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Livable City Ranking Problem

Senping Wang[1], Ran Yang[2], Xinru Zeng[3], Haiyan Zhang*[3]

[1]School of automation and information engineering, Sicuan University of Science & Engineering, Sichuan, China
[2]School of chemical Engineering, Sicuan University of Science & Engineering, Sichuan, China
[3]School of mathematics and statistics, Sicuan University of Science & Engineering, Sichuan, China

Abstract Livable city ranking problem is studied in this paper. Through the literature material broad selection of Qingdao, Beijing, Shanghai and other five indicators, livable city using rough set theory and grey incidence clustering method of combining the index reasonable classification, screening for related indicators. The evaluation model of multistage fuzzy composite ranking was established by using the improved AHP index weighting. In huaihai economic zone in the eight cities, for example the livability, according to the established urban livability rankings evaluation model, using matlab to calculate, eight city livability rankings are obtained. Finally, the practical significance and application promotion of this paper are illustrated in the conclusion.

Keywords Evaluation; Grey rough sets; Fuzzy comprehensive evaluation

1. Introduction

Along with the rapid development of industrialization and urbanization, the contradiction between man and nature is increasing. Urban development is facing resource shortage, environment pollution, traffic congestion and other issues, the residents' quality of living environment put forward higher requirements, plus the country not to attach importance to the construction of ecological civilization and the ecological environment problem. Under this background, the construction and to improve the livability of cities has become important issues of urban development [1], and is also the focus of the urban residents and government pay close attention to at present.

Livable city refers to the coordinated development of economy, society, culture, and environment. Livable city in recent years has successively developed and practice in some countries, such as vancouver habitable area strategic plans, and special protection plan in order to obtain a certain green zone. In the academic circles, the concept of livable city, enrich the connotation and theoretical research, and the development of the livable city is built on the basis of the coordinated development of human economic and social [2-5]. In January 2005, approved by the state council, "the Beijing city master plan (2004-2040)", "urban livability" was first proposed. On December 20, 2015, the central city work meeting made clear that the "to improve the habitability of the city" and "building livable city" as the important work of urban development [6-10]. After this, more than 100 cities across the country have come up with the goal of constructing livable cities.

1.1. Present Situation in Foreign Countries

Overseas for study of livable city, as the pioneer of the western classical culture and the cradle of European civilization, ancient Greece, at that time, such as Socrates, Plato put forward their ideal urban form, in 1898, Howard in the "the garden city of tomorrow", to be explicitly, livable city after the second world war, resources, environment, urban development to a certain limit, also in the city to the planning and construction, people pay

more attention to the harmonious development of human and nature, and the pursuit of the comfort of life, Dav L Smith pointed out in the book "pleasant and urban planning" that the amenity of the city should be analyzed from three aspects of life comfort, environment beauty, public health and so on. In the 1960 s, Jane jacobs was "the death and life of America's largest cities" to the question the livability of American cities, in 1961, the world health organization (WTO) officially puts forward the concept of environment livability, which embodies in the health, safety, comfortable, cheap four aspects. Urban development concept embodies in the 1970 s as the return to humanism, pay attention to improve and improve the quality of life of urban residents, jonhston, living environment of the evaluation factors mainly include the natural environment, cultural environment factors, place of residence, the international union of housing and planning, the evaluation of healthy city 9 standard H.L.L ennard proposed including citizens feel safe, people respect each other, such as urban environmental aesthetic nine standard with livable city, in 1996 the United Nations conference on human settlements, the second is put forward the concept of sustainable development of human settlements, become the important content of livable city, Salzano livable cities need to link the past and the future is put forward, and not to reduce the resources and environmental capacity at the expense of offspring. D.h.ahlwe thinks cities should have a healthy lifestyle, convenient travel, VaneSSaTimmer and Nola Kateseymoar propose the important indicators of the evaluation of livable cities include the perfection of facilities, the enjoyment of equity, the convenience of travel and the participation of decision making.

Above all, livable cities abroad research focus from the living environment, and began gradually to live environment [11-13] and social environment [14, 15], more and more from the social level to study whether urban residents enjoy the equal city life and equal participation in decision-making city, attaches great importance to the sustainable development of cities and the residents' quality of life.

