Complexity Review of NIMBY conflict: Characteristics, Mechanism and Evolution Simulation

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Abstract: Complexity is an essential characteristic of NIMBY systems, and few studies have analyzed NIMBY conflicts using the theory of complex adaptive systems. From the perspective of complexity, this study re-examines the characteristics and evolution mechanism of NIMBY conflicts and draws the following conclusions: (1) NIMBY conflicts are a complex system of interaction between multiple subjects and the environment, characterized by aggregation, Linearity, dynamics, flow characteristics, and hierarchy. (2) Build a stimulus-response model for the evolution mechanism of NIMBY conflicts based on the theory of complex adaptive systems and consider that adaptability is the driving force for the evolution of NIMBY conflicts. The effector promotes NIMBY subjects to gradually adapt to changes in the external environment and maximize their interests. (3) Using Agent simulation technology to simulate the evolution mechanism of NIMBY conflicts, we found that how the government responds to conflicts is more important than the intervention time; Residents' communication efficiency and connection probability will affect residents' behavior choices； The lower the residents' communication efficiency, the less likely it is to form NIMBY conflicts， and stronger resident relations can accelerate residents' convergence to the exit state, affecting the evolution of NIMBY conflicts. This study deepens the understanding of NIMBY conflicts and provides a new reference perspective for the governance of NIMBY conflicts.

Key word: NIMBY conflict; Complex adaptive system; Complexity characteristics; Evolution mechanism; Agent simulation

1. Introduction

With the rapid advancement of urbanization, in order to meet people's "needs for a better life", urban infrastructure construction is increasing. Among them, constructing "NIMBY" facilities can enhance the overall interests of

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society. However, its apparent negative externality has brought direct or potential harm to residents, and the resulting group conflicts occur frequently. From the Meimei substation in Guangdong in 2006 to the PX project in Ningbo, Zhejiang in 2012, and to the Lianyungang nuclear power plant in Jiangsu in 2016, the scale of NIMBY conflicts is increasing day by day, the intensity of confrontation is constantly escalating, and it shows a trend of "normalization"(Wang Dianli et al., 2017), so Some scholars have suggested that China has entered the "Nimy Era"(Wang Kuiming et al., 2014). The occurrence of the NIMBY conflict has aggravated social instability and uncertainty, damaged the government's public image, and endangered the safety of people's lives and properties. Therefore, properly defusing the NIMBY conflict has become an important yardstick for measuring the governance capabilities of urban administrators.

The practical dilemma of the NIMBY conflict has attracted widespread attention from scholars. Since O'Hare introduced the concept of NIMBY into the academic circle, scholars and research institutions from various countries have explored the nature of NIMBY conflict from different disciplines and theoretical perspectives, gradually developing into " Conflict Interpretation" and "Conflict Governance" are two fields of discourse. The former focuses on the causes and evolution mechanism of the NIMBY conflict, while the latter focuses on the governance strategy of the NIMBY conflict.

The interpretation of conflict is undoubtedly the core of scholars' attention because only by following the cause can we propose a targeted and operable governance strategy. For the interpretation of the conflict, scholars generally follow two primary paths: First, starting from the macro-external environment, it is believed that the emergence of NIMBY conflict is subject to the external environment, and it is a clustering behavior induced by the rapid changes in social structure and situational factors. Its representative views include "Social Transformation Theory"(Hu Xiangming et al., 2013; Guan Zaigao, 2010), "Right Awakening Theory"(Wang Dianli et al., 2012; Sun Xuyou, 2016; Xia Zhiqiang et al., 2015), " Network Field Theory"(Yang Yinjuan et al., 2020; Chen Yu et al., 2021). Second, starting from the micro-subject relationship, it is believed that the emergence of NIMBY conflict is the balanced result of the interactive game between the groups involved, and it is the irrational behavior of the group caused by individual rationality. The representative views include "Conflict of Interest Theory"(Hua Qihe, 2014; Hou Guanghui et al., 2014; Meng Wei et al., 2014), "Uneven Risk Distribution Theory"(Hou Guanghui et al., 2015; Zhu Zhengwei et al., 2017; Zhang Haizhu, 2019), "Public Value Failure Theory" (Wu Yuanzhuo et al., 2021; Yu Peng et al.,2019) and "Lack of Trust Theory"(Lu Yangxu et al., 2014; Zhang Le et al., 2013).

Although the existing NIMBY research results have deepened human understanding of the NIMBY phenomenon, the occurrence process of NIMBY conflict and its evolution mechanism, due to the dynamics and uncertainty of the

NIMBY conflict occurrence environment and the complex and changeable conflict process, the conflict results complex and challenging to control. At the same time, the process of conflict involves intricate relationships among multiple stakeholders, which makes the Complexity characteristics of NIMBY conflict particularly prominent. That is to say, the evolution of NIMBY conflict is essentially a complex phenomenon generated by the interaction of micro-subjects within the system in an objective environment. However, the academic community has not yet explored the interaction mechanism between the behavior of various stakeholders in the NIMBY conflict and the macro-environment. Therefore, this paper re-examines the characteristics of NIMBY conflict from the perspective of complex adaptation theory. On this basis, based on the stimulus-response model in complex adaptive system theory, this paper profoundly analyzes the various subjects in NIMBY conflict (mainly residents, government, and related enterprises) and their interaction mechanism with the environment, build a stimulus-response model to explain NIMBY conflict and use Agent simulation method to simulate the evolution process of NIMBY conflict, to provide a new reference for NIMBY governance.

2. Complexity characteristics of NIMBY conflict

With the development of society and the improvement of human cognitive ability, the scale of the system that human beings pay attention to is increasing, and the function and structure of the system are becoming increasingly complex. Therefore, scholars have proposed the concept of a complex system. Since Bertalanffy first proposed the concept of complex systems in 1928, and Qian Xuesen proposed complex giant systems, the development of complex system theory has gone through three generations: from the 1930s to the 1950s, complex systems were called the "Cybernetics Era" New concepts such as information, control, and feedback study the operation of the system, and find that there are universal control laws in the fields of biology and engineering(H. S. Tsien, 2011). The second-generation complex system concept originated from the synergy theory and dissipative structure theory in the 1970s. Scholars began to pay attention to the individual in the system but believed that the individual was static rather than dynamic. That is, the individual lacked goals and directions and could not change their behavior habits through the accumulation of learning and experience(G. Nicolis & I. Prigozine, 1986). In the 1990s, scholars began to pay attention to the interaction between individuals and the environment in the system. They put forward the Complex Adaptive System (CAS) theory, which believes that individuals are not static but dynamic "living bodies" able to actively and dynamically adapt to environmental changes(John H. Holland, 2011). Therefore, Complex Adaptive System Theory provides a reasonable window for interpreting the complexity of NIMBY conflict. Starting from the complex adaptive system theory, the complexity characteristics of NIMBY conflict mainly include the following aspects:

(1) Aggregation. The NIMBY conflict system is a multi-dimensional network structure composed of stakeholders such as residents, government, and related enterprises. At the subject level, each stakeholder is represented as a single node, and at the same time, each single subject node will form a new subject due to incentives such as value and interest convergence and identity recognition. During this process, subjects are not simply gathered mechanically, and the original subject nodes do not disappear, but a new type of higher-level subject nodes appears better to adapt themselves to changes in the living environment. At the aggregation layer, the subject appears as a group composed of a certain number of homogeneous individuals, such as a community alliance composed of residents of anti-NIMBY facilities. Although each resident has different specific cognitions and risk perceptions about NIMBY facilities, residents are not isolated actors. Once stimulated by changes in the external environment (for example, residents are not invited to participate in decision-making during the site selection process of NIMBY facilities), residents will have the same emotions and value appeals and thus gather together to form a new organization, in a more powerful way express group needs. Similarly, the local government and related companies will also form a growth alliance driven by the same interests and form a "political and economic integration of government and business" at a higher level to respond to residents' protests against NIMBY jointly.

