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Research Article

The AHP (1-9 Value Scale) Level Method to Analyze the Development of Logistics under the Perspective of Low-Carbon Environmental Protection: Taking Shandong Province, China, as an Example

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Reducing the total carbon emissions of the logistics industry is one of the basic requirements for the development of a low-carbon economy. Based on the AHP analytic hierarchy process and the 1-9 value scaling method, an evaluation index system for the low-carbon development of the logistics industry is constructed. At present, the development of low-carbon logistics requires the combination of low-carbon technology and low-carbon management to ensure the integrity and dynamics of low-carbon logistics control. The results of this study show that in the AHP index analysis of the development of logistics industry in Shandong Province, compared with 13 evaluation indexes of low-carbon logistics and traditional logistics, low-carbon logistics is significantly better than traditional logistics. Among them, the implementation of low-carbon logistics policy system has increased the energy utilization rate to 88.72%, the recovery rate of warehousing and logistics waste to 92.11%, and other relevant indicators have also been improved and optimized to varying degrees. Based on the EKC model curve, the total carbon emissions from 2015 to 2019 showed a downward trend month by month. The future development of low-carbon logistics mainly starts with reducing the total carbon emission of logistics transportation and improving energy utilization. Aiming at the main influencing factors of the development of low-carbon logistics, this paper puts forward specific measures for the development of low-carbon logistics, in order to promote the development of low-carbon logistics.

1. Introduction

The logistics industry is an accelerator and lubricant for social and economic development. With the continuous increase in the proportion and importance of the Internet economy in the national economy, the logistics industry will play an increasingly important role [1, 2]. At present, the global ecological environment tends to deteriorate as one of the main problems facing countries all over the world. Blind and unrestrained economic development, wild plunder to nature, and long-term excessive discharge are the main causes of environmental pollution. Under the background that all walks of life are actively advocating low-carbon environmental protection, the logistics industry should also reduce carbon emissions from various links such as cargo storage, long-distance transportation, and short-distance turnover and actively move towards the development of low-carbon logistics [3–8].

The logistics industry has always been one of the major carbon emitters, mainly including energy consumed by long-distance transportation and short-distance turnover of vehicles, air pollution caused by excessive vehicle exhaust emissions, and environmental pollution caused by solid waste generated in commodity packaging turnover [9–13]. It can be seen that with the continuous expansion of the overall scale of the logistics industry, controlling the pollution of the ecological environment caused by the development of the logistics industry has very important practical

Table 1: Evaluation index system for the development of low-carbon logistics industry.

Target layer	Criterion layer	Index layer
Carbon emission evaluation of logistics industry	Warehouse	Whether to use recycled environmentally friendly building materials
		Utilization rate of warehouse
	Transport	Fuel consumption rate
		Green energy usage rate
		Vehicle no-load rate
		Combination rate of various modes of transportation
		Reasonable transportation route planning
	Packing	Utilization rate of green packaging
		Waste recycling rate
		Whether the product is overpackaged
	Technology and management	Low-carbon new technology utilization rate
		Logistics management level evaluation
		Logistics cost chain index

significance [14–20]. The concept of low-carbon logistics derived from the low-carbon economy is also a concentrated expression of the concept of low-carbon development in the logistics management system. The current low-carbon logistics development model has been recognized by most countries in the world [21–23]. Countries around the world have begun to adopt technology from different perspectives, such as management and structural adjustment, and reduce the total carbon emissions in logistics activities and the pressure on the surrounding environment from logistics activities [24].

Under the background that the low-carbon and environmentally friendly economic development model has gradually become the mainstream, the development of the logistics industry has also shown some new characteristics. For this reason, this article analyzes the current development of the logistics industry based on the AHP analytic method and the 1-9 scale method in China. The main feature is that the EKC curve model is used to estimate the total carbon emissions of the logistics industry, and the mechanism of low-carbon development in the logistics industry is elaborated. Finally, relevant suggestions and countermeasures for the sound development of the low-carbon logistics industry in the future are given [25–27].