1.2. Domestic Research Status

The study of livable cities in China is relatively backward, "human habitation Environment" was put forward in the 1990s. In 1990, Xuesen Qian proposed the "landscape city", the city's ecological environment and historical background to coordinate comprehensive consideration, Wu Liangyong out of the "fusion of city planning, landscape architecture framework of city people live, and" living system, social system and natural system, human system, support system, cross system research "and so on six big research field. Liu binyi USES the analytic hierarchy process, which is based on the economic condition, ecological environment, living conditions, social security, public service and infrastructure. Zhang wenzhong and Yin weihong made a research evaluation on the livability of urban livable cities in Beijing. From the five aspects of urban security, environmental health, life convenience, travel convenience and living comfort, Zhang Yabin and PengWenying analyzed the gap between the developed world and the developed world, from reserves per capita GDP, transportation conditions, housing situation, the greenbelt area per capita, the urban air quality and biodiversity of the connotation of ecological city and livable cities of Beijing and the evaluation index system was studied.

All in all, the research and evaluation of livable cities in China is still to be improved. At present our country city development level is low, the focus of the urban development and urban construction still focused on urban economic construction, the city of "people" the attention is not enough, the city should pay more attention to in the process of research and development on human's subjective feeling.

2. Construction of Evaluation System

2.1. Index Selection System

Access to relevant information, broad selection of Qingdao, chongqing, Shanghai, Beijing and guangzhou five related index of the livable city, by using the rough set theory and grey incidence clustering method of combining the index of correlation between small reduction, to eliminate index information between the overlapping degree, finally get the selected five evaluation index of the livable city.

2.2. Index Based on Grey Rough Sets

The index system of the screened livable city is different, and the evaluation result will be different. In this paper, grey rough sets are used to screen the indexes of five livable cities. The following is the screening procedure of grey rough sets:

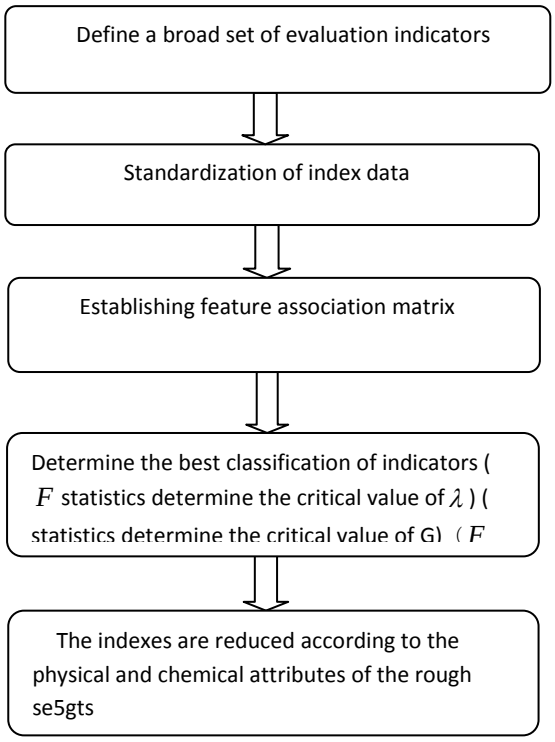

Figure 1: grey rough sets filtering steps

(1) Review and collect relevant data to determine the set of evaluation indicators

Referring to relevant data, we can get the relevant indexes of five livable cities in Qingdao, Chongqing, Shanghai, Beijing and Guangzhou.

Table 1: Indicators

Indicators	**Qing Dao** c_1	**Bei Jing** $c2$	**Guang Zhou** $c3$	**Shang Hai** $c4$	**Chong Qing** $c5$
Per capita GDP (yuan) X1	102519	106496	138377	103795	523 30
Disposable income of urban people (yuan) X2	40370	52859	46735	52962	27239
Rate of employment （%） X3	72.75	54.65	54.35	56.37	56.6
Third industry population proportio （%） X4	43.3	78.8	56.87	62.85	41.4
Per capita consumption expenditure of urban residents (yuan) X5	26016	41846	35752	34784	15140
General public budget revenue ($100 million) X6	1007.2	4723.8	1349.4	5519.5	2155.1
Air quality standard rate （%） X7	80.3	51	85.5	70.7	79.45
Water quality standard of drinking water source （%） X8	100	100	100	100	100
Sewage treatment ra （%） X9	70	87.9	86.72	91	93.67
Per capita green area (m^2) X10	14.6	16	16.5	7.6	16.1