(2) Nonlinearity. The evolution process of NIMBY conflict involves multiple stakeholders. There are many correlations among the subjects and among the members within the subject. They interact, influence each other, and restrict each other. A particular behavior or multiple behaviors have intricate nonlinear relationships rather than a simple linear relationship. Openness between subjects and between subject and environment, capable of exchanging information and energy, have a solid ability to actively adapt and adjust their behavior according to changes in the other party or the environment. For the "government-business" growth alliance that supports the construction of NIMBY facilities, residents can gather together to fight against it or choose to compromise. On the contrary, residents pre-emptively unite to oppose the construction of NIMBY facilities, and the government may suspend or even completely stop the construction of related facilities in response to public opinion. However, in the process of stalemate with residents, the government will also ally with enterprises under the lure of the interests of relevant enterprises to form a growth alliance and form an anomie situation of confrontation with residents. It can be seen that the interaction between the subjects of NIMBY conflict has a feedback nature, and the mutual influence between them is connected into a ring, and the input result is returned as the cause, which can actively adapt to each other, rather than a simple, passive, one-way chain of cause and effect. The nonlinear relationship

between subjects is the primary source of NIMBY conflict complexity.

(3) Dynamic. The behavior of stakeholders in the NIMBY conflict is dynamic. The development and changes in the external environment make NIMBY conflict always in the process of dynamic changes. Relevant stakeholders will continue to absorb relevant resources, learn from the behavior of other subjects, and accumulate their own experience according to changes in the external environment to adjust their behavior and improve their organizational structure. For example, residents will adjust their action strategies according to the government's NIMBY facility construction plan, and the government will also make changes to the decision-making model, compensation plan, and even the entire construction plan based on the feedback from residents, thereby promoting the evolution of the entire NIMBY system to a higher level. This characteristic is evident in the evolution of the government's decision-making model in the site selection process for NIMBY facilities and the change in the form of residents' protest organizations.

(4) Flow characteristics. In order to make full and effective use of external and internal information resources (NIMBY facility characteristics, site selection, EIA reports, etc.), it is necessary to exchange information and experience promptly among the various subjects, and the information flow between subjects presents the characteristics of fluidity and multi-directional transmission. During the construction of NIMBY facilities, relevant government departments will publicize the social and economic value of NIMBY facility construction and related compensation information to residents to persuade residents to accept the construction of NIMBY facilities. Due to the asymmetry of information, residents who are information-disadvantaged parties may believe the one-way propaganda of the government and choose to compromise and accept. In contrast, some residents who are sensitive to NIMBY facilities and have substantial information collection and absorption capabilities will use Learn relevant legal knowledge and actively fight, and at the same time, publicize their views to other residents. Therefore, there is a multi-directional flow of knowledge and information among the subjects of NIMBY conflict. In addition, the construction of NIMBY facilities involves a lot of human resources, material resources, and financial resources, so there are also energy flows of human, material, and financial resources in the leading network. Flow is not always there. It appears or disappears according to the suitability of the subject.

(5) Hierarchy. The theory of complex adaptive systems believes that the scale of the system is vast, and it often reflects the characteristics of a hierarchical structure. The main body in the system will form a "self-organized" subsystem layer in a specific environment. The main body in the system will create a "self-organized" subsystem layer within a particular environment(Bao Haijun et al., 2012), and the subsystem layer can be decomposed into several subsystem layers. The subsystems at different levels are connected to each other. NIMBY conflict runs

through different subsystem layers. The conflicts faced by stakeholders at different system layers are the structural emergence of conflicts between subjects at the previous (next) system layer. Still, the sharpness of conflicts at different levels is different. In addition, the diversity of NIMBY conflict subject characteristics, information exchange between subjects, and differences in capabilities enable NIMBY conflict to occur at different system levels of individuals, groups, and organizations. Therefore, the Complexity of NIMBY conflict has the characteristics of multi-structure and multi-level.

3. Stimulus-response model of NIMBY conflict evolution mechanism

3.1 Fundamentals of the stimulus-response model

The American behavioral psychologist Watson first proposed the stimulus-response model to explain the root of human behavior, later used by Professor Holland to describe the adaptability of complex systems, that is, the ability to respond between subjects in a complex system and after interacting with the environment. Since then, the stimulus-response model has become the core mechanism of complex adaptive system theory. The model consists of three elements: detectors, IF/THEN rules (rulers or execution systems), and effectors (see Figure 1). The detector is the organ for the subject to receive external environmental stimuli, representing the ability of the system subject to extract information from the external environment. The IF/THEN rule is the core organ for the subject to process information after receiving information and specifies the rules for the subject to respond based on the information; The effector is the response of the subject, which is used to output the behavior or behavior result of the system subject. The basic principle of the stimulus-response model is that the system's main body senses external environmental stimuli through detectors, classifies and filters the received external environmental information, and then matches with the rule set. The information is processed repeatedly through the rule set to find the optimal matching method, and new matching rules may be activated during the process. The effectors are then activated, i.e., the system subject performs adaptive behavior.

