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Assessing Sustainable Urbanization in Small Cities: A Life Satisfaction Perspective Using the Delphi Method and Analytic Hierarchy Process (AHP)

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KEYWORDS

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ABSTRACT

In recent years, small cities have experienced rapid development, and the living standards of their residents have increasingly approximated those of larger urban centers. Due to their smaller scale, these cities have inherent advantages in transitioning to sustainable development models. The post-pandemic era, characterized by job reductions in large cities and the economic appeal of lower living costs, has seen a migration flow from large to small cities. The Chinese government has traditionally emphasized urban growth. While recent policies have started to incorporate environmental considerations, there remains a limited focus on the well-being and living conditions of city inhabitants. This study aims to evaluate the sustainable urbanization of small cities from a life satisfaction perspective, emphasizing indicators closely related to residents' well-being. Employing the Delphi method and Analytic Hierarchy Process (AHP), this research identifies persuasive evaluation metrics tailored to the unique contexts of small cities. This work addresses the research gap in sustainable development indicators at the small city level. By emphasizing the perspective of residents' quality of life, it advocates for local governments to prioritize the well-being and experiences of their inhabitants.

1. Introduction

Urbanization is a global and irreversible trend and an important issue for future socio-economic development [1]. The world is experiencing the largest wave of urbanization in history, with more than half of the world's population now living in cities and towns, a figure that will increase to about 5 billion by 2030; at the same time, the problems caused by urbanization have become the object of increasing global concern, especially those that are occurring in developing countries [2]. The future urbanization process is mainly concentrated in developing countries [3]. Developing countries are urbanizing at a faster rate and generally have higher rates of urbanization, and this rapid urbanization process may lead to problems such as increased land use and resource consumption, traffic congestion, and air pollution [4]. The importance of sustainable urbanization is becoming increasingly important.

While metropolitan areas are an important part of the urbanization process, small cities are one of the important components of metropolitan areas [5]. There is an interdependent relationship between the center city of a metropolitan area and the surrounding cities, the economic growth of the center city can drive the economic growth of the surrounding

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cities, and the economic growth of the surrounding cities can also promote the economic growth of the center city [6]. The region around the central city can also drive the economic development of the central city and become the engine of economic growth of the metropolitan area [7]. Smaller cities face many challenges in integrating into the metropolitan area, not the least of which is the lack of sufficient scale, which makes it difficult for them to attract sufficient investment and talent, while at the same time leaving them highly vulnerable to strong external control [8]. Weak infrastructure and lack of good investment opportunities hinder the growth of small cities [9]. Economic inefficiency, poor transportation and population loss also marginalize small cities [10]. But on the other hand, despite the small size and population of small cities, this makes them easier to manage and more conducive to sustainability practices than large cities [11].

China's urbanization is growing rapidly in scale, but it is also facing complex problems and difficult challenges, which are typical in the world [12]. In rapid economic development and rapid urban growth, the development of the eastern coastal areas has been encouraged by the government, and the urbanization process is remarkable [13]. In China, the process of urbanization includes both the migration of population from rural to urban areas and the transformation of rural land into urban land [3]. Promoting the development of small towns is seen as a solution to the bottleneck of urbanization in China [14]. Small towns are transitional zones between cities and rural areas, with certain economic, cultural, and social gathering functions, and are an important link between urban and rural development [15]. The economic foundation of small towns is relatively weak and lacks the support of large-scale enterprises and industries, resulting in limited employment opportunities and economic growth. Meanwhile, the infrastructure and urban planning of small towns are relatively lagging and need to be improved and upgraded [16]. The sustainable development of small cities is one of the important factors in achieving sustainable development of China's new urbanization [17].

Managing the growth of urban areas in pursuit of sustainable development is necessary [18]. Cities and towns are transitional zones between cities and rural areas with certain economic, cultural, and social gathering functions, and are important links between urban and rural development [15] Land finance in Chinese cities is one of the key drivers of urban expansion [19]. Rapid urbanization may lead to socio-economic inequality, flat poverty and unemployment, and unsustainable urban planning and management. [20]. Rapid urbanization in Little China has led to a reduction in arable land, and a decrease in biodiversity, and an increase in carbon emissions [21], and it may also lead to waste of urban land resources and environmental pollution due to the city's over-reliance on land finance [19].

The development of small cities has become a focus of extensive attention in the research of China's new urbanization strategy. The assessment of the development of small cities is not only crucial for judging the quality of urbanization, but also provides a key reference for optimizing the regional urbanization process [22]. The degree of urbanization, the level of economic development and the level of social development are commonly used as indicators to assess the level of development of small cities [23]. Population and employment in small cities are also seen as an important aspect in assessing the level of urban development [24]. The amount of land use and supply also affects the development of small cities, reducing industrial land use reduces management costs and environmental pollution although it reduces economic efficiency and increases unemployment [25]. Transportation infrastructure is also an important factor in assessing the level of urban development [26]. Social justice is also often used as an indicator to assess the level of urbanization [27]. Fine management strategies are also an important factor in ensuring sustainable urban development [28]. The close correlation between tourism and ecological environment also makes the level of tourism development an evaluation indicator for assessing the level of development of small cities [29]. Residents' perception and the level of government investment have also been used as indicators to assess the level of sustainable development of small cities [30].

In 2015, the United Nations launched the 2030 Agenda for Sustainable Development, which has been widely recognized by the international community and widely cited in academic research and practical applications as an important indicator for assessing sustainable urban development. This agenda outlines 17 core Sustainable Development Goals (SDGs) for the period 2015-2030, which are further subdivided into 169 targets, the realization of which is quantified and assessed through 230 indicators.

While the SDGs established by the United Nations Development Programme (UNDP) provide a directional guide for countries around the globe, the indicators should be localized to make them more relevant and practical considering the specific circumstances and actual situation of each place. It is worth noting that although past studies have thor-

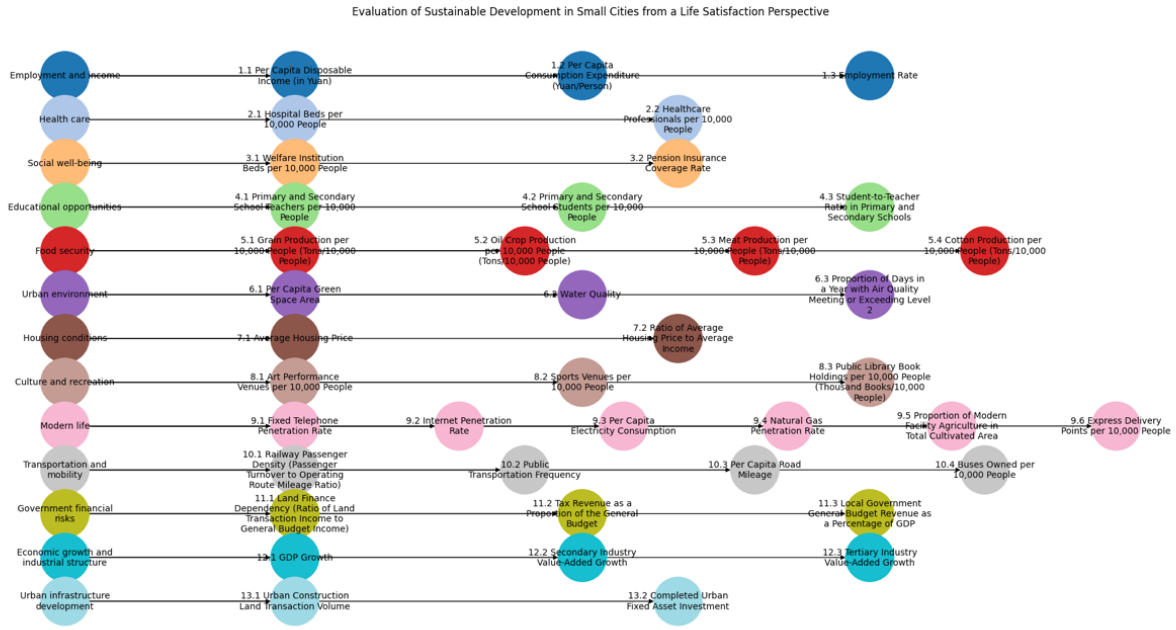

Fig. 1. Structure of small cities' sustainable development assessment from the perspective of life satisfaction

