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## Research on Low Carbon Level Evaluation of Urban Transportation System Based on Grey Comprehensive Evaluation

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# Research on Low Carbon Level Evaluation of Urban Transportation System Based on Grey Comprehensive Evaluation

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**Abstract.** With the rapid development of social economy, the demand for urban transportation is increasing, and the energy consumption and greenhouse gas emission of urban transportation are also increasing year by year. In this situation, energy saving and emission reduction of transportation industry is imperative. This paper studies the evaluation of the low carbon development level of urban transportation system. Based on the research of domestic and foreign literatures and the characteristics of Qingdao, the urban low-carbon traffic evaluation index system is constructed, including transportation infrastructure, transportation services, resources and environment, and transportation policies and regulations. There are 16 evaluation indicators. The entropy weight method is used to determine the weight value of the evaluation index, and then the gray correlation model is used for evaluation. Taking Qingdao as an example, the empirical analysis shows that in recent years, the low-carbon traffic level in Qingdao is constantly changing. At the same time, the correlation degree of each index is analyzed to find out the crux that hinders the development of low-carbon urban transportation.

## 1. Introduction

In recent years, with the development of China's social economy and urbanization, the car penetration rate is getting higher and higher, and the pace of the car process is also accelerating. Therefore, in the future, the urban transportation sector is still one of the sectors with large carbon emissions in China. In order to save energy and reduce emissions, the Ministry of Transport has proposed to build a green recycling low-carbon transportation system by 2020<sup>[1]</sup>. Establishing an evaluation index system for urban transportation low-carbon development is an important link in the realization of low-carbon sustainable urban transportation process, and has important research significance.

At present, the research on the evaluation indicators and methods of urban transportation system in foreign countries has been comprehensive, and has achieved certain results in practical applications [2]. Ghaderi et al. combined DEA and AHP to analyze and evaluate the transportation system [3]. Based on the analysis of the characteristics of urban traffic system, Vuchic V R carried out the comprehensive evaluation with the analytic hierarchy process and fuzzy comprehensive evaluation method [4]. Domestic research on urban traffic system evaluation has also made some achievements. Zhao shengnan proposed the low-carbon evaluation index system of urban passenger transport under three scenarios, and analyzed the example with the cloud matter-element model [5].



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## 2. Establishment of evaluation indicators

In order to evaluate the low-carbon development level of urban transportation objectively, the evaluation index system should be established first. On the basis of consulting a large number of literatures, domestic and foreign research results and relevant national norms and standards, this paper summarizes the research results. Considering that Qingdao itself is a mountainous city and located in the coastal area, the indicators are selected according to the establishment principles of the evaluation system. Referring to the expert opinions, the indicators are screened, and the subsystems such as transportation and facilities, operational efficiency, resources and environment, management policies, and social and economic transportation adaptability are covered as much as possible, and the final complete evaluation index system is obtained, as shown in Table 1.

**Table 1.** Urban transportation low-carbon level evaluation index system.

Goal layer	Criterion layer	Index layer
Evaluation of low carbon level in urban transportation system	Transportation infrastructure	Urban road network density
		Per capita road area
		Growth rate of private car ownership
		Number of port berths
	Transportation service	Traffic connection satisfaction
		Traffic congestion index
		10,000 public steam car ownership
		10,000car accident rate
	Resources and environment	Carbon dioxide emissions
		Traffic noise pollution rate
		Total energy consumption of the transportation system
		Green coverage rate in built-up areas
	Traffic policies and regulations	Low-carbon transport publicity efforts
		Comprehensive planning of transportation system
		Public transport priority policy
		Electric vehicle promotion policy

## 3. Grey system comprehensive evaluation

There are many comprehensive evaluation methods. Different evaluation methods have their own advantages and disadvantages. This paper evaluates urban low-carbon transportation system, which is a complex and multi-factor comprehensive evaluation. According to the characteristics of the system, the grey system theory evaluation method is selected by analyzing each evaluation method. The grey system theory focuses on the study of the uncertainty of some data, and has low requirements for the size of sample size. Because the data is limited, the sample data is small, and there is a certain error, the gray system method is used for evaluation.

