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ORIGINAL RESEARCH ARTICLE

Construction and empirical study of green development competitiveness evaluation index system under eco city planning

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ABSTRACT

Based on green development theory, green industrial system and green competitiveness, this paper puts forward the "green development theory, green industrial system and green competitiveness evaluation". This paper makes a horizontal comparative analysis of the actual development data of Tianjin, Beijing, Shanghai and Chongqing, and verifies the scientific, standardization, systematisms and rationality of the "green model" evaluation index system. Using the measurement method combining fuzzy analytic hierarchy process and entropy method to determine the index weight of the evaluation system, this paper makes an empirical study on the green development competitiveness of Tianjin from 2011 to 2016, and analyzes the development status and existing problems of Tianjin's green development competitiveness. Finally, aiming at the problems and weaknesses such as the lack of green social management function and the worrying overall quality of green environment in Tianjin, the paper puts forward countermeasures and suggestions to speed up the planning of green development demonstration area, make efforts to make up for the shortcomings of green environment, optimize the development strategy of industry city integration, build a smart ecological green city, publicize the concept of green development city and encourage the public to participate in green behavior.

Keywords: urban ecological planning; green development competitiveness; green model

1. Introduction

The idea of eco city planning originated from Howard's preferred combination of urban and rural areas—garden city and the city beautifying movement in Europe and America. This idea can be analyzed and understood from two aspects: Narrow sense and broad sense. In the narrow sense, it refers to introducing landscape ecological planning, ecological zoning, environmental mechanism planning, circular economy planning, ecological carrying capacity and other factors of ecological planning into urban planning based on ecological theory, so as to clarify the scale of urban development, transformation direction and implementation mode, and ensure a safe distance between urban expansion and the "red line" of ecological protection, then build an efficient, harmonious and sustainable urban livable environment[1]. On the basis of covering the narrow definition, the broad idea adds the guidance of basic theories such as public interest theory and self-discipline theory. The integration of ecological planning extends to urban culture, talent education,

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science and technology and legal system. Under the concept of sustainable development, ecological values and circular low-carbon green development, it advocates the harmonious coexistence between man and nature and promotes the development of urban planning in the direction of ecology and intelligence. The central idea of eco city planning is to achieve the urban goal of green development through the construction of eco city[2].

At the end of the 20th century, the concept of eco city was put forward and prevailed all over the world. The outbreak of the international financial crisis at the end of 2008 promoted the transformation and development of the economic paradigm from circular economy and low-carbon economy to green economy[3]. With the enhancement of national economic strength and the improvement of people's awareness of environmental protection, the perspective of concern of the state and the people has gradually changed from benefit development to green development[4]. One of the five development concepts put forward at the Fifth Plenary Session of the 18th CPC Central Committee is green development. At the same time, the importance of non-governmental environmental protection organizations to green development has also been recognized by the government, in March this year, the Ministry of environmental protection and the Ministry of Civil Affairs indicated that they support qualified environmental protection social organizations to be established according to law and give financial support to give full play to the role of the people in green development. The green development of cities has become a hot issue in the national development of green economy. With the increasing maturity of green development theories such as environmental economics, circular economics and ecological economics, the concept and practice of urban green development began to penetrate into the fields of humanistic education, industrial economic development and ecological city planning. At the same time, the universality of the scope of penetration set a barrier for a comprehensive, systematic, objective and accurate evaluation of urban green development, it also poses a challenge to the comprehensive evaluation of urban green development competitiveness under eco city planning. Therefore, define the concept of urban green development competitiveness, construct the evaluation index system of urban green development competitiveness and determine the weight, summarize the current situation of urban green development through empirical research and analysis, find out the stumbling block of urban green development, and point out that the potential of urban green development has become an important measure to improve the competitiveness of green development.

