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Research Article

Empirical Research on the Urban Development Level of Wuhan Urban Circle

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Abstract: The research object of this paper is the nine cities of Wuhan urban circle. Firstly, this paper establishes the comprehensive evaluation indicator system and evaluation model of the urban development level via systems analysis, then makes a PCA (Principal Components Analysis) to the original data by means of SPSS; Next, this paper analyzes the worked data via AHP (Analytic Hierarchy Process) and comprehensive score and ranking of the nine cities is obtained and the nine cities are divided into three clusters via K-means clustering analysis; Finally, this paper appraises urban development level of Wuhan urban circle.

Keywords: Analytic hierarchy process, empirical research, K-means clustering analysis, principal compound analysis, urban development level

INTRODUCTION

Wuhan urban circle is also known as the "1+8" urban circle, in which the capital of Hubei province: Wuhan municipality is the core city and surrounded by another eight municipalities including Huangshi municipality, Huanggang municipality, Xiaogan municipality, Xianning municipality, Ezhou municipality, Xiantao municipality, Tianmen municipality and Qianjiang municipality. The major strategic decision-making and implementation of "Rise of Central China" provides a good opportunity for the development of Hubei. And Wuhan urban circle is located in the bridge which can connect the four directions, has a strong resource of technology and culture education, and has professional and comprehensive trading market and regional logistics center and traffic transportation hub. Therefore, construction of the Wuhan city circle not only can drive the rapid economy development of Hubei, but also can become the backbone force which drives the rise of central China.

Discussion on the urban development level of the Wuhan urban circle under the background of the rise of central China can provide a basis for making the urban development strategy, which has great significance. Many scholars at home and abroad have studied the problems related to the issues from several aspects (Zhu *et al*., 2010; Chen, 2005; Luo, 2008; Li, 2009; Ai *et al*., 2011). On the basis of previous studies, the paper uses methods of principal component analysis and analytic hierarchy process, and combines the quantitative analysis and qualitative analysis combines, studies urban development level of the Wuhan urban circle.

THE COMPREHENSIVE EVALUATION INDICATOR SYSTEM

At present, many scholars from the different fields hold different opinions about the evaluation indicator system of the urban development level. They often establish the indicator system from their own research perspective. Due to the lack of unified definition in the connotation of urbanization and urban development, it is more difficult to make the evaluation and the evaluation results are often inconsistent. The author reviews the extensive literature study to establish the indicator system of urban development level. We think that the composite indicator system is more inclined to be used from the various angles and levels to evaluate and analyze the urban development level.

This article intends to establish a more scientific indicator system from the following five aspects (Ai *et al*., 2011):

- Economic scale and industrial structure standard, including the economic strength, economic structure, investment scale and other related indexes.
- People's lifestyle and living standard, including residents' living environment, living quality and other related indexes.
- Social development standard, including the urban construction, transportation, communication level, medical treatment, education and science and technology level and other related indexes.
- Opening-up standard, including the foreign trade, international investment, and foreign capital fusion,

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Table 1: The evaluation indicator system of the urban development level

First-level indicators	second-level indicators	Unit	NO
Economic scale and industrial structure standard (A_1)	gross regional product	100 million Yuan	B_1
	revenue of local governments	100 million Yuan	B_2
	Total investment in fixed assets	100 million Yuan	B_3
	Total retail sales of consumer goods	100 million Yuan	B_4
	Per capita gross regional product	Yuan	B_5
	Proportion of primary industry in GDP	%	B_6
	Proportion of secondary industry in GDP	%	B_7
	Proportion of tertiary industry in GDP	%	B_8
People's lifestyle and living standard (A_2)	Per capita total retail sales of consumer goods	Yuan	B_9
	Annual per capita disposable income of rural households	Yuan	B_{10}
	Annual per capita disposable income of urban households	Yuan	B_{11}
	Per capita housing area of urban households	Square meter	B_{12}
	Per capita public green area	Square meter	B_{13}
Social development standard (A_3)	Foreign trade dependence degree	100 million Yuan	B_{14}
	Number of students enrolled in institutions of higher education	10000 persons	B_{15}
	Number of health care institutions	Unit	B_{16}
	Possession of civil vehicles	Unit	B_{17}
Opening-up standard (A_4)	Foreign trade dependence degree	%	B_{18}
	Proportion of actual foreign direct investment in GDP	%	B_{19}
	Proportion of international tourism foreign earnings in GDP	%	B_{20}
Urbanization standard of the population (A_5)	Number of international tourists	10000 person-times	B_{21}
	Population density	Person/square kilometer	B_{22}
	Proportion of tertiary industry employment	%	B_{23}
	Natural population growth rate	%	B_{24}

