents choosing the cooperative participation strategy outweigh the benefits of choosing the resistant participation. When the above conditions are met, according to the different initial points of the tripartite strategy selection, the evolution of the strategic combination is stable at the point (negotiation, consideration of public appeals, and cooperative participation).

Case 2. When $\eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4 > 0$, $\sigma\alpha + \eta\beta_1 + \eta\lambda_2 - \varphi_4 > 0$, $\sigma\alpha + \eta\beta_1 + \omega + \ \eta\lambda_1 - \varphi_2 > 0$, based on the Table 3, $E_4\,(0,1,1)$ is the only stable equilibrium point of the model.

In this case, when the construction companies adopt the strategies without consideration of the public appeals, the residents' benefits of the cooperative participation strategy outweigh the benefits of resistant participation. Similarly, when the strategies for compensation and considering the public appeals are adopted by the local government and construction companies, respectively, the benefits of the surrounding residents performing the cooperative

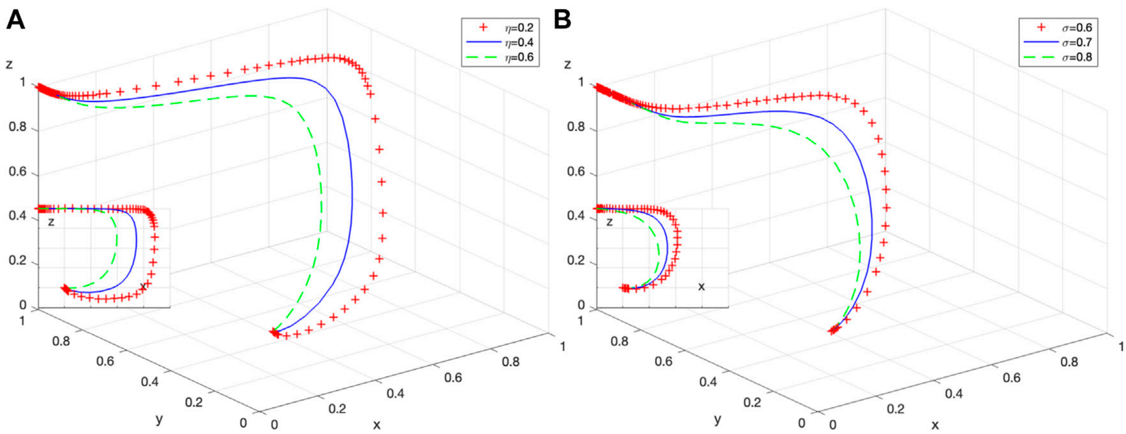

FIGURE 2
(A) Simulation results when $\eta = 0.2, 0.4, 0.6$. Figure 2. **(B)** Simulation results when $\sigma = 0.6, 0.7, 0.8$.

participation strategy outweigh the benefits of choosing the resistant participation. Consistently, when the above conditions are satisfied, the evolution of the strategic combination is stable at the point (negotiation, consideration of public appeals, and cooperative participation).

Case 3. When $\eta\beta_2 - \xi_2 + \eta\lambda_2 - \varphi_4 > 0$, $\sigma\alpha + \eta\beta_1 + \eta\lambda_2 - \varphi_4 > 0$, $\sigma\alpha + \eta\beta_1 + \omega + \eta\lambda_1 - \varphi_2 < 0$, based on the Table 3, $E_4(0,1,1)$ and $E_7(1,1,0)$ are the stable equilibrium point of the model.

Correspondingly, when the construction enterprises adopt the strategies ignoring the public appeals, the benefits of the surrounding public choosing the cooperative participation strategy outweigh the benefits of choosing the resistant participation. In addition, whereas the local government adopts the compensation strategies and the construction companies perform the strategies considering the public appeals, the residents' benefits of the cooperative participation strategy are less than resistant participation. Suppose the above conditions are met, according to the different initial points of the tripartite strategy selection, the evolution of the strategic combination is stable at the first point (negotiation, consideration of public appeals, and cooperative participation) and the second point (compensation, consideration of public appeals, and resistant participation).

