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Evolution of residents' cooperative behavior in neighborhood renewal: An agent-based computational approach

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ABSTRACT

The cooperative behavior of residents is complex and influenced by their complicated social relationships. This complexity is especially noticeable in neighborhood renewal, so the government does not know how to promote residents' cooperative behavior. Therefore, this study proposes an agent-based model (ABM) to investigate the development of residents' cooperative behavior in neighborhood renewal. Based on a questionnaire survey among residents of old neighborhoods in China, the parameters of ABM were determined in this study. Then, controlled experiments were conducted to investigate the effects of general trust among residents and government control of neighborhood renewal on cooperation patterns in renewal projects. In addition, this study examines the effects of different types of social network structures (small-world, scale-free, and random networks) on the evolution of residents' cooperative behaviors. The simulation results show that when residents' initial willingness to agree to renewal projects is high, their close social relationships need to be managed by the government to achieve better outcomes. Conversely, if initial willingness is low, residents' close relationships may pose a challenge to the government. In addition, government-led renewal projects should be encouraged to a greater extent. This study confirms that the different social network structures have an influence on the development of residents' cooperative behavior. The results of this study provide concrete evidence for understanding the factors that contribute to the emergence of residents' cooperative behavior and for studying the effects of government intervention on neighborhood renewal projects. In addition, the results of this study provide theoretical support for future studies of residents' social network structures.

1. Introduction

Neighborhood renewal is an essential strategic approach to improving and rehabilitating urban decay at the microscopic scale of urban renewal (Du, Fertner, Jiang, Andersen, & Vejre, 2023; Liu, Xinyue, Zhuang, Huang, & Hongjuan, 2022). Like other countries, the Chinese government is vigorously promoting neighborhood renewal (Liu, Xinyue, Han, Huang, & Zhuang, 2021; Tang, Gong, & Liu, 2022). In 2022 alone, China launched >52,500 projects to revitalize and renew old neighborhoods, benefiting 8.76 million households (Liao, 2023). In other words, neighborhood renewal has become a necessary approach to sustainable urban development in China (Zhu, Li, & Jiang, 2020).

However, the success of these renewal projects is often limited by the complexity of social relationships among residents of old neighborhoods in China. This complexity is first reflected in the interactions between residents' relationships and interests. In China, strong social relationships are crucial to getting things done, and a lack of them can lead to various difficulties in daily life and work (Chang, 2012). Therefore, a Chinese proverb states, 'A distant relative is not as good as a near neighbor (Ye & Chen, 2020).' Striving for a peaceful and stable coexistence with one's neighbors is thus a guiding principle for Chinese residents, as it lays the foundation for a harmonious future living environment. This cultural context also influences residents' cooperative behavior in neighborhood renewal. Residents determine their cooperative behavior based on whether they believe it will affect their relationships with their neighbors. Neighbors' opinions may affect their cooperative behavior in this situation (Scheller, 2015). In addition, residents who engage in similar behaviors tend to form homogeneous groups that strengthen their social relationships (Hua, Dong, & Goodman, 2021). As neighborhood renewal projects progress, residents'

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cooperative behaviors shift from individual to group competition. In this interdependent relationship, personal behavior is no longer determined only by individual desires but is also influenced by internal interests and group behavior. Second, it is difficult to measure the relationships among residents. As Zhang, Weiping, Zhong, Zeng, and Wang (2017) found during data collection, residents were unwilling to disclose complete and detailed personal information because of privacy invasion concerns and resistance to renewal projects. In this situation, it is difficult for researchers to determine residents' positions in a neighborhood's social network. Upon retrospective examination of prior research on social network analysis pertaining to residents or neighborhoods, it is apparent that the majority of studies have employed certain influential factors (Yu et al., 2017; Zhang, Wang, Wang, & Luo, 2023) or representatives of stakeholders as nodes within the social network (Wang, Yao, Zhang, & Xiang, 2022; Zhuang, Qian, Visscher, Elsinga, & Wendong, 2019). While certain investigations have conducted analysis on social networks, a limited proportion of studies have specifically constructed social networks of residents, with sample sizes primarily constrained to specific neighborhoods (Alexandrescu, Rizzo, Pizzol, Critto, & Marcomini, 2016; Du et al., 2023). Most studies on social network modeling focus on analyzing the real-world phenomenon, rather than examining whether the social network reflects the detailed situation of information exchange and social interaction among residents. To date, no research has yet proposed a comprehensive methodology for the developing of a social network of residents with detailed information, where residents are described as nodes and their relationships are described as edges. Furthermore, inadequate description of the intricacies of residents' social networks impedes their application in practical settings, thereby limiting their utility to grassroots government. In addition, existing research has demonstrated the influence of relationships on behavior (Umberson, Crosnoe, & Reczek, 2010; Videras, Owen, Conover, & Stephen, 2012). For governments, the impact of resident relationships on their behavior and the difficulty in measuring resident relationship networks have led to complexity in promoting cooperative behavior among residents. As a result, the intricacy of measuring resident relationships, coupled with the complexity of relationships among residents and their mutual influence on cooperation in renewal projects contribute to the complexity of social networks among residents in neighborhood renewal. The resulting complexity makes it difficult for governments to effectively implement renewal projects. It is uncertain what results the government will achieve in predicting the outcomes of its policies and actions within residents' networks. In China, grassroots governments typically need to govern multiple residential communities. Therefore, it is uncertain for the government whether the same policy will have the same expected cooperative effect on multiple renewal projects. In summary, the intricate nature of residents' social relationships has resulted in the government's limited understanding of how to manage neighborhood renewal projects effectively.

This study hypothesizes that the above problems stem from the shortcomings of top-down research methods traditionally used to study neighborhood renewal and community governance, as these approaches struggle to decipher the intricacies of residents' social networks. As Jin and White (2012) have pointed out, traditional research methods, such as aggregate statistical analysis and equation-based methods, are unable to analyze the complexity of neighborhoods, which can be viewed as a typical complex system created by residents' collective behavior. Therefore, agent-based modeling (ABM), a computer simulation method based on autonomous decision-making by agents, can be used to answer the research questions in this study (Cheliotis, 2020). Feedback processes (such as the interaction between residents) and bottom-up phenomena (such as the emergence of dynamic cooperation patterns for neighborhood renewal) can be easily and intuitively simulated using an ABM (Malleson, Heppenstall, & See, 2010). Therefore, the objective of this study is to develop an ABM for neighborhood renewal that provides a controlled environment for a better understanding of the complex social relationships among residents that manifest in the real world. This allowed us to examine the dynamic processes of interactions among residents and the role of government in those interactions. Specifically, the following two questions were addressed:

(1) How should the government deal with the complexity of relationships among residents in neighborhood renewal?
(2) How does the complexity of relationships among residents affect residents' cooperation on renewal projects?

The remainder of this study is organized as follows. The next section presents a literature review. Section 3 explains the ABM framework, and the details of its development. Section 4 presents a series of experiments and analyzes the test results, followed by a discussion of the results in Section 5.

2. Literature reviews

This section provides a comprehensive review of the existing literature on these two aspects. (1) The theoretical framework of residents' cooperative behavior in neighborhood renewal. This study aims to identify the behavioral mechanisms of residents as agents in the context of neighborhood renewal through a thorough literature review. (2) Previous research on resident relationships in neighborhood renewal. By reviewing the existing literature in this section, this study identifies how to construct complex social network structures of residents can be constructed in ABM.

2.1. The theoretical framework of residents' cooperative behavior in neighborhood renewal

With the increasing popularity of neighborhood renewal, a growing number of studies have shifted to the study of residents' behavior in such renewal projects (Tang et al., 2022). The study of resident behavior can be divided into two main categories: one that focuses on internal factors and analyzes the psychological motivations behind resident behavior (He & Zhu, 2018; Martín, García, & de los Salmones Sánchez, and Ángel Herrero., 2018), and another that takes an external perspective and examines the effect of the social environment on resident behavior (Huang, Xie, Xinyue, & Liu, 2023; Liu et al., 2014).

The first category often relies on a theoretical framework to identify the factors that influence intrinsic motivation. The theoretical frameworks commonly used in this type of research include the theory of planned behavior (Tan, Ying, Gao, Wang, & Liu, 2023; Tang et al., 2022; Y. Zhang, Zhang, & Guo, 2021), cumulative prospect theory (Ebrahimigharehbaghi, Qian, de Vries, & Visscher, 2022), and other relevant theories (Guo, Li, & Wang, 2018; Liang, Tao, Hong, & Shen, 2019). Among the various theoretical frameworks applied to the study of resident behavior, the theory of planned behavior is one of the most commonly used (Jin, Li, Jansen, Boumeester, & Boelhouwer, 2022; Li, Huang, Liu, Shrestha, & Xinyue, 2022). This theory hypothesizes that behavior is determined by three key factors: attitude, subjective norms, and perceived behavioral control (Bosnjak, Ajzen, & Schmidt, 2020). By examining these factors, researchers can gain insights into how residents respond to specific interventions or policies designed to promote behavior change in the context of neighborhood renewal. In this study, the three key factors of the Theory of Planned Behavior are defined as follows:

Attitude (ATT) refers to an individual's overall judgement about the behavior in question, based on beliefs about the outcomes and the value placed on those outcomes.

Subjective norm (SN) refers to the perceived social pressure to perform a behavior based on the perception of other individuals' expectations and opinions.

Perceived behavioral control (PBC) refers to a persons perceived ability to perform the behavior in question, taking into account both internal and external factors that may facilitate or impede the behavior.

The second category on resident behavior research exhibits greater methodological and topical diversity (Li, Jansen, van der Heijden, Jin, & Boelhouwer, 2022). The focus here is ones exploring the external factors that influence resident behavior, such as social norms, the physical environment, social capital, and community networks (Du et al., 2023). Research methods used ranged from qualitative to quantitative and included interviews (Zheng, Xinyue, Zhuang, & Wendong, 2023), social network analysis(Zhuang et al., 2019), evolutionary game analysis (Wang, Meiling, Jiulong, & Fan, 2022), and so forth. Social capital theory has gradually gained widespread application in these studies (Du, Zeng, Huang, & Vejre, 2020; Huang et al., 2023). This is due to its ability to explain various complex social relationships and the processes involved in their formation and effect (Mazumdar, Learnihan, Cochrane, & Davey, 2018). However, the definition and classification of social capital are currently not unanimously agreed upon among scholars. Li, Jansen, et al. (2022) suggest that previous research on social capital can be categorized into two perspectives: the functional perspective and the structural perspective. The functional perspective focuses on the functions of social capital, with Coleman (1988) being the first scholar to analyze social capital from this perspective. Coleman (1988) proposed that social capital is a combination of trust, reciprocity, and social norms that benefit specific functions of group members. The structural perspective, on the other hand, focuses on the outcomes of social networks. Bourdieu (1989) is the founder of this perspective and proposed that social capital is related to the persistence and institutionalization of social networks. In this study, we use the theory of social capital to observe the complex social network relationships among residents. Therefore, we adopt the structural perspective to define social capital among residents. From a structural perspective, a widely used classification of social capital is to categorize it into bonding (relationships within homogeneous group), bridging (relationships between heterogeneous group), and linking social capital (relationships between different levels of power) (Vera-Toscano, Garrido-Fernández, Gómez-Limón, & Cañadas-Reche, 2013). In addition, according to Lin Nan, social capital can be divided into individual and collective capital (Lin, 2002). Individual social capital refers to an individual's social networks and the resources and benefits derived from those networks, including bonding, bridging, and connecting social capital (Cofré-Bravo, Klerkx, & Engler, 2019). Collective social capital refers to shared social networks, norms, and values that exist within a group or community that can lead to cooperative behavior, collective action, and mutual benefits (Svendsen & Svendsen, 2009). According to Li, Huang, et al. (2022), collective social capital includes general trust, social norms, and system control, and collective social capital promotes the emergence of individual social capital. In this study, individual and collective social capital are defined as follows:

Individual social capital:

Bonding social capital (BOSC): the relationships within a group of residents who share the same interests regarding neighborhood renewal.