oughly explored the applicability of the UN's SDG indicators from the national level down to the prefecture level, research on county-level cities is still a gap in the field. Therefore, this paper attempts to explore the issue from two perspectives: first, based on the bottom-up approach, the indicators in SDGs that are directly related to residents' life, employment, education, medical care, and travel are selected and appropriately adapted and localized; and second, based on the top-down approach, the indicators that are related to governmental investment, infrastructure construction, economic development, and management level are selected and appropriately localization. This study aims to identify the indicators that best represent the economic sustainability of county-level cities in China.

When considering the sustainability of a small city, it includes a variety of elements, such as residential life, employment, education, healthcare, transportation, accessibility to public green space, and ease of living. However, these elements should not be given the same weighting when making an assessment. Certain key factors may have a greater impact on the assessment of sustainable development. Therefore, this study adopts a weight-based multilevel analysis to build an assessment model, aiming to reflect the level of sustainable development of small cities more accurately from the perspective of residents' life satisfaction based on a combination of more factors.

2. Materials and Methods

2.1. Selection of indicators

According to UN-HABITAT in 2002, sustainable urbanization is seen as a dynamic, multidimensional process that encompasses economic, social, and environmental sustainability. However, in practice, cities choose their development priorities according to their own context. The Chinese government has long emphasized economic growth in order to achieve high rates of economic development. In this context, economic sustainability was often regarded as the core evaluation indicator, which involves a number of factors, such as GDP, industrial output, energy consumption, and government management. However, as the economy matures and people's demand for quality-of-life increases, the limitations of this approach begin to emerge. Especially after the epidemic, while the economy was hit, the life satisfaction of the residents became especially important.

Life satisfaction is a multifaceted and comprehensive indicator that includes multiple dimensions such as healthcare, education, income, housing, cost of living, transportation, green space accessibility, environment, and recreation. With the rapid development of technology and e-commerce, logistics networks and takeaway services have also become crucial, especially in smaller cities. Thanks to well-developed logistics and takeaway systems, residents of small cities are able to enjoy similar

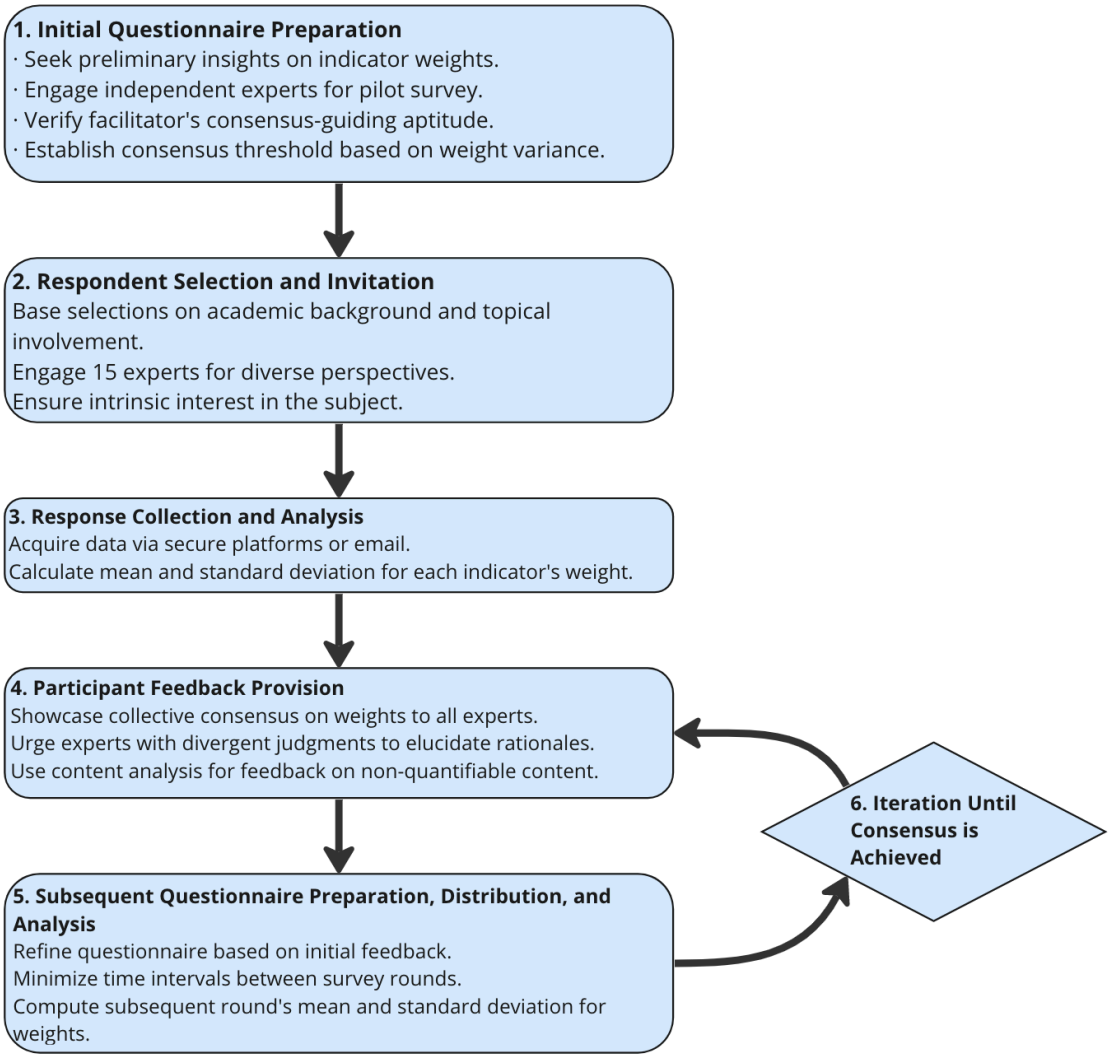

Fig. 2. Technical Flowchart for Determining the Weight of Sustainable Development Assessment Indicators for Small Cities Using the Delphi Method

consumer experiences and material living standards as those in big cities.