2. Construction of "green model" of urban green development competitiveness index system

2.1. Theoretical basis

Urban competitiveness is an important topic for many scholars to study Chinese cities. The research core focuses on the definition of the concept of urban competitiveness, the construction of evaluation model and index system, and the selection of measurement methods[5]. First is the definition of Urban Competitiveness. From a single perspective, for example, from the perspective of productivity development, it is considered that urban competitiveness interprets the production efficiency of a city. From the perspective of resource allocation, it is also defined as the ability to attract, acquire and apply multiple factors. From the comprehensive perspective of market supply and demand and government services, it is pointed out that urban competitiveness is the ability of a city to provide public and private products. At the same time, in the past, the evaluation objects of urban competitiveness mainly focused on the competitiveness of harmony, sustainability, ecology, culture, knowledge and information. Second is the model construction of Urban Competitiveness. Foreign scholars have studied urban competitiveness earlier, and their important contributions to urban competitiveness evaluation models mainly include five types: explicit and im-

plicit dual framework theory, “3 + 1” theory, multi factor structure model, “maze” model and “pyramid” model[6–8]. Domestic scholars have studied the urban competitiveness evaluation model based on the academic foundation of foreign experts. After revision, there are mainly four achievements, namely “urban value chain” model, “flywheel” model, “bow and arrow” model and “wheel and rudder” model[9–11]. Third, the construction of its evaluation indicators is mostly from the three levels of target level, criterion level and indicator level. The indicators of three levels are set, and the difference of indicators lies in 2.5%. Among the three-level indicators, for example, the two-level indicators can be divided into basic competitiveness and core competitiveness, as well as hard competitiveness and soft competitiveness. The three-level indicators are divided and determined from the perspectives of economy, system, environment, ecology, infrastructure, social management and so on[12]. Fourth, the evaluation idea comes from the weight determination of statistical analysis. After processing the original data of the evaluation index system, the total score is calculated by weighting to comprehensively evaluate the level of urban competitiveness. Among them, analytic hierarchy process, entropy method, principal component analysis method and fuzzy comprehensive evaluation method are widely used.

Although domestic scholars are still in the stage of exploring the concept and evaluation of urban competitiveness, they are still trying to keep up with the pace of building green research institutions and international competitiveness. Similar studies in academic circles are mainly accumulated in the comprehensive evaluation index system of green development of a city, the research on green competitiveness of an industry or enterprise, the index system of regional green development competitiveness, etc. However, targeted to take the urban green development competitiveness as the research subject, build the evaluation model and establish the index system from the perspective of eco city planning. The research on the comprehensive evaluation of urban green development competitiveness through empirical analysis has not yet formed.

2.2. Construction of evaluation model and index system

Based on the theoretical guiding ideology of ecological theory, modern urban planning theory, public interest theory, self-discipline theory and competitive advantage theory[13,14], this paper draws lessons from the above theoretical basis, carries forward the advantages of existing relevant evaluation models, makes up for research gaps and deficiencies, and puts forward the evaluation model of urban green development competitiveness on the basis of defining the concept of urban green development competitiveness. The urban green development competitiveness mentioned in this paper refers to the “green power” to promote the transformation of urban green economy based on urban ecological planning, green resource development and green trade system, provide citizens with a healthy and sustainable green environment for production, consumption and life, and promote urban green development. The evaluation model “green model” consists of green production, green governance, green industry, green society and green environment.

The evaluation index system of urban green development competitiveness needs to be comprehensive and targeted, scientific and relevant, controllable and practical, and has a wide range of coverage, so as to comprehensively, objectively and accurately reflect the main factors affecting urban green development competitiveness, and have comparable and measurable indicators to ensure that the evaluation factors and evaluation results of green development competitiveness tend to be optimized. Then analyze and summarize the main competitive advantages, development orientation and transformation direction of urban green development competitiveness, and put forward the corresponding development path and implementation countermeasures. The evaluation index system of urban green development competitiveness is divid-

ed into three levels. The first level indicators are five aspects of the evaluation model. The second level indicators are composed of eight influencing factors: production energy consumption A1, pollution emission A2, investment B1, treatment effect B2, industrial benefit C1, social management D1, living environment E1 and low-carbon travel E2. The third level indicators are composed of 20 subdivided influencing factors. The standard value, standard basis, index type and calculation method of the three-level index layer of the evaluation index system are shown in **Table 1**.