4 Numerical simulation

To verify the effectiveness of the model evolution analysis, we made practical assignments to each parameter and used MATLAB R2020a for numerical simulation. Let $\sigma = 0.6$, $\alpha = 100$, $\eta = 0.5$, $\delta_1 = 40$, $\gamma_1 = 60$, $\gamma_2 = 70$, $\nu = 10$, $\vartheta_1 = 20$, $\vartheta_2 = 40$, $\kappa_2 = 20$, $\pi = 50$, $\psi_1 = 0.5$, $\psi_2 = 0.8$, $\beta_1 = 30$, $\beta_2 = 50$, $\xi_2 = 10$, $\omega = 100$, $\lambda_1 = 25$, $\lambda_2 = 45$, $\varphi_1 = 20$, $\varphi_2 = 90$, which met the conditions of Case 1. Then, we analyzed the influence of σ , η, ψ_1, and ψ_2 on the evolution process separately.

Firstly, we analyzed the influence of different resistance levels on the evolutionary game process and results. Let $\eta = 0.2, 0.4, 0.6$, respectively, the number of iterations was set to 50 and the simulation results of replicating the dynamic equations were shown in Figure 2A. Our results displayed that with the increased levels of resistance by the public, the probability of local governments choosing negotiation strategies was elevating.

We next set out to investigate the effects of compensation on the game results, let $\sigma = 0.6, 0.7, 0.8$, the simulation results were shown in Figure 2B. According to the results, as compensation grows, it can accelerate the evolution of the stable choice of cooperative participation by the surrounding public.

Thirdly, let $\psi_1 = 0.1, 0.3, 0.5$ and set the number of iterations to 50, the simulation results were shown in Figure 3A. Meanwhile, let $\psi_2 = 0.8, 0.9, 1$ and as shown in Figure 3B. The results demonstrated that with construction companies reducing their taxation intensity when considering public appeals and increasing their taxation intensity when construction companies ignore public appeals, the rate of evolution for construction enterprises to determine the stable strategy, that is considering the public appeals, would expand. Consequently, the local government should reduce the taxation intensity of construction enterprises when they consider the public appeals and increase the taxation intensity of construction enterprises when they ignore the public appeals, thereby facilitating the determination of the strategy by construction enterprises to consider the public appeals.

For further analysis, let $\sigma = 0.5$, $\alpha = 30$, $\eta = 0.6$, $\delta_1 = 10$, $\gamma_1 = 50$, $\gamma_2 = 70$, $\nu = 20$, $\vartheta_1 = 20$, $\vartheta_2 = 40$, $\kappa_2 = 30$, $\pi = 50$,

