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Research on the Design of Evaluation System for Coordinated Development of Beijing-Tianjin-Hebei Region

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ABSTRACT

By analyzing the main factors affecting the coordinated development of the Beijing-Tianjin-Hebei region, the construction of the Beijing-Tianjin-Hebei regional coordinated development evaluation system plays an important supporting role in accelerating the progress of the coordinated development of the Beijing-Tianjin-Hebei region. Based on the overall situation of the national economic and social development of Beijing-Tianjin-Hebei region and from the dimensions of science and technology, economy, society and ecology, the paper conducts the qualitative screening of the evaluation indicators of coordinated development of Beijing-Tianjin-Hebei region by using method of policy literature review and combining the two categories of indicators of "policy orientation" and "document reference". On this basis, the principal component — correlation analysis method is used to quantitatively screen the evaluation indicators of the coordinated development of the Beijing-Tianjin-Hebei region. Then, the evaluation index system for the coordinated development of the Beijing-Tianjin-Hebei region can be determined. This evaluation index system helps to evaluate the coordinated development status of the Beijing-Tianjin-Hebei region from a comprehensive perspective, and makes up for the shortcomings of the existing results that are from a single perspective.

Keywords: *Beijing-Tianjin-Hebei region, coordinated development, dimensions, indicators, evaluation*

I. INTRODUCTION

The Beijing-Tianjin-Hebei region accounts for 2.3% of China's land area, carries 8% of China's population, and creates nearly 11% of China's total economic output. It is an important engine for promoting China's national economic and social development. The issuance and implementation of policy documents such as the "Beijing-Tianjin-Hebei Coordinated Development Plan Outline" and the "Beijing-Tianjin-Hebei National Economic and Social Development Plan During the 13th Five-Year Plan" provide important practical guidance for the design of evaluation indicators for the coordinated development of the Beijing-Tianjin-Hebei region. The "Beijing-Tianjin-Hebei National Economic and Social Development Plan During the 13th Five-Year Plan" clearly formulated 9 key development tasks including innovation and development, transformation and upgrading, and green development. At the same time, a number of special plans for science and technology, industry, ecological and environmental protection, transportation, and education have been implemented to continuously reduce the imbalance in the development of the Beijing-Tianjin-Hebei region. These policies and systems have provided important policy support for accelerating the coordinated development of Beijing-Tianjin-Hebei and narrowing the development gap of Beijing-Tianjin-Hebei. In the context of the implementation of the Beijing-Tianjin-Hebei coordinated development strategy, and based on the overall national economic and social development of the Beijing-Tianjin-Hebei region, constructing a relatively complete coordinated development evaluation system that is compatible with the economic and social development goals of the Beijing-Tianjin-Hebei region is conducive to provide theoretical guidance and decision support for the coordinated development practice of Beijing-Tianjin-Hebei.

II. LITERATURE REVIEW

Since the establishment of the Beijing-Tianjin-Hebei regional coordinated development strategy, Beijing-Tianjin-Hebei government management departments and academia have carried out a large number of practical and empirical studies. Aiming at

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the design of evaluation indicators for the coordinated development of the Beijing-Tianjin-Hebei region, technological innovation, economic development, social governance, and ecological environment have now become key factors to accelerate the development of the Beijing-Tianjin-Hebei region. Existing research focuses on the design of evaluation indicators around the dimensions of science and technology, economy, society, and ecology. Among them, the dimensions of science and technology mainly include indicators of science and technology resource stock, talent reserve, science and technology output, science and technology environment, achievement transformation, and science and technology output performance. [1-5] Economic dimensions mainly include economic scale, level, benefit, structure, quality, environment and other indicators [6-14]. Social dimensions mainly include public services, people's lives, medical education, human settlements, social structure, social welfare and other indicators [15-27]. The ecological dimensions focus on indicators such as ecological endowment, pollution status, and governance results [28-34].

To sum up, the coordinated development of the Beijing-Tianjin-Hebei region is fundamentally driven by innovation, and its physical content and key support are to accelerate the transformation and upgrading of the economy and industry. At the same time, ecological construction provides an important guarantee for the coordinated development of the Beijing-Tianjin-Hebei region. The evaluation of the coordinated development of the Beijing-Tianjin-Hebei region is a systematic evaluation conducted from the multi-dimensional perspectives of science and technology, economy, society, and ecology in the Beijing-Tianjin-Hebei region, which is beneficial to provide theoretical guidance and decision support for the coordinated development practice of the Beijing-Tianjin-Hebei region. Based on the findings of existing research literature, scholars currently have no unified standard dimension in the design of the evaluation index system for the coordinated development of the Beijing-Tianjin-Hebei region, and they tend to construct corresponding evaluation indicators from the single-dimensional perspective of technology, economy, society, and ecology. Few scholars consider integrating science and technology, economy, society, ecology and other dimensions into a unified framework system on the basis of evaluation from single-dimensional perspective, and establish a more complete coordinated development evaluation index that is compatible with the economic and social development goals of the Beijing-Tianjin-Hebei region. Therefore, based on the overall situation of the national economic and social development of Beijing-Tianjin-Hebei, it is necessary to systematically design the evaluation index system of the coordinated development of the Beijing-Tianjin-Hebei region from the multi-dimensional perspectives of science and technology, economy, society, ecology, etc. And then, the key constraints of the coordinated development of the Beijing-Tianjin-Hebei region can be explored to guide the coordinated development in the Beijing-Tianjin-Hebei region.

