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An evaluation system of ecology-safe and environment-friendly society - green production system

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To build the Green Production System is a practice of green development in China, which is an important way to transform the economic development mode and to complete ecological civilization construction. This study defined the meaning of Green Production System, constructed the green production evaluation index system and made empirical evaluations on green production situation of several advanced areas in China by using Analytic Hierarchy Process (AHP) and Factor Analysis method. The author also measured advantages in the green production system of these regions. The research showed that, as the first National Independent Innovating Demonstration Zone, Haidian District took the lead in all of indicators among developed areas. The reason lies in Haidian District has been focusing on the construction of green production system during the economic and social development in the past several years.

Key words: Green production evaluation system, Analytic Hierarchy Process, Factor analysis

INTRODUCTION

Green production, as a sustainable mode of production, develops in dealing with the problems of increasingly serious environmental pollution and energy resource constraints. Currently, many countries and regions around the world are actively exploring green production models. This paper, is part of a delegated task from the administration of Haidian District in Beijing, China. Although exploring the connotation of green development is complex, an ecology-safe and environment-friendly evaluation system should be the first step of such an exploration.

Current academic studies haven't carried out any specific researches on green production system, most of which now are focusing on the green economy or green manufacturing. It is Hall Who released green environmental quality indexes of the U.S states 1991-1992 and explained what green index is earliest [1]. The American National Geographic Society studied in terms of consumer's behavior of environmental protection and published the '2009 Global Consumer Green Indexes' report (The American National Geographic Society, 2009). To take the development level of green manufacturing system as target layer, SHEN De-cong and RUAN Ping-nan conducted a primary study on the evaluation index system of green manufacturing system of China [3]. By estimating the three first-grade indexes, degree of green economic growth, carrying capacity of resources and environment and supports of government, Li Xiaoxi, etc. released the 2010 Annual Report of China Green Index, which studied green development indexes of the all the provinces and cities in China[4]. Beijing Haidian District Government made a low-carbon economy index system from the perspective of the transformation of economic growth in 2009 [5].

In 2010, Beijing municipal party committee and municipal government formally promulgated 'Green Beijing' action plan (2010-2012) which put forward the city to developing the low carbon economy and creating green production system. But in that plan, it only included two guide indicators and four binding targets of the green production system, which didn't make a statement of questions like what green production system is and what complete framework should green production system include or something about.

Based on the above, this paper carried out a research on issues related to green production system, studied on the evaluation and structure of green production systems, and calculated and compared the competitiveness of green production of Beijing and several related economically developed areas. This paper will contribute to the development of low-carbon economy and the building of green production system, which is full of significant application value to 'Green China' construction and forward-looking meaning to theoretical innovation.

EXPERIMENTAL

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Green production is a general term for nuisance-free and pollution-free production. Establishing an indicator evaluation system for green production can help us to evaluate the green production development condition in a certain area.

Synthesizing the connotation of green production system, referencing the research to related indicators of green economy and low-carbon economy and under the guidance of principles above, we design the green production indicator system for three-tier structure, that is target layer, criteria layer and indicator layer. Table 1 shows the indicator framework.

Green production indicator system is composed of a whole group of interrelated indicators. It is used to reflect all aspects of the relationship which is interdependence and mutual restraint among socio-economic, natural resources and ecological environment in green production activities. The system structure is constructed by the use of socioeconomic and natural resources, environment and sustainable development.

Evaluation method

T.L.Saty, an America operational research expert, put forward the Analytic Hierarchy Process (AHP) method in 1970's. This method is based on the principle of arrangement of elements in system to divide a complex problem into multi-level structures which the first level is related to the next level. And factors among all the levels can be compared and calculated to get the weights of those factors which can be ranked, to lay down the solid foundation of research. .

Table 1. Green production index evaluation system.

