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Measurement and Strategy Research on the Green Development Level for the New Energy Vehicle Industry in Chongqing City

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This article takes 2016-2022 as the inspection period to construct an evaluation index system for the green development level of the new energy vehicle industry. The entropy method and comprehensive index are used to measure the green development level of the new energy vehicle industry in Chongqing, and compared with neighboring provinces such as Yunnan, Guizhou, and Sichuan. Policy recommendations are proposed to promote the development of the new energy vehicle industry in Chongqing City.

Keywords: Chongqing City, new energy vehicle industry, green development level

1 Introduction

Chongqing City is located in the southwest of China and is one of the important central cities of the People's Republic of China. It is an economic, financial, scientific and technological innovation, shipping, and commercial logistics center in the upper reaches of the Yangtze River. The total area of Chongqing is 82,400 square kilometers, with a permanent population of 32.1334 million at the end of 2022. In 2023, the gross domestic product of Chongqing was 3014.579 billion yuan, accounting for 2.39% of the national GDP. Chongqing is an important automobile production base in China. In recent years, the new energy vehicle industry has accelerated its development. In 2023, the number of new energy vehicles exceeded 500,000, an increase of 30% year-on-year. Based on this, this article takes the green development of Chongqing's new energy vehicle industry as the research object, establishes an evaluation index system for empirical analysis, and proposes optimization strategies , in order to provide policy reference for the high-quality development of Chongqing's new energy vehicle industry.

The quantitative analysis of green development plays an important role in the research or policy-making of industrial and regional economies. One is an important symbol used for industrial upgrading. Yang Haoran (2023) constructed an evaluation index system and measurement method for agricultural green development, believing that in order to improve the level of agricultural green development in the Yangtze River Economic Belt, more emphasis should be placed on enhancing the endogenous driving force of urban agricultural green development; Su Liyang (2013) and others measure the level of industrial green development from three aspects: green production, green products, and green industry. They believe that it is necessary to start from the actual situation

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of each province and adopt a classification management method to promote industrial green development. The second is to study the differences in regional green development. Wang Ling et al. (2023) investigated the development level of green economy in 30 provinces in China and found significant differences among them. From a regional perspective, there was a significant polarization difference in the eastern region, a significant backwardness in development in the central region, and a continuous narrowing of differences among provinces in the western region. Overall, there was a significant spatial correlation; Yang Zhijiang et al. (2017) conducted a study on the efficiency of green development between provinces in China, and found that the differences between provinces were increasing; Lin Li et al. (2023) investigated the level of green development in the Yangtze River Economic Belt and found that there were differences in the green development levels of the three major sectors: the eastern region had always had a higher level of green development than the central and western regions, but the gap was narrowing; there were differences in the level of green development among provinces and cities in the Yangtze River Economic Belt, but it was in a dynamic state of change. It was believed that a unified negative list of industrial access should be formulated. The research of existing scholars has laid a certain foundation for objectively evaluating the development of the new energy vehicle industry in Chongqing. However, there are currently few research results on the green development of the new energy vehicle industry in academia; especially the research on the green development level of the new energy vehicle industry in Chongqing has not yet been achieved.

This article takes 2016-2022 as the inspection period to construct an evaluation index system for the green development level of the new energy vehicle industry. The entropy method and comprehensive index are used to measure the green development level of the new energy vehicle industry in Chongqing, and compared with neighboring provinces such as Yunnan, Guizhou, and Sichuan to understand the status of green development in Chongqing's new energy vehicle industry. Proposing policy recommendations to promote the development of Chongqing's new energy vehicle industry is of great significance for promoting faster and better development of Chongqing's new energy vehicle industry.

