ISSN: 2710-0588

Research on Restraining Factors and Countermeasures of Old Residential Area Renovation Projects

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Abstract

In the context of urban renewal, the renovation of old residential communities has garnered significant attention from academia and policymakers as a crucial component of urban revitalization efforts. Facing multiple constraints during renovation processes, this study systematically identified 19 key limiting factors through literature analysis, case studies, and expert interviews to explore their underlying mechanisms. By applying the ISM model to construct hierarchical factor structures and employing the C-OWA operator for quantitative weight analysis, the research reveals five core constraints: policy standardization and regulatory completeness, rational renovation planning, resident satisfaction levels, government implementation intensity, and social capital participation. The study further delineates hierarchical transmission pathways among these critical factors. Based on these findings, a three-tiered policy framework is proposed, encompassing strengthened government coordination, improved policy standards, optimized design methodologies, enhanced resident satisfaction, and stimulated social capital engagement. This framework provides theoretical foundations and practical references for targeted interventions in old community renovation initiatives.

Keywords

Renovation of Old Residential Areas, Restraining Factors, ISM Model, C-OWA Combination Number Operator Model.

1. Introduction

In recent years, China has entered a stage of rapid urbanization, with a large number of rural populations flooding into cities in search of development. This has raised higher demands for urban inclusiveness and infrastructure, making urban renewal an inevitable path for many cities seeking high-quality development. Studying the constraining factors of urban renewal is of vital significance for advancing the urbanization process and the entire urban renewal cycle in China.Urban renewal and the renovation of aging residential communities have become pivotal directions in China's urbanization process. With urbanization accelerating and living standards steadily improving, however, a growing number of challenges and conflicts have emerged [1]. Statistics indicate that a significant portion of China's urban areas still contain old neighborhoods constructed before 2000, which commonly suffer from outdated infrastructure, limited public spaces, and inadequate management systems [2].Residents now not only demand higher living standards but also prioritize a vibrant community culture and high-quality public spaces. Consequently, the renovation of aging residential areas has become a key national initiative in urban renewal. Current research predominantly focuses on single-dimensional approaches to renovation challenges, while systematic analysis of constraining factors and quantitative evaluation of complex interrelationships remain insufficient. Therefore, systematically identifying critical limiting factors and elucidating their operational

ISSN: 2710-0588

mechanisms holds significant theoretical and practical implications for enhancing renovation effectiveness.

2. Research Methods and Data Sources

2.1. Preliminary Identification of Constraining Factors

This study first systematically reviewed 182 core academic papers on urban renewal and old neighborhood renovation published domestically and internationally over the past fifteen years through databases including CNKI, Web of Science, and China National Knowledge Infrastructure (CNKI). Preliminary analysis identified 22 key constraining factors. Subsequently, seven representative renovation case studies were selected for in-depth analysis to validate and supplement the identified factors. Finally, five domain experts (including 2 professors, 2 scholars, and 1 senior practitioner) were invited to refine the factor list by merging semantically related items and eliminating less significant elements. The final comprehensive list comprising 19 constraining factors across four dimensions was established (see Table 1).

Table 1. List of Constraints in Renovation of Aging Residential Communities

Factor category	restraining factor
Policy and regulatory factors	A1 Policy standardization and standard completeness A2 Government policy support level A3 Government law enforcement and supervision mechanism
economic factors	A4 Residents' income level A5 Government fiscal support level A6 Local economic development level A7 Level of social capital participation A8 Project investment return rate
Social environmental factors	A9 Resident Satisfaction A10 Residents 'Sense of Responsibility and Participation Willingness A11 Residents' Level of Awareness A12 Government Promotion Efforts A13 Residents 'Neighborhood Relationships A14 Diversified Residents' Renovation Demands A15 Community Atmosphere A16 Publicity Intensity
Attribute factor	Location Conditions of A17; Rationality of A18 Renovation Plan; Management of A19 Renovation Project Archives

2.2. Questionnaire Design and Data Collection

Based on the aforementioned factor list, a Likert five-point scale questionnaire was designed and distributed to experts, scholars, university faculty, students, and practitioners engaged in research on old residential community renovation. A total of 100 questionnaires were collected, with 94 valid responses yielding a 94% response rate. Among the respondents, 48.94% held a master's degree or higher, while 54.26% reported having "fair understanding" or "extreme understanding" of renovation projects. SPSS analysis revealed an overall reliability coefficient of 0.879, indicating good reliability.

