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Research Article

Data-Driven-Based Study on Sustainable Improvement of the Regional Logistics Industry

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The rapid growth and development of the logistics industry has brought productivity to commerce and trade and greatly contributed to national economy, but at the expense of vast energy consumption, which significantly affects sustainability. To improve sustainability of the development of the logistics industry (LISD) and identify its potential influencing factors more directly and efficiently, this study proposes a data-driven-based evaluation and optimisation method. First, a comprehensive evaluation index system is constructed for LISD from the aspects of economy, society, and environment (including the logistics industry, degree of specialisation, environmental effects, and innovation capability). Second, considering the diversity of dimensions and units, a min-max standardisation is utilised for data normalisation, providing dimensionless indicators for further weight determination via an entropy value method. Third, two coupling degree models are adopted to evaluate the degree of correlation among subsystems. Subsequently, a degree of obstacle model is applied to analyse the interaction between factors, providing theoretical support for improving regional LISD. Finally, an evaluation of LISD in Anhui Province is used as a case study to validate the practicability and feasibility of the proposed method, establish theoretical basis, and propose policy recommendations for future sustainable development.

1. Introduction

1.1. Research Background. The logistics industry (LI) is a composite service industry that integrates transportation, warehousing, freight, and information industries [1]. The sustainable development of the logistics industry (LISD) has great significance for the promotion of industrial structure and improvement of the competitiveness of national economies [2]. However, the LI is also a major industry related to energy consumption and carbon emissions [3]. To fulfill the requirements of sustainable economic development, the traditional LI needs to be updated to the modern LI, following the guidance of advanced operation and management concepts, thus, the energy consumption and traffic pressure can be effectively reduced [4].

Despite extensive research on LISD, previously developed models have emphasised the economic performance unilaterally, which is no longer suitable for the development of the regional LI [5]. Therefore, the enhancement of LISD in coordination has received increasing emphasis in the academic field [6–10]; the existing research can be divided into the following aspects:

(1) Research on the index evaluation system of regional logistics sustainability

Due to the serious environmental pollution, resource depletion, and climate deterioration, the LISD has received extensive attention [11–13], and related studies proposed that companies should integrate the concept of sustainability into business operations to improve their long-term competitiveness [14]. Therefore, various indicator systems for LISD have been constructed from the perspective of economy, society, environment, technological innovation, and industry policy [15]. Particularly, detailed indicators include the logistics carrying capacity [16], industrial performance, innovation capacity, emissions and industry output [17], logistics packaging sustainability [18], and ecological efficiency [19].

Based on the constructed indicator system, scholars in different fields explored methods to quantify the level of sustainability industries. For example, Liu [20] processed data from the perspective of energy. Kayikci [21] developed a stream processing data-driven decision-making model, resilience of the logistics infrastructure. As for the specific operation method, Cao [22] focused on using the DEA-Bayes method to study the sustainable development efficiency of the urban LI, while Long [23] employed the super-SBM-DEA model to evaluate regional differences in logistics efficiency. Huang [1] selected the entropy weight method to assign values to various indicators.

(2) Research on the improvement of the LISD

Besides the studies on the index evaluation system and calculation methods, the benefits and losses of logistics practitioners were investigated under the analysis of different policy environments, such as urban route planning, public space management [24], carbon tax policy [25], producer responsibility [26], policy subsidies, and construction logistics, which can provide suggestions for practitioners' optimal decision-making and reference for government policy equation. From the perspective of policy advice research methods, Liu [27, 28] used the Nash equilibrium strategy to study how to coordinate a three-party sustainable supply chain and improve the internal coordination of the sustainable supply chain for economic and environmental benefits. Previous studies have assessed regional logistics sustainability and incentive policies, but the evaluative indicators for regional logistics are relatively incomplete. Specifically, most of the index evaluation systems in the existing literature are focused on the national level [29] or are aimed at developed regions, and their index weight setting methods may not be appropriate when researching other regions; most existing literature focus on specific perspectives, such as logistics service providers [30], considering the government and the public less when setting the indicator system. Therefore, these evaluation methods require further studies.

1.2. Research Limitations. The existing research constructed a good foundation for determining the sustainable development level of the LI and its development path. However, the breadth and depth of this research must be further improved. For instance, the perspective of the existing research mostly from the government or LI practitioners unilaterally. Moreover, while analysing the calculation process, the impact of the COVID-19 has not been sufficiently taken into consideration. Despite the wide application of evaluation methods, such as the DEA and TOPSIS models, the process of selecting quantitative indicators is affected by subjective factors and can easily be disturbed by extreme values during data processing. Therefore, this study proposes a data-driven-based evaluation and optimisation method for LISD and further provides targeted optimisation countermeasures correspondingly. In the proposed approach, a comprehensive evaluation index system was first constructed from the aspects of economy, society, and environment (including the logistics industry, degree of specialisation, environmental effects, and innovation capability) for LISD. Then, due to the diversity of dimensions and units, a min-max standardisation was utilised for data normalisation, which provides dimensionless indicators for further indicator weight determination via the entropy value method. Following this, two coupling degree models were adopted to evaluate the degree of correlation and coordination among the subsystems, avoiding low system or the false coordination. This model can help different subsystems cooperate properly and achieve the overall improvement of the system. Subsequently, a degree of the obstacle model was applied to analyse the interaction between various factors, which provides theoretical support for improving the sustainability of the regional LI. Finally, the sustainability evaluation for the LI in Anhui Province was adopted as a case study to validate the practicability and feasibility of the proposed method and policy recommendation. In brief, this paper proposes a data-driven approach to evaluate the LISD, and the main novelty of the paper are: (1) Researching the LISD from a data-driven perspective and applying a quantitative evaluation model to explore the degree of the LISD. (2) A targeted government incentive mechanism is designed and through considering the cooperative relationship among logistics, the government and the market, provide policy recommendations to improve the LISD. These are the contributions and novelty of this paper. A theoretical basis for in-depth research on the development of the regional economy was provided for sustainable development. This paper contributes to studying the LISD in areas with economic potential. By comprehensively and systematically quantifying the sustainable development capability of the industry, it finds the factors that hinder the development and promotes the coordinated development of the regional economy. Anhui Province, located in the Yangtze River Delta region with abundant economic resources, has an above-average economy in China. Despite possessing an obvious location advantage, the GDP of Anhui Province still drops behind of that of surrounding provinces by a substantial amount. Therefore, with superior objective development conditions, the development potential of Anhui Province can be improved through critical suggestions.

