Evaluation of the Regional Green Circulation Low-Carbon Transportation Development

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Abstract: Green low carbon transport is the trend of the development of transportation industry. Based on the theory and method of sustainable development evaluation, combined with low-carbon transportation development connotation, Chinese Hebei province was taken as an example to carry out a comprehensive evaluation of the low-carbon transportation development. According to the social, economic and environmental characteristics of the area, using the pressure - state - response (PSR) model, and proposed the low-carbon transportation development evaluation model and index system, using the entropy value method to determine index weight, the comprehensive index method is adopted to get comprehensive development index value of every index. The result indicated: Hebei province low-carbon transportation development pressure index increases year by year; The state index of the low carbon transportation development sharp decline in 2005-2009 year, during the period of 2010-2014 year basic remain stable, but at low level; the response index promotes year by year; the integrated development index has the remarkable gradual characteristic; the 1st stage as a whole is from high to low , the 2nd stage as a whole from low to high, but rose is slower.

Keywords: low-carbon transportation; PSR model; sustainable development

1. Introduction

To deal with global warming and the development of low-carbon economy has become an important issue for the development of the world in the 21st Century. The development of low-carbon transport is conducive to accelerate the transformation of the mode of transport development, is conducive to promoting the transport of energy-saving emission reduction measures, but also is an important part of the development of low-carbon economy. Transportation industry is the leading and basic industry in the national economic structure, while promoting economic development, energy consumption and greenhouse gas emissions are also increasing year by year, to the environment and ecology to bring a heavy burden. Therefore, it is of great significance and urgent to construct a low-carbon transportation system for China's national conditions, and to establish the index system and the corresponding evaluation method for the evaluation of regional low-carbon transportation development process should be a problem to be solved urgently.

At present, foreign scholars have carried out a lot of research on traffic evaluation index and model. AMEKUDZI et al. chose the typical index to evaluate the impact factors and solutions of the transportation system. JACCO et al. analysis of the main obstacles to the implementation of green transportation. AZADEH et al. integrated the data envelopment analysis (DEA) and analytic hierarchy process (AHP) to establish the system simulation model and analyze the transportation system. By analyzing the

characteristics of the urban traffic system, VUCHIC use the analytic hierarchy process and fuzzy comprehensive evaluation. Chinese scholars on the evaluation of urban traffic system have achieved some results. Lu Hui-fen take energy conservation and emission reduction and benefit maximization as the breakthrough point, from the timeliness, convenience, service, patency, security and the standard of informatization 6 aspects, has constructed the low-carbon city p-traffic systems assessment indicator system, and has carried on the empirical analysis. Guo Jie has constructed one set of low-carbon transportation evaluating indicator system from the infrastructure, the transportation equipment, the municipal transportation and transportation system management, proposed quality synthetic evaluation method, and selected the East China area to carry on the region low-carbon transport development horizontal case study. At present, the existing evaluation studies only in order to describe the current situation of low carbon development in transportation, and not to propose a more comprehensive evaluation index system with low carbon development connotation the research of low carbon economic development evaluation.

Low-carbon transportation development as a new mode of transportation development which is characterized by high efficiency, low energy consumption, low pollution and low emission, is a strategic measure to meet the needs of social and economic development. The core is to meet the needs of social and economic development. Through

structural adjustment, scientific and technological progress, management, policy support and other strategic measures to improve transportation energy efficiency, optimize the use of energy structure, so as to reduce the high carbon energy consumption, and promote sustainable development of transportation. Therefore, the comprehensive evaluation of low-carbon transportation development should not only evaluate its development present situation, and deeply analyze the transportation system of low carbon development causation and mechanism of reaction to the pressure of development and ability, and through effective incentive and right institutional constraints to relieve stress, improve ability. "Pressure - State - Response" (PSR) model from the angle of the system, comprehensively analyze the pressure, status and countermeasures of the system development and changes, and dynamic reflects its causal relation and action mechanism, to provide a reference for further perfect the incentive and constraint, conform to the requirements to carry out research in low carbon transportation development evaluation. Therefore, the author try its theory and method to build a low-carbon transportation development model, development index is put forward and set up evaluation index system, using entropy method to determine the index weight, by using the comprehensive evaluation method to calculate, get the development of low-carbon transportation pressure index (P), state index (S), response index (R) and the integrated development index (PSR). Finally, the Hebei Province correlation data has been carried on the empirical analysis.