Table 1. Evaluation index system of urban green development competitiveness "green model"

Primary indicators (evaluation model)	Secondary indicators (influencing factors)	Tertiary indicators (impact factors)	Standard value	Standard basis	Calculation/acquisition method
Green production (A)	Production energy consumption (A1)	Proportion of added value of tertiary industry in GDP (A11)	\	\	(Added value of tertiary industry/GDP) × 100%
		Total energy consumption (A12)	\	\	Yearbook of Urban Statistics Bureau
		Energy consumption per RMB 10,000 GDP (A13)*	\	\	Energy consumption/GDP (RMB 10,000)
	Pollution emission (A2)	Industrial waste gas emission per RMB 10,000 GDP (A21)*	\	\	Industrial waste gas emission/GDP (RMB 10,000)
		RMB 10,000 GDP industrial wastewater discharge (A22)*	\	\	Industrial wastewater discharge/GDP (RMB 10,000)
		Output of industrial solid waste per RMB 10,000 GDP (A23)*	\	\	Output of industrial solid waste/GDP (RMB 10,000)
Green governance (B)	Investment intensity (B1)	Proportion of total investment in environmental protection in GDP (B11)	\	\	(Total investment in environmental protection/GDP) × 100%
		Proportion of industrial pollution control investment in industrial added value (B12)	\	\	(Industrial pollution control investment/industrial added value) × 100%
	Governance effect (B2)	Harmless treatment rate of domestic waste (B21)	80%	National city	China urban statistical yearbook
		Comprehensive utilization rate of industrial solid waste (B22)	54%	National standard	[Comprehensive utilization amount of industrial solid waste/(production amount of industrial solid waste + storage amount of comprehensive utilization in previous years)] × 100%
Green industry (C)	Industrial benefits (C1)	Energy processing conversion rate (C11)	\	\	(Energy processing and conversion output/energy processing) × 100%
		Proportion of environmental protection industry assets in total industrial assets (C12)	\	\	(Total assets of environmental protection industry/total assets of all industries) × 100%
Green society (D)	Social management (D1)	Green space protection level (D11)	12%	International City	(Protected green space area/total area of urban green space) × 100%
		Public participation (D12)	60%	International City	(Non official participation in the construction of green space area/total green space area) × 100%
		Citizen satisfaction (D13)	85%	International City	Number of people satisfied with the questionnaire/total number of people surveyed

Table 1. (*Continued*)

Primary indicators (evaluation model)	Secondary indicators (influencing factors)	Tertiary indicators (impact factors)	Standard value	Standard basis	Calculation/acquisition method
Green environment	Living environment (E1)	Forest coverage (E11)	50%	National City	China Urban Statistical Yearbook
		Per capita park green space area (E12)	60 m^2/person	Recommended by the United Nations	China Urban Statistical Yearbook
		Days of air quality reaching grade I and II standards (E13)	300 d	National Ecological Garden City standard	Yearbook of Urban Environmental Status Bulletin
	Low carbon travel (E2)	Bus traffic sharing rate (E21)	15%	National standard	(Public transport trips/total trips) × 100%
		Urban public transport ownership per 10,000 people (E22)	8	National standard	China urban statistical yearbook

Note: * is a negative indicator.

2.3. Connotation of "green model"

Firstly, based on the existing research results of urban competitiveness and green development evaluation at home and abroad, five criteria of green production, green governance, green industry, green society and green environment are selected to evaluate the urban green development competitiveness. These five criteria comprehensively reflect the basic meaning and overall characteristics of urban green development competitiveness, which is convenient for intuitive understanding.

Secondly, these five principles are interdependent and complementary, forming a dynamic circular and green development urban ecosystem, which constitutes the competitiveness of urban green development, so they are called "green model". Green production is the fundamental source of urban green development competitiveness, green governance is a powerful guarantee for green production and an essential link for cities to cultivate green development competitiveness. Industrial economy, social management and environmental quality are the basic composite ecosystem of cities. Green industry is the basic representation of the competitiveness of urban green development[15]. Green society is the social benefit consideration of urban green development competitiveness, and green environment is the value support for evaluating urban green development competitiveness.

Finally, in order to ensure the scientific and rationality of the evaluation indicators, the factor analysis method and analytic hierarchy process are used to eliminate the indicators with high correlation and retain the representative indicators, and then add some key indicators that can reflect the green development of the city. The fuzzy analytic hierarchy process is used to set the weight of the indicators so as to minimize the influence of human factors as much as possible.

3. Index weight setting of evaluation system

The index weight in the evaluation system represents the corresponding importance of the index in the whole system. In this paper, the Fuzzy Analytic Hierarchy Process (FAHP) is used to assign the index weight at all levels under the index system. The detailed steps are as follows.