2 Construction of Evaluation Index Systems for the New Energy Vehicle Industry in Chongqing City

2.1 Selection of Indexes and Construction of Index Evaluation Systems

The evaluation indexes for the green development level of Chongqing's new energy vehicle industry include 1 level-1 index, 3 level-2 indexes and 10 level-3 indexes. 1 level-1 index refers to the green development level index for the new energy vehicle industry; 3 level-2 indexes refer to the indexes for comprehensive resource use, pollution control, and economy and society; 10 level-3 indexes refer to the indexes for energy consumption total, energy consumption per GDP unit, water use per GDP unit, resource output rate, total chemical oxygen demand emission, ammonia and nitrogen emission total, sulfur dioxide emission total, percentage of new energy vehicle output value in the industry GDP, technology input ratio in the designated industry (namely the input strength of research and development), and number of accomplished projects for new products and new technologies. The 1evel-2 index comprehensive resource use indicator is composed of 4 level-3 indexes, namely, energy consumption total, energy consumption per GDP unit, water use per GDP unit, and resource output rate. The level-2 index pollution control indicator is composed of 3 level-3 indexes, namely, total chemical oxygen demand emission, ammonia and nitrogen emission total, and sulfur dioxide emission total. The level 2 index economy and society indicator is composed of 3 level-3 indexes, namely, percentage of new energy vehicle output value in the industry GDP, technology input ratio in the designated industry (namely the input strength of research and development), and number of accomplished projects for new products and new technologies of the given year. The evaluation index systems for the green development level of Chongqing's new energy vehicle industry are shown in Table 1.

Table 1
Evaluation Index Systems for the Green Development of Chongqing's New Energy Vehicle Industry

Level-1 index	**Level-2 indexes**	**Level-3 indexes**	**Order of level-3 indexes**	**Index nature**
Evaluation index for the green development of new energy vehicle industry	Comprehensive resource use index (B1)	Energy consumption total	B11	Negative index (-)
		Energy consumption total per GDP unit	B12	Negative index (-)
		Water use per GDP unit	B13	Negative index (-)
		Resource output rate	B14	Positive index (+)
	Pollution control index (B2)	Total chemical oxygen demand emission	B21	Negative index (-)
		Ammonia and nitrogen emission total	B22	Negative index (-)
		Sulfur dioxide emission total	B23	Negative index (-)
	Economy and society index (B3)	重 Percentage of new energy vehicle output value in the industry GDP	B31	Positive index (+)
		Technology input ratio in the designated industry (or R & D staff number)	B32	Positive index (+)
		Number of accomplished projects for new products and new technologies of the given year	B33	Positive index (+)

2.2 Specification of the Nature of Indexes

Explanations are rendered for positive, negative and moderate indexes. In the comprehensive multi-index evaluation those indexes whose bigger value is preferred are called positive indexes; those indexes whose smaller value is preferred are called negative indexes; those indexes whose constant value is preferred are called moderate indicators. In the comprehensive evaluation the three types of index should be communalized.

In the above-stated index systems B11, B12, B13, B21, B22 and B22 are negative indexes while B14, B31, B32 and B33 are positive indexes.

3 Measurement of Green Development Level of the New Energy Vehicle Industry

3.1 Research Methodology and Process

This dissertation collected the annual data for the above-mentioned 10 level-3 indexes from 2016 to 2022 in Chongqing City, Yunnan Province, Guizhou Province and Sichuan Province, which mainly come from the four places' 2016-2022 "Annual Statistics", "Public Report of Environmental Conditions" and "Public Report of Statistics" as well as the statistics provided by relevant departments of the four places. We did not have the 2022 statistics from Yunnan Province and Guizhou Province; instead the 2022 missing data was replaced through the use of linear interpolation method according to the two provinces' previous 5 years' relevant data. By means of entropy method and Matlab software we calculated the annual weight value and exponent of 10 level-3 indexes and finally the comprehensive indexes for the green development of Chongqing's new energy vehicle industry, and made a comparison with neighboring provinces' green development level of new energy vehicle industry.

As the nature of indexes varies in the comprehensive evaluation index systems of new energy vehicles, it is necessary to standardize the raw index data.

3.1.1 Index positivization (or called index standardized handling)

The formula for positive index handling for comprehensive evaluation is:

$$Y_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (1)$$

Formula (1) indicates that when the bigger the positive index value is the more Y value moves towards 1 and the more contribution it has to comprehensive evaluation.

