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Article

Comparison Analysis and Evaluation of Urban Competitiveness in Chinese Urban Clusters

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Abstract: With accelerating urbanization, urban competitiveness has become a worldwide academic focus. Previous studies always focused on economic factors but ignored social elements when measuring urban competitiveness. In this paper, a city was considered as a whole containing different units such as departments, individuals and economic activities, which interact with each other and affect its economic operation. Moreover, a city's development was compared to an object's movement, and the components were compared to different forces acting upon the object. With the analysis of the principle of object movement, this study has established a more scientific evaluation index system that involves 4 subsystems, 12 elements and 58 indexes. By using the TOPSIS method, the study has worked out the urban competitiveness of 141 cities from 28 Chinese urban clusters in 2009. According to the calculation results, these cities were divided into four levels: A, B, C, D. Furthermore, in order to analyze the competitiveness of cities and urban clusters, cities and urban clusters have been divided into four groups according to their distributive characteristics: the southeast, the northeast and Bohai Rim, the central region and the west. Suggestions and recommendations for each group are provided based on careful analysis.

Keywords: urban cluster; TOPSIS; urban competitiveness

1. Introduction

Economic globalization has become a prominent trend in the 21th century. Since they function as the dominant power of political, economic, cultural and environmental development and are a significant symbol of modernization level, urban clusters have gradually become an important development strategy for national urbanization [1–3]. As they are basic units of the urban cluster, cities' competitiveness has drawn more and more attention from scholars. In the context of urban clusters in China, the comparative competitiveness of urban clusters has usually been evaluated through the competitiveness of cities in urban clusters. Sun compared urban competitiveness among three urban clusters in China by using a factor analysis method and cluster analysis method [4]. Different methods have been adopted to evaluate cities' competitiveness in the Pearl River Delta [5,6]. The urban competitiveness of the Yangtze River Delta has been examined by various scholars as well [7,8]. However, previous studies were mainly confined to one or more urban clusters in a particular region, and always focused on the big urban clusters such as the Pearl River Delta and the Yangtze River Delta, while ignoring other urban clusters. Moreover, comparative studies aiming at different urban clusters were even less common. Hence, a study on the urban competitiveness of urban clusters in China is extremely essential.

Many published theoretical and empirical studies on urban competitiveness have focused on two aspects: the concept and model of urban competitiveness and its empirical analysis. The concept of urban competitiveness was proposed on the basis of national competitiveness. Michael Porter argued that urban competitiveness means the productivity of a city, which refers to its ability to create wealth and increase income [9]. He also pointed out that the "diamond model" is not only applicable to countries but also to regions and cities. Gordon and Paul put forward that urban competitiveness enables a city to create more income and employment than any other cities within its borders [10]. Douglas Webster thought that urban competitiveness is an urban area's ability to produce more products and services and that the improvement of urban competitiveness is mainly meant to raise urban residents' living standards [11]. In addition, other scholars have also contributed to the interpretation of urban competitiveness from other perspectives [12–15].

For empirical analysis of urban competitiveness, Kresl and Singh in 1999 developed a method of measuring competitiveness that involved sorting 24 large metropolitan areas in the United States and analyzed the ranking results with regression techniques [16]. Tong evaluated the competitiveness of central cities in northwest areas of China since 1990 [17]. Jiang and Shen examined the competitiveness of 253 Chinese cities at or above the prefecture level in 2000 by using the equal weighting method [18]. Singhal *et al.* compared the competitiveness performance of four cities in the UK [19]. A few studies on global urban competitiveness have been undertaken by scholars and research institutions [20–22].

Although scholars have made great progress in the theoretical and empirical study of urban competitiveness, these studies generally focused on factors that promote urban development, for example, the economic side, while ignoring factors that impede urban development, such as social problems and energy problems. We argue that engine growth, such as economic growth, does not guarantee urban competitiveness, and urban development resistance should be considered when evaluating urban competitiveness. Other conditions being equal, it is obvious that a city with less development resistance would be more competitive. Therefore, the purpose of this paper is to design a model for evaluating urban competitiveness by adopting a perspective of object movement, a model based on fully considering the forces acting on a city, including engine growth, development resistance, city interaction and environment conditions. On the basis of that model, a scientific, external and operable index system of urban competitiveness can then be constructed, and the TOPSIS method can be used to measure the competitiveness of 141 cities in 28 Chinese urban clusters in 2009.

The whole paper has been organized into five sections. Following the first section introduction, the second section introduces a three-layer hierarchical indicator system for measuring the urban competitiveness of 141 Chinese cities. The third section focuses on data sources for this study and evaluation of urban competeveness; in this section, using the TOPSIS method, the competitiveness of 141 cities in 28 Chinese urban clusters in 2009 is evaluated. After that, the comparative analysis on these cities and urban clusters is presented in the fourth section. At the end of this paper, the fifth section draws conclusions and provides suggestions for future studies.

2. An Evaluation Index System for Urban Competitiveness

2.1. Urban Competitiveness Model

As basic units of an urban cluster, component cities' competitiveness functions as an important indicator of the overall competitiveness of an urban cluster, and urban competitiveness manifests itself in many respects, such as economy, society, education and environment. Therefore, the question of how to build a scientific and external urban competitiveness model has attracted both domestic and international scholars. Up to now, quite a few models for evaluating urban competitiveness have been designed by previous researchers. There are some typical western models, such as the international competition evaluation system of countries' competitiveness established by the World Economic Forum and the Swiss International Management and Development Institute, the diamond model proposed by Michael Porter [23], and the urban competitiveness model designed by Rondinelli [24]. By contrast, a typical model in China, proposed by Ni in the Chinese Academy of Social Sciences, is the urban competitiveness model; another is the urban value chain model designed by the Beijing International City Development Research Institute [25,26].

Most of these models have been established on the basis of the theory of competitive advantages. However, previous studies mainly focused on the advantage factors of driving forces, but ignored those of development resistances. In other words, having little development resistance is also a competitive advantage. If a city was considered as a whole, the comprehensive competitiveness of a city would be the overall performance of driving forces and development resistances. Basing on this view, this paper establishes an urban competitiveness model by regarding city development as object movement.

Since a city was considered a whole in this study and the involved departments, individuals and economic activities were considered components of the whole, it is obvious that the interaction between them has an impact on the city as a whole. Likewise, the development of the city as a whole was compared to the movement of an object, and the components of the whole (department, individuals, *etc.*)

were compared to different forces acting upon the object. From the principle of object movement, it can be seen that the object receives not only driving and resistance forces, but also influences from external conditions and interaction with other objects. Therefore, urban competitiveness is reflected in not only its individual development but also its interaction with other cities. Based on this analysis, four dimensions—engine growth, development resistance, city interaction and environment conditions—have been chosen to measure comprehensive urban competitiveness. Engine growth is the driving forces in the development of a city, development resistance is the negative effects on urban development, city interaction reflects the ability to exchange resources nearby, and environment conditions describes quality of life; the four dimensions are further divided into 12 sub-elements (see Figure 1). A brief introduction on 12 sub-elements is given below.

Economic Strength (ES) is initially used as the primary competitive weapon, and can reflect the economic level and scale of a city. The basic indicators such as GDP growth rate and GDP are important to measure the economy's gross scale and level, and total industrial output value reflects both the degree of industrialization and urbanization. The share of the tertiary sector in GDP can also reflect the quality of urbanization.

The Role of Government (RG) reflects how efficiently the economy of a city is regulated by the government, which can be measured by five basic indicators. Financial revenue and expenditure both reflect government regulation ability. In this study, the difference between financial revenue and expenditure has not been considered, because the difference is within a controllable range in general. Thus, the financial (or expenditure) revenue and the growth rate are positive indicators for urban competitiveness. The retail price index of commodities and housing sales price index can reflect the macro-control ability for the market, and has an influence on financial revenue and expenditure. It has a positive effect on urban competitiveness.