(1) Build a hierarchy model.

(2) The elements at the upper level are used as the judgment basis, the elements at the same level at

the lower level are compared with each other, and the evaluation criteria are compared to determine the relative importance, so as to establish a fuzzy complementary judgment matrix. Suppose there are n factors in a certain layer, $X = \{x_1, x_2, \cdots, x_n\}$. When comparing the importance of the i-th factor and the j-th factor to a certain factor in the upper layer, the quantitative relative weight a_{ij} is used to describe it, then $a_{ij} = \frac{1}{a_{ij}}$, $A = (a_{ij})_{n\times n}$, A is called fuzzy complementary judgment matrix a_{ij} shall meet the following conditions: first, $a_{ij} = 0.5$, $i = 1,2,\cdots,n$; second, $a_{ij} + a_{ji} = 1$, $j = 1,2,\cdots,n$.

(3) Calculate the weight and check the consistency. The formula of weight of fuzzy complementary judgment matrix is:

$$W_i = \frac{\sum_{j=1}^{n} a_{ij} + \frac{n}{2} - 1}{n(n-1)}, \ i = 1,2,\cdots, m \tag{1}$$

Consistency inspection. Test the satisfactory consistency of m judgment matrices A_k:

$$I(A_k, W^{(k)}) \leq A, \ k = 1,2,\cdots, m \tag{2}$$

Verify the satisfactory compatibility between judgment matrices:

$$I(A_k, A_l) \leq A, \ k = 1,2,\cdots, m \tag{3}$$

It can be proved that when the $A_k (k = 1,2,\cdots,m)$ fuzzy complementary judgment matrix is uniformly acceptable, their comprehensive judgment matrix is also uniformly acceptable. The formula of weight vector is: $W = (W_1, W_2, \cdots, W_n)$; therefore, when equations (2) and (3) are satisfied at the same time, the mean value of m weight sets as the weight distribution vector of X is reliable and reasonable.

Using the above method, calculate and give the weight of each index in the cultivation index of urban green development competitiveness. When there are many indicators, FAHP method compares the indicators in pairs and solves the bottleneck of thinking consistency of analytic hierarchy process by effectively combining the advantages of fuzzy method and AHP. Considering the influence of human factors, in order to ensure the accuracy of the weight, after determining the weight, this paper further modifies the weight of each index obtained by the fuzzy analytic hierarchy process by using the entropy method[16,17], as shown in **Table 2**.

If m evaluation objects and n evaluation indexes are set to form a data matrix $X = (x_{ij})_{m\times n}$, the information entropy formula is: $H(x) = \sum_{i=1}^{m} f(x_i) \ln f(x_i)$. Calculate the proportion of the index value of the i-th evaluated object under the j-th index in matrix X q_{ij}: $q_{ij} = r_{ij} / \sum_{i=1}^{m} r_{ij}$. The entropy value of e_j is: $e_j = -k \sum_{i=1}^{m} q_{ij} \cdot \ln q_{ij}$, where $k = 1/\ln m$; the entropy weight of the j-th index w_j is: $w_j = (1 - e_j) / \sum_{j=1}^{n} (1 - e_j)$. Determine the comprehensive weight, assuming that the weight obtained according to FAHP method is δ, $j = 1,2,\cdots,n$, then the comprehensive weight of the j-th index can be obtained: $\beta_j = \frac{\delta_i w_i}{\sum_{i=1}^{m} \delta_i w_i}$.

This paper selects the measurement method combining FAHP (Fuzzy Analytic Hierarchy Process) and entropy method to statistically analyze and process the original data and correct to determine the final weight of each index, as shown in **Table 2**. The influence of the five criteria of urban green development competitiveness green production, green governance, green industry, green society and green environment is in descending order: Green environment, green production, green governance, green industry and green society. Among them, the weight of green environment is the largest, more than 30%, which further proves the im-

portance of urban green environment for urban green development competitiveness. It can be seen from the 20 indicator layers that the weight of public transport share rate, urban forest coverage rate, the proportion of added value of tertiary industry in GDP, industrial wastewater discharge per RMB 10,000 GDP, comprehensive utilization rate of industrial solid waste and other indicators is higher, all exceeding 6%, indicating that the competitiveness of urban green development is improved. Cities should focus on improving the share of public transport, forest coverage, the proportion of the added value of the tertiary industry in GDP, the comprehensive utilization rate of industrial solid waste and reducing the discharge of industrial wastewater.

