Evaluation and Research on Some Pilot Smart Cities

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Abstract: This paper, taking 30 pilot smart cities as the research objects, firstly presents a reasonable and comprehensive evaluation index system of smart city development from six aspects. Secondly, factor analysis method was used to reduce the dimension of 23 indicators, and 7 common factors and their weights were obtained. The total score of 30 cities' development status is ranked by the use of common factor and index data. The K-means clustering method makes cluster analysis on 30 cities, and divides each city into 4 categories according to the development situation of the indicators. Finally, based on the evaluation results, the author gives some suggestions on the construction of smart city.

1 Introduction

With the continuous progress of human society, the earth has been carrying more and more people. In order to support more population and provide people with a better life, many regions of the world have carried out urbanization construction. However, the acceleration and development of urbanization process have brought many problems to urban development. In order to effectively solve the dilemmas and problems faced by urban development and achieve sustainable urban development, the concept of "smart city" emerges as the times demand. All countries and regions have carried out the construction of smart cities, which has become an irreversible historical trend of urban development in today's world. Smart city development evaluation is an indispensable step in the process of smart city construction. Establishing a scientific and effective evaluation system is conducive to obtaining reliable and valuable development level information. Evaluating the development level of smart cities is conducive to urban management departments to grasp the current situation of urban development, adjust and optimize urban construction plans in time, and improve the feasibility of construction.

The construction of smart cities in China has been gradually carried out across the country. The Ministry of Housing and Urban-Rural Development, the National Development and Reform Commission, the Ministry of Industry and Information Technology and other departments have also put forward corresponding policies to guide and deploy the promotion of smart city construction. In 2013, the first batch of domestic pilot smart cities was set up, paving the way for the construction and exploration of smart cities in China. According to statistics, closed on February 2019, more than 700 cities in China have proposed or carried out the construction of smart cities, which has become a fashion trend. In the process of the construction of smart city, the factors that affect the construction of smart city have gradually become the focus of many scholars. For example, Zhang Xiekui and other scholars took smart cities in western China as an example to establish an analysis model of influencing factors from five aspects including infrastructure, economic development and industrial investment, as well as 16 secondary factors. Through quantitative analysis, the main influencing factors of smart city construction were extracted. Some scholars have also constructed a theoretical model of "factor-behavior-performance" through quantitative research. Zhang Yi and other scholars have analyzed and summarized the following three kinds of social factors that influence the success of smart city construction in China from the social perspective. This paper studies the development status of smart city to find out the key factors affecting the development of cities, and analyze the influence degree of these key factors. Through the analysis and comparison of the gap between cities, find out the characteristic competitiveness of cities, and put forward reasonable suggestions to promote the development of smart cities.

2 The construction of index system and data preprocessing

2.1. The construction of index system

Constructing a comprehensive and reasonable index system is the basis of objectively and accurately evaluating the development of smart cities. This paper constructs an evaluation index system including 6 first-level indicators and 23 second-level indicators from six aspects of smart infrastructure, smart economy, science and technology innovation driven, smart ecology, smart people's livelihood and smart population. See Table

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1 for details.

Table1 Evaluation Index of Smart City Development Level

Intelligent infrastructure	Fixed Internet broadband access userX1, mobile phone userX2, Total Business Volume of Posts and TelecommunicationsX3
Smart Economy	GDP per capitaX4, The per capita disposable income of urban residentsX5, The proportion of tertiary industry in GDPX6
Driven by scientific and technological innovation	Scientific and technological achievementsX7 Number of patent applications acceptedX8 Number of patents grantedX9 Number of research and experimental development enterprisesX10 Ratio of expenditure to GDPX11
Ecological Wisdom	Energy consumption of ten thousand yuan GDPX12 green coverage rate of built-up areaX13 Per capita park green areaX14 Annual air quality levelX15 urban sewage treatment rateX16 Harmless treatment rate of domestic garbageX17
Wisdom and people's livelihood	Public Library HoldingsX18 Comprehensive Population Coverage of Radio and TelevisionX19 Public transport vehicles per 10,000 peopleX20 Number of beds in medical and health institutionsX21
The wise crowd.	Research and Experimental Development StaffX22 Proportion of population with higher educationX23

