Comprehensive Strength Evaluation of Nanjing Metropolitan Area Based on Principal Component Analysis

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Abstract: Metropolitan circle is one of the important spatial organization forms to promote the development of regional economic integration. With the integration of urban regionalization and regional urbanization, the competitiveness of metropolitan area has become the focus of many disciplines. Based on the research results of the competitiveness of Nanjing metropolitan area at home and abroad, this paper constructed an evaluation system of the comprehensive competitiveness of Nanjing metropolitan area covering 14 indexes, and made a comprehensive evaluation of the competitiveness of Nanjing metropolitan area, and put forward some strategies to improve the comprehensive competitiveness of Nanjing metropolitan area according to the evaluation results. In this paper, the Nanjing metropolitan area were taken as the research geographic space scope, and the comprehensive strength of the eight cities in Nanjing metropolitan area were calculated and analyzed by SPSS software. The results showed that there was a big gap between the central cities in Nanjing metropolitan area and other cities in Nanjing metropolitan area, and other cities in Nanjing metropolitan area should put forward new development strategies according to the comparative results.

Keywords: comprehensive strength; Principal component analysis; Nanjing Metropolitan Area;

1 INTRODUCTION

Metropolitan area is an important area connecting link between the preceding and the following in China's national planning and development pattern[1]. The interactive ideas and Strategies of the cities in the metropolitan area, which are driven by the central city, the division of labor and cooperation of the surrounding cities and economic integration, have become an important strategic method for the development of the metropolitan area[2]. The cities of Nanjing Metropolitan area belong to South province since the Ming Dynasty. To the Qing Dynasty belong to Jiangnan province. These cities are connected in history, geography, humanities and economy, so they have the natural advantage of promoting the integrated development. Metropolitan area plays a very important role in the development strategy of the national Yangtze River economic belt.

In August 2006, Nanjing Construction Committee issued the outline of the five-year

construction plan of Nanjing metropolitan area from 2006 to 2010, which put forward that the main objectives of the construction of Nanjing metropolitan area are to form a rational division of labor with Nanjing as the core, with Yangzhou, Zhenjiang, Huai'an, Ma'anshan, Chaohu, Chuzhou and Wuhu as the main cities and 27 medium-sized cities and a large number of small cities as the basis, the city system of metropolitan circle with reasonable division of labor, sustainable, rapid and coordinated development will realize the rising trend of Nanjing metropolitan area in the western region of Yangtze River Delta. On December 1, 2019, the CPC Central Committee and the State Council issued the outline of the Yangtze River Delta regional integration development plan , which pointed out that it is necessary to accelerate the integrated development of metropolitan areas, to promote the coordination and linkage of metropolitan areas, and to improve the level of metropolitan area integration[3]. On February 8, 2021, the National Development and Reform Commission officially approved the Development Plan of Nanjing metropolitan area in principle, and clearly proposed to build Nanjing metropolitan area into a modern metropolitan area with national influence, help to develop world-class city clusters in the Yangtze River Delta and make greater contributions to serving China's overall modernization drive[4]. In 2021, Anhui and Jiangsu provinces will jointly build Nanjing metropolitan area, including four cities in Jiangsu province and four cities in Anhui Province. Since the "Yangtze River Delta Urban Agglomeration Development Plan" was put forward, the economic radiation of Nanjing metropolitan area has been continuously enhanced, and also played a role in promoting the development of surrounding cities. Since the 21st century, cities have played an increasingly important role in the integrated development of metropolitan areas. From the objective law, the spatial structure of China's economic development has undergone profound changes, with industries and population converging to large cities and urban clusters, and the growth engine with metropolitan areas as the main form is accelerating. It is a key step to promote the integrated development of Nanjing metropolitan area[5].