2. Analysis of low-carbon transportation development based on PSR model

2.1. Analysis of low-carbon transportation development model

PSR model is the result of the pressure - state - response relationship between social and economic system and environment, which has a clear causal relationship. According to the evaluation index system, the PSR model is divided into 3 types: pressure index, state index and response index, including pressure index refers to human economic and social activities on the environment system; Status indicators refers to a particular time phase of the natural resources and environment change situation; Response index refers to how to reduce and prevent human, recovery and prevent the negative impact of human activities on the environment and the ecological environment has adverse changes in remedy measures.

For transportation systems, namely, population growth and human social economic activities have the pressure to the transportation system, increase the energy consumption and co2 emissions of the transportation system, which affects system adverse changes in natural resources and environment, human

beings will make a response to the high energy consumption and carbon emissions, to reduce energy consumption and carbon emissions transportation system, the three links is during the process of low carbon transportation development strategy. As shown in figure 1. Low carbon transportation development based on PSR model.

2.1.1. Stress analysis

Transportation industry is the basic and leading industry in the development of social economy, the low carbon development pressure comes from the demand of transportation in order to meet the social and economic development. It can be divided into external pressure and internal pressure. External pressure is mainly embodied in the social and economic development indicators such as population, GDP, internal pressure is mainly embodied in the traffic and transportation development indicators, such as transport volume transportation turnover.

2.1.2. State analysis

State is low-carbon transportation development present situation under the function of pressure. Along with the development of social economy, the transportation develops certain stage, the development mode is bound to the high efficiency, low energy consumption, low pollution, low emission transition, the transportation system gradually to having the low-carbon characteristic condition and stage development, will adapt to certain time's economic and social development level, this condition may carries on synthesis measuring through the investment and GDP and output of carbon withdrawal energy.

2.1.3. Response analysis

Response is the behavior of human society in the development of low carbon transportation demand. Based on the status of the transportation development, according to the pressure of the low carbon development, taking measures to change the transportation development mode, while meet the demand of social economic development, promote the development of low-carbon transportation.

2.2. Index construction of low-carbon transportation development

Using the PSR model and comprehensive evaluation method structure low-carbon transportation integrated development index-PSR index, which can be used for the development of low-carbon transportation in certain regions, may be used in the crosswise comparison of different regions and the longitudinal comparison of different times at the same area, including: (1) pressure index-P index namely in a certain region the development and the situation of social economy and the demand for the development of transportation, which reflects the urgent degree of the external environment for the development of low carbon transportation; (2) condition index -S index,

namely in certain region the low-carbon transportation development current situation, reflects the adaptation of the transportation system to the low carbon development needs;(3) response index - R index, namely, in a certain region the development of low

