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Comprehensive Evaluation of Urban Renewal Based on Entropy and TOPSIS Method: A Case of Shandong Province

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ABSTRACT

This study offers a comprehensive evaluation of urban renewal efforts in Shandong Province, China, by employing the entropy method combined with the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). An evaluation index system was constructed to assess the weights of key factors influencing urban renewal, including the renovation of old residential areas, improvement in sewage treatment quality, development of sponge cities, adoption of clean heating, and enhancement of air quality. Analysis of 16 prefecture-level cities in 2019 reveals significant disparities in performance, with Jinan achieving the highest ranking due to notable improvements in infrastructure and environmental management. Meanwhile, other cities displayed varying levels of success, reflecting different developmental stages and capacities. The findings underscore the necessity for tailored strategies to optimize urban renewal outcomes, focusing on high-weight factors such as sewage treatment, clean heating, and residential renovation. This study provides actionable insights for policymakers, advocating adaptive renewal strategies that align with local contexts and encourage continuous innovation. The results highlight the importance of targeted policy interventions to enhance urban renewal quality across Shandong Province, promoting sustainable urban development and better living standards.

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Highlights:	Contribution to the field statement:
- The study introduces a new evaluation method for urban renewal using Entropy and TOPSIS. - Key focus areas include residential renovation, sewage treatment, sponge city construction, heating, and air quality. - Results show significant differences in renewal performance across 16 cities, with Jinan performing best. - Emphasizes locally tailored strategies and continuous innovation in urban renewal. - Provides actionable insights for policymakers to enhance urban renewal efforts.	-Constructed a comprehensive and scientific evaluation index system for urban renewal. -Introduced a new method that combines objective data weighting (entropy) with multi-criteria decision-making (TOPSIS) for comprehensive evaluation of urban renewal work.

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1. Introduction

As of 2023, China's urbanization rate has reached 66.16%. With the rapid advancement of urbanization in China, urban development issues are increasingly prominent. Urban renewal aims to comprehensively improve the urban living environment, optimize industrial structure, and promote sustainable urban development（Dan Wang, 2022). Urban renewal has gradually become a hot topic for governments and scholars recently. The concept of urban renewal was first proposed in the government work report at the Central Economic Work Conference in Dec. 2019. In Nov. 2020, the implementation of urban renewal actions was proposed in the Proposal on Formulating the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives for 2035 (from now on referred to as Proposal) drafted by the Central Committee of the Chinese Communist Party (Dong, 2022). Promoting urban renewal and achieving high-quality development is put forward.

Shandong Province, a vital economic hub in eastern China, has experienced rapid urban expansion and significant demographic shifts. This rapid development has resulted in outdated urban infrastructure, inadequate public facilities, and environmental degradation. Urban renewal in this context is not just about physical infrastructure but also about aligning urban environments with contemporary economic and social needs.

The views held by foreign scholars on urban renewal can be roughly divided into four categories. Firstly, urban renewal can bring environmental and economic benefits (Adedeji & Arayela, 2018). (Ekemode Benjamin Gbolahan, 2019) evaluated the rental value of commercial property after urban renewal from 2008 to 2017 in Osobo, the capital of Osobo state in Nigeria. Tangible urban infrastructure such as roads, drainage, water supply, and waste disposal in the region has been improved, and the investment performance of commercial properties in the area was significantly enhanced. Secondly, historical buildings should be preserved and repaired in urban renewal. Walaa Abou El Haggag Mehanna et al. (2019) believe that the traditional commercial streets in the city's historical center should be protected to the maximum extent, as they represent a city. Appropriate principles and standards are recommended to maintain continuity and interests. Promote local culture by preserving the historical characteristics and developing these streets. Thirdly, sustainable development in urban renewal strategies should be integrated. V I Sarchenko et al. (2020) analyzed concepts such as integrated real estate and sustainable development and how they are applied in urban renewal actions. The article explores the essential land and resource planning and sustainable development elements. Research shows that applying comprehensive and sustainable development tools can help attract more investment, change the urban structure, and improve the urban environment. Fourthly, people-oriented should be promoted in urban renewal. Boros Judit et al. (2021) analyzed the design driving and enabling factors that affect the park's human-centred and nature-based performance while investigating the design and implementation process of Biblioteca degli Alberti Park in Milan. They consider that it is necessary to integrate the urban ecological perspective into the overall design process to successfully re-examine urban design and planning practices and instil humanism in nature first.