Taking Nanjing as the central city of metropolitan area is beneficial to the integration and development of Nanjing and its surrounding cities. In order to reveal the economic development structure of metropolitan area and the law of urban space connection, this research carried out the comprehensive strength of Nanjing metropolitan area from the perspective of time and space and based on SPSS principal component analysis method. Through comparative analysis, we can understand the comprehensive strength of cities in Nanjing metropolitan area, and provide development suggestions for integrating Nanjing metropolitan area into the development strategy of Yangtze River Economic Belt, leading the development of Jiangsu and leading the follow-up of central Anhui, and building Nanjing metropolitan area into the most influential modern metropolitan area in China.

2 DETERMINATION OF INDEX SYSTEM, DATASOURCES

The comprehensive strength of a city reflects its overall strength and social development. Therefore, this paper selects indicators from five areas of a regional social economic system[5](Table 1). Nanjing statistical yearbook,Yangzhou statistical yearbook, Zhenjiang statistical yearbook, Huai'an statistical yearbook, Wuhu statistical yearbook, Ma'anshan statistical yearbook, Chuzhou statistical yearbook and Xuancheng statistical yearbook.

Table 1 Index system of urban comprehensive strength

Influence factor	Specific variables	Unit
Economic development level	Regional GDP	Hundred million
	Total imports and exports	Hundred million
	Proportion of added value of tertiary industry in GDP	%
Residents living standards	Annual person net income of farmers	Yuan
	Person Regional GDP	Yuan
Infrastructure construction	Number of health institutions	Pieces
	Highway mileage	Kilometre
Scientific research and education strength	Number of students in Colleges and Universities	Ten thousand
	Number of Public Libraries	Pieces
	Birth rate	%
	Population mortality	%
Social construction	Number of employed population	Ten thousand
	Total population at the end of the year	Ten thousand
	Total land area	Square kilometer

3 EMPIRICAL ANALYSIS OF URBAN COMPREHENSIVE STRENGTH

Principal component analysis, was first proposed by Hotelling in 1933. It is a multivariate statistical method that uses the idea of dimension reduction to transform multiple indicators into several comprehensive indicators on the premise of losing little information[6]. In principal component analysis, the amount of principal component information mainly depends on the eigenvalue of the covariance matrix of the evaluation matrix. The larger the eigenvalue, the more principal component information. The principal component with the largest eigenvalue is called the first principal component, followed by the second principal component and so on[7]. The number of eigenvalues is equal to the number of original indicators and the corresponding principal components are the same as the number of original indicators. But when selecting the principal components, it is not necessary to select all the principal components. Because the later the principal component information, the less, some even infinitely close to 0. Therefore, only a few principal components with a cumulative contribution rate of 85% - 90% need to be selected.

Based on the index system of urban comprehensive strength, this paper uses the principal component analysis method to analyze and evaluate the cities in Nanjing metropolitan area. By studying the internal structural relationship of the index system, the specific steps for converting multiple indicators into a few independent indicators and containing most of the information about the original indicators (80% to more than 85%) are as follows:

Standardize the original data and build a standardized matrix for the evaluation of the comprehensive strength development of Nanjing metropolitan area according to the selected 14 indicators. Zij represents the standardized data of the j indicator of the i city[8](Formula 1).

$$Z = (Z_{ij})_{n \times m} = \begin{bmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \cdots & \vdots \\ Z_{m1} & \cdots & Z_{mn} \end{bmatrix} \qquad (1)$$

Feasibility test. Before the principal component analysis, KMO and Bartlett test are carried out for each variable. The closer the KMO value is to 1, the better the correlation of variables is, and the more suitable this method is. The KMO test value is 0.618, indicating that there is correlation among variables.($P<0.001$ reject the original assumption of independent variables, that is, the data meet the conditions for principal component analysis).

Extract the principal components. The number of principal components is usually determined according to the principle that the eigenvalue is greater than or equal to 1.The analysis results of matrix eigenvalue and cumulative contribution rate can be obtained by using SPSS software. According to the principle that the eigenvalue is greater than 1 and the cumulative variance contribution rate is greater than 85%, three principal components are extracted. To some extent, the eigenvalue can be regarded as an indicator of the influence of the principal component. If the eigenvalue is less than 1, the interpretation of the principal component is not as strong as the average interpretation of directly introducing an original variable. Therefore, generally, the eigenvalue greater than 1 can be used as the inclusion standard, and the eigenvalue and contribution rate can be obtained based on the analysis of SPSS software, as shown in Table 2.The cumulative contribution rate of the first three principal components is greater than 85%, and the eigenvalues are greater than 1, so it is more appropriate to extract three principal components.