carbon transport development policy and its implementation effect, reflects the development direction and development ability of low carbon transportation.
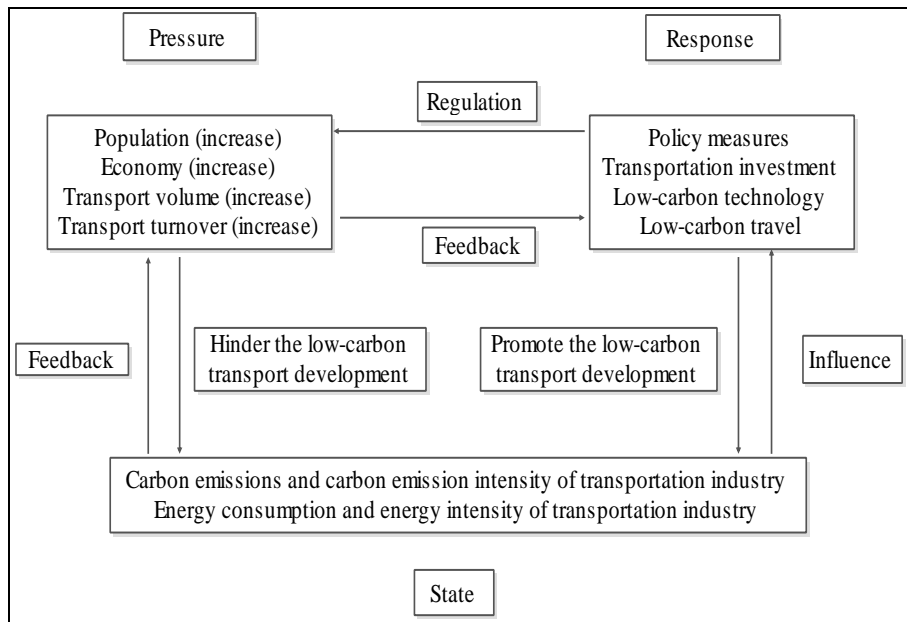

Figure 1. Low carbon transportation development model

Relational model:

$$\text{PSR index} = f(Pindex, Sindex, Rindex).$$

3. Evaluation index system Construction

3.1 Index system construction principle

Based on PSR model to establish low-carbon transportation development evaluation index system, system should not only objectively reflect the situation of the low-carbon transportation development, and has strong practicability and policy guidance. When choosing index, the author follows the principles of scientific, comparability, operability, systematic and guiding principles.

3.2 Index system construction method

According to the analysis of the PSR model and its index system construction principles, combined with the research of the low carbon economic development evaluation, sustainable development evaluation and PSR model, the author selects the index system from

the pressure, condition, response and other aspects of low-carbon transportation development, and highlights the dynamic relationship between the three aspects. Indicators can be adjusted according to the different regions and different stages of development. Evaluation index system can be summarized as:

(1) Target layer, which takes the low carbon transportation development level as the target layer;
(2) Standard layer, including low-carbon transportation development pressure (U1), low-carbon transportation development status (U2), low-carbon transportation development response (U3);
(3) Index layer, which can be directly measured.In addition, according to the function of the index, the reversion function index is defined as the negative index; the positive role of the index is defined as the positive index, the index system as the table 1.

Table 1. Evaluation index system of low carbon transportation development

Target layer	Standard layer	Index layer	Attribute
Low-carbon transportation development level	Pressure U1	Population density	Negative
		Per capita GDP	Negative
		Passenger volume	Negative
		Freight volume	Negative
		Passenger turnover	Negative
		Freight turnover	Negative
	State	Total energy consumption of transportation industry	Negative

U2	Total carbon emissions of transportation	Negative
	Unit GDP energy consumption of transportation	Negative
	Unit GDP carbon emissions of transportation	Negative
	Low carbon transportation development related policy planning	Positive
Response U3	Fixed asset investment in transportation	Positive
	Proportion of natural gas in the energy consumption of transportation industry	Positive
	Electricity consumption in transportation industry	Positive
	Input-output ratio of Low carbon transport technology transform	Negative

4. Evaluation model Construction based on comprehensive evaluation method and entropy method

4.1. Comprehensive evaluation model

From the analysis, *PSR*I composite index is synthesized by P index, S index and R index; and the model of its relationship is like the formula (1):

$$PSRI = f(PI, SI, RI) \tag{1}$$

Type: *PSRI* is composite index; *PI* is pressure index; *SI* is state index; *RI* is response index.