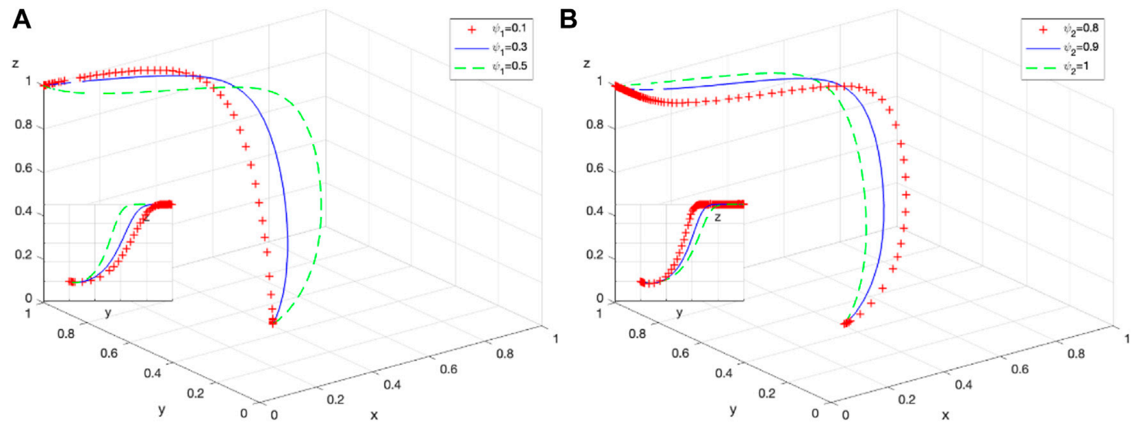

FIGURE 3
(A) Simulation results when $\psi_1 = 0.1,0.30.5$. Figure 3. **(B)** Simulation results when $\psi_2 = 0.8,\ 0.9,\ 1$.

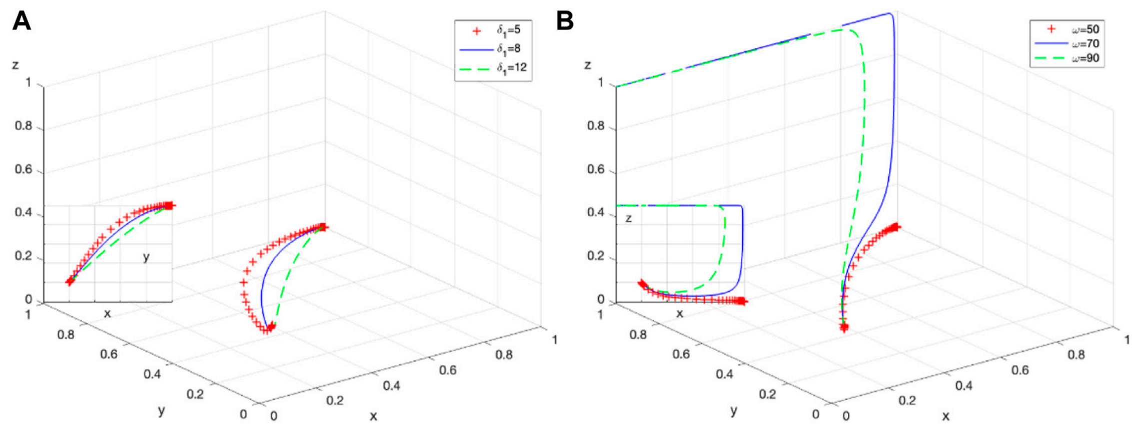

FIGURE 4
(A) Simulation results when $\delta_1 = 5,8,12$. Figure 4. **(B)** Simulation results when $\omega = 50,\ 70,\ 90$.

$\psi_1 = 0.5, \psi_2 = 0.8, \beta_1 = 10, \beta_2 = 70, \xi_2 = 10,\ \omega = 50, \lambda_1 = 48, \lambda_2 = 80,\ \varphi_1 = 105,\ \varphi_2 = 120$, which met the conditions of Case 2.

Based on the Figure 4A, when let $\delta_1 = 5,\ 8,\ 12$, the results showed that with the expansion of the total costs for negotiation, the rate of evolution for the local government to determine the stable negotiation strategy would decline. Thus, the local government should consider how to reduce the costs of negotiation in the game.

Then, when $\omega = 50,\ 70,\ 90$, as shown in Figure 4B, the simulation results revealed that with the growth of the public's extra benefits for cooperative participation, the strategic combination is stable from the sub-optimal point (compensation, consideration of public appeals, and resistant participation) evolved into the most optimal point (negotiation, consideration of public appeals, and cooperative participation). Hence, the local government and the construction enterprises should appropriately increase the public's extra benefits to facilitate the public to participate cooperatively in the NIMBY conflicts while avoiding the occurrence of unfavorable stable points.