2. Methods and Materials

(1) Data collection and AHP evaluation model construction

In accordance with the overall requirements of sustainable development, in the development process of the logistics industry, it is necessary to achieve low pollution, low energy consumption, and low emissions. In addition, it is better to improve the use efficiency of resources and energy and gradually replace coal, petroleum, and other nonstandard energy sources with green, clean, and renewable energy. The development of low-carbon logistics is more friendly to the ecological environment and at the same time can improve the operational efficiency of the logistics industry and reduce various costs. On the one hand, we need to seek technological breakthroughs in low-carbon emissions. On the other hand, we must implement innovations from a management perspective, such as the introduction of supply chain management, data information management, and intermodal management, to achieve the simultaneous progress of low-carbon technology and low-carbon management.

In addition, low-carbon logistics management is a dynamic, overall, and long-term management process. From the perspective of system theory, the development of low-carbon logistics industry should also be combined with supply chain management and logistics information management to meet the overall requirement for sustainable development. Compared with traditional high-pollution and high-emission traditional logistics, the development of low-carbon logistics has distinct characteristics. In this paper, AHP is used to construct an evaluation system to analyze some characteristics of the development of low-carbon logistics. AHP analysis is an efficient and practical quantitative analysis method. We take the logistics carbon emission problem as an example to build a multilevel structure and the weighting ratio between each layer. The levels are as shown in Table 1.

In order to make the judgment result easier to quantify, the 1-9 value method is used to compare each index pair by pair. The meaning of each scale is shown in Table 2.

Taking the overall development of the logistics industry in Shandong Province in the past 10 years as panel data, the province has vigorously promoted the low-carbon logistics model throughout the province since 2015, and the average data of the logistics industry development in the five years from 2010 to 2014 is used as the traditional logistics model. The development data of the logistics industry in 2015-2019 is used as the relevant data for the development of low-carbon logistics. Shandong Province is located in the eastern part of the North China Plain. Its economy has been active for a long time and its development is in good condition. At the same time, the province has convenient transportation such as roads, railways, water transport, and

Table 2: Corresponding meaning of 1-9 value scale.

Scaling	Meaning
1	Same importance of indicators
3	Compared with the index, the former is slightly more important than the latter
5	Compared with the index, the former is obviously more important than the latter
7	The index is very important compared to the former than the latter
9	The index is extremely important compared to the former than the latter
2, 4, 6, 8	Importance is in the middle
Reciprocal	The ratio of the former to the latter and the latter to the former is the reciprocal of each other

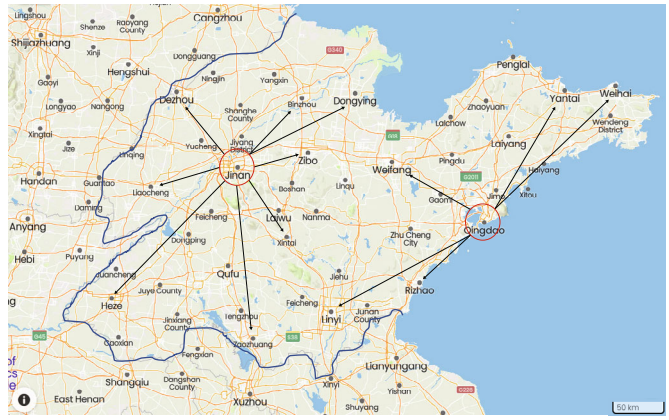

Figure 1: Schematic diagram of the spatial distribution of the logistics industry in Shandong Province.

aviation, and its logistics industry is very developed. The distribution of the logistics industry with Jinan and Qingdao as dual cores has gradually formed, as shown in Figure 1.

The logistics industry-related data of Shandong Province is input into the AHP analytic hierarchy model, and the 1-9 value scale method is used for comparison. Compared with the traditional logistics industry, the index analysis results of low-carbon logistics in Shandong Province are shown in Table 3.

