Construction Risk Assessment for Old Town Renovation Based on AHP-LEC

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ABSTRACT: Old city renovation can improve the living environment and quality of residents and enhance the image of the city, and in the process of urbanisation, old city renovation is always a people's livelihood project that cannot be ignored. This paper takes the old city renovation in County H as an example, through the combination of hierarchical analysis method (AHP) and construction safety evaluation method (LEC) in the renovation process, constructs the safety assessment model, uses the Delphi method to determine the factors that lead to the occurrence of safety accidents in the construction, assigns scores to each index and realises the quantitative analysis, and finally analyses the weighted size of the factors that lead to the occurrence of safety accidents and carries out the safety assessment. Based on the results of the safety assessment, it provides certain reference significance for the future transformation of the old city.

1 Introduction

Old city renovation can be traced back to the 18th century, but it has been taken seriously by the government since the 1950s. With the enactment of various Town and Country Acts in the United Kingdom in the 1950s, the "Urban Renewal" movement began to emerge in various countries. In China's rapid economic development today, the people's living standards on a large step, the process of urbanisation is also accelerating, the world's old houses in the 80s and 90s, no matter from the living conditions and safety are a big problem, with the relationship between the people's sense of well-being and the face of the city, the old city renovation is the current demand for sustainable development, is the need of the urban transformation, but also the need for community renewal. It is also the need for community renewal.

According to the Ministry of Housing and Urban-Rural Development[1], the General Office of the Ministry of Housing and Urban-Rural Development on the situation of production safety accidents in housing and municipal engineering in 2019, in 2019, a total of 773 production safety accidents in housing and municipal engineering occurred across the country, with 904 deaths,of which the largest share was fall from height and object strikes, each accounting for 53.69 percent and 15.91 percent. In today's accelerated urbanisation, various renovation projects are also in full swing, and all kinds of accidents are expected to surge (Ministry 2022). After 2000, many cities have raised questions about the urban renewal of old urban areas, including the city's cultural heritage, community network, urban planning, etc. and regions have adjusted their policies and plans in response to related issues, and have made a variety of practical innovations in the renovation of old communities. The regions have adjusted their policies and plans in response to the relevant problems and made various practical innovations in the transformation of old communities.

Currently, most of the research focuses on large building industry and green building energy efficiency, while there are relatively few studies on construction safety management in old city renovation, of course, there have been scholars using the hierarchical analysis method to analyse and research, basing on a certain point of safety in the renovation of old cities. Niu Changlin et al[2]. Used AHP (Analytic Hierarchy Process) method and combined the LEC method and FCE method to evaluate the fall safety in old districts from the roof renovation, façade renovation, scaffolding operations and other aspects of fall safety problems (Niu 2021). Chang Shenghong et al[3]. Took the construction safety risk in the mountainous highway project group as an example, combined with the risky evaluation method to determine the degree of influence of risk influencing factors in the whole project group, between projects and projects, also within projects (Chang 2014). Li Qian et al[4]. Prioritized 27 risk factors in old districts through entropy weight method and grey correlation method, and determined the key risks at each stage of the whole process of renovation (Li 2021). Li Yongfu et al[5]. Combined with the method of work decomposition structure-risk decomposition structure for the identification, and then evaluated the risk of the old districts in the aspects of facility renovation and intelligent renovation through hierarchical analysis method (Li 2021). Intelligent transformation and other aspects of the risk,

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Bilal Umut Ayhan et al[6]. established a prediction model through neural network to predict the possibility of accidents, Jongko Choi et al[7]. created an accident prediction model to study ways to improve the safety of site construction management and identify potential safety hazards.

Most of the existing researches are limited to the macro aspect or the single accident research level, without comprehensively identifying and analysing the various potential safety hazards that may occur in the construction. In this paper, we start from the aspects of potential safety hazards, identify the potential safety hazards through the expert Delphi method and brainstorming hair, use the AHP method and LEC method, establish a safety evaluation system, and carry out targeted and reasonable management for the construction of the old city renovation, so as to reduce the possibility of safety accidents.

