Evaluation of green transportation development based on pressure-state-response model

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ABSTRACT: In order to promote the green and low-carbon development of transportation in China and provide scientific guidance for green transportation construction, this paper adopts the pressure-state-response theory to construct a PSR model applicable to the development of urban green transportation system, and uses the statistical data of Tianjin, China, and assigns weights to each index with the help of entropy value method, which reasonably and accurately reflects the importance of evaluation indexes. And provides some suggestions for Tianjin transportation development.

1. INTRODUCTION

With the increasing modernization and rapid development of urban motorization in China, environmental problems caused by transportation have gradually developed into an important link in the construction of ecological civilization. Data from Report of China Carbon Neutral Development in 2022 shows that after 2011, the growth rate of per capita CO2 emissions in China has slowed down with the implementation of stricter environmental protection policies, but the Emissions from transportation industry still has about 1 billion tons per year, and it is also the third largest source of CO2 emissions in China. Firstly, the excessive amount of motor vehicles will cause traffic congestion in cities, and traffic congestion is more significant in first- tier and second-tier cities, and even traffic congestion in towns and villages also occur at special times. The development of green transportation can not only achieve the reduction of traffic congestion and reduce environmental pollution, reduce energy consumption and other problems, but also can realize the coordinated the coordination of transportation with environment, society and resources in the future. The scientific construction of green transportation evaluation index system and the accurate measurement of green transportation development level can identify the problems and shortcomings in time, explore the practical path for the green and low-carbon development of China's transportation, and provide scientific guidance to further promote the construction of environment-friendly and resource-saving transportation.

2. EVALUATION RESEARCH OF GREEN TRANSPORTATION IN CHINA

Evaluation research is to determine the green transportation influence factors, and on this basis, select evaluation indexes combined with local reality, use evaluation methods, scientifically evaluate the level of green transportation development in cities, discover the shortcomings and deficiencies in the process of green transportation development, and provide a basis for further promoting green transportation development, which is a key in the transformation of green transportation concept from theory to practice.

Chinese scholars have conducted many researches in constructing the evaluation index system. Gu Shanghua (2000) [1] systematically analyzed the current situation and problems faced by China's transportation planning, such as land use, energy consumption, traffic congestion and environmental pollution, and put forward the urgent need to build a green transportation system. Jiang Yuhong et al. (2008) [2] selected eight evaluation indexes from three levels, including traffic function index, environmental protection target and comprehensive benefit target, and used the value function method to evaluate the level of green transportation development in the city. Fu Li et al. (2011) [3] analyzed the current situation of Shenzhen's transportation development from four aspects, such as transportation facilities, residents' travel, energy consumption and environmental pollution, and constructed an evaluation index system for sustainable urban transportation development, and used the hierarchical analysis method to carry out an empirical study. Lu Huapu et al. (2012) [4] proposed seven main evaluation indexes of the green transportation system, mainly based on the analysis of the differences between green transportation planning and traditional transportation planning. Wu Hui (2015) [5] and Jin Dan et al. (2018) [6] established a green transportation evaluation index system for cities, and used the object element topologizable method and AHP-entropy value method to evaluate the research from five levels: driving force, pressure, state, impact and response. Wang Shuang et al. (2018) [7] compared and analyzed the existing index

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system in terms of energy saving and carbon reduction, ecological protection, comprehensive pollution prevention and control, resource saving and recycling, energy saving and environmental protection supervision and management according to the target requirements and task deployment of green transportation development in the 13th Five-Year Plan for Energy Saving and Environmental Protection Development of Transportation", and designed a set of industry-wide green transportation development evaluation index system is constructed. In summary, the method of using pressure-state-response model has not been applied to the evaluation of green transportation development.

3. PSR MODEL AND EVALUATION INDEX OF GREEN TRANSPORTATION

3.1. PSR Model of Green Transportation

The pressure-state-response model (PSR model), is a widely used sustainable development modeling framework in ecological assessment, proposed by Canadian statisticians David J. Rapport and Tony Friend. The PSR framework is built on the basis of a cause-and-effect relationship between the consumption of natural resources and the environmental stresses caused by human development activities, followed by a response to the current situation through relevant policy measures to maintain sustainable economic, social and environmental development.

