Risk Prediction Research of Old Residential Area Renovation Projects Based on WBS-RBS and Fuzzy Comprehensive Evaluation

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Abstract. As a key driver of urban renewal, the renovation of aging residential communities presents challenges such as tight schedules, dispersed work sites, and complex stakeholder relationships, harboring numerous potential risks. This study adopts a project management lifecycle perspective and employs the WBS-RBS matrix to identify risks in renovation projects. A risk assessment framework was developed encompassing three phases (pre-construction planning, construction execution, and post-commissioning operations) with 12 key indicators. A risk prediction model was established using fuzzy comprehensive evaluation methods, detailing the mapping relationship between composite scores (F) and five-tier risk classifications. Through AHP weight assignment and consistency checks (CR values <0.1) conducted by 15 cross-disciplinary experts, empirical analysis of a real-world project demonstrated a 75% prediction accuracy rate using multi-validation approaches including event logging, timeline deviation analysis, and post-construction evaluations. The study concludes with actionable risk mitigation strategies, providing quantitative decision-making references for risk prevention in similar projects.

Keywords: renovation of old residential areas; risk prediction; WBS-RBS; fuzzy comprehensive evaluation; AHP; consistency ratio

1 Introduction

As China's urban development enters the phase of "quality upgrading of existing assets," the renovation of old residential communities has become a crucial component of urban renewal. [1] Compared to new construction projects, renovating older neighborhoods faces unique challenges such as complex site conditions, unclear underground utility networks, difficulties in resident coordination, and funding shortages. [2,7-8] Traditional risk management approaches often rely on empirical judgments rather than systematic quantitative forecasting. [3,5-6] Scientifically identifying, accurately predicting, and effectively addressing these risks remains a pressing issue in engineering management. This study aims to develop a risk prediction model tailored for old community renovation projects, shifting the focus from "post-event remediation" to "pre-event risk control."

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2 Risk Characteristics and Identification of Old Residential Area Renovation Projects

2.1 Risk Characteristic Analysis

The renovation project for old residential areas exhibits distinct non-standardized characteristics. Firstly, high uncertainty: Most buildings constructed before 2000 lack original blueprints, with structural safety hazards being highly concealed. Secondly, diverse stakeholder demands: Residents' expectations for renovation outcomes vary significantly, which can easily trigger public opinion risks. [1-2] Thirdly, complex interface management: The renovation involves cross-disciplinary operations such as municipal pipeline systems, building facades, and elevator installations, posing substantial challenges in construction organization. [4,9-11]

2.2 Risk Identification Based on WBS-RBS

The WBS-RBS matrix was employed for systematic risk identification. The project lifecycle was decomposed into three primary work packages: A) Pre-construction Decision Phase (project approval, resident consultation, survey and design), B) Construction Phase (structural renovation, pipeline network upgrades, environmental remediation), and C) Operation and Handover Phase (final acceptance inspection, property handover, maintenance services). Risks were categorized into five types: R1 Technical Risks, R2 Management Risks, R3 Economic Risks, R4 Social Risks, and R5 Environmental Risks. Through constructing the WBS-RBS coupling matrix and conducting cell-by-cell analysis, 37 initial risk factors were identified. Subsequent screening and synthesis yielded 12 key risk indicators.

3 Construction of Risk Prediction Model

3.1 Establishment of Evaluation Indicator System

A three-tier evaluation structure was established based on identified key risk factors. The target layer represents the comprehensive project risk level; the criterion layer encompasses three phases: pre-construction, construction, and operation and maintenance; the indicator layer includes 12 specific risk points, with their codes, definitions, measurement sources, and scoring criteria detailed in Table 1.