Currently, the research hotspots of urban renewal in China mainly focus on three aspects. Firstly, study foreign urban renewal projects and get inspiration from them (Dai et al., 2023). Secondly, the urban renewal projects that are being implemented or have been completed in China should be studied (Cao et al., 2023). Then, the defects during implementation will be found, and recommendations will be made. Thirdly, the game among the public, government, and enterprise (Wang et al., 2022). Zheng Weihan (2021) combined the city backgrounds of the United Kingdom and the U.S.A. and analyzed the urban renewal models of the two countries. He proposes that urban renewal should aim at sustainable development, adhere to the market-leading, government-guiding policy, strengthen public participation, and adjust measures to local conditions. Taking the urban renewal project in the Yulin area of Chengdu as an example, Chen Guangqiong (2021) analyzed the problems existing in this area,

such as the existing low-end industrial level, unreasonable distribution of public support facilities, insufficient public space resources, and prominent contradiction between parking supply and demand, and put forward new models such as gathering high-end industries and people-oriented. Through the text analysis and comparison of the renewal methods of Shanghai, Guangzhou, and Shenzhen, Yang Xuan (2020) proposed combining top-level design and grassroots innovation, actively integrating the public into governance, and gradually improving the long-term urban renewal mechanism. Recent studies have explored various methods for evaluating urban renewal projects, with a focus on both qualitative and quantitative approaches. For instance, Zhao et al. (2023) integrated GIS, fuzzy theory, and the Decision-Making Trial and Evaluation Laboratory to develop a pre-assessment model for evaluating the sustainability potential of urban renewal projects. Wang &Yang (2022) used the developed framework to construct a demand potential constraint model that includes three dimensions of evaluation indicators.

These studies, published in high-impact Web of Science (WOS)-indexed journals underscore the critical role of comprehensive evaluation methods in urban renewal. Foreign and domestic scholars have slightly different focuses on urban renewal. Foreign scholars such as Shih-Yuan Liu et al.(2020), Mehmet Faruk Kocak(2023), and Beibei Zhang (2023) mainly focus on research on urban renewal work methods. Domestic scholars such as Yan Tang et al.(2019), Jingxian Tang(2016), Qing Zhang(2022), Kexin Cao et al.(2023), Liu H. et al. (2023) focus on studying successful project cases at home and abroad and analyzing work methods. However, the foreign experience should only be applied indirectly due to the influence of political, market, cultural, and other factors. It is necessary to improve methods to meet China's national conditions. In recent years, research on urban renewal evaluation has been relatively scarce, although China has vigorously promoted urban renewal measures. Urban renewal evaluation aims to check and provide feedback on the current urban renewal work, correct the existing problems in time, and promote the smooth implementation of urban renewal work.

Taking Shandong Province as an example, an evaluation system with four first-level indexes and ten second-level indexes is established. The entropy method and TOPSIS are used to comprehensively evaluate the urban renewal work of 16 prefecture-level cities in Shandong Province in 2019. This study introduces a novel approach that combines objective data weighting (Entropy) with multi-criteria decision-making (TOPSIS), offering a more nuanced and accurate evaluation of urban renewal projects. Moreover, this study not only evaluates urban renewal comprehensively but also aims to offer actionable insights and recommendations for policymakers and urban planners in Shandong Province, bridging the gap between theoretical evaluation and practical implementation.

2. Current status of urban renewal in Shandong Province

People's Government of Shandong Province passed the Three-Year Action Plan for Improving Urban Quality in Shandong Province (from now on, referred to as Plan) in 2019. Eight particular tasks are made in the Plan: actions on style and characteristics enhancement, blue and green space improvement, air cleanliness improvement, road traffic improvement, life service improvement, governance capacity improvement, safe operation improvement, and civilized quality improvement.

Actions on style and characteristics refer to protecting and utilizing historical buildings and cultural blocks, preserving their historical charm, and fully showcasing the city's characteristics and heritage. Up to now, most historic and cultural city districts have set up protection signs, and historical buildings that can be well protected and utilized have been listed. Cities such as Jinan, Qingdao, Zibo, Zaozhuang, Yantai, Weifang, Jining, Tai'an, Linyi, and Liaocheng have formulated plans to protect historical and cultural cities.

The blue-green space promotion action refers to building a blue-green intertwined space for citizens by promoting sponge city construction, improving sewage and black and odorous water treatment, carrying out urban greenway construction, three-dimensional greening, and other projects. Housing

and Urban-Rural Development Department, Ecology and Environment Department, and Development and Reform Commission of Shandong Province jointly issued a Notice on the 3-year Action for Improving Quality and Efficiency of Urban Sewage Treatment put forward that the black and odorous water bodies in the urban built-up areas should be eliminated. The black and odorous water bodies in the county (city) built-up areas should be eliminated by 70% in 3 years. The annual target requirements for the weighted BOD concentration of the influent of each urban sewage treatment plant were put forward.

Air cleanliness improvement action refers to actively promoting clean heating, expanding the coverage of central heating, increasing the proportion of clean heating, strengthening the prevention and control of air pollution sources such as industry, strengthening the construction of dust control, and improving the level of road cleaning. Under the joint guidance of the Housing and Urban-Rural Development Department Energy Administration of Shandong Province, 16 cities comprehensively manage the open-air barbecue in the built-up areas, strengthen the control of mobile source exhaust pipes, actively promote clean heating work, and establish multi-energy complementary heating systems.