The construction of transportation facilities and transportation activities create pressure (P) while capturing and consuming resources. The pressure model is selected as the negative behavior of green transportation planning, design, construction and operation that affects the ecosystem. State (S) reflects the change of natural resources and environment in a specific time range, which is the result of pressure (P) and the governance performance of response (R). The production method of high energy consumption and high emission will deteriorate the ecological environment and hinder the development of green transportation, which eventually leads to the intervention of environmental policy, economic policy and ministry policy, and the ability to restore the ecological imbalance caused by the construction of green transportation to a steady state, i.e. response (R). The response model is selected as low carbon travel, energy substitution, green planning and construction [8], and ecological restoration. The pressure-state-response model is shown in Figure 1.

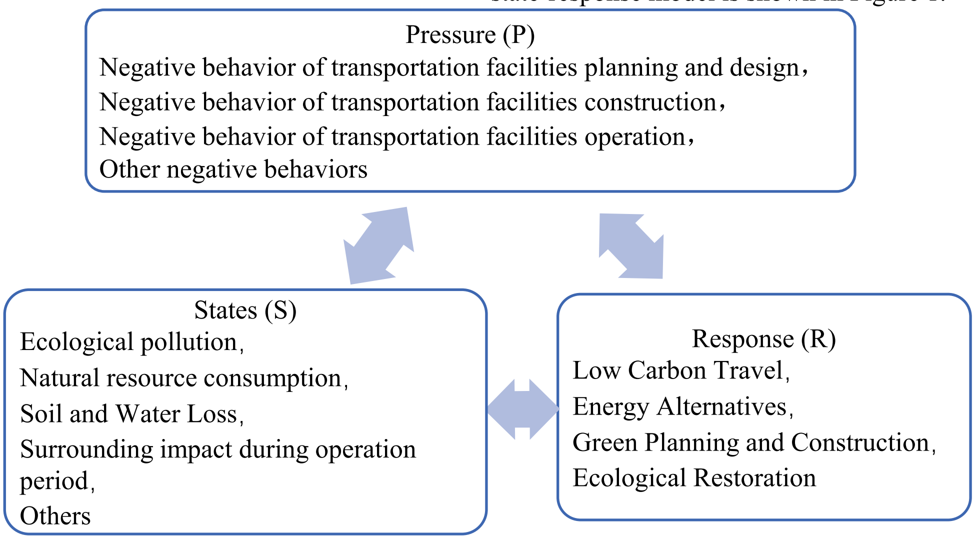

Figure 1. The pressure-state-response model

3.2. PSR Evaluation Indexes Construction

3.2.1. Selection of Evaluation Indexes

Through documentary research, the existing evaluation index system is summarized using theoretical analysis method and frequency statistics method. According to the principles of scientificity, representativeness, comparability and operability of index development, evaluation indexes are initially selected according to the PSR framework model of urban green transportation system. The initial selection of indexes are screened, refined and modified with reference to relevant domestic and foreign research and expert recommendations. The 19 basic evaluation indexes corresponding to the specific contents of the PSR framework are finalized, as shown in Table 1.

Table 1. Evaluation Indexes selected for the PSR model framework of green transportation

Index Type	Index Content
Pressure	Number of buses per 10,000 people, Rental car ownership per 10,000 people, Energy consumption per unit of GDP, Total pollutant emissions from motor vehicles, The proportion of land consumption for road transportation facilities, Road area per capita, Average noise of traffic arteries,
State	Number of days with good ambient air quality, Accident fatality rate of 10,000 vehicles, 90% of residents' travel time consumption, Comprehensive situation of ecological environment quality, the delay index of congestion peak period
Response	Greening coverage rate of built-up areas, Recycling rate of old road materials, solid waste and tunnel waste, Percentage of new energy vehicles in public transportation and cabs, Vehicle exhaust gas compliance rate, The proportion of investment in transportation infrastructure, Financial expenditure on road transportation, Fiscal expenditure on environmental protection

3.2.2. Calculation of evaluation index weights

In the index system of green transportation, the entropy value method [9] is used to determine the index data weights according to the degree of variability of the index data.