2.3. Analytical Methods

This study employs the Interpretive Structural Model (ISM) to analyze hierarchical structures and transmission pathways among factors. ISM decomposes complex systems into multiple subsystems, constructs adjacency matrices through expert judgment, and converts them into reachability matrices via Boolean operations, ultimately revealing intrinsic correlations and hierarchical relationships among factors.

Meanwhile, the continuous ordered weighted average (C-OWA) operator was introduced to objectively assign weights to factors. By ranking expert scores in descending order and assigning weights based on combination counts, the C-OWA operator effectively mitigates subjective biases caused by extreme values, resulting in more scientifically sound and rational

ISSN: 2710-0588

weight assignments. This study involved eight experts independently evaluating the importance of 19 factors using a 10-point scale.

3. Analysis of Research Findings

3.1. Hierarchical Structure and Pathways of Restraining Factors

The Interpretive Structural Modeling (ISM) is an analytical methodology developed by Professor J. Warfield in the United States in 1973. It employs the correlation matrix principle from graph theory to analyze the overall structure of complex systems such as socio-economic systems, using directed graphs to depict relationships between system components [3,4]. The ISM approach decomposes complex systems into subsystems containing multiple elements and factors, integrating expert judgment with computer-aided analysis to reveal hierarchical relationships among components, ultimately constructing a multi-level structural model [3]. The ISM modeling process involves the following key steps:

1) Clarify the research objectives, define the boundaries of the issues to be analyzed, and identify the core elements included in the system;

2) Establish an ISM expert evaluation panel by inviting specialists with theoretical knowledge and practical experience in relevant fields;

3) Construct a adjacency matrix of system elements based on experts' judgments of logical relationships among various elements;

4) By applying Boolean logic operations, the adjacency matrix is transformed into a reachability matrix to reflect the transitivity relationships among elements;

5) Hierarchical classification of system elements is performed based on the reachability matrix, followed by constructing a directed hierarchical structure diagram among elements to establish a system architecture model. This model serves as the foundation for conducting in-depth analysis of the research question.

(1) Adjacency matrix establishment

The adjacency matrix serves as the foundation for constructing structural models, enabling the representation of direct binary relationships among system elements. In this study, the construction of an adjacency matrix for identifying constraining factors in old residential area renovation projects follows these evaluation criteria: 1) If factor Ai directly influences factor Aj, the corresponding matrix element is assigned a value of 1; otherwise, it is assigned a value of 0 (where i, j = 1, 2,..., 19). 2) For factor pairs with bidirectional direct effects, discrimination should be made based on the differences in impact intensity, with the stronger influencing factor assigned a value of 1 and the weaker one assigned a value of 0.

To ensure the scientific rigor and reliability of the adjacency matrix, this study assembled an ISM expert panel comprising five specialists who participated in the initial factor screening. The expert group was first systematically briefed on the principles, operational procedures, and modeling significance of the explanatory structural model, with consensus reached through collective discussions. Disputable relationship determinations were resolved using majority voting principles. Based on expert interview transcripts, the data was systematically organized and analyzed to construct a directed adjacency matrix A reflecting direct relationships among 19 constraining factors, as detailed in Table 2.

