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Factors Driving Social Capital Participation in Urban Green Development: A Case Study on Green Renovation of Old Residential Communities Under Urban Renewal in China

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Abstract: Urban green development is crucial for citizen well-being and serves as a key pillar of sustainable development strategies. Collaborative governance mechanisms help address management, technical, and financial challenges in urban green development. The renovation of old residential communities within the context of urban renewal is becoming a focal point in the development of Chinese cities. To promote green development in the renovation of old residential communities in China, this study introduces the collaborative governance mechanism of government–social capital cooperation and identifies the factors influencing social capital participation in green development. A hybrid approach is proposed, combining grounded theory, IGAHP subjective weighting, CRITIC objective weighting, game theory, and ISM. This approach is applied to identify, evaluate, and analyze the factors driving social capital participation in the green renovation of old residential communities. The results indicate that government incentives and constraints, policy support, the costs and benefits of implementing green renovation, the development of green renovation technologies, and construction technical abilities significantly influence the decision-making of social capital. The findings provide theoretical support for decision-making by governments and social capital in participating in the green renovation of old residential communities and offer a methodological reference for analyzing social capital participation in other urban green development projects and for further policy formulation. Future research should focus on examining social capital involvement in other types of urban green development projects.

Keywords: social capital; green development; renovation of old residential communities; driving factor; collaborative governance

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1. Introduction

Amid profound adjustments in the global economic structure, new economic models such as green economy, circular economy, and low-carbon economy have gradually emerged. These models emphasize the simultaneous pursuit of economic growth, environmental protection, and resource conservation, aiming for coordinated development across economic, social, and environmental domains. The construction of green cities, which serve as crucial backdrops and vessels for daily life, has garnered global attention due to its impact on citizen well-being [1,2]. Consequently, evaluating urban ecosystems has become a focal point of research, with studies such as urban carbon stock assessments

gaining prominence [3]. In recent years, governments around the world have introduced a series of policies, measures, and regulations to support green development, providing robust guarantees for the advancement of urban green initiatives [4,5]. These policies not only define the objectives and tasks of green development but also incentivize social capital investment in green industries and environmental projects through financial subsidies, tax incentives, and green finance mechanisms [6]. At the same time, enhanced environmental regulation and enforcement ensure the effective implementation of green development policies. However, due to variations in urbanization processes across different countries, certain urban development models have not received sufficient attention, yet they significantly impact urban ecosystems.

Why focus on the renovation of old residential communities (RORC) within the context of urban green development? Urban development is a continuous process of renewal and transformation. In the case of China, with the urbanization rate approaching 65%, the country has entered the mid-to-late stages of urbanization, where the quality of urban development has become a focal point [7]. Migration-induced urban shrinkage has led to a series of issues, including housing vacancies and a downturn in the real estate market. At this juncture, the Chinese government has proposed an "urban renewal" strategy as part of its broader urban development agenda [8]. While new construction projects are gradually decreasing, the renovation of existing projects has become the primary focus of construction activities. Moreover, the core component of China's current urban renewal strategy is RORC [9]. This renovation is emerging as a central task within China's construction sector and a key public welfare initiative that cities are actively pursuing [10]. During rapid urbanization over the past three decades, urban residential areas in China were often planned, constructed, and managed in a relatively unrefined manner, leaving behind numerous deficiencies. As the focus of construction shifts from expanding new developments to upgrading existing ones, critical questions arise: How can the renovation of old residential communities be made greener? How can the goals of urban green development be better achieved? Addressing these questions is essential in the current context.

Collaborative governance is key to advancing urban green development. Collaborative governance, which involves the participation of government, social capital, researchers, and citizens, is recognized as a crucial approach to promoting urban green development [11]. In the current context of renovating old residential communities in China, government fiscal funds have dominated the financial support for these projects [12]. However, social capital's participation has been limited due to the lack of clear investment return pathways. As RORC progresses, the sustainability of government financial support is increasingly in question, necessitating the exploration of new market-driven approaches. Social capital brings substantial financial resources, market expertise, and technological advantages to the table. Therefore, to ensure the green development of these renovation projects, it is essential to understand the complex mechanisms that influence social capital's participation in green renovation initiatives. This study aims to investigate these mechanisms.

In addition to the motivations outlined above, another primary objective of this study is to identify the most appropriate method for analyzing the problem. This research aims to assist both government bodies and social capital in making actionable decisions regarding RORC within the context of promoting urban green development. We posit that different scenarios may have varying impacts on social capital's participation in green renovations. Our preliminary research findings have provided initial evidence supporting this hypothesis [13]. Therefore, we have designed a hybrid approach that aids in exploring the complex mechanisms driving social capital's involvement in the green renovation of old residential communities. To the best of our knowledge, no existing literature has employed the hybrid approach proposed in this study, particularly within the field of urban green development

research. The main contributions and innovations of this paper are as follows. Firstly, by focusing on green RORC within the context of urban renewal, this study introduces a new perspective that enriches the current research on urban green development. Secondly, considering that RORC is still a relatively new phenomenon in China, with its characteristics not yet fully explored, we have developed a comprehensive hybrid research framework. This framework integrates the principles of grounded theory, subjective and objective weighting methods based on IGAHP and CRITIC, game-theoretic weighted ranking, and ISM-based factor analysis. Finally, the study delves into the factors influencing social capital's participation in green renovation projects, offering theoretical support for government policymaking in urban green development and providing a reference for collaborative governance policies aimed at fostering urban sustainability.

The rest of this paper is organized as follows: Section 2 proceeds by presenting a literature review that discusses the current understanding of social capital participation in urban green development, particularly focusing on the green renovation of old residential communities within the context of urban renewal. In Section 3, the research methodology employed in this study is then outlined, detailing the hybrid approach that integrates grounded theory, subjective and objective weighting methods based on IGAHP and CRITIC, and game theory. This is followed by a comprehensive analysis of the influencing factors and their relationships, using interpretive structural modeling (ISM). In Section 4, the paper concludes with a discussion of the findings, highlighting the key drivers and barriers to social capital participation in green renovations, as well as recommendations for policymakers and practitioners. Finally, the conclusions, limitations, and potential further research are given in Section 5.

2. Literature Review

This study explores the connection between social capital participation and RORC in China within the broader context of urban green development, particularly from the perspectives of urban sustainability, community renewal, and encouraging social capital investment. This relationship was relatively overlooked in the existing literature.

Promoting green processes in urban development is a pressing issue that requires urgent attention. Existing studies have explored the spatial aspects of urban green development. Wang et al. [14] examined the spatiotemporal changes in urban environments across different stages of socioeconomic development, contributing to the theory of urban growth and the environment. Haaland et al. [15] conducted a review of green development in compact cities, suggesting measures such as improving green space quality to address the limitations of space for green development. Arshad et al. [16] argued that rapid and unplanned urban expansion has led to urban heat island effects, necessitating effective policies to improve living environments. Some researchers have also examined urban green development from the perspectives of government regulation and support. Vujičić et al. [17] studied the regulatory mechanisms of urban green development infrastructure, identifying obstacles and drivers that impact its development. The study emphasized that collaboration among stakeholders is essential for maximizing the benefits of green infrastructure. Yu et al. [18], using resource-based cities in China as a case study, evaluated the factors influencing green innovation, noting that government support plays a crucial role in fostering urban green development. Some researchers have also investigated the integration of green development with economic growth. Woon et al. [19] focused on urban green energy development, summarizing the challenges and recommendations across environmental, economic, and social dimensions—an important aspect of green city construction. Jiang et al. [20] explored the impact of the digital economy on urban green development, finding a positive relationship between the two. Ma et al. [21] studied the

green transformation of urban clusters, addressing efficiency measurements, influencing factors, and implementation mechanisms to build a systematic theoretical framework for urban green transition. In addition, the rapid infrastructure development in some Asian regions has drawn attention to the urban heat island effect and its related environmental and social challenges, leading to a surge of interest in this area of research [22]. It is evident that the green and low-carbon transformation of cities has become a global consensus. However, in existing research on urban green development, the focus was predominantly on the green development of expanding cities, or incremental development, with relatively little attention given to the green development of existing urban infrastructure, or stock development.