Resident Consumption Level (RCL) plays a critical role in both economic strength and people's material standard of living for a city, which can fuel economic growth by stimulating consumption. In this study, the average wage of staff and workers, per capita disposable income of urban residents and six other indicators can reflect the status of residents' income and consumption.

Human Resources (HR) reflect the quantity and quality of workers, which can be measured by four indicators; the second industry (or the third industry) of employment proportion can also reflect labor creation ability and economic structure.

Science and Technology Strength (S&T) plays an important role in urban competitiveness. Because it is the final promoter of productivity in urban development, six indicators can reflect science and technology strength, including number of colleges and universities in the urban area.

Social Problems (SP) reflects the social security and commercial crimes in a city. The number of fires and traffic accidents, the number of civil cases and the number of criminal cases are used to measure social problems, and the three indicators have negative effects on urban competitiveness

Energy Problems (EP) reflect energy gaps in urban development, which can be measured by two negative indicators: the energy gap and the power gap.

Human Problems (HP) concern labor's quality and education problems. It can be measured via the illiteracy rate and unemployment rate.

Opening to the Outside World (OOW) can best reflect how open a city is, that is, how many resources a city can provide for its neighboring cities. Urban imports and exports, domestic and foreign tourism income per year and the number of domestic and foreign tourists per year are used to measure it. Note that urban imports and exports are both profitability indicators, not considering the influence of the trade gap.

Foreign Trade Dependency (FTD) corresponds to the opening to the outside world, and represents how many advantages from resources from neighboring cities can be used to develop the city. It can be measured by the total amount of actual investment at home and abroad, actually utilized foreign investment, and urban economic concentration and diffusion ability. The urban economic concentration and diffusion reflects the economic impact on other surrounding cities.

Infrastructure (IFT) is the carriers of economic and social development. This can be measured using the area of paved roads per capita and other 6 basic indicators, which can reflect the living conditions, medical insurance and entertainment for residents in a city.

Environment level (EL) reflects the environmental pollution and management of a city. It can be measured specifically using green area per capita and five other basic indicators.

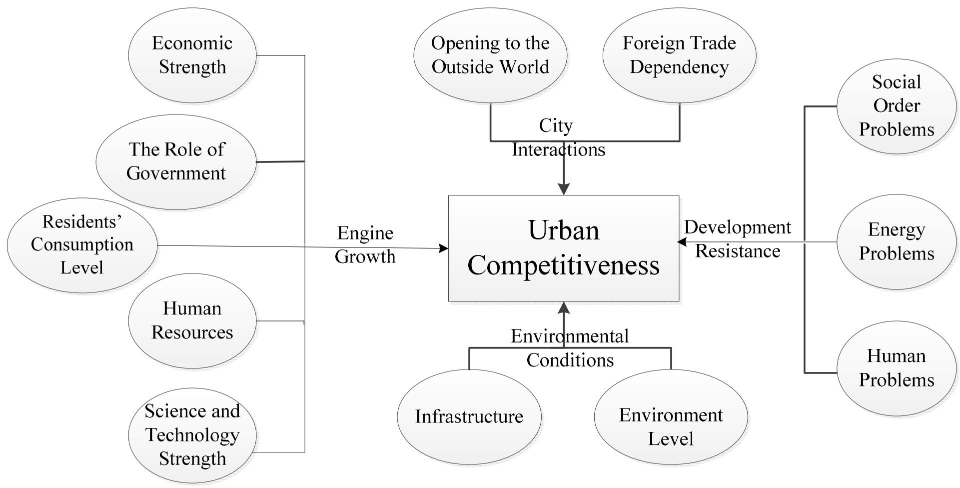

Figure 1. Urban competitiveness model.

2.2. Construction of Urban Competitiveness Evaluation Indicator System

Comprehensive evaluation of urban competitiveness is a complicated system to engineer and involves a series of indicators. It is not practical to consider all the factors that influence urban competitiveness. The selection of indicators is especially important and will have a direct impact on the results of the evaluation. Therefore, this paper selected some indicators that have been widely used in the previous studies, and added a few new indicators to comprehensively determine urban competiveness.

Given that comprehensiveness, science, comparability and operability are considered the four basic principles of index selection, the index system was carefully analyzed and the appearance percentages of related indicators in 138 papers written by researchers worldwide were calculated; indicators with an appearance percentage above 10% were selected as the main indicators. Meanwhile, some new indicators were involved in order to clearly reflect other factors' impact on cities' competitiveness. Firstly, the increasing demand for land area was considered a bench-marking indicator and the house sales price index was used to evaluate the government's adjustment on real estate. Secondly, the trading volume of the commodity exchanging market was considered an indicator under Residents' Consumption Level to reflect the local consumption level. Thirdly, college and university teachers were also taken into consideration as an indicator under Science and Technology Strength to evaluate the local education resources. Fourthly, the number of criminal and civil cases was viewed as an indicator of Social Order Problems as well as a reference to local stability. Fifthly, the energy gap fell under Energy Problems to evaluate the development level of local energy. Finally, an index system involving 4 subsystems, 12 elements and 58 indexes for the purpose of measuring urban competitiveness was established in detail and shown in Table 1.

Table 1. Index system of urban competitiveness.

Destination layer	Subsystem layer	Element layer	Basic Index layer
UC	EG	ES	GDP (x1); GDP growth rate (x2); GDP per capita (x3); Share of secondary sector in GDP (x4); Share of tertiary sector in GDP (x5); total industrial output value (x6)
		RG	Financial revenue of local government per capita (x7); Financial expenditure of local government per capita (x8); Retail price index of commodities (x9); Housing sales price index (x10); Local financial revenue growth rate (x11); Local financial expenditure growth rate (x12); The ruling government satisfaction (x13)
		RCL	Average wage of staff and workers (x14); Urban consumer price index (x15); Per capita disposable income of urban residents (x16); Per capita consumption expenditure of urban residents (x17); Engel coefficient of urban households (x18); Total retail sales of social consumer goods (x19); Total retail sales of social consumer goods per capita (x20); Total transaction amount of commodity trading market (x21)
		HR	The second industry employment proportion (x22); The third industry employment proportion (x23); On-the-job workers proportion (x24); Number of on-the-job workers at end of the year (x25)
		S&T	Number of colleges and universities (x26); Number of teachers in colleges and universities (x27); Number of patent applications (x28); Number of authorized patents and technology projects (x29); Number of all types of professional and technical personnel per 10 thousands persons (x30); Number of undergraduate students per 10 thousands persons (x31)
	DR	SOP	Number of fire and traffic accidents (x32); Number of civil cases (x33); Number of criminal cases (x34)
		EP	Annual energy gap (x35); Annual power gap (x36)
		HP	Illiteracy rate (x37); Unemployment rate (x38)

Table 1. *Cont.*

Destination layer	Subsystem layer	Element layer	Basic Index layer
	CI	OOW	Unban imports (x39); Unban exports (x40); Domestic and international tourism income per year (x41); Number of domestic and foreign tourists per year (x42)
		FTD	Total amount of actual domestic and international investment (x43); Actually utilized domestic and international investment (x44); Urban economic concentration and diffusion ability (x45)
	EC	IFT	Length of paved roads per capita (x46); Electricity consumption per capita (x47); Water consumption per capita (x48); Number of public transportation vehicles per 10 thousand persons (x49); Number of public library books per hundred persons (x50); Number of doctors per 10 thousand persons (x51); Number of telephones per 10 thousand persons (x52)
		EL	Area of green land per capita (x53); Percentage of greenery coverage in the built-up area (x54); Percentage of industrial sewage discharged meeting national standard (x55); Number of fine air days per year (x56); Solid waste comprehensive utilization rate (x57); Output of products that comprehensively utilized the "three wastes" (x58)

Note: In Table 1, UC = Urban Competitiveness, EG = Engine Growth, DR = Development Resistance, CI = City Interactions, EC = Environmental Conditions, ES = Economic Strength, RG = The Role of Government, RCL = Resident Consumption Level, HR = Human Resources, S&T = Science and Technology Strength, SOP = Social Order Problems, EP = Energy Problems, HP = Human Problems, OOW = Opening to the Outside World, FTD = Foreign Trade Dependency, IFT = Infrastructure, EL = Environment Level.