Table 2. Evaluation index weight of urban green development competitiveness

Target layer	Criterion layer	Index layer
Current situation of urban green development competitiveness	Green production A (0.273)	Proportion of added value of tertiary industry in GDP A11 (0.257)
		Total energy consumption A12 (0.128)
		Energy consumption per RMB 10,000 GDP A13 (0.115)
		RMB 10,000 GDP industrial waste gas emission A21 (0.186)
		Industrial wastewater discharge of RMB 10,000 GDP A22 (0.245)
		Output of industrial solid waste of RMB 10,000 GDP A23 (0.069)
	Green governance B (0.226)	Proportion of total investment in environmental protection in GDP B11 (0.225)
		Proportion of industrial pollution control investment in industrial added value B12 (0.274)
		Harmless treatment rate of domestic waste B21 (0.220)
		Comprehensive utilization rate of industrial solid waste B22 (0.281)
	Green industry C (0.109)	Energy processing conversion rate C11 (0.566)
		Proportion of environmental protection industry assets in total industrial assets C12 (0.434)
	Green society D (0.054)	Green space protection level D11 (0.381)
		Public participation D12 (0.176)
		Citizen satisfaction D13 (0.443)
	Green environment E (0.338)	Forest coverage E11 (0.218)
		Per capita park green space area E12 (0.159)
		Days of air quality reaching grade I and II E13 (0.132)
		Public transport share E21 (0.282)
		Urban bus ownership per 10,000 people E22 (0.209)

4. Empirical analysis of “green model” of urban green development competitiveness

The research on the competitiveness of urban green development selects Tianjin as the research object. Firstly, the four municipalities directly under the central government of Tianjin, Beijing, Shanghai and Chongqing are compared horizontally to verify the scientific and rationality of the evaluation index system, and then the urban green development situation of Tianjin in the six years from 2011 to 2016 is compared vertically to analyze the changes of Tianjin’s urban green development competitiveness, so as to carry forward the advantages of Tianjin in practicing green development, strive to overcome the problems encountered in development.

4.1. Evaluate the index system

Evaluate the constructed urban green development competitiveness index system, and the samples are Beijing, Tianjin and Shanghai.

According to the data of the China Bureau of statistics in 2016 of the four municipalities directly under the central government Shanghai and Chongqing, the evaluation process is to first obtain the specific original data of 20 index layers of the four cities, then positively process the negative index data, standardize the positive index data, calculate the entropy and difference coefficient of the pro-

cessed index data to determine the weight, and finally obtain the comprehensive evaluation results of the four cities of Beijing, Tianjin, Shanghai and Chongqing according to the above calculation method, As shown in **Table 3**.

Table 3. Comprehensive evaluation results of green development competitiveness of Beijing, Tianjin, Shanghai and Chongqing in 2016

Index \ City	Beijing	Tianjin	Shanghai	Chongqing
Proportion of added value of tertiary industry in GDP A11	0.287	0.213	0.375	0.125
Total energy consumption A12	0.379	0.262	0.235	0.124
RMB 10,000 GDP energy consumption A13	0.348	0.225	0.259	0.168
RMB 10,000 GDP industrial waste gas emission A21	0.315	0.289	0.164	0.232
RMB 10,000 GDP industrial wastewater discharge A22	0.202	0.438	0.137	0.223
RMB 10,000 GDP industrial solid waste production A23	0.288	0.375	0.146	0.191
Proportion of total investment in environmental protection in GDP B11	0.354	0.214	0.278	0.154
Proportion of industrial pollution control investment in industrial added value B12	0.682	0.049	0.118	0.151
Harmless treatment rate of domestic waste B21	0.228	0.207	0.359	0.206
Comprehensive utilization rate of industrial solid waste B22	0.269	0.251	0.294	0.186
Energy processing conversion rate C11	0.182	0.262	0.407	0.149
Proportion of environmental protection industry assets in total industrial assets C12	0.287	0.298	0.292	0.123
Green space protection level D11	0.295	0.103	0.438	0.164
Public participation D12	0.254	0.243	0.306	0.197
Citizen satisfaction D13	0.253	0.265	0.280	0.202
Forest coverage E11	0.263	0.154	0.405	0.178
Per capita park green area E12	0.253	0.086	0.487	0.174
Days of air quality reaching grade I and II E13	0.112	0.107	0.456	0.325
Public transport share E21	0.091	0.225	0.293	0.391
Urban public transport ownership of 10,000 people E22	0.146	0.213	0.275	0.368
Comprehensive score	0.218	0.197	0.242	0.180