In order to more accurately assess life satisfaction, we have constructed an assessment model by referring to the "Official Indicators of the Sustainable Development Goals" released by the United Nations in 2017, the "Sustainable Development Report 2022" and other relevant literature. Considering the characteristics of small cities and the availability of data, we have made adjustments based on the existing evaluation system. These adjustments are based on several principles: 1) close correlation with life satisfaction in small cities; 2) universality and easy accessibility; 3) reasonable reference ranges and thresholds; 4) time sensitivity and the ability to track development trends; and 5) statistical reliability. Although this evaluation system is not perfect, it provides a valuable reference framework. In the future, certain indicators may change or be replaced by new ones, but for the time being, this system provides a solid basis for our evaluation.

2.2. Localization of indicators and data sources

On the basis of various sustainable development evaluation index systems, such as the Sustainable Development Goals proposed by the United Nations in 2017, and various regional evaluation indexes successively introduced by local governments in China, this study constructs a specialized evaluation index system for small cities with the core perspective of residents' life satisfaction. To ensure the representativeness and accuracy of the indicators developed, we paid special attention to the localization of the indicators and the actual availability of data and made appropriate adjustments and optimizations accordingly.

2.3. Delphi method to confirm weights

The Delphi technique is an expert consensus-based methodology whose core purpose is to gather the views of experts on uncertain or controversial issues based on their knowledge and experience in order to inform decision-making [31].The Delphi methodology is regarded as a preferred methodology when confronted with multifaceted problems, where specific information is limited or contradictory, or when integrating different types of evidence [32]. This technique has been widely adopted in several academic fields including, but not limited to, medicine, nursing, social policy, tourism, and sustainability research [33].

In order to ensure the scientific validity and authority of the small city sustainability assessment model based on the life satisfaction perspective and its local relevance, we invited experts and representatives from different fields to participate, including urban planning experts, ecologists, sociologists, psychologists, economists, public policy researchers, geographic information system (GIS) specialists, representatives of the local government, and representatives of the local residents, totaling 15 The total number of participants was 15. Through three rounds of iterations of the Delphi technique, we determined the relative weights between the assessment indicators.

The following is the technical roadmap of the Delphi method for weighting indicators for assessing the sustainable development of small cities based on the perspective of life satisfaction:

2.4. Establishment of the Evaluation Model Using the Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), introduced by Thomas L. Saaty in 1980, is a multi-criteria decision-making method designed to assist decision-makers in addressing intricate decisions by constructing a hierarchical structure [34]. Typically, an AHP model commences with a decomposition of the problem into its constituent elements, encompassing both criteria and sub-criteria. Subsequent steps involve pairwise comparisons among these constituents to ascertain their relative priorities, followed by an integration of these priorities to yield an overall evaluation [35]. To develop an evaluation framework for sustainable urban development from a life satisfaction perspective, the present study instituted an AHP model grounded on the subsequent stages:

Problem Definition and Selection of Evaluation Criteria: The research team initiated by delineating a precise definition for sustainable development in small cities. The scope of the investigation was established, and the objective of the decision-making was discerned through the lens of life satisfaction. Building upon insights from various experts and decision-makers, evaluation criteria pertinent to sustainable development were enumerated, their definitions solidified, and they were organized into distinct hierarchical tiers.

Construction of the Hierarchical Structure: Leveraging group discussions, literature reviews, and consultations with experts spanning fields such as urban planning, ecology, sociology, psychology, economics, public policy, geospatial analysis, and local governance, a holistic and multi-tiered evaluation framework was instituted.

Preparation and Implementation of Pairwise Comparisons: Upon setting the hierarchical structure, the assessment phase commenced. Employing the superior tier criteria as benchmarks, pairwise comparisons were conducted among criteria within each tier to determine their relative significance. For 'n' criteria, there would be n (n − 1)/2 pairwise comparisons.

Formulation of the Assessment Matrix: Predicated on the outcomes of the pairwise comparisons, assessment matrices for each tier were established.

$$[A_k] = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}, \; k = 1,2,\cdots,n \qquad (1)$$

Computation of Weights and Consistency Testing: Initially, pairwise comparison matrices were constructed based on the evaluation data from Step 3. Subsequently, eigenvectors and the largest eigenvalue were computed. Thereafter, the Consistency Index (CI) was employed to assess the coherence of these data sets. With CI and the Random Consistency Index (RI) as references, a Consistency Ratio (CR) was derived. The Consistency Ratio serves as a measure to evaluate the acceptability of the assessment matrix.

Determination of Weights Using the Delphi Method: To ensure the fairness and precision of the evaluation framework, 15 experts from diverse domains, including urban planners, ecologists, sociologists, psychologists, economists, public policy analysts, geospatial experts, local government representatives, and resident representatives were convened. Utilizing the Delphi technique, the relative weights of each criterion were discerned. Through three iterative rounds, the final weights among the criteria were settled upon.

Aggregation of Weights and Establishment of Overall Priorities: The relative weights across all tiers were aggregated, leading to the computation of the overarching priority weights for the entire evaluation framework. These weights signify the importance of each sustainable development indicator under the purview of life satisfaction.

Assessment of Consistency for the Comprehensive Hierarchical Structure: Finally, the consistency of the entire hierarchical structure was scrutinized. The consistency ratio for the overall hierarchy should be less than 0.10. If it exceeds this threshold, the assessment needs to be re-evaluated to enhance its coherence.

3. Results

In this study, through three rounds of iterative deliberation, insights were aggregated from diverse professional fields including urban planning, ecology, sociology, psychology, economics, public policy, and geographic information science. Additionally, representatives from local governments and residents were incorporated, amounting to a total of 15 experts and representatives. These stakeholders collaboratively provided a comprehensive set of weightings for indicators, pivotal for evaluating sustainable development in small cities, closely intertwined with the daily lives of residents. Using the weightings from the final deliberation round, a heatmap was constructed, elucidating the 40 evaluation indicators, and underscoring the diverse emphases from varied expert backgrounds. To enhance this visualization, a treemap was crafted based on the derived average weights, transparently highlighting the relative significance of each evaluation indicator in the context of life satisfaction. Building upon these insights, we established an evaluative index system geared toward understanding sustainable development in small cities through the lens of life satisfaction.

3.1. Consensus-derived Weights from a Three-round Delphi Iteration Involving 15 Experts and Representatives

The Delphi method was meticulously employed to derive the weights for our indicators. The process initiated with a comprehensive questionnaire designed to extract preliminary insights into the weights of the indicators. To ensure the content's validity and efficacy, a pilot survey was conducted with the engagement of independent experts. Their feedback was pivotal in affirming the facilitator's competency in guiding consensus-building. A consensus threshold was then set, which was derived from the observed variance in the weights during this preliminary phase.

Subsequently, experts were chosen for the Delphi process based on their academic background and their involvement with the topic. A diverse panel of 15 experts, encompassing fields such as urban planning, ecology, sociology, psychology, economics, public policy, geographic information science, local governance, and resident representation, was constituted to ensure a comprehensive and multi-faceted perspective on the weights. Their intrinsic interest in the topic was crucial to ensure genuine and informed responses.

During the collection of responses, either through secure platforms or emails, the acquired data were critically analyzed. This involved computing the mean and standard deviation for each indicator's weight. After each round of analysis, feedback was shared with all experts to showcase the emerging consensus. Those whose weights deviated significantly from the consensus were encouraged to clarify their rationale, allowing for a deeper understanding, and fostering a move towards consensus in subsequent rounds. All feedback, particularly non-quantifiable content, was subjected to detailed content analysis to extract valuable insights.