Table 1. Risk Assessment Indicator System for Renovation of Aging Residential Communities (C11–C34)

name of index	definition	Measurement source	Expert scoring criteria (1-5 points)
policy change risk	Potential adverse changes in policies, subsidy standards, and approval processes	Government documents, industry news	1=Almost unchanged; 3=May require minor adjustments; 5=Significant changes
Difficulty in resident coordination	Low resident approval rate for renovation plans, along with risks such as complaints	Community surveys, council meeting minutes	1=Agreement rate>90%; 3=60%~80%; 5=<50% with repeated work stoppages

name of index	definition	Measurement source	Expert scoring criteria (1-5 points)
	and obstruction of construction work		
Insufficient depth of survey and design	Design changes due to missing original drawings and unidentified underground pipelines	Geological Survey Report, Design Change Order	1=Change <2 times; 3=2–5 times; 5=>5 times or major rework
Work safety accident	Probability of accidents such as falls from height, object strikes, collapses, and electric shocks	Security logs and incident reports	1=No accidents; 3=1-2 minor injuries; 5=Severe injuries or death
Risk of underground pipeline damage	Damage to gas, power, communication, and water supply/drainage pipelines during construction	Pipeline Handover Record, Emergency Repair Order	1=No damage; 3=Damage 1-2 times; 5=Damage more than 3 times
Construction material quality is non-compliant	Use of materials that do not comply with design or standard specifications	Material Testing Report, On-site Acceptance Form	1=Pass rate 100%; 3=90%~95%; 5=<85%
Construction activities interfere with residents' daily lives	Complaints and Claims Arising from Noise, Dust, and Traffic Congestion	Complaint records, environmental monitoring	1= Complaints <3 times; 3= 10–20 times; 5=>50 times or mass incidents
Delayed fund disbursement	Government subsidies and self-raised funds were not disbursed according to the scheduled milestones	Fund disbursement ledger and financial statements	1=Payment made on time; 3=Delay of 1–2 weeks; 5>Delay of more than 1 month
The completion acceptance is non-compliant	Incomplete renovation content, quality defects, incomplete documentation	Acceptance Report, Rectification Notice	1=Passed on the first attempt; 3=Rectified once; 5=Rectified more than twice
Lack of long-term management mechanisms	After renovation, there is no property management, no maintenance funds, and no management system in place.	Property Contract, Maintenance Fund Account	1=Property already occupied; 3=Planned occupancy; 5=No management
Low resident satisfaction	Residents were dissatisfied with the renovation outcomes	Satisfaction Survey Questionnaire	1=>90%；3=60%~80%；5=<50%
Rebound of illegal constructions left over from history	Reconstructed illegal structures reappear	Urban Management Patrol Record	1=No illegal constructions; 3=1-2 minor illegal constructions; 5=Multiple large-scale illegal constructions

3.2 Fuzzy Comprehensive Evaluation Model and its Mathematical Meaning

Given the inherent fuzziness and dynamism of risks, this study employs the fuzzy comprehensive evaluation method for forecasting.

Step 1: Determine the comment set and weights

Define the risk rating set V={v1, v2, v3, v4, v5} , corresponding to: low risk, relatively low risk, medium risk, relatively high risk, and high risk, respectively, with values assigned as V=(1,2,3,4,5) . The Analytic Hierarchy Process (AHP) is employed to determine the weight coefficients for each hierarchical indicator.

Step 2: Construct the fuzzy relation matrix

Experts were invited to score each risk factor according to the comment set.

Based on the membership degree formula

$$\mathbf{r}_{\mathrm{ij}} = \frac{\text{number of experts rating factor i as comment j}}{\text{total experts}} = \frac{\mathrm{n}_{\mathrm{ij}}}{\mathrm{N}}$$

a fuzzy relation matrix $\boldsymbol{R}$ is established.

Step 3: Fuzzy synthesis and comprehensive scoring

The synthesis operation is performed using a $\circ$ weighted average operator: B=W∘R, resulting in the composite fuzzy evaluation vector B=(b1, b2, b3, b4, b5). The composite score is then calculated as follows:

$$F = B \times V^T = \sum_{j=1}^{5} b_j \times v_j$$

Where F is a scalar variable with a value range of [1,5]. The mapping relationship to five risk levels is as follows: 1.0≤**F**<1.5 indicates low risk; 1.5≤**F**<2.5 indicates relatively low risk; 2.5≤**F**<3.5 indicates moderate risk; 3.5≤**F**<4.5 indicates relatively high risk; 4.5≤**F**≤5.0 indicates high risk.

3.3 Weight Setting and Data Reliability

Questionnaire response rate: A total of 15 questionnaires were distributed, with 15 valid responses collected, achieving a 100% valid response rate.

