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Research on the Coordinated Development of Regional Logistics and Ecological Environment based on the Collaborative Degree Model of Composite Systems

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Abstract

The concept of coordinated development is the fundamental principle for solving the problem of imbalanced development in the economy and society. From the perspective of sustainable development in the logistics industry, this article takes regional logistics and ecological environment as the research object, and based on the composite system synergy model, constructs a scientific system of logistics subsystem and ecological environment subsystem order parameter index system from the perspective of low-carbon emission reduction. Then use the Panel data of Anhui Province from 2010 to 2019 for empirical research, calculate the order parameter index order degree and subsystem order degree, and then obtain the coordination degree of regional logistics and ecological environment composite system. The results show that the coordination degree of logistics subsystem, ecological environment subsystem, and composite system in Anhui Province shows a fluctuating upward trend. Based on this, countermeasures and suggestions are proposed from three aspects: the formulation of regional development policies and regulations, the construction of regional logistics public information platforms, and the optimization of the energy structure of the logistics industry.

Keywords

Low Carbon Emission Reduction; Regional Logistics; Ecological Environment; Composite System Collaboration Model.

1. Introduction

With the increasingly obvious regionalization of China's economic development, the Yangtze Delta, the Pearl River Delta and the Bohai Rim have become the "troika" leading China's economic development. At the same time, the economic belt in the middle and upper reaches of the Yangtze River relying on Wuhan City Circle, Changzhutan, Chengdu Chongqing region, and Changjiu region, and the economic belt in the middle reaches of the Yellow River relying on the Central Plains region, Guanzhong region, and the national energy base have developed rapidly, with strong economic performance. Regional logistics, as a link between production and consumption, plays an important role in the development of regional economy and becomes the leading force driving economic growth. However, while promoting regional economic growth, regional logistics is also increasingly damaging and polluting the ecological environment. Overexploitation and extensive use of resources will inevitably lead to increased air pollution, accelerated soil erosion, and reduced biodiversity, among which the increase in carbon dioxide emissions is particularly significant.

The low-carbon emission reduction development model aims to achieve emission reduction and reduce carbon intensive production and consumption, which is an important step taken by China to promote the implementation of the Paris Agreement on climate change. At present,

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China is actively implementing the concept of green development from the national level to various provinces and municipal regions, transforming its economic development mode, and implementing a low-carbon development strategy to achieve sustainable development. In this context, regional logistics, as a major energy consumer and carbon emitter, must protect the ecological environment, reduce energy consumption, and shoulder the responsibility of carbon emissions reduction while developing rapidly. Therefore, from the perspective of low-carbon development, how to achieve coordinated and coordinated development between regional logistics and the ecological environment has become an inevitable and urgent practical problem. Conducting relevant research in this area also has extremely important theoretical and practical significance.

At present, in the research on coordinated development issues related to regional logistics, the common focus is on the coordinated development of regional logistics and regional economy [1-7], while there is still little research on the coordinated development of the composite system composed of regional logistics and ecological environment. Zhang Fengwei et al. evaluated the logistics ecological environment system in Shandong Province, analyzed the development factors that affect the logistics ecological environment system in various regions of Shandong Province, and proposed some suggestions for the coordinated development of the logistics ecological environment system in Shandong Province [8]. Lu Zhibin et al. elaborated on the composition of the regional logistics economic environment system and predicted the coupling development degree of the logistics economic environment system from 2003 to 2020 using the nonlinear autoregressive model in the BP network and data from the Northeast region [9]. Hu Yun constructed a coupling coordination index system for the logistics economic ecological environment system, calculated the different comprehensive development levels of logistics, economy, and ecological environment systems in Sichuan Province through factor analysis method, and analyzed these three systems using the coupling coordination theory [10]. Wang Na used factor analysis and membership function models to study the coordination degree between regional logistics and ecological environment based on statistical data from 31 provinces in China from 2005 to 2016, and divided their coordination levels [11].

Overall, the research on coordinated development issues related to regional logistics has achieved certain results, but due to scholars' different perspectives and depths of understanding, there are still some shortcomings in the existing research. The research focus mostly focuses on the coordination relationship between regional logistics and regional economy subsystems, while the ecological environmental factors that have a significant impact on these two systems are mostly not considered for research; In the construction of the indicator system for the ecological environment system, many indicators selected are not closely related to the development of regional logistics, and do not consider environmental factors such as resource occupation, energy consumption, and carbon emissions directly generated by logistics activities. Therefore, the ecological environment subsystem constructed cannot reflect the essence and characteristics of the composite system of regional logistics and ecological environment well.

Based on this, from the perspective of sustainable development of the logistics industry, this paper takes the regional logistics and ecological environment composite system as the research object, based on synergetics related theory, and from the perspective of low-carbon development, constructs the order parameter index system of the logistics subsystem and ecological environment subsystem of the scientific system, establishes the order degree model of the subsystem and the coordination degree model of the composite system, and then uses the Panel data of Anhui Province from 2010 to 2019 for empirical research, Calculate the order degree of logistics subsystem and ecological environment subsystem, as well as the coordination degree of regional logistics and ecological environment composite system, and analyze the rationality of the calculation results to explore new ways to study the coordinated development of regional logistics and ecological environment.

2. Construction of Collaborative Degree Model for Composite Systems

2.1. Order Parameter Index System

According to the principle of synergetics, the order parameter is a parameter variable that characterizes the evolution direction of the left and right systems and the degree of system ordering, as long as the order parameter is controlled. You can grasp the development direction of the entire system [12-14]. Due to the fact that order parameter variables can be decomposed into a series of components (indicators), and selecting different indicators will result in different order parameter calculation results, scientific and reasonable selection of indicators becomes the key to the accuracy of order parameter calculation results. This requires the selected order parameter indicators to conform to the connotation of order parameters and reflect the characteristics of order parameters.