According to **Table 3**, the order of green development competitiveness of Beijing, Tianjin, Shanghai and Chongqing in 2016 is: Shanghai–Beijing–Tianjin–Chongqing. The comprehensive evaluation results are analyzed, and the evaluation results of green development competitiveness are basically consistent with the actual situation of urban green development. Beijing and Tianjin are in the middle. With the integrated layout of Beijing, Tianjin and Hebei, Beijing and Tianjin are unified in terms of ecological city planning thought and green development action. However, due to the unique conditions of the city and the stubborn problems left over by history, such as Beijing is a livable city and Tianjin is an industrial center, there is still a certain gap between Tianjin and Beijing in ecological planning and green development. Shanghai ranks first in the list. It is not difficult to understand that Shanghai has always adhered to the guiding ideology of circular, low-carbon and green development in the process of urban planning, and established a high-tech park centered on Pudong New Area through technological innovation and industrial transformation, so as to improve the added value of the tertiary industry and reduce the total energy consumption. By optimizing the layout of ecological functions, expanding the capacity of urban ecological environment, and implementing the development of a world-class ecological island represented by Chongming, we can better protect water resources, conserve the ecological environment and promote the low-carbon, harmonious and green development of Shanghai[18]. Chongqing ranks last. Chongqing's urban goal is to become a competitive and livable ecological city, with applicable technology, green buildings, green transportation and service industries as its main competitive advantages. However, Chongqing's disadvantages are

also very prominent, the urban system structure is not perfect, there is a lack of radiation sources with strong complementarity such as Beijing and Tianjin, the economic development is unstable, and the urban GDP lags behind Tianjin. The overall level of urban green development competitiveness has been lowered to sum up, the evaluation index system of urban green development competitiveness is quite scientific and reasonable, and the evaluation results have certain reference value.

4.2. Overview of the study area

China Singapore Tianjin eco city is a resource-saving, environment-friendly and social harmonious eco city jointly constructed by the site selection initiative of China and Singapore[19]. Under resource constraints, China Singapore Tianjin eco city aims at ecological restoration and protection, takes green transportation as the support of urban layout, takes the index system as the basis to guide urban planning, development and construction, forms the urban basic framework with ecological Valley and ecological community, establishes an ecological circulating water system with urban direct drinking water as the symbol, and strengthens energy conservation and emission reduction with renewable energy utilization as the symbol, build a dynamic and open ecosystem with the integration and symbiosis of natural and artificial environment. In 2013, Tianjin launched the "beautiful Tianjin" No. 1 project and carried out the activity of "four cleans and one green". In February 2014, the coordinated development of Beijing, Tianjin and Hebei put forward the national strategy to explore the effective path of ecological civilization construction and promote the coordinated development of population, economy, resources and environment. On October 3, 2014, the State Council approved the implementation plan for China Singapore Tianjin eco city to build a national green development demonstration zone. Tianjin became the first city to establish a national green development demonstration zone (China Canada ecological demonstration zone). In April 2016, Tianjin municipal Party committee and Tianjin Municipal Government jointly issued the opinions on the implementation of the key work of the "four clean and one green" action in 2016, comprehensively deepening the "four clean and one green" green action and deepening the "five control" governance measures. It can be seen that Tianjin highlights the planning and layout of ecological city and is creating a demonstration city with livable human living environment, ecological sustainable development and urban green development under the new normal. Therefore, take Tianjin as the target city, quantitatively study the competitiveness level of green development in Tianjin, analyze the current situation and characteristics of green development in Tianjin, and put forward corresponding countermeasures, so as to provide some reference for the follow-up construction of national green development demonstration zone.

4.3. Evaluation on the current situation of green development competitiveness in Tianjin

It can be seen from **Table 4** that the comprehensive index of Tianjin's green development competitiveness increased year by year from 2011 to 2016, and the green development competitiveness increased year by year. From 2014 to 2016, it maintained a double-digit growth rate for three consecutive years, but there is still a large gap compared with Shanghai, Beijing and Tianjin's green development competitiveness mainly presents the following characteristics.