Bridging social capital (BRSC): the connection within different groups of residents with different interests regarding neighborhood renewal.

Linking social capital (LISC): vertical social connections that transcend both formal and systemic power structures, such as the relationship between residents and grassroots government.

Collective social capital:

General trust (GT): general trust refers to the confidence that someone else is trustworthy and will not try to take advantage of or hurt those around them.

Social norm (SON): social norms can be defined as implicit rules that are understood by residents and guide behavior without the force of law to produce proper behavior in the spirit of community harmony.

System control (STC): system control can be defined as a process proposed by the local government to improve the flow of information between different stakeholders.

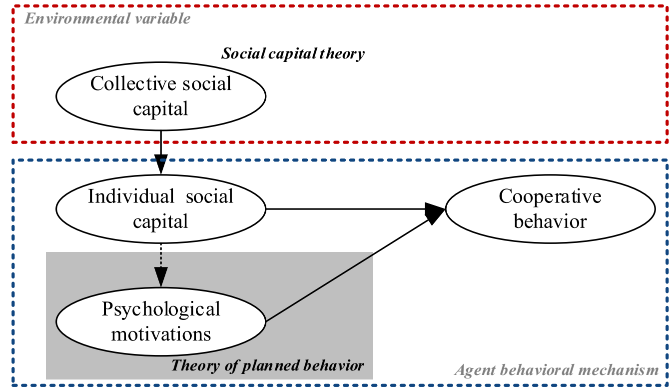


Fig. 1. The theoretical framework of residents' cooperative behavior.

Based on the above analysis, this study develops a comprehensive behavioral mechanism for resident agents by incorporating both internal and external factors. This study integrates the theory of planned behavior and the theory of social capital. The theory of planned behavior is used to construct the internal factors of the resident agent, while the theory of social capital is used to construct the external and environmental factors of the resident agent. Individual social capital was considered as an external factor, whereas collective social capital was considered as an environmental variable. Based on previous research demonstrating the influence of social capital on subjective norms, this study developed a pathway to examine the effects of individual social capital on subjective norms (Castillo, Lanza, & Wollni, 2021; Liao & Xing, 2022; Zheng, Liukai, Ma, Mi, & Jiao, 2021). The theoretical framework for resident behavior is illustrated in the following diagram (see Fig. 1).

2.2. Previous research on resident relationships in neighborhood renewal

The analysis and study of residents' social networks has always been a challenge in the field of neighborhood renewal research (Chao, Kou, Peng, Herrera-Viedma, & Herrera, 2021). Most previous research in the field of urban renewal has focused on analyzing the relationships between the stakeholders involved in the process (Du et al., 2023; Zhang, Zhang, & Guangdong, 2021). These studies have often used social network analysis. It should be noted that social network analysis studies rarely create comprehensive networks of stakeholders. Instead, most studies tend to view a node as representative of a particular type of stakeholder and present the social network as a conceptual diagram of stakeholder relationships (Zhuang et al., 2019). The main reason for this is the difficulty in accurately and comprehensively capturing social relationships.

There is a growing trend in research to construct or predict social networks among residents. However, many of these studies assume specific types of social networks among residents, such as small-world (Neal, 2015, 2018) or scale-free networks (Chao et al., 2021). Previous research has not systematically examined a particular type of social network structure. In other fields, it has been shown that differences in the structural types of social networks can have an effect (Jiang, Ma, Shang, & Chau, 2014; Rahmandad & Sterman, 2008). In the context of neighborhood renewal, therefore, exploring the structural types of social networks among residents is critical to understanding the complexity of their social relationships. However, this issue still needs to be addressed.

Therefore, this study aims to construct several types of social network structures in an agent-based model (ABM). By comparing the simulation results of different network structures, this study aimed to find out whether differences in structural types affect residents' cooperative behaviors, thus filling the research gap.

Through a literature review, it can be found that previous research has mostly focused on discussing how social capital affects behavior.

However, as pointed out by Du et al. (2020), a dynamic perspective is needed to examine the social capital of residents. Previous research often overlooked how the behavior of residents influenced by social capital can further affect the behavior of other residents through social networks. This study explores the dynamic relationship between resident social capital and behavior by applying the ABM method, enriching the research approach of social capital. Additionally, by constructing resident social capital using various types of social network structures, this study enriches the understanding of resident social capital from a structural perspective.

3. An agent-based model for residents' cooperative behavior in neighborhood renewal

In this study, Netlogo (version 6.3.0) was integrated to develop the agent-based model of residents' cooperative behavior in neighborhood renewal.

3.1. Model overview

In this study, an agent-based model was developed based on the practical process of neighborhood renewal in China. First, cooperative patterns in neighborhood renewal are the collective outcome of residents' individual cooperative behaviors. To simulate residents' cooperative behaviors, the theory of planned behavior is applied in this study. Second, as mentioned above, residents' behavior in China are usually influenced by their social relationships. Therefore, the social capital theory is integrated into this model to measure different types of relationships. Third, the effects of different types of social network structures (scale-free, small-world, and random networks) were analyzed in this study. Fourth, the effects of general trust, social norms, and system controls were examined. In this practice, residents build neighborships with their neighbors under the influence of general trust, social norms, and system controls. Residents' neighborships, along with their attitudes and abilities, influence their cooperative behaviors. At the same time, their cooperative behavior also influences the cooperative behavior of their neighbors'. An overview of the corresponding simulation framework is shown in Fig. 2 and next explained in detail.

It is important to note that the focus of this study is on the influence of social capital on residents' cooperative behavior and how residents' cooperative behavior further influences the surrounding residents through social networks. In this context, residents' other psychological, cultural, and historical backgrounds will no longer be the focus of this study. As Smith and Conrey (2007) stated, ABM is a representative of theory, not of detailed social reality. Macy and Willer (2002) also proposed in discussing the modeling principles of ABM that the development of ABM should simplify rules as much as possible, and the focus of research should be on complex phenomena emerging from simple rules. Therefore, based on the focus of this study, TPB and social capital theory are applied to design residents' cooperative behavior rules. Based on this framework, this study aims to observe the complex phenomena of interaction among residents under different network structures and environmental variable values through the simple behavior rules of residents designed based on TPB and social capital.

3.2. Environment variable

Environmental variables include system control, social norms, and general trust.

General trust. Previous research has proved that the higher general trust within the neighborhood, the higher probability for residents to have a social relationship with their neighbors (Dassopoulos & Monnat, 2011; Sampson, 1991). In other words, the harmonious atmosphere of the neighborhood will promote a more friendly relationship between residents and neighbors. In this model, general trust can be regarded as social cohesion, which refers not to the presence or absence of relationships within the social structure, but to the closeness of relationships, friendliness within organizations, and mutual trust. In the context of neighborhood renewal, residents' decision-making may be affected by their neighbors. High general trust may amplify this effect. This study used *GT* to describe the general trust in the neighborhood. *GT* is adjustable as a floating number from 0 to 1.

Social norm. With regard to social norms, the shared norms and values can establish a close connection and promote community cohesion. Prior research has indicated that a community may be defined as a homogenous aggregate of residents with shared norms and customs. *SON* is adjustable as a floating number from 0 to 1.

System control. In China, almost every neighborhood is governed by the corresponding grassroots government. The role of the grassroots government is to handle the daily affairs of the neighborhood and to implement the policies of a higher level of government (e.g., municipal, ward level). Neighborhood renewal is regarded as one kind of

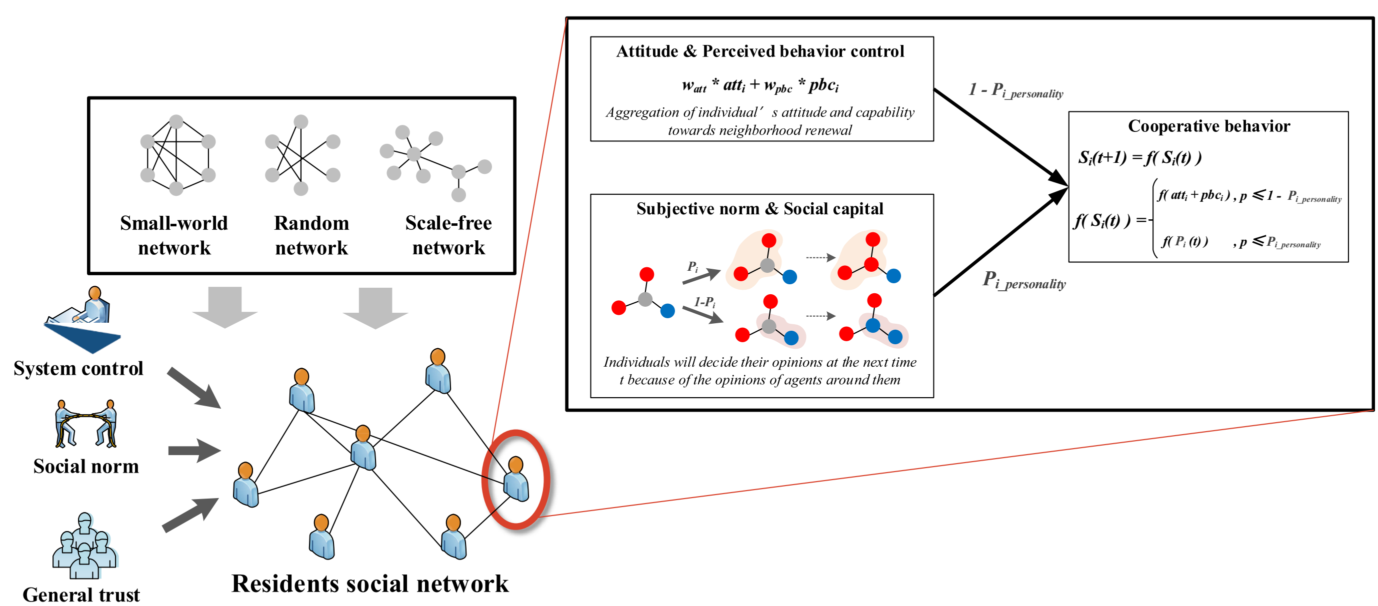


Fig. 2. Overview of the agent-based model.

government-led project in China. Therefore, the execution and facilitation of grassroots government may affect residents' opinions toward neighborhood renewal. This study used system control *SCT* to describe the execution and facilitation of grassroots government. *SCT* is adjustable as a floating number from 0 to 1.