Road traffic improvement refers to improving the level of public transport infrastructure and comprehensive pipe gallery construction, increasing the intensity of road construction in urban built-up areas, increasing the density of road networks, reducing the difficulty of citizens ' travel, and promoting economic development. General Office of the People's Government of Shandong Province promulgated Opinions on Implementing No.61 Document issued by the State Council in 2005 to Promote the Construction of Urban Underground Comprehensive Pipe Gallery, which put forward the target for each city's underground comprehensive pipe gallery. Regarding public transportation, cities keep improving the public transportation infrastructure and vigorously developing low-energy and efficient public transportation systems.

Life service promotion action refers to the overall layout of the three-level public service facilities, including city, group, and community, focusing on promoting the full coverage of community services such as education, medical care, and old-age care in 15-minute activity circle and actively promoting the transformation of old communities, accessibility, and other basic livelihood projects (Shanghai Urban Planning, 2020). Cities improve the planning of education facilities construction, increase community hospitals and daycare centers, and make up for the shortcomings of education, community medical care, community pensions, and other services. At the same time, the General Office of the People's Government of Shandong Province also issued an Implementation Plan for Further Promoting the Transformation of Old Urban Communities in Shandong Province, which aims to complete the transformation of old communities built before 2005 by the end of 14th Five-Year.

Governance capacity improvement action refers to the construction of a better environment and life in an all-round way, which can improve the urban grass-roots governance mechanism, upgrade the digital urban management system, build an innovative urban management platform, implement municipal solid waste classification activities, and improve system and mechanism of municipal solid waste classification. The Housing and Urban-Rural Development Department of Shandong Province issued the Implementation Plan for the Classification System of Municipal Solid Waste in Shandong Province, which requires five types of classification for municipal solid waste in each city. Key cities should build a waste classification and treatment system. In terms of intelligent city management platforms, digital urban management systems of 16 cities have been completed and implemented. They were upgraded to intelligent urban management platforms according to the relevant guidelines and standards, which passed the acceptance of provincial departments.

Safe operation improvement refers to the risk investigation and hidden danger management of the construction quality, operation, and maintenance support ability of various infrastructures, effectively preventing various urban disasters such as floods and fires, and building and improving various emergency shelters, ensuring the city's safe operation. General Office of the People's Government of

Shandong Province issued Implementation Opinions on Promoting the Safe Development of Cities in the Province, proposing that cities must improve urban safety regulations and standards, strengthen infrastructure safety management, and accelerate urban emergency management and rescue capacity building. Civilized quality improvement refers to the extensive education of citizens, the introduction of virtue and etiquette into the classroom, the severe punishment of social morality, the active development of social public welfare activities, the promotion of the construction of the credit system, which contributes to the continuous improvement of civilization quality and the level of urban culture. With the efforts of the Propaganda Department of Shandong Provincial Party Committee and other organizations, nine cities, including Jinan, Qingdao, Zibo, Dongying, Yantai, Weifang, Weihai, Rizhao and Linyi, have created national civilized cities. Qingdao, Weifang, and Weihai have been rated demonstration cities for constructing the national social credit system.

3. Entropy and TOPSIS methods

The entropy method is an objective weighting method that is determined according to the degree of dispersion of the data of each index. As the data is more dispersed, the entropy value is smaller. The data contains more information, so the weight is more significant, and vice versa. TOPSIS was first proposed in 1981. It constructs positive and negative ideal solutions to the multi-index problem. The ranking is based on the degree of proximity between the index and the perfect solution (Notice of the General Office of the People's Government of Shandong Province on Issuing the Three-Year Action Plan for Improving Urban Quality in Shandong Province, 2019). The entropy method and TOPSIS are comprehensive evaluation methods (Rao,R.V.,2012) that combine the entropy method and TOPSIS. After solving the weight of each evaluation index by the entropy method, the multi-objective is sorted based on the weight. It can avoid the subjectivity of data and has no strict limit on the number of indexes. It is suitable for both small samples and multi-evaluation units. Therefore, this paper uses this method to comprehensively evaluate the urban renewal work of 16 prefecture-level cities in Shandong Province in 2019. The methodological process is shown in Figure 1 and the specific steps are as follows.