Target layer	Criterion layer	Indicator layer
Green production index system	Socio-economic indicators	Annual per capita GDP (ten thousand Yuan)
		Residents average years of education(years)
		The number of scientific and technical personnel within a region
		The number of ecological demonstration zones
		The number of patent applications per year
		The total production of new energy and energy-saving environmental protection industry
		R & D expenditure accounts for GDP
		Value loss by pollution per year
		The tertiary industry output value accounts for GDP
	Resource utilization indicators	Renewable energy consumption accounts for total energy consumption
		Coal consumption accounts for total energy consumption
		The sales of new energy and energy-saving environmental protection industry in the proportion of total output value
		Ten thousand Yuan GDP energy consumption (kWh / ten thousand Yuan)
		Energy consumption per unit of GDP (Tce / ten thousand Yuan)
		Water consumption per unit of GDP (cubic meters / ten thousand Yuan)
		Sulfur dioxide emissions per unit of GDP (tons / ten thousand Yuan)
		Carbon dioxide emissions per unit of GDP (tons / ten thousand Yuan)
	Eco-environmental indicators	Compliance rate of city greening
		The number of enterprises through the ISO14000 certification
		Investment in environmental protection
		Rate of urban sewage treatment
		Recovery rate of electronics, electrical product
	Sustainable development indicators	Growth rate of per capita GDP
		Reduction rate of ten thousand Yuan GDP energy consumption
		Reduction rate of ten thousand Yuan GDP water consumption
		Reduction rate of occupational disease and public nuisance disease
		The growth rate of overall labor productivity

By using Haidian District as an access, this paper selects Guangdong, Jiangsu, Beijing, Shanghai, Henan, Fangshan district of Beijing and Binhai district of Tianjin such developed areas to conduct a research of green production system. All the data comes from 2010 Statistics Yearbook of each province (City) or district, related annual National economic and social development bulletin, and the 2009 China energy Statistical Yearbook.

Because of Haidian District, Tianjin Binhai New Area have great differences with all the provinces, the absolute value of the index cannot represent the real competitiveness. Therefore, this article selects the corresponding index for analysis. Because there are no new energy or energy-saving industries data, some provinces as Jiangsu, Shandong and Henan, this paper uses the high-tech industrial indicators to replace with. For those indicators that have negatively impacts on competitiveness, as per GDP (10,000 yuan) energy consumption, sulfur dioxide emissions per unit of GDP, they were gave a relative treatment as follows:

$$k_{ij} = \frac{X_{ij}}{\max(X_{ij})}, \quad p_{ij} = 1/k_{ij} * 100$$

X_{ij} is the observed value of j indicator in i region; k_{ij} represents the j entropy index of the i region; p_{ij} shows the j index values of i region after conversion. According to previously established indicator system and regional data, this paper selects 19 indicators to be assessed

RESULTS AND DISCUSSION

Outcome of AHP

By AHP analysis, each weight of indicators in criterion layer and the index layer is shown in Table 2 and Table 3:

Table 2. Weights of Criteria layer.

Criterion layer	B1	B2	B3	B4
Weight	0.3025	0.2857	0.2134	0.1984

* The above four indicators went through the consistency test.

Based on weight of each index above, it is easy to score the green production competitiveness of each region, which is shown in Table 4.

From Table 4, Haidian District, in terms of overall competitiveness, scored 132.532 points and ranked first, which are 39.458 points more than the second Binhai New Area whose score was 93.074 - The both regions had strong competitiveness of green manufacturing. With a score of 45.214, Henan Province ranked in the last place.

From the socio-economic development indicators, Haidian District with a score 41.476 points ranked first. It was 26.39 points more than Beijing which scored 15.086 points and ranked second. Haidian District has more than half amount of the science and technology persons in Beijing. The number of patents per capita and research investment costs are much higher than in other regions, which make Haidian District become one of the most powerful places for scientific research. This also provides a strong support for the social and economic development in Haidian District.

Table 3. Weights of Index layer.