PI, SI and RI were evaluated by comprehensive evaluation method, and the specific evaluation model were as the type (2) ~ (4):

$$PI = \sum_{i=1}^{n_p} w_{pi} \times r_{pij} \tag{2}$$

$$SI = \sum_{i=1}^{n_s} w_{si} \times r_{sij} \tag{3}$$

$$RI = \sum_{i=1}^{n_r} w_{ri} \times r_{rij} \tag{4}$$

Type: w_{pi} is the weight value of the *i*-th pressure index; w_{si} is the weight value of the *i*-th state index; w_{ri} is the weight value of the *i*-th response index; r_{pij}, r_{sij} and r_{rij} are the non-dimensional quantitative values; n_p, n_s and n_r are the number of pressure index, state index and response index.

4.2. Index weight calculation

Entropy value method is the mathematical method to calculate the index weight on the basis of comprehensive consideration of various factors information. As objective and comprehensive weighted method, the weights are determined by the amount of information passed to the decision maker. According to the entropy thought, many and quality of information which is obtained in the decision-making, is the deciding factor of the decision accuracy and the reliability, and entropy is an ideal criterion. In this paper, the author introduces the concept of entropy into the development evaluation of low carbon transportation system, according to the information provided by each index, objectively determine the weight. It is assumed that the region low-carbon transportation system development level has n index, and m years statistical data, suppose its matrix is:

$$R' = (r'_{ij})_{m \times n} \qquad (i = 1, \cdots, n; j = 1, \cdots, m) \tag{5}$$

Type: r'_{ij} is the j-th year's i-th index statistical value. In order to eliminate the influence of different units and quantity grade, R' is normalized, obtains the standardized matrix. Set the standard matrix for:

$$R = (r_{ij})_{m \times n} \qquad (i = 1, \cdots, n; j = 1, \cdots, m) \tag{6}$$

Set up the standard formula, the forward index data standardization (7), the reverse index data standardization (8):

$$r_{ij} = \frac{r'_{ij} - r'_{ij-min}}{r'_{ij-max} - r'_{ij-min}} \tag{7}$$

$$r_{ij} = \frac{r'_{ij-max} - r'_{ij}}{r'_{ij-max} - r'_{ij-min}} \tag{8}$$

Type: r'_{ij-max} is the i-th index in j-th year maximum value, r'_{ij-min} is the i-th index in j-th year minimum value.

The information entropy of each index can be calculated by the standard of the statistical data. The entropy Hi of the i index can be defined as:

$$H_i = -k \sum_{i=1}^{n} f_{ij} \ln f_{ij} \tag{9}$$

Type: $f_{ij} = f_{ij} / \sum_{i=1}^{n} r_{ij}$; $k = 1/\ln m$ (Assume: $f_{ij} = 0, \ln f_{ij} = 0$).

After determining the index entropy, the entropy weight W_i of the index i can be determined:

$$W_i = \frac{1 - H_i}{\sum_{i=1}^{n}(1 - H_i)} \tag{10}$$

According to type (1)~(4), the composite index, pressure index, state index and response index can be obtained.

5. Example analysis

5.1. Area survey

Hebei province is Chinese important economy big province, is at the critical phase that the industrialization, urbanization and quality of people's live improve, in recent years the Hebei province economic development was rapid, the yearly average rate of increment about 10%, by 2014, the gross national product(GNP) will achieve 20197. 1 hundred million Yuan, the per-capita GNP will achieve 28 668 Yuan/person, the population will achieve 7 193. 6 ten thousand people, the urbanization rate will achieve 45%, the year volume of freight turnover will achieve 7 673. 09 hundred million t.km, grows 28.3%;

Volume of passenger turnover 1 172. 9 hundred million people.km, grows 12. 4%, it is estimated that from now on a time still will maintain the fast growth the tendency.

Hebei province is Chinese important transport hub, is East China and South China and southwest and other regions connected Northeast, northwest and northern region's key position region and circulation of commodities stopover station, is Northeast, northwest and northern region important sea route, simultaneously is connects capital Beijing and land's the transport hub, has formed the more perfect land, sea and air synthesis three-dimensional transport transportation network, is assuming the huge transportation duty. Therefore, with the acceleration of industrialization and urbanization in Hebei Province, the energy consumption and CO_2 emissions in the area of transportation will continue to grow, and put forward the urgent need for the implementation of low carbon transportation.