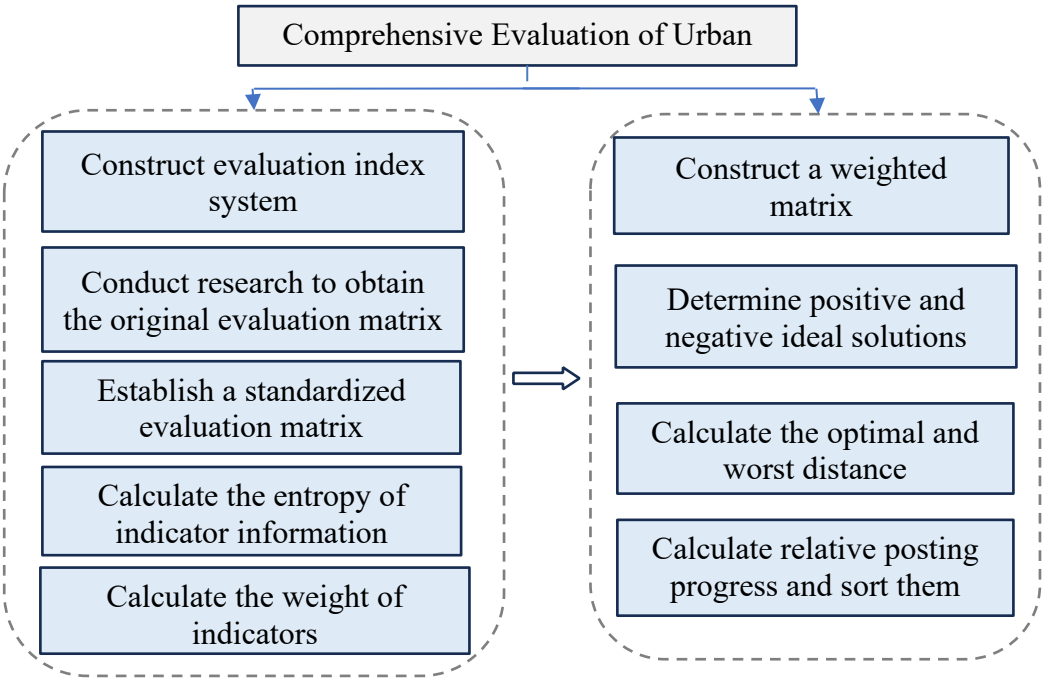

Figure 1. Methodological process of the research.

3.1. Constructing evaluation index system

A total of 4 first-level indexes and 10 second-level indexes are selected based on reviewing implementation policies and literature, measuring the quantifiable nature of indexes, and following the basic principles of establishing the index system. The index system is shown in Table 1. In the entropy method, the index types are divided into four categories. The more extensive positive index is the better one. The smaller negative indexes are the better ones. For the intermediate index, the best index is the one that tends to a specific value. The last index type is an interval index, which falls best in a particular interval. Implementing urban renewal work can reduce the number of black and odorous water, so the index is negative. And the other indexes are positive.

Table 1: Evaluation index system.

Contents	First-level indexes	Second-level indexes	Index explanation	Type of index
effect of urban renewal A	blue-green spaces B	black and odorous water treatment B_1	the number of existing black and odorous water	negative
		quality and efficiency improvement of sewage treatment B_2	influent weighted BOD concentration of sewage treatment plant（mg/L）	positive
		sponge City construction B_3	the proportion of built-up area to area of built-up district（%）	positive
	air cleaning C	urban clean heating C_1	new clean heating area (10,000 m2)	positive
		urban air quality C_2	excellent air duration (days)	positive
	road traffic D	the road network in urban built-up areas D_1	road network density of urban built-up area (km / km2)	positive
		public traffic D_2	number of public transport vehicles owned by 10,000 people in the city	positive
		comprehensive pipe gallery construction D_3	Length of new comprehensive pipe gallery construction (km)	positive
	life service E	15-minute life circle E_1	convenience（%）	positive
		renovation of old residential areas E_2	number of renovation households (households)	positive

3.2 Weight calculation-entropy method

3.2.1 Standardization

We find the required data through China's economic and social big data research platform and government bulletin and use the above database to ensure the authenticity of the data, making the calculation results more scientific.

There are 16(m) cities and 10(n) evaluation indexes. Table 2 defines the original data matrix Xij, which is the original data value of the ith evaluation object under the jth evaluation index.

Table 2: Original data matrix.

City	B_1	B_2	B_3	C_1	C_2	D_1	D_2	D_3	E_1	E_2
Jinan	103	100.23	11.96%	650	212.00	7.83	21.1	58	100.00%	95087
Qingdao	82	255.61	21.50%	639	287.00	8.20	14.12	66	100.00%	11510
Zibo	33	102.77	18.88%	912.07	186.00	7.94	15	27	100.00%	15253
Zaozhuang	50	70.87	22.63%	396	245.00	6.90	15.2	38	100.00%	31118
Dongying	118	103.76	21.67%	811.38	276.00	5.86	19.2	21	100.00%	597
Yantai	10	168.81	16.73%	345.8	286.00	8.22	15.2	28	100.00%	2844
Weifang	24	100.39	38.99%	893	218.00	8.19	12.27	36	66.67%	3738
Jining	317	79.56	15.43%	396	256.00	8.01	15.07	34	100.00%	8903
Taian	24	97.6	32.72%	354.77	189.00	8.72	13.29	34.2	100.00%	2560
Weihai	4	172.95	18.81%	650	295.00	6.79	14.7	40	100.00%	4921
Rizhao	25	159.75	16.02%	467.98	253.00	8.17	14.1	59	100.00%	5869
Linyi	94	118.83	33.96%	400	197.00	8.11	11	75	100.00%	12247
Dezhou	103	81.06	18.19%	597	188.00	6.51	12.36	22	100.00%	9409
Liaocheng	35	62.61	23.27%	350	177.00	5.35	14.4	20	100.00%	4819
Binzhou	138	80.59	29.56%	231	206.00	7.53	9	8.27	75.00%	7267
Heze	238	61.02	12.85%	586	254.00	3.25	12.08	18.23	100.00%	5214

To eliminate the influence of different dimensions on the evaluation results, the standardized matrix V is obtained by processing each index, and the calculation results are shown in Appendix A.