Let there be n objects to be evaluated and m indexes, then x_{ij} denotes the value of the jth index of the ith object to be evaluated, and its original data matrix is $X=\left[x_{ij}\right]_{n\times m}$.

In the first step, the original matrix x is dimensionlessly processed, and the matrix $p=\left[p_{ij}\right]_{n\times m}$.

In the second step, under the jth index, the proportion of the ith appraised object in this index is calculated. See Equation 1 below:

$$p_{ij}=\frac{x_{ij}}{\sum_{i=1}^{n}x_{ij}},(i=1,2,3...,n;j=1,2,3...,m) \quad (1)$$

In the third step, the entropy value of the jth index is calculated. See Equation 2 below:

$$e_j=-k\sum_{i=1}^{n}p_{ij}\ln(p_{ij}),(j=1,2,3...,m) \quad (2)$$

The fourth step, the calculation of the coefficient of variation of the jth index. See Equation 3 below:

$$d_j=1-e_j,0\le d_j\le 1. \quad (3)$$

The fifth step is the calculation of the entropy of the jth indicator. First, determine the entropy of the indicator: $E_e=\sum e_j$, then the entropy weight is: $w_j=d_j/(m-E_e)$.

3.2.3. Data analysis

(1) Data sources

This paper refers to data from 2015-2021, mainly from documents such as China Urban Statistical Yearbook, Statistical Yearbook of Urban Construction, Tianjin Transportation Yearbook, China Environmental Statistical Yearbook, China Environmental Yearbook, Tianjin National Economic and Social Development Statistical Bulletin, Tianjin Ecological and Environmental Status Bulletin, Tianjin Municipal Government Work Report, and Tianjin National Economic and Social Development Statistical Bulletin, Tianjin Ecological and Environmental Situation Bulletin, Tianjin Municipal Government Work Report and other documents, and the data derived from statistics and calculations by consulting relevant government websites such as statistical bureau, housing construction bureau ,traffic bureau, environmental protection agency, environmental protection agency to ensure the accuracy and authority of the statistical data. The indexes for which accurate data are not available are scored by 15 industry experts according to a 5-point Likert scale, and the mean value.

(2) Weight distribution

First, the obtained datas are standardized to eliminate the effects of variance differences in magnitudes and variables. Then the entropy value and the coefficient of variation are calculated, and then the weights are derived according to the calculation steps of the entropy value method to obtain the comprehensive weight assignment table of indexes, which is shown in Table 2.

Table 2. Green Transportation PSR Indexes and Weights·

Index Type	Index Content	Index Unit	Index Nature	Entropy value	Coefficient of variation	Weight
Pressure (0.370)	Number of buses per 10,000 people	Vehicles per 10,000 people	+	0.982	0.018	0.064
	Rental car ownership per 10,000 people	Vehicles per 10,000 people	+	0.99	0.01	0.036
	Energy consumption per unit of GDP	Tons of standard coal per million yuan	-	0.985	0.015	0.053

Index Type	Index Content	Index Unit	Index Nature	Entropy value	Coefficient of variation	Weight
	Total pollutant emissions from motor vehicles	million tons	-	0.984	0.016	0.057
	The proportion of land consumption for road transportation facilities	%	-	0.98	0.02	0.071
	Road area per capita	square meters per capita	+	0.988	0.012	0.043
	Average noise of traffic arteries	dB	-	0.987	0.013	0.046
State (0.238)	Number of days with good ambient air quality	day	+	0.99	0.01	0.036
	Accident fatality rate of 10,000 vehicles	%	-	0.989	0.011	0.039
	90% of residents' travel time consumption [10]	Minutes per time	-	0.985	0.015	0.053
	Comprehensive situation of ecological environment quality	-	+	0.985	0.015	0.053
	the delay index of congestion peak period	-	-	0.984	0.016	0.057
Response (0.391)	Greening coverage rate of built-up areas	%	+	0.985	0.015	0.053
	Recycling rate of old road materials, solid waste and tunnel waste	%	+	0.98	0.02	0.071
	Percentage of new energy vehicles in public transportation and cabs	%	+	0.979	0.021	0.075
	Vehicle exhaust gas compliance rate	%	+	0.984	0.016	0.057
	The proportion of investment in transportation infrastructure	%	+	0.978	0.022	0.078
	Financial expenditure on road transportation	%	+	0.984	0.016	0.057