international labor service, foreign tourism and other related indexes.

- Urbanization standard of the population, including the related index measured in terms of urbanization development level.

Based on the principles of authenticity, reliability, accuracy, timeliness about data collection and the principles of purpose, scientific, adaptability, comparability and overall system about indicators, an evaluation indicator system which contains five first-level indicators, 24 second-level indicators have been constructed (Table 1).

THE COMPREHENSIVE EVALUATION MODEL OF URBAN DEVELOPMENT EVALUATION MODEL

The evaluation model of first-level indicators of wuhan urban circle: During the calculating the development level of the first-level indicators of each city, the evaluation results are often associated with the determination of indicator weight and selection of merger rules. Therefore, the subjective factors have great influence on the evaluation result, and the numbers of each first-level indicator are different and big, which is particularly prominent. So, the principal component analysis method of economic statistics is always used to calculate the development level of each first-level indicator in the urban development evaluation system (Luo and Yang, 2010).

Principal component analysis was put forward by Hotelling in 1933 at first, whose main idea was dimension reduction. It is a multivariate statistical analysis method which can convert the many indicators into a few comprehensive indicators.

So the principal component analysis method is used to determine the weights of a comprehensive evaluation factor in this article, on the basis of which evaluation model will be constructed and the objective function is defined as follows (Zhang and Feng, 2004):

$$P_i = \sum_{i=1}^{n_i} U_i \times V_i \quad (1)$$

where,

$i = 1, 2, 3, 4, 5$;

P_i = The comprehensive score of the first-level indicator

U_i = The weights of the corresponding index of the first-level indicator

V_i = Principal component scores of the corresponding index of the first-level indicator

n_i = The numbers of the corresponding index of the first-level indicator

Comprehensive evaluation model of urban development level: From Eq. (1), the comprehensive development value of the first-level indicator can be calculated, on the basis of which the first-level indicators are further weighted. Because the 5 first-level

indicators belong to different categories, the correlation among them is not very strong, and the evaluation weights can be determined according to the important extent of factors evaluated. Therefore, it is appropriate to use analytical hierarchy process to determine weights among the first-level indicators and weighted calculation. Finally, we can use the analytic hierarchy process to establish a model, whose main steps are as follows (Duan *et al*., 2011):

- Establishing the hierarchical structure model
- Constructing all judgment matrices of every level
- Hierarchical single sorting and consistency check
- Total sorting of hierarchy and consistency check
- If necessary, the judgment matrix and hierarchical ranking model may be corrected and adjusted

Evaluation model of AHP:

$$F = \sum_{i=1}^{5} W_i \times P_i \quad (2)$$

where,

F = Total index of urban development level of each city

W_i = Weighting value of the first-level indicator of each city

P_i = Comprehensive development level index of first-level indicator of each city