2.3. Calculation of Index Weight

The Delphi Principle has been adopted to calculate the weight of each evaluation index. Firstly, a survey on questionnaire-designing was given out to related researchers on Provincial Development and Reform Commissions (PDRC) and some professors studying regional economy. Their feedback again contributed to the improvement of the questionnaire. Secondly, the formal questionnaires were given out and the data from those experts were collected. Thirdly, the weight of each index was calculated based on Formula (1).

$$W_j = \frac{\sum_{i=0}^{n} c_{ij}}{\sum_{i=0}^{n}\sum_{j=0}^{m} c_{ij}} \tag{1}$$

where *n* represents the number of experts, *m* represents the number of index, w_j represents the index j_{th} weight, c_{ij} represents the j_{th} score graded by i_{th} experts.

In order to obtain more scientific and authoritative opinions, through consulting experts, as mentioned above, this study firstly collected effective opinions from 36 experts from PDRCs and universities in China, of which 29 experts were from PDRCs and the other 7 from universities. According to their familiarity with the indexes, the following quantization table was designed (as shown in Table 2) and how these experts are authoritative in this area was further analyzed using Formula (2).

Table 2. The quantization of expert's familiarity with each index.

Judgment Criteria	Quantization	Familiarity	Quantization
Practical experience	0.8	Very familiar	1.0
Theoretical analysis	0.6	Familiar	0.8
Basic understanding	0.4	Not very familiar	0.4
Intuition	0.2	Minimally familiar	0.2
		Unfamiliar	0

$$C_R = \frac{C_J + C_F}{2} \quad (2)$$

where C_R represents the authority degree of experts, C_J is the quantitative value of judgment basis, C_F is the quantitative value of familiarity. According to the results, some experts who are less familiar with the variables were excluded. In this study, experts whose C_R is above 0.7 are selected.

Secondly, considering that even cities from the same region may not belong to the same urban cluster, it is obvious that the opinions of PDRC experts from regions that possess more urban clusters are more important than those of experts from other regions. For instance, cities from Henan province belong to four urban clusters respectively, meaning that opinions of experts from the Henan PDRC are more important than those of other PDRC experts. According to this point, a second round of selection was conducted. Experts from the Henan PDRC and other regions' PDRCs were selected because the numbers of urban clusters in these regions are bigger than or equal to 2. Table 3 shows the number of urban clusters in each region.

Table 3. The number of urban clusters in each region.

Region	Num	Region	Num	Region	Num	Region	Num
Henan	4	Shanxi	2	Hunan	1	Yunnan	1
Shandong	3	Inner-Mongolia	2	Guangxi	1	Ningxia	1
Anhui	3	Jilin	1	Hainan	1	Gansu	1
Guangdong	3	Heilongjiang	1	Sichuan	1	Qinghai	1
Hebei	3	Fujian	1	Chongqing	1	Shaanxi	1
Jiangsu	2	Shanghai	1	Fujian	1	Guizhou	1
Zhejiang	2	Beijing	1	Tianjin	1	Liaoning	1
Hubei	2	Tibet	0	Xinjiang	0		

Note: In Table 3, Num = the number of urban clusters

According to the steps described above, the study finally identified 16 authoritative experts and the formal questionnaires were modified according to all the experts' advice. In the end, 16 official questionnaires were given out, of which 11 validated questionnaires were collected. Moreover, the 8 PDRC experts are from Henan, Shandong, Anhui, Guangdong, Jiangsu, Hubei, Zhejiang and Jilin and the other 3 are from universities. Finally, based on Formula (1), this study worked out index weight in each layer as shown in Appendix I.

3. Evaluation of City Competitiveness

3.1. Data Sample

The Blue Book of Urban Competitiveness in 2007 defined 30 urban clusters in China [27]. Since the data from the Taiyuan urban cluster and Central Yunnan urban cluster is missing, this study has chosen 28 urban clusters consisted of 141 Chinese cities, nearly covering all provinces and municipalities in China (excluding Hong Kong, Macon and Taiwan). Specific information on these urban clusters and cities is provided in Appendix II.

3.2. Data Preprocessing

The data in this study were basically obtained from government documents, such as China City Statistical Yearbook of 2010 [28], China Statistical Yearbook on Environment of 2010 [29], China Energy Statistical Yearbook of 2010 [30], the Statistical Yearbooks of relevant provinces and cities, Statistical Bulletin for National Economic and Social development, municipal environment statistical bulletins, media and city soft power, *etc.* However, due to different statistical methods, data for some cities were actually inaccessible. Given the reliability and authenticity of this study, Table 4 demonstrates the processing modes that deal with the missing indices. The missing data was less than 3% of all data in this study.

Table 4. Processing mode for missing indices.

Index	Source and calculation method
Population	The total population at the end of the year in the statistics yearbook
Financial revenue (expenditure) of local government per capita	Local financial revenue (expenditure)/the total population in the end of the year
KLocal financial revenue growth rate	(Local financial revenue this year − Local financial revenue last year)/Local fiscal last year × 100%
Engel coefficient of urban residents family	Food spending amount/The amount of consumer spending × 100%
Commodity trading market clinches a deal amount	The wholesale of the total retail sales of consumer goods, retail sales in the statistics yearbook
The actual total investment of the abroad	The amount of foreign capital of the contract in statistics yearbook
Number of fire and traffic accidents	The number of known fire accidents × unknown urban land area/Known city land area
Number of civil/criminal cases	Known criminal/the number of civil cases × unknown urban population/Known urban population
Annual energy/power gap	Known annual energy/Power gap × Unknown urban GDP/Known urban GDP
Illiteracy rate	1-Primary school enrollment

3.3. TOPSIS Method

The TOPSIS method has been adopted for ranking the competitiveness of 141 Chinese cities in 2009. First put forward by Hwang and Yoon in 1981 [31], the TOPSIS method as one kind of MCDM (multiple criteria decision making) is a common assessment method in economic management and decision making. It defines both a positive ideal solution and a negative ideal solution and then ranks solutions on the basis of how close each alternative is to the ideal solution. If an alternative is closest to the positive ideal solution, and it is far away from negative ideal solution, then the alternative is the best solution, that is to say, the alternatives are finally ranked based on sorting the degree of closeness to ideal solution, which is calculated using Formula (3).

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (3)$$

where C_i represents the degree of closeness to the ideal solution, D_i^+ represents the distance between the alternative and the positive ideal solution, and D_i^- represents the distance between the alternative and the negative ideal solution. Therefore, TOPSIS has some advantages over others such as stronger geometric explanation, less computation and better operability. What's more, TOPSIS is not restricted by sample or index numbers, which means that TOPSIS is suitable for large samples and major indexes in urban competitiveness. However, the disadvantage of TOPSIS is that it cannot fully reflect whether the alternative is good when the alternative is close to both the positive ideal solution and the negative ideal solution. In order to avoid this problem, our paper's analysis is based on classification according to ranking results, rather than the rankings (see Section 4).