III. RESEARCH METHODS

A. Qualitative screening methods of evaluation indicators

The evaluation of the coordinated development of the Beijing-Tianjin-Hebei region cannot be limited to the research from the single perspective such as technological innovation, economic industry, and ecological environment. In practice, the scientific and technological, economic, social, and ecological dimensions should be integrated into a unified framework system to design the evaluation index system for the coordinated development of the Beijing-Tianjin-Hebei region. To this end, with reference to the "Beijing-Tianjin-Hebei Coordinated Development Plan" and the "Beijing-Tianjin-Hebei National Economic and Social Development Plan During the 13th Five-Year Plan" and other policy documents, the "policy-oriented" indicators for the development of the Beijing-Tianjin-Hebei region are defined. At the same time, referring to the core journal literature with the theme of "Beijing-Tianjin-Hebei Coordinated Development", the literature combing method is adopted to determine the "document reference" index for the coordinated development of the Beijing-Tianjin-Hebei region. Combining the two types of indicators of "policy orientation" and "document reference", the initial indicators for the evaluation of coordinated development in the science and technology dimension (see "Table I") and economic, social and ecological dimensions (see "Table II") of Beijing-Tianjin-Hebei region can be obtained respectively.

TABLE I. INITIAL INDICATORS OF SCIENCE AND TECHNOLOGY DIMENSIONS FOR THE EVALUATION OF COORDINATED DEVELOPMENT IN THE BEIJING-TIANJIN-HEBEI REGION

Dimension	Index	
	First-level indicators	Secondary index
Science and Technology	Technological innovation investment	R&D staff
		Full-time equivalent of R&D personnel
		Full-time equivalent of R&D personnel in high-tech industry
	Technological innovation environment	Internal expenditure of R&D expenses
		R&D internal expenditure in high-tech industry
		Expenditures for new product development in high-tech industries
		R&D investment intensity
		Local financial science and technology expenditure
	Scientific and technological innovation output	Number of patent applications accepted
		Number of granted patent applications
		Number of authorized invention patent applications
	Scientific and technological innovation effect	Number of patents per 10,000 people
		Technology market turnover
		Sales revenue of new products in high-tech industry
		New product export of high-tech industry

It can be seen from "Table I" that the technological dimension mainly includes 4 first-level indicators and 15 secondary indicators. Among them, scientific and technological innovation input includes 3 secondary indicators, scientific and technological innovation environment includes 5 secondary indicators, scientific and technological innovation output includes 3 secondary indicators, and scientific and technological innovation effectiveness includes 4 secondary indicators.

It can be seen from "Table II" that the economic dimension mainly includes 3 primary indicators and 13 secondary indicators. Among them, economic scale includes 8 secondary indicators, economic structure includes 3 secondary indicators, and economic quality includes 2 secondary indicators. The social dimension mainly includes 6 primary indicators and 21 secondary indicators. Among them, people's livelihood improvement includes 3 secondary indicators; education governance includes 4 secondary indicators; medical improvement includes 3 secondary indicators; insurance scale includes 5 secondary indicators; transportation scale includes 4 secondary indicators; and post and telecommunications scale includes 2 secondary indicators. The ecological dimension mainly includes 3 primary indicators and 14 secondary indicators. Among them, resource consumption includes 3 secondary indicators; ecological protection includes 6 secondary indicators; and environmental governance includes 5 secondary indicators. Integrating the four dimensions of technology, economy, society, and ecology, the rating index system includes a total of 63 initial indicators.

TABLE II. INITIAL INDICATORS OF ECONOMIC, SOCIAL AND ECOLOGICAL DIMENSIONS OF THE COORDINATED DEVELOPMENT EVALUATION OF THE BEIJING-TIANJIN-HEBEI REGION

Dimension	Indicator		Dimension	Indicator	
	First-level Indicator	Secondary index		First-level Indicator	Secondary index
Economics	Economic scale	Per capita GDP	Society	Improvement of people's livelihood	Urban registered unemployment rate
		GDP growth rate			Year-end balance of RMB savings deposits of urban and rural residents
		General budget revenue of local governments			Per capita disposable income of urban residents
		Total Investment in Fixed Assets		Educational governance	Enrollment of ordinary colleges and universities
		Total retail sales of social consumer goods			Student-teacher ratio in ordinary universities
		The total import and export volume of the place where the business entity is located			Local fiscal expenditure on education
		Added value of secondary industry			Number of persons aged 6 and above with education
		Industrial added value		Medical improvement	Number of medical and health institutions
	Economic structure	The ratio of output value of primary industry to GDP			Number of beds in medical and health institutions
		The ratio of output value of the secondary industry to GDP			Number of health personnel
		The ratio of output value of tertiary industry to GDP		Insurance scale	Number of participants in the basic medical insurance for urban employees at the end of the year
	Economic quality	Overall labor productivity			Number of urban employees participating in pension insurance
		Urbanization rate of permanent population			Number of people participating in unemployment insurance
Ecology	Resource consumption	Total water consumption			Number of participants in work injury insurance at the end of year
		Energy consumption			Number of people participating in maternity insurance at the end of the year
		Energy consumption per unit GDP		Traffic scale	Volume of freight traffic
	Ecological Protection	Forest coverage rate			Passenger capacity
		Forest growing stock			Highway mileage
		Local fiscal expenditure on environmental protection			Length of railroad lines in service
		Investment in industrial pollution control was completed		Post and telecommunications scale	Total gross of post and telecommunications business
		Investment in wastewater treatment project was completed			Year-end mobile phone users
		Investment in the waste gas treatment project was completed			
	Environmental governance	Household garbage clearance volume			
		Discharge amount of wastewater			
		Chemical oxygen demand emissions			
		Ammonia nitrogen emissions			
		Sulfur dioxide emissions			