Following the principles of systematicness, scientificity, objectivity, operability and comparability, guided by the sustainable Development theory theory and green logistics theory, this paper selects the typical order parameter indicators that can represent the respective development status and characteristics of regional logistics subsystem and ecological environment subsystem, and then uses the analytic hierarchy process to build a The three-level indicator system for the coordinated development of regional logistics and ecological environment composite system, consisting of three levels: element layer and indicator layer, is shown in Table 1.

Table 1. Coordinated Development Indicator System of Regional Logistics and Ecological Environment Composite System

Subsystem	Element	Index	Unit	Indicator Attribute
Logistics Subsystem	Input	Total fixed assets investment in logistics industry (Q11)	Ten thousand yuan	+
		Number of logistics industry employees (Q12)	Ten thousand people	+
	Output	Value added of logistics industry (Q13)	100 million	+
		Freight transportation volume (Q14)	10000 tons	+
		Freight transportation turnover (Q15)	10000 ton kilometers	+
		Port cargo throughput (Q16)	10000 tons	+
		The proportion of added value of logistics industry to regional GDP (Q17)	%	+
Ecological Environment Subsystem	Resource	Energy consumption intensity of logistics industry (Q21)	Tons/10000 yuan	-
		Ownership of Civil Vehicles (Q22)	Vehicle	+
		Road network density (Q23)	Kilometers/100 square kilometers	+
		Total Water Resources (Q24)	100 million cubic meters	+
	Environment	Carbon Emission Intensity of Logistics Industry (Q25)	Tons/10000 yuan	-
		Total afforestation area (Q26)	hectare	+
		Comprehensive utilization rate of industrial solid waste (Q27)	%	+
		Centralized treatment rate of urban sewage treatment plants (Q28)	%	+

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The logistics subsystem indicator system consists of two elements: input and output. Investing in the logistics system is the material foundation and necessary guarantee for the development of the logistics industry. The level of regional investment in the logistics system directly affects the development status of regional logistics and has an impact on the output effect of the logistics system. The investment in logistics system includes construction capital investment and human resources investment, and the corresponding indicators include the total amount of fixed assets investment in logistics industry and the number of employees in logistics industry. The output of the logistics system reflects the achievements made by the regional logistics industry in the development process, and is a visual evaluation of the effectiveness of regional logistics development. It can be reflected by indicators such as logistics industry added value, cargo transportation volume, cargo transportation turnover, and the proportion of logistics industry added value to regional GDP.

The ecological environment subsystem indicator system consists of two elements: resources and environment. Resources are an essential material foundation in the development of regional logistics. If resources are expensive or scarce, they will to some extent constrain the logistics development of the region. Resource elements reflect the degree to which regional logistics utilizes resources. It includes indicators such as energy consumption intensity in the logistics industry, ownership of civilian vehicles, road network density, and total water resources. The emission of pollutants, especially carbon emissions, during the development of regional logistics directly affects environmental quality, while soil and water management reflects the current situation of regional environmental improvement, which can be expressed in terms of carbon emission intensity of logistics industry, total afforestation area, comprehensive utilization rate of industrial solid waste, and centralized treatment rate of urban sewage treatment plants. Environmental factors measure the impact of logistics industry development on the ecological environment from two aspects: pollution and governance.

The following will only provide further explanations on the meaning and calculation methods of the two key indicators in the ecological environment subsystem, namely "energy consumption intensity of logistics industry" and "carbon emission intensity of logistics industry".

2.1.1. Energy Consumption Intensity of Logistics Industry

It is the ratio of the total energy consumption of the logistics industry to the added value of the logistics industry within a certain period of time in a region, representing the energy consumption of the logistics industry per unit output value, reflecting the energy Economic efficiency of the regional logistics industry, that is, the degree of energy utilization of the regional logistics industry in economic activities. The lower the energy consumption intensity, the stronger the energy economy of the regional logistics industry, and the higher the energy utilization efficiency. This indicator is an important indicator reflecting the degree of low-carbon regional energy structure, corresponding to tons per 10000 yuan. The calculation method is:

Energy consumption intensity of logistics industry=total energy consumption of logistics industry/added value of logistics industry.

2.1.2. Carbon Emission Intensity of Logistics Industry

The ratio of the total carbon emissions generated by the logistics industry in a region over a certain period of time to the added value of the logistics industry reflects the carbon emissions generated by the logistics industry per unit of GDP output. This indicator can intuitively reflect the efficiency of carbon resource utilization in regional logistics. Generally speaking, with the development of the logistics industry, carbon emissions will also increase. However, if the growth rate of the logistics industry is higher than the growth rate of carbon emissions, the carbon emission intensity value will decrease, indicating that the regional logistics has achieved a low-carbon development model. The unit corresponding to this indicator is; Tons/10000 yuan. The calculation method is:

Carbon emission intensity of logistics industry=total carbon emissions of logistics industry/added value of logistics industry.