3.3. Agents

The model is populated by "residents" agents. Each agent had the same structure and attributes. Agents are divided into "cooperative" residents and "uncooperative" residents depending on their behavior. All agents were embedded in a social network. The location of the agent and its relationship with the other agents did not change. Moreover, the number of residents in a neighborhood may change constantly. However, this model simplifies the real world and does not predict the actual number of residents in a neighborhood or the number of social relationships between residents. This is because the focus of this study is on the effect of residents' pre-existing relationships on cooperative behavior, rather than the effect of relationship evolution on cooperative behavior. Therefore, this study argues that the simplification is suitable.

The theory of planned behavior (TPB) is used to illustrate how residents' attitudes, abilities, and social pressures control their cooperative behavior. TPB is a classic theory in social psychology. According to Ajzen (1991), the likelihood that a person will perform an action depends largely on the strength of their behavioral intentions. The TPB states that individual behavioral intentions are influenced by individual attitudes (ATT), perceived behavioral control (PBC), and subjective norms (SN). Therefore, following Pouladi, Afshar, Afshar, Molajou, and Farahmand (2019), the following function is used to determine for residents' cooperative behavior intention:

$$BI \cong w_{att}{*}ATT + w_{pbc}{*}PBC + w_{sn}{*}SN \tag{1}$$

In Eq. (1), BI is the strength of behavioral intention; w_{att}, w_{pbc}, and w_{sn} are the weight for attitude, perceived behavioral control, and subjective norm separately. Meanwhile, previous studies suggest that personality can influence whether individuals heed others' opinions and, in turn, affect their decision-making (Gambetti & Giusberti, 2019; Marino et al., 2016; Roozmand et al., 2011). Likewise, residents may also accept or reject their neighbors' opinions based on their personality. This type of decision-making process is reflected in the influence of subjective norms on behavioral intentions. Therefore, this study proposes a cooperation behavior function for residents in neighborhood renewal:

$$f_i(t) = \begin{cases} \dfrac{w_{att}{*}ATT_i + w_{pbc}{*}PBC_i}{w_{att} + w_{pbc}}, & p \geq p_{i\_personality} \\ SN_i, & p \leq p_{i\_personality} \end{cases} \tag{2}$$

where $f_i(t)$ represent the probability of resident i to perform cooperative behavior; $p_{i\_personality}$ represent the probability of resident i to follow others' opinions. Based on the research of Jiang et al. (2014) and Du, Cao, Mao-Bin, Yang, and Zhou (2009), the function of residents' personality is proposed as follows:

$$p_{i\_personality} = \frac{1}{1 + e^{-r_i}} \tag{3}$$

where r_i is a random floating number from 0 to 3 that presents the agents' personality.

In the real world, at the beginning of a renewal project, residents' attitudes and abilities toward the renewal project are often randomly distributed. Therefore, in this study, ATT_i and PBC_i are set as random distributed number.

Social capital theory has been integrated into this model to measure SN_i. Social capital can be regarded as a resource embedded in individuals' relationships. Previous research has classified social capital into three categories: bonding, bridging, and linking (Li, Jansen, et al., 2022). Fig. 3 shows an example of social capital in neighborhood renewal. Recognizing that residents are typically embedded in social networks, a network to describe the residents' social relationships with their neighbors is shown in Fig. 3. As mentioned earlier, residents in this model are divided into two types: "cooperative" residents and "uncooperative" residents. Bonding social capital refers to the relationships between residents of the same type, who can also be considered as a homogeneous group. Bridging social capital refers to the relationship between different types of residents, who can be considered as a heterogeneous group. Fig. 3 shows no connection to social capital. Linking social capital refers to the relationship between different levels of power, which are difficult to describe in a social network. According to Fig. 3, residents first assess whether their neighbors are cooperative. Based on the behavior of their surrounding neighbors, residents determine which individuals represent bonding or bridging social capital. In this study, residents' linking of social capital is assumed to refer to the relationship between the government and residents. The relationship between the government and residents is influenced by two factors: whether the government actively communicates with the residents, and whether residents have social and self- governance skills that enable them to actively establish contact with the government. Residents determine their subsequent behavior based on their social capital. In this study, it is argued that this process is the process by which the subjective norm (SN) influences residents' behavior. Based on this, a function for bonding, bridging, and linking social capital is proposed.

Bonding social capital. Residents judge whether their neighbors' behavior is consistent with their own. At the same time, the proportion of neighbors whose behavior is consistent with their own, among all their neighbors, is considered their bonding social capital. As mentioned earlier, collective social capital influences individual social capital. Therefore, this study assumes that *GT*, *SON*, and *SCT* are positively related to bonding social capital. Therefore, the bonding social capital function was proposed as follows:

$$BOSC_i = \frac{n_{i\_co}/N_i + w_{bo\_gt}{*}GT + w_{bo\_son}{*}SON + w_{bo\_sct}{*}SCT}{1 + w_{bo\_gt} + w_{bo\_son} + w_{bo\_sct}} \tag{4}$$

where $BOSC_i$ represents the bonding social capital of resident i; n_{i_co} represents the residents around resident i who engage in the same type of behavior (cooperative or uncooperative); N_i represents the total number of residents around resident i; w_{bo_gt}, w_{bo_son}, and w_{bo_sct} are the weight value of general trust, social norm, and system control for bonding social capital separately.

Bridging social capital. Redistribution of benefits among residents is part of the neighborhood renewal process. As a result, there may be conflict between residents due to an imbalance in distribution of benefits. This may lead to a situation where some residents cooperate and others do not. Therefore, neighbors who hold different opinions serve as the bridging social capital among residents. Collective social capital influences bridging social capital. Based on this, the following bridging social capital function is proposed:

$$BRSC_i = \frac{n_{i\_un}/N_i + w_{br\_gt}{*}GT + w_{br\_son}{*}SON + w_{br\_sct}{*}SCT}{1 + w_{br\_gt} + w_{br\_son} + w_{br\_sct}} \tag{5}$$

where $BRSC_i$ represents the bridging social capital of resident i; n_{i_un}

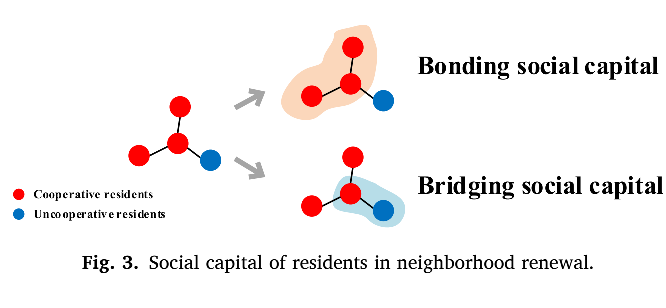


Fig. 3. Social capital of residents in neighborhood renewal.

represents the residents around resident *i* who engage in the different type of behavior; w_{br_gt}, w_{br_son}, and w_{br_sct} are the weight value of general trust, social norm, and system control for bridging social capital separately.

Linking social capital. As mentioned earlier, linking social capital among residents is influenced by both the residents themselves and the collective social capital during neighborhood renewal. This study argues that for residents themselves, the extent of their social relationships is an important factor. Therefore, the linking social capital is proposed as follows:

$$LISC_i = \frac{N_i/N + w_{li\_gt}{*}GT + w_{li\_son}{*}SON + w_{li\_sct}{*}SCT}{1 + w_{li\_gt} + w_{li\_son} + w_{li\_sct}} \quad (6)$$

where $LISC_i$ represents the linking social capital of resident *i*; *N* represents the total number of agents; w_{li_gt}, w_{li_son}, and w_{li_sct} are the weight value of general trust, social norm, and system control for linking social capital separately.

After calculating the bonding, bridging, and linking social capital, the SN function can be further developed. SN however, is different for residents with different behaviors. For cooperative residents, bridging social capital can help them understand why uncooperative residents disagree with renewal projects, which in turn reduces their intention to cooperate. Similarly, building social capital can make uncooperative residents more likely to support the renewal plan. Grassroots governments often encourage residents to agree with the renewal plan. Therefore, it is necessary to set different SN functions for resident agents with different behaviors. Considering the following calculation of the probability of residents' behavior, the SN function was normalized with an exponential function: For cooperative residents:

$$SN_i = \frac{1}{1 + e^{-a{*}\left(\frac{w_{bosc}{*}BOSC_i - w_{brsc}{*}BRSC_i + w_{lisc}{*}LISC_i + w_{brsc}}{w_{bosc} + w_{brsc} + w_{lisc}} - b\right)}} \quad (7)$$

And, for uncooperative residents:

$$SN_i = \frac{1}{1 + e^{-a{*}\left(\frac{-w_{bosc}{*}BOSC_i + w_{brsc}{*}BRSC_i + w_{lisc}{*}LISC_i + w_{bosc}}{w_{bosc} + w_{brsc} + w_{lisc}} - b\right)}} \quad (8)$$

where variables *a* and *b* are used for calibration. Through trial-and-error, the values for a and b were set to −10 and 0.5 respectively, which produced the best simulation results.

3.4. Residents' social network

The social network of the residents is difficult to analyze. According to Chao et al. (2021), due to missing information and complex social relationships, it is difficult to construct complete social relationships between residents. Due to this limitation, previous studies on social networks in residential communities often do not have a large number of samples (Crowe, 2010). However, based on this, this study asks a question: Does the social network structure of residents matter? In previous research, the need to construct social network relationships in the real world led to the assumption that the type of social network structure may have an influence. If the type of social network structure does not have an influence, the type of social relationships between nodes in a network where nodes share the same characteristics is no longer important. Given the limited sample data, this study found it necessary to examine the evolution of residents' cooperative behaviors in neighborhood renewal under different types of networks.

There has been much discussion in previous research on the possible network structure models of the real world (Anderson, Lee, & Menassa, 2014; Barabási et al., 2002). However, it is important to acknowledge that resident social networks exhibit complexity and may feature a combination of various network structural characteristics. Consequently, it is challenging to represent all the structural features of resident social networks with a single network structure. Nevertheless, by simulating and comparing models with different network structural characteristics, we can explore the impact of various network structural features on the evolution of resident cooperation behavior. According to Jiang et al. (2014), this study proposed the first model for network structure, that is, the scale-free network, characterized by a small number of nodes dominating a large number of connections, while the majority of nodes only possess a few connections. Therefore, it is possible to assess whether the behavior of residents with a significant number of social relationships can efficiently influence other residents (Jia, Hoberock, Garland, & Hart, 2008). The second model proposed in this study is the small-world network, where the social network is presumed to be a highly clustered world with minimal distance between people's relationships (Li, He, Niu, & Li, 2017). Consequently, the propagation of different behavior types among residents is highly efficient. Finally, the third model proposed in this study is the random network, which is a more universal network feature. Each resident has a probability of contacting others, and any resident may act as a broker for behavior propagation (Aldrich & Kim, 2007). The development method for each network feature is as follows.