### 3.1. Entropy weight method to determine index weight

The entropy weight method is an objective method of weighting and has certain application prospects in the field of evaluation and decision-making. The concept of entropy stems from thermodynamics and is a measure of system state uncertainty.

*3.1.1. Data standardization.* The first step is to standardize the raw data. The main role of data standardization is to eliminate dimensional relationships between variables, making data comparable. The evaluation indicators in the urban low-carbon transportation system are mainly the smaller the better the cost type and the bigger the better the benefit type. The larger and better the benefit index adopts the formula (1), the smaller the better the cost type index adopts the formula (2), ie

$$r_{ij} = \frac{1 - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad (1)$$

$$r_{ij} = \frac{\max(x_{ij}) - 1}{\max(x_{ij}) - \min(x_{ij})} \quad (2)$$

*3.1.2. Find the information entropy of each indicator.* According to the definition of information entropy in information theory, the information entropy of a set of data is

$$E_j = -\ln(n)^{-1} \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (3)$$

$$\text{Among them } p_{ij} = Y_{ij} / \sum_{i=1}^n Y_{ij}.$$

*3.1.3. Determine the weight of each indicator.* The eigenvalues and eigenvectors are calculated by using the Jacobian formula. According to the calculation formula of information entropy, the information entropy of each index is calculated as  $E_1, E_2, \dots, E_k$ , and the weight of each index is calculated according to company (4) through the obtained information entropy.

$$W_i = \frac{1 - E_i}{k - \sum E_i} \quad (i = 1, 2, \dots, k) \quad (4)$$

### 3.2. Grey system evaluation model

The comprehensive evaluation model of grey correlation is:  $S=T$ . Where  $S$  represents the comprehensive evaluation result matrix of each evaluation object,  $W$  represents the weight matrix vector of each evaluation index, and  $T$  represents the correlation coefficient matrix.  $\tau_{ij}$  indicates the correlation coefficient between the  $i$ -th index value of the  $j$ th evaluation object and the  $i$ -th optimal index. The size of the grey coefficient reflects the degree of association of the two series on the  $i$ th indicator. The formula for calculating the grey correlation coefficient is as follows:

$$\tau_{ji} = \frac{\min_j \min_i |r_i^* - r_{ij}| + \alpha \max_j \max_i |r_i^* - r_{ij}|}{|r_i^* - r_{ij}| + \alpha \max_j \max_i |r_i^* - r_{ij}|} \quad (5)$$

Where  $\alpha$  denotes the resolution coefficient and takes a value of 0-1. In order to reduce the impact of extreme values on the calculation results, this paper takes 0.5. Finally, the correlation is calculated by the following formula:

$$S_j = \sum_{i=1}^m \tau_{ji} \omega_i \quad (i = 1, 2, 3, \dots, n) \quad (6)$$

The results of the evaluation are ranked in descending order, that is, the scores of urban low-carbon traffic construction levels are ranked in recent years. The greater the degree of association, the higher the score.

#### 4. Evaluation on the low carbon level of Qingdao transportation system

Taking Qingdao as an example, this paper comprehensively evaluates the low-carbon system of Qingdao traffic based on the grey system theory. For quantitative indicators, by consulting the "Shandong Province Statistical Yearbook", "Qingdao City National Economic and Social Development Statistical Bulletin" and other relevant literature and query the official website of the National Bureau of Statistics and other data obtained, qualitative indicators are obtained through surveys or expert scoring. The data obtained in the final evaluation index are shown in Table 2.