EMPIRICAL RESEARCH

According to the urban development theory and the actual situation, the original data corresponding to the evaluation system of the urban development can be collected. Assuming the vector $E = (E_1, E_2, \ldots, E_{m1})$, $P = (P_1, P_2, \ldots, P_{m2})$, $S = (S_1, S_2, \ldots, S_{m3})$, $O = (O_1, O_2, \ldots, O_{m4})$, $U = (U_1, U_2, \ldots, U_{m5})$ represent respectively the vector which is composed of each first-level indicator; represent respectively the number of the second-level indicators responding to their own first-level indicator. In the course of the evaluation of 12 main cities in Hubei, and the following data matrix will be obtained (Chen and Li, 2011):

$$(E_{ij}) = \begin{pmatrix} E_{11} & \cdots & E_{18} \\ \vdots & \ddots & \vdots \\ E_{m1} & \cdots & E_{m8} \end{pmatrix} (P_{ij}) = \begin{pmatrix} P_{11} & \cdots & P_{15} \\ \vdots & \ddots & \vdots \\ P_{m1} & \cdots & P_{m5} \end{pmatrix}$$

$$(S_{ij}) = \begin{pmatrix} S_{11} & \cdots & S_{14} \\ \vdots & \ddots & \vdots \\ S_{m1} & \cdots & S_{m4} \end{pmatrix} (O_{ij}) = \begin{pmatrix} O_{11} & \cdots & O_{14} \\ \vdots & \ddots & \vdots \\ O_{m1} & \cdots & O_{m4} \end{pmatrix}$$

$$(U_{ij}) = \begin{pmatrix} U_{11} & \cdots & U_{13} \\ \vdots & \ddots & \vdots \\ U_{m1} & \cdots & U_{m3} \end{pmatrix}$$

where : $m_1 = 8, m_2 = 5, m_3 = 4, m_4 = 4, m_5 = 3$

To determine urban development level index of the first-level indicator: This study uses the descriptive command of SPSS software to standardize the original data, and use the program of dimension reduction to determine the number of principal components and the contribution rate of the principal component of each first-level. And then according to the city development level indicator evaluation model which can be denoted by Eq. (1), the score of urban development level of first-level indicator of each city can be calculated, whose results are as shown in Table 2.

The negative values in Table 2 indicate their level is below the average level in all comparison cities, are not the true sense of the negative.

Comprehensive evaluation of the urban development level of wuhan urban circle: Based on the above calculation of the principle component, the paper continues to use analytical hierarchy process to determine weights among the first-level indicators and weighted calculation. Finally, we can get the

Table 2: Principal component score and rank of five first-level indicators

Item	A_1	Rank	A_2	Rank	A_3	Rank	A_4	Rank	A_5	Rank
Wuhan municipality	4.986	1	2.217	1	5.193	1	3.521	1	2.063	1
Huangshi municipality	-0.375	3	-0.096	4	-0.433	3	1.004	2	-0.410	6
Ezhou municipality	-0.895	8	0.372	2	-0.893	6	-0.371	5	-0.334	5
Xiaogan municipality	-0.383	4	-0.281	5	-0.443	4	-0.489	6	-0.249	4
Huanggang municipality	-0.260	2	-1.350	9	-0.049	2	-0.893	7	-0.785	8
Xianning municipality	-0.441	5	-0.491	8	-0.531	5	-0.259	3	-1.134	9
Xiantiao municipality	-0.659	6	0.318	3	-0.965	9	-0.324	4	0.471	3
Qianjiang municipality	-0.839	7	-0.326	6	-0.929	7	-0.974	8	-0.655	7
Tianmen municipality	-1.134	9	-0.363	7	-0.950	8	-1.215	9	1.033	2

Data derive from the 2011 statistical yearbook of Hubei province

Table 3: The judgment matrix of 5 first-level indicators

First-level indicators	A_1	A_2	A_3	A_4	A_5
A_1	1	3	4	2	5
A_2	1/3	1	2	1/2	3
A_3	1/4	1/2	1	1/3	2
A_4	1/2	2	3	1	4
A_5	1/5	1/3	1/2	1/4	1

Table 4: The indicator of average random consistency

n	3	4	5	6	7	8	9	10	11
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.46	1.49	1.52

comprehensive evaluation score of development of the urban development level of Wuhan urban circle