For the positive index, the v_{ij} Calculation method is as follows:

$$v_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

The $\max(x_j)$ 、 $\min(x_j)$ represent all evaluation objects' maximum and minimum values under j evaluation indexes, respectively. In particular, when the maximum value is equal to the minimum, there will be uncertain situations, such as 0/0, and v_{ij} can be taken as 1.

For the negative index, the v_{ij} Calculation method is as follows:

$$v_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

3.2.2 Normalization

The characteristic proportion matrix P can be obtained by further processing the standardized matrix. Let p_{ij} be the characteristic proportion of the ith evaluation object under the jth evaluation index. The calculation method is as follows, and the calculation results are shown in Appendix B.

$$p_{ij} = \frac{v_{ij}}{\sum_{i=1}^{m} v_{ij}} \quad (3)$$

3.2.3 Define weight

The entropy matrix E is calculated, e_j is the entropy value of the jth evaluation index. The calculation method is shown in Formula (4), and the calculation results are shown in Appendix C. To avoid the case of $ln(0)$, the whole data of P can be shifted, and a smaller number (0) can be added.

$$e_j = -\frac{1}{ln(m)} \sum_{i=1}^{m} p_{ij} \cdot ln\, p_{ij} \quad (4)$$

Calculate the weight matrix W, $w_{(e)j}$ is the weight of the jth evaluation index, the calculation method is as follows, and the calculation results are shown in Table 3.

$$w_{(e)j} = \frac{(1-e_j)}{\sum_{j=1}^{n}(1-e_j)} \quad (5)$$

Table 3: Weight matrix.

Index	$w_{(e)j}$
B_1	3.75%
B_2	15.58%
B_3	11.02%
C_1	8.51%
C_2	10.90%
D_1	3.44%
D_2	5.94%
D_3	8.30%
E_1	3.42%
E_2	29.14%

3.3 Comprehensive evaluation-TOPSIS method

3.3.1 Constructing a weighted matrix

Before constructing the weighting matrix, the original data is first positively processed. Positive processing converts all types of indexes into positive indexes. For the negative indexes appearing in this chapter, the formula (6) is used.

$$x'_{ij} = \frac{1}{x_{ij}} \qquad (6)$$

After normalizing the original matrix, the standardized method is processed. The standardized matrix is calculated, and the weighted matrix C is constructed. The formula is shown in (7), and the calculation result is shown in Appendix D.

$$c_{ij} = v'_{ij} * w_j \qquad (7)$$

3.3.2 Determining positive and negative ideal solution

The positive ideal solution is the best solution of an idea (denoted by C^+), for which various index values reach the best value of each candidate scheme. The negative ideal solution is the worst solution of another idea (denoted by C^-), for which various index values reach the worst value of each candidate scheme.

The method of determining the positive ideal solution is different for different indexes. The formula is as follows.

$$c_j^+ = \begin{cases} max\ c_{ij}, \text{j is a positive index} \\ min\ c_{ij}, \text{ j is a negative index} \end{cases} \text{j=1, 2, ···, n} \qquad (8)$$

Similarly, the determination method of negative ideal solution is different for different types of indexes. The formula is as follows.

$$c_j^- = \begin{cases} min\ c_{ij}, \text{ j is a positive index} \\ max\ c_{ij}, \text{j is negative index} \end{cases} \text{j=1, 2, ···, n} \qquad (9)$$

Positive and negative ideal solutions are shown in Appendix E.

3.3.3 Optimal and worst distance

The distance between the evaluation object and the positive ideal solution is denoted by d_i^+, and the distance between the evaluation object and the negative ideal solution is denoted by d_i^-. They are calculated respectively. The distance information between them is used as the standard to rank the 16 cities.

The distance from each evaluation object to the positive ideal solution is called the optimal distance, and the calculation formula is as follows.

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^+)^2}, \ i = 1, 2, \cdots, m \qquad (10)$$

The distance from each evaluation object to the negative ideal solution is called the worst distance d_i^-, and the calculation formula is as follows.

$$d_i^- = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^-)^2}, \ i = 1, 2, \cdots, m \qquad (11)$$

The results of the optimal distance and the worst distance are shown in Appendix F.

3.3.4 Establish relative closeness

Finally, the relative closeness Z between the evaluation object and the positive ideal solution is calculated, and the formula is as follows:

$$Z_i = \frac{d_i^+}{d_i^+ + d_i^-} \ (i = 1, 2, \cdots, m) \qquad (12)$$

According to Formula (12), Z_i ranges from 0 to 1. Project schedule management can be sorted according to relative proximity. The smaller Z_i is, the closer to the positive ideal solution, which means the comprehensive evaluation's result is better. The relative closeness and ranking are shown in Table 4.