1.3. Structure. This paper is organised as follows: Section 1 describes the development status of the LI in Anhui Province through the operation of the local logistics industry and energy consumption. Section 2 presents the model development and data processing method. Section 3 evaluates the LISD in Anhui Province and proposes corresponding development suggestions according to the calculation results. Section 4 presents the background and data analysis. In Section 5, the management implications and future work are discussed. Finally, the conclusion is given in Section 6.

2. Materials and Methods

In the following sections, the proposed methods, including model selection, data processing, result analysis, and further suggestions are systematically described.

2.1. Method Flow. This paper evaluated LISD and put forward development suggestions based on data from four aspects: logistics industry basis, degree of specialisation, environmental effects, and innovation ability. Specifically, this research first adopted the min-max standardisation method to perform dimensionless and standardised processing of the original data. Then, the entropy method was utilised to determine the index weight and calculate the sustainability of the logistics industry according to the indicator weights. Subsequently, two coupling degree models are adopted to evaluate the degree of correlation and coordination among subsystems, respectively. Finally, the targeted optimisation countermeasures and suggestions were put forward. The flowchart of the proposed method is illustrated in Figure 1.

2.2. Data Collection. The data was mainly obtained from the China Logistics Yearbook, Anhui Provincial Statistical Yearbook, China Energy Statistical Yearbook, and similar sources. Some missing data were obtained by a weighted average method. By collecting various data of the regional LI in a fixed period, a comprehensive assessment of the LI was carried out to determine the key influencing factors. The detailed evaluation indicators are shown listed in Table 1. “LI basic” refers to the inherent factors of sustainable development of the LI, including many measurement factors such as employees, equipment, infrastructure construction, and gross production value. “Degree of specialisation” demonstrates the service efficiency and benefits of the corresponding logistics services. “Environmental effects” refer to environmental pollution and resource utilisation [26, 27]. Lastly, the “ability of innovation” refers to the drive of sustainable development and evaluates the deepest benches in high-tech, scientific payoffs, and financial support. The logistics industry basic and degree of specialisation represent the existing development foundation. Moreover, degree of specialisation and ability of innovation indicate the ability that the region’s natural and social resources can support the LISD in the future.

2.3. Data Processing

2.3.1. Min-Max Standardisation. Due to the different characteristics of the original data, with some being positive and some being negative indicators, mechanical aggregation was not advisable. Moreover, as the units of the collected data were different, data standardisation is required to remove the unit limitation of the original data and perform co-chemotropic/dimensionless processing before data analysis. After data standardisation, a min-max normalisation approach was adopted to transform the dimensionless evaluation indicators linearly. To avoid results deviation induced by the occurrence of 0 and 1, $\min\{X_{ij}\}$ was set as 0.99 times the actual minimum value of $\{X_{ij}\}$, while $\max\{X_{ij}\}$ was set as 1.01 times the actual maximum value of $\{X_{ij}\}$. The specific calculation steps and corresponding equations were as follows [28]:

Positive indicators:

$$X_{ij}^{*} = \frac{X_{ij} - \min\left\{X_{ij}\right\}}{\max\left\{X_{ij}\right\} - \min\left\{X_{ij}\right\}} + 0.1, i = 1, 2, 3 \ldots, m; \ j = 1, 2, 3 \cdots, n. \quad (1)$$

Negative indicators:

$$X_{ij}^{*} = \frac{\max\left\{X_{ij}\right\} - X_{ij}}{\max\left\{X_{ij}\right\} - \min\left\{X_{ij}\right\}} + 0.1, i = 1, 2, 3 \ldots, n; \ j = 1, 2, 3 \cdots, m, \quad (2)$$

where n is the number of the first level indicators, m is the number of the second level indicators, X_{ij} is the j^{th} second level indicator of the first level indicator I, $\max\{X_{ij}\}$ and $\min\{X_{ij}\}$ are the maximum and minimum of X_{ij}, respectively. The calculation result of these two equations, i.e., X_{ij}^{*}, was the data after non-negative processing.

2.3.2. Entropy Value Method for Determining Index Weight. The entropy method is an objective weighting method which can determine the index weights according to the degree of variation in the values of each index, avoiding the interference of human factors. The weight of indicators X_{ij} and μ_{ij} was determined as follows [28–30]:

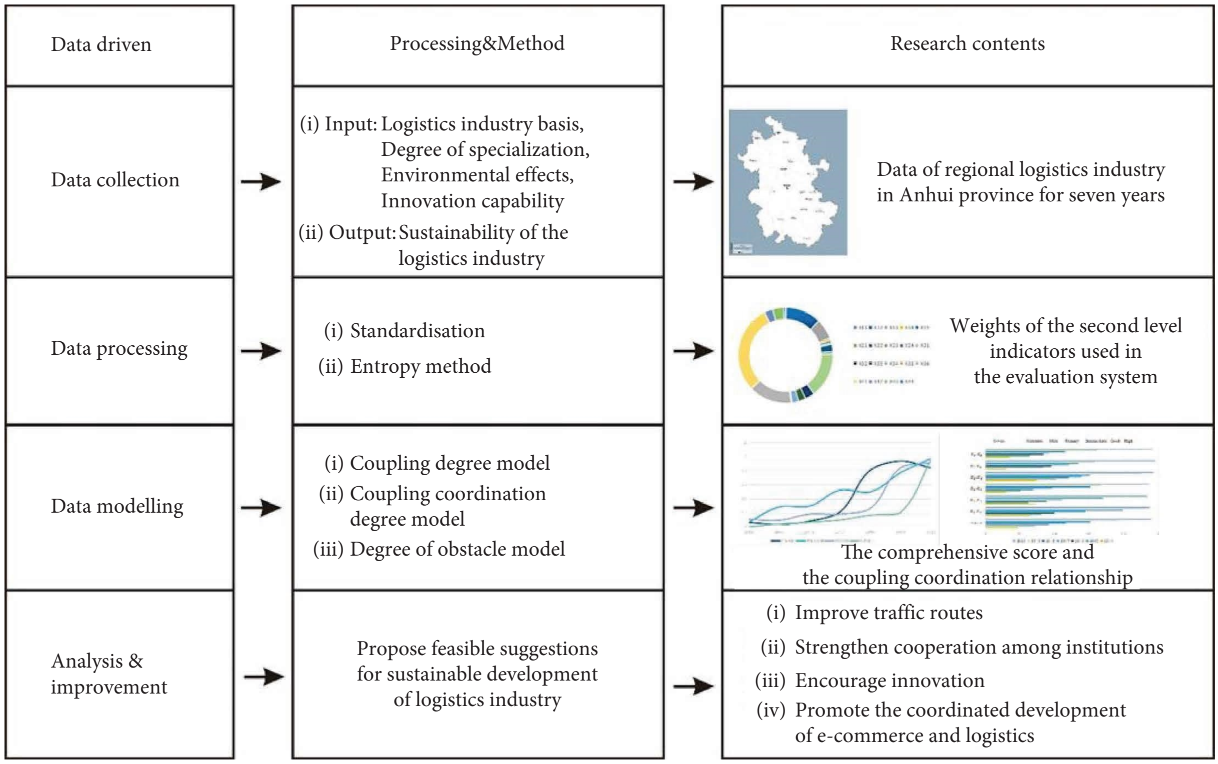

FIGURE 1: Flowchart of the proposed method.

TABLE 1: Evaluation index system of the sustainable development of the logistics industry (LISD).

Primary indicators	Secondary indicators	Direction of indicators
Logistics industry basic X_1	X_{11} number of employed persons in urban nonprivate units in the logistics industry (persons)	+
	X_{12} GDP of the logistics industry (100 million RMB)	+
	X_{13} fiscal expenditure general public services (100 million RMB)	+
	X_{14} fixed asset investment in the logistics industry (10,000 RMB)	+
	X_{15} number of trucks in urban highway operation (vehicles)	+
Degree of specialisation X_2	X_{21} ratio of total logistics costs to GDP	−
	X_{22} number of business outlets (offices)	+
	X_{23} transport line length (km)/service area (km^2)	+
	X_{24} permanent population/business outlets	−
Environmental effects X_3	X_{31} added value of the logistics industry (billion)	+
	X_{32} total energy consumption of the logistics industry (10,000 tons of standard coal)	−
	X_{33} wastewater discharge in the logistics industry (10,000 tons)	−
	X_{34} exhaust gas emissions from the logistics industry (10,000 tons)	−
	X_{35} solid waste discharge in the logistics industry (10,000 tons)	−
	X_{36} energy consumption per unit of logistics output (= total energy consumption of the logistics industry/added value of the logistics industry)	−
Ability of innovation X_4	X_{41} number of authorised patent applications for logistics technology innovation (items)	+
	X_{42} income from the education funds of higher education schools (10,000 RMB)	+
	X_{43} research and experimental development (R&D) expenditure (10,000 RMB)	+
	X_{44} number of graduate students in colleges and universities	+

$$X_{ij}, \mu_{ij} = \frac{X_{ij}}{\sum X_{ij}}. \tag{3}$$

The information entropy of index j (e_j) was calculated as follows:

$$e_j = -k \sum \mu_{ij} \times \ln \mu_{ij}, k = \left(\frac{1}{\ln m}\right). \tag{4}$$

The value of the information entropy redundancy of index g_i, behaves as follows: the higher the value, the higher the index redundancy, and it was calculated as:

$$g_i = 1 - e_j. \tag{5}$$

The weight of the indicator w_j was calculated as follows:

$$w_j = \frac{g_i}{\sum g_i}. \tag{6}$$

2.4. Data Modelling

(1) Determining the comprehensive score of the indicators

The sustainability level of the LI was calculated according to the standardised logistics industry-related data weights, which were determined by the entropy value method [31, 32]:

$$\gamma_i = \sum_j \left(w_j \times X_{ij}^*\right), \tag{7}$$

where γ_i is the comprehensive score of the sustainability level of the LI and is used to calculate the comprehensive level of various first level indicators similarly (including logistics industry basic, degree of specialisation, environmental effects, and innovation ability).

(2) Coupling degree model

Based on the obtained comprehensive score of the sustainability level of each first level indicator, the coupling degree (A) between the four first level indicators was calculated using the following equation [33–35]:

$$\mathrm{A} = \frac{5 \times \sqrt[5]{X_1 X_2 X_3 X_4 X_5}}{X_1 + X_2 + X_3 + X_4 + X_5}, \tag{8}$$

where A is in the interval of (0, 1), X_1, X_2, X_3, and X_4 are the comprehensive levels of industry basics, specialisation, environmental effects, and innovation ability, respectively. In this method, a higher coupling degree value indicates the greater degree of coupling relationship between the internal indicators of the LISD.