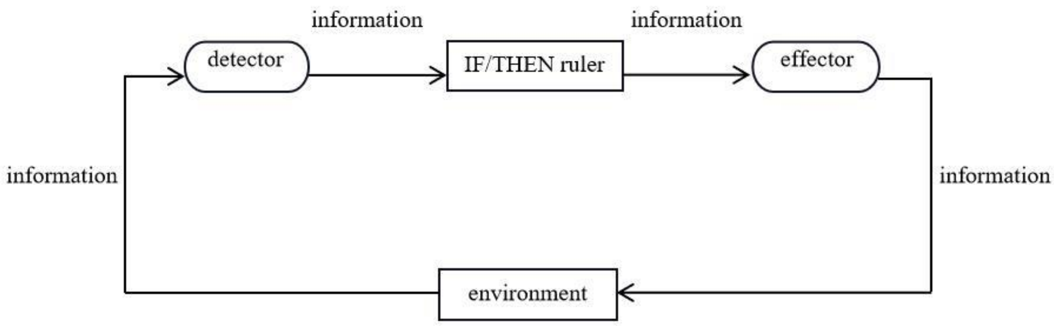

Fig. 1 Stimulus-response model

3.2 Adaptability mechanism of NIMBY conflict system

The core of the stimulus-response model is to explain the adaptability of complex systems. Therefore, when constructing the stimulus-response model of NIMBY conflict, it is necessary first to analyze the adaptive mechanism of the NIMBY conflict system. According to the complex adaptive system theory, the adaptive mechanism of complex systems can be divided into two levels: micro-adaptability and macro-adaptability. Adaptability at the microcosmic level is mainly that the main body of the system constantly "learns" or "accumulates experience" through the interaction between each other and the environment to adjust its behavior and improve the organizational structure. Adaptability at the macro level refers to the interaction between subjects and the environment, which leads to the whole system's evolution (Zeng Zhenxiang et al., 2019). From the reality of NIMBY conflict, combined with the theory of complex adaptive systems, we can consider that NIMBY conflict is essentially a complex adaptive system. Still, it pays more attention to the interaction, mutual influence, and restriction between relevant stakeholders. In fact, the evolution process of the NIMBY conflict is a tripartite game process among residents, government, and related enterprises. They unite or confront each other with the goal of maximizing their respective interests. In the initial stage of site selection or construction of NIMBY facilities, various stakeholders "emerge" into new interest groups at a higher level due to the convergence of values or interests, identity recognition, etc. Afterward, these new groups interact and adapt to each other as well as between the groups and the environment. In the process, each subject adjusts its behavior and organizational structure according to its own "learning" or "accumulated experience" In summary, the adaptability of the micro-subjects in NIMBY conflict creates the Complexity of the macro system of NIMBY conflict.

3.3 stimulus-response model of NIMBY conflict system evolution

AAccording to the stimulus-response model and the adaptive mechanism of the NIMBY conflict system, a stimulus-response model of the NIMBY conflict system evolution is constructed.

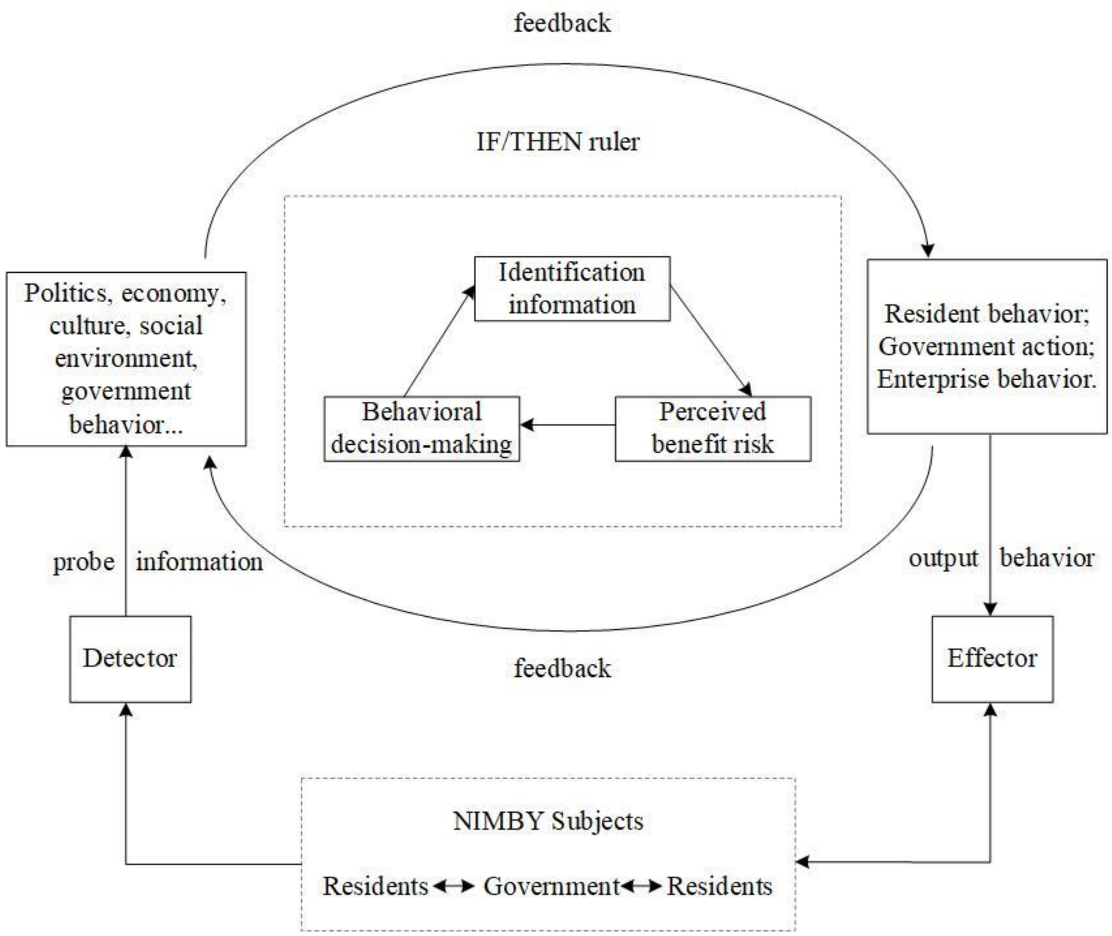

Fig. 2 Stimulus-response model of NIMBY conflict evolution mechanism

(1) Detector. The external environment of the NIMBY project includes the political environment, economic environment, cultural environment, and social environment from the macro level. When the external environment changes, the system subject will perceive various information about the external environment through the detector. But objectively speaking, the macro environment is relatively stable for a period of time, and its change is relatively slow. Therefore, the system subject perceives more environmental changes closely related to a NIMBY project, such as NIMBY project site selection, NIMBY project construction, environmental assessment report, land acquisition compensation, etc. Such information is mainly led and released by the government. At the same time, the change in the macro environment is reflected primarily on the change in government behavior. Therefore, although the government is the subject of interest game in the system, its behavior is also an essential symbol of the external environment of NIMBY conflict.

(2) Ruler. Ruler is an integral part of the stimulus-response model and a way for the system subject to screen information-matching behavior. Combined with the reality of NIMBY conflict, it mainly includes the following

steps: first, information recognition. NIMBY system subject will further filter and classify the information obtained from the detector, eliminate redundant information, and identify information highly related to its interests; Secondly, interest risk perception. Interest is the root of the behavior of the system subject. The essence of NIMBY project construction is the redistribution of interests and risks. Therefore, according to its information, the system subject will perceive and evaluate the interests and risks brought about by the NIMBY project construction. The community alliance dominated by residents and the government-led growth alliance in the NIMBY system often have different interpretations of NIMBY's risks and interests; Once again, the system subject will choose to adopt individual or group behavior according to the perceived benefits and risks. When individual behavior is difficult to maintain their reasonable interests, the system subject will "glue" with individuals whose values and interests appeal to converge.

(3) Effectors. Effectors are behaviors or behavior results made by system subjects. The NIMBY system subject performs various behaviors after matching with the ruler through its perception of the external environment. Suppose some residents find that the government has not followed the legal procedures in the NIMBY project site selection process. In that case, they will invite residents to participate in the hearing and ask for their opinions. They will immediately inform other residents around to rally against the illegal operation of the government and even petition. Under the pressure type system, the government is greatly influenced by superiors and public opinion. If the government suffers tremendous pressure from superiors and public opinion due to residents' petitions, the government will appease and guide the residents and suspend, delay or stop the construction of the NIMBY project; Relevant enterprises will also adjust their own behavior according to the environment and the behavior changes of other subjects.

In general, the stimulus-response model evolved by NIMBY conflict is a cycle process of continuous optimization. Through "stimulus-screening-matching-reaction-viewing- optimization," the system subject is gradually adapted to changes in the external environment to maximize its interests (see Figure 2).