- Scale-free network. A scale-free network is characterized by a degree distribution that follows a power law. This study draws on the research of Barabási, Albert, and Jeong (1999) to create a scale-free network called the BA model. The BA model first develops a very small network, and then for each additional node added during the growth process, it preferentially attaches the node to the higher-degree nodes, resulting in a scale-free network.
- Small world network. In a small-world network, the average path length between any two vertices is significantly smaller than the total number of vertices in a network with a large number of vertices. Based on the research of Watts and Strogatz (1998), also known as the WS model, the small-world network was developed in this study.
- Random network. Based on the research of Erdős and Rényi (1960), also called ER random graph, the random network was developed in this study.

This study aims to analyze whether typical characteristics of resident complex social network structures have an impact on the evolution of resident cooperative behavior by selecting three typical social network structural features. Additionally, we will examine whether the impact of different network structural features on resident cooperative behavior is diverse, which can broaden our understanding of resident social networks.

4. Model experimentation and results

The model was used applied to test the evolution of residents' cooperative behavior during neighborhood renewal. This section covers three distinct tasks: determining the model weight values, testing the responsiveness of the model output through sensitivity analysis, and comparing the results under different social network structures.

4.1. Statistical analysis of the field survey and the theoretical model

The purpose of this section is to confirm the model parameters, in particular the weight values. Because the agent-based model designed in this study included both agent attribute values and environment variables, it involved a nested data structure. Therefore, this study applied a multilevel structural equation model.

The study was conducted between June 2021 and March 2022 with a target population of residents living in neighborhoods that were undergoing or about to begin renewal, or had completed renewal. The survey was administered in three Chinese cities - Chongqing, Nanjing, and Xuzhou, which had published their own policies and developed pilot projects for neighborhood renewal. Questionnaires were distributed to

Table 4-1
The results of multilevel structural equation model.

Path	Standardized path coefficient	*P*-value
GT —> BOSC	0.923	***
GT —> BRSC	/	ns
GT —> LISC	/	ns
SON —> BOSC	/	ns
SON —> BRSC	/	ns
SON —> LISC	/	ns
SCT —> BOSC	/	ns
SCT —> BRSC	0.432	*
SCT —> LISC	0.597	**
BOSC —> SC	0.933	***
BRSC —> SC	0.806	***
LISC —> SC	0.821	***
SN —> BI	0.140	*
ATT —> BI	0.344	***
PBC —> BI	0.357	***

Note: *** is $p < 0.001$, ** is $p < 0.01$, * is $p < 0.05$, ns is not significant.

Table 4-2
The parameters of agent-based model.

Parameters	Value	Parameters	Value
w_{att}	0.344	w_{br_sct}	0.432
w_{pbc}	0.357	w_{li_gt}	0.000
w_{sn}	0.140	w_{li_son}	0.000
w_{bo_gt}	0.932	w_{li_sct}	0.597
w_{bo_son}	0.000	w_{bosc}	0.933
w_{bo_sct}	0.000	w_{brsc}	0.806
w_{br_gt}	0.000	w_{lisc}	0.821
w_{br_son}	0.000	–	–

residents of the pilot programs. To ensure representativeness, only one questionnaire was given per household member, with distribution adjusted proportionally to each building's total number of households. The survey was conducted in the field with control measures to minimize selection bias. Respondents repeatedly selecting the same answer or giving conflicting responses were excluded. Although some households in older neighborhoods faced challenges completing the questionnaires due to capacity or trust issues, a total of 1232 residents from 98 neighborhoods participated in the survey, with 1039 providing valid responses (valid response rate: 84.33%).

The rationale for selecting the three cities in this study is because they share similar policies for neighborhood renewal. These cities are located in eastern and western China, covering both first-tier and second-tier cities, making them relatively representative. Furthermore, the most important reason for selecting these cities is that they have similar types of old neighborhood renewal projects: government-mandated, government-guided, and resident-led. Government-mandated projects refer to those where the government is the initiator and often provides funding, managing the project's implementation, and making most of the decisions regarding the renewal plan. In these three cities, government-mandated projects primarily focus on repainting the exterior walls and road improvement within the neighborhood. Government-guided projects are a type that has gradually been promoted in these cities in recent years. In this model, residents play the role of designer and participate in the renewal plan's design, while the government acts as a coordinator and organizer. Finally, resident-led projects refer to a type where residents play the role of initiator and even funder, with the government only responsible for key process approvals. In these three cities, the resident-led projects are mainly represented by elevator installation projects for old residential buildings. The differences between these three types of projects primarily reflect differences in resident willingness and government execution. In other words, differences in renewal project types have a more significant impact on resident cooperation behavior than differences between cities. In the results and discussion section, this study will examine the impact of different project types on residents' cooperative behavior by setting different values for resident willingness and government execution.

In addition, because the focus of this study was not on the analysis of the multilevel structural equation model and its results, this section does not provide a detailed introduction to the analysis process. The specific process of the multilevel structural equation model analysis is presented in the Supplementary Materials. The results of the multilevel structural equation model are shown in Table 4-1.

The parameter values of the ABM were determined based on the results of the multilevel structural equation model (as shown in Table 4-2).

In addition, this study aims to determine the number of agents for each experiment. According to Rand and Rust (2011), setting the number of agents too small would make evolutionary game theory more suitable for data analysis, while setting the number of agents too large would make econometrics more appropriate. Therefore, this study will consider a moderate number of agents for comparison. The study will compare the results of different numbers of agents at levels of 100, 200, 300, 400, and 500, and perform a Kruskal-Wallis H test on the results. Since the final number of cooperating resident agents cannot be directly compared among different numbers of agents, the number of cooperating resident agents will first be divided by the total number of agents in the corresponding group. Then, the proportion of cooperating resident agents will be analyzed for differences between groups. The results of the analysis are presented in Table 4-3.

Based on Table 4-3, it can be seen that there is no significant difference in the simulation results for different numbers of agents. In other words, there is no significant difference in the number of agents among

Table 4-3
Statistical results of simulation data for different number of Agents.

Network type	Parameters	Agent numbers	The number of cooperative residents (mean, standard deviation)	*p*-Value
Scale-free	GT = 0.5	100	48.95, 9.72	0.052
	SCT = 0.5	200	94.73, 14.15	(Accept)
	I_Pro = 50%	300	136.65, 17.06	
		400	185.69, 22.69	
		500	226.02, 21.29	
Small world	GT = 0.5	100	36.85, 7.28	0.280
	SCT = 0.5	200	72.76, 9.57	(Accept)
	I_Pro = 50%	300	106.95, 11.68	
		400	141.92, 13.21	
		500	177.46, 13.49	
Random	GT = 0.5	100	37.25, 6.56	0.069
	SCT = 0.5	200	70.18, 8.77	(Accept)
	I_Pro = 50%	300	107.18, 12.06	
		400	141.15, 11.57	
		500	176.25, 14.68	

Note: I_Pro represents the proportion of initial cooperating resident agents to the total number of agents; *p*-Value is value from Kruskal-Wallis H test.

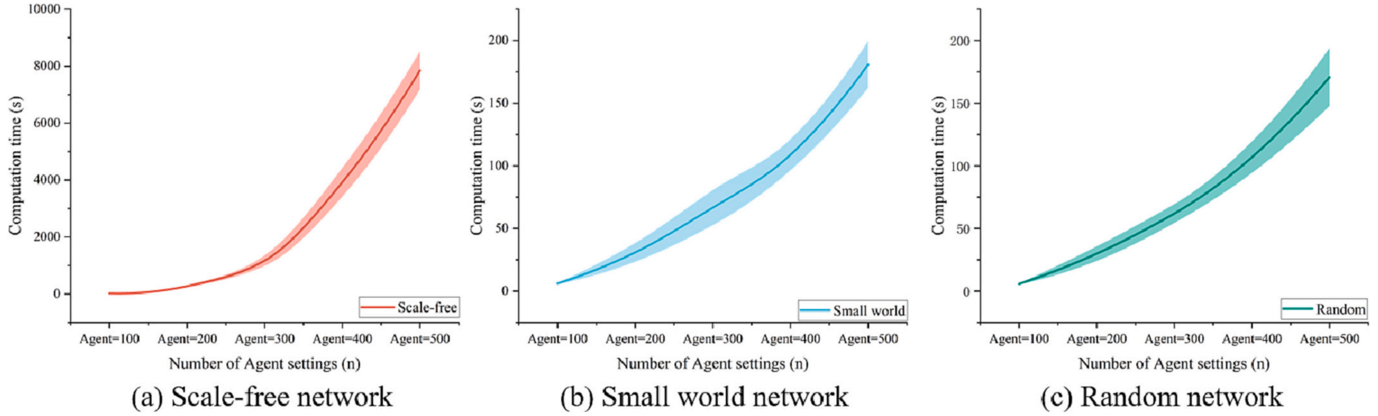


Fig. 4. Model computation time with different number of Agents.

the five levels. This study further calculated the model computation time for different numbers of agents (as shown in Fig. 4). It can be seen that as the number of agents increases, the model computation time for all three network structures significantly increases. Specifically, the computation time for the scale-free network increases the most noticeably. Therefore, to improve the efficiency of this study, a fixed number of 100 agents was chosen for future calculations.

4.2. The control experimentation

The control experiment tested the influence of different parameter values on the overall output. This was achieved by separately progressively changing different parameters at 0.1, intervals, to determine the operating ranges of the model parameters and their effects. The following model parameters were tested: general trust (*GT*), and system control (*SCT*). According to Malleson et al. (2010), in each test, the model was executed 100 times in each test, and each time it ran for 1000 iterations, allowing the robustness and sensitivity of the initial starting conditions to be assessed.

General trust. In the real world, it can happen that in some neighborhoods the majority of residents support renewal projects from the start, whereas in others, very few residents support renewal from the start. This leads to differences in the initial distribution of the agent types. In this study, two scenarios were established: one with high initial cooperation between residents (90 cooperative residents and 10 non-cooperative residents), and the other with low initial cooperation between residents (10 cooperative residents and 90 non-cooperative residents). Under different scenarios, the size of the government's role is further differentiated into the following sub-scenarios: high initial cooperation among residents-high *SCT*, high initial cooperation among residents-low *SCT*, low initial cooperation among residents – high *SCT*, and low initial cooperation among residents – low *SCT*. The last scenario, i.e., low initial cooperation among residents – low *SCT* is unlikely in the real world, because if neither the government nor the residents intend to promote the renewal project, the project will not be implemented. Therefore, a sensitivity analysis of *GT* for only the first three scenarios was performed in this study.