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Table 2. Adjacency Matrix A of Constraints on the Progress of Renovation Projects in Aging Residential Communities

i\j	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19
A1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
A2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A6	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A8	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
A9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A11	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
A12	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
A13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
A14	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A15	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A16	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
A17	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A18	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
A19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

(2) Reachability Matrix Solution

Table 3. Reachability Matrix R of Constraints on the Progress of Old Residential Area Renovation Projects

i\j	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19
A1	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
A2	1	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0
A3	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
A4	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A5	1	1	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0
A6	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	0	0	0
A7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
A8	1	1	1	1	0	1	1	1	1	1	0	1	0	1	0	1	0	0	0
A9	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
A10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A11	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0
A12	1	1	1	0	0	0	1	0	1	1	0	1	0	1	0	1	0	0	0
A13	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0
A14	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
A15	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
A16	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0
A17	1	1	1	1	0	1	1	0	1	1	0	1	0	1	0	1	1	0	0
A18	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0
A19	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1

The reachability matrix describes whether any two elements in a system are connected through specific paths. Its construction is based on adjacency matrices and transformed using power

ISSN: 2710-0588

operation rules from Boolean algebra. The specific transformation process involves: First, summing the adjacency matrix A with the identity matrix I, then performing matrix multiplication operations according to Boolean algebra calculation criteria. The process stops when the resulting matrix (A+I)k no longer changes, i.e., when (A+I)k equals (A+I)k+1. This yields the reachability matrix R=(A+I)k=(A+I)k+1. After constructing the adjacency matrix, Boolean operations are applied to (A+I)k until reaching (A+I)k=(A+I)k+1, ultimately obtaining the reachability matrix R=(A+I)k. Here, A represents the adjacency matrix, I denotes the n-order identity matrix, R stands for the reachability matrix, and k indicates the number of operations satisfying stability conditions. The reachability matrix R was calculated using SPSSPRO software on the constructed adjacency matrix A, with results presented in Table 3.

(3) Factor Level Classification

This study employs the reachability matrix R and utilizes the concepts of reachability sets and antecedent sets to conduct hierarchical classification of constraining factors. The reachability set R(Ai) denotes the set of factors corresponding to row i in matrix R with value "1", representing factors directly influenced by factor Ai. The antecedent set Q(Aj) refers to factors in column j of matrix R with value "1", representing all factors that can directly influence Aj. By calculating their intersection M(Ai), this study adopts a result-oriented UP-type extraction rule for iterative analysis. The specific methodology involves sequentially evaluating whether each factor satisfies M(Ai = R(Ai)). If satisfied, the factor is extracted as the top-level factor of the current layer. Subsequently, the factor is removed from the system, and the remaining factors undergo repeated evaluation until complete hierarchical classification is achieved. The reachability sets, antecedent sets, and their intersections for factors extracted at each hierarchical level are detailed in Table 4.

Table 4. Reachable Set, Preceding Set, and Their Intersection

factor (Fi)	acyclic set R(Ai)	acyclic set Q(Aj)	be mixed M=R∩Q
A1	1,7,9,10	1,2,5,6,8,12,17	1
A2	1,2,3,7,9,10	2,5,6,8,12,17	2
A3	3,9,10	2,3,5,6,8,12,17	3
A4	4,10	4,6,8,17	4
A5	1,2,3,5,7,9,10	5	5
A6	1,2,3,4,6,7,9,10,12,14,16	6,8,17	6
A7	7	1,2,5,6,7,8,12,16,17	7
A8	1,2,3,4,6,7,8,9,10,12,14,16	8	8
A9	9,10	1,2,3,5,6,8,9,12,17,18,19	9
A10	10	1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,19	10
A11	10,11,14	11	11
A12	1,2,3,7,9,10,12,14,16	6,8,12,17	12
A13	10,13,15	13	13
A14	10,14	6,8,11,12,14,16,17	14
A15	10,15	13,15	15
A16	7,10,14,16	6,8,12,16,17	16
A17	1,2,3,4,6,7,9,10,12,14,16,17	17	17
A18	9,10,18	18,19	18
A19	9,10,18,19	19	19

ISSN: 2710-0588

Based on the ISM model, 19 factors were categorized into seven hierarchical levels, forming a multi-tiered hierarchical structure model (Figure 1). The model clearly delineates the causal pathways of constraining factors: The foundational support layer (L7-L5) includes fundamental determinants such as Project A8's return on investment, Location A17's advantages, Local Economic Development Level A6, and Government Fiscal Support A5. These factors influence the core driving layer (L4-L3) through A1 policy comprehensiveness, A2 policy support mechanisms, A3 regulatory enforcement, and A18 program rationality. Ultimately, these effects propagate to the direct impact layer (L2-L1), affecting Social Capital Participation A7, Resident Engagement Willingness A10, and Satisfaction A9, thereby determining project success or failure.The specific results are shown in Table 5.