(3) Coupling coordination degree model

The coupling model described above was employed to evaluate the degree of correlation between the subsystems; however, this model cannot reflect the coordination within the system. Therefore, the coupling coordination model was used to evaluate the degree of benign coupling between the subsystems, i.e., low-quality mutual hindrance or high-quality mutual promotion [36–38].

$$\mathrm{B} = \sqrt{A \times Z}, \mathrm{Z} = \mathrm{aX}_1 + \mathrm{bX}_2 + \mathrm{cX}_3 + \mathrm{dX}_4, \tag{9}$$

where B is the coupling degree, Z is the comprehensive evaluation index used to reflect the overall level of subsystem (including logistics industry basic, degree of specialisation, environmental effects, and innovation capability), and a, b, c, and d are the undetermined weight coefficients. This model assumes that each subsystem is equally important in the LISD, so $a = b = c = d = 1/4$. Based on the determined coupling degree, the coordination level is divided into seven grades: high-quality coordination, good coordination, intermediate coordination, primary coordination, mild dysregulation, moderate maladjustment, and serious maladjustment, which has been proven to be the most practical. Table 2 shows the standard values of these seven divisions.

(4) Degree of obstacle model

The degree of obstacle was calculated as follows [39, 40]:

$$\mu_{ij} = \frac{\left(1 - X_{ij}^*\right) \times w_{ij\times 100\%}}{\sum\left(1 - X_{ij}^*\right) \times w_{ij}},$$
$$\mu_{\mathrm{i}} = \sum \mu_{\mathrm{i}}, \tag{10}$$

where μ_{ij} is the obstacle degree of the j^{th} second level index in the first level index i, μ_i represents the obstacle degree of the first level index, X_{ij}^* represents the standardised value of the j^{th} second level index, $1 - X_{ij}^*$ indicates the degree of deviation of the index, and w_{ij} is the weight of the j^{th} indicator.

3. Method Application

As shown in Figure 2, the proposed LISD approach consists of three stages. To systemically weigh the indicators at all levels after standardising the original data and calculate the sustainability scores of different subsystems in the logistics industry, an entropy method is utilised for experimental design in the first stage. During the second stage, the coupling degree and coupling coordination degree models were adopted to evaluate the degree of benign coupling between the subsystems. For the third stage, an obstacle degree model was utilised to calculate the obstacle degree of each index and identify the obstacle factors and the key breakthroughs in the sustainable development of the regional LI. Finally, based on the combined data processing results and official government documents, feasible development suggestions were proposed for optimising LISD. In this research, the data which were collected from various fields, including GDP of regional logistics industry, infrastructure construction, wastewater, waste gas, solid waste discharge, and scientific research results in a fixed period, will be used to construct a comprehensive evaluation index system for the regional LISD, Also, scientific methods were applied to the industry operation process, providing positive feedback to optimise and improve the logistics industry.

4. Results

4.1. Background. Anhui Province covers an area of 140,100 km^2. In 2020, its total population was 61.027 million and the corresponding GDP was 3,868.063 billion RMB, ranking 11th in China. It is located in the Yangtze River

Table 2: Seven levels of classification for the evaluation of the coupling harmonious degree.

Harmonious degrees	Harmonious levels
0–0.3	Serious maladjustment
0.3–0.4	Moderate maladjustment
0.4–0.5	Mild maladjustment
0.5–0.6	Primary coordination
0.6–0.7	Intermediate coordination
0.7–0.8	Good coordination
0.8–1	High-quality coordination

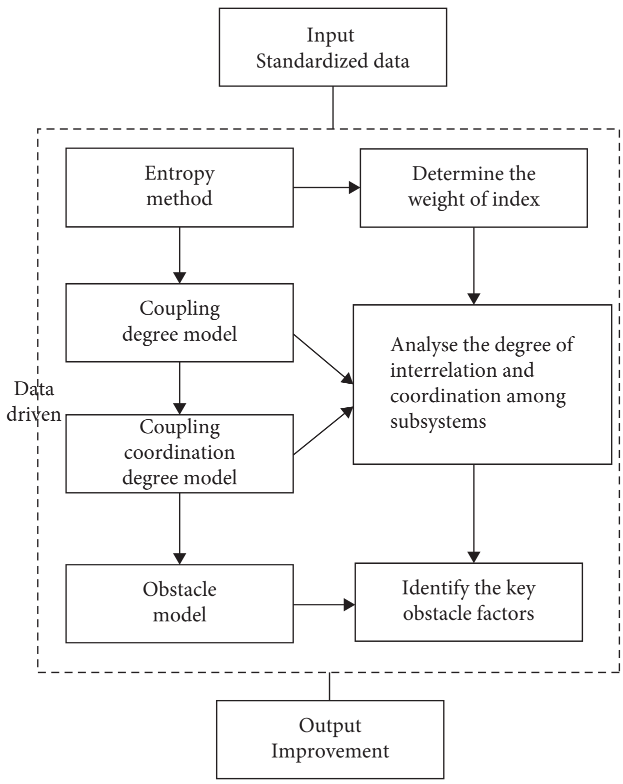

Figure 2: Data analysis process of the LISD.