Table 4: Relative closeness and ranking.

City	Relative closeness	Ranking
Jinan	0.3774	1
Qingdao	0.5567	2
Zibo	0.7207	10
Zaozhuang	0.6654	4
Dongying	0.6996	9
Yantai	0.6843	7
Weifang	0.6781	6
Jining	0.7615	12
Taian	0.7557	11
Weihai	0.6411	3
Rizhao	0.6918	8
Linyi	0.6769	5
Dezhou	0.8146	15
Liaocheng	0.8388	16
Binzhou	0.8025	14
Heze	0.7905	13

4. Results

The results show that Jinan ranks highest in evaluating urban renewal work. Qingdao, Weihai, Zaozhuang, Linyi, Weifang, Yantai, Rizhao, Dongying, Zibo, Tai 'an and Jining follow closely behind. The urban renewal work of Heze, Binzhou, Dezhou, and Liaocheng needs to be further improved.

Among the ten evaluation indexes, the weight of blue-green space (first-level index) is 30.35%, of which the weight of black and odorous water treatment (second-level index) is 3.75%, the quality and efficiency of sewage treatment (second-level index) is 15.58%, and the sponge city construction (second-level index) is 11.02%. The weight of air cleanliness (first-level index) is 19.4%, of which the weight of urban clean heating (second-level index) is 8.51%, and the urban air quality (second-level index) is 10.9%. The weight of road traffic (first-level index) is 17.68 %, of which the weight of urban built-up area road networks (second-level index) is 3.44%, public transportation is 5.94 %, and

utility tunnel construction is 8.3 %. The weight of life service (first-level index) is 32.56%, of which the weight of the 15-minute circle (second-level index) is 3.42%, and the old community transformation accounts for 29.14 %.

Among the evaluation indexes, the weight of old community renovation, sewage treatment quality and efficiency improvement, sponge city construction, urban clean heating, and urban air quality is relatively high. The remaining indexes are all less than 10%. Therefore, the high-weight indexes mentioned above are the focus of urban renewal. The number of renovated households in old residential areas in Jinan is 95087, which is far higher than that in other cities. That explains why urban renewal work in Jinan gets the best results in a comprehensive evaluation.

Cities with low ranking in comprehensive evaluation, including Dezhou, Liaocheng, Binzhou, and Heze, should focus more on improving the quality and efficiency of sewage treatment, sponge city construction, and comprehensive pipe gallery construction. In addition, urban air quality, urban built-up area road network, and public transportation indexes in Dezhou are relatively weak. Relevant policies should be formulated to improve the weak aspects of the above. Air quality, road network in urban built-up areas, and renovation of old residential areas in Liaocheng City are relatively weak. The urban air quality ranks the lowest among 16 prefecture-level cities. Public transportation in Binzhou City should be improved because its public transportation level does not reach the same level as other cities. The density of the road network in the built-up area of Heze City is far lower than that of Shandong Province. So, road network construction should be strengthened.

5. Discussions

Some cities failed to complete the annual goal of urban renewal in government gazettes and provincial statistics. The main problems are as follows. Regarding promoting blue-green space, treating influent-weighted BOD concentration in urban sewage treatment plants in Dezhou and Heze is close to the annual target requirements. The related work in Jinan, Zaozhuang, Jining, Tai 'an, Linyi, and Liaocheng is far from the annual target. The proportion of sponge city-built area to urban-built area is less than 20% in half of the 16 prefecture-level cities. The ratio in several cities is less than 13%, which is far lower than the target. Regarding air cleanliness improvement actions, the number of days with good air quality in most cities failed to meet the annual assessment targets, and nearly half of the cities had a large gap with the annual targets.

Regarding road traffic improvement actions, the number of public transport vehicles per 10,000 people in Qingdao, Weifang, Dezhou, Binzhou, and Linyi cities failed to meet the relevant standards. More than half of the cities failed to complete the construction of a comprehensive pipe gallery. The percentage of built comprehensive pipe galleries in Zibo, Liaocheng, Binzhou, and Heze completed is less than 70%.

The following are the existing problems and corresponding promotion strategies.

1. As the main responsible body for urban renewal work, governments should build a smooth and perfect mechanism to coordinate and promote related work. 16 prefecture-level cities should take precise measures based on the local situation and economy. At the same time, a corresponding supervision department should be established to carry out dynamic monitoring, tracking analysis, and regular work checks. Besides, fund support, including financial support and social capital investment, is vital.

2. Multimedia platforms should be fully used to carry out various urban renewal publicity and education activities. Public participation should be enhanced through bulletin boards, science brochures, etc. Urban renewal work plans should be made with high satisfaction by public opinion solicitation on public communication service platforms. So potential interest conflicts can be eliminated in advance. Public satisfaction with completed and ongoing urban renewal projects should be online or offline to provide ideas for follow-up work. Open question options can be added to fully obtain public appeals as well.