2.2. Order Parameter Index Weight

This article uses the entropy weight method to determine the weights of order parameter indicators. The entropy weight method is an objective weighting method, which essentially uses the information utility value contained in indicators to calculate weights, and can avoid the influence of subjective factors [15]. In the composite system coordinated development indicator system, there are two types of indicators: forward and reverse. For reverse indicators, they need to be processed through subtraction and consistency to become positive indicators. Assuming there is m objects n if there are indicators, then i the consistent formula for subtracting indicators is:

$$x'_{ij} = \max_{1\leqslant j\leqslant m} x_{ij} + \min_{1\leqslant j\leqslant m} x_{ij} - x_{ij}, i = 1, 2, \cdots, n \quad (1)$$

2.3. Order Parameter Index Order Degree

Drawing on the research results of Meng Qingsong et al. [12-14], this article assumes that: k the composite mechanism formed by the interaction of subsystems constitutes a composite system $S = \{S_1, S_2, \dots S_j, \dots, S_k\}$ among them S_j for the composite system j subsystem, $j = 1, 2, \dots, k$. For subsystems $S_j, j \in [1, k]$ let the order parameter variable in its development and evolution process be $e_j = \{e_{j1}, e_{j2}, \dots, e_{ji}, \dots, e_{jn}\}$ among them e_{ji} is an order parameter component with $\alpha_{ji} \leq e_{ji} \leq \beta_{ji}, \beta_{ji}, \alpha_{ji}$ divided into components e_{ji} the upper and lower limits of the critical point, n is the number of ordered parameter components (i.e. indicators), and there are $n \geq 1, i \in [1, n]$.

When e_{ji} when it is a positive indicator, as the indicator value increases, the degree of order of the system increases, and as the indicator value decreases, the degree of order of the system decreases; When e_{ji} when it is a reverse indicator, the index value increases, the degree of order of the system decreases, the index value decreases, and the degree of order of the system increases; In this way, the size of the power function of each subsystem's order parameter index can be used to measure the contribution of each order parameter index to the order of the subsystem, thus obtaining the subsystem S_j order parameter index (component) e_{ji} order degree of $u_j(e_{ji})$ the calculation expression for is as follows:

$$u_j(e_{ji}) = \begin{cases} \frac{e_{ji}-\alpha_{ji}}{\beta_{ji}-\alpha_{ji}}, & e_{ji} \text{ is a positive indicator} \\ \frac{\beta_{ji}-e_{ji}}{\beta_{ji}-\alpha_{ji}}, & e_{ji} \text{ is a reverse indicator} \end{cases} \quad (2)$$

According to equation (2), $u_j(e_{ji}) \in [0, 1]$ the higher the value, the indicator e_{ji} the greater the contribution of ordered heap subsystems.

2.4. Order Degree of Subsystems

The order degree of subsystems reflects the order parameter variables e_j all components are paired with subsystems S_j the total contribution of the degree of order can be determined by $u_j(e_{ji})$ perform integrated operations to obtain, and this article uses the linear weighted summation method to calculate the degree of subsystem order $u_j(e_j)$ for:

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$$u_j(e_j) = \sum_{i=1}^{n} \omega_i u_j(e_{ji}), \omega_i \geqslant 0, \sum_{i=1}^{n} \omega_i = 1 \tag{3}$$

Among them, ω_i for section i the weight of individual order parameter indicators. $u_j(e_j) \in [0,1]$, $u_j(e_j)$ the larger it is, the more it indicates e_j for subsystems S_j the greater the contribution of order, the higher the degree of subsystem order, and vice versa.

2.5. Coordination Degree of Composite System

For a given initial moment t_0 set up a subsystem S_j the order degree of is $u_j^0(e_j), j = 1, 2, \dots, k$ when the overall development of the composite system evolves to a moment t_1 at this time, if the subsystem S_j the order degree of is $u_j^1(e_j), j = 1, 2, \dots, k$ then the coordination degree of the composite system C for:

$$C = \theta \cdot [| \prod_{j=1}^{k} [u_j^1(e_j) - u_j^0(e_j)] |]^{1/k} \tag{4}$$

$$\theta = \min_j [u_j^1(e_j) - u_j^0(e_j) \neq 0] / |\min_j [u_j^1(e_j) - u_j^0(e_j) \neq 0]|, j = 1, 2, \cdots, k \tag{5}$$

In equation (4) $u_j^1(e_j) - u_j^0(e_j)$ for subsystems S_j from t_0 reach t_1 the magnitude of changes in the order of the time period system, and$[u_j^1(e_j) - u_j^0(e_j)] \in [-1, 1]$; The higher the value, the higher the degree of coordinated development of the composite system, and vice versa; Introducing parameters θ the significance is that only when the conditions are met $u_j^1(e_j) - u_j^0(e_j) > 0, \forall j \in [1, k]$ the coordination degree of a composite system can only be positive.

If in the $[t_0, t_1]$ during a period of time, if the degree of order of one subsystem increases significantly, while the degree of order of other subsystems increases slightly or even decreases, the coordinated development state of the entire composite system is not good or not coordinated at all, manifested as $C \in [-1, 0]$.

Due to the fact that the regional logistics and ecological environment composite system in this article only has two subsystems, there are k=2 this style (4) can be written as:

$$C = \theta \cdot \sqrt{|[u_1^1(e_1) - u_1^0(e_1)][u_2^1(e_2) - u_2^0(e_2)]|} \tag{6}$$

3. Calculation of Coordination Degree between Regional Logistics and Ecological Environment Composite System

3.1. Data Source and Processing

3.1.1. Source of Indicator Data

This article takes Anhui Province as the research area for empirical analysis. Considering that "transportation, warehousing, and postal services" have always been the main components of China's logistics industry, and considering the availability of data, the logistics industry data required in this article are all based on the relevant data of these three industries. In addition, due to the use of "transportation, warehousing, and postal industry" instead of "transportation, warehousing, and postal industry" in the "China Energy Statistical Yearbook" and "Anhui Statistical Yearbook" from 2004 to 2005, in order to ensure consistency in statistical caliber, this article selected relevant time series data from Anhui Province from 2010 to 2019 for research, The raw data required for all indicator calculations in Table 1 are from Anhui

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Statistical Yearbook, China Statistical Yearbook and China Energy Statistical Yearbook in 2010-2019.