B. Quantitative screening methods of evaluation indicators

As the science and technology, economic, social, and ecological dimensions of the Beijing-Tianjin-Hebei region involve many related indicators, the principal component — correlation analysis method is used to screen the indicators for dimensionality reduction. Principal component analysis is using the idea of dimensionality reduction to convert multiple indicators into a few comprehensive indicators (principal components), in which each principal component can reflect most of the information of the original variable. The principal component analysis method is used to

screen the indicators of science and technology, economy, society and ecological dimensions, and the indicators that have a large contribution to the principal components are screened out, and the indicators of science and technology, economy, society and ecology are obtained. At the same time, due to the high correlation between the indicators and the phenomenon of information overlap, the principal component analysis method cannot solve this problem. At this time, the correlation analysis method is used to supplement the screening of indicators. The correlation analysis method can eliminate the index with high repeatability by calculating the correlation coefficient between the indexes, and eliminate the influence of the linear correlation of the indexes. This paper adopts the principal component analysis — correlation analysis method. And the initial index screening steps for the evaluation of the coordinated development of the Beijing-Tianjin-Hebei region are as the following:

First, it can use principal component analysis to quantitatively pre-screen the initial indicators according to the factor loading. Then, it can screen the index with the principal component factor load greater than 0.9, and the second or third principal component factor load with the largest absolute value.

Second, it is required to use correlation analysis method. According to the size of correlation coefficient, a secondary quantitative screening on the remaining indicators after principal component analysis and screening can be performed. In this paper, the author calculates the correlation coefficients between any two indicators under the secondary indicator level in the dimensions of science and technology, economy, society, and ecology in the Beijing-Tianjin-Hebei region, and sets the threshold value M ($0 < M < 1$) of the index correlation coefficient. If the correlation coefficient of the two indicators is less than the threshold value M, then two indicators are retained at the same time; if the correlation coefficient between the two indicators is greater than the threshold value M, the indicator with the smaller absolute value of the factor load in the two indicators is deleted, that is, the indicator with small influence on the evaluation result. In this paper, the threshold value M = 0.9.

IV. EMPIRICAL RESEARCH

A. The design of scientific and technological indicators for the evaluation of coordinated development in the Beijing-Tianjin-Hebei region

According to "Table I", the technological dimension mainly includes technological innovation input indicator, technological innovation environment indicator, technological innovation output indicator, technological innovation effectiveness indicator. R&D personnel (X_1), R&D personnel full-time equivalent (X_2), and R&D personnel full-time equivalent in high-tech industry (X_3) are selected as indicators of technological innovation input; R&D internal expenditure (X_4), R&D internal expenditure in high-tech industry (X_5) expenditures for new product development in high-tech industries (X_6), R&D expenditure input intensity (X_7), and local financial science and technology expenditures (X_8) are indicators of the technological innovation environment; number of patent applications granted (X_9), number of patent applications accepted (X_{10}), number of invention patent applications authorized (X_{11}) are indicators of technological innovation output; the number of patents per 10,000 population (X_{12}), technology market turnover (X_{13}), sales revenue of new products in high-tech industries (X_{14}), the export of new industrial products in high-tech industry (X_{15}) are the indicators of the effectiveness of technological innovation. According to the significance of each indicator, the principal component analysis method is used to make the first quantitative screening of the initial indicators of technological innovation. Using SPSS20 software, KMO and Bartlett tests were performed on 15 science and technology indicators in Beijing, Tianjin, Hebei, and Beijing-Tianjin-Hebei from 2009 to 2017 (see "Table III").

TABLE III. KMO AND BARTLETT TEST OF TECHNOLOGICAL INDICATORS

Items		Value
Kaiser-Meyer-Olkin measurement with sufficient sampling		0.767
Bartlett's sphericity test	The approximate chi-square	1554.987
	Sig	0
	The total variance of the interpretation	86.36%

The test results show that the KMO value of science and technology indicators is 0.767, which is greater than the minimum value 0.5, indicating that the initial indicator structure is reasonable and suitable for factor analysis. The Sig value of the Bartlett sphericity test is 0, indicating that there is a correlation between the science and technology indicators, and the principal component can be extracted. The extracted principal components can explain 86.36% of the original indicator information. First, it is required to quantitatively pre-screen the initial scientific and technological indicators according to the size of the factor loading, and screen out the indicators with the principal component factor loading greater than 0.9 and the secondary or third principal component factor loading with the largest absolute value, and obtain the

principal component screening results of the scientific and technological indicators (see "Table IV").

TABLE IV. PRE-SCREENING RESULTS OF PRINCIPAL COMPONENT OF SCIENTIFIC AND TECHNOLOGICAL INDICATORS

Indicator layer	First principal component factor loading	Secondary principal component factor loading	Principal component screening results
X_1	0.961	-0.214	Retain
X_2	0.958	-0.206	Retain
X_3	0.945	-0.262	Retain
X_4	0.362	0.384	Delete
X_5	0.985	-0.052	Retain
X_6	0.989	-0.001	Retain
X_7	0.564	0.646	Delete
X_8	0.992	-0.017	Retain
X_{10}	0.971	-0.028	Retain
X_{11}	0.938	0.216	Retain
X_{12}	0.417	0.807	Retain
X_{13}	0.95	0.226	Retain
X_{14}	0.922	-0.245	Retain
X_{15}	0.602	-0.5	Delete