- **Constructing the judgment matrix and calculation:** According to 1~9 judgment scale table proposed by the mathematician T. L. Saaty, the importance degree among the 5 first-level indicators can be judged through research and experts' evaluation. And then the judgment matrix is as follows in Table 3.
  Then the maximum eigenvalue and the corresponding eigenvectors of the matrix can be calculated directly by means of Matlab software. The procedures are as follows:

```
A          =  [1,3,4,2,5;1/3,1,2,1/2,3;1/4,1/2,1,
              1/3,2;1/2,2,3,1,4;1/5,1/3,1/2,1/4,1]
[x, y]     =  eig (A)
Eigenvalue =  diag (y)
lamda      =  eigenvalue (1)
w1         =  x (:,1)/sum (x(:,1))
And the output results are:
Eigenvalue =  5.0681
              0.0050 + 0.5828i
              0.0050 - 0.5828i
             -0.0390 + 0.0683i
             -0.0390 - 0.0683i
Lamda      =  5.0681
    w1     =  0.4185
              0.1599
              0.0973
              0.2625
              0.0618
```

where,
w1 = The weight corresponding to the every the first-level indicator.

- **Consistency check:** The main steps of the consistency check are as follows:
- To calculate the indicator CI used to judge the consistency of judgment matrix deviation, whose calculation formula is:

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

where,
λ_{max} = The maximum eigenvalue
n = The rank of judgment matrix

- Select the indicator RI which indicates the average random consistency of different rank judgment matrix and its values can be selected from Table 4.
- To calculate the indicator which indicates the random consistence rate, whose calculation formula is $CR = \frac{CI}{RI}$

If CR<0.1, the results of hierarchical sorting ca satisfy the requirement for consistency, otherwise the judgment matrix will need to be revised.
so the matrix A can be solved:

$$CI = \frac{\lambda_{max} - n}{n-1} = \frac{5.0681-5}{5-1} = 0.017025$$

$$CR = \frac{0.017025}{1.12} = 0.0152 < 0.10$$

As is seen from above, the judgment matrix A satisfies the requirement for consistency check. So the weight among the first-level indicators W1 is acceptable.

- **Comprehensive evaluation:** According to Eq. (2), total sorting of hierarchy and rank will be obtained, which can be seen in Table 5. Through the analysis

Table 5: Score of hierarchical sorting, rank and classification

Item	A_1	A_2	A_3	A_4	A_5	Total score	Rank	Classification
Wuhan municipality	4.986	2.217	5.193	3.521	2.063	3.998	1	1
Huangshi municipality	-0.375	-0.096	-0.433	1.004	-0.410	0.024	2	2
Ezhou municipality	-0.895	0.372	-0.893	-0.371	-0.334	-0.520	6	3
Xiaogan municipality	-0.383	-0.281	-0.443	-0.489	-0.249	-0.392	4	2
Huanggang municipality	-0.260	-1.350	-0.049	-0.893	-0.785	-0.612	7	2
Xianning municipality	-0.441	-0.491	-0.531	-0.259	-1.134	-0.453	5	2
Xiantiao municipality	-0.659	0.318	-0.965	-0.324	0.471	-0.375	3	3
Qianjiang municipality	-0.839	-0.326	-0.929	-0.974	-0.655	-0.790	8	3
Tianmen municipality	-1.134	-0.363	-0.950	-1.215	1.033	-0.880	9	3

of comprehensive score and rank of development level of Wuhan urban circle, we can see that the top two of rank are Wuhan Municipality and Huangshi Municipality, and Qianjiang Municipality and Tianmen Municipality are backward.

At last, the clustering analysis can be performed by the means of K-means clustering method in SPSS software. And it is supposed that the cluster number is 3 and the convergence criteria value is 0.02, the final classification results can be shown in the last column of Table 5.