In response to the initial feedback, the questionnaire was iteratively refined for clarity, relevance, and precision. To ensure momentum and continuity in expert engagement, the intervals between survey rounds were kept minimal. After every round, statistical measures (mean and standard deviation) for the weights were recalculated.

After three rigorous rounds of iteration, a consensus was finally achieved among the 15 experts and representatives regarding the weights of the indicators, highlighting the robustness and credibility of the Delphi method in this research endeavor.

In the ensuing section, a heatmap is presented, illustrating the weights conferred by the 15 experts and representatives after three rounds of Delphi iteration. Additionally, a dendrogram is provided to showcase the averaged weights across these inputs. Detailed results from each of the three iterative rounds are comprehensively documented in the appendices.

3.2. Establishment of the Hierarchical Analysis Model Using the Delphi-Derived Weights as Reference

While the weights obtained from the Delphi method provide insightful information about the

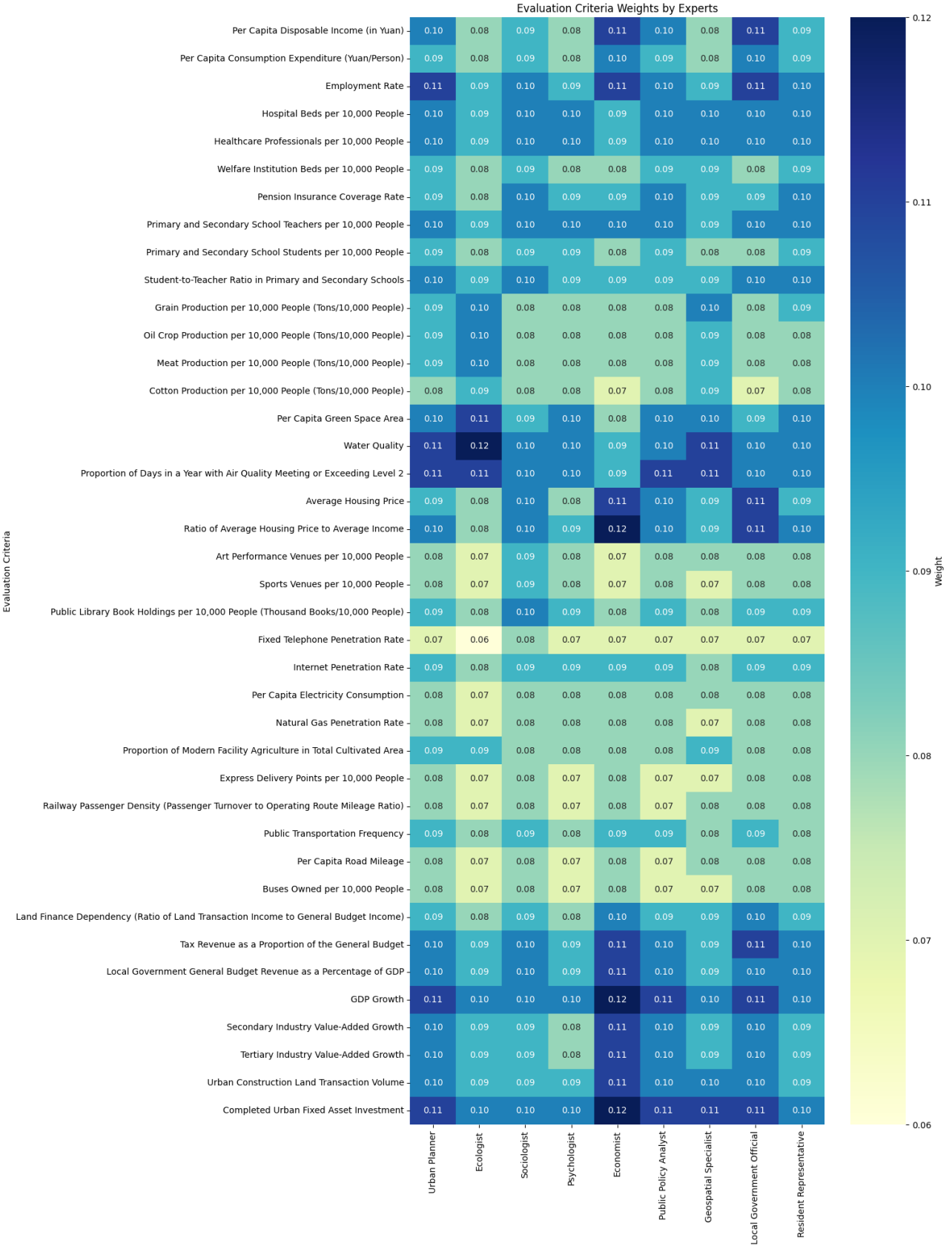

Fig. 3. Heat map of weights given by 15 experts after 3 rounds of iteration

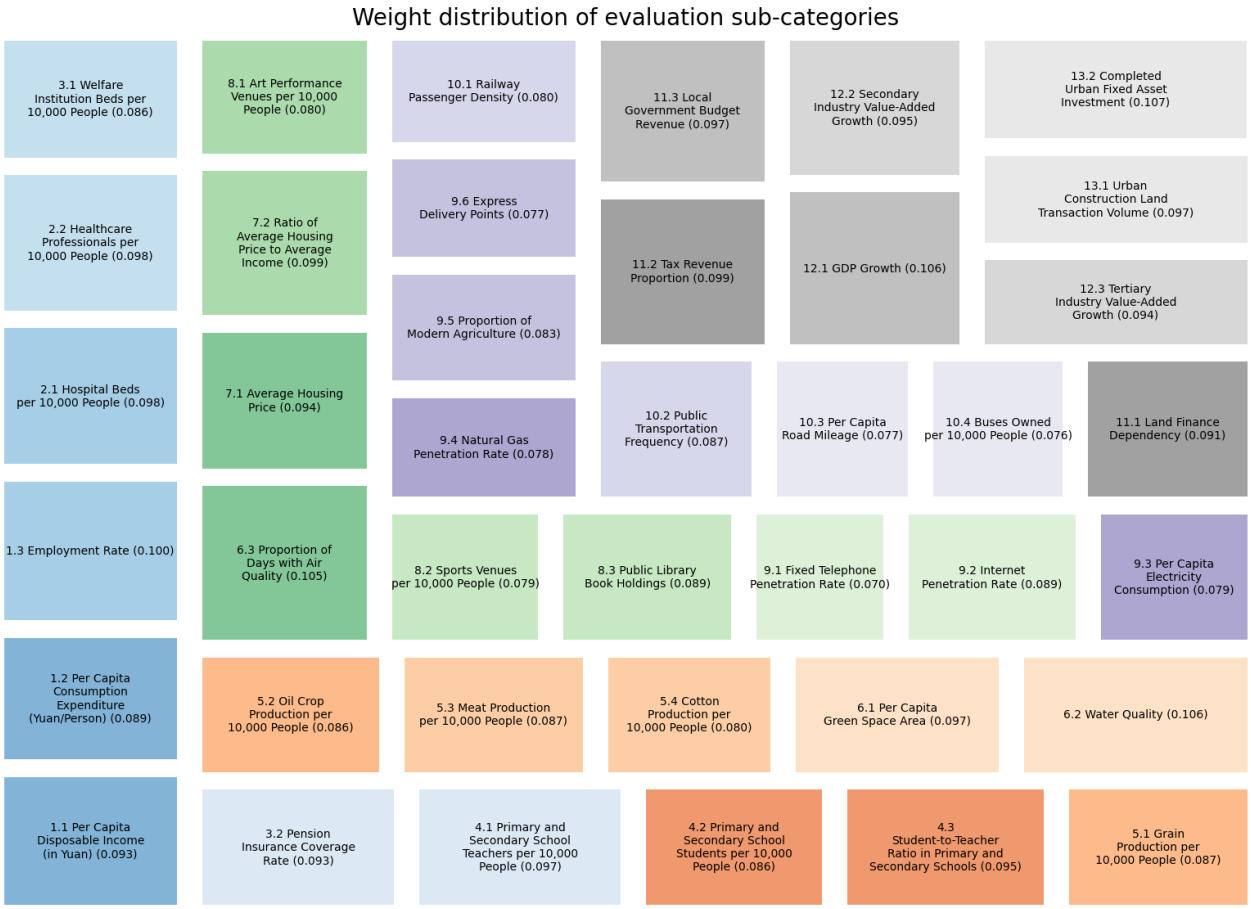

Fig. 4. Treemap of the Mean Weight Matrix

significance of each indicator, they are not directly configured for a multi-tiered evaluative model. In order to adapt these weights to the hierarchical structure inherent to the Analytic Hierarchy Process (AHP), a normalization process was executed to ensure that each weight within a specific criterion summed up to one, and the global summation of all weights also equaled one. After this essential recalibration, the multi-tiered evaluative model, which takes into account the weights derived from the Delphi method, is presented in the subsequent table:

4. Discussion

4.1. Comparison with Previous Research and Existing Evaluation Models

Historically, growth-centric paradigms have predominantly shaped China's urban developmental strategies. This predominance largely stems from the bureaucratic promotional evaluations in China, which emphasize economic progress as a pivotal metric. Past scholarly discourses have predominantly revolved around the sustainable advancement of the economy. In attempts to counterbalance the sole emphasis on economic growth, some have disproportionately shifted focus towards environmental sustainability, often sidelining the quintessential stakeholders of urban landscapes: the residents.

In contrast, introducing an assessment rooted in a bottom-up life satisfaction paradigm breathes novel vitality into the appraisal of urban sustainable development. To tailor the evaluation criteria to the nuanced realities of Chinese small cities, this research incorporates insights from the United Nations' 17 Sustainable Development Goals and their 169 associated targets. Subsequently, a meticulous local adaptation was conducted based on data availability, authoritative relevance, and comparability.

Diverging from conventional sustainable development indicators, the assessment model proposed in this study, rooted in a human habitat perspective, underscores the significance of enhancing population numbers and refining demographic structures as key drivers for urban metamorphosis and sustainable progression. Through the lens of life satisfaction, this model of sustainable urban development in small cities fosters the phenomenon of population return, rejuvenating these smaller urban entities.

Table 1. Evaluation Model Based on the Analytic Hierarchy Process for Sustainable Development of Small Cities from Life Satisfaction Perspective

Level 1	p (L1)	Level 2	p (L2)	Glb. Pr.
Employment and income	0.078203	Per Capita Disposable Income	0.329787	0.02579
		Per Capita Consumption Expenditure	0.315603	0.024681
		Employment Rate	0.35461	0.027732
Health care	0.054354	Hospital Beds per 10K People	0.5	0.027177
		Healthcare Professionals per 10K People	0.5	0.027177