The formula for reverse index handling is:

$$Y_i = \frac{X_{max} - X_i}{X_{max} - X_{min}} \quad (2)$$

Formula (2) indicates that the smaller the negative index value is the more Y value moves towards 1 and the more contribution it has to comprehensive evaluation.

3.1.2 Calculation of index weights

The key for comprehensive evaluation is the confirmation of index weight, and the empowering method is to classify the subjective and objective empowering. This dissertation used the entropy value method for confirmation of index weight, which is an objective empowering method widely adopted by scholars in recent years (Lin, Wang, & Xiao, 2023, pp. 122-130; XIAN, LIU, & LIU, 2005, pp. 107-109, 127). In the information theory entropy is used to measure uncertainty: the bigger the information amount is contained in index, the smaller uncertainty is, the smaller entropy is, and the bigger weight is; the smaller the information amount is contained in index, the bigger uncertainty is, the bigger entropy is, and the smaller weight is. Hence, through such a feature of entropy we can judge the dispersion degree of a certain index: the bigger an index's dispersion degree is the more influential it is to comprehensive evaluation.

Let us calculate the weight of each observed value for Index J. The formula is rendered below:

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{n} Y_{ij}} \quad (3)$$

Let us calculate the information entropy of Index J. The formula is rendered below:

$$e_j = -\frac{1}{ln\,n}\sum_{i=1}^{n} p_{ij}\,ln(p_{ij}) \quad (4)$$

Let us calculate the variation coefficient for Index J. The formula is rendered below:

$$g_j = 1 - e_j \quad (5)$$

Let us calculate the weight for Index J. The formula is rendered below:

$$W_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \quad (6)$$

3.1.3 Calculation of comprehensive evaluation indexes

Following the post-handling index data and the calculated weights we adopted the comprehensive index method to calculate the comprehensive evaluation indexes for the green development of new energy vehicle industry in Chongqing City and other provinces. The specific formula is rendered below:

$$V_j = \sum_{i=1}^{n} W_j \times Y_{ij} \quad (7)$$

In the above-stated formula, W_j is the weight of Index J. Meanwhile, in order to better understand the situation of level-2 indexes in the comprehensive index systems for the new energy vehicle industry development in Chongqing: first, the level-2 indexes were calculated, and then the level-2 indexes were added so that the level-1 index was obtained, namely, the comprehensive index for the green development of new energy vehicle industry. The calculation formula for level-2 indexes is Formula (7); notably the summed index number should be based on the level-3 index number under each level-2 index. For instance, the calculation formula for comprehensive resource use index is B1 = $\sum_{i=1}^{4} W_j Y_{ij}$.

3.2 Empirical Analysis

We adopted the evaluation index systems and evaluation method for the green development of Chongqing's new energy vehicle industry, and based on the 2016-2022 data calculated the development level of new energy vehicle industry in four places (Yunnan Province, Guizhou Province, Chongqing City and Sichuan Province) and made a comparison on the calculated outcome.

3.2.1 The standardization of raw data

Next, we standardized the 2016-2022 raw data of level-3 indexes in Yunnan Province, Guizhou Province, Chongqing City and Sichuan Province and made calculations according to Formulas (1) and (2), whose results are shown in Table 2 to Table 5.

Table 2
Standardized Data of Chongqing's New Energy Vehicles

Index name	Index value						
	2016	2017	2018	2019	2020	2021	2022
Energy consumption total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Energy consumption per GDP unit	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Industrial water use per GDP unit	0.0000	0.0000	0.0000	0.0000	0.6413	0.5367	0.6712
Resource output rate	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Chemical oxygen demand emission total	1.0000	1.0000	0.3954	0.4658	1.0000	1.0000	1.0000
Ammonia and nitrogen emission total	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
Sulfur dioxide emission total	1.0000	0.9350	0.8751	1.0000	1.0000	1.0000	0.7439
Percentage of new energy vehicle	0.0429	0.2446	0.3787	0.4476	0.3328	0.5757	1.0000

output value in the industry GDP							
Technology input ratio in the designated industry (or R & D funds input strength)	1.0000	1.0000	1.0000	1.0000	0.9524	0.9254	1.0000
Number of accomplished projects for new products and new technologies of the given year	0.0000	0.2644	0.3090	0.2972	0.3326	0.6867	1.0000