Through research based on AHP analytic hierarchy process, low-carbon logistics has some unique characteristics compared with traditional logistics methods and has obvious advantages in environmental protection control and the application of new technologies. From the results of data analysis, it can be concluded that the main characteristics of low-carbon logistics at this stage are as follows: (1) low-carbon technology and low-carbon management are integrated and developed. The use of clean energy is the main measure to reduce carbon emissions. For example, in the short-distance logistics turnover, electric vehicles and solar vehicles are gradually substituted for fuel vehicles. In every link of low-carbon logistics, technological innovation and management innovation are inseparable, including the management of logistics processes, the management and training of logistics personnel, and the training of various software and hardware technologies. The continuous progress of low-carbon technology and the continuous improvement of low-carbon management level influence and promote each other, which are the basic characteristics of the development of low-carbon logistics. (2) Low-carbon logistics is a comprehensive and dynamic logistics management process. Low-carbon logistics is a complex and dynamic system engineering. Only by ensuring low-carbon and environmental protection in every link and every component of the low-carbon system in the logistics system can the information in the system have better integrated flow, capital flow, and value flow, reducing the total carbon emissions in logistics turnover and transportation as a whole. Whether in technology introduction or low-carbon management, we should follow all-round and three-dimensional development requirements to improve every aspect of low-carbon logistics management. (3) Low-carbon logistics management should be supervised by the government environmental protection department. Different from traditional logistics methods, low-carbon logistics is related to the key future development plan. It is impossible to implement various logistics environmental protection policies in a comprehensive and quality manner only by relying on the leadership of enterprises. Government departments play a leading role in environmental remediation and implementation of environmental protection policies. Through macrocontrol, policy formulation, tax, and fee adjustments, they ensure that logistics companies improve the efficiency of introducing high-tech and logistics business management levels and reduce corporate management costs and operations. At the same time, it achieves the goal of reducing carbon emissions. At present,

Table 3: Analysis of AHP indicators for the development of logistics industry in Shandong Province.

No.	Index	Low-carbon logistics	Traditional logistics
1	Whether to use recycled environmentally friendly building materials	Yes	No
2	Utilization rate of warehouse	95.56%	77.41%
3	Fuel consumption rate	88.72%	68.97%
4	Green energy usage rate	93.36%	58.90%
5	Vehicle no-load rate	5.41%	32.48%
6	Combination rate of various modes of transportation	98.15%	74.51%
7	Reasonable transportation route planning	12.85% more than the theoretical transportation journey	33.15% more than the theoretical transportation journey
8	Utilization rate of green packaging	97.82%	84.10%
9	Waste recycling rate	92.11%	68.14%
10	Whether the product is overpackaged	No	Yes
11	Low-carbon new technology utilization rate	77.98%	61.15%
12	Logistics management level evaluation	9.5 points	7.0 points
13	Logistics cost chain index	Overall reduction 2.6%	1.1% overall reduction

the low-carbon economy in China is in its infancy. Most logistics companies are not very aware of low-carbon environmental protection. Only relying on the conscious adjustment of enterprises is far from meeting the requirements of low-carbon environmental protection policies. It must be managed and coordinated by relevant government environmental protection departments and supervision to help logistics companies shift from supervising and implementing low-carbon policies to consciously implementing low-carbon policies.

(2) Estimation of total carbon emissions based on EKC model

Since the logistics management system in China has not yet established a complete monitoring system, there is no uniform standard for measuring carbon emissions. To this end, this article uses the EKC model (Environmental Kuznets Curve Model) commonly used internationally to estimate the energy consumption of low-carbon logistics. The formula is described as follows:

$$c_T = \sum_{i=1}^{n} c_i = \sum_{i=1}^{n} \frac{e_i}{e_T} \times \frac{c_i}{e_i} \times e_T = \sum_{i=1}^{n} \omega_i \times \kappa_i \times e_T. \quad (1)$$

In the formula, c_T is the total carbon emissions of the logistics industry in a certain area, c_i is the carbon consumption of the ith energy, e_T is the total energy consumption of a certain place, e_i is the total consumption of the ith energy, ω_i is the proportion of ith energy in the total energy, and κ_i represents the carbon emission intensity of the ith energy.