3. As the connotation of urban renewal differs in different periods and city levels, cities must formulate urban renewal strategies according to local conditions based on full investigation. One size fits all must be avoided. The urban renewal model needs to be continuously innovated with the continuous development of the urban economy. Cities should study successful cases of urban renewal at home and abroad, innovate urban renewal strategies based on local conditions, and monitor and adjust related measures in time to achieve urban renewal goals.

6. Conclusions

The main problems with urban renewal in Shandong Province are 1) Inefficient blue-green space promotion, particularly in Jinan, Zaozhuang, Jining, Tai'an, Linyi, & Liaocheng; low sponge city-built area ratio (<20% in half, <13% in several cities). 2) Poor air quality improvement, with most cities failing to meet good air quality days targets. 3) Inadequate road traffic improvements, such as insufficient public transport vehicles in Qingdao, Weifang, Dezhou, Binzhou, & Linyi, and unfinished comprehensive pipe gallery construction in >50% of cities, with Zibo, Liaocheng, Binzhou, & Heze <70% complete. It can be seen that although urban renewal work has been actively promoted in various cities, the quality of urban renewal work varies greatly due to the different development levels of each city. Existing urban construction and management systems in China have been established to support rapid urbanization, but they are no longer suitable for urban development and transformation. They even conflict with urban renewal. The findings are specific to urban renewal projects in Shandong Province. Future research will explore how the research results can be applied or adapted to other regions facing similar urban renewal challenges, considering how cultural factors affect the outcomes of urban renewal projects.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data availability statement

Data is not available due to commercial restrictions.

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Appendices

Appendix A: Standardized matrix.

City	B_1	B_2	B_3	C_1	C_2	D_1	D_2	D_3	E_1	E_2
Jinan	0.6837	0.2015	0.0000	0.6152	0.2966	0.8373	1.0000	0.7452	1.0000	1.0000
Qingdao	0.7508	1.0000	0.3529	0.5991	0.9322	0.9049	0.4231	0.8651	1.0000	0.1155
Zibo	0.9073	0.2146	0.2560	1.0000	0.0763	0.8574	0.4959	0.2807	1.0000	0.1551
Zaozhuang	0.8530	0.0506	0.3947	0.2423	0.5763	0.6673	0.5124	0.4455	1.0000	0.3230
Dongying	0.6358	0.2196	0.3592	0.8522	0.8390	0.4771	0.8430	0.1908	1.0000	0.0000
Yantai	0.9808	0.5539	0.1765	0.1686	0.9237	0.9086	0.5124	0.2957	1.0000	0.0238
Weifang	0.9361	0.2023	1.0000	0.9720	0.3475	0.9031	0.2702	0.4156	0.0000	0.0332
Jining	0.0000	0.0953	0.1284	0.2423	0.6695	0.8702	0.5017	0.3856	1.0000	0.0879
Taian	0.9361	0.1880	0.7680	0.1817	0.1017	1.0000	0.3545	0.3886	1.0000	0.0208
Weihai	1.0000	0.5752	0.2534	0.6152	1.0000	0.6472	0.4711	0.4755	1.0000	0.0458
Rizhao	0.9329	0.5074	0.1502	0.3480	0.6441	0.8995	0.4215	0.7602	1.0000	0.0558
Linyi	0.7125	0.2971	0.8139	0.2481	0.1695	0.8885	0.1653	1.0000	1.0000	0.1233
Dezhou	0.6837	0.1030	0.2305	0.5374	0.0932	0.5960	0.2777	0.2058	1.0000	0.0933
Liaocheng	0.9010	0.0082	0.4184	0.1747	0.0000	0.3839	0.4463	0.1758	1.0000	0.0447
Binzhou	0.5719	0.1006	0.6511	0.0000	0.2458	0.7824	0.0000	0.0000	0.2500	0.0706
Heze	0.2524	0.0000	0.0329	0.5212	0.6525	0.0000	0.2545	0.1493	1.0000	0.0489

Appendix B: Characteristic proportion matrix.