Secondly, it is required to carry out the secondary quantitative screening of scientific and technological indicators according to the size of the correlation coefficient. It is necessary to calculate the correlation coefficient (see "Table V") between any two indicators in the secondary indicator layer retained after passing the principal component screening, and use the threshold M value for screening. Among them, under the investment in technological innovation, R&D personnel (X_1), R&D personnel full-time equivalent (X_2), and R&D personnel equivalent full-time equivalent in high-tech industry (X_3) are highly correlated, which is greater than the threshold value 0.9, but R&D personnel (X_1) has the largest factor loading among the three and has the largest contribution to the principal component, so X_1 is retained. Under the environment of technological innovation, R&D internal expenditures in high-tech industries (X_5), expenditures for new product development in high-tech industries (X_6), and local fiscal science and technology expenditures (X_8)are highly correlated, greater than the threshold value 0.9, but the local fiscal science and technology expenditure (X_8) has the largest factor loading among the three, and has the largest contribution to the principal component, so X_8 is retained. Under the output of technological innovation, the number of patent applications granted (X_9), the number of patent applications accepted (X_{10}), and the number of invention patent applications accepted (X_{11}) are highly correlated, which is greater than the threshold value 0.9. However, the number of patent applications accepted (X_{10}) has the largest factor loading among the three and has the largest contribution to the principal component, so X_{10} is retained. Under the effect of scientific and technological innovation, the correlation coefficient of patent ownership per 10,000 population (X_{12}), technology market turnover (X_{13}), and high-tech industry new product sales revenue (X_{14}) is less than the threshold value 0.9, so X_{12}, X_{13} and X_{14} are retained.

TABLE V. CORRELATION COEFFICIENTS OF SCIENTIFIC AND TECHNOLOGICAL INDICATORS

	X_1	X_2	X_3	X_5	X_6	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_1	1.000	0.998	0.955	0.944	0.954	0.966	0.923	0.923	0.869	0.191	0.884	0.912
X_2	0.998	1.000	0.946	0.933	0.950	0.960	0.904	0.905	0.856	0.198	0.882	0.917
X_3	0.955	0.946	1.000	0.970	0.944	0.927	0.926	0.936	0.819	0.168	0.814	0.924
X_5	0.944	0.933	0.970	1.000	0.985	0.970	0.981	0.985	0.919	0.366	0.912	0.902
X_6	0.954	0.950	0.944	0.985	1.000	0.982	0.964	0.963	0.933	0.405	0.950	0.892
X_8	0.966	0.960	0.927	0.970	0.982	1.000	0.967	0.964	0.944	0.400	0.959	0.905
X_9	0.923	0.904	0.926	0.981	0.964	0.967	1.000	0.991	0.957	0.391	0.929	0.841
X_{10}	0.923	0.905	0.936	0.985	0.963	0.964	0.991	1.000	0.938	0.390	0.915	0.874
X_{11}	0.869	0.856	0.819	0.919	0.933	0.944	0.957	0.938	1.000	0.532	0.978	0.753
X_{12}	0.191	0.198	0.168	0.366	0.405	0.400	0.391	0.390	0.532	1.000	0.571	0.257
X_{13}	0.884	0.882	0.814	0.912	0.950	0.959	0.929	0.915	0.978	0.571	1.000	0.791
X_{14}	0.912	0.917	0.924	0.902	0.892	0.905	0.841	0.874	0.753	0.257	0.791	1.000

Through the use of principal component analysis and related analysis methods, it is finally determined that R&D personnel, local financial science and technology expenditures, the number of patent

applications accepted, the number of patents per 10,000 people, the turnover of the technology market, and the sales revenue of new products in high-tech industries are the technology dimension indicators (see "Table VI").

TABLE VI. SCIENTIFIC AND TECHNOLOGICAL INDICATORS FOR THE EVALUATION OF COORDINATED DEVELOPMENT IN THE BEIJING-TIANJIN-HEBEI REGION

Dimension	Indicator		Unit
	First-level indicators	Secondary index	
Scientific and technological innovation	Scientific and technological innovation investment	R&D staff	Person
	Technological innovation environment	Local financial science and technology expenditure	100 million yuan
	Scientific and technological innovation output	Number of patent applications accepted	Piece
		Number of patents per 10,000 people	Piece/ten thousand persons
	Scientific and technological innovation effect	Technology market turnover	100 million yuan
		Sales revenue of new products in high-tech industry	100 million yuan

B. Design of economic indicators for the evaluation of coordinated development in the Beijing-Tianjin-Hebei region

According to "Table I", economic indicators mainly include economic scale indicator, economic structure indicator and economic quality indicator. It is required to select per capita GDP (Y_1), GDP growth rate (Y_2), local fiscal general budget revenue (Y_3), total social fixed asset investment (Y_4), total retail sales of consumer goods (Y_5), total import and export volume of the place where the business entity is located (Y_6), the added value of the secondary industry (Y_7) and industrial added value (Y_8) are indicators of economic scale; the ratio of output value of primary industry to GDP (Y_9), the ratio of output value of secondary industry to GDP (Y_{10}), and the ratio of output value of tertiary industry to GDP (Y_{11}) are indicators of economic structure; the overall labor productivity (Y_{12}) and the urbanization rate of permanent population (Y_{13}) are indicators of economic quality. According to the significance of each indicator, the principal component analysis method is used to make quantitative pre-screening of economic indicators. It is required to use SPSS20 to perform KMO and Bartlett tests on 13 economic indicators in Beijing, Tianjin, Hebei, and Beijing-Tianjin-Hebei from 2009 to 2017 (see "Table VII").