3.1.2. Calculation of Indicator Data

Among the 15 indicators in Table 1, except for the two indicators of "energy consumption intensity of the logistics industry" and "carbon emission intensity of the logistics industry", the data of the remaining 13 indicators can be obtained directly or through simple calculation by referring to the original data obtained in the above statistical yearbook;

a) Calculation of total energy consumption

According to the statistical data in China Energy Statistical Yearbook, from 2010 to 2019, the energy consumption of Anhui logistics industry mainly includes six types of energy, including raw coal, gasoline, kerosene, diesel, natural gas and electricity. See Table 2 for the original data of energy consumption of each type.

Table 2. Total Energy Consumption of Various Types of Logistics Industry in Anhui Province from 2010 to 2019

Year	Raw Coal (10000 tons)	Gasoline (10000 tons)	Kerosene (10000 tons)	Diesel Oil (10000 tons)	Natural Gas (100 million cubic meters)	Power (100 million kilowatt hours)
2010	38.35	70.32	7.74	217.92	1.17	14.58
2011	42.18	73.31	8.55	249.51	3.00	17.93
2012	15.52	109.26	10.33	373.74	4.12	19.75
2013	18.40	112.39	9.12	423.91	4.10	21.09
2014	19.09	129.33	10.26	459.13	5.43	22.47
2015	19.30	188.18	13.64	405.25	4.93	26.74
2016	21.77	193.12	15.66	403.51	5.00	32.23
2017	22.16	224.94	15.24	411.42	4.50	36.42
2018	1.26	232.12	15.23	429.22	5.51	41.36
2019	0.36	174.05	16.05	454.09	6.23	47.57

When calculating the total energy consumption of the logistics industry in Anhui Province, it is necessary to convert various types of energy consumption into standard coal consumption. The conversion coefficient of each type of energy into standard coal is based on the reference data in Appendix 4 of the China Energy Statistical Yearbook 2020, as shown in Table 3.

Table 3. Reference Coefficients for Converting Various Types of Energy into Standard Coal

Energy Type	Raw Coal	Gasoline	Kerosene	Diesel Oil	Natural Gas	Power
Conversion Coefficient of Standard Coal	0.7143	1.4714	1.4714	1.4571	1.3300	0.1229
	Kg standard coal/kg	Kg standard coal/kg	Kg standard coal/kg	Kg standard coal/kg	Kilogram standard coal/cubic meter	Kilogram standard coal/kilowatt hour

According to Tables 2 and 3, the consumption of various types of energy in the logistics industry in Anhui Province from 2010 to 2019, converted into standard coal, and the total energy consumption can be calculated, as shown in Table 4.

Table 4. Total Consumption of Various Types of Energy Converted into Standard Coal in the Logistics Industry of Anhui Province from 2010 to 2019 (10000 tons of standard coal)

Year	Raw Coal	Gasoline	Kerosene	Diesel Oil	Natural Gas	Power	Total Energy Consumption
2010	27.3934	103.4688	11.3886	317.5312	15.5610	17.91882	493.2619
2011	30.1292	107.8683	12.5805	363.5610	39.9000	22.03597	576.0750
2012	11.0859	160.7652	15.1996	544.5766	54.7960	24.27275	810.6960
2013	13.1431	165.3706	13.4192	617.6793	54.5300	25.91961	890.0618
2014	13.6360	190.2962	15.0966	668.9983	72.2190	27.61563	987.8617
2015	13.7860	276.8881	20.0699	590.4898	65.5690	32.86346	999.6662
2016	15.5503	284.1568	23.0421	587.9544	66.5000	39.61067	1016.8143
2017	15.8289	330.9767	22.4241	599.4801	59.8500	44.76018	1073.3200
2018	0.9000	341.5414	22.4094	625.4165	73.2830	50.83144	1114.3817
2019	0.2571	256.0972	23.6160	661.6545	82.8590	58.46353	1082.9474

b) Calculation of total carbon emissions

The CO2 emissions generated by logistics activities come from direct or indirect CO2 emissions caused by various energy and substances consumed in logistics activities. Due to the diverse types of substances consumed in logistics activities, such as various packaging materials, pallets, labels, etc., it is difficult to uniformly calculate the CO2 emissions during the logistics process. In addition, the monitoring data of carbon emissions in China's logistics industry is not yet complete. Therefore, this article adopts the direct energy consumption method of logistics operations to calculate carbon emissions, The actual energy consumption of logistics activities is converted to calculate the CO2 emissions generated by logistics activities [16-17]. The specific calculation method adopts the carbon emission estimation method provided in the "2006 IPCC National Greenhouse Gas Inventory Guidelines (Volume 2 Energy)", which is equation (7) to calculate carbon emissions.

$$Q = \sum_{i=1}^{n} Q_i = \sum_{i=1}^{n} E_i \cdot \mathrm{NCV}_i \cdot \mathrm{CEF}_i \cdot \mathrm{COF}_i \tag{7}$$

Equation (7) is the CO2 emission measurement model for the regional logistics industry, where Q it is the total carbon emissions, i it is the type of energy, E_i it's the number i the consumption of various energy sources, NCV_i is the average low calorific value (using data from Appendix 4 of the China Energy Statistical Yearbook 2020), CEF_i it is the CO2 emission factor provided by IPCC (2006), COF_i it is the carbon oxidation factor (IPCC (2006) defaults to 1). Therefore, $\mathrm{NCV}_i \cdot \mathrm{CEF}_i \cdot \mathrm{COF}_i$ the CO2 emission coefficient of fossil gas energy is shown in Table 5.