C layer	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Weight	0.027	0.054	0.039	0.108	0.042	0.032	0.049	0.074	0.069	0.094
C layer	C11	C12	C13	C14	C15	C16	C17	C18	C19	
Weight	0.031	0.061	0.055	0.067	0.031	0.061	0.043	0.067	0.040	

*The above four indicators through the consistency test

Table 4. Scores of the Green production competitiveness

Region	socio-economic development		Resource use efficiency		Eco-environment construction		Sustainable development		Comprehensive competitiveness	
	scores	rank	scores	rank	scores	rank	scores	rank	scores	rank
Handian	41.476	1	40.680	1	19.246	1	10.377	3	132.532	1
Fangshan	9.886	5	2.954	10	13.270	10	9.323	5	54.080	8
Beijing	15.086	2	12.161	2	16.486	7	9.119	6	71.090	4
Shanghai	13.120	3	10.513	4	18.984	2	10.778	2	74.951	3
Jiangsu	5.734	8	11.219	3	16.805	5	8.610	7	59.590	5
Guangdong	5.464	7	5.940	7	14.815	9	7.920	10	49.979	9
Henan	2.463	10	3.698	9	14.865	8	8.063	9	45.214	10
Binhai N.A	11.270	4	8.743	5	17.339	6	18.574	1	93.074	2
Shandong	3.529	9	4.978	8	18.434	3	10.098	4	57.233	7
Zhejiang	7.894	6	6.969	6	17.565	4	8.400	8	57.627	6

Table 5. Green production index system.

X	Index
X1	Annual per capita GDP (ten thousand Yuan)
X2	The number of scientific and technical personnel within a region(Units per ten thousand people)
X3	The number of patent applications per year
X4	R & D expenditure accounts for GDP
X5	The tertiary industry output value accounts for GDP
X6	Energy-saving and environmental protection industry
X7	Ten thousand Yuan GDP power consumption (kWh / ten thousand Yuan)
X8	Energy consumption per unit of GDP (Tce / ten thousand Yuan)
X9	Water consumption per unit of GDP (cubic meters / ten thousand Yuan)
X10	Sulfur dioxide emissions per unit of GDP (tons / ten thousand Yuan)
X11	Compliance rate of city greening
X12	Rate of urban sewage treatment
X13	Industrial dust removal rate
X14	The utilization rate of industrial solid waste
X15	Growth rate of per capita GDP
X16	Reduction rate of ten thousand Yuan GDP energy consumption
X17	Reduction rate of ten thousand Yuan GDP water consumption
X18	The rate of overall labor productivity
X19	The growth rate of new energy and energy-saving environmental protection industry

Table 6. Characteristic value of factor loading and contribution rate**.**

Factor	Characteristic value	Rate of Contribution(%)	The cumulative contribution rate(%)
1	8.248	45.823	45.823
2	3.240	17.997	63.820
3	2.382	13.231	77.051
4	1.465	8.141	85.192
5	1.051	5.841	91.033
6	0.695	3.862	94.895
7	0.440	2.444	97.339
8	0.295	1.638	98.977

Table 7. Orthogonal factor table.

Index	F_1	F_2	F_3	F_4	F_5
X1	0.132	0.096	0.006	0.963	0.148
X2	0.958	-0.218	-0.010	0.158	-0.007
X3	0.876	0.090	0.366	0.161	0.026
X4	0.895	-0.404	0.014	0.022	-0.077
X5	0.829	-0.166	0.295	-0.025	0.235
X6	0.944	0.005	0.129	0.151	0.237
X7	0.806	0.111	0.243	0.485	-0.016
X8	0.937	0.138	0.217	0.007	0.111
X9	0.758	0.243	-0.074	0.166	0.500
X10	0.231	-0.088	0.004	0.621	-0.127
X11	0.278	-0.877	0.372	0.135	-0.037
X12	0.563	-0.001	0.549	0.156	0.173
X13	0.362	0.801	0.162	-0.201	-0.088
X14	0.392	0.728	0.279	0.289	0.074
X15	-0.441	-0.607	-0.488	0.064	0.130
X16	0.232	0.844	-0.039	0.121	-0.091
X17	-0.196	0.070	0.935	-0.017	0.186
X18	0.101	-0.087	-0.143	0.970	0.060
X19	-0.620	0.019	0.138	0.075	0.755

From energy efficiency, as water and other resources, Haidian District scored 40.680 points. It was 28.519 points more than Beijing which scored 12.161 points and ranked second. From the individual indicators, various energy indicators in Haidian District are lower than Beijing, which shows that the economic development of Haidian District has entered the low-power stage.