Table 2 Eigenvalue and variance contribution rate in 2013-2019

particular year	principal component	characteristic value	Variance contribution rate/%	Cumulative variance contribution rate/%	particular year	principal component	characteristic value	Variance contribution rate/%	Cumulative variance contribution rate/%
	F1	6.999	49.995	49.995		F1	6.572	46.943	46.943
2013	F2	3.316	23.683	73.678	2015	F2	4.613	32.949	79.892
	F3	1.780	12.715	86.393		F3	1.654	11.813	91.706
	F1	6.533	46.664	46.664		F1	5.760	41.140	41.140
2017	F2	3.822	27.297	73.961	2019	F2	4.478	31.989	73.129
	F3	2.076	14.830	88.791		F3	1.762	12.585	85.714

By calculating the linear combination of the three principal components, the coefficient corresponding to each index in the three principal components can be obtained by dividing the load number by the square of the corresponding eigenvalue of the principal components. Firstly, calculating the weight of each principal component, and take the proportion of the

eigenvalue corresponding to each major constituent to the sum of the total eigenvalues of the extracted principal components as the weight, so as to obtain the weights of F1, F2 and F3, and calculate their weights. The scores F1, F2 and F3 of each principal component can be calculated from the score coefficient of the principal component and the standardized value of the original variable(Table 3). Through calculation, the comprehensive strength score of each region is obtained(Table 4).

Table 3 The initial load factor matrix in 2013-2019

particular year	2013			2015			2017			2019		
principal component	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
Number of health institutions	0.693	0.543	0.192	0.749	7.899	0.473	0.667	0.557	-0.314	-0.591	0.639	-0.106
Number of employed population	0.911	0.346	-0.036	0.881	10.899	-0.158	0.851	0.475	0.105	-0.810	0.295	-0.048
Number of Public Libraries	0.945	0.123	0.068	0.882	5.899	-0.370	0.811	0.236	0.292	0.445	0.856	-0.084
Highway mileage	0.130	0.881	0.404	-0.114	12.899	0.134	-0.179	0.943	0.081	-0.805	0.542	-0.003
Total population at the end of the year	0.789	0.476	-0.222	0.898	1.899	0.081	0.778	0.500	0.129	0.155	0.870	-0.024
Regional GDP	0.964	-0.206	-0.078	0.992	-0.101	0.070	0.988	-0.097	0.029	0.748	0.590	0.202
Birth rate	0.041	0.517	-0.682	0.478	8.899	-0.616	0.266	0.366	0.804	-0.287	0.628	-0.178
Population mortality	0.157	-0.485	0.443	0.054	9.899	0.985	-0.124	-0.254	0.576	-0.145	-0.350	0.829
Total imports and exports	0.962	-0.176	-0.018	0.628	2.899	0.314	0.977	-0.038	0.069	0.301	0.911	0.007
Total land area	-0.128	0.914	0.326	-0.283	11.899	0.207	-0.233	0.941	-0.148	-0.793	0.440	0.310
Person Regional GDP	0.766	-0.634	-0.079	0.927	0.899	0.080	0.847	-0.508	-0.024	0.883	0.290	0.136
Annual person net income of farmers	0.050	-0.141	0.816	0.568	4.899	-0.027	0.520	-0.845	0.060	0.948	-0.267	-0.138
Number of students in Colleges and Universities	0.946	-0.092	-0.148	0.966	6.899	-0.204	-0.369	-0.078	0.907	0.012	-0.215	-0.911
Proportion of added value of tertiary industry in GDP	0.881	-0.202	0.238	0.860	3.899	0.261	0.935	-0.132	-0.163	0.907	0.330	0.133