Urban green coverage rate （%） X11	44.7	48.4	41.53	38.5	45
The total amount of wastewater discharge (million tons) X12	5.323	7.612	16.19	22.45	3.52
Acid rain frequency （%） X13	14.18	4.8	38.4	60.8	78.1
Per capita available fresh water(m^3) X14	247	123.8	135.2	116.9	124.8
Per capita urban land area （ m^2 ） X15	31.5	43.6	23.2	18.1	19.7
Food safety acceptance rate （%） X16	96.67	96.8	95.2	97	98.06
Reuse rate of industrial water （%） X17	87.51	87.87	75.4	86.14	73.1
Power generation (billion KWH) X18	170.41	541.44	426.33	821.19	644.64
Total energy consumption (10000 tons of standard coal) X19	1484	6852.6	5688.8	11387.4	8068.4
Number of traffic accidents (starting) X20	1323	2312	2676	1044	1528
Number of students in school (10000 persons) X21	179.32	373.42	297.4	198.97	535.36
Number of health institutions (Institutions) X22	4326	5425	3724	5016	1568
Number of institutions of higher learning (Institutions) X23	24	90	81	67	64
Achievements in science and Technology (item) X24	639	3054	2861	2356	2706

(2) Standardized processing of data

Standardized processing of index data, the formula is as follows：

$$x_{ij} = 1 - x_{ij} / x_j \max$$

(3) Characteristic relational grade matrix

With m observation objects, each observation object has n characteristics, and the sequence is as follows:

$$x_1 = (x_1(1), x_1(2), ..., x_1(n))$$
$$x_2 = (x_2(1), x_2(2), ..., x_2(n))$$
$$\cdots\cdots$$
$$x_m = (x_m(1), x_m(2), ..., x_m(n))$$

for all $i = j, j = 1,2,...,m$, the grey absolute correlation between x_i and x_j is calculated:

$$X_{ij}(n) = \frac{\min_i \min_j |x_i(n) - x_j(n)| + a \max_i \max_n |x_i(n) - x_j(n)|}{|x_i(n) - x_j(n)| + a \max_i \max_n |x_i(n) - x_j(n)|}$$

among them, $X_{ij} = 1$， $i = 1,2,3,...,m$.

The above formula is applied to *matlab* to standardize the data, and then the grey incidence matrix is as follows:

$$\begin{pmatrix} 1.0000 & 0.7112 & 0.7372 & 0.6997 & 0.7174 \\ 0.7344 & 1.0000 & 0.7964 & 0.7701 & 0.7372 \\ 0.7128 & 0.7504 & 1.0000 & 0.7330 & 0.7258 \\ 0.7083 & 0.7583 & 0.7630 & 1.0000 & 0.7352 \\ 0.7393 & 0.7372 & 0.7685 & 0.7479 & 1.0000 \end{pmatrix}$$

(4) F statistic is used to determine the critical value, and the reasonable classification of indexes is further determined.

$$\bar{X} = (\bar{X}_1, \bar{X}_2, \ldots, \bar{X}_m)$$

$$\bar{X}_k = \frac{1}{n}\sum_{i=1}^{n} x_{ik}(k = 1,2,\ldots,m)$$

Sets the number corresponding to the λ value is γ, and the cluster sample of class j is n_j, The sample of class j is denoted as $x_1^{(j)}, x_2^{(j)}, \ldots, x_{nj}^{(j)}$, The cluster center vector of class j is $\bar{x}^{(j)} = (\bar{x}_1^{(j)}, \bar{x}_2^{(j)}, \ldots, \bar{x}_{nj}^{(j)})$, Where $\bar{x}_k^{(j)}$ is the average of the k characteristic, that is:

$$\bar{X}_k^{(j)} = \frac{1}{n_j}\sum_{i=1}^{n_j} x^{(j)}{}_{ik}(k = 1,2,\ldots,m)$$

for F statistics:

$$F = \frac{\sum_{j=1}^{r} n_j \left\|\bar{x}^{(j)} - \bar{x}\right\|^2 / (r-1)}{\sum_{i=1}^{r}\sum_{j=1} \left\|x_i^{(j)} - \bar{x}^{(j)}\right\|^2 / (n-r)}$$

among them:

$$\left\|\bar{x}^{(j)} - \bar{x}\right\| = \sqrt{\sum \left(\bar{x}_k^{(j)} - \bar{x}_k\right)^2}$$

is the distance between $\bar{x}^{(j)}$ and $\bar{x}$ .The numerator of the F statistic represents the distance between the class and the class, and the denominator indicates the distance between the classes within the class.