4. Construction of Agent evolution simulation model of NIMBY conflict

4.1 Simulation method

Traditional research methods are challenging to apply when studying complex systems, and modeling and simulation provide a new way to solve these problems. The simulation adopts a top-down integrated approach. That is, by observing the complex system, in reality, we can abstract the simple rules that individuals follow, simulate the interaction between individuals in the computer, and observe their emerging macro behavior to explain and understand the complex phenomena of the system. Currently, there are many methods of social simulation, such as system dynamics, micro-simulation, permutation model, multi-layer simulation, cellular automata, agent simulation, etc. Among them, Agent simulation has become a meaningful way to study complex social phenomena by constructing artificial societies for computing experiments(Li Dayu et al., 2011). This research uses the Q-learning algorithm in Agent simulation to simulate the evolution process of NIMBY conflict.

Q-learning is a common reinforcement learning method (also known as incentive learning), often used in discrete and small-scale research(Qin Xuan et al., 2021). There are three core elements: State, Action, and Reward. The core idea of the algorithm is that the agent will take some action under a certain state at a certain time, and the environment will give feedback on the corresponding Reward according to the agent's behavior. Q (Quality) is a Q-table matrix composed of State and Action, which is used to store Q values and represent the rewards obtained by the agent when taking actions in a certain state. The agent will choose the corresponding behavior according to the size of the Q value and optimize its behavior through continuous learning and accumulation of experience to achieve the purpose of obtaining maximum benefits. The iteration of the Q value follows the Bellman equation:

$$Q'(s,a) = Q(s,a) + \alpha[R(s,a) + \gamma maxQ(s',a') - Q(a,a0] \qquad (1)$$

In the equation, $Q(s,a)$ and $R(s,a)$ respectively represent the expected reward and current reward obtained by the agent when it takes a actions in s states, $Q(s',a')$ represents the expected reward obtained by the agent when it takes a' actions in the next state s', $\alpha \in [0,1]$ represents the learning rate of the agent, and α is larger, indicating that the faster the agent updates information, the less it retains previous training experience; $\gamma \in [0,1]$ is the discount factor. The larger the γ is, the more long-term benefits are considered by the agent. On the contrary, the more immediate benefits are concerned. In the initial state, all Q values in Q-table are 0. At the same time, in order to avoid the possible local optimal solution, it is also necessary to assume that the intelligent experience will explore the unknown new strategy and use the exploration results for more effective iteration, that is, use the exploration/utilization strategy(Chao Y et al, 2016), expressed by the exploration rate of ε. In the process of reinforcement learning, the intelligent experience explores the optimal strategy in the previous experience with a probability of ε, and conducts new exploration with a probability of 1-ε.

In the process of Q-learning reinforcement learning, agents take certain actions after observing the environment, constantly learn and iterate their actions based on the feedback and return of the environment to achieve the goal of maximizing benefits. Although the NIMBY conflict involves three subjects: residents, government, and related enterprises, the evolution process of the NIMBY conflict is mainly the conflict between the community alliance dominated by residents and the government-led growth alliance. Residents will take action according to the government's behavior and take further action according to the government's feedback transformation strategy. Therefore, in this study, residents are regarded as agents. The government is regarded as the real environment of agents. In combination with reality, the government's main goal of NIMBY governance is to conduct risk management and control. It is hoped that the residents can understand the social and economic benefits of NIMBY projects and then withdraw from NIMBY's resistance behavior. The goal of the residents is to maximize their interests.

4.2 Residents' Behavior Strategies and Evolution in the Evolution of NIMBY Conflict

During the evolution of the NIMBY conflict, according to different environments, conditions, and conflict stages, residents may take four actions: Wait, Appeal, Fight, or Exit. In the initial state, it is assumed that residents will choose to be waiters, petitioners, or protesters according to their perception of the interests and risks of the NIMBY project. When residents think that the construction of the NIMBY project can not only promote local economic and social development but also improve the overall social benefits, their perception of the project benefits is greater than the project risk perception, and these residents will not participate in NIMBY group events from the beginning; When residents think that the negative externalities of a NIMBY project not only cause harm to the ecological environment, but also endanger the health of residents and even the long-term development of their children, or are harmed by other rights, the perceived project risks of residents are more significant than the project benefits, and this part of the residents will appeal and fight; there are also some residents who do not have a clear perception of the risks and benefits of the NIMBY project and will adopt a wait-and-see strategy.

The change in residents' behavior is a sign of NIMBY conflict evolution. According to the theory of the Complex adaptive system, the behavior change of the system subject results from interaction with other subjects and the environment. Therefore, the learning interaction among residents and the government feedback as the environmental representation are two significant factors that induce the change in residents' behavior. Individual residents conduct interactive learning through communication networks. After receiving feedback from the government, residents will measure the cost and benefit of their behavior to choose whether to change strategies and behaviors. Maslow believes that rational people have five levels of basic needs and show a trend of increasing demand intensity. When a level of demand has not been met, rational people will not change their needs and reduce to a lower level of demand(Hu Wanzhong, 2000). The intensity of demand for watching, demanding, and fighting is increasing, so residents will not reduce their own needs and return to a lower level of demand. However, it should be pointed out that the particular situation of the petitioner in the state of appeal: Typically, claimants drop out because their demands are met or join protests when their demands are not met as expected, but when the appeal of the petitioner is low, it may return to the state of observation. However, no matter the initial residents, they will eventually converge to the exit state because NIMBY group events will always end. Therefore, there are eight possible behavior change paths for residents (as shown in Table 1).

Table 1 Evolution Path of Residents' Behavior in the Evolution of NIMBY Conflict

SN	Behavior Change Path
Path 1	Wait - Exit
Path 2	Wait - Appeal - Exit
Path 3	Wait - Fight - Exit
Path 4	Wait - Appeal - Fight - Exit
Path 5	Appeal - Exit
Path 6	Appeal - Fight - Exit
Path 7	Appeal - Wait... Exit
Path 8	Fight - Exit

In the initial state, it is assumed that the residents are in the three states of wait, appeal, and Fight with the same probability. The state space set is S ($s = \{\text{wait}, \text{appeal}, \text{fight}\}$), the optional behavior set is A ($a = \{\text{wait}, \text{appeal}, \text{fight}\}$), and the ultimate goal is to exit. The objective function is $Argmax\{Q(s,a)|s \in S, a \in A\}$, that is, the intelligent experience selects the behavior set with the largest Q value. The agent's strategy selection follows the following equation:

$$\pi(s) = \begin{cases} Argmax[Q(s,a)], if \varepsilon \leq 1-\varepsilon \\ a_{random,} otherwise \end{cases} \qquad (2)$$

In formula (2), ε is the exploration rate, and a_{random} is the random action in the current behavior set.