The city competitiveness index system constructed in this study can be divided into three parts: the subsystem layer, the element layer and the basic index layer. In order to compare and analyze how these different indicators would impact urban competitiveness, the final score of urban competitiveness has to be calculated step by step. Specifically, the score of the element layer can be obtained through index weight and index data of the basic index layer. Similarly, through combining the index weight of the element layer, the score of the subsystem layer can be calculated by using the TOPSIS method. The specific steps are demonstrated in Figure 2.

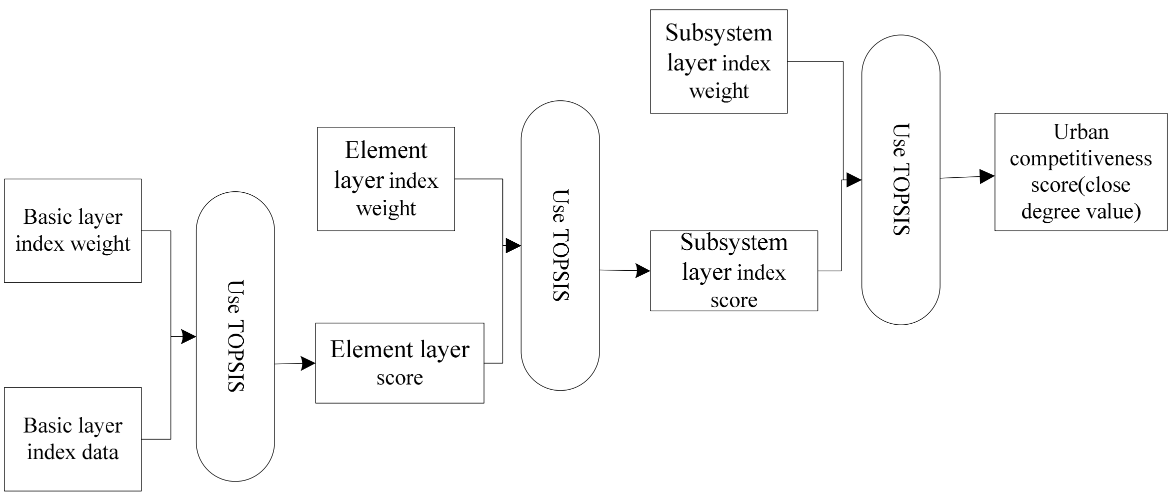

Figure 2. Calculation process of urban competitiveness.

3.4. The Ranking Results

As a result, scores for the subsystem layer and urban competitiveness were finally obtained by calculating the collected indexes and their corresponding rankings, which are shown in Appendix III.

4. Comparative Analysis of Calculation Results

Since rankings of cities' competitiveness have shed light on the classification of urban competitiveness, four levels (A, B, C, D) were finally defined. Among all the cities, the top 35 belonged to level A, the middle 36–70 and 71–105 belonged to level B and level C respectively, while the bottom 106–141 belonged to level D.

4.1. Overview of Urban Competitiveness

Based on cities' rankings and levels of competitiveness, Figure 3 shows the distributive characteristics of urban competitiveness. More than half of the A-level cities , nearly a third of the B-level cities and ten or more of the C-level cities are located in the southeast area of China, mainly because most cities obviously have enjoyed various geographic advantages and superior industrial foundations in this area. The central area has the largest A-level cities except the southeast area, but it also has the largest D-level cities, and the number is about half. According to this, urban competitiveness in the central area is very unbalanced. With the rise of the central region strategy, there is a great opportunity for cities in this area to promote their development and competiveness. The competitiveness of cities in the Bohai Rim area is mainly at the B and C levels. The overall competitiveness of this area is obviously weaker than that of the southeast, but is stronger than the central area and other regions. Cities in this area should strengthen their economic cooperation and enhance their competitiveness to increase their number of A-level cities. The remaining three regions have more than half C-level and D-level cities, especially the southeast area, which has 4 C-level and 7 D-level cities, while the total number of this area is 15. Due to constraints in geographical location, resource conditions and policy reasons, cities in the west region are still undeveloped. It is necessary for less advanced cities to develop their economies, because economy is the foundation of both social and culture development.

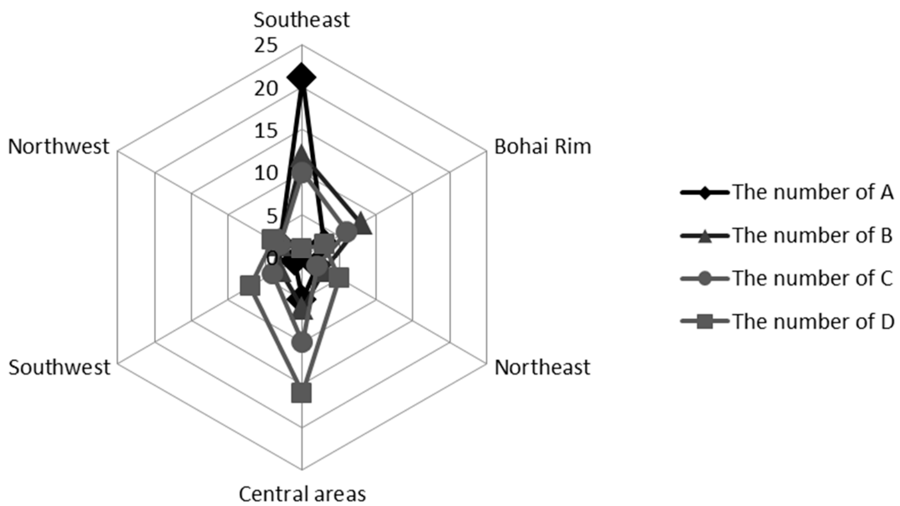

Figure 3. Area profile of each level.

4.2. Relationship among the Four Dimensions of Urban Competitiveness

The urban competitiveness score is calculated by integrating engine growth, development resistance, city interaction and environment conditions. According to this, it is necessary for a city to achieve good performance in all dimensions for higher urban competitiveness. However, there are many possible trade-offs in the process of urban development, which lead to unbalanced development of different dimensions. For example, the contradiction between economic growth and environmental protection is prominent in developing countries such as China. Therefore, the relationship among four dimensions in urban competitiveness has been examined directly by correlation coefficient and scatter plot in this section. The Pearson correlation coefficients of the scores of overall competitiveness and four components were calculated. Given that cities with different levels of competitiveness may have differences in the relationships among dimensions, the analysis of relationships among dimensions is divided into five groups according to cities' levels of competitiveness.

(1) Relationships among the four dimensions of urban competitiveness of 141 cities.

The calculation result reveals that engine growth, city interaction and environment conditions are positively correlated and statistically significant at 0.05, and the relationship between urban competitiveness and the four dimensions is also positive. However, the relationship between development resistance and other dimensions are weak, which also can be seen from the Figure 4. Figure 4 shows that there is an obvious linear positive correlation between urban competitiveness and engine growth, with a Pearson correlation coefficient of 0.92. Similarly, the engine growth and city interaction present a positive correlation at a Pearson correlation coefficient of 0.81. This is probably because engine growth and city interaction are closely related and interactive with each other. The relationship between engine growth and environmental conditions (0.58) was closer than the correlation between city interaction and environmental conditions (0.41). Perhaps a city with better performance in EG and city interaction will help provide better environmental conditions.