As a crucial component of China's urban renewal strategy, the government is actively promoting the renovation of old residential communities. To improve the environment and living conditions in these communities, it is essential to make scientifically informed decisions regarding their renovation [23]. The relationship between the renovation of old residential communities and urban green development has gradually garnered attention. These communities, being a significant part of urban renewal, have a substantial impact on reducing carbon emissions in the urban building sector. For instance, Luo et al. [24] conducted a life-cycle assessment of the carbon emission impacts of renovating old residential communities, uncovering the carbon reduction potential of such projects. Similarly, Kertsmik et al. [25] discussed the effects of various renovation strategies on carbon emissions in heritage residential buildings, while Zhang et al. [26] advocated for maximizing climate and resource utilization to enhance resident comfort and drive decarbonization in these projects. Renovating old residential communities requires significant investments, making financing a critical area of related research. Galvin [27], using Germany as a case study, analyzed the costs associated with such renovations, finding that they require substantial financial input, with traditional returns unable to offset these costs. Liu et al. [28] argued that if the government can design systems to reduce coordination costs, the renovation of old residential communities can be sustainable. In recent years, researchers have begun to explore innovative financing models for these projects. For example, Han et al. [29] proposed the innovative "EPC + O + F" model to address financial bottlenecks in renovation projects. Additionally, some researchers have started considering the introduction of Public–Private Partnership (PPP) models into China's old residential community renovations, analyzing the factors that drive social capital participation [30]. Market-oriented financing models are likely to become key solutions to the funding challenges faced by these renovation projects [31]. While there is growing attention on green RORC and its financing, research on the involvement of social capital in these green renovations remains scarce.

The participation of social capital in construction projects is increasingly influenced and constrained by various internal and external factors. Social capital, in the context of PPP, refers to the entity providing advanced technology, management, and funding for construction projects [32]. From the perspective of the definition and characteristics of social capital, Liu et al. [33] discussed a range of factors affecting the escalation of social capital commitment. Government policies that support the involvement of social capital in PPP projects are also rooted in the fundamental nature of the collaboration between government and social capital [34]. For example, Filippini et al. [35] analyzed the determinants of investment decisions in energy-efficient renovations in Switzerland, emphasizing the supportive role of government policies. Kavishe et al. [36], focusing on the housing sector in Tanzania, identified professional skills, project management, and institutional frameworks as key factors influencing the implementation of PPP projects. The factors influencing social capital participation were continuously explored by researchers. Qin et al. [37], using coastal infras-

tructure projects as a case study, examined how the financial characteristics of social capital entities impact project outcomes, finding that factors like debt repayment capacity and equity structure can negatively affect participation. Solheim-Kile et al. [38] found that trust, reciprocity, and other relational factors significantly influence social capital participation and the quality of project collaboration. Hou et al. [39] proposed a novel dynamic subsidy mechanism that effectively enhances government incentives and the operational quality of social capital. Additionally, some researchers have highlighted risk factors as critical to social capital investment decisions. A well-balanced risk-sharing arrangement can increase the willingness of social capital to invest [40]. Wang et al. [41] demonstrated that social capital's focus on long-term versus short-term benefits is a key determinant of positive or negative decision-making behaviors, with "reasonable risk-sharing" and "partnerships" being effective means to promote positive decision choices. It is evident that the factors influencing social capital participation in PPP models are complex and diverse. Current research has produced a wealth of findings that provide valuable references and insights for the successful advancement of this study. In the process of urban renewal for aging residential communities, collaboration among multiple stakeholders—including governments, social capital, community residents, and professional organizations—is particularly critical. Existing studies have highlighted various aspects of stakeholder involvement. For instance, Teng et al. [42] evaluated and simulated key conflict-inducing factors based on stakeholder analysis, demonstrating that increasing income for both governments and residents significantly reduces the likelihood of conflict. Sun et al. [30] refined the application of the Public–Private Partnership (PPP) model in urban renewal projects by adopting the perspective of social capital. Meanwhile, Huo et al. [43] analyzed the distribution of benefits among stakeholders in urban renewal, providing a foundation for the sustainable advancement of such projects. However, research specifically addressing the factors influencing green renovation in aging residential communities remains limited. This study, while exploring social capital participation in the green renewal of older residential areas, aims to delve deeper into the progress of multi-stakeholder collaboration and its impact on social capital involvement. Nonetheless, challenges and obstacles exist in the collaboration process, such as unequal benefit distribution, communication barriers, and information asymmetry. These issues warrant further attention and resolution in future research.

In summary, the review of the existing literature provides important references for establishing a preliminary framework of the factors influencing social capital participation in urban green development projects, laying a solid theoretical foundation for future research. Additionally, it is worth noting that RORC is still a relatively new phenomenon in China, and the relevant literature may be incomplete, with respondents' understandings of the renovation process potentially showing some degree of bias.

3. Methodology

3.1. Research Philosophy

This study primarily examines the driving factors influencing social capital participation in the green renovation of old residential communities. In the foreseeable future, social capital is expected to play a central role in such renovation projects, making its willingness to engage in green construction a critical determinant of the overall success of these initiatives. Understanding the characteristics of social capital and how these characteristics shape their motivation to participate in renovation projects can provide valuable insights for the government in formulating strategies to promote the green development of old residential community renovation efforts.

However, the current literature on social capital participation in the green renovation of old residential communities remains limited and does not directly address the issues

explored in this study. Additionally, relying solely on interviews with a subset of stakeholders risks introducing subjective biases. To address these gaps, this study adopts a scientific approach to investigate the research problem, ensuring a more rigorous and objective analysis beyond the subjective experiences of a limited group of participants.

3.2. Research Approach

To analyze the driving factors behind social capital participation in the green renovation of old residential communities, this study recognizes the limitations of existing literature in terms of relevance and sufficiency, as well as the inherent subjectivity of expert interviews. Therefore, a mixed-method approach combining qualitative and quantitative methodologies was adopted. Mixed-method research, as a branch of multi-method studies, integrates quantitative and qualitative data collection techniques with systematic empirical analysis procedures, making it particularly valuable for addressing complex practical issues.

Considering the nature of the research questions, the study's contextual background, and the anticipated research outcomes, this study ultimately selects a mixed-method approach, incorporating both qualitative and quantitative analyses, to provide a comprehensive understanding of the driving factors influencing social capital participation.