Social well-being	0.049639	Welfare Institution Beds per 10K People	0.480447	0.023849
		Pension Insurance Coverage Rate	0.519553	0.02579
Educational opportunities	0.077094	Primary and Secondary School Teachers per 10K	0.348921	0.0269
		Primary and Secondary School Students per 10K	0.309353	0.023849
		Student-to-Teacher Ratio in Primary and Secon	0.341727	0.026345
Food security	0.094287	Grain Production per 10K People	0.255882	0.024126
		Oil Crop Production per 10K People	0.252941	0.023849
		Meat Production per 10K People	0.255882	0.024126
		Cotton Production per 10K People	0.235294	0.022185
Urban environment	0.085413	Per Capita Green Space Area	0.314935	0.0269
		Water Quality	0.344156	0.029395
		Proportion of Days in a Year with Air Quality	0.340909	0.029118
Housing conditions	0.053522	Average Housing Price	0.487047	0.026068
		Ratio of Average Housing Price to Average Inc	0.512953	0.027454
Culture and recreation	0.068774	Art Performance Venues per 10K People	0.322581	0.022185
		Sports Venues per 10K People	0.318548	0.021908
		Public Library Book Holdings per 10K People	0.358871	0.024681
Modern life	0.132002	Fixed Telephone Penetration Rate	0.147059	0.019412
		Internet Penetration Rate	0.186975	0.024681
		Per Capita Electricity Consumption	0.165966	0.021908
		Natural Gas Penetration Rate	0.163866	0.021631
		Proportion of Modern Facility Agriculture in	0.17437	0.023017
		Express Delivery Points per 10K People	0.161765	0.021353
Transportation and mobility	0.088741	Railway Passenger Density	0.25	0.022185
		Public Transportation Frequency	0.271875	0.024126
		Per Capita Road Mileage	0.240625	0.021353
		Buses Owned per 10K People	0.2375	0.021076
Government financial risks	0.07959	Land Finance Dependency	0.317073	0.025236
		Tax Revenue as a Proportion of the General Bu	0.344948	0.027454
		Local Government General Budget Revenue as a	0.337979	0.0269
Economic growth and indus-	0.081808	GDP Growth	0.359322	0.029395
		Secondary Industry Value-Added Growth	0.322034	0.026345
		Tertiary Industry Value-Added Growth	0.318644	0.026068
Urban infrastructure devel-	0.056572	Urban Construction Land Transaction Volume	0.47549	0.0269
		Completed Urban Fixed Asset Investment	0.52451	0.029673

4.2. Model Efficacy and Limitations Discussion

In the realm of data acquisition and assimilation, small cities are at a disadvantage compared to their larger metropolitan counterparts, presenting a limited pool of available data resources. Present sustainable development indicators in China predominantly focus on the collaborative progression of broader regions without delving into the specific nuances of individual small cities. To cater to the distinct characteristics of Chinese small cities, this study, drawing from existing sustainable development assessment models, meticulously considered data accessibility, comparability, and representativeness for indicator refinement. By integrating the Delphi method with a hierarchical analysis approach, we comprehensively assessed the sustainable development landscape of small cities from multiple dimensions. The Delphi method marshaled experts from diverse fields, iteratively allocating weights to indicators, ensuring a holistic, authoritative, and accurate evaluation process. The hierarchical analysis further segmented the evaluation criteria, effectively breaking down a complex theme into 13 subsidiary criteria. These encompass factors intrinsically linked to residents' quality of life and urban sustainable development, such as employment, healthcare, education, living standards, housing conditions, urban environment, cultural and recreational activities, transportation, fiscal health, industrial progression, and infrastructure. Upon validation, the model was deemed highly efficacious. Nonetheless, it is imperative to acknowledge that, despite our endeavors to guarantee diversity and representativeness in indicator selection and weight assignment, certain aspects of the model inevitably bear a degree of subjectivity. Some sub-criteria might be more aptly replaced by other more fitting standards.