Table 5. CO2 Emission Coefficients of Various Types of Energy Sources

Energy Type	Raw Coal	Gasoline	Kerosene	Diesel Oil	Natural Gas	Power
CO_2 Emission Coefficient	2.0553	2.9848	3.0795	3.1605	2.1840	0.9439
	Kg CO_2/ kg	Kg CO_2/kg	Kg CO_2/kg	Kg CO_2/kg	Kg CO_2/ cubic meter	Kg CO_2/ Kilowatt hour

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According to Tables 2 and 6, the CO2 emissions and total carbon emissions of various types of energy in the logistics industry in Anhui Province from 2010 to 2019 can be calculated, as shown in Table 6.

Table 6. Total CO2 Emissions of Various Types of Energy in the Logistics Industry in Anhui Province from 2010 to 2019 (10000 tons of CO2)

Year	Raw Coal	Gasoline	Kerosene	Diesel Oil	Natural Gas	Power	Total Carbon Emissions
2010	78.8208	209.8911	23.8353	688.7362	25.5528	137.6206	1164.4568
2011	86.6926	218.8157	26.3297	788.5764	65.5200	169.2413	1355.1756
2012	31.8983	326.1192	31.8112	1181.2053	89.9808	186.4203	1847.4351
2013	37.8175	335.4617	28.0850	1339.7676	89.5440	199.0685	2029.7443
2014	39.2357	386.0242	31.5957	1451.0804	118.5912	212.0943	2238.6214
2015	39.6673	561.6797	42.0044	1280.7926	107.6712	252.3989	2284.2140
2016	44.7439	576.4246	48.2250	1275.2934	109.2000	304.2190	2358.1058
2017	45.5454	671.4009	46.9316	1300.2929	98.2800	343.7684	2506.2192
2018	2.5897	692.8318	46.9008	1356.5498	120.3384	390.3970	2609.6075
2019	0.7399	519.5044	49.4260	1435.1514	136.0632	449.0132	2589.8982

After measuring the total energy consumption and carbon emissions of the regional logistics industry, combined with the indicator data of "added value of logistics industry (Q13)" in Table 7, the data of "energy consumption intensity of logistics industry" and "carbon emission intensity of logistics industry" can be calculated. Based on this, all data of the indicators for the coordinated development of regional logistics and ecological environment composite system in Anhui Province from 2010 to 2019 are presented in Table 7.

3.2. Calculation of Order Parameter Index Weights

Using the indicator data in Table 7, calculate the entropy weights of the order parameter indicators for the logistics subsystem and the ecological environment subsystem, as shown in Table 8.

3.3. Calculation of Order Parameter Index Order Degree

This article uses the self comparison method to calculate the order degree of the order parameter indicators of the subsystem. The lower limit of the critical point of the indicators is set to the minimum value in the same indicator, and the upper limit is set to the maximum value in the same indicator.

According to equation (2) and the data in Table 7, calculate the order parameter indicators of the logistics subsystem and the ecological environment subsystem, as shown in Table 9.

Table 7. Index System Values for Coordinated Development of Regional Logistics and Ecological Environment Composite System in Anhui Province

Year	Logistics Subsystem							Ecological Environment Subsystem							
	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
2010	6682157	180584	527.02	228106	71536800	1049.70	3.9776	0.9359	2432339	107.16	922.82	2.2095	65612	84.60	71.58
2011	5592573	200935	589.82	268416	84466179	1065.84	3.6219	0.9767	2894286	107.27	602.08	2.2976	88731	78.70	79.04
2012	6536148	163223	650.21	312442	98315954	964.80	3.5450	1.2468	3301757	118.48	701.00	2.8413	112197	81.50	86.39
2013	8125253	220051	730.36	356711	111589620	965.81	3.5482	1.2187	3760219	124.65	585.59	2.7791	208099	84.00	88.44
2014	10986882	217155	784.44	434300	135008915	926.77	3.4834	1.2593	4373284	125.09	778.48	2.8538	157745	84.40	90.19
2015	14697696	222641	791.72	345756	104025651	1180.02	3.3222	1.2627	5128318	134.10	914.12	2.8851	128415	88.50	91.80
2016	18414227	229305	826.89	364549	108832411	1063.16	3.1431	1.2297	6110469	141.74	1245.17	2.8518	128042	82.60	92.03
2017	20364578	242102	875.38	403421	114145165	12805.88	2.9498	1.2261	7160878	145.83	784.90	2.8630	144926	90.90	93.90
2018	20830927	245180	1865.40	406628	117836922	12015.95	5.4847	0.5974	8200687	149.80	835.78	1.3990	138493	88.10	94.90
2019	23976397	237028	1973.90	368078	102173083	12777.86	5.3572	0.5486	9128465	155.81	539.87	1.3121	138746	78.65	93.40

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Table 8. Entropy Weight of Order Parameter Indicators

Logistics Subsystem							Ecological Environment Subsystem							
Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
0.1343	0.0576	0.1837	0.0598	0.0583	0.3699	0.1363	0.2363	0.1077	0.0985	0.1041	0.2493	0.0612	0.0983	0.0447

Table 9. Ordering Degree of Order Parameter Indicators for Logistics Subsystem and Ecological Environment Subsystem