Table 5. Hierarchical Classification Results (Results Priority–UP Type Extraction)

administrative levels	restraining factor
L_1	A7, A10
L_2	A4, A9, A14, A15
L_3	A1, A3, A11, A13, A16, A18
L_4	A2, A19
L_5	A5, A12
L_6	A6
L_7	A8, A17

3.2. Identification of Key Restraining Factors

The C-OWA operator proposed by scholar Xu Zeshui further extends the concept of OWA operator, effectively addressing uncertainty issues in interval numbers. This operator enables efficient ordered weighting processing of interval numbers, thereby supporting decision-making processes [5]. The C-OWA operator method primarily comprises the following steps:

(1) First, invite n experts to evaluate and score the indicators in the evaluation index system based on their importance, typically using a 10-point scale. When selecting experts for scoring, strive to include experts from various aspects of the research field to ensure more reasonable and scientific scoring results. Subsequently, distribute the survey questionnaire to each expert to form the original dataset.

(2) The original dataset $A=\{a_1,a_2,...,a_j,...,a_n\}B=\{b_0,b_1,...,b_j,...,b_{n-1}\}b_0\geq b_1\geq b_{2\geq}...\geq b_j\geq...\geq b_{n-1}$ is represented, then further processed by descending order from largest to smallest, and renumbered starting from 0 to obtain the new dataset, where.

(3) The weighted $Bb_j\omega_{j+1}C_{n-1}^{j}n\sum_{j=0}^{n-1}\omega_{j+1}=1$coefficients in the dataset can be determined by combinatorial formulas, where is the number of experts, and then

$$\omega_{j+1}=\frac{C_{n-1}^{j}}{\sum_{j=0}^{n-1}C_{n-1}^{j}}=\frac{C_{n-1}^{j}}{2^{n-1}} \quad (1)$$

In the $C_{n-1}^{j}n\text{-}1jj=0,1,2,...,n-1,\omega_{j+1}\in[0,1]$formula, denotes the combination count after selecting data from a dataset.

(4) Apply weighted $\omega_{j+1}B\widetilde{w}_i$coefficients to the dataset to derive the absolute value weights for each evaluation metric, then

$$\widetilde{w}_i=\sum_{j=0}^{n-1}\omega_{j+1}{}^{*}\,b_j \quad (2)$$

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In the formulai=1,2,...,mm,, denotes the number of indicators in the indicator system.

(5) The absolute value weights of each indicator are normalized to obtain ω_{bi} their relative weights, calculated as follows:

$$\omega_{bi}=\frac{\widetilde{w}_i}{\sum_{i=1}^{m}\widetilde{w}_i} \tag{3}$$

In the formulai=1,2,...,mm,, denotes the number of indicators in the indicator system.

Repeat the above steps to calculate the weights of each indicator.

The expert scoring was processed using the C-OWA operator to derive weights and rankings for 19 constraining factors. As shown in Table 6, the top five core constraining factors by weight are: A1 Policy standardization and regulatory completeness, A18 Rationality of renovation plans, A9 Resident satisfaction, A12 Government implementation intensity, and A7 Social capital participation level. This indicates that the success of old residential area renovations hinges on five key dimensions: comprehensive top-level design, precise plan execution, tangible benefits for residents, government leadership, and market-driven complementarity – all working in synergy across multiple dimensions.