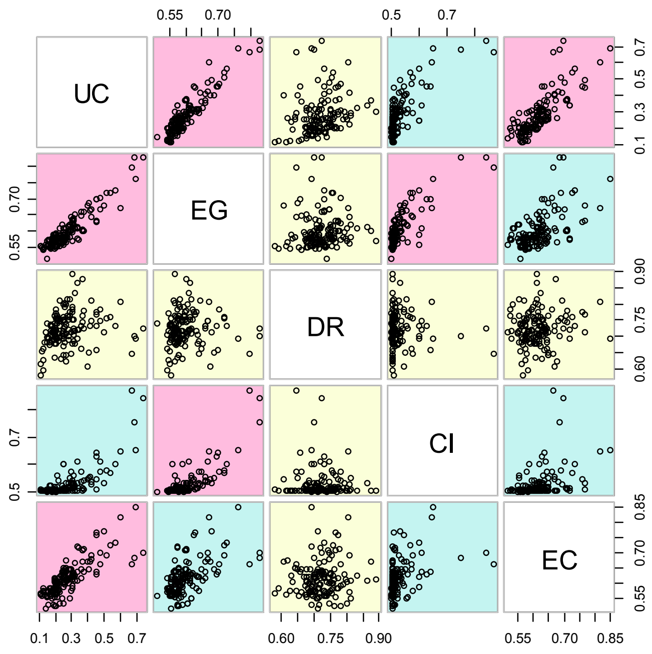

Figure 4. The scatter plot of dimensions of 141 cities.

(2) Relationships among the four dimensions of urban competitiveness of A-level cities

Similar to the result of 141 cities, Figure 5 shows that urban competitiveness has a strong linear positive correlation with engine growth, city interaction and environmental conditions, but has a weak negative correlation with development resistance. Moreover， engine growth and city interaction both have a negative correlation with development resistance, and the correlation coefficients are respectively 0.36 and 0.34. According to the ranking result in every dimensions of urban competitiveness, this reveals that some A–level cities may have unbalanced performance, with DR rank far behind. For instance, Guangzhou, Shenzhen, Beijing and Tianjin, the rank of development resistance are all after 90. The quick development of a city may produce some negative effects, such as social problems and energy shortages, which will increase development resistance.

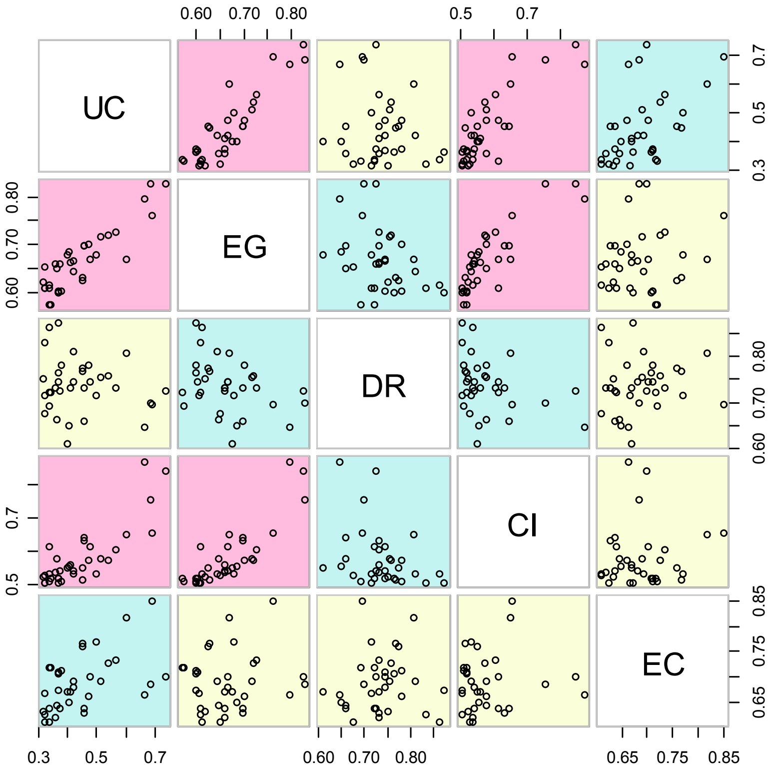

Figure 5. The scatter plot of dimensions of A-level cities.

(3) Relationships among the four dimensions of urban competitiveness of B-level cities

Compared with the two cases introduced, urban competitiveness has a weaker positive correlation with engine growth and city interaction. Figure 6 shows that the relationship between urban competitiveness and development resistance, urban competitiveness and environmental conditions are not correlated, which indicates that the urban competitiveness of B-level cities is more unbalanced in all dimensions. In addition, the negative correlation between engine growth and environmental conditions confirms that these cities may achieve rapid development at the expense of the environment. It is necessary for these cities to pay more attention to the environment while developing their economy.

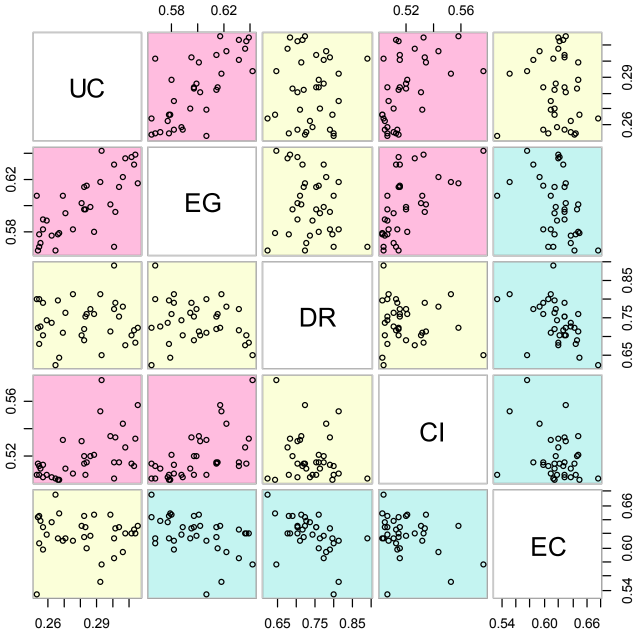

Figure 6. The scatter plot of dimensions of B-level cities.

(4) Relationships among the four dimensions of urban competitiveness of C-level cities

Figure 7 shows that urban competitiveness has a weaker positive relationship with engine growth, city interaction and environmental conditions. But according to the calculation of the correlation coefficient, only the relationship between urban competitiveness and EC is at a significant level of 0.05, with a correlation coefficient of 0.45. That is to say, the urban competitiveness of C-level cities mainly depends on environmental conditions. Engine growth has a negative relationship with development resistance and environmental conditions, suggesting that these cities are currently in the developing period, because there are some conflicts among these dimensions which have restricted the overall development of the city.

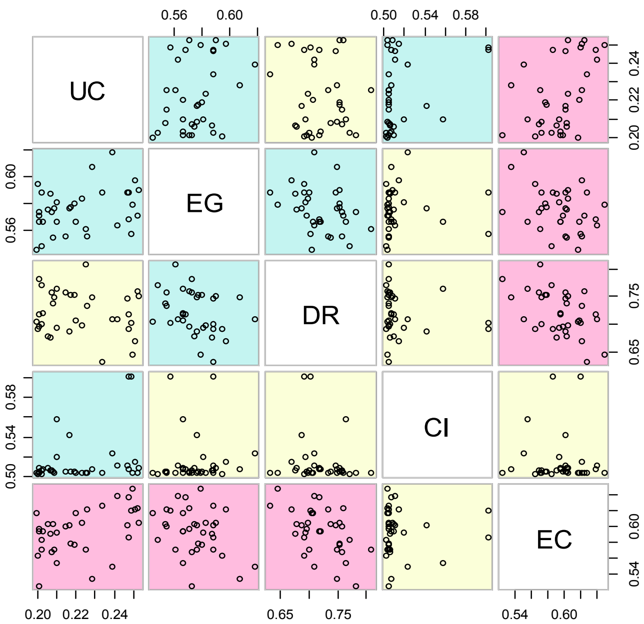

Figure 7. The scatter plot of dimensions of C-level cities.