According to the inequality $F > F_a(r-1, n-r)$ related mathematical operations, and through the t distribution table access to $(F - F_a)/F_a$, the solution was obtained:

$$\lambda \leq 0.75$$

That is, when $\lambda = 0.75$, the classification is more reasonable,

$$C = U/x = \{\{C_1\},\{C_2\},\{C_5\},\{C_3, C_4\}\}$$

(5) The grey clustering method is used to combine the classification, and the optimal classification is calculated according to the grey incidence matrix:

$$C = U\Big/\begin{pmatrix} x_3 - x_4 - x_5 - x_6 - x_8 - x_{10} - x_{12} - \\ x_{13} - x_{17} - x_{18} - x_{19} - x_{21} - x_{23} - x_{24} \end{pmatrix} = \{\{C_1\},\{C_2\},\{C_5\},\{C_3, C_4\}\}$$

as far as we know, indicators: $x_3, x_4, x_5, x_6, x_8, x_{10}, x_{12}, x_{13}, x_{17}, x_{18}, x_{19}, x_{21}, x_{23}, x_{24}$, and after reduction, the classification result is not affected, So you can get the minimum attribute set as:

$$\{x_3, x_4, x_5, x_6, x_8, x_{10}, x_{12}, x_{13}, x_{17}, x_{18}, x_{19}, x_{21}, x_{23}, x_{24}\}$$

The 8 original 24 indexes can be reduced to 10 indexes.

2.3. Construction of multi index evaluation system

The filtered index definition, access to relevant information and degree of livable city combined with the actual situation that has significant influence on the degree of livable city mainly includes the following four categories: economic prosperity, beautiful environment, resources, cheap life of bearing.

Table 2: Index of urban livability evaluation

Urban livability	**Index**	
	Economic affluence C_1	Percapita GDP x_1
		Disposable income of urban residents x_2
	Environmental beauty C_2	Air quality standard rate x_3
		Urban green coverage rate x_4
		Sewage treatment rate x_5

	Resource carrying capacity C_3	Percapita available fresh water x_6
		Percapita urban land area x_7
		Qualified rate of food safety x_8
	Cost of living C_4	Number of safety accidents x_9
		Number of health institutions x_{10}

According to the index of urban livability, the evaluation model of livable city can be established by the improved analytic hierarchy process (AHP).

2.4. Determination of weights based on Improved AHP

The design of a 3-scale method, which adopts the familiar (0,1,2) of the 3-scale method, according to the definition of related literature experts on the index for each element of 22 to establish a comparison matrix: $B=(b_{ij})_{n\times n}$

This defines:

$$b_{ij}=\begin{cases}2 & \text{the effect of elemental i is greater than that of j}\\ 1 & \text{The influence of the element i is equal to the influence of j}\\ 0 & \text{the effect of elemental i is less than j}\end{cases}$$

(1) According to the improved formula and the formula, the comparison matrix of economic richness, environment beauty degree, resource carrying capacity and life cost degree is constructed $B=(b_{ij})_{n\times n}$:

$$B=\begin{bmatrix}1&1&2&2\\1&1&2&0\\0&0&1&2\\0&2&0&1\end{bmatrix}$$

(2) Furthermore, the comparison matrix is transformed into the judgment matrix C

First, the $r_i=\sum b_{ij}$, $(i=1,2,...,n)$ iscomputed, that is, the sum of the columns, and the matrix is formulated as follows:

$$C_{ij}=\begin{cases}\left[(r_i-r_j)/(r_{\max}-r_{\min})\right]\times(bm-1)+1 & r_i\geq r_j\\ \left[\left[(r_i-r_j)/(r_{\max}-r_{\min})\right]\times(bm-1)+1\right]^{-1} & r_i<r_j\end{cases}$$

among them: $r_{\max}=MAX\{r_i\}$, $r_{\min}=MIN\{r_i\}$, $bm=r_{\max}/r_{\min}$。