4.3 Environment settings during NIMBY conflict evolution

The interaction between the subject and environment in complex systems is an important factor affecting system evolution. This study characterizes government feedback as the external environment of the NIMBY system. According to reinforcement learning, the government determines the return R value of residents through feedback, thus affecting the behavior change of residents. In NIMBY conflict, the government's feedback mainly refers to the government's ability to respond to conflict events. Therefore, the R value is determined by the government's ability to respond to conflicts. The government's conflict response capability is mainly related to its response method and response intervention time(Chao Y et al., 2016), which means the government's conflict response capability is a function of the response method and response intervention time. See Formula (3) and (4) for details:

$$R = f(Method, Time) \qquad (3)$$

$$\left\{\frac{R(s,a)=u_1\times Method_S^R+u_2\times Time^R}{u_1+u_2}\right. \qquad (4)$$

In formula (4), u_1 and u_2 respectively represent the weight of the coping style and time in the government's conflict response capability, and the weight is determined by taking a positive integer at random. $Method_S^R$ represents the return R obtained by different coping styles in the state S, and $Time^R$ represents the R value obtained by different coping interventions.

Faced with the NIMBY cluster behavior of residents, the government can often effectively guide citizens' behavior and resolve conflicts by adopting the correct response. In this study, the government's coping styles are divided into good, general and poor, as shown in Formula (5). The government's different coping styles will affect the residents' perception of the benefits and risks of the NIMBY project, thus affecting the residents' behavior change. The government will give different positive feedback (negative value) or negative feedback (positive value) according to the behavior of agents (residents). Residents will try to focus on any kind of behavior and gradually maximize their benefits through continuous learning and accumulated experience to strengthen learning. Positive feedback does not mean encouraging this kind of behavior but guiding residents to exit the state as soon as possible and end the conflict. Therefore, if the government responds better to residents in a certain state, the return value R of the better response is set to a negative value. It shows that the government's conflict response method has played a role, can better guide residents' behavior, and reduce the frequency of residents' transfer to this behavior.

$$R_{Method} = \begin{cases} -1, \text{Good way, effectively guide} \\ 0, \text{General way, passive neglect} \\ 1, \text{Poor way, forced suppression} \end{cases} \qquad (5)$$

The intervention time of conflict response is the time choice for the government to intervene in the NIMBY cluster process. Suppose the government can intervene as early as possible in the initial stage of the NIMBY project site selection or construction, actively communicate and understand residents' reasonable demands, and resolve residents' fears and doubts about the NIMBY project. In that case, it may effectively prevent residents' NIMBY complex from evolving into NIMBY conflict. Assuming that the evolution time of NIMBY conflict from germination to outbreak is T, the three-way time node is taken as the government's response intervention time. The setting principle of the R value is the same as above, as shown in Formula (6):

$$R_{Time} = \begin{cases} -1, Early\ intervention, & 0\sim\frac{T}{3} \\ 0, Intermediate\ intervention, & \frac{T}{3}\sim\frac{2T}{3} \\ 1, Late\ intervention, & \frac{2T}{3}\sim T \end{cases} \quad (6)$$

5. Analysis of agent evolution simulation results of NIMBY conflict

5.1 Experimental simulation

The research uses MATLAB software to program and simulate the complex evolutionary process of the NIMBY system. The specific steps are as follows:

Step 1: initialize the value. In addition to the feedback from the external environment, individual residents' learning is based on their own experience or communication between individuals. The network structure among residents has an essential impact on residents' learning, so it is necessary to set the network structure among residents. As a topological structure, the small world network can better reflect the real interpersonal network(Chen B et al., 2018), so this study uses the small world network to simulate communication among residents. Each node in the small world network represents a resident, and each resident has the right to choose behavior freely and can choose any behavior in the behavior set A. The connection between nodes indicates the interaction between residents, that is, the communication and exchange among residents, which determines the efficiency of information transmission among residents. In this study, the average communication efficiency and relationship strength are used to express the mutual learning among residents, that is, the information transmission efficiency (Formula 7). The relationship strength is expressed by the random connection rate P, p∈ [0~0.1], the larger the p value is, the more closely the individuals in the network node are connected. The average communication efficiency is expressed by e, e∈ [0~1], and the larger the e value is, the more successful the individuals in the network node can transfer information to another individual.

Small world network information transmission efficiency=random connection rate * average communication efficiency * total number of people (7)

The research assumes that the number of residents of agent in NIMBY system is 900, the learning and communication follow the rules of small world network, and the initial state is set as 300 waiters, 300 petitioners and 300 protesters respectively. The values are shown in Table 2.

Table 2 NIMBY conflict evolution simulation initialization parameters

Category	Parameter	Value	Meaning

Small World Network	N	900	Total number of residents
	K	30	Initial average number of connections
	e	0.1	Average communication efficiency
	p	0.01	Random connection rate
Q-learning	α	0.1	Learning rate
	γ	0.8	Discount factor
	ε	0.1	Exploration rate
	R_{Method}	-1	Government response
	R_{Time}	1	Government response time

Step 2: Agent reinforcement learning process. In the evolution process of the entire NIMBY conflict system, residents make iterative behavior choices and change through individual exchanges and government feedback.

Step 3: Adjust the parameters. Observe the influence of different parameter settings on NIMBY conflict evolution.

5.2 Result analysis

5.2.1 The government's conflict response capability (when e=0.1, p=0.01)

First of all, it is assumed that the government intervened in NIMBY conflict late, but took a better response to actively guide the residents, that is, $R_{Method} = -1$, $R_{Time} = 1$. The change in the number of people in each state after 100 simulation iterations is shown in Figure 3. At the initial stage of NIMBY project site selection or construction, the government did not intervene in time to resolve NIMBY risks. As a result, residents in a wait state quickly chose to fight. The number of protesters increased, and the number of quitters was almost zero. Then increase the number of iterations to 1000, and the number of people in each state changes, as shown in Figure 4. It can be seen from Figure 4 that the number of people in all states changed dramatically when the number of iterations reached about 750. The number of quitters increased sharply, while the number of waiters, petitioners, and protesters decreased rapidly, especially the number of protesters. The results show that the government has realized that the mass behavior of the people has reached a severe state and can respond to the dissatisfaction of the people in a better way.

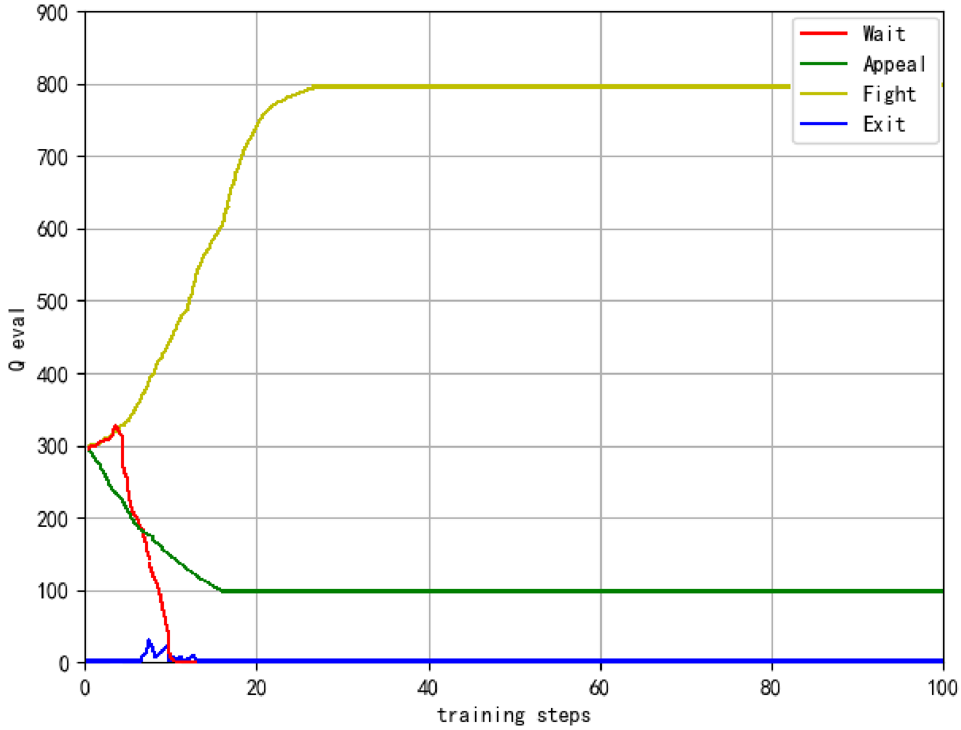

Fig. 3 $R_{Method} = -1$, $R_{Time} = 1$After 100 iterations, the number of people changes