TABLE VII. KMO AND BARTLETT TEST OF ECONOMIC INDICATORS

Items		Value
Kaiser-Meyer-Olkin measurement with sufficient sampling		0.683
Bartlett's sphericity test	The approximate chi-square	1363.098
	Sig	0
	The total variance of the interpretation	91.5%

The test results show that the KMO value of economic indicators is 0.683, which is greater than the minimum value 0.5, indicating that the initial indicator structure is reasonable and suitable for factor analysis; the Sig value of Bartlett's sphericity test is 0, indicating that there is a correlation between economic indicators, and the principal component can be extracted. The extracted principal components can explain 91.5% of the original indicator information. According to the size of the factor loading, it is required to carry out a secondary quantitative screening of economic development indicators, and screen out the indicators with the first principal component factor loading greater than 0.9 and the second or third principal component factor loading with the largest absolute value. Then, the principal component screening results of the economic indicators are obtained (see "Table VIII").

TABLE VIII. PRE-SCREENING RESULTS OF PRINCIPAL COMPONENT OF ECONOMIC INDICATORS

Indicator layer	First principal component factor loading	Second principal component factor loading	The third principal component factor loading	Principal component screening results
Y_1	0.849	-0.236	-0.138	Delete
Y_2	-0.059	-0.205	0.958	Retain
Y_3	0.242	0.954	-0.081	Retain
Y_4	-0.349	0.891	-0.219	Delete
Y_5	-0.046	0.982	-0.135	Retain
Y_6	0.472	0.781	0.242	Delete
Y_7	-0.405	0.892	-0.136	Delete

Indicator layer	First principal component factor loading	Second principal component factor loading	The third principal component factor loading	Principal component screening results
Y_8	-0.411	0.900	-0.070	Retain
Y_9	-0.880	0.163	-0.158	Delete
Y_{10}	-0.875	-0.142	0.021	Delete
Y_{11}	0.957	0.070	0.028	Retain
Y_{12}	0.956	-0.063	-0.114	Retain
Y_{13}	0.888	-0.333	0.089	Delete

According to the size of the correlation coefficient, the second quantitative screening of economic indicators is carried out. By calculating the correlation coefficient between any two indicators in the secondary index layer retained after quantitative pre-screening (see "Table IX"), the threshold value M is used for screening. Among them, under the economic scale, local fiscal general budget revenue (Y_3), and total retail sales of social consumer goods (Y_5) are highly correlated, which is greater than the threshold value 0.9, but the factor loading of total retail sales of social consumer goods (Y_5) is the largest, which contributes the most to the principal component. Therefore, Y_5 is retained. The correlation coefficient among GDP growth rate (Y_2), total retail sales of consumer goods (Y_5) and industrial added value (Y_8) is less than the threshold value 0.9, so all of them are retained. Under the economic structure and economic quality, the remaining indicators are the proportion of tertiary industry output value to GDP (Y_{11}) and total labor productivity (Y_{12}), so they are retained.

TABLE IX. CORRELATION COEFFICIENT OF ECONOMIC INDICATORS

	Y_2	Y_3	Y_5	Y_8	Y_{11}	Y_{12}
Y_2	1.000	-0.270	-0.312	-0.222	-0.058	-0.118
Y_3	-0.270	1.000	0.944	0.765	0.272	0.189
Y_5	-0.312	0.944	1.000	0.898	0.028	-0.080
Y_8	-0.222	0.765	0.898	1.000	-0.372	-0.448
Y_{11}	-0.058	0.272	0.028	-0.372	1.000	0.909
Y_{12}	-0.118	0.189	-0.080	-0.448	0.909	1.000

By using principal component analysis and correlation analysis, GDP growth rate (Y_2), total retail sales of consumer goods (Y_5), industrial added value (Y_8), the proportion of tertiary industry output value to GDP (Y_{11}), and total labor productivity (Y_{12}) are finally determined as economic indicators (see "Table X").

TABLE X. ECONOMIC INDICATORS OF THE EVALUATION OF COORDINATED DEVELOPMENT IN BEIJING-TIANJIN-HEBEI REGION

Dimension	Indicator		Unit
	First-level indicators	Secondary index	
Economics	Economic scale	GDP growth rate	%
		Total retail sales of social consumer goods	100 million yuan
		Industrial added value	100 million yuan
	Economic structure	The ratio of output value of tertiary industry to GDP	%
	Economic quality	Overall labor productivity	Yuan/person

C. The design of social indicators for the evaluation of coordinated development in the Beijing-Tianjin-Hebei region

According to "Table I", social indicators mainly include people's livelihood improvement, education governance, scale of post and telecommunications, scale of transportation, improvement of medical treatment, and scale of insurance. The urban registered unemployment rate (Z_1), RMB deposit balance of urban and rural residents at year end (Z_2), and the per capita disposable income of urban residents (Z_3) are selected as indicators for improving people's livelihood; enrollment of ordinary colleges and universities (Z_4), ratio of students to teachers in ordinary colleges and universities (Z_5)), local fiscal expenditure on education (Z_6), the number of people aged 6 and over with education (Z_7) are indicators of education governance; total post and telecommunications business (Z_8) and year-end mobile phone users (Z_9) are indicators of post and telecommunications scale; freight volume (Z_{10}), passenger traffic (Z_{11}), highway mileage (Z_{12}), railway operating mileage (Z_{13}) are the traffic scale indicators; the number of beds in medical and health institutions (Z_{14}), the number of medical and health institutions (Z_{15}), and the number of health personnel (Z_{16}) are

medical improvement indicator; the number of urban employees participating in pension insurance (Z_{17}), the number of persons participating unemployment insurance (Z_{18}), the number of urban employees participating in basic medical insurance at the end of the year (Z_{19}), the number of participants participating in work injury insurance at the end of the year (Z_{20}), and the number of participants participating maternity insurance at the end of the year (Z_{21}) are indicators of insurance scale. According to the significance of each indicator, the principal component analysis method is used to make the quantitative screening of social indicators. In order to make the sample structure reasonable, the 21 indicators were divided into two parts for testing. First, it is required to perform KMO and Bartlett tests on the first 16 livelihood and welfare indicators and the last 5 social security indicators in Beijing, Tianjin, Hebei, and Beijing-Tianjin-Hebei from 2009 to 2017 (see "Table XI").