Year	Logistics Subsystem							Ecological Environment Subsystem							
	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
2010	0.0593	0.2118	0	0	0	0.0103	0.4055	0.4576	0	0	0.5430	0.4295	0	0.4857	0
2011	0	0.4601	0.0434	0.1955	0.2037	0.0117	0.2651	0.4005	0.0690	0.0023	0.0882	0.3735	0.1623	0.0041	0.3199
2012	0.0513	0	0.0851	0.4090	0.4219	0.0032	0.2348	0.0222	0.1298	0.2327	0.2285	0.0279	0.3269	0.2327	0.6351
2013	0.1378	0.6934	0.1405	0.6237	0.6310	0.0033	0.2361	0.0616	0.1983	0.3595	0.0648	0.0674	1	0.4367	0.7230
2014	0.2934	0.6581	0.1779	1	1	0	0.2105	0.0047	0.2899	0.3686	0.3383	0.0199	0.6466	0.4694	0.7980
2015	0.4953	0.7250	0.1829	0.5706	0.5119	0.0213	0.1469	0	0.4026	0.5538	0.5306	0	0.4408	0.8041	0.8671
2016	0.6974	0.8063	0.2073	0.6617	0.5876	0.0115	0.0763	0.0462	0.5493	0.7108	1	0.0212	0.4381	0.3224	0.8769
2017	0.8035	0.9624	0.2408	0.8502	0.6713	1	0	0.0512	0.7062	0.7949	0.3474	0.0141	0.5566	1	0.9571
2018	0.8289	1	0.9250	0.8658	0.7295	0.9335	1	0.9317	0.8614	0.8765	0.4196	0.9448	0.5115	0.7714	1
2019	1	0.9005	1	0.6788	0.4827	0.9976	0.9497	1	1	1	0	1	0.5133	0	0.9357

3.4. Calculation of Order Degree of Subsystems and Coordination Degree of Composite Systems

According to equation (3) and the data in Table 9, calculate the orderliness of the logistics subsystem and the ecological environment subsystem from 2010 to 2019, respectively. On this basis, 2010 will be used as the base period for development evaluation. According to equations (5) and (6), the coordination degree of the regional logistics and ecological environment composite system in Anhui Province from 2010 to 2019 relative to the base period is calculated, as shown in Table 10.

Table 10. Order and Coordination of Logistics and Ecological Environment Subsystems and Composite Systems

Year	Orderliness of Logistics Subsystems	Order Degree of Ecological Environment Subsystem	Coordination Degree of Composite System
2010	0.0793	0.3194	-
2011	0.0985	0.2292	-0.0417
2012	0.1048	0.1441	-0.0231
2013	0.1918	0.2313	0.0871
2014	0.2568	0.2301	-0.0086
2015	0.2338	0.2979	-0.0395
2016	0.2667	0.3471	0.0403
2017	0.6675	0.3812	0.1168
2018	0.9148	0.8302	0.3333
2019	0.9372	0.7650	-0.0382

In order to more intuitively reflect the order parameter order degree of the logistics subsystem and the ecological environment subsystem and the characteristics and change trend of the coordination degree of the regional logistics and ecological environment composite system, use the data in Table 10 to make a Line chart chart of their change trend, as shown in Figure 1.

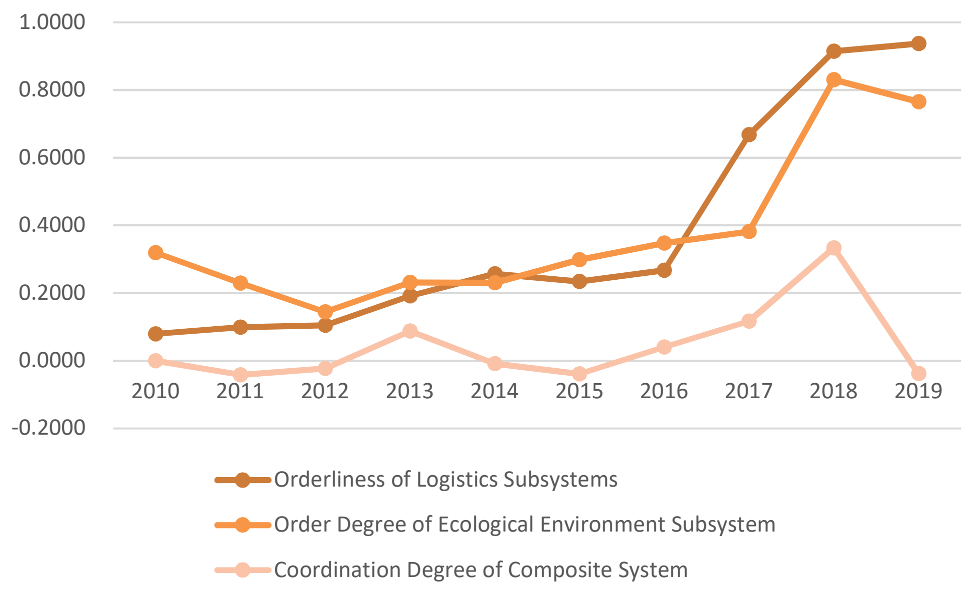

Figure 1. Development Trend of Orderliness and Coordination of Logistics and Ecological Environment Subsystems and Composite Systems

4. Empirical Result Analysis

From Table 10 and Figure 1, it can be seen that the development of coordination between regional logistics and ecological environment composite systems in Anhui Province during the 10-year period from 2010 to 2019 presents two main characteristics.