**Table 2.** Raw data.

indicators	2013	2014	2015	2016	2017
Urban road network density(km/km <sup>2</sup> )	147	147	147	146	146
Per capita road area(m <sup>2</sup> )	24.7	24.3	23.5	18.2	19.1
Growth rate of private car ownership (%)	0.065	0.088	0.151	0.142	0.114
Number of port berths	88	90	97	100	127
Traffic connection satisfaction(point)	1.40	1.39	1.41	1.41	1.44
Traffic Congestion Index	4.1	4.2	4.1	4.3	4.5
10,000 public steam car ownership (Vehicle/10,000)	7.63	8.35	8.27	9.11	8.97
10,000car accident rate (%)	1.75	1.58	1.43	1.32	1.24
Carbon dioxide emissions (million metric tons)	877.766	799.612	796.612	797.685	801.442
Traffic noise pollution rate	68.9	67.8	68.5	68.2	68.8
Total energy consumption of the transportation system (10,000 tons of standard coal)	359.74	327.71	326.48	326.92	328.46
Green coverage rate in built-up areas (%)	44.7	44.7	39.4	38.6	39.1
Low-carbon transport publicity efforts(point)	71	73	76	77	80
Comprehensive planning of transportation system(point)	80	79	80	81	83
Public transport priority policy(point)	77	79	80	83	85
Electric vehicle promotion policy(point)	80	82	81	82	80

Use excel to calculate the weight of the indicator. Since the dimension of each indicator data is not uniform, the data must first be dimensionlessly processed to obtain standardized data, and then the information entropy of each indicator is obtained, and the weights are as shown in Table 3.

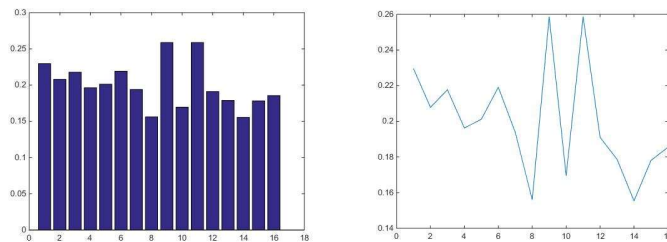
**Table 3.** Weight of indicator.

Guidelines	Weight	Index	Weight
Transportatin infrastructure	0.249	Urban road network density	0.06262
		Per capita road area	0.06242
		Growth rate of private car ownership	0.06153
		Number of port berths	0.06239
Transportatin service	0.250	Traffic connection satisfaction	0.06260
		Traffic Congestion Index	0.06261
		10,000 public steam car ownership	0.06257
		10,000car accident rate	0.06243
Resources and environment	0.250	Carbon dioxide emissions	0.06260
		Traffic noise pollution rate	0.06262
		Total energy consumption of the transportation system	0.06260
		Green coverage rate in built-up areas	0.06256
Traffic policies and regulations	0.251	Low-carbon transport publicity efforts	0.06260
		Comprehensive planning of transportation system	0.06261
		Public transport priority policy	0.06260
		Electric vehicle promotion policy	0.06262

According to the formula (5) above, the gray correlation system evaluation is carried out, and the MATLAB software is used to solve the operation. The results are as follows. The greater the grey correlation, the closer to the optimal solution, that is, the greater the gray correlation, the more optimal.

result =

1.0000	0.2295	0.1554	14.0000
2.0000	0.2078	0.1560	8.0000
3.0000	0.2177	0.1695	10.0000
4.0000	0.1962	0.1781	15.0000
5.0000	0.2012	0.1787	13.0000
6.0000	0.2191	0.1854	16.0000
7.0000	0.1938	0.1910	12.0000
8.0000	0.1560	0.1938	7.0000
9.0000	0.2587	0.1962	4.0000
10.0000	0.1695	0.2012	5.0000
11.0000	0.2587	0.2078	2.0000
12.0000	0.1910	0.2177	3.0000
13.0000	0.1787	0.2191	6.0000
14.0000	0.1554	0.2295	1.0000
15.0000	0.1781	0.2587	9.0000
16.0000	0.1854	0.2587	11.0000



**Figure 1.** Gray correlation calculation result graph of each indicator.

According to the formula (6) above, the gray correlation degree of low-carbon traffic development level in Qingdao in recent years is calculated. The calculation and sorting results are shown in Table 4.