TABLE XI. KMO AND BARTLETT TEST OF SOCIAL INDICATORS

Items		**Well-being of the people**	**Social insurance**
		Value	Value
Kaiser-Meyer-Olkin measurement with sufficient sampling		0. 808	0.742
Bartlett's sphericity test	The approximate chi-square	1650.567	578.545
	Sig	0	0
	The total variance of the interpretation	89.90%	98.09%

The test results show that the KMO value of the people's livelihood and welfare indicator is 0.808, and that of the social security is 0.742, both of which are greater than the minimum value 0.5, indicating that the initial indicator structure is reasonable and suitable for factor analysis; the Sig value of the Bartlett sphericity test is 0, indicating that there is a correlation between social indicators, and the principal component can be extracted. The extracted principal components can explain 89.90% and 98.09％ of the original indicator information respectively. First, it is required to perform the first quantitative screening of social indicators according to the size of the factor loading, and screen out the indicators with the principal component factor loading greater than 0.9 and the second or third principal component factor loading with the largest absolute value, so as to obtain the principal component screening results of the social indicators (see "Table XII").

TABLE XII. PRE-SCREENING RESULTS OF PRINCIPAL COMPONENTS OF SOCIAL INDICATORS

Indicator	**First principal component Factor loading**	**Second principal component Factor loading**	**The third principal component Factor loading**	**Principal component screening Result**
Z_1	0.257	0.907	0.161	Retain
Z_2	0.907	-0.373	0.106	Retain
Z_3	-0.132	-0.786	0.444	Delete
Z_4	0.900	-0.291	0.220	Retain
Z_5	0.359	-0.044	0.655	Retain
Z_6	0.977	0.007	-0.128	Retain
Z_7	0.174	0.816	0.246	Delete
Z_8	0.817	-0.325	-0.083	Delete
Z_9	0.972	-0.159	0.072	Retain
Z_{10}	0.958	0.235	0.006	Retain
Z_{11}	0.651	-0.251	-0.568	Delete
Z_{12}	0.959	0.224	-0.021	Retain
Z_{13}	0.982	0.137	0.030	Retain
Z_{14}	0.994	0.016	0.035	Retain
Z_{15}	0.939	0.254	-0.104	Retain
Z_{16}	0.992	-0.116	-0.013	Retain
Z_{17}	0.991			Retain
Z_{18}	0.984			Retain
Z_{19}	0.997			Retain
Z_{20}	0.997			Retain
Z_{21}	0.983			Retain

According to the size of the correlation coefficient, the second quantitative screening of social indicators is carried out. By calculating the correlation coefficient (see "Table XIII") in the secondary index layer retained

after quantitative pre-screening, the threshold value M is used for screening. Among them, with the improvement of people's livelihood, the correlation coefficient between the urban registered unemployment rate (Z_1) and the RMB deposit balance of urban and rural residents at year end (Z_2) is less than the threshold value 0.9, while Z_1 and Z_2 are retained; under the governance of education, the correlation coefficient among the enrollment of ordinary colleges and universities (Z_4), the ratio of students to teachers in colleges and universities (Z_5) and the local financial expenditure on education (Z_6) is lower than the threshold value 0.9, while Z_5 and Z_6 are retained; under the scale of post and telecommunications, the end-of-year mobile phone users (Z_9) are retained; under the traffic scale, freight volume (Z_{10}), highway mileage (Z_{12}) and railway operating mileage (Z_{13}) are highly correlated, which are greater than the threshold value 0.9, but the factor loading of railway operating mileage (Z13) is the largest, which contributes the most to the principal component, so Z_{13} is retained; with the medical improvement, the number of beds in health institutions (Z_{14}), the number of medical institutions (Z_{15}) and the number of health personnel (Z_{16}) are highly correlated, which is greater than the threshold value of 0.9, but the factor loading of the number of beds in medical and health institutions (Z_{14}) is the largest, which contributes the most to the principal component, so Z_{14} is retained. Under the scale of insurance, the number of urban employees participating in endowment insurance (Z_{17}), unemployment insurance (Z_{18}), urban employees' basic medical insurance (Z_{19}), industrial injury insurance (Z_{20}) and birth insurance (Z_{21}) are highly correlated, which is higher than the threshold value of 0.9. However, compared with the number of insured at the end of the year (Z_{20}), the number of urban workers participating in the basic medical insurance at the end of the year (Z_{19}) is frequently used, so Z_{19} is retained.