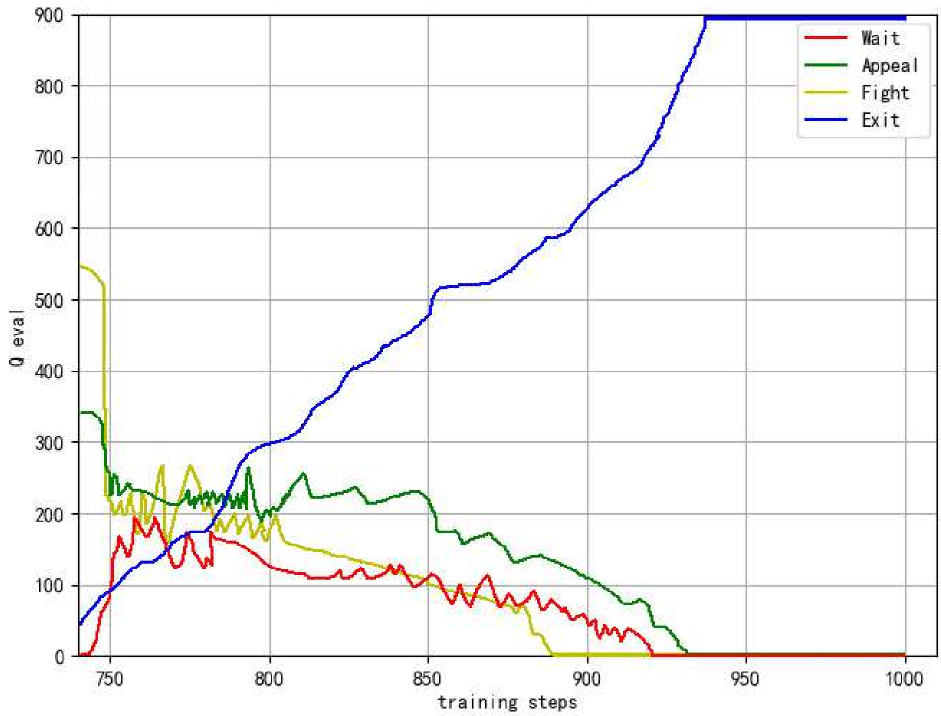

Fig. 4 $R_{Method} = -1$, $R_{Time} = 1$After 1000 iterations, the number of people changes

Change the response time of government conflict, and assume that the government can actively respond to NIMBY conflict in its infancy. The experimental simulation results are shown in Figure 5. By comparing Figures 4 and 5, it can be found that if the government intervened in the NIMBY conflict late and took a better response, the number of waiters, petitioners and protesters began to change after about 750 iterations, and the public gradually withdrew; However, if the government responds to the intervention early, the residents will exit at a fast rate after about 300 iterations. The above results show that in the evolution process of NIMBY conflict, the earlier the government starts to respond, the sooner residents can converge to exit.

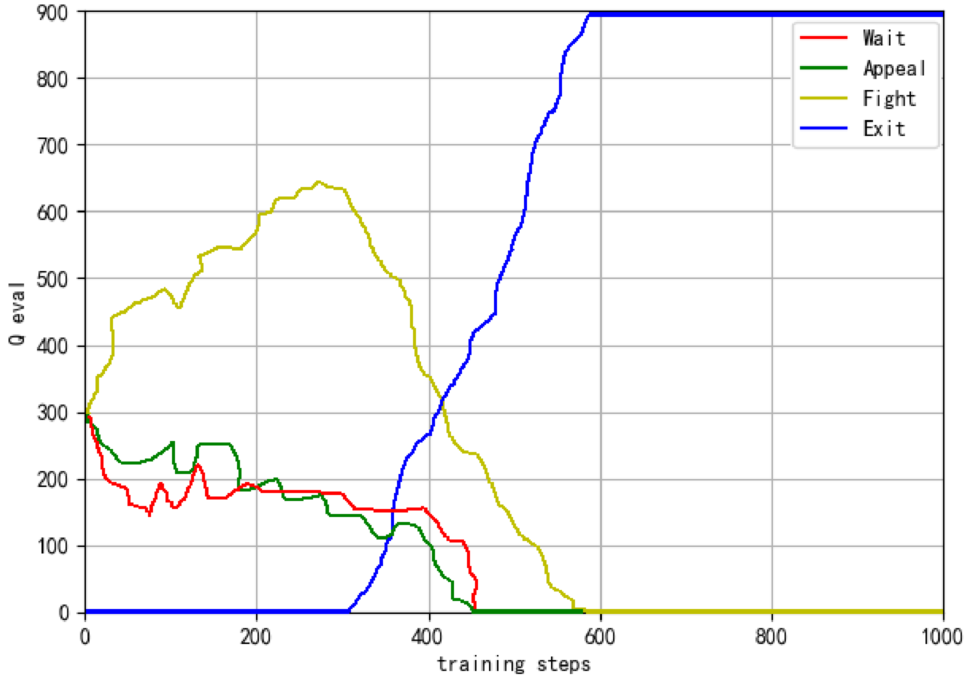

Fig. 5 $R_{Method} = -1$, $R_{Time} = -1$After 1000 iterations, the number of people changes

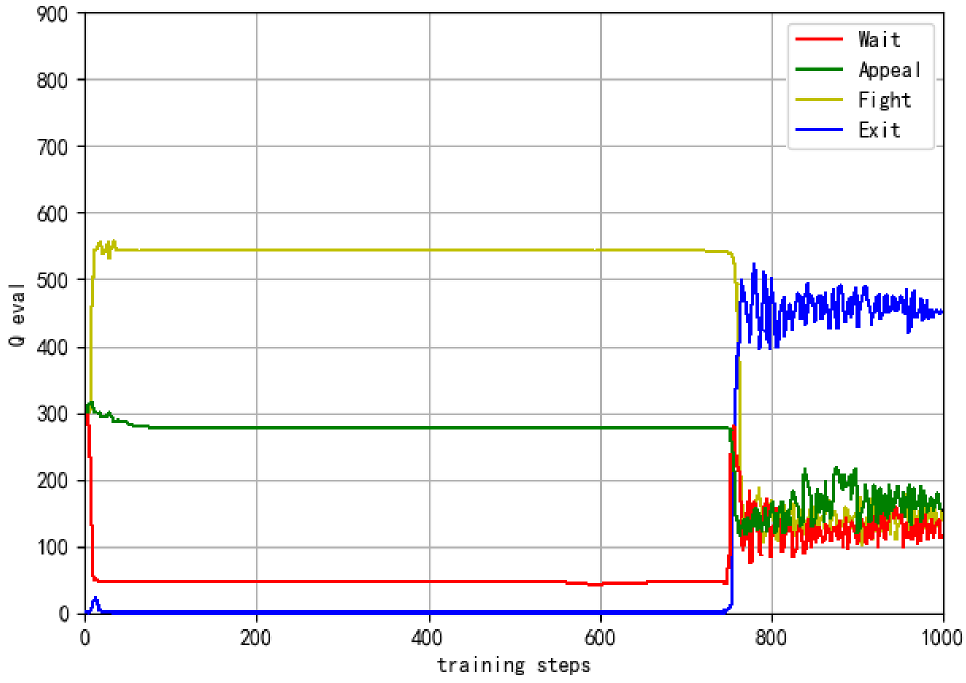

Fig. 6 $R_{Method} = 1$, $R_{Time} = -1$After 1000 iterations, the number of people changes