2 Identification of hazardous factors during the construction phase of old city renovation

County H, for example, is located in the northwestern part of Hunan Province, the northern end of Huaihua City, east and Taoyuan, Anhua connected to the south of Xupu, Chenxi, west and Guzhang, Luxi, Yongshun adjacent to the north and Zhangjiajie border, known as the "Gateway to the west of Hunan Province", and "the key to the southern sky". Now the H County old district is in disrepair, the district building is old, the outer wall has shedding phenomenon, canopy, fitness facilities and other clutter, road damage, pipeline and fire facilities are broken, messy circuit and so on, living and living in a greater security risks, urgent need for renovation.

The Delphi method of risk identification is a fast and objective method to identify the risk, Delphi method is called as the expert survey method, also. In 1946, the United States RAND Corporation for the first time to use Delphi method for qualitative prediction, and later the method was widely used (Hu 2010)[8]. H County old city transformation may affect the construction safety factors distributed to the hands of the experts, and then after anonymous feedback, the expert's opinion summary collated, and then feedback to the experts to ask for opinions, after many cycles of feedback, take a more unified opinion, the final expert identification opinion combined with the "housing and municipal engineering production safety major accident potential hazard determination standard (2022 version)" of the opinion[9], get Hazardous risk factors.

2.1 Wall modifications

Wall transformation in the most important safety hazards is the work at height, in the head of the datum 2 metres above the work, is the construction of the most important place of operation, and therefore the possibility of falling caused by injury is relatively large, but also in the construction of the main accidents, accounting for the total number of accidents, 35%-40%. Most of the work occurs in the hole, edge work, scaffolding, cradles, templates, gantries and other operations above.

2.2 Electricity for construction

Renovation construction is inseparable from the use of electricity, almost all kinds of work site to use the point, at this time the safety of electricity has become particularly important, electrocution accidents are also frequent accidents, accounting for 18-20 per cent of the number of accidents.

2.3 Object strikes

Because of the constraints of the construction site by the schedule, there will be a lot of cross work in the construction process, falling objects, debris injuries, explosion injuries, etc. are common, accounting for 12-15 per cent of the total number of accidents.

2.4 Mechanical injuries to implements

The main types of plant and machinery on the renovation site are vertical lifting equipment, steel processing equipment, cutting equipment, concrete mixing, construction vehicles, etc. These types of machinery can cause injuries to operators or bystanders, which account for 10 per cent of accidental injuries and are the fourth most common injury.

2.5 Demolition works

Renovation will inevitably dismantle and rebuild old buildings, which may result in wall collapse in the demolition of old walls, the use of dangerous operations such as manual digging, tugging and pulling, standing on the demolished object and slamming, as well as personal injuries caused by the instability of the construction surface of the machinery in the process of dismantling, which is an important cause of the accidents.

3 Constructing construction safety assessment models for old city renovation

3.1 Establishment of a security evaluation index system

Experts and scholars in project management and safety management of old city transformation were invited, and five primary indicators and 32 secondary indicators of construction safety were obtained through the summary processing of feedbacks for many times, and the safety evaluation index system of old city transformation construction site was constructed, as shown in Table 1.

Table 1 Construction safety evaluation index system for old city renovation projects

target level	quasi-testing layer	programme level
Old City Renovation Construction Security assessment A	Wall remodelling B_1	Failure to wear a safety belt when working on a high wall B_{11}
		Unauthorised ascent of heights by workmen B_{12}
		Illegal entry to cradle B_{13}
		Workers labouring on duty B_{14}
		Damage to scaffolding and guardrail B_{15}
		Operators operating at the edge B_{16}
	Electricity for construction B_2	Leakage protection damaged B_{21}
		Leakage from energised connectors B_{22}
		Multi-machine use in one box B_{23}
		Haphazard wiring B_{24}
		Circuit ageing B_{25}
		Unauthorised work under high voltage lines B_{26}
		Irregular use of electrical equipment B_{27}
	Object strike B_3	Falling of tools, parts, masonry, etc. from a height B_{31}
		Man-made littering of waste, debris and injuries B_{32}
		Injuries caused by falling materials during lifting, dismantling and removal of moulds B_{33}
		Injury to a person injured by a boulder during a blasting operation B_{34}
		Pressure vessel explosion with injuries from flying objects B_{35}
		Equipment operating "sick", objects flying out of equipment and injuring people B_{36}
	Mechanical injuries to implements B_4	Substandard quality of cradles B_{41}
		Scaffolding erection does not meet the requirements B_{42}
		Driving offences for construction vehicles B_{43}
		Basket overloading B_{44}
		Irregular use of cutting equipment B_{45}
		Overloading of lifting equipment using B_{46}
		Engineering equipment not inspected and maintained in a timely manner B_{47}
		Old wall eradication Wall collapse B_{51}
	Demolition work B_5	Unstable mechanical construction surface during dismantling B_{52}
		Defective construction and design programmes B_{53}
		Failure to set up a safety cordon and to assign special guards during demolition work B_{54}
		Use of dangerous operations such as manual digging, pulling, standing on the demolished object and slamming B_{55}
		Transitional concentration of personnel during the dismantling process B_{56}