(5) Relationships among the four dimensions of urban competitiveness of D-level cities

Urban competitiveness has a strong positive relationship with development resistance that is different from other cities with other levels (as shown in figure 8). Meanwhile, the scores for both environmental conditions and development resistance are low, similar to the overall urban competitiveness. Due to their late start, these cities ranked far behind in all four dimensions. The different dimensions are also almost uncorrelated. Therefore, specific advantages of these cities should be identified and fully taken advantage of to achieve their balanced development in other aspects.

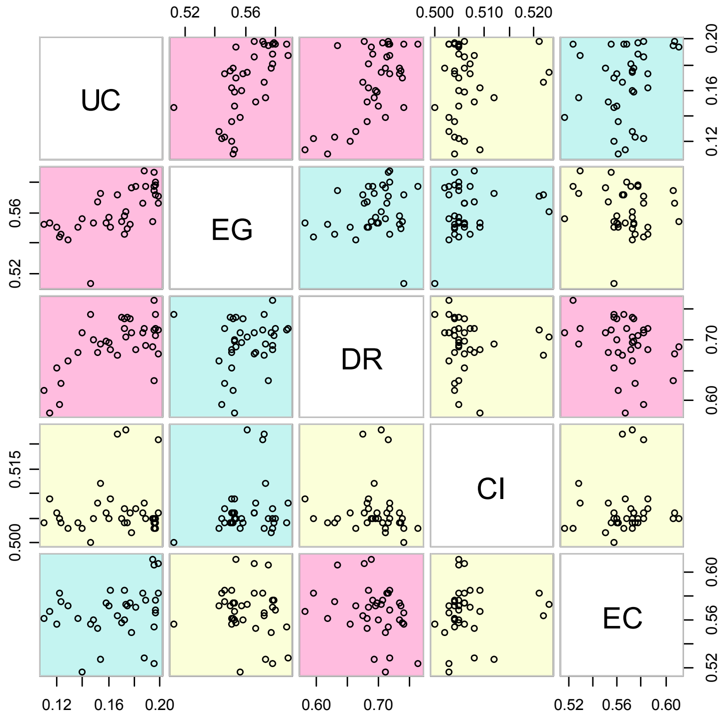

Figure 8. The scatter plot of dimensions of D-level cities.

5. Conclusions

Based on previous study models of urban competitiveness, this study has designed and established an evaluation system for urban competitiveness involving 12 indicators in the element layer and 58 indicators in the basic index layer. It adopted the TOPSIS method to evaluate cities' competitiveness in 28 urban clusters (including 141 Chinese cities) in 2009. Based on measurement results, four levels (A, B, C, and D) have been defined to conduct comparative analysis between cities in different regions. In addition, the relationship among different dimensions has been examined and analyzed using scatter plots and the Pearson correlation coefficient. Based on their own situations, different urban clusters and cities should improve their overall competitiveness by enhancing the competitiveness of other relevant dimensions. No doubt there are flaws in the study and further improvement is necessary. For future research, Yunnan city clusters and Taiyuan city clusters should be taken into consideration, and a comprehensive and dynamic evaluation should be performed for demonstrating long-term urban competitiveness.

Acknowledgments

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Author Contributions

Haixiang Guo guided this research and proposed the integrated system solution. Xiao Liu conducted the literature review, discussed the data and drew the main conclusions. Yijing Li gathered and processed the data. Deyun Wang processed the data. Xiaohong Cheng discussed the data. All of the authors participated in the writing of the paper. The final manuscript has been approved by all authors.

Appendix I

Table A1. Index weights in each layer.

Subsystem layer	Element layer	Basic index layer		Subsystem layer	Element layer	Basic index layer	
EG (0.33)	ES (0.223)	x1	0.1606	DR (0.15)	SOP (0.325)	x32	0.2783
		x2	0.1647			x33	0.4261
		x3	0.1847			x34	0.2957
		x4	0.1647		EP (0.360)	x35	0.4848
		x5	0.1727			x36	0.5152
		x6	0.1526		HP (0.315)	x37	0.4000
	RG (0.188)	x7	0.1497			x38	0.6000
		x8	0.1395	CI (0.23)	OOW (0.537)	x39	0.2453
		x9	0.1497			x40	0.2767
		x10	0.1599			x41	0.2516
		x11	0.1224		FTD 0.463	x42	0.2264
		x12	0.1224			x43	0.3382
		x13	0.1565			x44	0.3235
	RCL (0.198)	x14	0.1589			x45	0.3382
		x15	0.1246	EC (0.29)	IFT (0.500)	x46	0.1515
		x16	0.1526			x47	0.1515
		x17	0.1340			x48	0.1414
		x18	0.1402			x49	0.1549
		x19	0.0935			x50	0.1380
		x20	0.0997			x51	0.1414
		x21	0.0966			x52	0.1212

Table A1. *Cont.*

Subsystem layer	Element layer	Basic index layer		Subsystem layer	Element layer	Basic index layer	
EG (0.33)	HR (0.178)	x22	0.2806	EC (0.29)	EI (0.500)	x53	0.1707
		x23	0.2950			x54	0.1672
		x24	0.2158			x55	0.1742
		x25	0.2086			x56	0.1847
	S&T (0.213)	x26	0.1435			x57	0.1498
		x27	0.1390			x58	0.1533
		x28	0.1973				
		x29	0.2108				
		x30	0.1749				
		x31	0.1345				

Note: x1–x58 express indexes that correspond to the indexes of the basic index layer in Table 1.

Appendix II

Table A2. Urban clusters and cities.

Regions	Urban clusters	Cities
The southeast region	Yangtze River Delta	Nanjing, Wuxi, Hangzhou, Suzhou, Huzhou, Changzhou, Zhoushan, Taizhou, Shaoxing, Ningbo
	Pearl River Delta	Zhongshan, Shenzhen, Dongguan, Jiangmen, Guangzhou, Foshan, Zhuhai, Zhoqing, Huizhou
	Qionghai	Zhanjiang, Maoming, Yangjiang, Sanya, Haikou
	Xuzhou	Xuzhou, Lianyungang, Suqian, Huaibei, Suzhou, Zaozhuang, Jining, Linyi
	Shantou	Chaozhou, Shanwei, Jieyang, Shantou
	West Strait	Ningde, Xiamen, Putian, Quanzhou, Zhangzhou
	East Zhejiang	Taizhou, Wenzhou, Lishui
The central region	Hube-Henan	Suizhou, Xiangfan, Nanyang
	Circle of the Poyang Lake	Fuzhou, Jingdezhen, Jiujiang, Nanchang, Yingtan, Shangrao
	Anhui-Jianghuai	Huainan, Maanshan, Liuan, Chuzhou, Bengbu, Anqing, Hefei, Xuancheng, Tongling, Chizhou, Chaohu
	Wuhan	Huangshi, Ezhou, Wuhan, Huanggang
	Hebei-Shandong-Henan	Puyang, Handan, Liaocheng, Hebi
	Henan-Anhui	Fuyang, Bozhou, Shangqiu, Zhoukou
	Chang-Zhu-Tan	Changsha, Zhuzhou, Xiangtan
	Central Plains	Pingdingshan, Xinxiang, Xucang, Luoyang, Kaifeng, Zhengzhou
The west region	Yinchuan	Yinchuan, Wuzhong, Wuhai
	Hohhot-Baotou-Ordos	Baotou, Hohhot, Ordos
	Central Shaanxi	Xi'an, Xianyang, Baoji, Tongchuan
	Central Guizhou	Guiyang, Zunyi, Liupanshu
	Lanzhou	Lanzhou, Wuwei, Xining
	Chengdu-Chongqing	Chongqing, Chengdu, Nanchong, Mianyang, Deyang, Deyang, Leshan, Suining, Guang'an
	Nanning	Nanning, Beihai, Fangchenggang, Qinzhou

Table A2. *Cont.*

Regions	Urban clusters	Cities
The northeast and Bohai Rim region	Shijiazhuang	Yangquan, Hengshui, Cangzhou, Langfang, Xingtai, Baoding
	Shandong Peninsula	Rizhao, Qingdao, Dingying, Weifang, Yantai
	Beijing-Tianjing-Tangshan	Tangshan, Tianjin, Zhangjiakou, Beijing, Qinhuangdao
	Harbin	Tsitsihar, Daqing, Harbin, Shuangyashan
	Changchun	Changchun, Songyuan, Siping
	Central-southern of Liaoning	Fuxin, Shenyang, Dandong, Daqing, Anshan

Appendix III

Table A3. Score of urban competitiveness.