TABLE XIII. CORRELATION COEFFICIENT OF SOCIAL INDICATORS

	Z_1	Z_2	Z_4	Z_5	Z_6	Z_9	Z_{10}	Z_{12}	Z_{13}	Z_{14}	Z_{15}	Z_{16}	Z_{17}	Z_{18}	Z_{19}	Z_{20}	Z_{21}
Z_1	1.000	-0.073	0.262	0.791	0.034	0.124	0.465	0.426	0.372	0.275	0.427	0.148	-0.088	-0.333	-0.206	-0.174	-0.143
Z_2	-0.073	1.000	0.870	-0.099	0.983	0.968	0.794	0.774	0.841	0.906	0.725	0.945	0.987	0.914	0.946	0.966	0.972
Z_4	0.262	0.870	1.000	0.162	0.858	0.932	0.927	0.918	0.940	0.955	0.913	0.970	0.894	0.787	0.859	0.876	0.835
Z_5	0.791	-0.099	0.162	1.000	0.003	0.055	0.345	0.305	0.253	0.178	0.319	0.080	-0.106	-0.294	-0.204	-0.181	-0.135
Z_6	0.034	0.983	0.858	0.003	1.000	0.961	0.812	0.768	0.840	0.900	0.710	0.926	0.968	0.868	0.912	0.934	0.957
Z_9	0.124	0.968	0.932	0.055	0.961	1.000	0.913	0.898	0.941	0.976	0.860	0.986	0.952	0.832	0.890	0.916	0.930
Z_{10}	0.465	0.794	0.927	0.345	0.812	0.913	1.000	0.977	0.981	0.965	0.956	0.925	0.775	0.585	0.683	0.720	0.726
Z_{12}	0.426	0.774	0.918	0.305	0.768	0.898	0.977	1.000	0.991	0.967	0.991	0.927	0.751	0.567	0.661	0.701	0.701
Z_{13}	0.372	0.841	0.940	0.253	0.840	0.941	0.981	0.991	1.000	0.990	0.970	0.959	0.817	0.641	0.730	0.769	0.770
Z_{14}	0.275	0.906	0.955	0.178	0.900	0.976	0.965	0.967	0.990	1.000	0.940	0.986	0.886	0.729	0.807	0.843	0.841
Z_{15}	0.427	0.725	0.913	0.319	0.710	0.860	0.956	0.991	0.970	0.940	1.000	0.905	0.716	0.547	0.637	0.672	0.663
Z_{16}	0.148	0.945	0.970	0.080	0.926	0.986	0.925	0.927	0.959	0.986	0.905	1.000	0.943	0.829	0.891	0.916	0.904
Z_{17}	-0.088	0.987	0.894	-0.106	0.968	0.952	0.775	0.751	0.817	0.886	0.716	0.943	1.000	0.954	0.982	0.991	0.982
Z_{18}	-0.333	0.914	0.787	-0.294	0.868	0.832	0.585	0.567	0.641	0.729	0.547	0.829	0.954	1.000	0.990	0.979	0.951
Z_{19}	-0.206	0.946	0.859	-0.204	0.912	0.890	0.683	0.661	0.730	0.807	0.637	0.891	0.982	0.990	1.000	0.996	0.967
Z_{20}	-0.174	0.966	0.876	-0.181	0.934	0.916	0.720	0.701	0.769	0.843	0.672	0.916	0.991	0.979	0.996	1.000	0.969
Z_{21}	-0.143	0.972	0.835	-0.135	0.957	0.930	0.726	0.701	0.770	0.841	0.663	0.904	0.982	0.951	0.967	0.969	1.000

Through principal component analysis and related analysis methods, the town's registered unemployment rate (Z_1), RMB deposit balance of urban and rural residents at year end (Z_2), the number of students enrolled in ordinary colleges and universities (Z_4), the student-teacher ratio in ordinary colleges and universities (Z_5), and local financial government expenditure on education (Z_6), mobile phone users at the end of the year (Z_9), road operating mileage (Z_{13}), the number of beds in medical and health institutions (Z_{14}), and the number of participants in the basic medical insurance for urban employees at the end of the year (Z_{19}) are social development indicators (see "Table XIV") .

TABLE XIV. SOCIAL INDICATORS FOR THE EVALUATION OF COORDINATED DEVELOPMENT IN THE BEIJING-TIANJIN-HEBEI REGION

Dimension	**Indicator**		**Unit**
	First-level indicators	Secondary index	
Society	Improvement of people's livelihood	Urban registered unemployment rate	%
		Year-end balance of RMB savings deposits of urban and rural residents	100 million yuan
	Educational governance	Enrollment of ordinary colleges and universities	Thousands of people
		Student-teacher ratio in ordinary universities	-
		Local fiscal expenditure on education	100 million yuan
	Post and telecommunications scale	Year-end mobile phone users	Thousands of households
	Traffic scale	Length of railroad lines in service	Thousands of kilometres
	Medical improvement	Number of beds in medical and health institutions	Thousands of beds

	Insurance scale	Number of participants in the basic medical insurance for urban employees at the end of the year	Thousands of people

D. Ecological indicator design of the evaluation for coordinated development in Beijing-Tianjin-Hebei region

According to "Table I", ecological indicators mainly include resource consumption, ecological protection and environmental pollution. Energy consumption (V_1), energy consumption per unit GDP (V_2) and total water consumption (V_3) are selected as resource consumption indicators; forest coverage rate (V_4), forest stock volume (V_5), local fiscal environmental protection expenditure (V_6) and investment in wastewater treatment project completed (V_7), investment in waste water treatment project (V_8) and investment completed in waste gas treatment project (V_9) are ecological protection indicators; household garbage clearance volume (V_{10}), wastewater discharge (V_{11}), COD demand (v_{12}), ammonia nitrogen emission (V_{13}) and sulfur dioxide emission (V_{14}) are environmental pollution indicators. The principal component analysis method is used to make the quantitative screening of ecological indicators. Firstly, it is required to perform KMO and Bartlett test on 14 ecological indicators of Beijing, Tianjin, Hebei and Beijing-Tianjin-Hebei region from 2009 to 2017 respectively (see "Table XV").