According to the above formula, applying *matlab* and combining the comparison matrix, the judgment matrix C is as follows:

$$C=\begin{bmatrix}1.0000&0.1429&5.0000&7.0000\\7.0000&1.0000&11.0000&13.0000\\0.2000&0.0909&1.0000&3.0000\\0.1429&0.0769&0.3333&1.0000\end{bmatrix}$$

(3) Through the judgment matrix to calculate the weight of each index

The above comparison matrix has been transformed into a judgment matrix, and the weights of the 4 primary indexes of livable city can be further solved by the judgment matrix:

$$\omega=(\omega_1,\omega_2,\omega_3,...\omega_n)$$

apply *matlab* to obtain the weight of 4 first class indexes of livable city:

$$\omega_1=0.1796,\quad \omega_2=0.4394,\quad \omega_3=0.2250,\quad \omega_4=0.2153$$

(4) for consistency checking of the index weight

$$CR=CI/RI$$

In the upper part, $CI=\frac{\lambda_{\max}-n}{n-1}$, λ is the largest eigenvalue, and n is the order.

applying *matlab* to obtain:

$$CI = 0.1014, \quad CR = 0.0768 < 0.1$$

Table 3: Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
R.I	0	0	0.25	0.89	1.12	1.26	1.36	1.41	1.46	149

General if $CR \le 0.1$, is that the consistency of the judgment matrix is satisfied.

(5) Similarly, the above method is used to obtain the weight of the two level indexes corresponding to the four first level indicators, and the corresponding weights are obtained by using *matlab*:

Index of economic richness index:

（0.534 0.466）;

Environmental grace index weight:

（0.317 0.285 0.398）;

Resource carrying capacity index weight:

（0.364 0.310 0.326）;

Life cost index weight:

（0.429 0.571）;

3. Ranking of urban livability

3.1. Index in Huaihai Economic Zone and its standardization

Since the index data units of 8 cities are not the same, to ensure the results are reasonable and authentic, it is necessary to standardize the original values of urban indicators. Adopting $Min-\max$ standardization.

$\text{New data}=(\text{Raw -Minimum})/(\text{maximum -Minimum})$ After the data is standardized, the value range of the element in x is $[0,1]$.

3.2. Comprehensive evaluation in Huaihai Economic Zone

According to the 8 city livability indices standardized data, combined with the level of index weights by improved analytic hierarchy process and the two indicators, using the method of multi-layer fuzzy comprehensive evaluation of the 8 city in Huaihai Economic Zone liveability rankings.

（1） Evaluation object set

p =the livability of 8 cities in Huaihai Economic Zone

（2） Evaluation factor set

$$U=\{u_1,u_2,.....u_p\}$$
$$=\begin{Bmatrix}\text{Economic affluence，Environmental beauty,}\\ \text{Resource carrying capacity，Cost of living}\end{Bmatrix}$$

（3） Comment hierarchy

Through the livability score of 8 cities, the author compares the scores of 22 cities, and makes a relative ranking of their livability, to determine the relative size of the livability of 8 cities in Huaihai economic zone.

（4） Weighted average fuzzy synthetic evaluation of urban livability

The weighted average fuzzy synthesis operator is adopted to calculate the following formula:

$$b_i=\sum_{i=1}^{p}(w_i\cdot r_{ij})=\min(1,\sum_{i=1}^{p}w_i\cdot r_{ij}),\ j=1,2,...m$$

In the upper part, b_i, a_i and r_{ij} are subordinate degree j grade membership degree respectively, and the weight of the i evaluation index and the i index belong to the subordinate degree of grade j.