**Table 4.** Qingdao Low Carbon Traffic Development Level Comprehensive Evaluation Result.

Year	2013	2014	2015	2016	2017
Result	0.342	0.632	0.628	0.496	0.637
Order	5	2	3	4	1

It can be concluded from Table 4 that in the past five years, the development level of low-carbon transportation in Qingdao has shown an irregular trend. In 2017, Qingdao has the highest level of low-carbon transportation. From 2014 to 2016, it has been decreasing year by year. In 2013, the level of low-carbon transport was the lowest. It can be seen that in 2017, with the development of economy and the increase of population, the level of transportation infrastructure has been somewhat reduced, which cannot keep up with the development of cities. However, the high level of transportation services and policies and regulations indicates that the city attaches great importance to the development of urban transportation. In recent years, Qingdao is in the stage of rapid development, and the urban transportation is also in constant adjustment. The subway is under planning and construction, and many roads are also being rebuilt, so the low-carbon transportation level is also in constant change. But on the whole, the development level of low-carbon transportation in Qingdao is relatively low, and there is a certain gap between Qingdao and other cities such as Beijing, Shanghai, Guangzhou and Shenzhen.

In order to further compare the scores of each evaluation index, a set of reviews  $V = \{\text{good, better, general, poor, very bad}\}$  was established, and 16 evaluation indicators were evaluated. The results are shown in Table 5. It can be concluded that the low-carbon transport development in Qingdao is evaluated as good by two indicators, with the better index accounting for only 25% and most of the indicators being average or poor. Among them, the evaluation result of one index is very bad, which needs special attention. Indicators with higher evaluation results need to continue to maintain the level of development of these projects. Indicators with poor evaluation, such as berth number of port, traffic noise pollution index and comprehensive planning of traffic system, are the shortcomings of the development of low-carbon transportation in Qingdao, which have great room for improvement and need to be vigorously developed. In the future planning and development, we should pay more attention to the development

of public transport. Increase the number of buses and facilities, set up bus lanes, and strengthen people's awareness of low-carbon environmental protection. For the construction of ports, low-carbon and environmental protection should also be considered instead of focusing on development. The overall transfer system in the main urban area needs to be further improved and the planning of the system should be taken into account.

**Table 5.** Evaluation results of each evaluation index.

Index	Good	better	general	poor	Very bad
Urban road network density		√			
Per capita road area			√		
Growth rate of private car ownership		√			
Number of port berths				√	
Traffic connection satisfaction			√		
Traffic Congestion Index		√			
10,000 public steam car ownership			√		
10,000car accident rate			√		
Carbon dioxide emissions	√				
Traffic noise pollution rate				√	
Total energy consumption of the transportation system	√				
Green coverage rate in built-up areas		√			
Low-carbon transport publicity efforts					√
Comprehensive planning of transportation system				√	
Public transport priority policy			√		
Electric vehicle promotion policy			√		

## 5. Conclusion

This paper filters the evaluation indicators through the research of domestic and foreign literatures, and combines the quantitative and qualitative means to establish an urban low-carbon traffic evaluation index system. The entropy weight method is used to analyze the data of each index from 2013 to 2017, and the weight of each indicator is established, and then the evaluation is based on the gray system correlation. Taking Qingdao as an example, the evaluation results show that the overall development of urban low-carbon transportation system in Qingdao needs to be further improved and is at a medium level. The results of most indicators are general or poor, and the development potential is large. It is necessary to focus on the indicators with lower evaluation results and larger weights to make up for the shortcomings and improve the overall level of low-carbon transportation development in Qingdao. If the traffic noise pollution index is poor, municipal road construction needs to be rationally planned, and sound barriers should be set up when railway locomotives pass through the urban area. It is necessary to increase the propaganda of low-carbon transportation, change the way people travel, and raise people's awareness of low carbon. Finally, transform the urban transportation development model, optimize the traffic structure, and achieve the goal of low-carbon transportation development.

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