Next, change the government's conflict response style. The government adopts a poor response style, namely $R_{Method} = 1$, $R_{Time} = -1$. It can be seen from the comparison between Figure 5 and Figure 6 that the government's conflict response style will also change the convergence process. If the government does not adopt a better response style, even if the response time is earlier, the governance effect of the NIMBY conflict will be difficult to achieve the desired goal. As shown in Figure 4, if the government can intervene in the NIMBY conflict at an early stage and adopt appropriate handling methods when the number of iterations reaches about 300, the number of quitters will show a sharp increase, and the number of protesters will also decline rapidly. According to the observation of Figure 6, although the government started to intervene in the NIMBY conflict earlier, it did not take the appropriate response, which did not ease the residents' panic about the NIMBY project, but further exacerbated the contradiction between the residents and the government, leading to the rapid growth of the number of protesters at the beginning, and led to a large number of waiters to join the ranks of petitioners or protesters. When the number of iterations reaches about 750, the number of petitioners and protesters starts to drop sharply, while the number of quitters shows a trend of sharp increase. The change in the number of people fighting may be due to a long time of fighting, and some residents choose to compromise, or they may choose to quit because their emotions have been soothed in the process of fighting. Therefore, in the evolution of NIMBY conflict, the way of conflict response is more critical for the government's conflict response capability than the time of conflict response intervention.

5.2.2 Communication between individuals (when $R_{Method} = -1$, $R_{Time} = -1$)

Assuming that the communication between residents is invalid and the communication efficiency is 0, which means when e=0.1 and p=0.01, the changing trend of the number of people in each state is shown in Figure 7. When communication between individual residents fails, they are isolated from each other. Individual residents can only make behavioral changes based on the benefits obtained from government feedback. Through the observation of curve changes, it can be found that the number of waiters has shown a trend of first rising and then declining over time, which may be due to the fact that some of the petitioners in the state of appeal have turned from appeals to wait due to their low appeals; The number of protesters increased slightly at the beginning, then decreased rapidly under certain fluctuations, and then decreased slowly; The number of quitters did not change significantly in the initial state, but after that, although the number of quitters fluctuated to a certain extent, it still showed a sudden rise. It can be seen that when communication among residents is ineffective, it is challenging to form NIMBY cluster behavior and NIMBY conflict breaks out.

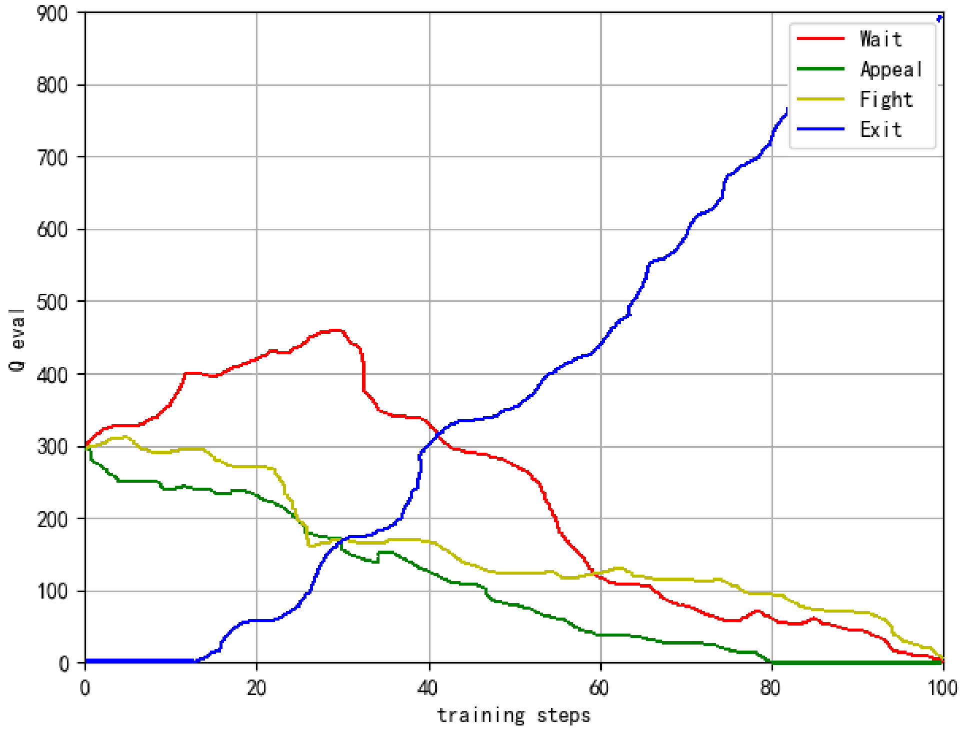

Fig. 7 $R_{Method} = -1$, $R_{Time} = -1$; e = 0.1, p = 0.01, the number of people changes

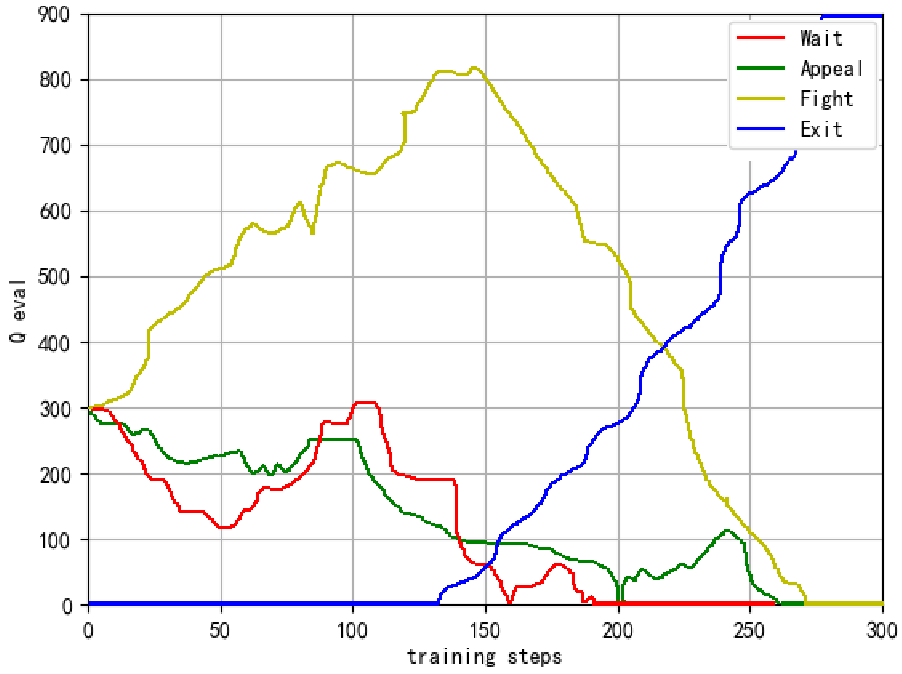

Fig. 8 $R_{Method} = -1$, $R_{Time} = -1$; $e = 0.1$, $p = 0.08$, the number of people changes.