From the ecological environment construction, Haidian District scored 19.246 points and ranked first. It was 0.262 points higher than the second Shanghai with a score 18.984 points. Beijing scored 16.486 and ranked seventh. Due to all the areas have paid attention to environmental protection, the gap of each regional ecological environment construction is not so great. Take Haidian District as an example, its urban sewage treatment rate reached 94.3% and disposal rate of solid waste utilization reached nearly 100%, which showed the Haidian District emphasized much about ecological environment development.

From a sustainable development perspective, Haidian District scored 10.377 points and ranked third, which is behind the Binhai New Area and Shanghai. Binhai New Area with a score 18.574 ranked first. Shanghai scored 10.788 points and ranked second. The sustainable development of Haidian District is behind the Binhai New Area and Shanghai. On one hand, this shows that the economic development in Haidian District has reached advanced level under the current technology conditions and it has limited tap potentials in further developing. On the other hand, it is vital to break the constraints of existing land and other resources for the future economic development of the Haidian District. How to promote the use of technology and expand the use of various elements and resources are essential.

Outcome of Factor Analysis

Obviously, these 28 indices above explained green production system from different angles, but in different regions the contribution of these 28 indices is different. Therefore, it is of significance to analyze the competition of green production in different regions. This paper use factor analysis to go on the next research. Based on the results of AHP, all the selected indexes are shown in Table 5.

By using SPSS 13 statistical software, we got the factor analysis characteristic value, contribution rate and the accumulative contribution rate which are shown in Table 6. As the KMO value is 0.795, so it is suitable to use factor analysis. According to the information of original data reflected by the contribution rate of each factor, the top 5 factors have already contained more than 91.033% of the information of original variables, which satisfy all the requirements of factor analysis (≥ 85%).

In order to make the right and reasonable roots of load factor is polarized to 0 or l. The 19 explanation for the main factor, each of square factor loading matrix is rotated by varimax method. Results are shown in table 7.

From table 7, the first main factor has greatest ability to explain the green production and its rate is 45.825%.In the first mainfactors, x_2、x_3、x_4、x_5、x_6、x_7、x_8、x_9 the load factors have the larger coefficient. x_2 represents the technical personnel quantity in every million people in different region. x_3 represents the numbers of patents granted per million people. x_4 represents the R &D expenditure accounts for GDP. x_5 represents the third industries accounted for the proportion of GDP. x_6 represents the new energy and energy-saving environmental protection industry added value accounted for the proportion of GDP. x_7 represents Ten thousand Yuan GDP power consumption. x_8 represents the energy consumption per unit of GDP. x_9 represents the water consumption per unit of GDP. The Eight indicators reflect three aspects of local condition, which include science and technology level, advanced industrial structure and energy efficiency.

The stronger the regional green production ability is, the more developed the region is. Therefore, the region like Haidian District, the third industrial output has reached 80% of total output value. Those regions must be able to continue to increase investment in science and technology. So they can promote the development of new technology, new products. And the combination of Produces, study and grinds will increase the utilization rate or circular utilization of renewable energy resources. And then those regions will achieve the goal of promoting the progress of green production.

CONCLUSION

To build the Green Production System is a practice of green development in China, which is an important way to transform the economic development mode and to complete ecological civilization construction.

For the AHP results, it is obvious that Haidian District performs a good condition in each kind of indicators and it has reached advanced level under the current technology conditions. But what cannot be ignored is that Haidian District is facing a limitation in further developing. So it is vital to break the constraints of existing land and other resources for the future economic development of

the Haidian District. How to promote the use of technology and expand the use of various elements and resources are essential.

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