First, the green production capacity advances steadily and the capacity emission is properly controlled. In terms of production energy consumption, the proportion of the added value of the tertiary industry in GDP increased year by year. In 2016, a11 reached 54.018%, with a year-on-year increase of 3.6%. With the injection of "green genes" such as new energy, new materials, biotechnology and high and new technology into traditional industries, the use of high consumption energy is decreasing day by day, and the total energy consumption is decreasing in an accelerated manner. In 2016, it was 4.9% lower than that in 2015. In terms of pollution discharge, the

discharge of industrial waste gas and wastewater per RMB 10,000 GDP decreased year by year, falling to 30.154 tons per RMB 10,000 and 5.418 tons per RMB 10,000 respectively in 2016, but the production of industrial solid waste per RMB 10,000 GDP showed an overall growth trend.

Table 4. Original data and comprehensive calculation results of green development competitiveness of Tianjin from 2011 to 2016

Index \ Year	2011	2012	2013	2014	2015	2016
Proportion of added value of tertiary industry in GDP A11 (%)	46.158	46.987	48.328	49.566	52.153	54.018
Total energy consumption A12 (10,000 tons)	9,204.390	9,264.080	9,485.520	9,123.990	8,701.900	8,275.356
Energy consumption per RMB 10,000 GDP A13 (t/RMB 10,000)	0.814	0.718	0.657	0.580	0.526	0.497
RMB 10,000 GDP industrial waste gas emission A21 (t/RMB 10,000)	58.876	49.854	42.654	40.123	32.252	30.154
RMB 10,000 GDP industrial wastewater discharge A22 (t/RMB 10,000)	5.938	6.423	5.831	5.682	5.623	5.418
Output of industrial solid waste of RMB 10,000 GDP A23 (t/RMB 10,000)	0.85	0.96	0.105	0.110	0.127	0.132
Proportion of total investment in environmental protection in GDP B11 (%)	0.293	0.207	0.213	0.283	0.278	0.285
Proportion of industrial pollution control investment in industrial added value B12 (%)	0.281	0.205	0.222	0.312	0.344	0.368
Harmless treatment rate of domestic waste B21 (%)	100	99.8	96.8	96.7	92.7	92.13
Comprehensive utilization rate of industrial solid waste B22 (%)	98.320	98.616	98.775	99.386	99.225	99.402
Energy processing conversion rate C11 (%)	72.2	72.7	73.0	73.5	73.7	74.3
Proportion of environmental protection industry assets in total industrial assets C12 (%)	5.78	6.19	7.96	17.52	329.6	47.94
Green space protection level D11 (%)	29.032	30.493	31.466	30.435	31.338	31.621
Public participation D12 (%)	65.157	68.523	68.116	70.238	71.472	72.265
Citizen satisfaction D13 (%)	85.391	88.247	89.985	88.346	87.565	88.413
Forest coverage E11 (%)	16.65	9.91	9.97	8.14	9.79	9.87
Per capita park green space area E12 (m^2/person)	10.30	10.54	10.97	9.73	10.13	9.29
Days of reaching the standard of class I and II air quality E13 (days)	300	305	145	175	220	226
Public transport share E21 (%)	15.239	17.984	20.192	23.451	30.096	49.165
Urban public transport ownership E22 (standard set)	15.19	17.34	18.99	18.14	16.30	16.94
Composite index	0.129	0.142	0.154	0.165	0.185	0.197

Source: According to the statistical yearbook, statistical bulletin and data of Tianjin Environmental Protection Bureau in relevant years.

Second, the effect of green governance is prominent, and the investment is increasing Investment in environmental protection and pollution control in Tianjin is increasing. The harmless treatment rate of domestic waste was more than 96% from 2011 to 2014. It has declined in recent two years, but it is still higher than 92%. The comprehensive utilization rate of industrial solid waste has always been stable at a high level of more than 98%.

Third, the management function of green society is insufficient, and public services need to be improved. The level of green space protection is higher than the national standard value, but there is still much room for progress. Public participation and public satisfaction are low, only the qualified level, and there is an obvious grade difference from the high standard of green development demonstration area.