3.3. Research Strategy

Based on the objectives of this study, the following research strategy was adopted: First, drawing on the principles of grounded theory, we utilized a combination of literature review and interviews to gather information relevant to the research objectives, serving as the primary data sources. Subsequently, given the widespread application of subjective and objective weighting methods in existing research for factor identification and indicator system development [44,45], this study employed a mixed-method approach integrating these methodologies. Specifically, in the process of constructing the indicator system, the Improved Group Analytic Hierarchy Process (IGAHP) method was used for subjective weighting, while the Criteria Importance Through Intercriteria Correlation (CRITIC) method was employed for objective weighting. The combination of these methods, based on game theory, was used to select key indicators. Finally, the interpretive structural modeling (ISM) approach was chosen to represent the causal and hierarchical relationships among these key indicators.

We believe that through systematic data collection and analysis, the key role and influencing factors of social capital in the green renovation of old residential communities can be revealed. We collected data through literature reviews, interviews, and surveys. During the research process, a stratified random sampling method was employed to ensure the representativeness and diversity of the samples. The selected old residential communities were required to be representative and should have undergone renovation between 2021 and 2024.

3.4. Time Horizon

Given that old residential community renovation projects have only recently emerged in China, the government is still in the process of refining its conceptual framework, particularly for green renovation projects, which are far from widespread. Therefore, this study focuses on the planning and policy definitions for old residential community renovations in China during the five-year period from 2020 to 2024. This includes the policy orientation for social capital participation in such projects and the national-level policy guidance on urban green development under the "dual carbon" goals.

The case samples selected for analysis are old residential communities built before the year 2000. The interview participants consist of experts, technical professionals, and

management personnel who were involved in theoretical research and practical work on old residential community renovation projects and urban green development between 2020 and 2024.

3.5. Data Collection and Data Analysis

This study aims to explore the factors influencing social capital participation in green RORC and to analyze the relationships among these factors. The evaluation of these influencing factors is conducted in three steps, as illustrated in Figure 1.

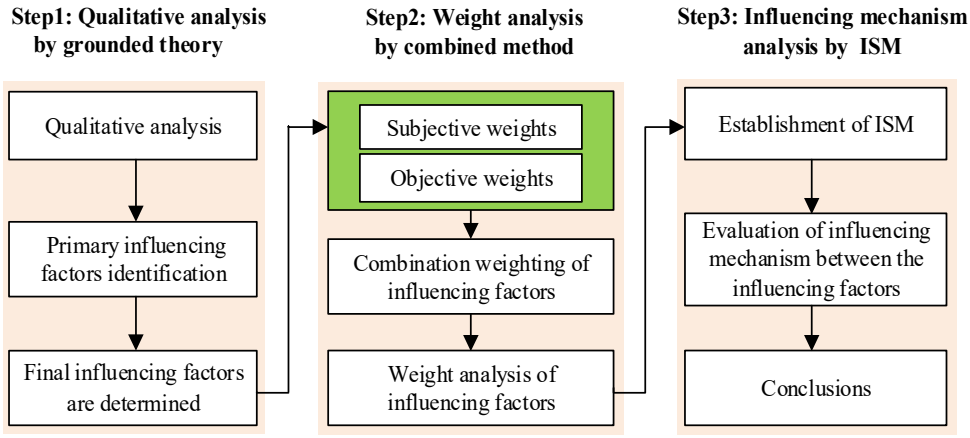

Figure 1. Research framework of hybrid approach.

3.5.1. Determination of Influencing Factors

The first step in the research framework proposed in this study is to identify the influencing factors. In this process, the study draws on the principles of grounded theory and employs literature reviews and expert interviews to identify the influencing factors. The process of identifying the preliminary influencing factors is illustrated in Figure 2.

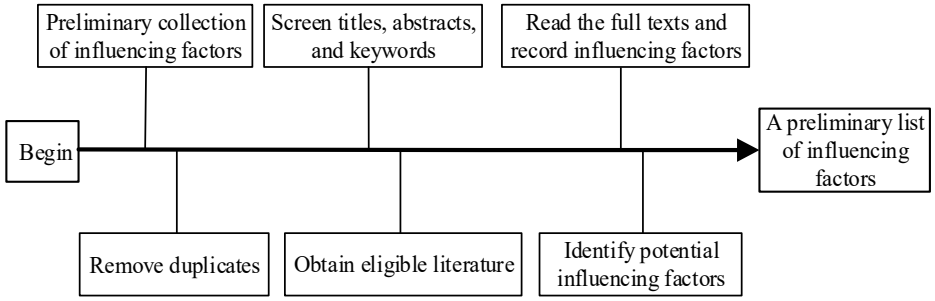

Figure 2. Identification of preliminary influencing factors.

3.5.2. Determination of Subjective Weights

The index weight vectors provided by the a-th and b-th experts for social capital participation in green RORC are denoted as $Y_a = (y_{a1}, y_{a2}, \ldots, y_{an})^T$ and $Y_b = (y_{b1}, y_{b2}, \ldots, y_{bn})^T$, respectively. Assuming that the degree of similarity between the decisions of the two experts is expressed by the Euclidean distance $d_{ab}(a, b = 1, 2, \ldots, T)$, the following formula is derived:

$$d_{ab} = d(Y_a, Y_b) = \sqrt{\sum_{i=1}^{n} (y_{ai} - y_{bi})^2} \quad (1)$$

where if $d_{aa} = 0$, $d_{ab} = d_{ba} \geq 0$, and the smaller the value of d_{ab}, the closer Y_a and Y_b are, indicating that the judgments of the two experts are more aligned. If and only if $d_{ab} = 0$, it shows that the judgments of the two experts are completely consistent.

Let the degree of similarity between the judgment of the *i*-th expert and the judgments of all other experts be expressed as d_i.

$$d_i = \sum_{j=1}^{m} d_{ij} \tag{2}$$

when if $d_i \geq 0$, a smaller d_i indicates that Y_i is closer to other weight vectors. When $d_i = 0$, and $d_{i1} = d_{i2} = \cdots = d_{im} = 0$, all feature vectors are equal, and the opinions of each expert are unified. At this point, the decision-making weight coefficient of the *i*-th expert is as follows:

$$\lambda_i = \begin{cases} 1/m, d_i = 0 \\ \frac{1/d_i}{\sum_{j=1}^{m} (1/d_j)}, d_i \neq 0 \end{cases} \tag{3}$$

The final comprehensive weight of an index of social capital participating in green RORC is denoted as *Y**. Then, the following can be expressed:

$$Y^* = \sum_{i=1}^{m} \lambda_i \times Y_i = (y_1^*, y_2^*, \ldots, y_n^*) \tag{4}$$

3.5.3. Determination of Objective Weights

Assuming that the existing dataset includes *m* objects to be evaluated and *n* evaluation indicators, the original data matrix *X* is structured as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \mathrm{L} & x_{1n} \\ x_{21} & x_{22} & \mathrm{L} & x_{2n} \\ \mathrm{M} & \mathrm{M} & 0 & \mathrm{M} \\ x_{m1} & x_{m2} & \mathrm{L} & x_{mn} \end{bmatrix} \tag{5}$$

where x_{mn} represents the value of the *n*-th evaluation indicator for the *m*-th object.

Then, the data are standardized to eliminate the influence of dimensionality, allowing for analysis according to a uniform standard. For positive indicators, the data can be processed using Equation (6). For negative indicators, the data can be processed using Equation (7).

$$x'_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{6}$$

$$x'_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \tag{7}$$

Then, the information carrying capacity should be calculated, which is represented by the standard deviation to indicate the contrast strength. The equation is as follows:

$$S_j = \sqrt{\frac{\sum_{i=1}^{m} (x_{ij} - \overline{x}_j)^2}{n-1}} \tag{8}$$

where $\overline{x}_j$ is the mean value of each index (column) data.