2.2. Data reprocessing

This paper takes 30 smart pilot cities such as Beijing, Tianjin and Harbin as the research objects, and collects the index data of these cities in the past five years. According to the relationship between the value of the index and the degree of construction, the index is divided into positive and negative indexes, and the original data is preprocessed according to Equations (1) and (2)

Positive index:

$$X'_{ij} = (X_{ij} - minX_{ij})/(maxX_{ij} - minX_{ij}) \quad (1)$$

Negative index:

$$X'_{ij} = (maxX_{ij} - X_{ij})/(maxX_{ij} - minX_{ij}) \quad (2)$$

Part of the original data and processing results are shown in Table 2.

Table 2 Part of The City Index Data

City	X1		X2		X3	
	before	after	before	after	before	after
Haerbin	393.2	-0.10	1403.0	-0.11	963.2	0.48
Changchun	549.0	0.37	1092.0	-0.43	243.2	-0.53
Shenyang	250.4	-0.54	1273.2	-0.24	766.2	0.20
Beijing	688.5	0.80	4019.7	2.63	2759.6	2.99
Tianjin	523.6	0.30	1704.7	0.21	1343.8	1.01
Huhehaote	256.1	-0.53	459.3	-1.10	203.3	-0.58

3 Factor analysis

Factor analysis method is a multivariate statistical analysis method that simplifies some variables with complex relations into a few comprehensive factors, starting from the study of the internal dependence of Variable Correlation Matrix.

3.1. Variable correlation test

KMO and Bartlett tests were carried out to check whether the partial correlation between variables was strong enough and to determine whether the correlation matrix was the Identity Matrix. According to Table 3, the KMO value is 0.717, which indicates that the effect of factor analysis and the amount of information overlap among variables is acceptable. Bartlett test shows that there is a strong correlation between the variables, which can be analyzed in the next step.

Table 3 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.717
Bartlett's Test of Sphericity	Approx. Chi-Square	2607.067
	df	253
	Sig.	.000

3.2. Extraction of common factors

The number of principal component eigenvalues indicates how many original variables it carries. The factor contribution rate indicates the ratio of the factor to all principal component variances. The first seven principal components are used to describe the overall level of urban development instead of all the variables, because the cumulative contribution rate of variance is 74.951% in table 4, which conforms to the selection principle.

Table 4 Total Variance Explained

component	Initial eigenvallues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.143	31.058	31.058	6.132	26.662	26.662
2	2.452	10.659	41.717	2.424	10.540	37.202
3	1.830	7.955	49.672	1.839	7.996	45.198
4	1.709	7.433	57.105	1.797	7.813	53.011
5	1.560	6.783	63.888	1.703	7.402	60.413
6	1.442	6.269	70.157	1.702	7.402	67.815
7	1.103	4.794	74.951	1.641	7.136	74.951

The seven common factors were named F1 ~ F7.

3.3. Calculate the overall score of each city

First, the regression algorithm was used to calculate the scoring coefficient of each common factor, as shown in Table 5.

Table 5 Component Matrix

	Component						
	1	2	3	4	5	6	7
X1	-.080	.397	-.008	-.045	.076	-.040	.192
X2	.075	.198	-.009	-.067	.054	-.013	-.101
X3	.169	-.007	-.107	-.102	.108	-.026	.052
X4	.139	-.163	.068	.052	-.062	-.010	.175
X5	.146	-.124	.078	.069	-.081	.066	-.009
X6	.120	.025	-.168	.111	.199	.019	-.134
X7	.062	-.089	-.167	.135	-.251	-.203	-.169
X8	.149	.000	-.014	.006	-.028	.011	-.008
X9	.156	-.005	-.017	-.024	-.030	.017	-.024
X10	.052	.025	.076	-.123	-.292	.101	.146
X11	-.001	-.031	.126	.462	-.094	.101	-.121
X12	-.055	.315	.059	-.006	-.147	.311	.048
X13	-.021	-.050	.427	.105	.121	-.089	-.018
X14	.029	-.007	.089	-.048	.504	.009	-.054
X15	.111	-.110	.134	-.333	.011	.286	-.251
X16	-.016	.055	-.102	.055	-.035	-.068	.498
X17	-.084	.077	.507	-.063	-.006	.020	-.130
X18	.136	-.020	-.005	.081	-.034	.027	-.228
X19	.012	-.120	.106	.019	-.045	-.408	.158
X20	.024	-.024	-.037	.115	-.055	.433	.027
X21	-.071	.385	.034	.023	-.028	.031	-.083
X22	.162	-.071	-.179	-.155	.197	-.137	.230
X23	.004	-.030	-.094	.349	.182	.148	.225