By extracting the principal components from the indicators of the comprehensive strength of each city, calculating the principal component function and calculating the comprehensive score according to the weight, we can get the ranking of five cities in five aspects. Among the Nanjing metropolitan area, the urban area of Nanjing ranks first, with the highest score, absolutely ahead of other cities, reflecting the cohesion of the core cities of Nanjing metropolitan area. Followed by Yangzhou City and Zhenjiang City, which scores are higher than those of other cities except Nanjing City. In Anhui Province, except Wuhu City, the scores of other cities are low. As can be seen from several tables that in 2013, 2015, 2017 and 2019, the development of Nanjing metropolitan area is relatively unbalanced. The scores of four cities in Anhui Province are basically negative, and the change of ranking in five years is not significant. Nanjing has the highest comprehensive score, illustrating that the economic development scale of the city is relatively coordinated with people's living standards, reflecting its solid economic strength, Secondly, Yangzhou, Zhenjiang have higher

comprehensive scores, indicating that the two cities are also relatively strong in economic strength, the scores of the other cities are relatively low, indicating that the economies of these cities are small and people's living standards are average. At the same time, it is also found that there are great differences in economic development among the eight cities in Nanjing metropolitan area. Generally speaking, the urban development of Nanjing metropolitan area in Jiangsu Province is better than Anhui Province.

Table 4 The comprehensive strength score of Nanjing metropolitan area in 2013-2019

particular year	Region /city	Principal component F1	Principal component F2	Principal component F3	Comprehensive score	sort	particular year	Region /city	Principal component F1	Principal component F2	Principal component F3	Comprehensive score	sort
2013	Nanjing	5.93	0.06	-0.67	5.32	1	2015	Nanjing	5.93	0.06	-0.67	5.32	1
	Huai'an	0.1	-1.5	1.76	0.36	4		Huai'an	0.1	-1.5	1.76	0.36	4
	Zhenjiang	-0.45	0.53	0.91	0.99	3		Zhenjiang	-0.45	0.53	0.91	0.99	3
	Yangzhou	1.31	2.29	-2.47	1.13	2		Yangzhou	1.31	2.29	-2.47	1.13	2
	Wuhu	-1.93	1.51	0.3	-0.11	6		Wuhu	-1.93	1.51	0.3	-0.11	6
	Chuzhou	-0.54	-1.95	2.45	-0.04	5		Chuzhou	-0.54	-1.95	2.45	-0.04	5
	Xuancheng	-2.22	0.33	-3.14	-5.03	8		Xuancheng	-2.22	0.33	-3.14	-5.03	8
	Ma On Shan	1.93	-0.8	-1.91	-0.78	7		Ma On Shan	1.93	-0.8	-1.91	-0.78	7
2017	Nanjing	-1.72	6.23	3.04	7.55	1	2019	Nanjing	3.21	5.42	-0.43	8.2	1
	Huai'an	0.43	-1.21	0.8	-0.02	4		Huai'an	-1.54	0.25	-0.69	-1.98	5
	Zhenjiang	0.75	-0.21	-0.14	0.4	3		Zhenjiang	0.75	-0.21	-0.14	0.4	3
	Yangzhou	-1.2	2.12	0.38	1.3	2		Yangzhou	-1.2	2.12	0.38	1.3	2
	Wuhu	1.25	-0.84	-0.44	-0.03	5		Wuhu	-0.67	1.54	-2.44	-1.57	4
	Chuzhou	0.26	-1.24	-1.49	-2.47	7		Chuzhou	-5.56	0.21	2.43	-2.92	7
	Xuancheng	2.12	0.24	-5.49	-3.13	8		Xuancheng	2.12	-5.58	-1.14	-4.6	8
	Ma On Shan	0.63	-1.23	-0.84	-1.44	6		Ma On Shan	1.32	-1.64	-2.46	-2.78	6