3.2 Hazard classification based on LEC method

The LEC method is a risk level evaluation of the degree of risk of operations exposed to hazards, which is obtained by the product of three risk-related factors, which are L (Likelihood) the likelihood of accidents, E (Exposure) the frequency of operations exposed to hazards, and C (Consequence) the consequences of accidents(Yu 2014,Li 2022)[10]. The scores of these three factors were assigned by the experts after a joint discussion, and the results of the experts' assignments are shown in Table 2. The final risk score D=L*E*C, the larger the value of D, representing the greater the likelihood of the risk[11], the risk score as shown in Table 3.

Table 2 Values for L, E and C

Likelihood of accident L	value of a score	Frequency of exposure to hazardous situations E	value of a score	The severity of the consequences of the accident C	value of a score
Totally predictable.	10	ongoing exposure	10	More than 10 deaths	100
easily	6	Exposure during working hours	6	3-9 deaths	40
Possible, but infrequent	3	Weekly or occasional exposure	3	1-2 deaths	15
Less likely, totally unexpected	1	once a month	2	seriously hurt	7

Very unlikely. Conceivable.	0.5	Several times a year	1	be crippled (in an accident etc)	3
extremely unlikely	0.2	extremely rare	0.5	conspicuous	1
Practically impossible.	0.1	-	-	-	-

Table 3 Risk scores

D-value	degree of danger
≥ 320	Extremely dangerous. Stop work immediately.
160-320	Highly dangerous, needs immediate rectification
70-160	Significantly dangerous and in need of rectification
20-70	General hazards, requiring attention
< 20	Slightly dangerous. Acceptable.

3.3 Hazard class data calculation and processing

The importance of each factor in the safety evaluation system is scored by 10 experts, those experts who are 4 university professors, 3 constructors and 3 residents of the renovated community. The results of the comparison between each other are shown in Table 4. The experts are only to score the objective conditions in the construction process, and the human factors and material factors involved in the construction process will be scored anonymously.

Table 4 Results of the evaluation of each safety hazard

Category of Hazard	considerations	L	E	C	D	hazard class
Wall remodelling B_1	B_{11}	6	6	15	540	extreme danger
	B_{12}	3	6	7	126	marked risk
	B_{13}	6	3	7	126	marked risk
	B_{14}	6	3	15	270	high risk
	B_{15}	6	6	15	540	extreme danger
	B_{16}	6	6	15	540	extreme danger
Electricity for construction B_2	B_{21}	6	10	15	900	extreme danger
	B_{22}	3	10	7	210	high risk
	B_{23}	6	6	7	252	high risk
	B_{24}	6	10	7	420	extreme danger
	B_{25}	3	10	7	210	high risk
	B_{26}	3	2	15	90	marked risk
	B_{27}	3	2	3	18	Slightly dangerous.
Object strike B_3	B_{31}	6	6	7	252	high risk
	B_{32}	10	2	3	60	General Danger
	B_{33}	3	1	7	21	General Danger
	B_{34}	10	1	7	70	marked risk
	B_{35}	1	10	15	150	marked risk
	B_{36}	10	10	3	300	high risk
Mechanical injuries to implements B_4	B_{41}	10	6	15	900	extreme danger
	B42	10	10	15	1500	extreme danger
	B_{43}	1	2	15	30	General Danger
	B_{44}	10	2	40	800	extreme danger
	B_{45}	6	6	3	108	marked risk
	B_{46}	10	6	7	420	extreme danger
	B_{47}	6	10	7	420	extreme danger