Then according to the variance contribution rate of each common factor after rotation in Table 4, the weight of each common factor is 0.356, 0.141, 0.107, 0.104, 0.099, 0.099 and 0.095.

The calculation formula for the total score of each city is as follows:

$$\mathrm{Score} = 0.356 * \mathrm{F1} + 0.141 * \mathrm{F2} + 0.107 * \mathrm{F3} + 0.104 * \mathrm{F4} + 0.099 * \mathrm{F5} + 0.099 * \mathrm{F6} + 0.095 * \mathrm{F7} \quad (3)$$

$$\mathrm{Fj} = \sum_{i=1}^{23} a_{ij} * \mu_i, \ \ \mathrm{j} = 1 \sim 7 \quad (4)$$

a_{ij} is the scoring coefficient of the jth common factor on the ith index, and u_i is the value of the city on the ith index.

The total scores and rankings of the 30 cities were calculated, as shown in Table 6

Table 6 City Scores And Rankings

City	Score	Rank	City	Score	Rank
Beijing	1.36	1	Ningbo	0.06	17
Suzhou	1.07	4	Zhengzhou	0.4	10
Shenzhen	1.07	3	Huhehaote	-0.12	21
Guangzhou	1.23	2	Shenyang	-0.13	22
Nanjing	0.55	6	Nanchang	-0.25	25
Shanghai	0.72	5	Foshan	0.02	19
Hangzhou	0.52	7	Changsha	0.15	15
Wuxi	0.45	9	Guiyang	-0.07	20
Chengdu	0.47	8	Fuzhou	-0.18	24
Hefei	0.35	11	Wuhu	-0.26	26
Jinan	0.06	18	Wenzhou	-0.15	23
Chongqing	0.23	12	Tianjin	-0.32	28
Changchun	-0.3	27	Lanzhou	0.21	13
Qingdao	0.17	14	Haerbin	-0.42	29
Wuhan	0.14	16	Yinchuan	-0.68	30

3.4. Regional ranking

The 30 cities are divided into 7 regions according to their geographical location. The score for the development level of each region is the average score for all the cities in the region. The specific results are shown in Table 7.

South China has maintained its leading position in the past three years, and its scores have increased greatly every year. The gap between North China, East China, Southwest China and Central China is narrowing year by year. In general, the scores of each region have made great progress in the past three years, and the gap between regions is getting smaller and smaller. The number of regions with positive scores is increasing gradually. Especially in the past two years, the development of various regions is particularly rapid. The construction of smart cities in all regions is proceeding in an orderly way, forming a favorable situation.

Table 7 Region Scores And Rankings

Region	2017		2018		2019	
	score	Ranking	score	Ranking	score	Ranking
South China	0.34	1	0.55	1	0.77	1
north China	0.08	2	0.23	2	0.31	2
East China	0.02	4	0.12	3	0.24	3
Southwest	0.05	3	0.12	4	0.21	5
Central China	-0.07	5	0.06	5	0.23	3
Northeast	-0.37	6	-0.21	6	-0.24	6
Northwest	-0.53	7	-0.29	7	-0.28	7

4 Clustering analysis

K-means clustering algorithm is an iterative solution of the cluster analysis algorithm. It uses distance as a similarity metric to find K classes in a given data set. The center of each class is obtained according to the mean value of all the values in the class, and the center of each class is described by the cluster center. Clustering centers and the objects assigned to them represent a cluster. For each sample allocated, the cluster center of the cluster will be recalculated based on the existing objects in the cluster. This process does not stop until some termination condition is met. The specific steps are as follows：

Input: Sample set $D = \{x_1, x_2, \dots x_m\}$,K is the number of clusters in the cluster，N is the maximum number of iterations.