The equation for calculating conflict is as follows:

$$A_j = \sum_{i=1}^{n} (1 - r_{ij}) \tag{9}$$

where r_{ij} denotes the correlation coefficient between the *i*-th and *j*-th indicators.

The equation of information quantity is as follows:

$$C_j = S_j \times A_j \tag{10}$$

Finally, the equation for calculating the weight using the CRITIC method is as follows:

$$W_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{11}$$

3.5.4. Combinatorial Weighting Based on Game Theory

The previous steps have employed the IGAHP method and the CRITIC method to determine the subjective weights and objective weights, respectively. Let the basic weight vector be $v_p = \left\{v_{p1}, v_{p2}, \ldots, v_{pn}\right\}(p = 1, 2, \ldots, n)$; n represents the number of indicators, p represents the number of methods for calculating weights, and p takes 2. Let the linear index weight combination be $\alpha = \left\{\alpha_1, \alpha_2, \ldots, \alpha_p\right\}$, that is, any linear combination is as follows:

$$v = \sum_{p=1}^{n} \alpha_p \cdot v_p^T \tag{12}$$

where v represents the linear combination of weights, α_p is the weight coefficient, and ${v^T}_p$ is the transpose matrix of the basic weight vector set.

According to the aggregation theory of game theory, in order to minimize the sum of the deviation between v and v_p, the optimal combination weight coefficient should be sought. The equation is as follows:

$$\min \left\| \sum_{p=1}^{2} \alpha_p v_p^T - v_p \right\|_2, (p = 1, 2) \tag{13}$$

Equation (13) is transformed into a linear system of equations with the optimal first-order derivative conditions, resulting in the following:

$$\begin{bmatrix} v_1 v_1^T & v_1 v_2^T \\ v_2 v_1^T & v_2 v_2^T \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} = \begin{bmatrix} v_1 v_1^T \\ v_2 v_2^T \end{bmatrix} \tag{14}$$

Then, the optimized combination coefficients α_1 and α_2 are derived from Equation (14). These coefficients are subsequently normalized to yield the following:

$$\begin{cases} \alpha_1^* = \dfrac{\alpha_1}{\sum\limits_{p=1}^{2} \alpha_p} \\ \alpha_2^* = \dfrac{\alpha_2}{\sum\limits_{p=1}^{2} \alpha_p} \end{cases}, \tag{15}$$

The final combined weight is calculated as follows:

$$v^* = \alpha_1^* \cdot v_1^T + \alpha_2^* \cdot v_2^T, \tag{16}$$

3.5.5. Constructing the Interpretive Structural Model (ISM)

First, an ISM expert panel is established. Based on the defined problem and their years of accumulated experience, the expert panel engages in repeated discussions and research to identify the system elements and requirements. They then create a directed graph that illustrates the relationships between the system elements.

Next, the adjacency matrix and reachability matrix are determined. Based on the directed graph depicting the relationships between the system elements, the adjacency matrix A is established. The elements a_{ij} of matrix A are defined as follows:

$$a_{ij} = \begin{cases} 1 & S_i R S_j \quad R \text{ means that } S_i \text{ is related to } S_j \\ 0 & S_i \overline{R} S_j \overline{R} \text{ means that } S_i \text{ is not related to } S_j \end{cases} \tag{17}$$

where S is the set of directed graph nodes.

The unit matrix I is introduced into the adjacency matrix, and the reachability matrix M is obtained after multiple operations by Boolean algebra operation rules. The Boolean algebra operation process is as follows:

$$(A + I)^{K-1} \neq (A + I)^K = (A + I)^{K+1} = M, \tag{18}$$

Subsequently, hierarchical division is performed. The reachable set R is derived from the reachability matrix, the initial set Q, and the common set T, where $T = R \cap Q$. The reachable set represents all elements that can be accessed from node S_i; the antecedent set represents all elements that can reach node S_i. The intersection of the reachable set and the antecedent set represents the set of all elements that both reach and are reachable by node S_i. At this point, the elements within the set are identified as the top-level elements. By iteratively removing these top-level elements and reapplying the process, the subsequent levels are determined, ultimately resulting in the construction of a hierarchical directed graph.

Finally, interpretive structural modeling (ISM) is constructed.

3.6. Methodological Advantages and Limitations

This study primarily analyzes the factors influencing social capital participation in green RORC. Given that such renovations represent an emerging urban development model in China, with its specific connotations still being explored, there is a need to refine and improve traditional research methodologies. The advantages of the proposed hybrid approach in this study are as follows:

- Traditional Analytic Hierarchy Process (AHP) methods struggle to effectively capture expert opinions, particularly when there is significant disagreement among experts, leading to potential biases in evaluation results. The IGAHP method addresses these shortcomings by analyzing the variance in expert judgment weights and determining the decision-making weight coefficients among experts [46]. This approach mitigates the randomness of individual expert evaluations, reduces the uncertainty associated with subjective perceptions, and minimizes the impact of divergent opinions on the final evaluation. By balancing the commonality and individuality in expert decisions, IGAHP enhances the scientific rigor and rationality of subjective weightings. Ultimately, the aggregation of expert group decisions results in more reasonable indicator weights.
- The CRITIC method is a superior objective weighting technique compared to entropy weighting and standard deviation methods [47]. It calculates the objective weights of indicators by utilizing the standard deviation and correlation coefficients from statistical data, fully leveraging the data's objective properties to evaluate the research subject. Unlike methods that assume higher numerical values imply greater importance, CRITIC considers the correlation between indicators. For instance, a strong correlation between two indicators suggests a lower degree of conflict, while a weaker correlation indicates a higher degree of conflict. By accounting for both contrast intensity and inter-indicator correlation, CRITIC is particularly well suited

for calculating the objective weights of factors influencing social capital's involvement in green RORC.

- The study incorporates game theory principles and ISM to enhance the analytical process. The core idea of game theory in this context is to seek consistency in the weighting of evaluation indicators across different methods while minimizing the deviation between the composite weights of all evaluation indicators and the individual weights derived from each method [48]. ISM not only categorizes and stratifies the factors but also visually represents and explains the causal relationships between them, making the analysis more reliable and scientifically robust [49]. By integrating game theory and ISM, the study fully accounts for the practical experience and expertise of professionals, breaking down a complex system into multiple subsystems with various elements. This approach ultimately constructs a multi-level hierarchical model that clearly identifies the factors influencing social capital participation in the renovation of old residential communities.

Despite the careful design of the methodology in this study, several limitations still exist. For example, due to constraints on time, resources, and sample size, we may not have covered all relevant types of social capital and influencing factors. Furthermore, the subjectivity and uncertainty inherent in the data collection and analysis process may introduce some errors and biases in the research results. Therefore, future research should aim to expand the sample size and optimize data collection and analysis methods in order to enhance the accuracy and reliability of the findings.

4. Results and Discussion

4.1. Identifying Driving Factors for Social Capital Participation in Green RORC

The effectiveness of grounded theory in the selection of indicators was well documented in previous studies [50]. Green RORC in China represents an emerging type of construction project, with its specific characteristics and underlying principles still being refined. As such, the broader society has yet to fully recognize the unique aspects of these renovation projects, particularly those involving green initiatives. This study integrates the principles of grounded theory with a review of existing literature and expert interviews to identify relevant influencing factors.

