Comprehensive Evaluation Model of Livable City Based on Fuzzy Comprehensive Evaluation Method

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Abstract This paper firstly introduced the degree of livability of a city from the social civilization, economic affluence, environmental beauty, resource carrying capacity, and life convenience. Based on the principle of the fuzzy comprehensive evaluation, it analyzed the connection between influencing factors, and established a comprehensive evaluation model for calculation of the livability index of a city. Finally, it obtained the relative livability of each city and the ranking of livability of each city.

Key words Dynamic entropy weight method, Fuzzy comprehensive evaluation method, MATLAB

1 Introduction

A livable city is characterized by beautiful environment, social stability, advanced civilization, comfortable life, economic harmony, and high reputation, which are comprehensive evaluation of the degree of livability. The China Institute of City Competitiveness (CICC) has released the "Top Ten Livable Cities in China" for many consecutive years. In the mathematical models, commonly used evaluation models include composite index method, TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method, AHP (analytic hierarchy process), RSR (Reshaped Sequential Replacement) method, fuzzy comprehensive evaluation method, grey system method and so on. In this study, we mainly applied the fuzzy comprehensive evaluation method. In the evaluation of livable cities, the livability of the city is evaluated according to the livability index, and the comprehensive evaluation method converts the qualitative evaluation into quantitative evaluation based on the subordination theory in fuzzy mathematics.

2 Comprehensive evaluation method

2.1 Dynamic entropy method If the information entropy e_j of a certain index is smaller, it means that the degree of variation of the index is greater, and the information it provides is more, the function it plays in the comprehensive evaluation is greater, and its weight is greater. Conversely, if the information entropy e_j of a certain index is greater, it means that the degree of variation of the index is smaller, and the information it provides is less, the function it plays in the comprehensive evaluation is smaller, and its weight is smaller. The entropy method can measure the amount of information provided by the data and avoid the influence of invalid information. Effectively measuring the impact of information on the research object is the importance of comprehensive indicators and the amount of information provided by the indicators. It determines the final weight through these two aspects.

Assume there are m items to be evaluated, and n evaluation indicators, forming the original data matrix $H = (h_{ij})_{m\times n}$

$$H = \begin{pmatrix} h_{11} & h_{12} & \mathrm{L} & h_{1n} \\ h_{21} & h_{22} & \mathrm{L} & h_{2n} \\ \mathrm{M} & \mathrm{M} & \mathrm{M} & \mathrm{M} \\ h_{m1} & h_{m2} & \mathrm{L} & h_{mm} \end{pmatrix}_{m\times n}$$

Calculate the proportion p_{ij} of the i-th indicator value in the j-th indicator:

$$p_{ij} = \frac{h_{ij}}{\sum_{i=1}^{m} h_{ij}}$$

Calculate the entropy of the j-th indicator: $e_j = -k\sum_{i=1}^{m} p_{ij} \operatorname{gln} p_{ij}$, where $k = \frac{1}{\ln m}$.

Obtain the entropy weight w_j of the j-th indicator:

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n}(1 - e_j)}$$

Determine the comprehensive weight β_j of the indicator: assume that the evaluator determines the weight of indicator importance according to his purpose and requirement as α_j, $j = 1, 2\cdots n$, combined with the entropy weight w_j of the indicator, it is able to calculate the comprehensive weight of the indicator j:

$$\beta_j = \frac{\alpha_j w_j}{\sum_{j=1}^{n} \alpha_j w_j}.$$

2.2 Fuzzy comprehensive evaluation method The fuzzy comprehensive evaluation method needs determining the factor set $U = \{u_1, u_2, \cdots u_n\}$, determining the judgment set (evaluation set or decision set) $V = \{v_1, v_2, \cdots v_m\}$, and establishing the single factor judgment $f: U \to F(V) \cdot u_i \to f(u_i) = (r_{i1}, r_{i2}, \cdots r_{im}) \in F(V)$, and also determining the subordinate function (Fig. 1):

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$$A(x)=\begin{cases}0, & x\leqslant a\\ \dfrac{x-a}{b-a}, & a<x<b\\ 1, & x\geqslant b\end{cases}$$

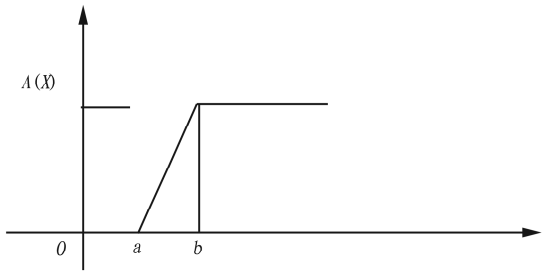

Fig. 1 Subordinate function

Then, we can get the single factor evaluation matrix R.

$R=\begin{pmatrix} r_{11} & r_{12} & L & r_{1n}\\ r_{21} & r_{22} & L & r_{2n}\\ M & M & M & M\\ r_{n1} & r_{n2} & L & r_{nn}\end{pmatrix}$, where (U, V, R) forms a fuzzy comprehensive evaluation model, and U, V, and R are three essential factors of this model.