Delta region, which has many metropolitan circles along the river, such as the Nanjing Metropolitan Circle, Central Plains Economic Circle, and Hangzhou Metropolitan Circle, providing abundant outside resources for economic development. Anhui Province gains the economic benefits of the coastal areas. In 2020, the total social logistics of the LI in Anhui Province was 7,021.3 billion RMB with a year-to-year increase of 3.5%. Moreover, the ratio between total social logistics costs and GDP in the same year was 14.7%, which was a 0.2% decrease from the previous year, and the overall trend was steadily rising (Anhui Provincial Statistical Yearbook, 2020). In terms of policies, the published "14th Five-Year Plan for the Development of the Logistics Industry in Anhui Province" pointed out the direction for the sustainable legal exhibition of the LI in Anhui Province. Specifically, while strengthening the construction of logistics infrastructure and improving logistics efficiency, Anhui Province has improved city- and county-level township nodes and introduced multimodal transportation to reduce logistics costs by building a high-quality comprehensive three-dimensional transportation network. To sum up, Anhui Province has a relatively superior geographical location, population, and infrastructure, but the development of the LI lags behind the surrounding provinces. The inconsistency between the actual development of Anhui Province of LI and the anticipation remains to be investigated. Therefore, this study adopted Anhui Province as a case study, providing relevant development suggestions for the local LI and validating the effectiveness of the employed method.

4.2. Data Analysis. Dimensionless standard processing was performed, and the processed original data are shown in Table 3.

Following that, based on equation (7), a comprehensive score of the 2014–2020 Anhui logistics industry sustainability evaluation was obtained, which is shown in Table 4.

As shown in Figure 4, the comprehensive scores of various indicators of the LI in Anhui Province demonstrated an overall upward trend from 2014 to 2020, but the increase in specific time periods varied individually. Specifically, the composite score of industry basic indicator increased slowly from 2014 to 2017 and rapidly from 2017 to 2019, reaching its peak in 2019 followed by a downward trend. This trend was mainly attributed to the development plan of the Anhui Provincial Government for the logistics industry in 2017 and 2018.

To improve the logistics network, the Anhui Provincial Government has reconstructed and expanded some roads, built new bridges to connect them, improving the hub collection and distribution system. These policies mean that the government has increased the financial support for the logistics industry and improved the industry foundation. While improving the transportation network, the Provincial Department of Transportation urges noncompliant transport vehicles to be updated and eliminated in an orderly fashion as soon as possible. In general, the comprehensive score of the industry's basic indicators has improved significantly from 2017 to 2019 and declined slightly after 2019. This phenomenon was related to the reduction in employees and transport vehicles caused by the optimisation and upgrade of the logistics industry.

The degree of specialisation refers to indicators such as the ratio of total logistics costs to GDP and density of transportation routes. Over the past five years, it has mainly shown a fluctuating upward trend. This phenomenon is closely linked to the government's policies to promote e-commerce and express logistics, as well as to the cold chain infrastructure network. Environmental effects mainly include the burden caused by the LISD on the environment. The increase rate was relatively low from 2014 to 2018, and increased exponentially from 2018 to 2019, after which the level improved gradually. Similar to the reason for the changes in the degree of specialisation, this phenomenon mainly occurs because the Anhui Provincial government

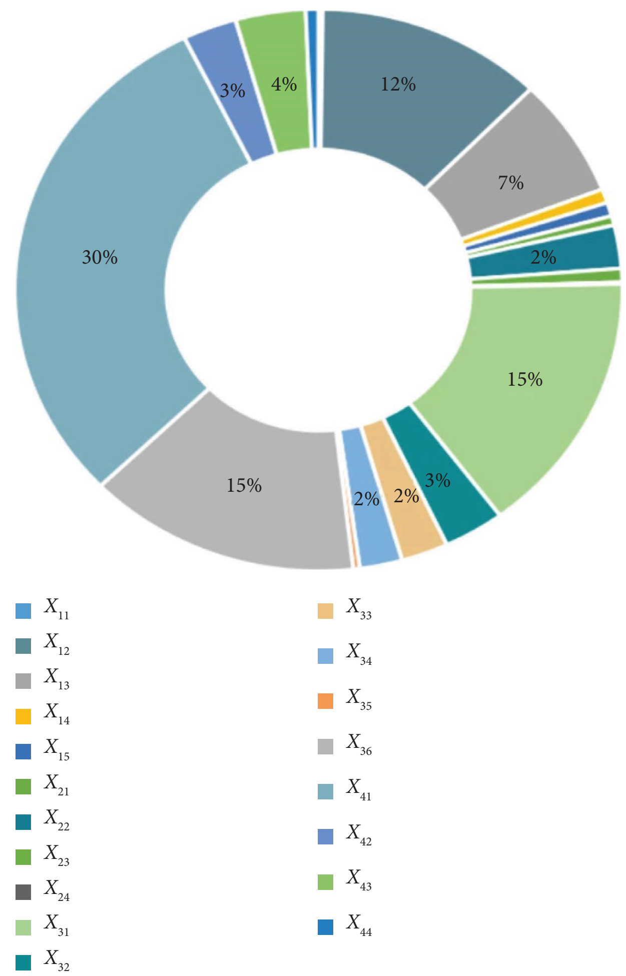

Figure 3: Weights of second level indicators in the adopted evaluation system.

vigorously built grassroots express outlets and planned the coordinated development of e-commerce and express logistics.

The innovation capability indicator is mainly used to measure the input and output of science and education in Anhui Province. From 2014 to 2019, its comprehensive score increased steadily and slightly, after which it started to increase sharply. This was mainly because the number of authorised patent applications for logistics technology innovation increased rapidly during this period. Based on the coupling coordination degree model and equation (9), the four first level indicators were calculated, and the results are shown in Figure 5. Specifically, the internal comprehensive coupling coordination level of the LISD in Anhui Province increased at a relatively stable rate from 2014 to 2020. The degree of coupling coordination among the four first level indicators (the average values in 2014 and 2020 were 0.2046 and 0.9596, respectively) has changed from serious imbalance to quality coordination. This showed that the logistics industry development policy of Anhui Province took both economic and environmental benefits into consideration by improving the transportation network, increasing investments in science and education, and promoting the mutual beneficial effects of various subsystems.