Initially, relevant literature was reviewed through databases such as China National Knowledge Infrastructure (CNKI) and Web of Science (WOS) using keywords such as "old residential community renovation", "green renovation", "PPP", "social capital", "government regulation," and "influencing factors". A total of 448 relevant papers were identified. The process of extracting influencing factors from these papers was conducted in three steps. First, duplicate papers were removed, retaining only one representative study for analysis. Second, the outlines and abstracts of the remaining papers were reviewed to exclude those not aligned with the research objectives. Third, full-text readings were conducted, and the content that initially met the research criteria was recorded, organized, and summarized. This process resulted in the identification of 30 potential influencing factors, including competitiveness [51], government support [52], information disclosure [53], stakeholder needs [54], social responsibility [55], implementation costs [56], project benefits [57], technological levels [58], and financing capabilities [59]. Due to the lack of direct literature specifically addressing social capital participation in green RORC, this phase was primarily used to establish a preliminary list of potential influencing factors. This preliminary list of factors is presented in Table 1.

Table 1. Preliminary identified influencing factors.

No.	Influencing Factor	No.	Influencing Factor
1	Competitive ability promotion	16	Payback period
2	Government incentive and restraint mechanisms	17	Preferential tax policy
3	Information transparency	18	Completeness of policies and standards
4	Enterprise talent cultivation	19	The enterprise's own capabilities
5	Greenness of old residential community	20	The content of green renovation
6	Trust between partners	21	Improve the social visibility of enterprises
7	Uncertainty of the natural environment	22	Corporate social responsibility
8	Policy support	23	Research and development of green renovation technology
9	Patent rental fees	24	The cost of renovation
10	Government supervision	25	Benefits of renovation
11	Needs of participants	26	Project operation mode
12	Expected revenue	27	Project characteristics
13	Cost of publicity and education	28	The attitude of stakeholders
14	Environmental benefit	29	The stability of the economic environment
15	Social enterprise financing ability	30	Project characteristics

Subsequently, field research was conducted in old residential communities. Given that RORC in Liaoning Province was designated as a pilot project in China, the province's initiatives are considered representative. As the sample size reaches or exceeds 30, the properties of the normal distribution can be leveraged for inference of population parameters. Therefore, it is recommended to use at least 30 data points as the sample size. Thus, 30 old residential communities across 14 cities in Liaoning Province were selected for this study. Based on the findings from this field research, the initially identified influencing factors were refined. The revised list of influencing factors is presented in Table 2.

Table 2. Revised influencing factors.

NO.	Data Sources	Influencing Factors
1	The first field research survey	Competitive ability promotion, payback period, preferential tax policy, social capital responsibility consciousness, less profit space, expanding the market, research and development of green renovation technology, the competitive advantage is not obvious
2	The second field research survey	Laws and regulations, enrich the content of green renovation, reform enthusiasm, the government 's sense of responsibility, promotion of new technologies and methods, the quality of PPP projects, alleviate government financial pressure
3	The third field research survey	Improve the social visibility of enterprises, the degree of effort of social capital, the cost of implementing green renovation, benefits of implementing green renovation, the cost of implementing ordinary renovation, the income of ordinary transformation, sign a multi-party cooperation agreement, BOT mode is adopted, the renovation of the communities into a package

Finally, the influencing factor system was established. Considering that RORC in China is still relatively new, the content available in the literature may be incomplete, and the understanding of the renovation process by those surveyed may contain certain biases. Therefore, industry experts were invited to finalize the influencing factors. Five experts were consulted: two university professors specializing in urban green development, a government official involved in managing old residential community renovation projects,

and two technical experts from a consulting firm. Through semi-structured interviews with these experts, their professional knowledge and practical experiences were leveraged to optimize the revised indicator system, ensuring that it is both scientifically sound and reasonable. This process laid a solid foundation for subsequent research. The final set of indicators is presented in Table 3.

Table 3. Finalized influencing factors.

NO.	Criterion Layer	Schematic Layer	NO.	Criterion Layer	Schematic Layer
1	Government institutional factors	Government incentive and restraint mechanisms	15	Cooperation mechanism factors	Trust between partners
2		Information sharing platform	16		Sign a multi-party cooperation agreement
3		Policy support	17	Technological factors	Enrich the content of green renovation
4		Government supervision	18		Research and development of green renovation technology
5		Preferential tax policy	19		construction technical ability
6		The renovation of the communities into a package	20	Demand factors	Environmental benefit
7	Economic factors	The cost of implementing green renovation	21		Residents' preference for greenness
8		Benefits of implementing green renovation	22		Needs of participants
9		The cost of ordinary renovation	23	Social capitals' own factors	Corporate social responsibility
10		The income of ordinary renovation	24		Reform enthusiasm
11		The government publicizes the cost of green renovation	25		Social capital financing ability
12		Patent rental fees	26		Improve the social visibility of enterprises
13		Payback period	27		The scale of social enterprises
14		Less profit space	28		Enhance the market competitiveness of enterprises

4.2. Determining the Indicator Weights

Following the establishment of the indicator system for factors influencing social capital participation in green RORC, the IGAHP-CRITIC method is employed to assign weights to the data. Subsequently, the game theory-based combinatorial weighting method is used to determine the final weights of the indicators. This process integrates both subjective and objective factors from the data, addressing the limitations of single weighting methods that may yield partial or incomplete results.

4.2.1. Determining Subjective Weights Using IGAHP Method

Given that the green renovation of old residential communities is still in its preliminary stages in China, and there are few mature and scalable practice cases to serve as references, this study adopts an expert evaluation approach based on a questionnaire survey. In select-

ing experts for evaluation, this study invited individuals from academia who specialize in old community renovation or green construction, policymakers involved in formulating policies for old community renovation and green construction, and project managers with practical experience in old community renovation or green construction within enterprises.

Five experts were invited to participate in the evaluation process, including two university professors, one government official, and two senior executives from enterprises. For 28 secondary indicators, each expert provided initial subjective weight values W_i using a scale of 1 to 9, as shown in Table 4.

Table 4. Subjective weight of secondary indicators.

NO.	Influencing Factors	Weight	NO.	Influencing Factors	Weight
1	Less profit space	0.1301	15	The government publicizes the cost of green renovation	0.0190
2	Policy support	0.1125	16	Residents' preference for greenness	0.0167
3	Research and development of green renovation technology	0.1043	17	Information sharing platform	0.0160
4	Benefits of implementing green renovation	0.0920	18	Payback period	0.0130
5	Government incentive and restraint mechanisms	0.0784	19	The scale of social enterprises	0.0127
6	The cost of implementing green renovation	0.0629	20	The renovation of the communities into a package	0.0097
7	Environmental benefit	0.0558	21	Sign a multi-party cooperation agreement	0.0095
8	Government supervision	0.0470	22	Patent rental fees	0.0092
9	The income of ordinary renovation	0.0423	23	Improve the social visibility of enterprises	0.0070
10	Trust between partners	0.0380	24	Needs of participants	0.0067
11	construction technical ability	0.0328	25	Social capital financing ability	0.0045
12	The cost of ordinary renovation	0.0283	26	Enhance the market competitiveness of enterprises	0.0030
13	Preferential tax policy	0.0250	27	Corporate social responsibility	0.0019
14	Enrich the content of green renovation	0.0207	28	Reform enthusiasm	0.0013

4.2.2. Determining Objective Weights Using CRITIC Method

A questionnaire survey was conducted to determine the objective weights. The survey participants included university faculty, government staff, consulting technicians, business managers, and residents of old residential communities. A total of 120 questionnaires were distributed, of which 98 were valid, resulting in an effective response rate of 81.67%. The questionnaire utilized a 5-point Likert scale for scoring, with the following criteria: "Very Strong" (5 points), "Relatively Strong" (4 points), "Neutral" (3 points), "Relatively Weak" (2 points), and "Very Weak" (1 point).