City	Level	Rank of UC	Score of UC	Rank of EG	Score of EG	Rank of DR	Score of DR	Rank of CI	Score of CI	Rank of EC	Score of EC
Suzhou	A	1	0.7367	2	0.826	64	0.724	2	0.841	14	0.699
Guangzhou	A	2	0.6922	4	0.762	101	0.695	4	0.652	1	0.851
Shenzhen	A	3	0.6844	1	0.828	96	0.700	3	0.753	17	0.684
Beijing	A	4	0.6659	3	0.795	131	0.646	1	0.869	24	0.664
Dongguan	A	5	0.6020	14	0.670	9	0.807	5	0.648	2	0.818
Hangzhou	A	6	0.5658	5	0.726	59	0.731	10	0.603	6	0.734
Nanjing	A	7	0.5396	6	0.719	30	0.759	17	0.570	7	0.726
Wu'xi	A	8	0.5137	7	0.718	34	0.756	13	0.578	16	0.691
Xiamen	A	9	0.4982	12	0.678	79	0.714	35	0.531	3	0.769
Qingdao	A	10	0.4758	15	0.668	44	0.746	9	0.611	13	0.701
Foshan	A	11	0.4732	8	0.702	15	0.782	16	0.574	25	0.661
Tianjin	A	12	0.4545	9	0.699	127	0.660	6	0.642	39	0.637
Ningbo	A	13	0.4544	10	0.697	58	0.732	7	0.629	48	0.628
Zhuhai	A	14	0.4539	30	0.626	21	0.773	24	0.547	5	0.759
Edos	A	15	0.4493	29	0.630	23	0.767	63	0.511	4	0.767
Changzhou	A	16	0.4226	16	0.667	45	0.746	28	0.539	18	0.680
Zhongshan	A	17	0.4199	22	0.645	7	0.810	37	0.530	15	0.692
Dalian	A	18	0.4108	17	0.662	56	0.733	20	0.556	21	0.670
Chengdu	A	19	0.4022	11	0.686	129	0.650	22	0.552	28	0.648
Wuhan	A	20	0.3998	13	0.677	139	0.609	23	0.548	22	0.669
Haikou	A	21	0.3769	47	0.602	18	0.780	68	0.510	10	0.712
Shenyang	A	22	0.3733	18	0.661	62	0.726	27	0.541	40	0.637
Linyi	A	23	0.3674	46	0.603	46	0.744	54	0.515	11	0.710
Sanya	A	24	0.3667	50	0.600	2	0.874	111	0.504	20	0.672
Xuzhou	A	25	0.3664	51	0.599	24	0.765	50	0.516	12	0.707
Changsha	A	26	0.3614	21	0.649	126	0.661	15	0.575	33	0.644
Shaoxing	A	27	0.3576	19	0.661	60	0.731	29	0.536	60	0.619
Jining	A	28	0.3403	92	0.573	68	0.721	53	0.516	9	0.717
Quanzhou	A	29	0.3365	37	0.614	3	0.863	32	0.533	70	0.610
Zhoushan	A	30	0.3353	41	0.609	67	0.721	8	0.612	36	0.638
Xiangfan	A	31	0.3351	89	0.575	106	0.692	91	0.506	8	0.719
Ezhou	A	32	0.3227	40	0.610	4	0.832	127	0.503	52	0.625

Table A3. *Cont.*

City	Level	Rank of UC	Score of UC	Rank of EG	Score of EG	Rank of DR	Score of DR	Rank of CI	Score of CI	Rank of EC	Score of EC
Xi'an	A	33	0.3207	20	0.652	120	0.677	39	0.525	72	0.610
Yinchuan	A	34	0.3190	42	0.608	78	0.715	132	0.503	23	0.667
Nanchang	A	35	0.3157	32	0.620	38	0.752	46	0.520	42	0.632
Yantai	B	36	0.3156	35	0.617	63	0.725	19	0.558	43	0.631
Changchun	B	37	0.3144	24	0.639	112	0.684	33	0.533	58	0.620
Hohhot	B	38	0.3131	27	0.631	70	0.717	61	0.513	51	0.626
Baotou	B	39	0.3122	25	0.637	89	0.704	57	0.515	56	0.621
Zhengzhou	B	40	0.3080	26	0.636	118	0.678	38	0.527	59	0.620
Harbin	B	41	0.3061	31	0.622	16	0.782	25	0.544	89	0.594
Huzhou	B	42	0.3042	38	0.614	39	0.752	52	0.516	45	0.629
Huizhou	B	43	0.3021	56	0.595	13	0.792	31	0.534	49	0.628
Suizhou	B	44	0.3013	102	0.568	1	0.892	110	0.504	68	0.613
Wenzhou	B	45	0.3007	28	0.631	19	0.775	49	0.516	93	0.585
Daqing	B	46	0.2989	49	0.601	80	0.713	30	0.535	29	0.647
Chongqing	B	47	0.2936	23	0.642	130	0.648	14	0.576	104	0.576
Dongying	B	48	0.2924	33	0.618	5	0.815	21	0.553	132	0.552
Lianyungang	B	49	0.2886	73	0.580	28	0.762	43	0.521	30	0.647
Jiangmen	B	50	0.2861	52	0.599	20	0.775	45	0.520	63	0.617
Taizhou	B	51	0.2838	36	0.615	29	0.761	51	0.516	84	0.599
Shantou	B	52	0.2832	54	0.597	36	0.753	78	0.507	46	0.629
Hefei	B	53	0.2824	55	0.597	108	0.691	48	0.520	31	0.646
Taizhou	B	54	0.2822	39	0.614	66	0.721	56	0.515	65	0.615
Guiyang	B	55	0.2805	48	0.602	93	0.703	36	0.531	44	0.631
Langfang	B	56	0.2751	70	0.582	6	0.813	73	0.508	73	0.610
Zhangzhou	B	57	0.2705	57	0.594	27	0.763	64	0.511	66	0.614
Weifang	B	58	0.2693	43	0.607	84	0.710	34	0.532	71	0.610
Rizhao	B	59	0.2665	76	0.579	132	0.644	136	0.503	26	0.649
Chaozhou	B	60	0.2664	79	0.578	12	0.797	128	0.503	67	0.614
Xingtai	B	61	0.2644	112	0.565	137	0.622	124	0.504	19	0.676
Jingdezhen	B	62	0.2622	84	0.577	52	0.736	101	0.505	41	0.637
Liaocheng	B	63	0.2589	61	0.588	47	0.744	80	0.507	61	0.618
Putian	B	64	0.2569	71	0.582	14	0.791	59	0.514	85	0.598
Tongling	B	65	0.2567	60	0.589	90	0.704	103	0.505	47	0.629
Deyang	B	66	0.2555	99	0.571	61	0.727	66	0.511	37	0.638
Handan	B	67	0.2546	80	0.578	115	0.680	85	0.507	32	0.645
Zhaoqing	B	68	0.2544	103	0.568	10	0.801	60	0.513	75	0.606
Qinhuangdao	B	69	0.2538	113	0.565	65	0.723	55	0.515	34	0.643
Wuzhong	B	70	0.2528	44	0.607	11	0.800	77	0.507	136	0.534
Ma'anshan	C	71	0.2526	59	0.590	40	0.752	74	0.508	77	0.605
Suqian	C	72	0.2524	98	0.571	31	0.759	126	0.503	53	0.624
baoding	C	73	0.2508	53	0.597	124	0.669	58	0.515	54	0.622
Hengshui	C	74	0.2497	77	0.579	133	0.644	137	0.503	27	0.649
Leshan	C	75	0.2487	118	0.557	94	0.703	11	0.602	57	0.620