4.1. Overall Showing an Upward Trend of Volatility

From Figure 1, it can be seen that during the 10-year period from 2010 to 2019, the coordination degree of the regional logistics and ecological environment composite system in Anhui Province showed a fluctuating upward trend compared to the base period (2010), and reached its peak in 2018. This indicates that the regional logistics and ecological environment composite system in Anhui Province is in an unstable but overall coordination level is gradually increasing. Among them, the orderly growth of the logistics subsystem is relatively stable, and it has made rapid progress between 2016 and 2018, with a coordination level close to 1. The order of the ecological environment subsystem shows a trend of first suppressing and then increasing, followed by a steady growth of the logistics subsystem after 2012. The change trend of orderly development within the two subsystems and relatively synchronous growth between them shows that the development relationship of the two subsystems is coordinated and consistent, and Co-determination that the coordination degree of the composite system shows a growing trend.

4.2. Overall Showing a Phased Evolution Trend

Table 10 and Figure 1 show that from 2010 to 2019, the phased evolution characteristics of the coordination degree of regional logistics and ecological environment composite system in Anhui Province are relatively obvious. The coordinated development process of regional logistics and ecological environment in Anhui Province is divided into four distinct stages.

4.2.1. Phase 1: 2011-2013

During these two years, the coordination degree of regional logistics and ecological environment composite system in Anhui Province was low. In 2011 and 2012, the coordination degree even showed negative values, ranging from -0.0417 to -0.0231, respectively. The coordination degree of the composite system grew slowly, with an average annual growth of

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0.0644. During this stage, the level of coordinated development between regional logistics and ecological environment in Anhui Province was low, the development speed was slow, and the sustainability was poor.

From 2010 to 2012, the order degree of the logistics subsystem showed a decreasing trend, with an increase of 0.0193 and 0.0063, respectively. The order degree of the ecological environment subsystem showed a decreasing trend, with a decrease of 0.0903 and 0.0851, respectively. This indicates that the negative effect of the decrease in order degree of the ecological environment subsystem is greater than the positive effect of the increase in order degree of the logistics subsystem, resulting in a negative coordination degree of the composite system. From 2012 to 2013, the order degree of logistics subsystems and ecological environment subsystems showed an increasing trend, with increases of 0.0870 and 0.0872, respectively. The positive effect of the increase in order degree of logistics subsystems and ecological environment subsystems jointly promoted the increase in coordination degree of composite systems.

4.2.2. Phase 2: 2013-2015

During these two years, the coordination degree of the regional logistics and ecological environment composite system in Anhui Province showed a decreasing trend, decreasing by 0.0956 and 0.0309 respectively, causing the coordination degree of the composite system to once again fall to a negative value, with an average annual decrease of 0.0632. During this stage, the level of coordinated development of regional logistics and ecological environment in Anhui Province decreased.

From 2013 to 2014, the order degree of the logistics subsystem showed a gradual increase of 0.0651, while the order degree of the ecological environment subsystem showed a decreasing trend of 0.0011, indicating that the negative effect of the decrease in order degree of the ecological environment subsystem was greater than the positive effect of the increase in order degree of the logistics subsystem, leading to a negative coordination degree of the composite system. From 2014 to 2015, the order degree of the logistics subsystem showed a decreasing trend, decreasing by 0.0230, while the order degree of the ecological environment subsystem showed an increasing trend, increasing by 0.0677. This indicates that the negative effect of the decrease in order degree of the logistics subsystem is greater than the positive effect of the increase in order degree of the ecological environment subsystem, leading to a negative coordination degree of the composite system.

4.2.3. Phase 3: 2015-2018

During these three years, the coordination degree of regional logistics and ecological environment composite systems in Anhui Province has shown a continuous growth trend, increasing by 0.0798, 0.0765, and 0.2165 respectively. The coordination degree of composite systems has achieved explosive growth, with an average annual increase of 0.1243. During this stage, the level of coordinated development between regional logistics and ecological environment in Anhui Province has gradually improved, indicating that the development relationship between logistics subsystems and ecological environment subsystems is relatively coordinated and consistent, with each developing in an orderly manner, Synchronous growth, jointly promoting the continuous increase in coordination of composite systems.

From 2015 to 2018, the orderliness of logistics subsystems and ecological environment subsystems showed an increasing trend, with increases of 0.0329, 0.4008, 0.2474, and 0.0493, 0.0340, and 0.4490, respectively. The order degree of the logistics subsystem increases by an average of 0.2270 per year, and the order degree of the ecological environment subsystem increases by an average of 0.1775 per year. The positive effect of the increase in order of the logistics subsystem and the ecological environment subsystem jointly drives the increase in coordination of the composite system.

4.2.4. Phase 4: 2018-2019

During this year, the coordination degree of the regional logistics and ecological environment composite system in Anhui Province suddenly decreased by 0.3715, and the coordination degree of the composite system once again fell to a negative value. At this stage, the level of coordinated development between regional logistics and ecological environment in Anhui Province was low, indicating poor internal coordination ability of the logistics subsystem and ecological environment subsystem, failure to achieve collaborative efforts, and poor sustainable development ability.

During this period, the order degree of the logistics subsystem showed a gradual increasing trend, increasing by 0.0223, while the order degree of the ecological environment subsystem showed a decreasing trend, decreasing by 0.0653. This means that the negative effect of the decrease in order degree of the ecological environment subsystem is greater than the positive effect of the increase in order degree of the logistics subsystem, resulting in a negative coordination degree of the composite system.