5.2. Data source

Index data of example analysis are collected from "China Transport Statistics Yearbook 2014", "China Energy Statistical Yearbook", "Hebei Province Economic Statistical Yearbook" and field survey; the energy CO_2 conversion coefficient from the "2006 IPCC national greenhouse gas emissions guide"; the indicators value of low-carbon transportation development policy planning implementation is every year Hebei province promulgated quantity.

5.3. Index weight setting

The index weight is calculated according to the entropy value method, the comprehensive weight distributions are shown in table 2.

According to the weight distribution of the standard layer, the weight of the pressure index is the smallest, and the response index weight is the biggest, which is in line with the actual situation of the development of low carbon transportation in Hebei province, because in the evaluation index system, the pressure index is generally classified as the reverse index, but (for example, the level of economic development of per capita GDP) can also promote the development of low carbon transportation in a certain extent, and its partial function effect can be offset, and the corresponding pressure index number is reduced in recent years, so the impact of the overall results is also weakened; Along with the thorough implementation of low carbon transportation development strategy in Hebei province and the pilot work gradual development of low carbon transportation system, the impact of the corresponding response action on the overall development level is becoming more and more prominent, therefore, the response index weight is large.

5.4. Result analysis

The pressure index *PI*, the state index *SI*, the response index *RI* and the composite index *PSRI* of the low carbon transportation development in Hebei province are obtained according to table 2, see table 3.

Table 2: Weight distribution

Target layer	Standard layer	Index layer	Weight
Low-carbon transportation development level	Pressure U_1(0.295)	Population density U_{11}	0.041
		Per capita GDP U_{12}	0.055
		Passenger volume U_{13}	0.060
		Freight volume U_{14}	0.033
		Passenger turnover U_{15}	0.064
		Freight turnover U_{16}	0.042
	State U（0.318)	Total energy consumption of transportation industry U_{21}	0.113
		Total carbon emissions of transportation U_{22}	0.107
		Unit GDP energy consumption of transportation U_{23}	0.047
		Unit GDP carbon emissions of transportation U_{24}	0.050
	Response U（0.387)	Low carbon transportation development related policy planning U_{31}	0.066
		Fixed asset investment in transportation U_{32}	0.069
		Proportion of natural gas in the energy consumption of transportation industry U_{33}	0.109
		Electricity consumption in transportation industry U_{34}	0.042
		Input-output ratio of Low carbon transport technology transform U_{35}	0.102

Table 3: Development index of low carbon transportation in Hebei province

Year	PI	SI	RI	PSRI
2005	0.270	0.296	0.040	0.606

2006	0.266	0.276	0.051	0.593
2007	0.242	0.276	0.065	0.583
2008	0.224	0.238	0.066	0.528
2009	0.210	0.105	0.072	0.387
2010	0.125	0.131	0.134	0.390
2011	0.101	0.126	0.167	0.395
2012	0.082	0.116	0.217	0.414
2013	0.076	0.104	0.293	0.474
2014	0.069	0.104	0.356	0.530

1) Pressure index PI analysis. The pressure index of low carbon transportation development in Hebei Province in 2005-2014 year shows a trend of rapid decline, because the pressure index is negative, which indicates that the pressure is increasing with the development of social economy in Hebei province. According to table 2 index weight analysis results, the impact of the passenger volume and the passenger flow volume on the pressure index is higher.

2) Status index SI analysis. The development of low carbon transportation development status index in 2005-2014 year is generally decreased, and the decline range of 2005-2009 year is big, and the fluctuation of 2010-2014 year is smaller than that of 2005-2014 year. The main reason is that the traffic transportation energy consumption and transportation carbon emissions index weight is larger, and the actual energy consumption and carbon emissions increased rapidly, so will lead to rapid decline in the status index. In addition, the change of 2010-2014 year is small, which shows that although the pressure of low carbon transportation development continues to increase, the effect of the response measures are gradually highlighted, which has relieved the low carbon development status, rapid deterioration, and the state change is relatively stable.