Table 3

Standardized Data of Yunnan's New Energy Vehicles

Index name	Index value						
	2016	2017	2018	2019	2020	2021	2022
Energy consumption total	0.6889	0.6734	0.6680	0.6588	0.6048	0.6296	0.6515
Energy consumption per GDP unit	0.5568	0.5004	0.5218	0.5979	0.4451	0.3874	0.3824
Industrial water use per GDP unit	0.6170	0.4892	0.9580	0.7882	0.6612	0.7145	1.0000
Resource output rate	0.4706	0.3564	0.4000	0.4554	0.3008	0.2562	0.2570
Chemical oxygen demand emission total	0.0000	0.5795	0.0000	0.0000	0.6274	0.6413	0.4862
Ammonia and nitrogen emission total	0.9432	1.0000	1.0000	0.7182	0.8702	0.8543	0.6622
Sulfur dioxide emission total	0.3380	0.6528	0.5252	0.3677	0.0000	0.1124	0.2737
Percentage of new energy vehicle output value in the industry GDP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Technology input ratio in the designated industry (or R & D funds input strength)	0.2455	0.2203	0.2131	0.0796	0.0714	0.0896	0.0097
Number of accomplished projects for new products and new technologies of the given year	0.0795	0.0000	0.0000	0.0000	0.0000	0.0000	0.1287

Table 4

Standardized Data of Guizhou's New Energy Vehicles

Index name	Index value						
	2016	2017	2018	2019	2020	2021	2022
Energy consumption total	0.7850	0.7834	0.7927	0.7912	0.7789	0.7785	0.8437
Energy consumption per GDP unit	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Industrial water use per GDP unit	1.0000	1.0000	0.9328	0.3968	0.0000	0.0000	0.0000
Resource output rate	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Chemical oxygen demand emission total	0.9983	0.0000	1.0000	1.0000	0.1391	0.1711	0.0396
Ammonia and nitrogen emission total	1.0000	0.9505	0.9189	0.6289	0.8536	0.8675	0.7054
Sulfur dioxide emission total	0.0000	0.0000	0.0000	0.0000	0.3607	0.0000	1.0000
Percentage of new energy vehicle output value in the industry GDP	1.0000	1.0000	0.6594	0.5537	0.6082	0.2772	0.1525
Technology input ratio in the designated industry (or R & D funds input strength)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Number of accomplished projects for new products and new technologies of the given year	1.0000	1.0000	1.0000	0.8065	0.7057	0.7288	0.6900

Table 5

Standardized Data of Sichuan's New Energy Vehicles

Index name	Index value						
	2016	2017	2018	2019	2020	2021	2022
Energy consumption total	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Energy consumption per GDP unit	0.8613	0.7697	0.8539	0.8470	0.7289	0.6772	0.7479
Industrial water use per GDP unit	0.0283	0.3124	1.0000	1.0000	1.0000	1.0000	0.9948
Resource output rate	0.7941	0.6535	0.7700	0.7624	0.5865	0.5537	0.5703
Chemical oxygen demand emission total	0.2955	0.6070	0.0178	0.0765	0.0000	0.0000	0.0000
Ammonia and nitrogen emission total	0.0917	0.1081	0.0450	0.0000	0.0000	0.0000	0.0000
Sulfur dioxide emission total	0.9483	1.0000	1.0000	0.6709	0.4439	0.0789	0.0000
Percentage of new energy vehicle output value in the industry GDP	0.5648	0.6966	1.0000	1.0000	1.0000	1.0000	0.8675
Technology input ratio in the designated industry (or R & D funds input strength)	1.0000	0.8644	0.8361	0.8938	1.0000	1.0000	0.8358
Number of accomplished projects for new products and new technologies of the given year	0.6266	0.5412	0.8700	1.0000	1.0000	1.0000	0.0000

3.2.2 Calculation of index weights

According to the above standardized data and Formulas (3), (4), (5) and (6) we calculated the weights for level-3 indexes and level-2 indexes, as shown in Table 6 and Table 7.