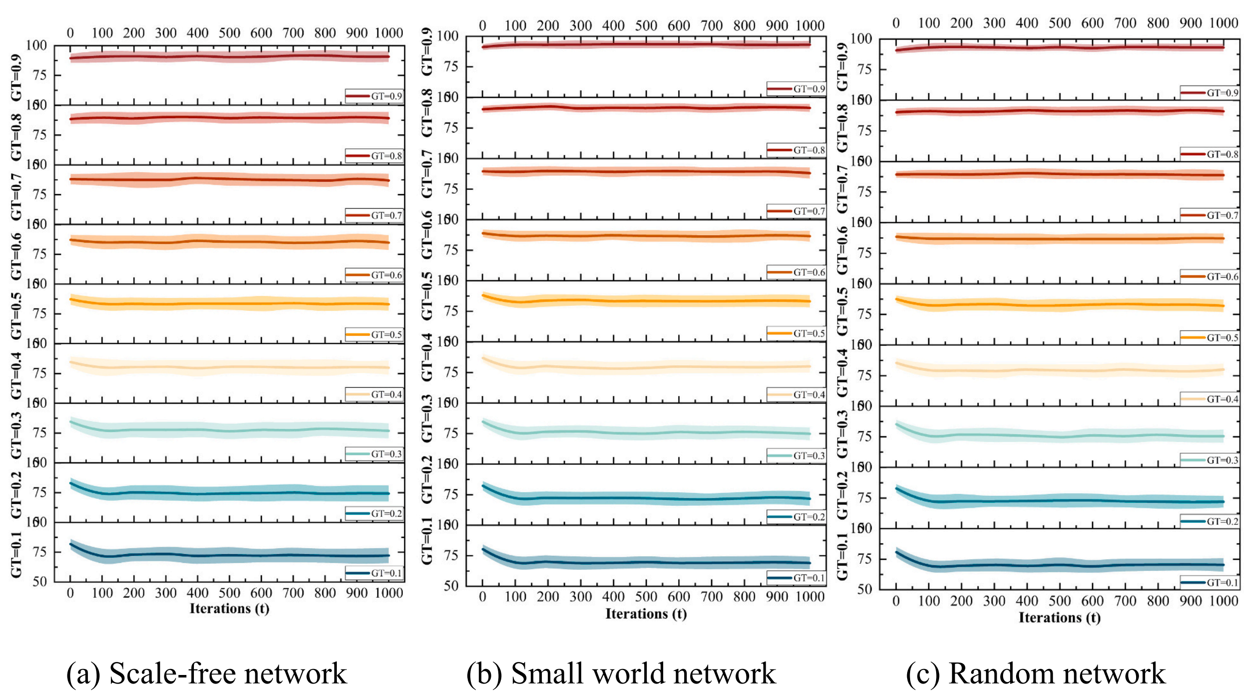


Fig. 5. Results of sensitivity analysis under the scenario of high initial cooperation among residents-high *SCT*.
Note: The solid line denotes the mean values of the number of cooperative residents, whilst the shade indicates the corresponding standard deviations.

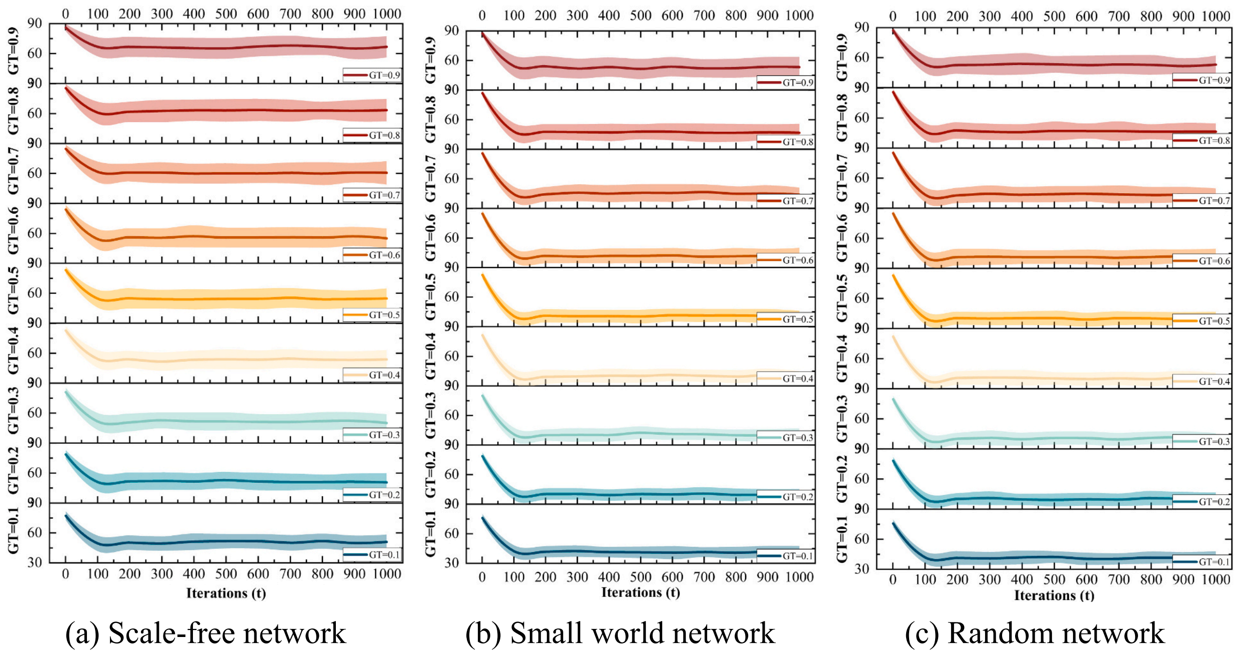


Fig. 6. Results of sensitivity analysis under the scenario of high initial cooperation among residents-low SCT.
Note: The solid line denotes the mean values of the number of cooperative residents, whilst the shade indicates the corresponding standard deviation.

(1) High initial cooperation among residents-high *SCT*. In this study, the agent-based model was run for *GT* values ranging from 0.1 to 0.9 in increments of 0.1, with *SCT* was set as 0.9. Experiments were conducted on the models of all three kinds of networks. The results are shown in Fig. 5. Fig. 5 shows that lower *GT* values lead to fewer cooperative residents in later stages. The number of cooperative residents in all three network types eventually stabilized at approximately 65. Also, lower *GT* values often resulted in higher standard deviations. This result was observed for all three types of networks.

(2) High initial cooperation among residents-low *SCT*. In this study, the agent-based model was run for *GT* values ranging from 0.1 to 0.9 in increments of 0.1, with SCT was set as 0.1. As shown in Fig. 6, similar to the scenario with a high *SCT*, a low *GT* reduces the number of cooperative residents. However, unlike the previous scenario, in the low *SCT* scenario, a lower *GT* value will result in a lower standard deviation.

(3) Low initial cooperation among residents – high *SCT*. In this scenario, the *SCT* is set at 0.9, but the initial number of cooperating residents has decreased from 90 to 10. As shown in Fig. 7,

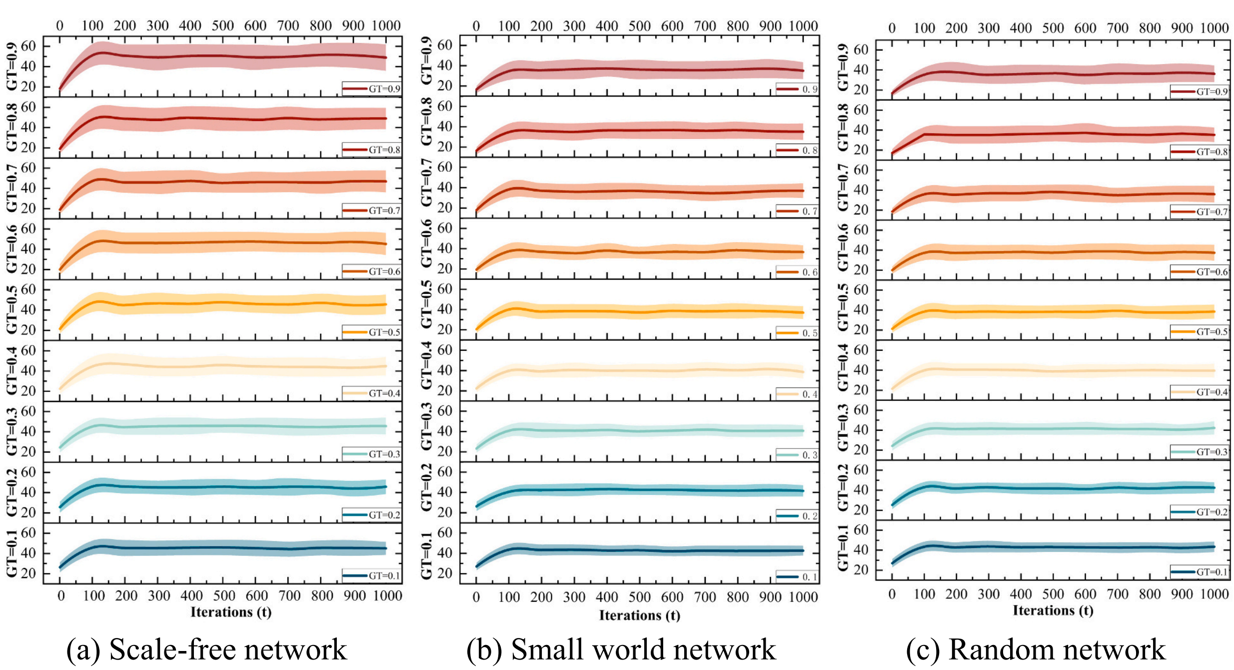
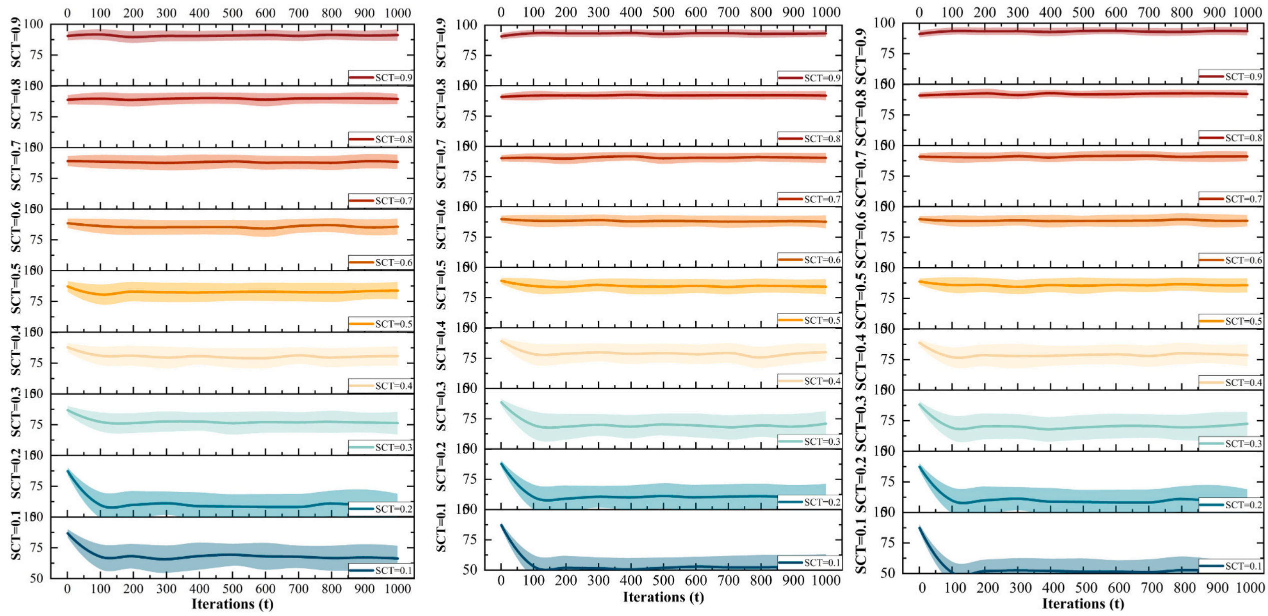


Fig. 7. Results of sensitivity analysis under the scenario of low initial cooperation among residents - high SCT.
Note: The solid line denotes the mean values of the number of cooperative residents, whilst the shade indicates the corresponding standard deviation.