Fourth, the overall quality of green environment is worrying, and the living environment needs to be improved. The urban forest coverage rate is too low, far lower than 50% of the national urban standard; the average area of park green space per capita is about 10 m^2/person, which is only one sixth of the United Nations standard and has decreased since 2014. The number of days when the air quality meets the standard is extremely worrying, and it only reaches the national standard baseline of Ecological

Garden City in 2011 and 2012.

4.4. Countermeasures and suggestions to enhance the competitiveness of green development in Tianjin

First, accelerate the planning of green development demonstration areas and strive to make up for the shortcomings of green environment. Above all, strengthen the strategic top-level design of green development demonstration area. Accelerate the urban planning, design and construction of low-carbon, sustainable and green development demonstration areas, build and improve the evaluation model and index system of urban green development competitiveness, and provide scientific theoretical content and clear strategic guidance for standardizing the construction of smart, ecological and green cities. Secondly, deepen the construction action of "four cleans and one green" in the demonstration area. Take the transformation and upgrading of Tianjin's industrial economy as the fundamental treatment of haze and sewage problems, and take the "five control" treatment measures as the auxiliary to implement the action of fresh air and clean water rivers. Set up green transportation, advocate low-carbon and civilized travel, strengthen the guarantee of public service infrastructure such as sharing bicycles and cars, avoid the risk of "small yellow cars" manufacturing urban garbage, and prevent citizens from taking it for themselves and malicious destruction. Design and build green buildings, give priority to building green development demonstration areas suitable for living and business, then drive urban green development with regional green development, and deeply carry out clean communities, business areas and villages in the whole city. Vigorously carry out afforestation activities for regional industrial dust prevention and highway greening, expand the overall scale of urban green space, improve urban forest coverage, and build a solid urban ecological security barrier.

Second, optimize the development strategy of industry city integration and build a smart ecological green city Tianjin's economy is developing rapidly. In order to build a smart ecological green city, the future development trend of the city should pay more attention to the integrated development of industrial economy and urban quality[20,21]. First, we should give priority to the development of smart industries and accelerate industrial transformation. Based on the resource-based theory, make use of the rich natural resources such as sea salt and geothermal in Tianjin and the location advantages of ports and important places in Gyeonggi, give full play to the comparative advantages of resources, and focus on the development of green biological manufacturing industry and new energy industry integrate information technology, knowledge management and ecological concepts to cultivate new advantages of wisdom. For example, establish the enterprise information database of the high-tech zone, strengthen the construction of information infrastructure, and inject new impetus into improving the conversion rate of scientific and technological achievements. Secondly, focus on talent support and national development to promote urban upgrading. Create an urban atmosphere of coordinated, sustainable and green development among people, industry and city. Combine the talent advantages of urban colleges and universities, grasp the industrial innovation drive of "mass innovation and mass innovation", and improve the urban industrial innovation ability. Improve the urban ecological environment, improve the quality of public services such as housing, education and transportation, enhance people's satisfaction with production and life, and improve the overall level of green development competitiveness of Tianjin, which is livable and business friendly.

Third, publicize the concept of green development city and encourage the public to participate in green behavior. First, publicize green behavior on the premise of ideological transformation. Pay attention to publicizing the concept of green development city, and strengthen the urban cultural construction of green behaviors such as green consumption and green life. For example, organize green education activities on campus, in communities and in villages and towns, prepare publicity and education manuals, and set up urban green columns

with the help of media platforms such as newspapers, radio and television and the Internet to promote green culture. Stimulate the public's ecological and moral awareness by strengthening theoretical publicity and actively encourage the public to participate in green behavior. Secondly, take the activities as the carrier to implement green behavior. Carry out voluntary activities to organize the public to participate in green behavior, such as "Car Free Day" for green travel, green energy-saving "turn off the lights for an hour", green protection "I'm an environmental supervisor", etc. Finally, guide and encourage the public to promote green behavior. Strengthen the construction of incentive system and social supervision mechanism for public participation in green behavior[22], promote carbon point system or "green" credit card, link green behavior with carbon point and credit line, and accumulate a certain amount to exchange free prizes or enjoy preferential policies for some public services in the city, so as to give full play to and make use of the radiation effect of public participation in green behavior.

Conflict of interest

The authors declare no conflict of interest.

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