City	B_1	B_2	B_3	C_1	C_2	D_1	D_2	D_3	E_1	E_2
Jinan	0.0582	0.0467	0.0000	0.0841	0.0392	0.0720	0.1439	0.1099	0.0702	0.4458
Qingdao	0.0640	0.2316	0.0590	0.0819	0.1232	0.0779	0.0609	0.1276	0.0702	0.0515
Zibo	0.0773	0.0497	0.0428	0.1366	0.0101	0.0738	0.0714	0.0414	0.0702	0.0692
Zaozhuang	0.0727	0.0117	0.0659	0.0331	0.0761	0.0574	0.0737	0.0657	0.0702	0.1440
Dongying	0.0542	0.0509	0.0600	0.1164	0.1109	0.0411	0.1213	0.0281	0.0702	0.0000
Yantai	0.0836	0.1283	0.0295	0.0230	0.1220	0.0782	0.0737	0.0436	0.0702	0.0106
Weifang	0.0797	0.0469	0.1670	0.1328	0.0459	0.0777	0.0389	0.0613	0.0000	0.0149
Jining	0.0000	0.0221	0.0215	0.0331	0.0885	0.0749	0.0722	0.0569	0.0702	0.0392
Taian	0.0797	0.0435	0.1283	0.0248	0.0134	0.0860	0.0510	0.0573	0.0702	0.0093
Weihai	0.0852	0.1332	0.0423	0.0841	0.1321	0.0557	0.0678	0.0701	0.0702	0.0204
Rizhao	0.0795	0.1175	0.0251	0.0476	0.0851	0.0774	0.0606	0.1121	0.0702	0.0249
Linyi	0.0607	0.0688	0.1359	0.0339	0.0224	0.0764	0.0238	0.1475	0.0702	0.0550
Dezhou	0.0582	0.0239	0.0385	0.0734	0.0123	0.0513	0.0400	0.0304	0.0702	0.0416
Liaocheng	0.0768	0.0019	0.0699	0.0239	0.0000	0.0330	0.0642	0.0259	0.0702	0.0200
Binzhou	0.0487	0.0233	0.1088	0.0000	0.0325	0.0673	0.0000	0.0000	0.0175	0.0315
Heze	0.0215	0.0000	0.0055	0.0712	0.0862	0.0000	0.0366	0.0220	0.0702	0.0218

Appendix C: Entropy value matrix.

Index	e_j
B_1	0.9638
B_2	0.8496
B_3	0.8936
C_1	0.9179
C_2	0.8948
D_1	0.9668
D_2	0.9426
D_3	0.9199
E_1	0.9670
E_2	0.7187

Appendix D: Weighted matrix.

City	B_1	B_2	B_3	C_1	C_2	D_1	D_2	D_3	E_1	E_2
Jinan	0.0365	0.0314	0.0000	0.0523	0.0323	0.0288	0.0594	0.0619	0.0342	0.2914
Qingdao	0.0361	0.1558	0.0389	0.0510	0.1016	0.0311	0.0252	0.0718	0.0342	0.0337
Zibo	0.0334	0.0334	0.0282	0.0851	0.0083	0.0295	0.0295	0.0233	0.0342	0.0452
Zaozhuang	0.0349	0.0079	0.0435	0.0206	0.0628	0.0229	0.0305	0.0370	0.0342	0.0941
Dongying	0.0367	0.0342	0.0396	0.0725	0.0914	0.0164	0.0501	0.0158	0.0342	0.0000
Yantai	0.0228	0.0863	0.0194	0.0143	0.1006	0.0312	0.0305	0.0245	0.0342	0.0069
Weifang	0.0317	0.0315	0.1102	0.0827	0.0379	0.0310	0.0161	0.0345	0.0000	0.0097
Jining	0.0375	0.0148	0.0141	0.0206	0.0729	0.0299	0.0298	0.0320	0.0342	0.0256
Taian	0.0317	0.0293	0.0846	0.0155	0.0111	0.0344	0.0211	0.0323	0.0342	0.0061
Weihai	0.0000	0.0896	0.0279	0.0523	0.1090	0.0222	0.0280	0.0395	0.0342	0.0133
Rizhao	0.0319	0.0791	0.0166	0.0296	0.0702	0.0309	0.0251	0.0631	0.0342	0.0163
Linyi	0.0364	0.0463	0.0897	0.0211	0.0185	0.0305	0.0098	0.0830	0.0342	0.0359
Dezhou	0.0365	0.0160	0.0254	0.0457	0.0102	0.0205	0.0165	0.0171	0.0342	0.0272
Liaocheng	0.0336	0.0013	0.0461	0.0149	0.0000	0.0132	0.0265	0.0146	0.0342	0.0130
Binzhou	0.0369	0.0157	0.0718	0.0000	0.0268	0.0269	0.0000	0.0000	0.0085	0.0206
Heze	0.0373	0.0000	0.0036	0.0443	0.0711	0.0000	0.0151	0.0124	0.0342	0.0142

Appendix E: Positive and negative ideal solution.

Type	B_1	B_2	B_3	C_1	C_2	D_1	D_2	D_3	E_1	E_2
Positive ideal solution	0.0000	0.1558	0.1102	0.0851	0.1090	0.0344	0.0594	0.0830	0.0342	0.2914
Negative ideal solution	0.0375	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix F: Optimal distance and the worst distance.

City	Optimal distanced_i^+	Worst distanced_i^-
Jinan	0.1907	0.3147
Qingdao	0.2745	0.2186
Zibo	0.3131	0.1214
Zaozhuang	0.2754	0.1385
Dongying	0.3338	0.1434
Yantai	0.3223	0.1487
Weifang	0.3260	0.1548
Jining	0.3318	0.1039
Taian	0.3429	0.1109
Weihai	0.3043	0.1703
Rizhao	0.3124	0.1391
Linyi	0.3062	0.1461
Dezhou	0.3400	0.0774
Liaocheng	0.3601	0.0692
Binzhou	0.3478	0.0856
Heze	0.3537	0.0937