Demolition work B_5	B_{51}	6	6	40	1440	extreme danger
	B_{52}	6	10	3	180	high risk
	B_{53}	6	10	7	420	extreme danger
	B_{54}	3	10	7	210	high risk
	B_{55}	1	10	100	1000	extreme danger
	B_{56}	6	6	3	108	marked risk

4 Construction safety evaluation based on ahp method and lec method

4.1 Principles and steps of the AHP method

Hierarchical analysis (AHP) is a simple method to make decisions on complex and vague problems, it is more suitable for those problems that are difficult to quantify and qualify, by dividing the problem into the objective layer, criterion layer and programme layer, through the study of the degree of influence and affiliation between them, and ultimately get the ranking of the various levels, and ultimately get the optimal solution.The calculation of the weight between the various levels of AHP can use the square root method, the sum normalization method and the eigenvector method. The square root method, the summation normalisation method, the power method and the eigenvector method can be used[12], and the square root method is used in this paper(Liu 2014).

4.2 Applying the two-by-two comparison method to construct a judgement matrix

Judgement Scale. The judgement scale represents the value of the relativity of Bi to the element Bj , as shown in Table 5.

Table 5 Judgement scales for the two-by-two comparison method

Implications (B_{ij})	scale
i-Factors are equally important than j-factors	1
i-factor is slightly more important than the j factor	3
i − factor is significantly more important than the j factor	5
i −Factors are much more important than j-factors	7
i-Factors are definitely more important than j-factors	9
The importance of the I and j factors is in the middle of the above neighbouring scales.	2, 4, 6, 8

The stochastic consistency indicators are shown in Table 6.

Table 6 Values of the randomness indicator RI

n	1	2	3	4	5	6	7	8	9	10	11
R	0	0	0.	0.	1.	1.	1.	1.	1.	1.	1.
I			58	9	12	24	32	41	45	49	51

Coherence indicator CI formula:

$$CI = \frac{\lambda_{max} - 1}{n - 1} \quad (1)$$

where (1) in the equation λ_{max} is the largest characteristic root in the judgement matrix A. The algorithm is as follows:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{[AW]_i}{nW_i} \quad (2)$$

where $[AW]_i$ represents the matrix $[AW]$ The first component of thei component of the matrix.

Consistency ratio formula:

$$CR = \frac{CI}{RI} \quad (3)$$

When the consistency ratio CR < 0.1, the consistency of the judgement matrix is considered to be recognisable.

4.3 Matrix calculations

Various safety hazards that may occur in the transformation, constructed the first-level indicators and second-level indicators as shown in Table 1, calculated the weight of the five first-level indicators on the target level is recorded as W =(W_1, W_2,W_3,W_4, W_5), and then the weight of the influence of the 32 second-level indicators on the five first-level indicators is recorded as W=(W_{i1},W_{i2},W_{i3},W_{i4}...W_{in}), and the value of i is 1,2,3,4,5. where n indicates the number of safety hazards corresponding to each level 1 indicator, each indicator is assigned by 10 experts in two-by-two comparisons, and the weighted average is used to neutralise the opinions of the two experts, and then finally, the relative weights of the level 1 and level 2 indicators are calculated by the sum-product method, as shown in Table 7.

Table 7 Overall risk judgement matrix for retrofit construction.

A	B_1	B_2	B_3	B_4	B_5
B_1	1	2	4	7	5
B_2	1/2	1	3	9	2
B_3	1/4	1/3	1	2	4
B_4	1/7	1/9	1/2	1	1/2
B_5	1/5	1/2	1/4	2	1

After calculating λ_{max} = 5.364, CR = 0.081, the weight of each level of indicators to the target layer W = (0.43507,0.28477,0.14670,0.04824,0.08523) is obtained by matrix consistency test. Similarly, B_1-(B_{11}-B_{16}), B_2-(B_{21}-B_{27}), B_3-(B_{31}-B_{36}), B_4-(B_{41}-B_{47}), B_5-(B_{51}-B_{56}) are constructed, and the relative weights of each second-level indicator to the first-level indicator are obtained by assigning the experts to the five judgement matrices:

$\lambda_{max}^{B_1}$ = 6.159, CR = 0.015, W_1 = (0.44749,0.23999,0.05657,0.03113,0.14003,0.08479), passes the consistency test.