3) Response index RI analysis. The response index of low carbon transportation development in 2005-2014 is increasing, and the increase of 2005-2009 is small, and the increase of 2010-2014 is high. According to table 2, the weight of natural gas and low carbon transportation technology in the transportation industry is larger than those of other indicators, and the index value is rising rapidly from 2010 year, which has a great relationship with the development of Hebei province.

4) Comprehensive index PSRI analysis. Low-carbon transportation development composite index of Hebei province in 2005-2014 year showed the "first down and then up" the development trend, and can be divided into two stages: The first stage is 2005-2009 year, the composite index from high to low, which is the highest level at 2005-2007 year, the main socio-economic development is relatively small, energy consumption and carbon emissions is relatively small, also fell sharply in 2008-2009, and in 2009 year reached a minimum, the synthesized index is only 0.387, mainly because of social and economic development pressure gradually increased, while the transportation energy consumption and carbon emissions increased sharply, and the corresponding policy measures have not played a significant role; The second stage is 2010-2014 years, the composite index increased year by year, the social and economic development of Hebei Province, the low carbon transportation development level is also gradually improved, low carbon development policies and measures are more obvious. But it should be noted that the overall index rose slowly, so Hebei province should increase the development of low-carbon transportation and support efforts to maintain a good momentum of sustained low carbon development.

5) Development phase analysis. According to the low carbon transportation development in Hebei Province, the comprehensive index of low carbon transportation is from high to low ranking, which reflects the change of first to inferior, and the evaluation results are divided into 6 grades: ① [0.9, 1.0] is in optimal state; ② [0.8, 0.9] is good condition; ③ [0.6, 0.8] in better state; ④ [0.4, 0.6] in alert state; ⑤ [0.2, 0.4] is in poor state; ⑥ [0, 0.2] is in terrible state. According to the comprehensive evaluation of low carbon transportation development level in Hebei Province, only 2005 year is in the "better state", 2009-2011 years are in "poor state", the rest of the year are in "alert state", so the development of low carbon transportation in Hebei province is not optimistic.

6. Conclusion

(1) The pressure index of low carbon transportation development in Hebei province is increasing year by year. The state index of the low carbon transportation development sharp decline in 2005-2009 year, during the period of 2010-2014 year basic remain stable, but at low level; The response index promotes year by year, and during this period, the function highlights gradually; and the PSRI comprehensive evaluation index "first down and then up", can be divided into two stages: The first stage is 2005-2009 years from high to low, the lowest value appeared in 2009 year, the index value is only 0.387; the second

stage is 2010-2014years from low to high, but the rise is slow, and with small fluctuations, with the implementation of the low carbon development policies and measures, the comprehensive index will be further enhanced.

(2) The low-carbon transportation development comprehensive evaluation index system is constructed, using entropy method to determine the index weight. the result showed that the weight of passenger turnover, passenger volume and other index in the pressure index are bigger, the weight of transportation energy consumption and carbon emissions in state index are bigger, the weight of the natural gas proportion and low-carbon transportation technology input-output of respond index in the transportation industry energy consumption are bigger, the weight determination is the foundation of quality synthetic evaluation, compared with Hebei Province transportation development present situation, can be used to provide a reference for the establishment of related policies and measures.

(3) With the social and economic sustainable development, Hebei province transportation low carbon development pressure will further increase, transportation energy consumption and carbon emissions will further increase, in the future to promote low-carbon transportation development process, should increase policy support, expand transportation infrastructure investment and low carbon technology investment, improve the contribution rate of alternative energy and new energy to low carbon development, reduce transportation unit GDP energy consumption and per unit GDP carbon emissions.

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