Expert representation evaluation: The panel comprises 15 specialists representing four key stakeholders—construction entities (4 members including project leaders and design supervisors), contractors (4 members including project managers and safety directors), community representatives (4 members including community secretaries and homeowners' association members), and university scholars (3 professors specializing in engineering management). This structure achieves balanced perspectives across four key stakeholders: investors, implementers, beneficiaries, and researchers.

Consistency verification method: For each expert's judgment λ_{max}, calculate the maximum eigenvalue max to obtain the consistency index $CI = (\lambda_{max} - n) / (n - 1)$. Determine the average random consistency index RI from the table, then compute the consistency ratio $\mathrm{CR} = \mathrm{CI/RI}$. Evaluation criteria: CR <0.1 indicates satisfactory consistency. In this study, all 15 experts achieved CR values below 0.1 (maximum 0.087, minimum 0.021), demonstrating logical consistency in weight assignment and reliable results.

Bias control measures: Anonymous scoring, back-to-back feedback, and geometric mean weighting method were employed, with the involvement of university scholars to balance commercial interests.

4 Empirical Analysis

4.1 Project Overview

Taking the "XX Street Old Residential Area Renovation Project" in a certain city as an example, this initiative involves 23 buildings with a total floor area of approximately 87,000 square meters, benefiting 1,120 households. The total investment amounts to around 45 million yuan, with a construction period of 8 months. The renovation scope includes building energy efficiency upgrades, roof waterproofing, road resurfacing, and the installation of security facilities. [12]

4.2 Risk Prediction Process

Through scoring 12 indicators by 15 experts, the weight distribution across phases was calculated: construction phase with the highest weight (0.539), followed by preliminary phase (0.297), and operation and maintenance phase (0.164). After fuzzy synthesis, the comprehensive risk vector B=(0.112,0.284,0.386,0.158,0.06) was obtained, yielding a composite score of F=2.77 corresponding to "moderate risk." The primary risk points were identified as C12 (residential coordination challenges) and C22 (underground pipeline damage risk).

4.3 Validation Design

To evaluate the model's predictive accuracy, multiple validation methods were employed:

Comparison of event records and timeline discrepancies: As shown in Table 2, the actual occurrence aligns closely with predictions.

Table 2. Comparison of Predicted Results with Actual Observations

risk factor	Prediction level	Actual occurrence	Timeline deviation	Event record source
C22 Underground pipeline damage	Higher risk	During the third week of construction, the gas pipeline was excavated, resulting in a one-day gas outage.	2 weeks earlier than predicted	Supervision Log Entry 15
C12 resident coordination difficulty	High risk	The elevator installation project triggered three work stoppages, resulting in a cumulative downtime of 5 days.	Consistent with predictions	Three Community Mediation Records
Delayed disbursement of C25 funds	Medium risk	The second progress payment was delayed by 10 days.	The delay was lower than predicted	financial payment voucher
C21 Work Safety Accident	Medium risk	One minor scaffold component fall occurred with no casualties reported.	The frequency of occurrence is lower than predicted	Security inspection record

Prediction accuracy rate: Among the 12 risk factors, 9 had consistent actual risk levels with predicted levels, achieving an accuracy rate of 75%.

Follow-up re-evaluation: Three months after project completion, experts from the same batch were invited to conduct a retrospective re-evaluation. The cosine similarity between the two membership vector matrices reached 0.88, indicating that the model demonstrates excellent cross-temporal stability.

Multicase analysis recommendations: It is recommended to subsequently select 3–5 old residential community projects with distinct characteristics and employ the 'leave-one-out method' for cross-validation to further validate the model's generalization capability.

5 Risk Response Strategies

Based on the prediction results, proactive control strategies are proposed for different stages:

5.1 Preliminary Stage: Deepening Design and Co-governance Mechanism

To address the coordination challenges for C12 residents, a joint Party building mechanism involving "Community Party Committee + Owners' Committee + Construction Parties" was established, with resident reception days implemented. For C13, where survey and design depth was insufficient, the "Designer into Community" model was introduced, utilizing 3D laser scanning technology to supplement existing base maps.