(a) Scale-free network (b) Small world network (c) Random network

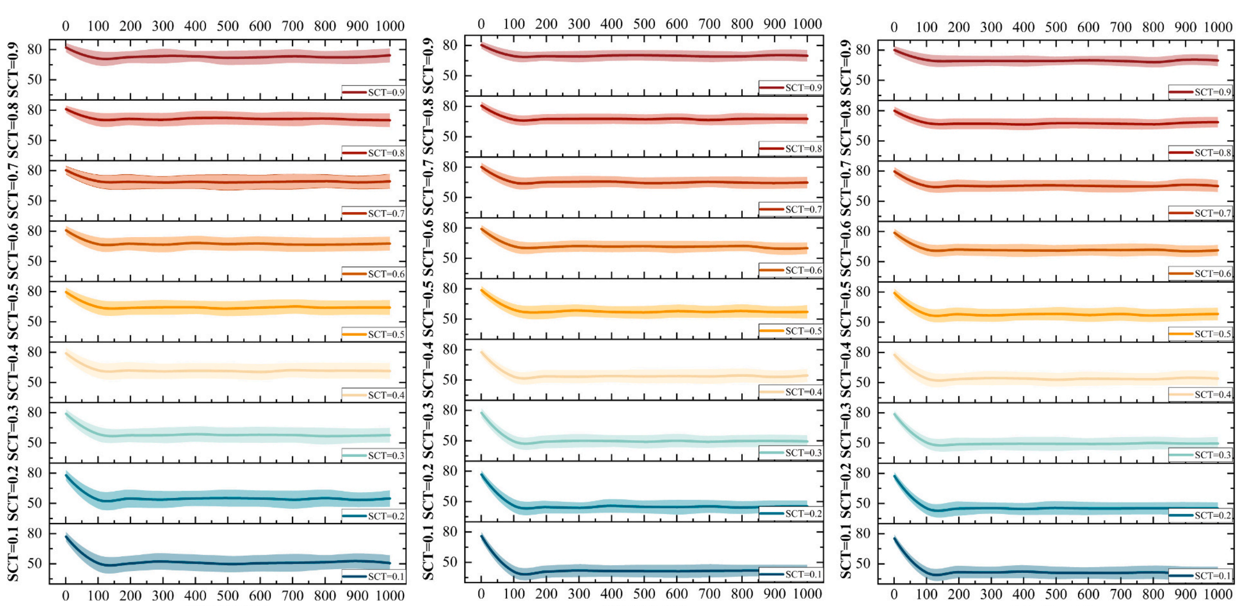
Fig. 8. Results of sensitivity analysis under the scenario of high initial cooperation among residents – high GT.
Note: The solid line denotes the mean values of the number of cooperative residents, whilst the shade indicates the corresponding standard deviation.

changing the *GT* had little effect on the mean number of cooperating residents. However, higher *GT* values result in higher standard deviations.

System control. As mentioned earlier, in a neighborhood where residents generally do not support renewal projects, the likelihood of a renewal project going ahead is very low unless the government sponsors it. Therefore, the scenario design for the *SCT* includes two situations: high initial cooperation among residents (high *GT*) and high initial cooperation among residents (low *GT*).

(4) High initial cooperation among residents – high GT. In this study, the agent-based model was run for *SCT* values ranging from 0.1 to 0.9 in increments of 0.1, with GT was set as 0.9. As shown in Fig. 8, low SCT will significantly decrease the number of cooperative residents. In addition, a lower SCT value will result in a lower standard deviation.

(5) High initial cooperation among residents – low GT. In this study, the agent-based model was run for *SCT* values ranging from 0.1 to 0.9 in increments of 0.1, with GT was set as 0.1. As shown in



(a) Scale-free network (b) Small world network (c) Random network

Fig. 9. Results of sensitivity analysis under the scenario of high initial cooperation among residents – low GT.
Note: The solid line denotes the mean values of the number of cooperative residents, whilst the shade indicates the corresponding standard deviation.

Table 4-4
Statistical results of simulation data.

Scenario	Parameters	Network type	The number of cooperative residents (mean, standard deviation)	*p*-Value (p1, p2, p3, p4 (Decision))	Box-plot
1	GT = 0.1	Scale-free	45.20, 7.26	0.000, 0.054, 0.003, 0.023 (Reject)	Fig. 10
	SCT = 0.9	Small world	42.58, 4.72		
	I_data = 10	Random	42.86, 5.39		
2	GT = 0.9	Scale-free	48.18, 11.18	0.050, 0.065, 0.000, 0.000 (Reject)	Fig. 11
	SCT = 0.9	Small world	36.65, 9.79		
	I_data = 10	Random	36.17, 8.40		
3	GT = 0.1	Scale-free	73.13, 5.94	0.188, 0.068, 0.000, 0.000 (Reject)	Fig. 12
	SCT = 0.9	Small world	70.06, 4.82		
	I_data = 90	Random	68.69, 5.81		
4	GT = 0.9	Scale-free	91.01, 3.70	0.082, 0.120, 0.000, 0.000 (Reject)	Fig. 13
	SCT = 0.9	Small world	92.70, 3.37		
	I_data = 90	Random	93.25, 3.10		
5	GT = 0.9	Scale-free	65.87, 10.48	0.195, 0.060, 0.000, 0.000 (Reject)	Fig. 14
	SCT = 0.1	Small world	53.47, 9.39		
	I_data = 90	Random	53.38, 9.28		
6	GT = 0.1	Scale-free	50.98, 7.44	0.123, 0.064, 0.000, 0.000 (Reject)	Fig. 15
	SCT = 0.1	Small world	41.26, 6.19		
	I_data = 90	Random	41.46, 6.59		

Note: *p1* is value from Levene test; *p2* is value from Shapiro-Wilk test; *p3* is value from one-way ANOVA; *p4* is value from Kruskal-Wallis H test.

Fig. 9, similar to the scenario with low GT, low SCT will significantly decrease the number of cooperative residents. However, in the low GT scenario, SCT will not cause a significant change in standard deviation.

4.3. Different types of social network structure under different scenarios

In this section, different social network structures were investigated to see whether they lead to differences in the number of cooperating residents under different scenarios. Therefore, this study first design scenarios based on the real world. In this study, a total of 6 scenarios were designed:

(1) Scenario 1 and Scenario 2: Government-mandated renewal project. This type of project is characterized by government-led initiatives with little participation from residents. In some Chinese cities, the municipal government may plan to renew most of the neighborhoods, with a focus on renovating the exterior facades and cleaning the neighborhoods' public spaces. However, these projects may also affect the daily lives of residents. Therefore, most community residents do not support the renewal. The outcomes of these projects may also depend on the general trust in the neighborhood. Therefore, two scenarios can be outlined: Scenario 1, a government-mandated project with low *GT*, and Scenario 2, a government-mandated project with high *GT*.

(2) Scenario 3 and Scenario 4: government-guided renewal project. This type of transformation project is characterized by the government playing the role of a service provider, offering knowledge and financial support for neighborhood renewal. In such projects, residents are often willing to renew. However, it is difficult to form an effective self-governing organization among residents due to factors such as general trust. The government needs to provide proper guidance to residents in performing renewal projects. Therefore, two other scenarios can be designed: Scenario 3, a government-guided renewal project with low *GT*, and Scenario 4, a government-guided renewal project with high *GT*.

(3) Scenario 5 and Scenario 6: resident-led renewal project. This type of project is characterized by a lower level of government involvement, with residents taking the lead in the renewal process. In China, the main example of this type of project was the installation of elevators in old residential buildings. In this type of project, the closeness of relationships between residents can affect the results of the renewal project. Therefore, two scenarios can be designed: Scenario 5, a resident-led renewal project with high *GT*, and Scenario 6, a resident-led renewal project with low *GT*.

Table 4-4 shows the parameter design for each scenario. In addition, this study examined whether there were significant differences between the different social network structure models. This study first used the Levene test to determine if there was homogeneity of variance in the data. If the *p*-value was >0.05, we concluded that the data met the assumption of homogeneity of variance. The second step was to apply the Shapiro-Wilk test to check the normality of the data. The Shapiro-Wilk test is suitable for testing small sample sizes. If the p-value was >0.1, we concluded that the data were normally distributed. Third, if the data were normally distributed and met the homogeneity of variance, a one-way analysis of variance was performed to compare whether there was a significant difference between the means of the different groups. If the p-value is <0.05, it indicates that the different types of social network structures have a significant effect on the number of residents cooperating in the renewal project. Fourth, if the data did not follow a normal distribution or did not satisfy the homogeneity of variance, the Kruskal-Wallis H test (a non-parametric method) was used to test the samples. If the p-value is <0.05, it also indicates that different types of social network structures have a significant influence on the

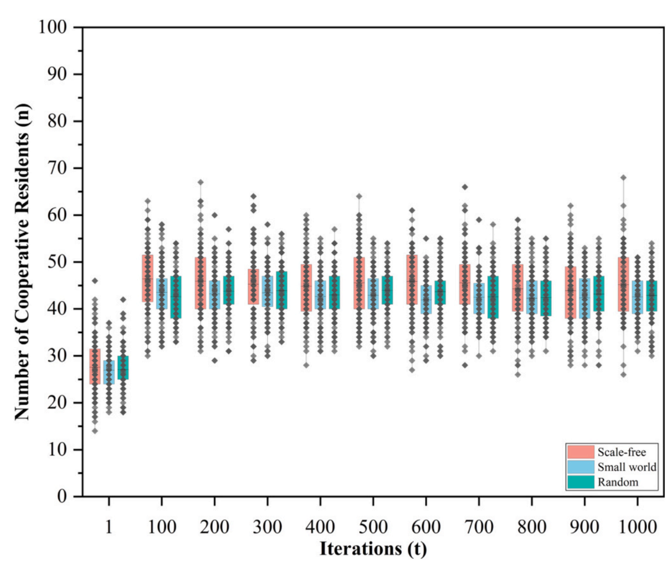


Fig. 10. Box-plot of Scenario 1.

number of residents cooperating in the renewal project. Based on the above steps, simulations and statistical analysis were conducted. The results are summarized in Table 4-4. The boxplots of the simulation results for each scenario are shown in Fig. 10 to Fig. 15.