Output: Cluster partition $C = \{C_1, C_2, \dots C_k\}$

1) Randomly select k samples from sample set D as the initial k centroid vectors:$\{u_1, u_2, \dots u_k\}$
2) For n=1,2…,N
   a) Initialize the cluster partition C as $C_t = \emptyset \ t = 1,2 \dots k$
   b) Calculate the distance d_{ij} between the sample x_i and each centroid vector $u_j(j = 1,2 \dots k)$
   $d_{ij} = \|x_i - u_j\|_2^2$ For i = 1,2 ... m (5)
   The smallest mark of x_i is the class δ_i corresponding to D_{ij}.
   Update $C_{\delta_i} = C_{\delta_i} \cup \{x_i\}$ (6)
   c) The new center u_j of mass is recalculated for all sample points in C_j.
   $u_j = \frac{1}{|C_j|}\sum_{x \in C_j} x$, For j = 1,2 ... k (7)
   d) If all k centroid vectors have not changed, go to step 3)
3) Output cluster partition $C = \{C_1, C_2, \dots C_k\}$

The 30 cities were classified into 4 categories by K-means clustering according to the scores of each common factor. The specific classification of cities is shown in Table 7.

Table 8 City Clustering

cluster	1	2	3	4
Num	5	10	13	2
Cities	Suzhou Shanghai Nanjing Hangzhou Beijing	Changchun Changsha Chengdu Foshan Hefei Jinan Wuxi Wuhan Zhengzhou Chongqing	Fuzhou Guangzhou Huhehaote Haerbin Nanchang Ningbo Qingdao Shenzhen Shenyang Tianjin Wenzhou、 Wuhu Yinchuan	Guiyang Lanzhou

The total scores of the four categories obtained by cluster analysis are basically decreasing. Each category has its own advantages and disadvantages in the evaluation index. The first kind of cities performs well in the comprehensive level of urban life and the development level of urban science and technology, but they do not perform well in the level of urban sewage treatment. The total score of the second type of cities is excellent in infrastructure, but poor in urban planning. The third kind of cities perform well in comprehensive living standard and urban planning development level, but not well in urban science and technology development level and urban traffic culture level. The fourth kind of cities performs well in urban planning, urban traffic culture and urban sewage treatment, but they do not perform well in the comprehensive level of urban living and urban environmental protection.

5 Conclusion

The construction of smart city in our country is still in the exploration stage, the construction of smart city is not mature, there are still big differences in the development among regions, and the construction of each city in the construction process cannot be well coordinated in all aspects.

Shenzhen performed best in terms of overall urban living standards. Chongqing performed best in terms of the level of urban infrastructure. Foshan topped the list in terms of urban environmental protection. Beijing performed best in terms of the level of urban science and technology development. Guangzhou performed best in terms of the level of urban planning and development. Lanzhou is the most outstanding city in terms of the development level of urban transportation culture. Zhengzhou performs best in the aspect of urban transportation literacy.

1) Building a sound SMART infrastructure. Perfect and good infrastructure is an important guarantee for the success of urban construction.

https://doi.org/10.1051/e3sconf/202126103008

2) Implementing the strategy of innovation-driven development. Innovation is the vitality of a smart city. Urban construction can be faster and stronger only by enhancing the innovation capacity of cities.

3) Formulating urban development program which reflects the characteristics of the city and adapts to local conditions;

4) Strengthening inter-city cooperation and jointly building regional economic integration.

Acknowledgements

The authors would like to thank the anonymous reviewers for their valuable suggestions as to how to improve this paper. This work was supported by the social Science Foundation of the Anhui Educational Committee of China (Grant Nos. Sk2017A0684)

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