From the perspective of carbon emissions, the carbon sources generated by logistics companies mainly come from the exhaust emissions of fuel-fueled vehicles and natural gas vehicles in transportation, the emissions from nonenvironmental materials used in the construction of warehouses and logistics centers, and cargo packaging accessories solid waste. When estimating the total carbon emissions of the logistics industry, we analyze various types of energy used in the logistics industry in a certain area and calculate the total carbon emissions of the logistics industry after calculating each energy consumption separately.

(3) Analysis of low-carbon development mechanism of logistics enterprises

Exceeding carbon emissions in the logistics industry is a very complex issue. In order to analyze the causes of high carbon emissions and the development mechanism of the low-carbon logistics industry more clearly, this article uses the LMDI decomposition method (Di's logarithm method) to investigate the impact of logistics enterprises' carbon emissions as the reason. The variables that affect the carbon emissions of the logistics industry will change in different time periods. Taking the time series as the research object to investigate the change trend of the total carbon emissions of the logistics industry. H_{ij} is used to indicate the change in carbon emissions from period i to period j, Δc_{ij} is used to indicate the change in total carbon emissions from period i to period j, and H_{ij} and Δc_{ij} are denoted as:

$$H_{ij} = \frac{c_i}{c_j} = H_{xi} H_{xi+1} H_{xi+2} \cdots H_{xj} \varepsilon,$$
$$\Delta c_{ij} = c_j - c_i = \Delta c_{xi} + \Delta c_{x(i+1)} + \Delta c_{x(i+2)} + \cdots + \Delta c_{xj} + \varepsilon. \quad (2)$$

Among them, c_i and c_j denote the total carbon emissions in period i and period j, respectively, and ε denotes the residual after decomposition. If the residual value is too large, the secondary decomposition can be used to decompose

multiple times to reduce the influence of the residual. According to the change of the external environment in the statistical annual cycle, we analyze the weight of the change value of each period in the model. According to the principle of the LMDI decomposition method, the total carbon emissions of the logistics industry in the study area c_T are decomposed into five factors, namely, the overall scale of logistics X_1, the structure of the logistics industry X_2, the energy consumption structure X_3, the efficiency of energy use X_4, and the total amount of regional carbon emissions X_5. From period i to period j after decomposition, the reasons for the change in the total effect of carbon emissions can be decomposed into:

$$\Delta E_T = \Delta E_{X_1} + \Delta E_{X_2} + \Delta E_{X_3} + \Delta E_{X_4} + \Delta E_{X_5} + \varepsilon. \quad (3)$$

Finally, we use the logarithmic tie method to decompose the weight value of each influencing factor and specifically analyze the contribution value of each influencing factor:

$$\omega_i = \frac{E_i - E_j}{\ln\left(E_i/E_j\right)}. \quad (4)$$

According to the contribution value of different influencing factors, each influencing factor in the carbon emission process is decomposed, and targeted measures are formulated to control the total amount of carbon emission.

3. Results and Analysis

3.1. Verification of Carbon Emission Statistics Results of the Logistics Industry. Taking the overall development and carbon emissions of the logistics industry in Shandong Province from 2010 to 2019 as the research object, the EKC model is used to estimate the total carbon emissions of the logistics industry in Shandong Province over the years. The statistical results are shown in Figure 2.

Statistics show that since the strict implementation of carbon emission control measures in the logistics industry in 2015, the total carbon emissions from 2015 to 2019 have shown a slow downward trend year by year. Compared with the average carbon emissions in the past five years, the total amount has dropped by nearly 50%. This shows that strict implementation of carbon emission policies has played a very important role in reducing total carbon emissions. We apply the LMDI decomposition method to further analyze the carbon impact emission decomposition factors of the logistics industry over the years 2015-2019, that is, the overall scale, the logistics industry structure, the energy consumption structure, the energy use efficiency, and the total intensity of regional carbon emissions. The analysis results are shown in Figure 3.