To ensure the reliability of the questionnaire data, it is essential to conduct validation tests on the collected data. Both the reliability analysis and validity analysis of the data meet the required standards. In this stage, the weight calculation results using the CRITIC method are obtained, as shown in Table 5.

Table 5. Objective weight of secondary indicators.

Influencing Factors	Variability of Indices	Conflict of Indicators	Information Content	Weight
Government incentive and restraint mechanisms	0.781	42.111	32.871	0.0838
Information sharing platform	0.778	13.648	10.617	0.0271
Policy support	0.699	21.757	15.207	0.0388
Government supervision	0.713	13.449	9.586	0.0245
Preferential tax policy	0.736	13.630	10.027	0.0256
The renovation of the communities into a package	0.679	20.557	13.962	0.0356
The cost of implementing green renovation	0.773	18.135	14.019	0.0358
Benefits of implementing green renovation	0.741	35.037	25.976	0.0663
The cost of ordinary renovation	0.799	13.861	11.082	0.0283
The income of ordinary renovation	0.760	13.901	10.562	0.0269
The government publicizes the cost of green renovation	0.684	13.645	9.329	0.0238
Patent rental fees	0.664	14.569	9.679	0.0247
Payback period	0.569	15.556	8.849	0.0226
Less profit space	0.707	13.467	9.525	0.0243
Trust between partners	0.700	14.102	9.875	0.0252
Sign a multi-party cooperation agreement	0.736	13.480	9.917	0.0253
Enrich the content of green renovation	0.729	13.940	10.163	0.0259
Research and development of green renovation technology	0.844	41.940	35.388	0.0903
Construction technical ability	0.715	41.721	29.819	0.0761
Environmental benefit	0.655	14.496	9.489	0.0242
Residents' preference for greenness	0.684	13.801	9.433	0.0241
Needs of participants	0.791	13.509	10.691	0.0273
Corporate social responsibility	0.766	17.810	13.650	0.0348
Reform enthusiasm	0.751	18.079	13.575	0.0346
Social capital financing ability	0.771	17.918	13.812	0.0352
Improve the social visibility of enterprises	0.730	17.907	13.064	0.0333
The scale of social enterprises	0.611	14.602	8.917	0.0227
Enhance the market competitiveness of enterprises	0.741	17.583	13.031	0.0332

4.2.3. Combining Weighting Based on Game Theory

Using the game theory-based combined weighting method, the comprehensive weights of the influencing factors were calculated. By substituting the above subjective and objective weights into Equations (11) through (15), the linear combination coefficients α_1^* and α_2^* were determined as 0.0432 and 0.0568, respectively. The final combined weights of the influencing factors for social capital participation in green RORC are presented in Table 6.

Table 6. Combination weight of secondary indicators.

NO.	Influencing Factors	IGAHP	CRITIC	Weight (%)
1	Government incentive and restraint mechanisms	0.0784	0.0838	8.14%
2	Information sharing platform	0.0160	0.0271	2.23%
3	Policy support	0.1125	0.0388	7.06%
4	Government supervision	0.0470	0.0245	3.42%
5	Preferential tax policy	0.0250	0.0256	2.53%
6	The renovation of the communities into a package	0.0097	0.0356	2.44%
7	The cost of implementing green renovation	0.0629	0.0358	6.75%
8	Benefits of implementing green renovation	0.0920	0.0663	7.74%
9	The cost of ordinary renovation	0.0283	0.0283	2.83%
10	The income of ordinary renovation	0.0423	0.0269	3.35%
11	The government publicizes the cost of green renovation	0.0190	0.0238	2.17%
12	Patent rental fees	0.0092	0.0247	1.80%
13	Payback period	0.0130	0.0226	1.84%
14	Less profit space	0.1301	0.0243	4.00%
15	Trust between partners	0.0380	0.0252	3.07%
16	Sign a multi-party cooperation agreement	0.0095	0.0253	1.85%
17	Enrich the content of green renovation	0.0207	0.0259	2.36%
18	Research and development of green renovation technology	0.1043	0.0903	9.63%
19	Construction technical ability	0.0328	0.0761	6.74%
20	Environmental benefit	0.0558	0.0242	3.78%
21	Residents' preference for greenness	0.0167	0.0241	2.09%
22	Needs of participants	0.0070	0.0273	1.85%
23	corporate social responsibility	0.0019	0.0348	2.06%
24	Reform enthusiasm	0.0013	0.0346	2.02%
25	Social capital financing ability	0.0045	0.0352	2.19%
26	Improve the social visibility of enterprises	0.0070	0.0333	2.19%
27	The scale of social enterprises	0.0127	0.0227	1.84%
28	Enhance the market competitiveness of enterprises	0.0030	0.0332	2.01%

According to the calculation results of the combined weights, the highest weight factor is "Research and development of green renovation technology", which is 9.63 %. The influencing factor with the lowest weight ratio is "Patent rental fees", which is 1.80 %. Therefore, the greater the combined weight of the index, the more obvious the effect of the index on the target layer.

In this study, the indicators selected for the ISM analysis were screened based on composite weights. Given that an excessive number of indicators can increase the complexity and uncertainty of the analysis, the final set of indicators was chosen after a comprehensive consideration of their importance, representativeness, and data availability in reflecting the role of social capital in the green development process. Six indicators were selected from the 28 indicators in Table 7 as the key influencing factors for social capital to participate in green RORC, and 20% of the indicators reflect 99% of the original information. These six indicators are selected according to the size of the combined weight, which are the research and development of green renovation technology, the government incentive and restraint mechanisms, the benefits of implementing green renovation, policy support, the cost of implementing green renovation, and the construction technical ability. Although only six indicators were selected, these indicators encompass a substantial amount of information, effectively capturing the primary challenges and opportunities faced by social capital in the process of green renovation of old residential communities. They provide a comprehensive reflection of the key factors and their interrelationships in social capital's involvement in green RORC thus enabling a thorough understanding of the critical elements influencing this process.

Table 7. The adjacency matrix.

	Q1	Q2	Q3	Q4	Q5	Q6
Q1	0	0	1	0	0	0
Q2	1	0	0	0	1	0
Q3	0	0	0	1	0	0
Q4	0	0	0	0	0	0
Q5	0	0	0	0	0	1
Q6	0	0	1	0	0	0

4.3. Hierarchical Structure of Key Influencing Factors

According to the six key influencing factors identified above, we can study the internal relationship between these factors and explore the internal motivation of driving social capital to participate in green RORC.

The six key influencing factors of the government incentive and restraint mechanisms, policy support, the cost of implementing green renovation, the benefits of implementing green renovation, the research and development of green renovation technology, and the construction technology ability are coded as Q1, Q2, Q3, Q4, Q5, and Q6. According to the opinions of the ISM expert group, the relationship between the key influencing factors of the whole system is obtained, as shown in Figure 3. According to Figure 3, the grid diagram of the relationship between the factors of the whole system can be obtained. The grid diagram is shown in Figure 4.