On the other hand, the coupling coordination level between the industry foundation-specialisation degree and the degree of specialisation-environmental effects is relatively high. This is because of the geographical location of Anhui Province and the relatively complete basic transportation network. Compared with the abovementioned coordination relationship, the level of coupling coordination between industry basic-innovation ability, degree of specialisation-innovation ability, and environmental effect-innovation ability was relatively poor.

According to equation (10), the obstacle degree model was utilised to analyse and compare the obstacle degree of each index and diagnose the obstacle factor of the LISD in Anhui Province. As shown in Figure 6, the main obstacles to the LISD in Anhui Province are innovation ability and environmental effects. From 2014 to 2017, the values of the barrier factors of each indicator were relatively stable, and the main barrier obstacles including innovation ability and environmental effects. This was mainly because the early development model of the logistics industry in Anhui Province was relatively extensive (by high cost and low efficiency), relying on the blind abuse of road networks and human and economic resources (obtained from the number of employees and the emission data in the statistical yearbook and combined with the logistics policies of Anhui Province in that period). From 2018 to 2020, the barrier to innovation capability increased initially and then decreased to 19.93%. Conversely, the industry-based barrier increased to 40% in this period. This drastic change in the degree of barriers was closely related to the outbreak of COVID-19 in 2019. After the outbreak of the new crown pneumonia, Anhui Province implemented traffic control, and closed type management was adopted in residential areas. Therefore, the demand in the private logistics market decreased sharply, resulting in a substantial increase in the basic obstacles for the logistics industry. Meanwhile, different types of anti-epidemic materials from around the world had to be sorted, repackaged, and transported within a specific time. The demand for the distribution of medical and disaster relief material distribution as well as e-commerce terminal surged, consequently increased the energy consumption and emission of the regional LI.

5. Discussion

5.1. Policy Suggestions. Based on the abovementioned calculations and analyses, this research provides the following suggestions for the LISD in Anhui Province:

(1) The grassroots traffic network should be improved, and transportation vehicles require an upgrade to lay a solid foundation for the LISD. To optimise the layout of the express logistics network, the density of the road network, traffic capacity, and rural distribution network should be improved in coordination. The implementation plan of the Anhui Provincial Department of Transportation and the Provincial Department of Finance shows that the proportion of highways (above the third level) in the

Table 3: Standardised values (X_1–X_2) of original data of the LISD in Anhui Province from 2014 to 2020.

Years	X_1 *logistics industry basic*					X_2 *degree of specialisation*				X_3 *environmental effects*						X_4 ability of innovation			
	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{21}	X_{22}	X_{23}	X_{24}	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}	X_{36}	X_{41}	X_{42}	X_{43}	X_{44}
2014	0.51384	0.00646	0.06861	0.00993	0.86109	0.45691	0.00306	0.02373	0.01291	0.00645	0.94140	0.08006	0.01214	0.96405	0.03394	0.00069	0.01437	0.01058	0.02881
2015	0.08180	0.01246	0.02269	0.34546	0.24758	0.22017	0.24857	0.41137	0.58094	0.01244	0.83052	0.02225	0.16348	0.64676	0.01746	0.01596	0.16938	0.11315	0.35098
2016	0.32665	0.04134	0.04537	0.68150	0.44245	0.07813	0.27136	0.49820	0.60378	0.04128	0.67231	0.70158	0.63799	0.76840	0.04729	0.02036	0.27557	0.22979	0.47257
2017	0.79683	0.08138	0.32433	0.85785	0.51339	0.55161	0.50949	0.52023	0.80439	0.08122	0.27605	0.90761	0.73893	0.96345	0.03777	0.01117	0.46814	0.47123	0.59375
2018	0.90992	0.89696	0.62370	0.90002	0.91357	0.45691	0.49630	0.50581	0.79058	0.17193	0.11722	0.92094	0.80922	0.64137	0.19375	0.04208	0.64140	0.69719	0.82821
2019	0.61040	0.96791	0.96786	0.92846	0.33021	0.83570	0.69639	0.95616	0.89066	0.98378	0.06734	0.74392	0.40192	0.04514	0.97381	0.04010	0.82493	0.97972	0.90304
2020	0.29130	0.98376	0.67473	0.98036	0.07808	0.93040	0.98710	0.96684	0.99693	0.98123	0.23519	0.98740	0.99772	0.31088	0.99229	0.98942	0.97602	0.67156	0.96186

The abovementioned standardised data were adopted by equations (3)–(6), and the weight of each indicator was obtained using the entropy method. Figure 3 shows the weight of each second-level indicator. The results show that the following indicators have a greater weight than those of the other indicators: the GDP of the LI, number of patent applications for logistics technology innovation, energy consumption per unit of logistics output, and financial expenditures of public services. Thus, the economic background, technology level, and financial support were important conditions for LISD.

Table 4: Comprehensive scores of the 2014–2020 Anhui logistics industry sustainability evaluation.