Finally, as shown in Figure 5, we started simulating using the two assignments arrays from different strategic points and set the number of iterations to 50. Our results displayed an evolutionarily stable strategy combination in the tripartite evolution system (Figure 5A), which consisted of the negotiation strategy of local government, consideration of public appeals by enterprises, and cooperative participation of

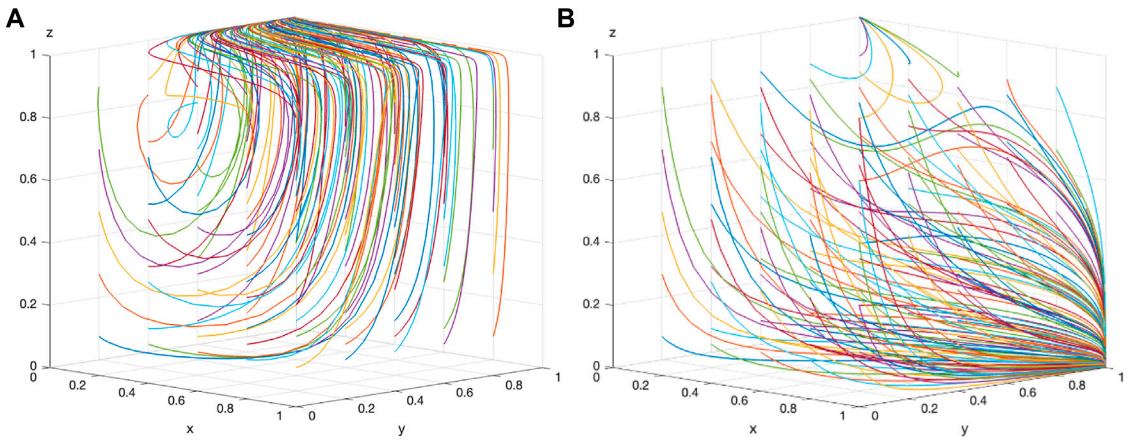

FIGURE 5
(A) The result of 50 simulations of array 1. Figure 5. **(B)** The result of 50 simulations of array 2.

the surrounding residents. Moreover, from the Figure 5B, the evolutionary game model has two stable equilibrium points, the first one is $E_4\,(0, 1, 1)$, which refers to the strategic combination (negotiation, consideration of public appeals, and cooperative participation), and another one is $E_7\,(1, 1, 0)$, which represents the strategic combination (compensation, consideration of public appeals, and resistant participation).

5 Conclusion

Based on evolutionary game theory, this paper constructs a tripartite evolutionary game model of the government, construction enterprises and the surrounding residents, and considers the influence parameters such as the degree of government compensation, the corporate taxation index and the degree of civil resistance. Then, the article focuses on the evolutionary stability of game tripartite strategies under the three scenarios, concluding (government's negotiation strategy, enterprise considering people's requests, people's cooperative participation) as the ideal evolutionary stable strategy. Based on numerical analysis, we conduct further simulation experiments to verify the main factors influencing the evolution of participant behavior strategies, and preliminarily explored the effectiveness of common policy tools in NIMBY conflicts.

5.1 Research conclusion

Firstly, the government should set a reasonable fiscal subsidies and taxation index, to ensure that the sum of profits of enterprises considering the public demands and people's cooperative participation is greater than the sum of profits of enterprises ignoring the public demands and people's opposition of NIMBY facilities, promoting the formation of the ideal evolutionary stable strategy, which is (government's negotiation strategy, enterprise considering people's requests, people's cooperative participation). Secondly, with the improvement of the government's economic compensation to the public, it plays a positive role in promoting the behavior strategy of people's cooperative participation. Furthermore, the total amount of compensation provided by the government and the amount of additional incremental benefits when people choosing cooperative participation are also affecting people's choice of behavioral strategies. At the same time, with the increase of the cost of government negotiation, the evolution speed of the behavioral strategy of people's cooperative participation slows down. Thirdly, the taxation index plays an important role in the choice of enterprise behavior strategy. With the change of taxation index under different behavior strategies of enterprises, that is, reducing the taxation index when considering public demands and increasing the taxation index when ignoring the public demands, the evolution speed of enterprises choosing to consider public demands will increase. Therefore, local governments can actively guide enterprises to consider public appeal strategies by adjusting the taxation index. Moreover, it is also an effective way to improve the probability of enterprises considering public demands by increasing enterprises' additional income and reducing the negotiation cost.