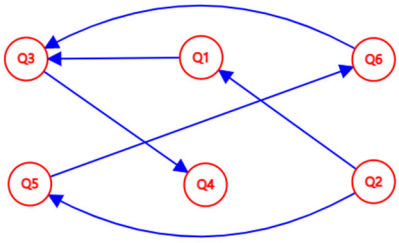

Figure 3. Relationships among key influencing factors.

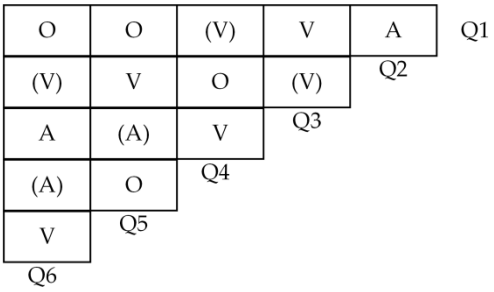

Figure 4. Network of relationships among influencing factors.

In Figure 4, "A" indicates that the column factor has an effect on the row factor, and "V" indicates that the row factor has an effect on the column factor. "O" indicates that the factors of ranks do not affect each other.

4.3.1. Establish Adjacency Matrix and Accessible Matrix

As seen in Figure 4, if one key influencing factor has an effect on another key influencing factor, mark it as "1"; however, if there is no connection between the key influencing factors (the connection between the influencing factors and themselves does not need to be judged), mark it as "0" and establish the adjacency matrix, as shown in Table 7.

The adjacency matrix indicates the direct relationship between the influencing factors. When the adjacency matrix is added to the unit matrix, the adjacency multiplication matrix can be obtained, as shown in Table 8.

Table 8. Adjacent multiplication matrix.

	Q1	Q2	Q3	Q4	Q5	Q6
Q1	1	0	1	0	0	0
Q2	1	1	0	0	1	0
Q3	0	0	1	1	0	0
Q4	0	0	0	1	0	0
Q5	0	0	0	0	1	1
Q6	0	0	1	0	0	1

According to the data in Table 8, the accessible matrix is obtained by using the SPSSPRO online data analysis platform. The accessible matrix shows that the transfer between influencing factors can bring indirect influence. The accessible matrix is shown in Table 9.

Table 9. The accessible matrix.

	Q1	Q2	Q3	Q4	Q5	Q6
Q1	1	0	1	1	0	0
Q2	1	1	1	0	1	1
Q3	0	0	1	1	0	0
Q4	0	0	0	1	0	0
Q5	0	0	1	0	1	1
Q6	0	0	1	1	0	1

4.3.2. Hierarchical Classification of Influencing Factors

The hierarchical classification of influencing factors is also the process of model decomposition. Based on the obtained reachability matrix, each influencing factor is classified into reachable sets and dominating sets, from which the intersection of the reachable and dominating sets is calculated. This allows for the extraction of the influencing factor set for hierarchical classification. The initial state of model decomposition is shown in Table 10, with the results of the first to fourth extractions listed in Tables 11–14, respectively. The hierarchical classification results are presented in Table 15.

Table 10. Initial state.

	Reachable Set	Reachable Set and Dominating Set
Q1	Q1, Q3, Q4	Q1
Q2	Q1, Q2, Q3, Q4, Q5, Q6	Q2
Q3	Q3, Q4	Q3
Q4	Q4	Q4
Q5	Q3, Q4, Q5, Q6	Q5
Q6	Q3, Q4, Q6	Q6

Table 11. Results after first extraction.

	Reachable Set	Reachable Set and Dominating Set
Q1	Q1, Q3	Q1
Q2	Q1, Q2, Q3, Q5, Q6	Q2
Q3	Q3	Q3
Q5	Q3, Q5, Q6	Q5
Q6	Q3, Q6	Q6

Table 12. Results after second extraction.

	Reachable Set	Reachable Set and Dominating Set
Q1	Q1	Q1
Q2	Q1, Q2, Q5, Q6	Q2
Q5	Q5, Q6	Q5
Q6	Q6	Q6

Table 13. Results after third extraction.

	Reachable Set	Reachable Set and Dominating Set
Q2	Q2, Q5	Q2
Q5	Q5	Q5

Table 14. Results after fourth extraction.

	Reachable Set	Reachable Set and Dominating Set
Q2	Q2	Q2

Table 15. Hierarchical decomposition.

Hierarchy	Factors
1	The benefits of implementing green renovation
2	The cost of implementing green renovation
3	The government incentive and restraint mechanisms, the construction technical ability
4	Research and development of green renovation technology
5	Policy support

4.3.3. Constructing Interpretative Structural Model

According to the division of Table 15, the influencing factors of the same layer are represented by boxes of the same level, different levels are divided by dashed lines, and the hierarchical relationship is represented by upward arrows. The specific key influencing factors explain the structural model, as shown in Figure 5.

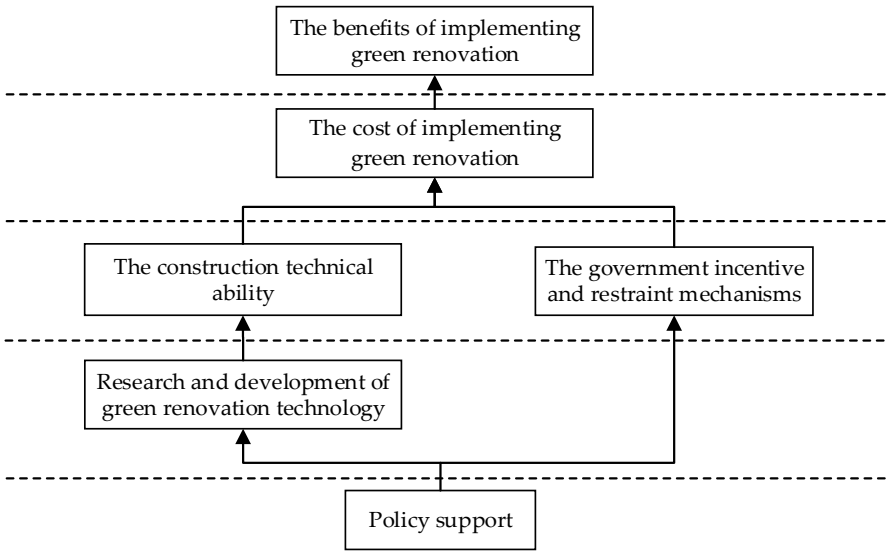

Figure 5. Interpretative structural model of key influencing factors.

4.4. Discussion

Unlike urban ecological renewal and redevelopment projects in the United States [60], which focus on telling the story of valuable communities, or those in Europe that integrate historical cultural heritage with the ecological environment [61], RORC in China is primarily focused on improving citizens' living conditions. Consequently, the factors influencing social capital participation in RORC under the urban green development goals differ not only from those in standard renovation projects but also from other types of urban green development initiatives. The findings of this study confirm this distinction.