5.2 Construction Phase: Intelligent and Refined Management

For the C22 underground pipeline risks, the "dual confirmation" system (on-site briefing by the property rights unit + manual pit inspection) was implemented, along with the purchase of Industrial Defect Insurance (IDI) for potential engineering quality defects. For C24 construction interference, the "smart construction site" system was adopted to enable real-time monitoring of noise and dust emissions.

5.3 Operation and Maintenance Phase: Integration of Construction and Management with Long-term Operations

To address the lack of long-term management mechanisms for C32, "full coverage of property management" was established as a prerequisite for project acceptance; in response to the resurgence of illegal constructions at C34, a joint prevention and control mechanism involving urban management, property management, and residents was implemented.

6 Conclusion

Risk management in old residential area renovation projects constitutes a systematic engineering endeavor. This study establishes quantitative risk prediction through a WBS-RBS identification framework and fuzzy comprehensive evaluation model. Research demonstrates that the model effectively addresses challenges such as ambiguous risk factors and quantification difficulties in renovation projects. By incorporating AHP consistency ratio ($CR<0.1$) and multi-role expert scoring systems, the model ensures scientific weighting and data reliability. Multiple validation methods including event logging and re-evaluation confirm a 75% model accuracy rate. In engineering practice, dynamic resource allocation should be adjusted based on predictive outcomes to transition from "reactive firefighting" to "proactive fire prevention," thereby ensuring high-quality implementation of urban renewal initiatives.

References

1. Cui J, Li C X. Stepwise initiation of policy agendas from the perspective of urban governance: A case study of the old residential community renovation policy in Z City[J]. Dongyue Tribune, 2026, 47(02): 132-142+192. DOI:10.15981/j.cnki.dongyueluncong.2026.02.013.
2. Lin X Y, Zhang W Y. Research on rebound risk measurement in comprehensive renovation of old residential communities[J]. Journal of Xi'an University of Technology, 2024, 40(02): 291-300. DOI:10.19322/j.cnki.issn.1006-4710.2024.02.015.
3. Ren J G, Wang D H. Research on safety management of old residential community renovation projects based on the AHP-PHA method[J]. Construction Economy, 2022, 43(S1): 641-644. DOI:10.14181/j.cnki.1002-851x.2022S10641.
4. Sun H L, Zhang S Q, Yang Y, et al. Analysis of a sponge renovation scheme for old residential communities in Siping City based on the InfoWorks ICM model[J]. Water & Wastewater Engineering, 2025, 61(01): 70-76. DOI:10.13789/j.cnki.wwe1964.LS2024.06.27.0001.
5. Zhang Z .Analysis of Fund Management Issues in Old Residential Area Renovation Projects[J].Scientific Innovation in Asia,2026,4(1):
6. Nie T ,Li L ,Lai X .Research on Cost Management of Old Residential Area Renovation Projects under EPC Mode[J].Applied Science and Innovative Research, 2025, 9(3): DOI:10.22158/ASIR.V9N3P12.
7. Zhang J ,Shen C ,Tang C , et al.Research on Multi-Objective Optimization of Renovation Projects in Old Residential Areas Based on Evolutionary Algorithms[J]. Buildings, 2024, 14(5): 1485-1485.DOI:10.3390/BUILDINGS14051485.
8. Li W, Li Q, Liu Y, et al. Decision-making factors for renovation of old residential areas in Chinese cities under the concept of sustainable development[J]. Environmental science and pollution research, 2023, 30(14): 39695-39707.
9. Luo X, Ren M, Zhao J, et al. Life cycle assessment for carbon emission impact analysis for the renovation of old residential areas[J]. Journal of Cleaner Production, 2022, 367: 132930.
10. Ye Z, Ouyang S, Gao X, et al. Micro-Renovation Method of Old Residential Areas Based on Parametric Energy Simulation: An Aging Community in Middle China as an Example[J]. Buildings, 2025, 15(5): 758.
11. Haoyu S. " Micro Renovation" of Old Residential Quarter for Aging: a Case Study of Qingshanhu Community of Nanchang City[J]. Journal of Landscape Research, 2022, 14(5): 7-10.
12. Choi J, Kim J. Techno-economic feasibility study for deep renovation of old apartment[J]. Journal of Cleaner Production, 2023, 382: 135396.