4.3. Discussion on the Rationality of Weight Selection

In formulating the evaluation criteria, this study integrated insights from the United Nations' "2030 Agenda for Sustainable Development", China's Ministry of Natural Resources' "Territorial Spatial Planning and Urban Health Assessment Procedures", and the Ministry of Housing and Urban-Rural Development's "Urban Health Index System". This localized approach ensured that the selected sustainability indicators were intimately linked with residents' life satisfaction. While placing emphasis on the quality of life for residents, the indicators concurrently addressed the multifaceted concerns of the economy, environment, and society. By employing the Delphi method and multi-criteria analysis, the authority and efficacy of the model were bolstered.

Though the 15 experts and representatives from diverse fields assigned varying weights to the 13 primary indicators, encompassing a total of 40 sub-indicators, certain metrics, such as GDP growth and the completion amount of fixed urban assets investment, consistently received high consensus weights. These metrics respectively symbolize the economic vigor and infrastructure development level of a city, both pivotal to ensuring a satisfactory urban life. The role of housing prices was also underscored, as the ratio of housing prices to income directly influences residents' decisions to settle long-term. Moreover, indicators like per capita green space and water quality, which are closely tied to life satisfaction, garnered widespread endorsement. Additionally, modern living factors were highlighted in the assessment, exemplified by the internet penetration rate metric. This aligns with China's escalating reliance on the internet and its burgeoning online service ecosystem. This urban sustainability evaluation, approached from the perspective of life satisfaction, not only correlates closely with residents' daily experiences but also the distribution of its weights resonates with actual circumstances, further attesting to its rationality.

5. Conclusions

Within the context of China's pursuit for sustainable development, this study innovatively integrates 'life satisfaction' as a fresh dimension to evaluate the sustainability of small cities. This offers an alternative to the predominantly economic-centric evaluation indicators of the past. Given China's ongoing regional integration, small cities are emerging as pivotal in absorbing both industrial relocations and population inflows from larger cities. Extant literature underscores the potential of small cities as catalysts propelling regional economic growth.

Our proposed evaluative framework delves deeply into 13 facets intimately related to residents' lives in assessing the sustainability of small cities. These facets encompass not only the conventional dimensions of economic, social, and environmental sustainability but also resonate with the United Nations' Sustainable Development Goals. This reflects a comprehensive grasp of sustainable development principles and an astute understanding of local contexts.

With China's intensifying regional integration trajectory, small cities manifest their indispensable role in absorbing industrial relocations and population inflows from their larger counterparts. Compared to metropolises, small cities, characterized by their scale and demographic composition, possess a heightened agility for adaptation and transformation. This paves the way for sustainable growth. Post-pandemic economic and societal shifts further bolster the centrality of small cities in regional development. Especially those with close cultural and transportational ties to major cities stand on the brink of unprecedented opportunities. To fully harness these, it's imperative for small cities to ramp up efforts in attracting tertiary education and skilled professionals, thereby ensuring robust human capital underpinning their transitions.

Future endeavors could delve deeper into how life satisfaction facilitates the sustainable transition of small cities, particularly post-pandemic. This entails charting a holistic, human-centric, and eco-friendly developmental trajectory for small cities. Emphasis should be accorded to those cities nestled adjacent to major cities, benefiting from robust transportation networks and frequent cultural exchanges. Investigations can prioritize how they can leverage their cultural and transportation assets to attract and retain a higher educated and skilled populace, propelling their economic and societal metamorphosis towards sustainability.

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Appendix A: Process results of 3 iterations of Delphi method

First Iteration

Evaluation Indicators	Urban planning experts	Ecologists	Sociologists	Psychologists	Economists	Public policy researchers	Geographic information experts	Local government representatives	Resident Representatives	Average weights
1.1 Per capita disposable income (Yuan)	0.08	0.06	0.09	0.07	0.10	0.08	0.07	0.09	0.08	0.080
1.2 Per capita consumption amount (Yuan/person)	0.07	0.06	0.08	0.07	0.09	0.07	0.06	0.08	0.08	0.075
1.3 Employment rate	0.08	0.05	0.07	0.06	0.09	0.08	0.07	0.07	0.08	0.072
2.1 Number of hospital beds per 10,000 people	0.07	0.07	0.07	0.07	0.06	0.08	0.06	0.08	0.08	0.073
2.2 Number of medical staff per 10,000 people	0.07	0.06	0.08	0.07	0.06	0.07	0.06	0.07	0.07	0.069
3.1 Number of welfare institution beds per 10,000 people	0.06	0.05	0.07	0.07	0.06	0.07	0.05	0.06	0.07	0.065
3.2 Pension insurance coverage rate	0.08	0.06	0.07	0.07	0.08	0.08	0.07	0.08	0.08	0.075
4.1 Number of primary and secondary school teachers per 10,000 people	0.06	0.05	0.06	0.07	0.06	0.07	0.06	0.07	0.07	0.065
4.2 Number of primary and secondary school students per 10,000 people	0.06	0.05	0.06	0.06	0.06	0.07	0.05	0.07	0.07	0.065
4.3 Primary and secondary school teacher-student ratio	0.07	0.06	0.07	0.07	0.07	0.07	0.06	0.07	0.07	0.067
5.1 Grain yield per 10,000 people (tons/10,000 people)	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.065
5.2 Oil crop yield per 10,000 people (tons/10,000 people)	0.06	0.07	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.064
5.3 Meat yield per 10,000 people (tons/10,000 people)	0.06	0.06	0.06	0.06	0.07	0.06	0.05	0.06	0.06	0.064
5.4 Cotton yield per 10,000 people (tons/10,000 people)	0.06	0.06	0.05	0.06	0.06	0.06	0.05	0.05	0.06	0.061
6.1 Per capita green area	0.07	0.08	0.06	0.07	0.06	0.07	0.08	0.07	0.08	0.071
6.2 Water quality	0.07	0.08	0.07	0.07	0.07	0.07	0.08	0.08	0.07	0.073
6.3 Proportion of days within a year when air quality reaches or exceeds Level 2	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.075
7.1 Average house price	0.08	0.06	0.08	0.07	0.09	0.08	0.06	0.09	0.08	0.079
7.2 Housing supply-demand ratio	0.07	0.06	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.076
8.1 Degree of transportation infrastructure completeness	0.07	0.06	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.075
8.3 Number of sports stadiums per 10,000 people	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.061
8.4 Number of public library books per 10,000 people (thousands of books/10,000 people)	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.061
9.1 Fixed telephone penetration rate	0.05	0.05	0.06	0.05	0.06	0.06	0.05	0.05	0.05	0.055
9.2 Internet access rate	0.07	0.06	0.08	0.06	0.08	0.07	0.06	0.07	0.07	0.070
9.3 Per capita electricity consumption	0.06	0.06	0.07	0.06	0.07	0.06	0.06	0.07	0.06	0.065
9.4 Natural gas popularization rate	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.062
9.5 Proportion of modern agricultural facilities in total cultivated land area	0.05	0.07	0.06	0.05	0.06	0.05	0.07	0.06	0.05	0.058
9.6 Number of express delivery points per 10,000 people	0.06	0.05	0.06	0.05	0.06	0.06	0.05	0.06	0.06	0.061
10. Railway passenger traffic density (ratio of passenger turnover to operating route mileage)	0.07	0.06	0.07	0.06	0.08	0.07	0.07	0.08	0.07	0.072
10.2 Public transportation frequency	0.07	0.06	0.07	0.06	0.08	0.07	0.07	0.07	0.07	0.071
10.3 Per capita road mileage	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.064
10.4 Number of buses owned per 10,000 people	0.06	0.05	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.062
11.1 Dependency on land finance (ratio of land transaction income to general budget income)	0.08	0.07	0.08	0.07	0.09	0.08	0.08	0.09	0.08	0.082
11.2 Tax revenue as a percentage of the general budget	0.08	0.07	0.08	0.07	0.09	0.08	0.07	0.09	0.08	0.081
11.3 Percentage of local government general budget income in GDP	0.08	0.07	0.08	0.07	0.09	0.08	0.07	0.08	0.08	0.080
12.1 GDP growth	0.09	0.07	0.08	0.07	0.10	0.09	0.08	0.09	0.09	0.085
12.2 Growth of added value in the secondary industry	0.08	0.07	0.07	0.06	0.09	0.08	0.08	0.08	0.08	0.079
12.3 Growth of added value in the tertiary industry	0.08	0.07	0.08	0.07	0.09	0.08	0.07	0.08	0.08	0.080
13.1 Urban construction land transaction volume	0.08	0.07	0.08	0.07	0.09	0.08	0.08	0.09	0.08	0.082
13.2 Completed urban fixed asset investment	0.08	0.07	0.08	0.07	0.09	0.08	0.08	0.08	0.08	0.081