For the weight $A=(a_1, a_2, L, a_n)$, the comprehensive evaluation takes the fuzzy matrix synthesis operation, we can get the comprehensive evaluation B:

$B=AoR=(b_1, b_2, L, b_m)\in F(V)$

3 Research object

We selected eight cities (Suqian, Lianyungang, Suzhou, Shangqiu, Jining, Zaozhuang, Xuzhou and Huaibei) for comprehensive evaluation of livable cities. According to the survey data, the degree of livability of a city is generally evaluated from five factors: social civilization, economic affluence, environmental beauty, resource carrying capacity, and life convenience. However, considering that there are many uncertainties in the search of data in these five fields, we surveyed some related data by the conversion method, namely, we calculated the degree of livability of these eight cities through the survey and reasoning. According to survey data, a city's environmental beauty can be measured by the degree of beautification of a city's construction, while an important indicator of social civilization degree is morality and education level; economic affluence is measured mainly through GDP and per capita GDP; the resource carrying capacity is mainly measured through the urban infrastructure carrying capacity, and in the life convenience, the per capita commercial facilities takes up the largest portion. Then, we took the per capita GDP, school coverage density, air quality index (AQI), per capita commercial floor space, and beauty spot density as the sub-indicators of the social civilization, economic affluence, environmental beauty, resource carrying capacity, and life convenience.

4 Fuzzy comprehensive evaluation

(i) Based on the dynamic entropy weight method, we calculated the weight of the five factors in the evaluation of livable cities:

$A=(0.146\ 7 \quad 0.264\ 4 \quad 0.015\ 6 \quad 0.007\ 6 \quad 0.565\ 7)$

(ii) The single factor evaluation matrix for eight cities is as follows:

$$R=\begin{pmatrix} 0.393\ 3 & 0 & 0.098\ 3 & 1.000\ 0 & 0.105\ 6\\ 1.000\ 0 & 0.210\ 0 & 1.000\ 0 & 1.000\ 0 & 0.655\ 6\\ 0 & 0.348\ 0 & 0.997\ 7 & 1.000\ 0 & 0\\ 0 & 1.000\ 0 & 0.956\ 5 & 0.924\ 2 & 0.105\ 6\\ 1.000\ 0 & 0.790\ 0 & 0.821\ 3 & 0.895\ 3 & 0.594\ 4\\ 1.000\ 0 & 0.790\ 0 & 0.821\ 3 & 0.895\ 3 & 0.594\ 4\\ 1.000\ 0 & 0.290\ 0 & 0.948\ 0 & 1.000\ 0 & 0.777\ 8\\ 0.439\ 6 & 0.840\ 0 & 1.000\ 0 & 1.000\ 0 & 0.011\ 1\end{pmatrix}$$

(iii) Through multiplying the weight of each evaluation indicator with the single factor evaluation matrix, we obtained the livability index of these eight cities (Table 1 and Fig. 2).

Table 1 Livability index of eight cities

City	Livability index
Suqian	0.140 3
Lianyungang	0.596 3
Suzhou	0.115 2
Shangqiu	0.346 1
Jining	0.538 6
Zaozhuang	0.711 5
Xuzhou	0.685 8
Huaibei	0.316 1

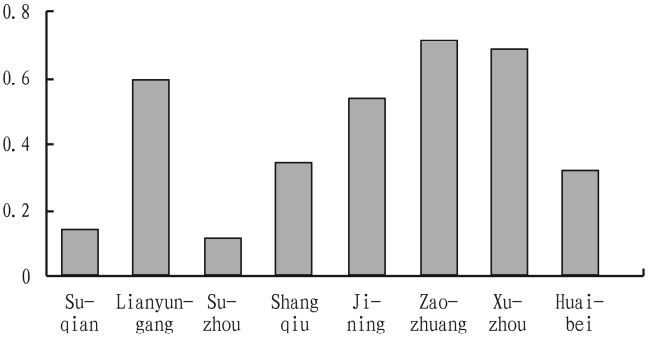

Fig. 2 Livability index of eight cities

(iv) According to the livability ranking of cities, the livability degree of Zaozhuang was relatively high, while the livability degree of Suzhou was relatively low.

5 Conclusions

In this study, taking the fuzzy comprehensive evaluation method, we evaluated the livability degree of eight cities, and established an evaluation model integrating many factors. This model is objective in evaluation of livability degree of cities. On the basis of the established model, we selected eight cities to make evaluation and obtained the different livability of eight cities in different evaluation criteria. Finally, we concluded that the livability degree of Zaozhuang was relatively high, while the livability degree of Suzhou was relatively low. We are intended to provide a quantitative analysis method on the basis of qualitative analysis for evaluation of livable cities.

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market. First, we need to strengthen subsidies for "software" in agricultural production, such as increasing investment in agricultural technology and accelerating agricultural technology popularization and training, accelerating the cultivation of new-type specialized farmers, strengthening the scientific and cultural quality of farmers, providing talent support for the green sustainable development of agriculture, *etc.* Second, we should appropriately adjust the structure of agricultural investment and reduce the use of chemical fertilizers and pesticides. The focus of agricultural investment should be tilted to the departments or agencies that are conducive to the agricultural ecological environment.

4.3 Strengthening the supervision of agricultural subsidies

In the process of implementing the agricultural subsidy policy, we should strengthen government supervision. First, we must strengthen organizational leadership. According to the local demands for subsidies based on green development, there is a need to develop a practical subsidy program, refine the tasks of all departments, clarify the corresponding responsibilities, strengthen coordination and push forward solidly. The second is to strengthen supervision and improve the legal transparency of subsidies. The arrangement of agricultural subsidy funds must strictly comply with Budget Law, and they should be legal subsidies, sunshine subsidies and transparent subsidies. Third, we should be extensively under the supervision of the masses and strengthen the supervision over the interception, misappropriation and fraud of subsidized funds through websites, news media, Weibo, *etc.* [4].

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