TABLE XV. KMO AND BARTLETT TESTS OF ECOLOGICAL INDICATORS

Items		**Value**
Kaiser-Meyer-Olkin measurement with sufficient sampling		0.742
Bartlett's sphericity test	The approximate chi-square	1337.745
	Sig	0
	The total variance of the interpretation	89.60%

The test results show that the KMO value of the ecological indicators is 0.742, which is greater than the minimum value of 0.5, indicating that the initial indicator structure is reasonable and suitable for factor analysis; the Sig value of the Bartlett sphericity test is 0, indicating that there is a correlation between ecological indicators, and the principal component can be extracted. The extracted principal components can explain 89.60% of the original indicator information. First, it is required to carry out quantitative pre-screening of ecological indicators according to the size of the factor loading, and screen out the indicator with the principal component factor loading greater than 0.9 and the second or third principal component factor loading with the largest absolute value, and obtain the principal component screening results of the ecological indicators (see "Table XVI") .

TABLE XVI. PRE-SCREENING RESULTS OF PRINCIPAL COMPONENTS OF ECOLOGICAL INDICATORS

Indicator	**First principal component factor loading**	**Secondary principal component factor loading**	**Third principal component factor loading**	**Principal component screening results**
V_1	0.978	0.052	0.033	Retain
V_2	0.537	-0.661	0.275	Delete
V_3	0.974	-0.027	0.159	Retain
V_4	0.031	0.595	0.640	Retain
V_5	0.957	-0.055	0.189	Retain
V_6	0.575	0.726	-0.127	Retain
V_7	0.826	0.116	-0.491	Delete
V_8	0.739	-0.443	0.048	Delete
V_9	0.779	0.158	-0.492	Delete
V_{10}	0.770	0.542	0.163	Delete
V_{11}	0.959	0.203	0.078	Retain
V_{12}	0.912	-0.177	-0.040	Retain
V_{13}	0.929	-0.305	0.169	Retain
V_{14}	0.958	-0.118	-0.030	Retain

Secondly, according to the size of the correlation coefficient, the secondary quantitative screening of ecological indicators is carried out. By calculating the correlation coefficient between any two indicators in the secondary index layer retained after quantitative pre-screening (see "Table III-Table XVII"), the threshold value M is used for screening. Among them, under resource consumption, energy consumption (V_1) is highly correlated with total water consumption (V_3), which is greater than the threshold value of 0.9, but the factor loading of energy consumption (V_1) is the largest, so the energy consumption (V_1) is retained. Under ecological protection, the correlation coefficient among forest coverage rate (V_4), forest growing stock

(V_5) and local fiscal expenditure on environmental protection (V_6) is less than the threshold value of 0.9, so they are all retained. Under the environmental treatment, the correlation coefficient among total wastewater discharge (V_{11}), COD emission (V_{12}), ammonia nitrogen emission (V_{13}) and sulfur dioxide emission (V_{14}) is less than the threshold value of 0.9, so they are all retained.

TABLE XVII. CORRELATION COEFFICIENT OF ECOLOGICAL INDICATORS

	V_1	**V_3**	**V_4**	**V_5**	**V_6**	**V_{11}**	**V_{12}**	**V_{13}**	**V_{14}**
V_1	1.000	0.984	-0.002	0.967	0.636	0.968	0.836	0.892	0.916
V_3	0.984	1.000	0.061	0.994	0.557	0.945	0.839	0.935	0.906
V_4	-0.002	0.061	1.000	0.083	0.260	0.147	-0.008	-0.044	-0.028
V_5	0.967	0.994	0.083	1.000	0.531	0.912	0.824	0.927	0.889
V_6	0.636	0.557	0.260	0.531	1.000	0.675	0.342	0.276	0.440
V_{11}	0.968	0.945	0.147	0.912	0.675	1.000	0.825	0.851	0.894
V_{12}	0.836	0.839	-0.008	0.824	0.342	0.825	1.000	0.804	0.881
V_{13}	0.892	0.935	-0.044	0.927	0.276	0.851	0.804	1.000	0.820
V_{14}	0.916	0.906	-0.028	0.889	0.440	0.894	0.881	0.820	1.000

Through principal component analysis and correlation analysis, energy consumption (V_1), forest coverage rate (V_4), forest growing volume (V_5), local fiscal environmental protection expenditure (V_6), total wastewater discharge (V_{11}), COD emission (V_{12}), ammonia nitrogen emission (V_{13}), and sulfur dioxide emission (V_{14}) are finally determined as ecological indicators (see "Table XVIII").

TABLE XVIII. ECOLOGICAL INDICATORS OF COORDINATED DEVELOPMENT EVALUATION IN BEIJING-TIANJIN-HEBEI REGION

Dimension	**Indicator**		**Unit**
	First-level indicators	Secondary index	
Ecology	Resource consumption	Energy consumption	Ten thousand tons
	Ecological protection	Forest coverage rate	%
		Forest growing stock	Hundred million cubic meters
		Local fiscal expenditure on environmental protection	100 million yuan
	Environmental governance	Discharge amount of wastewater	Ten thousand tons
		Chemical oxygen demand emissions	Ten thousand tons
		Sulfur dioxide emissions	Ton
		Ammonia nitrogen emissions	Ten thousand tons

According to "Table VI", "Table X", "Table XIV" and "Table XVIII", the evaluation indicator system of coordinated development in Beijing-Tianjin-Hebei region is finally determined.

V. CONCLUSION

Based on relevant literature, practical empirical exploration, and overall situation of the Beijing-Tianjin-Hebei national economy and social development, and from the multi-dimensional perspectives of science and technology, economy, society, and ecology, the coordinated development evaluation indicator system of the Beijing-Tianjin-Hebei region is systematically designed. This indicator system can comprehensively reflect the differences in the development of different dimensions in the Beijing-Tianjin-Hebei region in different periods, make up for the lack of separate analysis of existing results from different dimensions, and better grasp the comprehensive problems in the development of the Beijing-Tianjin-Hebei region.

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