Table 6

Calculated Outcome of Level-3 Index Weights in the Evaluation Index Systems for the Green Development of New Energy Vehicles

	Energy consumption total	Energy consumption per GDP unit	Industrial water use per GDP unit	Resource output rate	Total chemical oxygen demand emission	Ammonia and nitrogen emission total	Sulfur dioxide emission total	percentage of new energy vehicle output value in the industry GDP	R & D funds input strength	Number of accomplished projects for new products and new technologies of the given year
2016	0.0663	0.0697	0.1428	0.0733	0.0881	0.1197	0.0834	0.1386	0.0937	0.1244
2017	0.0791	0.0854	0.1055	0.0964	0.0843	0.1376	0.0797	0.1092	0.1133	0.1094
2018	0.0737	0.0785	0.0704	0.0855	0.1784	0.1468	0.0785	0.0878	0.1063	0.0942
2019	0.0785	0.0802	0.0911	0.0869	0.1544	0.0798	0.0940	0.0906	0.1437	0.1009
2020	0.0802	0.0879	0.0805	0.1024	0.1290	0.0755	0.1020	0.0984	0.1469	0.0972
2021	0.0720	0.0837	0.0753	0.0988	0.1102	0.0684	0.1971	0.0956	0.1278	0.0711
2022	0.0690	0.0811	0.0692	0.0951	0.1483	0.0696	0.0911	0.1095	0.1524	0.1146

Table 7
Calculated Outcome of Level-2 Index Weights in the Evaluation Systems for the Green Development of New Energy Vehicles

	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Comprehensive resource use index	0.3522	0.3664	0.3081	0.3367	0.3510	0.3298	0.3145
Pollution control index	0.2911	0.3017	0.4037	0.3281	0.3065	0.3756	0.3090
Economy and society index	0.3567	0.3319	0.2882	0.3352	0.3425	0.2946	0.3765

3.2.3 Overall green development level of Chongqing's new energy vehicle industry

Based on Formula (7) we calculated the indexes for the overall green development level of Chongqing's 2016-2022 new energy vehicle industry. The calculated outcome is shown in Table 8.

Table 8
Indexes for the Overall Green Development Level of Chongqing's New Energy Vehicle Industry

	Index name	2016	2017	2018	2019	2020	2021	2022	Annual averaged value
Level-1 index	Evaluation index for the green development of new energy vehicle industry	0.4805	0.5887	0.5456	0.7055	0.8336	0.8927	0.9539	0.7143
Level-2 index	Index of comprehensive resource use	0.2093	0.2609	0.2377	0.2456	0.3221	0.2949	0.2916	0.2660
	Pollution control index	0.1715	0.1588	0.1392	0.2457	0.3065	0.3757	0.2857	0.2404
	Economy and society index	0.0997	0.1689	0.1686	0.2142	0.2050	0.2222	0.3765	0.2079

Table 8 indicates that regardless of the level-1 comprehensive index or the level-2 comprehensive resource use and economy and society indexes, the green development level of Chongqing's new energy vehicle industry in 2016 was the lowest, mainly because the policies and practice prior to 2016 paid little attention to the green development of new energy vehicles. After 2016 the green development concept, particularly the green development of new energy vehicles, was much emphasized in both policies and practice. As the policies and concept entered people's mind and were put into effect, a quality-oriented breakthrough was achieved in the green development level for Chongqing's new energy vehicle industry.

Specifically, the analysis of level-1 comprehensive index indicates that the green development level for Chongqing's new energy vehicle industry went upward gradually; except for 2018 when the green development level dropped by 4.31% as over 2017, the other years witnessed an annual growth of 6% to 16% as over the previous year in terms of the comprehensive evaluation index for green development. The growth rate changed from 0.4805 in 2016 to 0.9536 in 2022, an increase of 0.4731, which was a relatively big margin.