5.2 Policy enlightenment

Collectively, based on our results, we summarized the following policy recommendations. 1) As the main body of supervision for the construction of NIMBY facilities, on the one hand, the government should change corresponding coping methods and governance concepts, and change the concept of "stability maintenance and control" in the traditional governance mode into the concept of "multiple participation" in the consultative governance mode. On the other hand, the government should design diversified compensation schemes, bring the consideration of reducing the cost of negotiation into the policy design process, set up special funds for NIMBY issue, reduce the participation cost of stakeholders, and enhance the enthusiasm of the public for institutionalized participation with financial incentive measures. 2) As the contractor and operator of NIMBY facilities, enterprises must assume the social responsibility of safety maintenance and environmental protection, put public demands first and get rid of the wrong orientation of one-sided pursuit of economic interests. On the one hand, enterprises should establish a conflict coordination mechanism, introduce third-party regulatory agencies, strengthen the integration of corporate responsibility subjects, so as to establish a complete joint regulatory coordination mechanism. On the other hand, the enterprise side should improve the technical level of project selection and construction, and at the same time break down the "information gap", "data barrier" and other problems, so as to ensure the feedback and accessibility of information sharing. 3) As the main undertaker of NIMBY environmental conflicts, the public should, on the one hand, eliminate their own prejudices and thinking patterns, establish an open, compatible and cooperative cognitive attitude, avoid extensive, subjective and emotional participation, and improve their own cognitive concepts and thinking ability. On the other hand, they should express their interests reasonably and legally, improve their governance ability to solve environmental conflicts, and realize the organic unity between people's environmental rights and environmental responsibilities, as well as the effectiveness of procedures and substantive effectiveness.

5.3 Research limitations and future issues

However, there are some limitations and deficiencies we need to acknowledge. First of all, the game model constructed for NIMBY conflicts is not comprehensive enough. Because environmental NIMBY conflict is a complex system with multiple subjects interacting with each other, only studying the three-party game relationship is easy to leads to incomplete research results. Future studies must place non-governmental organizations, social media, experts, and other participants in a unified analytical framework, to analyze the dynamic evolution process of different participants' strategic choices more comprehensively and completely. Secondly, this study has not discussed NIMBY dilemma deeply enough. We attempted to introduce the degree of government compensation, the corporate taxation index and the degree of civil resistance, and discuss the influence of the change in their value range on the behavioral strategies of stakeholders. However, the interfering factors in the actual strategy selection are bound to be more complex, which leads to the limitations of the conclusions drawn in this study. The relevant parameters still need to be further comprehensively investigated on this basis in the future studies, and conducted multi-level comparative studies on different types of NIMBY facilities, to accurately implement classified policies. Thirdly, the selection of research methods needs to be improved. Based on game theory, this study explores the influencing factors and selection mechanism of stakeholder behavioral strategies in environmental NIMBY conflicts, and the research conclusion is only derived from mathematical model analysis. Therefore, more empirical studies and relevant data are needed in the future study. We will conduct further research to address the gaps mentioned above in the future.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

Conceptualization, ZL and SW; Methodology, ZL and SW; Software, ZL and SW; Validation, ZL and SW; Formal Analysis, ZL and SW; Resources, ZL and SW; Data Curation, ZL and SW; Writing-Original draft preparation, ZL and SW; Writing-Review and editing, ZL and MTS; Supervision, ZL and SW; Project Administration, ZL and SW; Funding Acquisition, XL and SW. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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