（5）Hierarchical comprehensive evaluation of the two indicators For the environmental grace degree

$$u_2 = \{u_{21}, u_{22}, u_{23}\},$$

there is a weight $w_2 = (0.317 \quad 0.285 \quad 0.398)$, and the single factor judgment matrix is composed of the fuzzy evaluation of Table 3 to u_{21}, u_{22}, u_{23}:

$$R_2 = \begin{bmatrix} 0.6 & 0.71 & 0.77 & 0.60 & 0.82 & 0.95 & 0.65 & 0.76 \\ 0.6 & 0.71 & 0.70 & 0.60 & 0.80 & 0.95 & 0.65 & 0.76 \\ 0.91 & 0.90 & 0.93 & 0.91 & 0.95 & 0.93 & 0.81 & 0.89 \end{bmatrix}$$ By means of *matlab* weighted average fuzzy synthetic operator, comprehensive evaluation is carried out:

$$B_2 = W_2 \circ R_2 = (0.703 \quad 0.773 \quad 0.800 \quad 0.703 \quad 0.857 \quad 0.943 \quad 0.703 \quad 0.803)$$

Similarly, according to the weights of the two levels of indicators and the judgment matrix, the weighted average evaluation of them is carried out by using *matlab* respectively:

For the sake of economic prosperity, that is:

$$B_1 = (0.905 \quad 0.828 \quad 0.920 \quad 0.905 \quad 0.668 \quad 0.663 \quad 0.863 \quad 0.910)$$

For resource carrying capacity, that is:

$$B_3 = (0.800 \quad 0.680 \quad 0.844 \quad 0.899 \quad 0.758 \quad 0.745 \quad 0.800 \quad 0.822)$$

For the sake of cheap living, that is:

$$B_4 = (0.905 \quad 0.828 \quad 0.920 \quad 0.905 \quad 0.668 \quad 0.663 \quad 0.863 \quad 0.910)$$

（6）Make a high-level comprehensive evaluation of the first level indicators

Evaluation factor set $U = \{u_1, u_2, u_3, u_4\}$, The weight of each level index is $w = (0.179 \quad 0.439 \quad 0.225 \quad 0.215)$, Then the synthetic judgment vector is:

$$B = w \circ R = w \circ \begin{pmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{pmatrix} = (0.433, 0.500, 0.295, 0.499, 0.332, 0.342, 0.273, 0.338)$$

3.3. Comprehensive score in Huaihai Economic Zone

From the above results, we can get the comprehensive score of livability in each city:

Table 4: comprehensive score of livability ineight cities

Index	Huaibei	Xuzhou	Zaozhuang	Jining
Livability score	0.433	0.500	0.295	0.499
index	Shangqiu	Suzhou	Lianyungang	Suqian
Livability score	0.332	0.342	0.273	0.338

The analysis can be seen in Table 4, Huaibei City livability scores above 0.5, significantly higher than that of other city, livable city is relatively high; and Lianyungang, Zaozhuang City livability score below 0.3, the low degree of livable city. Therefore, according to table 4 data, you can do city livability rankings are as follows:

Table 5: ranking of urban livability in eight cities

City	Liveability ranking
Xuzhou	1
Jining	2
Huaibei	3
Suzhou	4
Suzhou	5
Shangqiu	6
Zaozhuang	7
Lianyungang	8

As can be seen from table 5, Xuzhou, Jining, Huaibei and Suzhou have better urban livability than other cities, so urban livability is higher. While Suqian, Shangqiu, Zaozhuang and Lianyungang rank in the lower reaches of the eight cities, urban livability is lower.

4. Conclusion

The research status at home and abroad about the city livable city in this paper, found by understanding, most of the research for livable city is belong to the qualitative research, there is no specific quantitative, and quantitative research of the few methods defined in the selection of indicators, the current through the use of grey rough set theory influence index livable city is selected from multiple indicators, through quantitative calculation to derive influence index of livable city, and then use the improved AHP method to determine the weight of the evaluation index system of livable city.Combined with fuzzy comprehensive evaluation to rank the specific city, this paper chooses Suzhou, Huaibei, Jining, Shangqiu, Suqian, Zaozhuang, Lianyungang, Xuzhou and other eight regions of Huaihai livable city ranking, and finally get the ranking are Xuzhou, Jining, Huaibei, Suzhou, Suqian, Shangqiu, Zaozhuang, Lianyungang, ranked first, livable degree is better, after access to relevant documents found the city livable ranking and the actual results are similar, which shows the validity of the method used in this paper, through the study of the government can introduce relevant policies to increase the local livability, at the same time for the selection of city residents is moved a very good help.

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