According to Table 4-4, this study concludes that, in all scenarios, the type of social network structure has an impact on the number of cooperative residents. In addition, based on Fig. 10 to Fig. 15, this study found that small-world and random networks had small differences, while scale-free networks exhibit larger differences compared to the other two types of networks. In addition, the number of cooperating residents was higher in scale-free networks than in the other two types of networks, with the exception of scenario 4.

5. Discussion and conclusion

Neighborhood renewal depends on the participation and cooperation of numerous residents, and their cooperative behavior plays a crucial role in this process. However, it is difficult to study of residents' cooperative behavior on the neighborhood renewal. The complexity of residents' social networks and how environmental variables, such as the role of government and community cohesion, affect collaborative outcomes within residents' social networks for renewal projects have not yet been clarified. This study integrates social capital theory and planned behavior theory to propose an agent-based model of the cooperative behavior of residents in old neighborhoods with different social network structures for neighborhood renewal projects. Specifically, there are two research questions. (1) How should the government deal with complexities of relationships between in neighborhood renewal? (2) How does the complexity of resident relationships affect residents' cooperation on renewal projects? The innovative and theoretical contributions of this study primarily manifest in: Firstly, this study not only explores how social capital affects residents' cooperative behavior, but also analyzes how resident behavior influences other residents through social networks. The study's findings break through the limitations of previous research on how resident behavior is "influenced", adding the process of how resident behavior "influences others". The research has achieved a closed loop analysis of resident cooperative behavior. Secondly, the study's conclusions demonstrate the differential impact of social capital on behavior diffusion under different network structure types. Through comparative analysis of various network structure characteristics, this research enriches the understanding of resident social capital from a structural perspective. On the whole, this study contributes to the analysis of the "black box" of complex social networks between residents, enriches the theory of complex systems, supports government decision-making, and promotes the implementation of neighborhood renewal projects.

5.1. *Adding flowers to brocade: When residents have a strong willingness to renewal, the government needs to guide their relationships*

Relying solely on closed neighborhoods, residents are not always capable of handling neighborhood public affairs, especially neighborhood renewal projects. Government guidance can leverage the role of general trust in fostering consensus among residents. According to Sections 0 (1) and (2), when the GT increases at different SCT values, the change in the standard deviation varies in the direction. When the SCT value is high, an increase in GT leads to a decrease in the standard deviation, whereas when the SCT value is low, an increase in GT leads to an increase in the standard deviation. This means that close social relationships among residents can lead to conflicts of opinion when there is a lack of government leadership and management. Hu, Yue, and Tong (2018) proposed three examples to illustrate the effects of different levels of government intervention on residents' collective behavior. Hu et al. (2018) also concluded that when the level of cohesion among residents is high, resident self-governance is more likely to pose risks to residents' collective behavior. In other words, without government leadership, close social relationships among residents may lead to disagreement and social exclusion (Daly & Silver, 2008). According to Cheng, Zhong, and Li (2021), a neighborhood network cannot be sustainable without any external intervention. Similarly, in China, the "Fengqiao Model" has recently been promoted again in grassroots governance (Suyun Ding, 2022). The main theoretical basis of the "Fengqiao Model" is based on emotional governance. This model proposes to use close social relationships among residents to achieve residents' self-governance, with grassroots government responsible for guiding and supporting residents. The "Fengqiao Model" effectively improves the efficiency of neighborhood governance and reduces administrative costs. Neighborhood renewal, a typical project of neighborhood management, can also draw lessons from the "Fengqiao Model". In line with Sundquist et al. (2016), a neighborhood with a lower connection between the government and residents tends to be more disorganized. If residents have good social relationships, the government can guide them to reduce conflict and reach consensus.

Moreover, the underlying rationale for this phenomenon may be attributed to the structure of grassroots governance in China and the entrenched attitudes of its citizenry toward public affairs. Parés, Bonet-Martí, and Martí-Costa (2012) have conducted a rigorous inquiry into the urban renewal policies and governance networks of Catalonia, Spain, and have contended that areas with superior social capital exhibit more efficacious functioning of resident organizations and heightened levels of cooperation among inhabitants. This is not consistent with the findings of this study. Li (2013) has performed a comparative analysis of social capital and social class between China and Britain, and has posited that Chinese citizens evince relatively less inclination to partake in neighborhood affairs and governance-related activities than their British counterparts. This is explicable in part by the paucity of a tradition in China akin to that which endures in countries like Britain, whereby citizens engage in self-governing organizations. Although some grassroots self-governing organizations in China have rapidly developed over the past three decades, they remain subject to governmental surveillance and are regarded with circumspection and suspicion by the citizenry. This deficiency in grassroots governance capabilities poses a formidable obstacle to the residents' ability to rely exclusively on their own collective efforts to drive public affairs such as neighborhood renewal. In particular, the more social cohesion there is among residents, the easier it is for residents' organizations to be generated (Bruce & Clarson, 2017). The lack of self-governance capacity, in turn, can easily lead to conflicts among residents during renewal projects. As such, this study recommends that prior to the implementation of resident-led neighborhood renewal project in China, the government must disseminate governance-related knowledge at the neighborhood level, foster enhanced residents' self-governance capabilities, or even participate in project implementation. Such measures are germane not only to the advancement of neighborhood renewal projects, but also to the cultivation of Chinese neighborhood resident self-governance.

5.2. *Adding insult to injury: When residents have a low willingness to renewal, the government needs to be cautious of their relationships*

Social networks among residents may also cause problems for the government. Although in Section 5.1 of this study mentions that the government can promote a greater effect of general trust among residents, this conclusion mainly applies to scenarios where the government's interests are aligned with those of residents. However, according to Section 0 (3), this study found that higher *GT* scores lead to larger standard deviations when residents are unwilling to participate in neighborhood renewal. At the same time, increasing *GT* did not significantly increase the number of cooperative residents. Therefore, this study suggests that, in situations where there is disagreement between the government and residents, an excessively high level of social capital among residents may lead to more intense conflicts of interest within the community. In line with Dai, Fan, Wang, Yanghong, and Ma (2021), this study suggests that high levels of social cohesion do not necessarily lead to good governance and may instead cause conflicts among residents.

The reason for these conflicts lies in the sense of betrayal that occurs when close relationships between residents and opposing opinions come into play simultaneously. For example, the government of Shijingshan District in Beijing, China, had proposed a renewal plan for a neighborhood called "Shi Wan Ping" located in the district (Sijiu City Story, 2021). However, some residents of this neighborhood preferred demolition to renewal, because they would receive higher compensation for demolition. Therefore, they used their neighborhood relationships to convince other residents of the neighborhood to oppose the renewal project. These opposing residents even chanted slogans such as "Residents who agree with the renewal plan are all traitors." Based on this case, we can see that it is difficult to achieve absolute equity in the distribution of benefits to residents in renewal projects. Therefore, each neighbor has their own interests and attitudes. If a resident's close neighbors do not support their viewpoint, the resident may feel betrayed. In such a situation, residents' cooperative behavior in the renewal project is determined not only by their own interests, but also by their relationships with others (Huang et al., 2023). Therefore, the conflicts that arise during the redevelopment process are not only due to conflicts of interest, but also include conflicts based on social relationships. Pillai, Hodgkinson, Kalyanaram, and Nair (2017) proposed close social relationships can hinder the emergence of comprehensive cooperation when actors identify too closely with their network partners.

This phenomenon is not only observed in neighborhood renewal in China, but has also been examined in research conducted in other countries. Cento Bull and Jones (2006) analyzed the role of social capital in urban renewal processes in two cities: Naples, Italy and Bristol, United Kingdom. Cento Bull and Jones (2006) found that in Bristol, residents with high levels of social capital facilitated participation in social organizations and provided valuable input for the urban renewal process. However, in Naples, Cento Bull and Jones (2006) discovered that although social capital was also abundant, virtuous resident organizations were lacking. In addition, some social actors sought to advance their interests by engaging with other levels of government when there was disagreement between the government's overall plan and the opinions of residents. This greatly impeded the progress of the renewal project. Thus, although governance structures differ across nations, caution should be exercised with respect to residents' social capital. As Woolcock (1998) has argued, social capital is not a panacea and more is not necessarily better.

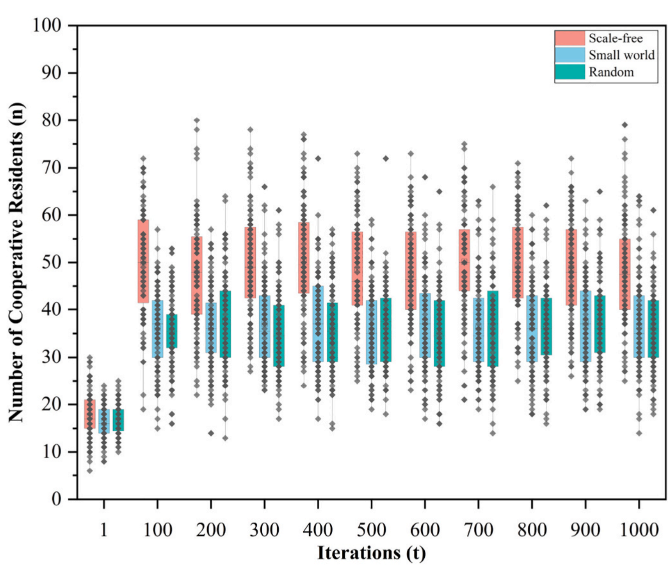


Fig. 11. Box-plot of Scenario 2.

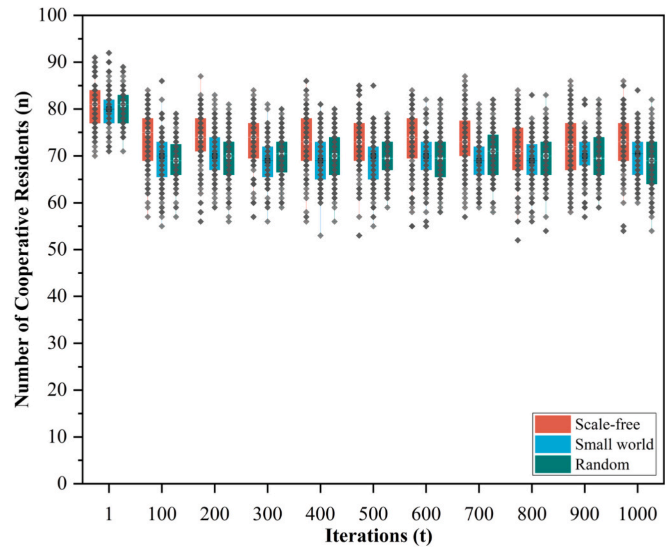


Fig. 12. Box-plot of Scenario 3.