Table A3. *Cont.*

City	Level	Rank of UC	Score of UC	Rank of EG	Score of EG	Rank of DR	Score of DR	Rank of CI	Score of CI	Rank of EC	Score of EC
Xiangtan	C	76	0.2476	62	0.588	105	0.692	12	0.602	92	0.586
Huaibei	C	77	0.2475	104	0.568	73	0.717	82	0.507	38	0.638
Zaozhuang	C	78	0.2467	63	0.588	43	0.747	65	0.511	82	0.602
Nanning	C	79	0.2418	114	0.563	86	0.709	67	0.511	35	0.639
Anshan	C	80	0.2393	34	0.618	85	0.709	40	0.523	133	0.550
Cangzhou	C	81	0.2339	64	0.588	135	0.631	122	0.504	50	0.627
Lanzhou	C	82	0.2283	45	0.607	42	0.748	79	0.507	135	0.535
Chuzhou	C	83	0.2257	121	0.555	57	0.733	116	0.504	55	0.622
Maoming	C	84	0.2254	115	0.561	8	0.809	112	0.504	115	0.571
Huainan	C	85	0.2233	69	0.583	98	0.698	120	0.504	78	0.605
Xuchang	C	86	0.2200	106	0.566	88	0.707	119	0.504	62	0.618
Chizhou	C	87	0.2192	74	0.580	37	0.753	98	0.505	101	0.577
Hebi	C	88	0.2174	85	0.577	35	0.754	97	0.505	100	0.579
Tangshan	C	89	0.2170	87	0.576	111	0.687	26	0.542	81	0.602
Zhanjiang	C	90	0.2149	122	0.555	33	0.757	96	0.505	83	0.601
Yangjiang	C	91	0.2099	107	0.566	25	0.765	18	0.558	129	0.555
Zhuzhou	C	92	0.2098	72	0.581	102	0.694	47	0.520	90	0.593
Beihai	C	93	0.2086	88	0.576	41	0.749	130	0.503	112	0.572
Yingtan	C	94	0.2079	123	0.554	50	0.738	99	0.505	80	0.603
Jieyang	C	95	0.2074	93	0.573	32	0.757	86	0.506	116	0.569
Anqing	C	96	0.2066	67	0.587	122	0.676	93	0.506	91	0.591
Jiujiang	C	97	0.2057	90	0.575	119	0.678	71	0.509	79	0.603
Lishui	C	98	0.2031	108	0.566	69	0.720	81	0.507	88	0.595
Songyuan	C	99	0.2023	135	0.548	22	0.770	138	0.502	96	0.584
Xining	C	100	0.2022	65	0.588	95	0.701	89	0.506	109	0.572
Mianyang	C	101	0.2012	109	0.566	74	0.717	69	0.509	87	0.595
Shanwei	C	102	0.2011	94	0.573	17	0.782	113	0.504	139	0.525
Huangshi	C	103	0.2010	100	0.571	100	0.696	105	0.505	86	0.598
Wuhai	C	104	0.2006	58	0.594	104	0.692	140	0.502	121	0.564
Suzhou	C	105	0.1996	138	0.545	92	0.704	134	0.503	64	0.617
Ningde	D	106	0.1981	101	0.571	77	0.716	44	0.521	97	0.582
Xinxiang	D	107	0.1980	110	0.566	121	0.677	92	0.506	74	0.607
Tongchuan	D	108	0.1964	78	0.579	87	0.707	118	0.504	103	0.577
Fangchenggang	D	109	0.1963	96	0.572	48	0.741	131	0.503	119	0.566
Guangan	D	110	0.1961	75	0.580	72	0.717	102	0.505	117	0.568
Fuxin	D	111	0.1956	81	0.578	26	0.764	129	0.503	140	0.524
Shuangyashan	D	112	0.1954	68	0.587	76	0.716	117	0.504	130	0.555
Huanggang	D	113	0.1946	91	0.575	134	0.634	108	0.505	76	0.606
Bengbu	D	114	0.1937	125	0.554	110	0.689	95	0.505	69	0.611
Pingdingshan	D	115	0.1883	82	0.578	109	0.690	107	0.505	102	0.577
Baoji	D	116	0.1870	66	0.588	71	0.717	75	0.508	137	0.529
Puyang	D	117	0.1863	111	0.566	81	0.712	88	0.506	98	0.582
Xianyang	D	118	0.1806	83	0.578	113	0.684	84	0.507	114	0.571
Siping	D	119	0.1773	86	0.577	82	0.711	139	0.502	134	0.550

Table A3. *Cont.*

City	Level	Rank of UC	Score of UC	Rank of EG	Score of EG	Rank of DR	Score of DR	Rank of CI	Score of CI	Rank of EC	Score of EC
Zunyi	D	120	0.1770	129	0.552	55	0.734	87	0.506	106	0.574
Xuancheng	D	121	0.1746	134	0.550	53	0.735	114	0.504	111	0.572
Suining	D	122	0.1735	116	0.561	91	0.704	41	0.523	108	0.573
Tsitsihar	D	123	0.1726	136	0.546	75	0.717	83	0.507	95	0.585
Fuzhou	D	124	0.1725	117	0.558	54	0.734	115	0.504	125	0.560
Qinzhou	D	125	0.1697	124	0.554	51	0.737	100	0.505	126	0.558
Luoyang	D	126	0.1669	97	0.572	123	0.675	42	0.522	120	0.564
Kaifeng	D	127	0.1616	131	0.551	114	0.683	70	0.509	94	0.585
Zhangjiakou	D	128	0.1601	119	0.557	103	0.694	106	0.505	110	0.572
Nanchong	D	129	0.1584	126	0.553	99	0.697	90	0.506	107	0.574
Dandong	D	130	0.1539	95	0.573	107	0.692	62	0.512	138	0.528
Shangrao	D	131	0.1512	105	0.567	116	0.680	76	0.508	131	0.553
Chaohu	D	132	0.1483	127	0.553	97	0.699	104	0.505	124	0.560
Wuwei	D	133	0.1467	141	0.513	49	0.741	141	0.500	128	0.557
Liupanshui	D	134	0.1392	120	0.556	83	0.711	133	0.503	141	0.517
Liu’an	D	135	0.1362	132	0.551	117	0.680	121	0.504	122	0.561
Bozhou	D	136	0.1287	140	0.542	125	0.664	135	0.503	113	0.572
Shangqiu	D	137	0.1237	137	0.546	136	0.628	123	0.504	105	0.575
Zhoukou	D	138	0.1226	139	0.544	140	0.595	109	0.505	99	0.582
Nanyang	D	139	0.1201	133	0.551	128	0.653	94	0.506	127	0.557
Yangquan	D	140	0.1142	128	0.553	141	0.580	72	0.509	118	0.567
Fuyang	D	141	0.1103	130	0.552	138	0.617	125	0.504	123	0.561

Conflicts of Interest

The authors declare no conflict of interest.

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