	2014	2015	2016	2017	2018	2019	2020
Logistics industry basic	0.06500	0.03822	0.08537	0.21530	0.80750	0.93837	0.83972
Degree of specialisation	0.06980	0.28605	0.29919	0.52488	0.50024	0.77306	0.97546
Environmental effects	0.11041	0.09939	0.18279	0.18259	0.26699	0.84307	0.91726
Ability of innovation	0.00325	0.04358	0.06918	0.10296	0.16804	0.21018	0.95609

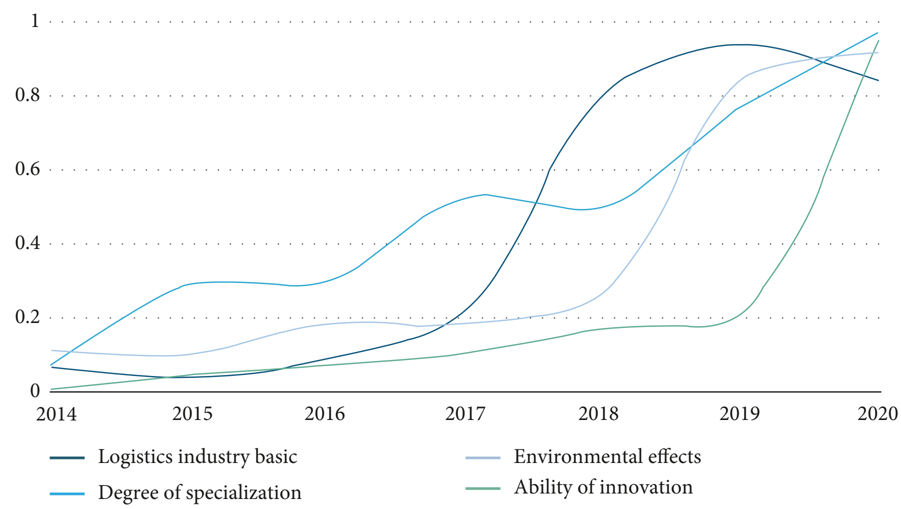

Figure 4: Visualised comprehensive scores of the first level indicators corresponding to Table 4.

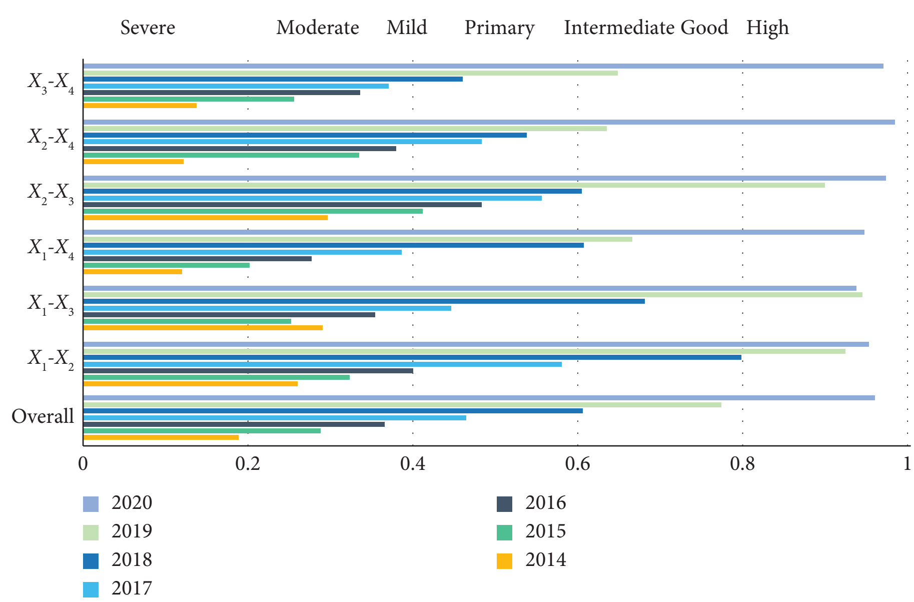

Figure 5: The coupling coordination relationship among the first level indicators.

demonstration counties and county roads was ≥85% in 2017. At the same time, according to the Anhui Provincial Statistical Yearbook, the number of people engaged in economic activities in Anhui Province has also risen steadily over the same period. These measures are also conducive to increasing local employment rates and promoting consumption growth. In addition, the operating vehicles engaged in the logistics industry should be strictly regulated, substandard vehicles required to be scrapped in time, and new energy vehicles need to be promoted vigorously, which is conducive to energy saving and emission reduction. Overall, improving the grass-roots road network and upgrading transportation vehicles can promote energy consumption in the short term, but in the long run, it is conducive to

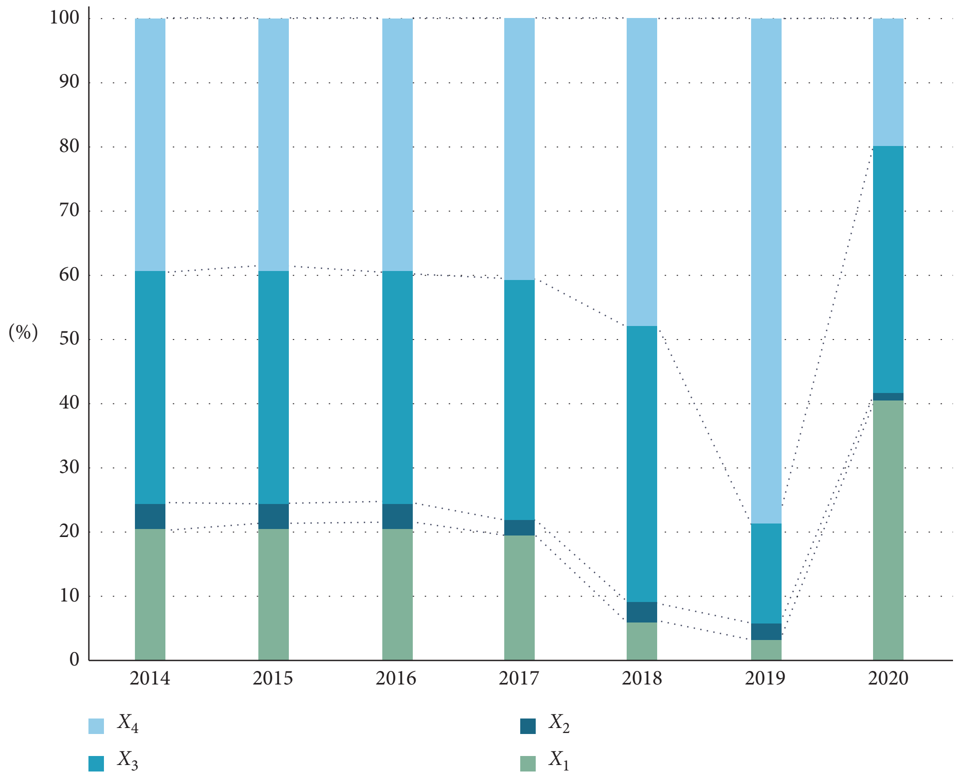

FIGURE 6: Obstacles of the first level indicators in Anhui province from 2014 to 2020.

energy saving and emission reduction as well as to improving the local LISD.