When the communication efficiency between residents is set as e=0.1, and the random connection rate is set as p=0.01 and p=0.08, respectively, the changing trend of the number of people in each state is shown in Figure 5 and Figure 8. Through the observation and comparison of the two images, it can be found that when p=0.01, the residents begin to withdraw gradually after about 300 iterations, and the public is basically in an exit state after 300 iterations; When p=0.08, after 130 iterations, the number of residents in the exit state starts to increase, and after about 135 iterations, the number of residents is basically in the exit state. Therefore, it can be seen that a strong resident relationship can accelerate the convergence of residents to the exit state.

When the connection probability between residents is set as p=0.01, and the residents' communication efficiency is set as e=0.1 and e=0.8, respectively, the changing trend of the number of people in each state is shown in Figure 5 and Figure 9. It can be found that lower residents' communication efficiency will reduce the number of petitioners and protesters. Due to ineffective communication among residents, individuals are isolated from each other, and it is challenging to form large-scale group appeals. The number of petitioners shows a downward trend, while the peak number of protesters is less than 650 (see Figure 5). When the communication efficiency among residents is improved, the residents can successfully transmit information, so the change rate of residents' behavior is also fast (see Figure 9).

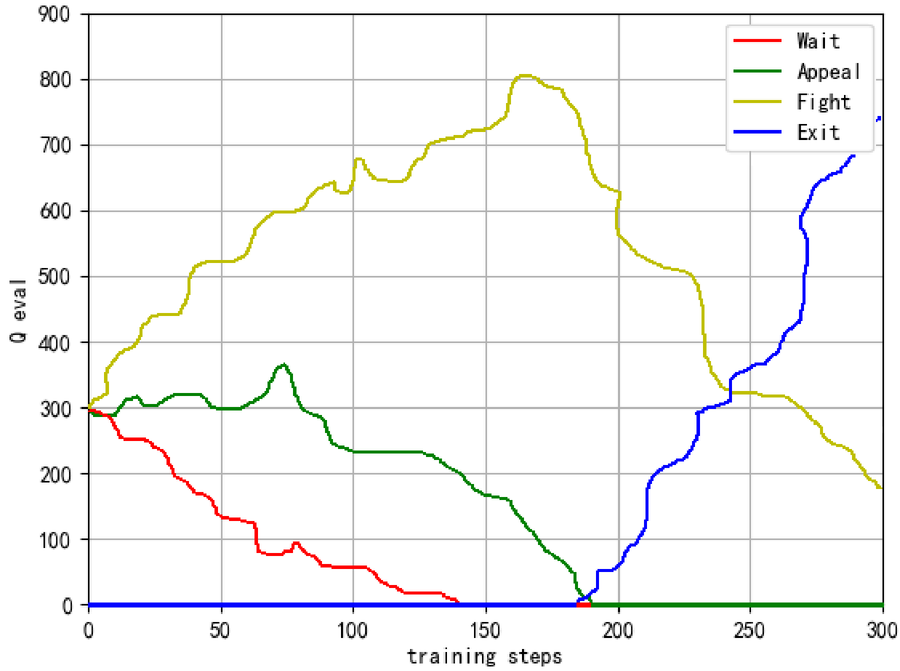

Fig. 9 $R_{Method} = -1$, $R_{Time} = -1$; e = 0.8, p = 0.01, the number of people changes

It can be seen from this that when the communication efficiency among residents is low, it is difficult for individuals to carry out effective information transmission and communication is not smooth. At this time, even though residents have many dissatisfactions with the NIMBY project and become appealers or even protesters, it is challenging to form group strength due to mutual isolation, and individual strength is very weak, which will cause residents to change to a withdrawal state quickly. However, with the arrival of the significant data era, the speed and frequency of information exchange have been growing unprecedentedly. It is easy for residents to aggregate NIMBY projects on the network and then evolve into offline NIMBY conflict. Therefore, to block the formation of NIMBY conflict, it is necessary to strengthen the conflict response capability of the Complex adaptive system.

6. Conclusion and discussion

The construction of public infrastructure in the process of urbanization has improved the quality of life of residents. However, NIMBY projects are also prone to lead to NIMBY group events due to their specific negative externalities. Complexity is an important characteristic of NIMBY projects. Although current scholars' research has deepened human understanding of the phenomenon of NIMBY, they often ignore its complexity. Few studies use complex adaptive system theory to analyze the NIMBY conflict. From the perspective of complexity, this study re-examines the characteristics and evolution mechanism of NIMBY conflict and draws the following conclusions:

First, NIMBY conflict is a complex system with multiple subjects and interactions with the environment, characterized by aggregation, nonlinearity, dynamics, flow characteristics, and hierarchy. Secondly, a stimulus-response model of the evolution mechanism of NIMBY conflict is constructed based on the complex adaptive system theory. Adaptability is considered the driving force for the evolution of the NIMBY conflict. Through detectors, rulers, and effectors, the NIMBY subjects gradually adapted to external environmental changes to maximize their interests. Finally, using Agent simulation technology to simulate the evolution mechanism of NIMBY conflict. The results show that: in NIMBY conflict, the government conflict response method is more important than the intervention time; Residents' communication efficiency and connection probability will affect residents' behavior choices. The lower the residents' communication efficiency, the less likely it is to form NIMBY conflict. Stronger resident relations can accelerate residents' convergence to the exit state, which in turn affects the evolution of the NIMBY conflict.

This study is the first attempt to analyze NIMBY conflict from the perspective of complexity and uses simulation technology to simulate, which can deepen the knowledge and understanding of the NIMBY phenomenon and evolution mechanism. Nevertheless, there are also certain limitations. For example, in Agent simulation, only government behavior is used to represent the external environment, ignoring the impact of other external environments, such as network public opinion, opinions of experts and scholars, etc. The simulation model can be further improved in future research.

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Author's Contribution

The paper, ”Complexity Review of NIMBY conflict: Characteristics, Mechanism and Evolution Simulation” ,was co-authored by Cui Luxin, Chen Yu, Wang Xing, and Liu ShiYu. Among them, Cui Luxin and Liu Shiyu completed the writing of the background, review, research framework and conclusion of the article, and were responsible for the translation; Chen Yu and Wang Xing were mainly responsible for the writing of the simulation test. These authors contributed to the work equally and should be regarded as co-first authors.

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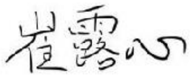

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Data Availability Statement

All the data and conclusions used in the paper "Complexity Review of NIMBY conflict: Characteristics, Mechanism and Evolution Simulation" are authentic and reliable.

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