5. Countermeasure Suggestions

Realizing the coordinated development of regional logistics and ecological environment from the perspective of low-carbon development has extremely important practical significance, but currently there is very little research in this area. This paper takes the regional logistics and ecological environment composite system as the research object, constructs the order parameter index system of logistics subsystem and ecological environment subsystem guided by the sustainable Development theory theory, and then uses the synergetics principle to establish the order degree model of the two subsystems and the coordination degree model of regional logistics and ecological environment composite system, and then conducts empirical research based on the historical data of Anhui Province from 2010 to 2019, We obtained the calculation results of the order degree of the two subsystems and the coordination degree of the composite system, and analyzed the calculation results based on the development of logistics and ecological environment in Anhui Province over the years.

Considering that a composite system can only have a continuously increasing coordination degree when each subsystem is in an orderly growth state and has a synchronous and consistent growth rate, relevant suggestions are proposed to promote the coordinated development of regional logistics industry and ecological environment from three aspects: the formulation of regional development policies and regulations, the construction of regional logistics public information platforms, and the optimization of logistics industry energy structure.

5.1. Develop Sound Supporting Regional Development Policies and Practical Regulations

Regional governments should fully play a guiding role and formulate comprehensive development policies for both the logistics industry and the ecological environment, without neglecting one side, providing a solid policy platform for the coordinated development of the regional logistics industry and the ecological environment. In terms of the development of the logistics industry, it is necessary to timely introduce a series of preferential policies in terms of finance, taxation, credit, investment, and land to promote the development of regional logistics industry based on the latest development trends of the global and domestic logistics industry, providing strong policy support and financial guarantee for the construction of logistics infrastructure and the development of logistics enterprises in the region, thereby continuously increasing the investment in the logistics system.

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In terms of low-carbon development in the logistics industry, on the one hand, we will continue to actively formulate support policies, encourage logistics enterprises in the region to engage in energy conservation and emission reduction through relevant financial and tax support policies such as government subsidies, tax exemptions, and the establishment of special funds. We will use preferential policies to create a good industrial investment environment, attract domestic and foreign high-end logistics enterprises who master energy conservation and emission reduction technologies to settle in the region, and vigorously support, cultivate, and introduce specialization Low carbon logistics enterprises promote the internal structural transformation and upgrading of regional logistics industry; Actively guide the behavior of logistics practitioners, cultivate their low-carbon concept, promote external exchanges among logistics practitioners in the region through incentive and preferential policies, learn from advanced logistics industry and ecological environment coordinated development experiences in developed countries and regions, and reserve high-quality human resources for the low-carbon development of regional logistics industry.

5.2. Strengthen the Construction of Regional Logistics Public Information Platforms

The regional logistics public information platform provides strong support for the development of goods tracking, vehicle scheduling, and transportation plans for various logistics enterprises in the region through the collection, analysis, and processing of shared information such as cargo tracking and traffic flow in regional logistics hubs. This platform can integrate existing industry resources, truly achieve industry resource sharing and information sharing, and solve problems such as information collection, processing, and sharing that cannot be completed by a single logistics enterprise, Fundamentally improve the current situation of decentralized operation of the logistics industry in the region, and unleash the overall advantages of regional logistics.

The construction of a regional logistics public information platform is a win-win measure. On the one hand, it can make internal logistics information in the region fully open and circulate at a high speed, enabling various organizations in regional logistics activities to obtain logistics information in a timely manner. Effectively solving various unreasonable logistics problems caused by poor and untimely information communication during the operation of regional logistics, achieving optimal allocation of various resources, improving the operational level and service quality of regional logistics, reducing the total cost of regional logistics, increasing the output of logistics systems, and promoting the continuous growth of logistics subsystem orderliness.

5.3. Accelerate the Optimization of Energy Structure in the Logistics Industry

Based on the calculation results of the types of energy consumption, energy consumption, and carbon emissions in the logistics industry, it can be seen that the energy consumption structure is a key factor affecting energy conservation and emission reduction in the logistics industry, and achieving coordinated development with the ecological environment. At present, the inland logistics industry mainly relies on land transportation, with a large proportion of fossil energy types such as non clean fuels, non renewable coal, and oil consumed in energy consumption. Clean energy logistics equipment such as natural gas and electricity are not widely used in the market due to their high development and operation costs and relatively unstable technology.

Regional governments should actively develop and call for the use of energy-saving and emission reduction technologies and renewable energy technologies, and provide more financial and tax incentives and convenient transportation policies to logistics enterprises using new and clean energy vehicles. While providing subsidies, they should also expand their operating rights, improve the traffic conditions of enterprise vehicles, reduce usage costs, and

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gradually increase the popularity of new and clean energy trucks in the region. We should also increase support for various energy-saving and emission reduction renovation projects such as energy transformation of heavy machinery and recyclable logistics packaging in regional logistics operations, to promote the diversification and clean transformation of energy consumption in the logistics industry. In addition, we should advocate the use of water and rail transportation that consumes less energy and emits less carbon than road transportation, actively carry out multimodal transportation, and optimize regional logistics transportation methods. Continuously optimize the energy structure of the logistics industry through multiple approaches, and effectively reduce the energy consumption intensity and carbon emissions intensity of the logistics industry.

6. Conclusion

The composite system coordination model used in this article can objectively and effectively evaluate the coordinated development level of logistics and ecological environment. The research methods and achievements can be used for reference by relevant research institutions in logistics, ecological environment, economy, and other fields. When conducting research on the coordinated development of regional logistics and ecological environment, this article mainly conducts vertical comparative analysis based on historical data of one region, without horizontal comparison with other regions. Therefore, in future research, relevant data from other regions in China can be further extensively collected for horizontal comparison, making the research on the coordinated development of regional logistics and ecological environment more in-depth.

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