$\lambda_{max}^{B_2}$ = 7.259, CR = 0.032, W_2 = (0.18440,0.05720,0.23637,0.36939,0.02517,0.03663, 0.09084), passes the consistency test.

$\lambda_{max}^{B_3}$ = 6.148, CR = 0.023, W_3 = (0.42472,0.08815,0.13574,0.26508,0.03427,0.05204), passing the consistency test.

$\lambda_{max}^{B_4}$ = 7.266, CR = 0.033, W_4 = (0.11199,0.37783,0.03985,0.15440,0.02689,0.22949, 0.05955), passes the consistency test.

$\lambda_{max}^{B_5}$ = 6.135, CR = 0.021, W_5 = (0.26386,0.05592,0.03963,0.15142,0.40020,0.08897), passing the consistency test.

Combined with the weight of the previous level 1 indicators on the target level, the weight of each level 2 indicator on the target level is obtained as Q. The result of Q is obtained by weighting the weights of the influencing factors between each level of indicators, and then combined with the results of the evaluation of the safety hazards in Table 4 is recorded as P, and ultimately, the weighted risk value of the total of all the factors is obtained as D, which is calculated by the formula:

$$D=Q*P \tag{4}$$

The results of the calculations are shown in Table 8.

Table 8 Total weighted values of factors

risk factor	Secondary indicator weights Q	Evaluation result P	Weighted value-at-risk D	arrange in order
B_{11}	0.1947	540	105.14	1
B_{12}	0.1044	126	13.15	11
B_{13}	0.0246	126	3.10	17
B_{14}	0.0135	270	3.65	15
B_{15}	0.0609	540	32.89	5
B_{16}	0.0369	540	19.93	8
B_{21}	0.0525	900	47.25	2
B_{22}	0.0163	210	3.42	16
B_{23}	0.0673	252	16.96	9
B_{24}	0.1052	420	44.18	3
B_{25}	0.0072	210	1.51	22
B_{26}	0.0104	90	0.94	25
B_{27}	0.0259	18	0.47	30
B_{31}	0.0623	252	15.70	10
B_{32}	0.0129	60	0.77	28
B_{33}	0.0199	21	0.42	31
B_{34}	0.0389	70	2.72	18
B_{35}	0.0050	150	0.75	29
B_{36}	0.0076	300	2.28	20
B_{41}	0.0054	900	4.86	13
B_{42}	0.0182	1500	27.30	7
B_{43}	0.0019	30	0.06	32
B_{44}	0.0074	800	5.92	12
B_{45}	0.02013	108	2.17	21
B_{46}	0.0111	420	4.66	14
B_{47}	0.0029	420	1.22	24
B_{51}	0.0225	1440	32.40	6
B_{52}	0.0048	180	0.86	26
B_{53}	0.0034	420	1.43	23
B_{54}	0.0129	210	2.71	19
B_{55}	0.0341	1000	34.10	4
B_{56}	0.0076	108	0.82	27

5 Conclusion

For the current development of old urban areas , there are many problems need the government and enterprises to invest a lot of money for transformation. However, the old district has a superior geographical location, the surrounding has a complete set of facilities, convenient traffic, from the perspective of urban renewal and development, this is the reuse of resources, but also the opportunity for urban planning and development.

Applying the AHP-LEC method to calculate the old city renovation process, we can quickly and more accurately determine the size of the risk factor of various safety hazards, so that we can target prevention and management, from the weighting of the various safety hazards shown in Table 8, we can conclude that among several risk factors, the proportion of unfastened safety belts, damage to the leakage protection, injury caused by the fall of tools and bricks and mortar from a high place, damage to scaffolding and guardrail, and hazardous work is larger and needs to be focused on prevention. damage, and hazardous work account for a large proportion and need to be prevented.

For the crisis seat belt behaviour not only to stop, but also to do a good job of safety education; construction site circuit management should be standardised, dangerous work areas set up eye-catching warning signs, and resolutely prevent the phenomenon of workers pulling and connecting the phenomenon; construction throughout the whole process must wear helmets, set up anti-fall net; scaffolding and guardrail safety inspection should be routinely done every day to do a good job of safety education, to prevent the danger of the occurrence of the incident. The construction process of safety prevention is a complex and dynamic process, which requires us to avoid these safety accidents in the management of the time, so that our old city renovation can be more safe and standardised construction, and make more contribution to our city construction.

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