Second Iteration

Evaluation Indicators	Urban planning experts	Ecologists	Sociologists	Psychologists	Economists	Public policy researchers	Geographic information experts	Local government representatives	Resident Representatives	Average weights
1.1 Per capita disposable income (Yuan)	0.09	0.07	0.08	0.08	0.09	0.08	0.07	0.08	0.09	0.081
1.2 Per capita consumption amount (Yuan/person)	0.08	0.07	0.08	0.08	0.09	0.08	0.07	0.08	0.09	0.080
1.3 Employment rate	0.09	0.08	0.09	0.08	0.10	0.08	0.07	0.08	0.09	0.084
2.1 Number of hospital beds per 10,000 people	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.09	0.080
2.2 Number of medical staff per 10,000 people	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.079
3.1 Number of welfare institution beds per 10,000 people	0.07	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.076
3.2 Pension insurance coverage rate	0.08	0.07	0.08	0.08	0.09	0.08	0.07	0.08	0.09	0.080
4.1 Number of primary and secondary school teachers per 10,000 people	0.07	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.076
4.2 Number of primary and secondary school students per 10,000 people	0.06	0.06	0.07	0.06	0.07	0.07	0.06	0.07	0.07	0.067
4.3 Primary and secondary school teacher-student ratio	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.075
5.1 Grain yield per 10,000 people (tons/10,000 people)	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.06	0.06	0.064
5.2 Oil crop yield per 10,000 people (tons/10,000 people)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.062
5.3 Meat yield per 10,000 people (tons/10,000 people)	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.06	0.07	0.065
5.4 Cotton yield per 10,000 people (tons/10,000 people)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.062
6.1 Per capita green area	0.08	0.09	0.08	0.07	0.08	0.07	0.08	0.07	0.09	0.079
6.2 Water quality	0.09	0.09	0.08	0.07	0.08	0.07	0.08	0.08	0.09	0.081
6.3 Proportion of days within a year when air quality reaches or exceeds Level 2	0.09	0.10	0.08	0.07	0.08	0.07	0.09	0.08	0.09	0.083
7.1 Average house price	0.09	0.08	0.09	0.08	0.10	0.08	0.07	0.09	0.09	0.086
7.2 Housing supply-demand ratio	0.10	0.08	0.10	0.09	0.11	0.09	0.08	0.10	0.09	0.094
8.1 Degree of transportation infrastructure completeness	0.07	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.076
8.3 Number of sports stadiums per 10,000 people	0.07	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.076
8.4 Number of public library books per 10,000 people (thousands of books/10,000 people)	0.07	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.076
9.1 Fixed telephone penetration rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.061
9.2 Internet access rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.069
9.3 Per capita electricity consumption	0.06	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.064
9.4 Natural gas popularization rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.062
9.5 Proportion of modern agricultural facilities in total cultivated land area	0.07	0.08	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.071
9.6 Number of express delivery points per 10,000 people	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.061
10. Railway passenger traffic density (ratio of passenger turnover to operating route mileage)	0.08	0.07	0.08	0.07	0.08	0.08	0.07	0.08	0.08	0.077
10.2 Public transportation frequency	0.09	0.08	0.09	0.08	0.09	0.09	0.08	0.09	0.09	0.087
10.3 Per capita road mileage	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.07	0.08	0.074
10.4 Number of buses owned per 10,000 people	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.07	0.08	0.074
11.1 Dependency on land finance (ratio of land transaction income to general budget income)	0.08	0.08	0.08	0.08	0.09	0.09	0.08	0.09	0.08	0.084
11.2 Tax revenue as a percentage of the general budget	0.09	0.08	0.08	0.08	0.10	0.10	0.08	0.09	0.09	0.088
11.3 Percentage of local government general budget income in GDP	0.09	0.08	0.08	0.08	0.10	0.09	0.09	0.10	0.09	0.090
12.1 GDP growth	0.10	0.09	0.09	0.09	0.11	0.10	0.09	0.11	0.10	0.098
12.2 Growth of added value in the secondary industry	0.09	0.09	0.09	0.08	0.10	0.09	0.08	0.10	0.09	0.090
12.3 Growth of added value in the tertiary industry	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.10	0.09	0.093
13.1 Urban construction land transaction volume	0.08	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.09	0.084
13.2 Completed urban fixed asset investment	0.09	0.08	0.09	0.08	0.10	0.10	0.09	0.09	0.09	0.090