Table 6. Final Impact Degree and Ranking of Restraining Factors on Renovation of Aging Residential Communities

Indicator Details	Weighted score value	Relative weight	Impact Ranking
Policy Standardization and Standard Completeness of A1	8.4570	0.0619	1
A2 Government policy support level	7.7000	0.0564	8
A3 Government Law Enforcement Supervision Mechanism	7.5484	0.0553	9
A4 Household Income Level	7.4117	0.0543	10
A5 Government Financial Support Level	7.3023	0.0535	11
A6 Local economic development level	7.0656	0.0517	13
A7 Social Capital Participation Level	8.2531	0.0604	5
ROI of A8 Project Investment	7.1781	0.0526	12
A9 Resident Satisfaction	8.3266	0.0610	3
A10 Residents' Sense of Responsibility and Participation Willingness	8.1070	0.0594	6
A11 Residents' Level of Awareness	6.7852	0.0497	16
A12 Government Promotion Efforts	8.2648	0.0605	4
A13 Neighborhood Relationships Among Residents	5.1500	0.0377	17
Diversified Demands for Residential Renovation in A14	6.9664	0.0510	15
A15 Community Atmosphere	5.1250	0.0375	18
A16 Promotion Efforts	7.7273	0.0566	7
A17 Location Factors	7.0438	0.0516	14
Rationality of A18 Reconstruction Plan	8.4000	0.0615	2
Archival Data Management for A19 Renovation Project	3.7328	0.0273	19

This approach demonstrates that addressing challenges in renovating old residential communities cannot be limited to superficial measures such as resolving resident disputes or enhancing publicity efforts. It requires fundamental solutions at the foundational level, including optimizing project profit models, strengthening government coordination, and

ISSN: 2710-0588

ensuring fiscal support. Only through these measures can the transmission chain be fundamentally unblocked, thereby stimulating endogenous motivation from both social capital and residents.

4. Policy Recommendations

4.1. Basic Support Layer: Strengthening Government Driving Force

Strengthening government-driven initiatives forms the institutional foundation for transformation. A cross-departmental task force should be established to break down barriers and enable collaborative operations. Central government subsidies, social contributions, and resident funding should be coordinated, adhering to the principle of government-backed guarantees for basic categories and multi-party shared responsibility for improvement initiatives. An enhanced evaluation mechanism must be implemented, incorporating completion rates and satisfaction metrics into assessment criteria, with public disclosure of red/black lists and accountability measures to ensure tangible outcomes.

4.2. Core Driving Layer: Refining Policy Standards, Optimizing Program Design, and Enhancing Resident Satisfaction

The core layer serves as a crucial bridge between upper and lower levels. The national government should establish unified technical standards, while local authorities refine specifications to prevent quality disparities. Renovation plans require conducting thorough needs assessments, offering tiered options for resident voting, and deploying professionals to provide community guidance. During construction, real-time public information disclosure and prompt issue resolution are essential. Upon completion, property management systems and maintenance funds must be implemented to extend the project's lifespan.

4.3. Direct Action Layer: Stimulating the Participation Vitality of Social Capital

The participation level of social capital influences scale and sustainability. Innovative profit models should be adopted to revitalize idle spaces for upgrading public facilities, while integrating adjacent commercial land development to achieve break-even. Governments must commit to minimum returns and provide interest-subsidized loans to mitigate risks. Comprehensive idle asset surveys, franchise operations, and revenue distribution mechanisms should be implemented to establish a dual-tier safeguard system combining market-driven approaches with government-backed support.

5. Conclusion

This study systematically identified 19 constraining factors in the renovation of old residential communities. By employing an integrated ISM-C-OWA model, we pinpointed five core constraints and elucidated the hierarchical transmission mechanisms among key factors. Breaking free from single-perspective limitations, the research establishes a systematic analytical framework that provides new insights into the intrinsic logic of community revitalization. The proposed hierarchical countermeasures offer theoretical foundations for government-targeted policy implementation. Future studies could expand sample sizes and incorporate methods like system dynamics to investigate dynamic evolution patterns of constraining factors throughout the entire lifecycle.

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