(3) Analysis of results

The article established the Tianjin green transportation evaluation index system based on PSR model and measured the industry index datas from 2015-2021 by entropy method. It is found that the response category indicator has the largest weight among the three categories of PSR indexes, it is 0.391; the smallest weight is the state category indicator, it is 0.238; the pressure level indicator with the middle weight is 0.370. This is inextricably related to the high importance attached by the Chinese government to environmental management in the past few years and the rapid development of the industry.

The pressure indexes of the proportion of land consumption for road transportation facilities, number of buses per 10,000 people, total pollutant emissions from motor vehicles, energy consumption per unit of GDP, average noise of traffic arteries, road area per capita, and Rental car ownership per 10,000 people are decreasing in order. In the green transportation evaluation model system of Tianjin, it is shown that the influence of the above indexes on the green transportation pressure indexes decreases gradually. Among them, number of buses per 10,000 people, road area per capita, Rental car ownership per 10,000 people are positive indexes, which promote the development of green transportation to a certain extent and partially offset the effects of the negative indexes of the overall road traffic facilities land consumption, Total pollutant emissions from motor vehicles, energy consumption per unit of GDP, and Average noise of traffic arteries.

The weight of the state indicator is 0.238.Among them, the number of good days ambient air quality and the comprehensive condition of ecological environment quality are positive indexes, while accident fatality rate of 10,000 vehicles , 90% of residents' travel time consumption and the delay index of congestion peak period are negative indexes, which the delay index of congestion peak period is the largest, indicating that the congestion peak period is the main expression of the current traffic operation status of Tianjin, and is also an urgent traffic problem.

Tianjin's green transportation infrastructure investment has the highest proportion in the response category index. Increasing investment in transportation infrastructure will greatly relieve the pressure layer and improve the state layer. The proportion of new energy vehicles in public transportation vehicles and cabs ranks second, showing that in the response layer, improving the use of new energy and reducing the use of traditional vehicles is also the first priority.

4. CONCLUSION AND IMPLICATION

4.1. Research Conclusion

At present, there are various methods to evaluate the development of urban green transportation. The PSR model constructed in this paper starts from the mechanism of the development of urban green transportation system, takes into account the socio-economic, resource and environmental factors and the relationship between them, solves the interconnection between several environmental indexes from the perspective of system analysis, and highlights the core regulating role of people in the urban green transportation system. Based on this model, the weighting of each index is assigned with the help of entropy value method, which reflects the importance of evaluation indexes reasonably and accurately. The PSR model provides a methodological basis for the evaluation of green transportation development.

4.2. Implications

Tianjin traffic system green construction has a long way to go. Urban transportation and land use need to be reasonably planned under the leadership of the government, and traffic demand management needs to be improved by relevant economic and administrative means; to create a good green transportation infrastructure and travel environment, the public transportation system should be further optimized and slow traffic should be actively developed [11]; pollutant emissions should be strictly controlled, and the new energy vehicle market will be vigorously developed; to advocate public participation in transportation decision making and strengthen Citizens' awareness of green travel will play an important role in transportation decision making; the relevant excellent experience will be strengthened to learn and exchange with other cities and regions. Through gradual and steady progress, we should create an atmosphere of green travel life in the whole society, achieve steady growth in the process of green transportation, and form a deep-rooted green transportation concept.

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