THE EVALUATION OF CALCULATION RESULTS

According to above statistical data and the results of the analysis by means of our system, nine regions of Wuhan urban circle are sorted into three clusters, of which the urban development level of Wuhan municipality and Huangshi Municipality is higher than the average level of the whole area; other municipalities are also a larger promotion space.

The first cluster: The first cluster includes Wuhan municipality. As the capital city of Hubei Province, every aspect of Wuhan municipality plays the leading role in the overall regions, whose urban development level is higher than that of other cities. By virtue of its special administrative status and a powerful economic strength, Wuhan municipality is the only core growth pole and center of Wuhan urban circle.

The second cluster: The second cluster includes Huangshi municipality, Xiaogan municipality, Huanggang municipality, Xianning municipality. Their situations will be introduced separately:

- **Huangshi municipality:** It has a long history of mining, rich in cultural heritage, a solid industrial foundation, convenient geographical location. As the deputy core city of Wuhan urban circle, the comprehensive score of Huangshi municipality is second only to Wuhan municipality. Huangshi municipality has made outstanding achievements in the opening-up, and its proportion of actual foreign direct investment in GDP is 43.47%, which is the highest of the Wuhan urban circle, and its foreign trade dependence degree is higher, which is second-highest after Wuhan municipality. Therefore, Huangshi municipality should place emphasis on the export-oriented economy, and achieve balanced development.
- **Xiaogan Municipality:** All aspects of the city are on the middle level of Wuhan urban circle. Per capita public green area of Xiaogan municipality is 12 square meters, which is the highest of Wuhan urban circle, and the number of international tourists is second only to Wuhan municipality. Xiaogan municipality should make good use of the geographical advantages of Wuhan municipality close, introduce foreign capital, and promote the development of tourism and industry.
- **Huanggang municipality:** It is a typical agricultural city, its proportion of primary industry in GDP is 28.64%, which is the largest in nine cities. But the score of people's lifestyle and living standard is the lowest. The proportion of international tourism foreign earnings in GDP is 0.359%, which is the lowest of the Wuhan urban circle. Combined with its natural condition, the primary industry and revolutionary red travel industry have a larger development advantage.
- **Xianning municipality:** Per capita housing area of urban households of Xianning municipality is 41.48 square meters, which is the highest of the Wuhan urban circle. But the score of people's lifestyle and living standard is the second lowest. The development of Xianning municipality is mainly focused on the characteristics of agriculture, tourism and the textile industry.

The third cluster: The third cluster includes EZhou municipality, Xiantiao municipality, Qianjiang municipality, Tianmen municipality; their situations will be introduced separately:

- **EZhou municipality:** Per capita total retail sales of consumer goods, annual per capita disposable income of rural households, and annual per capita disposable income of urban households of EZhou municipality is second largest in Wuhan urban circle. Therefore, the score in people's lifestyle and living standard is higher, which is second only to Wuhan municipality. The proportion of secondary industry in GDP of EZhou municipality is 58.52%, which is the highest of the Wuhan urban circle. Ezhou municipality should primarily develop the secondary industry, of which metallurgical industry and manufacturing industry is its development advantage.
- **The other municipalities**: Xiantao municipality, Qianjiang municipality, and Tianmen municipality all belong to the county-level city, and their economic development lags behind other cities. But the three municipalities have rich labor resources and are located in Jianghan plain which is the

important commodity grain base in China. Therefore, construction of integrated rural development and agricultural industry chain in three municipalities has a clear advantage.

CONCLUSION

In this paper, the method of system analysis is used to establish the comprehensive evaluation indicator system and evaluation model of the urban development level evaluation. On this basis of this, the principal component analysis 、 analytic hierarchy process and K-means clustering algorithm are integrated to evaluate and analyze the development level of nine cities of Wuhan urban circle. Through this research, on one hand urban development level of the Wuhan urban circle can be deeply understudied, which can provide a reliable basis for making urban development strategy of the Wuhan urban circle; on the other hand, the method of data processing and analysis also has practical guiding significance to the urban development level of the Wuhan urban circle.

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