(2) The cooperation among scientific research institutions, colleges and universities, and enterprises should be strengthened to encourage the innovation and application of logistics technology. Specifically, scientific research institutions should attract high-precision professionals, increase capital investment, and promote the research and transformation of the logistics technology to achieve innovation-driven industrial development. Colleges and universities in the province should offer courses to provide students with the skills required by contemporary logistics practitioners. Enterprises should undertake their own social responsibilities actively, assist in building a logistics laboratory platform in colleges and universities, and help students exercise their business practice ability.

(3) The coordinated development of e-commerce and express logistics should be promoted, along with precise positioning, and the construction of logistics parks should be expedited. In particular, the local government and practitioners should consider the economic background and local market demand comprehensively and combine on-site market research to locate logistics parks [27]. On the one hand, it is necessary to clarify the location advantages, make full use of the transportation advantages in combination with the location characteristics, give priority to road transportation, and consider multimodal transportation. On the other hand, avoiding the blind and disorderly construction of logistics parks can decrease the waste of resources. For instance, the scale and number of logistics parks should be set mainly according to the local market demand, and the needs of potential customers should be determined through on-the-spot investigation to ensure the continuous operation of local logistics parks.

5.2. Management Implications. Compared with existing research, this research provides some improvements from different aspects. First, the entropy method is adopted to analyse the status of the LISD in 16 cities in Anhui Province, providing a more comprehensive and objective measurement standard for quantitative research on the LISD, and offering a theoretical basis for in-depth research on high-quality development of the regional economy. Second, the two-coupling model is utilised to reveal the coordinated development level among the subsystems and the key obstacle factors hindering the LISD. The adopted model can analyse the problems and causes of obstacles, determine the sustainable development direction of the LI in Anhui Province, and propose countermeasures accordingly. Therefore, the analysis process and results can help the government to analyse, evaluate, and predict the sustainability of the development of the regional logistics industry, and can contribute tools for the analysis and evaluation of the LISD based on data-driven methods, providing a reference for the sustainable development of regional logistics.

Based on the abovementioned research, the following management implications are suggested:

Primarily, as there are many factors involved in the sustainability of the LI, the proposed research identifies, analyses, and optimises the influencing factors according to the actual situation, to build a set of evaluation indicators (a system) for LISD to evaluate the actual level of sustainable development of the industry. The weight of different indicators is calculated by the entropy method, which reflects the importance of each indicator in theory. The government can start from the most influential factor, logistics industry basic, and try to determine the impact of a single indicator on the LISD. Only then can the government understand and grasp the status quo of LISD and provide a reasonable direction for further improvement of the sustainable development of the logistics industry.

Moreover, as the sustainable development system of the logistics industry is a complex ecosystem and the interaction between the internal subsystems affects the level of LISD, the LI should be studied as an organic whole, and the system theory should be emphasised. Moreover, LISD is a basic industry for a country's economic development. Hence, related research needs to achieve the sustainability of economy, society, and environment, and to provide corresponding optimisation policy recommendations from different perspectives.

6. Conclusions

The rapid development of the LI not only contributes to economic development but also reveals problems such as environmental pollution and misuse of resources. Carrying out technological innovations and improving the efficiency of resource utilisation are inevitable requirements for improving the regional LISD. Therefore, a comprehensive sustainability evaluation model for the LI was established in Anhui Province based on the data-driven model, providing suggestions for the development direction of the LI based on the results of the model analysis.

Compared with the existing research, this article provides improvements from different aspects as follows: (1) we evaluated several historical indicators of the LI comprehensively, considering the industry development background, environmental pollution, and development potential, and estimated the LISD in Anhui Province in the past seven years accurately and quantitatively; (2) we revealed the degree of mutual influence and coordinated development between different development indicators within the logistics industry development system using the coupling coordination degree model; (3) we identified the main obstacle factors affecting the development of the logistics industry through the obstacle degree model, and proposed corresponding suggestions to the government, enterprises, logistics industry practitioners, and colleges and universities, mainly including infrastructure, personnel training, technology research, and development and applications.

The logistics industry is the mainstay of regional economic development, while research on LISD involves many aspects. With the deepening of related research and improvement of various regional cases, the regional LI sustainability evaluation model will achieve higher accuracy and applicability. However, the model does not consider regional development differences caused by the radiation of surrounding economic regions; when we analysed indicators data, indicators are divided into positive and negative indicators, but in practice, the impact of different factors may be inversed in different a period. Therefore, future research should design more comprehensive models that combine universality and particularity. More aspects can be considered when establishing the evaluation index system and designing model, such as regional synergies, the degree of packaging recycling in the logistics, and the interaction among data that used in the model.

Data Availability

All data included in this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Heping Ding conceptualized the study. Yujia Liu performed investigation. Heping Ding provided resources. Yujia Liu and Heping Ding performed methodology and data curation, wrote the original draft, and reviewed the manuscript.

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