Using the inverse distance weight interpolation method of ArcGIS, the comprehensive strength value display map of 8 cities in Nanjing metropolitan area is drawn. On the isopleth map, the comprehensive strength of the same isoline is equal, and the difference of the comprehensive strength of adjacent isolines is also the same, the density of contour distribution reflects the speed of the change of comprehensive strength. The more dense the contour, the faster the change of comprehensive strength, and the stronger the comprehensive strength of the city, on the contrary, the more sparse the contour distribution, the slower the change of comprehensive strength and the weaker the comprehensive strength of the city. It can be seen from Figure 1 that the isolines in Nanjing are dense and dense, and it can be seen that Nanjing has the highest score, which has a great impact on the radiation in the weekend area. The scores of Yangzhou and Zhenjiang are higher than those of other cities after Nanjing,

while Chuzhou and Xuancheng in Anhui Province have lower scores in metropolitan cities, ranking at the end, and their comprehensive strength is weak.
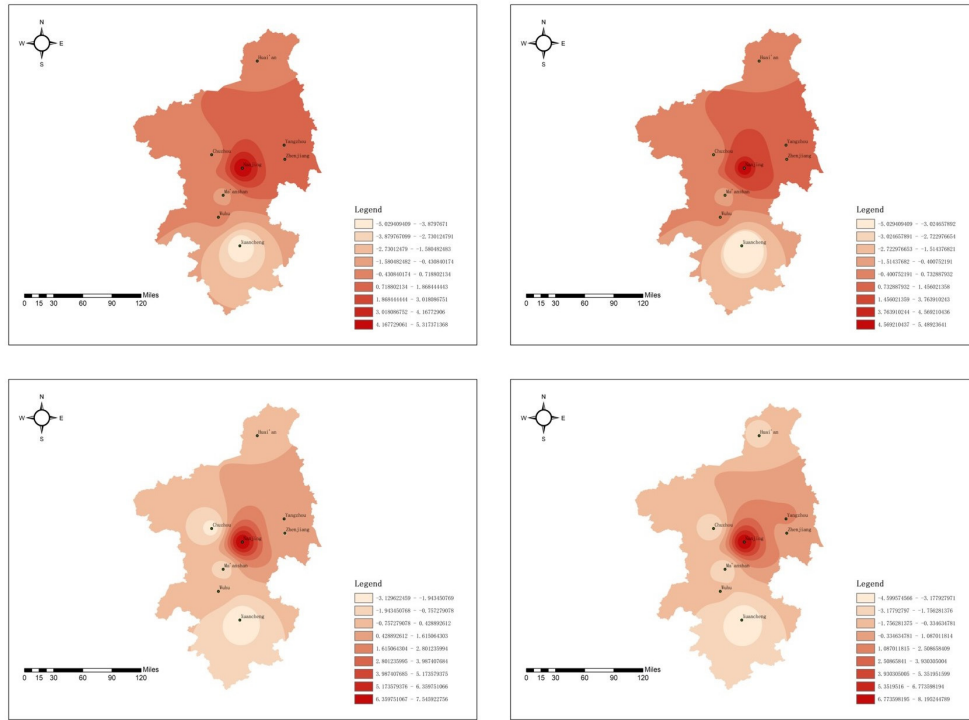

Figure 1: Contour map of comprehensive strength of Nanjing Metropolitan Area

4 CONCLUSIONS

4.1 Analysis

In 2021, the GDP of metropolis circle accounted for 4.1% of the country, Accounting for 16.9% of the Yangtze River Delta region. Among the 10 regions, the GDP growth rate of 8 regions is higher than that of the whole country. The total GDP of Nanjing ranks first in all regions of the metropolis circle, accounting for 35.0%.With the coordinated promotion of strong and complementary industrial chains in metropolis circle, the industrial structure has been continuously optimized. In 2021, the added value of the primary industry in Nanjing metropolitan coordinating region will be 203.26 billion yuan, accounting for 2.4% of the country and 19.6% of the Yangtze River Delta region. The added value of the secondary industry is 2033.006 billion yuan, accounting for 4.5% of the country and 18.1% of the

Yangtze River Delta. The added value of the tertiary industry was 243.30 billion yuan, accounting for 4.0% of the country and 15.8% of the Yangtze River Delta. The level of industry, foreign investment and foreign trade and residents' income in the metropolis circle have all improved.