From the analysis of the changes in the proportional relationship of various influencing factors, the influence of industry scale, industry structure, energy consumption, and other factors is gradually weakening, while the influence of energy efficiency factors and total carbon emissions factors is gradually increasing. To further reduce the total carbon emissions of the logistics industry, corresponding measures should be taken in terms of improving resource and energy efficiency, using more green and clean energy, and reducing total carbon emissions.

3.2. In-Depth Discussion of Analysis Results. From the analysis results in the previous section, it can be seen that the overall emission level of the logistics industry is showing a downward trend year by year, and the importance of energy use efficiency and total carbon emission factors is getting higher and higher. Therefore, in order to further reduce the overall carbon emissions, the following aspects need to be studied:

(1) We need to establish a comprehensive transportation system, use clean energy for short-distance transportation, and implement low-carbon distribution. Pollutant emissions from fuel-fueled vehicles in the logistics transportation process are one of the important reasons that lead to excessive emissions in the logistics industry. The logistics transportation process of commodities is a dynamic evolution process. To control carbon emissions, logistics transportation should be considered as a whole. We also need to establish a comprehensive transportation system covering road transportation, railway transportation, water transportation, and air transportation and choose the most economical and environmentally friendly transportation method according to the type of goods and the distance of transportation. For short-distance transportation within a city or internal transportation and loading and unloading of logistics centers, cleaner electric drive methods need to be selected to avoid excessive vehicle emissions and aggravate environmental pollution to the city

(2) We have to improve energy efficiency and focus on the harmless treatment of carbon emission pollutants. The large-scale use of nonrenewable energy is an important factor that leads to excessive carbon emissions. To reduce carbon emissions in the logistics industry, on the one hand, it is necessary to reduce the proportion of traditional energy sources such as oil and natural gas and to use solar energy, electricity, and other clean energy. On the other hand, it is necessary to improve the efficiency of various energy sources and reduce energy consumption. At the same time, logistics companies should do a good job in the assessment and management of energy consumption for employees in various departments, reward departments and employees with better energy consumption control, and take corresponding warnings and penalties for departments and employees with poor control

(3) We must improve the rationality of warehouse layout. The location, design, and layout of the new logistics park should all be considered from a low-carbon perspective. For example, the logistics center

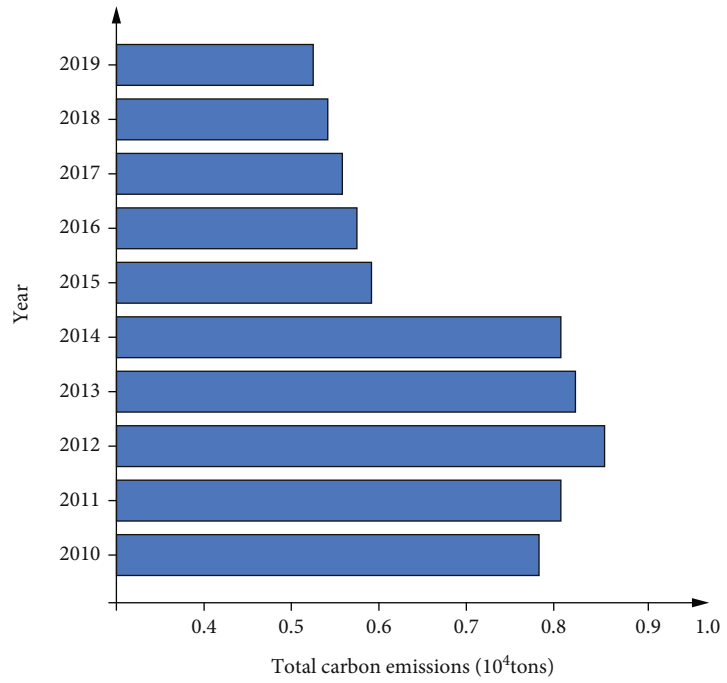

Figure 2: The total carbon emission forecast and change trend of the logistics industry in Shandong Province over the years.