1. Firstly, the urban environment serves as the foundation for residents' work and life, and its green development has garnered widespread global attention. Innovative solutions continue to emerge, such as the implementation of smart city initiatives to achieve low-carbon development [62]. Collaborative governance among multiple stakeholders is conducive to urban green development, with demand-driven initiatives and cost–benefit considerations being key to successful collaboration [63]. In particular, the coordinated governance between government and private capital can significantly reduce urban carbon emissions and promote sustainable urban development [64]. Davies et al. [65] investigated 30 companies of varying sizes and industries, analyzing their willingness to invest in urban green development projects. Key factors influencing their participation included project cost–benefit analysis, regulatory mechanisms, and corporate social responsibility. Meanwhile, He et al. [66], in their study on urban heat islands and sponge cities, emphasized that shared interests among stakeholders are critical in driving participation in green urban projects. They recommended considering technological, financial, institutional, and social aspects. For businesses, factors such as attitudes, subjective norms, and perceived behavioral control have a positive influence on their green development behaviors [67]. Most existing studies on factors influencing urban green development focus on production efficiency [68,69]. However, urban renewal projects, with their unclear return mechanisms, present more complex financing models under the green urban development framework. This study's findings also demonstrate that the factors social capital must consider in these projects are more intricate compared to traditional urban green development initiatives.
2. Secondly, existing research has already addressed the participation of private capital in traditional old residential community renovation projects. When making investment decisions, social capital involvement in such projects tends to focus more on factors like profitability and the financial strength of the enterprises themselves [30]. LIU et al. [70] explored the mechanisms behind corporate participation in old community renovations, concluding that participation attitude is the key factor influencing willingness to engage. However, their study was conducted from the perspective of internal capabilities and external conditions of the companies. While other studies on urban renewal projects have touched upon low-carbon urban development, the primary focus was on the models of social capital participation rather than on renovation projects for old residential communities, or the factors influencing such participation [71]. Collaborative governance is often regarded as an effective solution to the obstacles encountered during urban renewal processes, but cooperation among diverse stakeholders remains a key topic in current research [72]. Traditional urban renewal projects focus on collaboration among stakeholders, conflict resolution efficiency, and public participation, constrained by factors such as partnerships, location, and power dynamics [73]. Social capital typically views its involvement in these projects as an investment, with economic returns being the primary consideration, and governments have a variety of partners to choose from in such collaborations [74]. The

findings of this study however reveal that in the context of green urban development, social capital places more emphasis on factors such as government support policies for green development, green renovation technologies, environmental benefits, and corporate social responsibility. From the perspective of collaborative governance, this aligns with the profit-driven nature of social capital.

3. Thirdly, when analyzing the factors influencing social capital's involvement in green urban or old residential community renovation projects, existing studies have proposed various valuable research methods. For novel research topics where the concepts are still somewhat ambiguous, grounded theory is often employed to screen and analyze influencing factors [30,63]. The FUZZY-DEMATEL method, which can analyze the causal relationships between factors, is also frequently used in such analyses, especially when combined with grounded theory [30]. With the rapid development of artificial intelligence and big data, the methods for identifying influencing factors have also evolved. For instance, WANG et al. [64] used ChatGPT to identify valuable green urban development PPP projects. BU et al. [75] explored evolutionary stable equilibrium strategies and the factors influencing stakeholder decisions using evolutionary game theory. Case study methods are also widely applied, and analyzing existing data and conducting structured interviews are common approaches [65,76]. This study employs a mixed-methods approach, integrating grounded theory, IGAHP for subjective weighting, CRITIC for objective weighting, game theory, and the ISM method, leveraging the strengths of each methodology. The findings of this study demonstrate the effectiveness of the chosen research methods.

5. Conclusions, Recommendations, and Limitations

5.1. Conclusions

This study, using the example of green RORC within the context of urban renewal in China, explores the driving factors behind social capital participation in urban green development and promotes a healthy and sustainable real estate market. Through a comprehensive literature review, social practice surveys, and expert interviews, a multi-layered index system was established. By applying integrated weighting and interpretive structural modeling (ISM) methods, the interactions and hierarchical structure of the influencing factors were thoroughly analyzed, ultimately revealing the mechanisms through which social capital functions in this field. The main conclusions of this study are as follows:

First, the study finds that the research and development of green renovation technology, the government incentive and restraint mechanisms, the benefits of implementing green renovation, policy support, the cost of implementing green renovation, and the construction technical ability have significant impacts on social capital participation in green RORC. Among these, government policy support and incentives play a critical role in motivating social capital involvement. Moreover, the benefits of implementing green renovation and the level of development in green renovation technologies directly affect the feasibility and attractiveness of such projects.

Second, the study reveals a certain level of correlation and hierarchy between different factors. For instance, policy support can facilitate the development and application of green renovation technologies thereby enhancing both the economic and environmental benefits of the projects. On the other hand, the construction technical ability is influenced by multiple factors, such as the policy environment, market conditions, and the enterprises' own strengths. These interrelated factors together form the complex mechanism driving social capital's participation in green renovations.

Third, through empirical analysis and case studies, the effectiveness of the proposed research framework and methods was validated. The findings demonstrate that a com-

prehensive application of multiple research methods can more holistically uncover the influencing factors and their relationships in social capital participation in green renovations of old residential communities. This provides a scientific basis and valuable reference for relevant policy formulation and practical implementation.

This study explores the involvement of social capital in urban green transformation from the perspective of the renovation of old residential communities, leading to several valuable conclusions. In future research, the findings of this study should be continuously validated and refined based on the specific implementation of old residential community renovations. Additionally, further research should actively explore the participation of social capital in other urban green development projects.

5.2. Recommendations

Based on the research findings discussed earlier, we propose the following recommendations to enhance the involvement and overall effectiveness of social capital in the green renovation of old residential communities:

- Improve government incentive and constraint mechanisms: The government can implement more incentive measures, such as tax reductions and subsidies, to encourage social capital investment in the green renovation of old residential communities. Additionally, corresponding constraint mechanisms should be established to ensure the quality and sustainability of the projects.
- Enhance technical and managerial support: Governments or relevant institutions can provide advanced technical and managerial support to improve the efficiency and effectiveness of social capital involvement in green renovation projects of old residential communities.
- Establish risk assessments and sharing mechanisms: When guiding social capital participation in the green renovation of old residential communities, the government should emphasize the importance of developing risk assessments and sharing mechanisms to reduce the perceived risks of social capital investments thereby increasing their willingness to participate.
- Promote community involvement and feedback mechanisms: Communities should actively participate and establish feedback mechanisms to better meet residents' needs and expectations thereby enhancing the social acceptance and overall benefits of the projects.

5.3. Limitations and Research Prospects

5.3.1. Limitations

Despite the achievements of this study, several limitations remain. First, this research primarily focuses on the factors influencing social capital participation in green RORC but does not delve into the specifics of project implementation or the evaluation of outcomes. Second, the study sample is limited in scope, which may not fully represent all regions and types of green renovation projects for old residential areas. Therefore, future research should expand the sample size and increase the depth of analysis. Furthermore, as green RORC in China is still in an exploratory phase within the country's urban green development, stakeholders' understandings of the process is limited. With the continuous introduction of new policies and increasing public awareness, the findings of this study may need to be further refined.

5.3.2. Research Prospects

Despite these limitations, we believe that this study has explored a compelling topic within the urban green development literature, addressing an area that was not fully

explored. To address the identified limitations, the following recommendations are proposed for potential future research: First, a more in-depth examination of the specific implementation processes and evaluation methods for green renovation projects could provide a more comprehensive understanding of the role and contribution of social capital. Second, expanding the scope of the study to include other countries and different types of urban renewal projects would help to better reveal the factors influencing social capital participation and the relationships among them. Additionally, integrating new technologies and methods, such as big data analysis and artificial intelligence, could enhance the accuracy and efficiency of the research. These efforts could further encourage active social capital participation in urban green development and foster a healthy, sustainable real estate market.

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