It needs to connect and rely on each other with surrounding cities to form a core edge model in structure. In Nanjing's leading industrial structure, advanced manufacturing, modern service industry and future industries, including advanced manufacturing industry, which is dominated by high-end intelligent equipment, biomedicine, new energy-saving and environmental protection materials, new electronic information and green intelligent vehicles. The cities around Nanjing metropolitan area also have different leading industries. For example, the leading industries in Zhenjiang are equipment manufacturing, new materials, new energy, etc; Yangzhou's leading industry is machinery and equipment; Chuzhou's leading industries are equipment manufacturing, new materials and intelligent automobile supporting facilities; Ma'anshan's leading industries are electrical machinery and equipment manufacturing. This homogenization competition not only has an adverse impact on the overall industrial competitiveness of the metropolitan area, but also restricts the economic integration of the metropolitan area.

In order to realize the integrated construction and development, Nanjing metropolitan area needs to consider the integration of economic integration, industrial development integration, transportation integration and other ways. Nanjing is rich in educational resources. In the second round of double first-class evaluation by the Ministry of education, 13 colleges and universities have settled in Nanjing, second only to Beijing and Shanghai. Nanjing Medical University, Nanjing University of Chinese Medicine and China Pharmaceutical University belong to medical education schools, which provide intellectual support for Nanjing's top medical resources in China. These advantageous educational resources are the intellectual support provided by Nanjing for the surrounding cities and the leading medical resources in the country. The surrounding cities are rich in labor, it can meet the needs of urban infrastructure and ordinary workers in Nanjing. Cities in the metropolitan area can attract high-quality talents to work in neighboring cities through the introduction of talent policies.

4.2 Policy Suggestion

4.2.1 Innovation leading: adhere to market orientation.

Adhere to the people-centered development idea, give full play to the decisive role of the market in allocating resources and the main role of enterprises, encourage social organizations to participate in the co construction and co governance of the metropolitan area, and give full play to the role of the invisible hand of the market. Firmly establish the concept of "development is the first priority, while talent is the first resource and innovation is the first driving force". Government should adhere to the combination of scientific and technological innovation and institutional innovation, and actively build a collaborative innovation community[9]. Actively benchmark the world-class metropolitan area, promote reform first and system trial first, drive "innovation" with "innovation", and drive the stock with increment, so as to comprehensively form a unified market and build a more perfect cost sharing and benefit sharing mechanism.

4.2.2 Government guidance: breaking administrative barriers.

Give play to the guiding and supporting role of the government in space development and regulation, infrastructure layout, public service supply and business environment construction, and highlight the "one map" planning, "one chess" construction and "integrated" development[10]. Cities in the metropolitan area should give full play to their strengths and jointly build a new pattern of all-round, wide-ranging and multi-level opening and cooperation, so as to form a new pattern of metropolitan area integration with clear spatial structure, complementary urban functions, orderly flow of factors, coordinated industrial division of labor, smooth traffic, balanced public services, harmonious and livable environment, and a working pattern of concentric, simultaneous and concerted development.

4.2.3 Win-win cooperation: develop transportation advantages.

Closely bench marking the Yangtze River Delta integration action plan, aim to build a world-class urban agglomeration and an innovative city with global influence. From the four aspects of trunk railway, intercity railway, urban (suburban) railway and urban rail transit, promote the "integration of four networks", jointly build the "one-hour commuter circle" and "one-day life circle" of Nanjing metropolitan area, effectively connect the trunk railway, intercity railway and subway network, and comprehensively improve the overall function of multi-level rail transit network. Nanjing's rail transit will usher in new opportunities for high-quality, sustainable, coordinated and rapid development, and promote the Nanjing metropolitan area and the Yangtze River Delta to accelerate into the "fast lane" of development.

4.2.4 Complementary functions: sharing education and medical care.

Truly let the people of Nanjing metropolitan area and the Yangtze River Delta economic belt feel the convenience of "one-hour metropolitan area" and "one-day life circle", and enjoy Nanjing's high-quality education and medical resources.

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