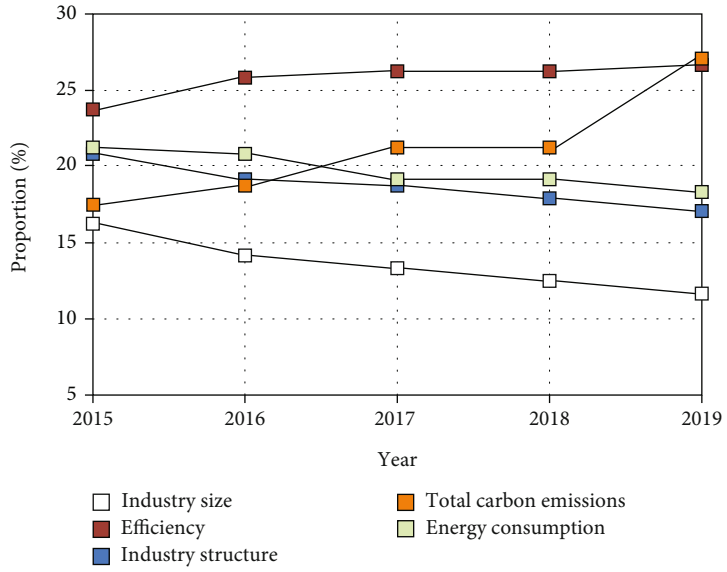

Figure 3: Trends of various factors affecting the development of low-carbon logistics industry.

is designed in the center of the transportation hub to reduce unnecessary short-distance transportation. In the overall scale design of the logistics park, the design is based on the design, and the future is prepared for future expansion of the park. The investment in infrastructure construction aims at regional sharing and supporting services, as far as possible radiating to surrounding areas to achieve regional scale effects and reducing the pressure on the environment caused by repeated infrastructure construction. In the selection of construction materials for the logistics center, the use of environmentally friendly materials that can be reassembled and disassembled is advocated to facilitate further expansion or dismantling

4. Conclusions

(1) Based on AHP and 1-9 scale method, this paper constructs the evaluation index system of low-carbon development of logistics industry and estimates the total carbon emission of logistics industry based on

EKC model curve. The total carbon emission of transportation and energy utilization are the main factors affecting the development of low-carbon logistics

(2) In a low-carbon economic environment, implementing low-carbon logistics standards and environmental protection policies can significantly reduce the total carbon emissions of the logistics industry. Since logistics companies are also market entities whose purpose is to make profits, they need the constraints and supervision of relevant government department managers when implementing low-carbon environmental protection policies to formulate long-term and effective environmental protection control systems and dynamically monitor the implementation of environmental protection policies of enterprises

(3) In view of the current development status of the logistics industry, controlling the total amount of carbon emissions and improving the efficiency of resource and energy use are the key and difficult issues that need to be resolved. On the one hand, the use of nonrenewable energy sources such as oil and natural gas should be minimized, and electric-powered transportation vehicles should be used as much as possible for short-distance transportation within the city or the internal turnover of logistics centers. On the other hand, complete vehicle distribution and transportation route planning should be done to reduce the empty rate of vehicles

(4) From the perspective of the future development trend of the logistics industry, work needs to be carried out simultaneously in terms of improving the overall structure of logistics and transportation, strictly implementing the harmless treatment of carbon emission pollutants, and optimizing the layout of logistics and warehousing. We should design the location of the new warehousing and logistics center in a more convenient location to reduce the logistics turnover in the urban area. In addition, we need to strictly implement new environmental protection policies and regulations, especially for long-distance transportation vehicles that must install emission reduction devices in time to reduce environmental pollution

Data Availability

The figures and tables used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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