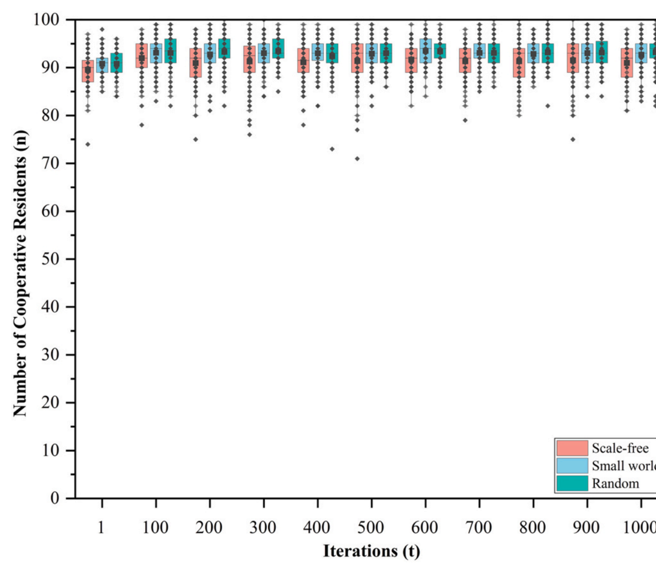


Fig. 13. Box-plot of Scenario 4.

5.3. The most favorable scenario for neighborhood renewal is when the government guides and residents cohere

This study concludes that there are three types of scenarios, all based on the real world: government-mandated, government-guided, and resident-led renewal projects. As described in Section 4.3, government-guided renewal projects tend to generate the highest number of collaborators regardless of whether GT is high or low. Fig. 12 and Fig. 13 show that government-guided renewal projects can always stabilize at a percentage of cooperative residents of approximately 60% or more. Therefore, this study suggests that government-guided renewal projects are the best form of neighborhood renewal in China. What are the reasons for this? This study attempts to analyze the simulation results and real-world cases.

These kinds of government-mandated renewal projects have gradually decreased in China. These kinds of projects mainly exist as government-funded and managed projects such as façade renovation. However, when physical demolition and reconstruction were the main focus, this kind of project was once the mainstream. This type of project is characterized by the government acting as a point of contact and coordinator between the various parties; however, the government is actually a major stakeholder (Sun, Yung, Chan, & Zhu, 2016). Through these projects, the government can achieve political gains and financial revenue. These benefits, in turn, motivate the government to advocate for the successful implementation of renewal projects, which may lead to the loss of residents' sense of social identity (Tavano Blessi, Giorgio, Sandri, & Pilati, 2012). In Shenzhen, China, there was even a case where the grassroots government spent 14 million RMB to repaint the facades of houses that were to be demolished (Jiang, 2020). Although a small number of residents may agree to renewal under the authority of the government, this causes more residents to lose trust in the government, as shown in Fig. 10 and Fig. 11. This kind of dissatisfaction can expand into collective action with the support of general trust, as mentioned in Section 5.2. Therefore, this study does not recommend the implementation of this type of renewal project.

For resident-led renewal project, we can conclude from Fig. 6 in Section 0 that, when the level of social capital is low, the proportion of cooperative residents with different *GT* values usually stabilizes at approximately 60%. In China, the installation of elevators in old neighborhoods is a typical neighborhood renewal project. In many cities, the installation of elevators is often performed by the residents themselves, with the government providing only political support and financial subsidies. In other words, elevator installation is a typical project with a low level of *SCT*. However, this study found that in many cities in China, the policy is that elevators can be installed if two-thirds of the residents agree (The People's Government of Guangzhou Municipality, 2016; The People's Government of Shantou Municipality, 2014). According to the results of this study, this kind of policy can improve the efficiency of elevator project implementation, because in most cases the requirements of two-thirds of the residents can be met. However, this study also raises the question of whether this type of policy is a means by which the government can shift its responsibility to the residents. Because the government does not have to play a very important role (low *SCT*), it can promote the installation of elevator systems without much involvement. In the online mailbox of the Shanghai Municipal People's Government in China, a citizen pointed out the disadvantages of this type of policy. This citizen believed that this type of policy would shift conflict from residents to the government, residents, and enterprises within the resident group itself (The People's Government of Pudong New Area, Shanghai., 2022). Therefore, this study does not recommend relying solely on residents for neighborhood renewal.

Such projects are gradually being advocated as government-guided renewal projects. For example, the Jinsong neighborhood renewal project is a project initiated by a private-sector group in Beijing (Colin, 2020). This renewal project applied the "five-party linkage" model, which refers to the cooperation between residents, the neighborhood committee, government, private-sector, and community coordination (Zhang, Zhang, & Guo, 2021). Shen, Yao, and Wen (2021) proposed that in this model, the effective involvement of residents, government, private sector, and other stakeholders in the project implementation process effectively brings them together to participate in the governance of the renewal project. In this type of project, the government does not force residents to undergo renewal projects, but instead plays the role of a coordinator. As a result, on the one hand, the government can leverage and even enhance residents' social capital (as per Section 5.1); On the other hand, because there is no conflict of interest between the government and residents, the social relations between the residents will not cause any problems for the government (as per Section 5.2). Therefore, this study suggests that this type of project should be promoted more in the future.

5.4. The differences in social network structure types have an impact on residents' cooperation

According to Section 4.3 Table 4-4, this study found that network structure has a significant impact on the evolution of residents'

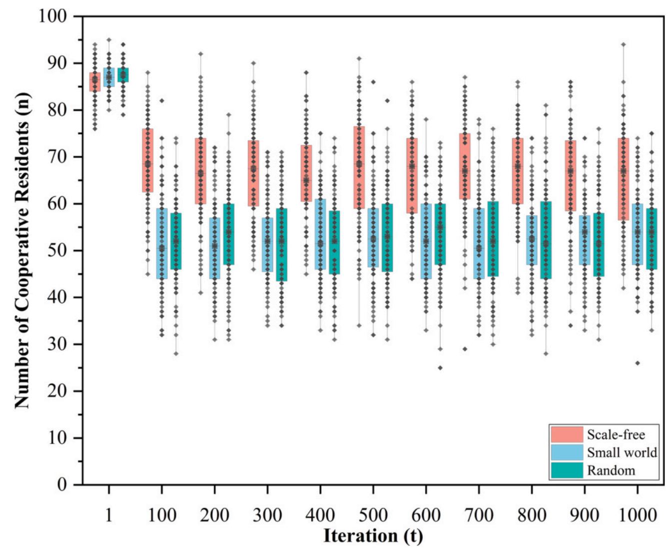


Fig. 14. Box-plot of Scenario 5.

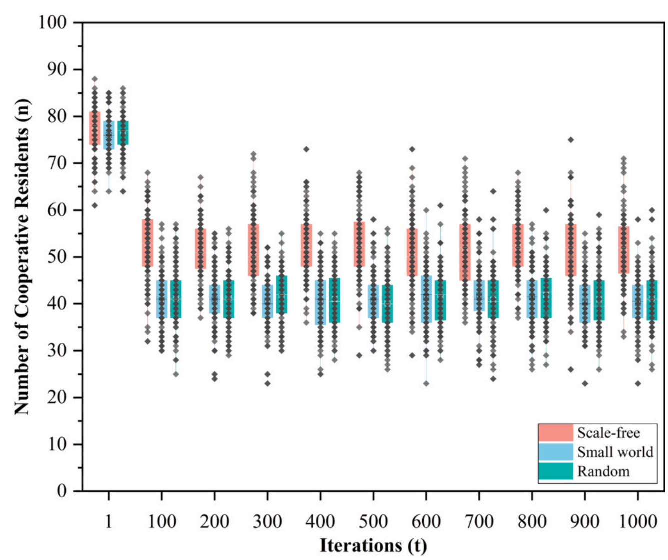


Fig. 15. Box-plot of Scenario 6.

cooperative behavior. The percentage of residents with cooperative behavior varied with the different network structures. This result supports Jiang et al. (2014), who also assumed that network structure has an influence on cooperative behavior. As shown in Sections 4.3 Fig. 10 to Fig. 15, the number of cooperative residents is highest in the scale-free network in most scenarios. However, in Scenario 4, the number of cooperative residents was lowest in the scale-free network. Because this study does not clarify what causes the differences in network structure, further research on the residents' social network structure is needed.

5.5. Limitations and future research

Like many studies, this study is not without limitations. Firstly, due to the constraints of time and research focus, the study did not take into account the formation and dissolution of social relationships among residents. Secondly, due to the difficulty in obtaining data, the study did not develop a detailed social network of residents in the real world and compare it with the results obtained. Nonetheless, as Bonabeau (2002) suggests, the results of agent-based modeling should be interpreted qualitatively rather than quantitatively. Therefore, this study undertook a qualitative comparison between the simulation results and real-world observations in order to demonstrate the validity of the results. Lastly, due to resource and time constraints, the study did not conduct surveys in more cities to further enhance the explanatory power of the theoretical model. Instead, the research team constructed the model based on a careful selection of three sample cities that met the research needs.

Future research should investigate the following three aspects: First, the method of developing residents' social network structures can be researched. Because it is difficult to obtain complete information about residents' social networks, it is difficult to develop a complete social network structure. This study also suggests that differences in network structures influence residents' cooperative behaviors. Therefore, future research should further investigate the use of algorithms to generate network structures for residents. Second, the evolution of residents' networks can be studied. Residents may establish or break social relationships with their neighbors based on cooperation or conflicts of interest. This may cause the network structure to change over time, which can have significant effects on residents' cooperative behavior. Future research should therefore focus on examining how residents' networks evolve and how they influence their cooperative behavior. Finally, residents' demographic characteristics should also be considered in future research. Residents' income, gender, age, and living space may influence their cooperative behavior. Therefore, future research should examine how these demographic characteristics affect residents' cooperative behavior and consider them when developing strategies to promote cooperation.

CRediT authorship contribution statement

Ruopeng Huang: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Guiwen Liu:** Data curation, Formal analysis, Validation, Writing – review & editing. **Kaijian Li:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Conceptualization. **Zhengxuan Liu:** Data curation, Formal analysis, Validation, Writing – review & editing. **Xinyue Fu:** Supervision, Resources, Investigation, Conceptualization. **Jun Wen:** Writing – review & editing, Validation, Supervision.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compenvurbsys.2023.102022.

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