Third Iteration

Evaluation Indicators	Urban planning experts	Ecologists	Sociologists	Psychologists	Economists	Public policy researchers	Geographic information experts	Local government representatives	Resident Representatives	Average weights
1.1 Per capita disposable income (Yuan)	0.10	0.08	0.09	0.08	0.11	0.10	0.08	0.11	0.09	0.093
1.2 Per capita consumption amount (Yuan/person)	0.09	0.08	0.09	0.08	0.10	0.09	0.08	0.10	0.09	0.089
1.3 Employment rate	0.11	0.09	0.10	0.09	0.11	0.10	0.09	0.11	0.10	0.100
2.1 Number of hospital beds per 10,000 people	0.10	0.09	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.098
2.2 Number of medical staff per 10,000 people	0.10	0.09	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.098
3.1 Number of welfare institution beds per 10,000 people	0.09	0.08	0.09	0.08	0.08	0.09	0.09	0.08	0.09	0.086
3.2 Pension insurance coverage rate	0.09	0.08	0.10	0.09	0.09	0.10	0.09	0.09	0.10	0.093
4.1 Number of primary and secondary school teachers per 10,000 people	0.10	0.09	0.10	0.10	0.09	0.10	0.09	0.10	0.10	0.097
4.2 Number of primary and secondary school students per 10,000 people	0.09	0.08	0.09	0.09	0.08	0.09	0.08	0.08	0.09	0.086
4.3 Primary and secondary school teacher-student ratio	0.10	0.09	0.10	0.09	0.09	0.09	0.09	0.10	0.10	0.095
5.1 Grain yield per 10,000 people (tons/10,000 people)	0.09	0.10	0.08	0.08	0.08	0.08	0.10	0.08	0.09	0.087
5.2 Oil crop yield per 10,000 people (tons/10,000 people)	0.09	0.10	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.086
5.3 Meat yield per 10,000 people (tons/10,000 people)	0.09	0.10	0.08	0.08	0.08	0.08	0.09	0.08	0.09	0.087
5.4 Cotton yield per 10,000 people (tons/10,000 people)	0.08	0.09	0.08	0.08	0.07	0.08	0.09	0.07	0.08	0.080
6.1 Per capita green area	0.10	0.11	0.09	0.10	0.08	0.10	0.10	0.09	0.10	0.097
6.2 Water quality	0.11	0.12	0.10	0.10	0.09	0.11	0.11	0.10	0.11	0.106
6.3 Proportion of days within a year when air quality reaches or exceeds Level 2	0.11	0.11	0.10	0.10	0.09	0.11	0.11	0.10	0.11	0.105
7.1 Average house price	0.09	0.08	0.10	0.08	0.11	0.10	0.09	0.11	0.09	0.094
7.2 Housing supply-demand ratio	0.10	0.08	0.10	0.09	0.12	0.10	0.09	0.11	0.10	0.099
8.1 Degree of transportation infrastructure completeness	0.08	0.07	0.09	0.08	0.07	0.08	0.08	0.08	0.09	0.080
8.3 Number of sports stadiums per 10,000 people	0.08	0.07	0.09	0.08	0.07	0.08	0.07	0.08	0.09	0.079
8.4 Number of public library books per 10,000 people (thousands of books/10,000 people)	0.09	0.08	0.10	0.09	0.08	0.09	0.08	0.09	0.10	0.089
9.1 Fixed telephone penetration rate	0.07	0.06	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.070
9.2 Internet access rate	0.09	0.08	0.09	0.09	0.09	0.09	0.08	0.09	0.09	0.089
9.3 Per capita electricity consumption	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.079
9.4 Natural gas popularization rate	0.08	0.07	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.078
9.5 Proportion of modern agricultural facilities in total cultivated land area	0.09	0.09	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.083
9.6 Number of express delivery points per 10,000 people	0.08	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.07	0.077
10. Railway passenger traffic density (ratio of passenger turnover to operating route mileage)	0.08	0.07	0.08	0.07	0.09	0.08	0.08	0.08	0.07	0.080
10.2 Public transportation frequency	0.09	0.08	0.09	0.08	0.09	0.09	0.08	0.09	0.08	0.087
10.3 Per capita road mileage	0.08	0.07	0.08	0.07	0.08	0.07	0.08	0.08	0.07	0.077
10.4 Number of buses owned per 10,000 people	0.08	0.07	0.08	0.07	0.08	0.07	0.07	0.08	0.07	0.076
11.1 Dependency on land finance (ratio of land transaction income to general budget income)	0.09	0.08	0.09	0.08	0.10	0.09	0.09	0.10	0.09	0.091
11.2 Tax revenue as a percentage of the general budget	0.10	0.09	0.10	0.09	0.11	0.10	0.09	0.11	0.10	0.099
11.3 Percentage of local government general budget income in GDP	0.10	0.09	0.10	0.09	0.11	0.10	0.09	0.10	0.09	0.097
12.1 GDP growth	0.11	0.10	0.10	0.10	0.12	0.11	0.10	0.11	0.10	0.106
12.2 Growth of added value in the secondary industry	0.10	0.09	0.09	0.09	0.11	0.10	0.09	0.10	0.09	0.095
12.3 Growth of added value in the tertiary industry	0.10	0.09	0.09	0.08	0.11	0.10	0.09	0.10	0.09	0.094
13.1 Urban construction land transaction volume	0.10	0.09	0.09	0.09	0.11	0.10	0.10	0.10	0.09	0.097
13.2 Completed urban fixed asset investment	0.11	0.10	0.10	0.10	0.12	0.11	0.11	0.11	0.10	0.107

Appendix B: Final Average Weights

Evaluation Criteria	Criteria Description	Average Weight
1. Employment & Income	1.1 Per capita disposable income (yuan)	0.109
	1.2 Per capita consumption (yuan/person)	0.108
	1.3 Employment rate	0.108
2. Healthcare	2.1 Hospital beds per 10,000 people	0.089
	2.2 Medical personnel per 10,000 people	0.088
3. Social Welfare	3.1 Welfare institution beds per 10,000 people	0.085
	3.2 Pension insurance coverage rate	0.086
4. Educational Opportunities	4.1 Primary and secondary school teachers per 10,000 people	0.086
	4.2 Primary and secondary school students per 10,000 people	0.085
	4.3 Student-teacher ratio in primary and secondary schools	0.085
5. Food Safety	5.1 Grain production per 10,000 people (tons/10,000 people)	0.083
	5.2 Oil crop production per 10,000 people (tons/10,000 people)	0.082
	5.3 Meat production per 10,000 people (tons/10,000 people)	0.083
	5.4 Cotton production per 10,000 people (tons/10,000 people)	0.082
6. Urban Environment	6.1 Per capita green space	0.089
	6.2 Water quality	0.088
	6.3 Proportion of days with air quality at level 2 or better	0.088
7. Living Conditions	7.1 Average housing price	0.092
	7.2 Ratio of average housing price to average income	0.092
8. Culture & Entertainment	8.1 Art performance venues per 10,000 people	0.087
	8.2 Sports venues per 10,000 people	0.086
	8.3 Public library books per 10,000 people (thousands/10,000 people)	0.086
9. Modern Living	9.1 Fixed telephone penetration rate	0.078
	9.2 Internet access rate	0.079
	9.3 Per capita electricity consumption	0.078
	9.4 Natural gas penetration rate	0.078
	9.5 Proportion of arable land with modern facilities	0.078
	9.6 Express service locations per 10,000 people	0.077
10. Transportation & Mobility	10.1 Rail passenger density (passenger turnover to route mileage ratio)	0.08
	10.2 Public transportation frequency	0.087
	10.3 Per capita road mileage	0.077
	10.4 Buses owned per 10,000 people	0.076
11. Government Financial Risk	11.1 Land finance dependency (land transaction revenue to general budget revenue)	0.091
	11.2 Tax revenue as a proportion of the general budget	0.099
	11.3 Local government general budget revenue as a percentage of GDP	0.097
12. Economic Growth & Industrial Structure	12.1 GDP growth	0.106
	12.2 Secondary industry added value growth	0.095
	12.3 Tertiary industry added value growth	0.094
13. Urban Infrastructure Development	13.1 Urban construction land transaction volume	0.097
	13.2 Completion of fixed asset investment in the city	0.107