The analysis of level-2 indexes indicate that from 2016 to 2022 the "economy and society" index fluctuated somehow but the upward trend was obvious mainly because of economic development and the increase of people's incomes, the index growth rate being 0.2768. Generally speaking, the "economy and society" index made the biggest contribution to the green development level of new energy vehicle industry. The overall trend of pollution control index was upward. From 2016 to 2022 its growth rate was 0.1142; the "pollution control" index offered relatively big support for the green development level of Chongqing's new energy vehicle industry, partly due to the city's efforts on eco-civilization construction and the development of "green mountains, bright water and beautiful place". The comprehensive resource use index changed upward: from 2016 to 2020 its growth rate was 0.1128; by 2022, due to the Covid-19 pandemic its growth rate was slight—0.0823; relatively, "the comprehensive resource use" made the smallest contribution to the green development of Chongqing's new energy vehicle industry, and needs more improvement.

3.2.4 Contribution rate of level-2 indexes

Contribution rate can be used to measure the contributions of level-2 indexes to the green development level of new energy vehicle industry. The calculation formula (An & Xin, 2020, pp. 1801-1815) is rendered below.

$$R_t = \frac{Z_{it_2} - Z_{it_1}}{F_{it_2} - F_{it_1}} \times 100\% \qquad (7)$$

In the above formula F_{it1}、F_{it2} respectively indicate the comprehensive indexes for the green development of new energy vehicles in 2 research stages—the early and late stages in Area i. Z_{it1}、Z_{it2} indicate a certain level-2 index development in Area I in 2 research stages—the early and late stages. R_t indicates that the contribution rate: the bigger R_t is the bigger contribution the level-2 index has in this research stage to the green development of new energy vehicles, and the stronger its leading role is. The contribution rates of level-2 indexes to the overall green development of new energy vehicles in Chongqing and neighboring Yunnan Province, Guizhou Province and Sichuan Province were calculated as shown in Table 9.

Table 9
Contribution Rates of Level-2 Indexes to the Green Development of New Energy Vehicles

Area	Contribution rate of the comprehensive resource use index (%)	Contribution rate of the pollution control index (%)	Contribution rate of the economy and society index (%)	Comprehensive index growth of green development of new energy vehicles 2016-2022
Chongqing City	17.39	24.13	58.48	0.4731
Yunnan Province	71.98	-3.84	32.05	-0.052
Guizhou Province	37.38	16.86	45.76	-0.3654
Sichuan Province	-74.82	141.24	33.58	-0.0822

Tables 8 and 9 indicate that the green development of 2016-2022 new energy vehicle industry in Chongqing moved upward and each level-2 index growth rate was amazing. The level-2 index contributions to the overall green development level of Chongqing's new energy vehicles varied much, of which the contribution rate of the economy and society index was the highest—58.48%, playing the biggest leading role in the green development of new energy vehicle industry; the contribution rate of the pollution control index was 24.13%, playing a relatively big supporting role in the green development of new energy vehicles; relatively speaking, the contribution rate of comprehensive resource use index was the lowest—17.39%.

The leading role that the economy and society index played in the green development of Chongqing's new energy vehicle industry is obvious. First, with the ongoing improvement of economic and social development and people's living standard the general public's incomes were improved and their sense of environmental protection was strengthened. Hence, more and more people changed their purchase from fuel vehicles to new energy vehicles, and as the demand for new energy vehicles rose, the consumption market of the city's new energy vehicles was directly expanded. Second, with the country's fiscal subsidies to new energy vehicles, the initiative of the city's new energy vehicle-making corporations was mobilized, the inputs of the vehicle corporations into research and development on new energy vehicles were stimulated, and ever-growing efforts were made in ushering in new products and new technologies for new energy vehicles. Also, the national and local purchase tax subsidies to new energy vehicles pushed higher the consumers' initiative of purchase. An outcome of these factors combined is the increased contribution rate of the economy and society index to the overall green development level of the city's new energy vehicle industry.

The pollution control index made a relatively contribution to the green development of new energy vehicles, mainly because of the powerful implementation of the national eco-civilization development, which carried the new concept of green development into all production fields and required a strict assessment system for pollution control as to local officials. For Chongqing's new energy vehicle corporations, as new technologies and new products were ushered in and used and the inputs into research and development on new technologies were increased, the chemical oxygen demand emission total, the sulfur dioxide emission total and the ammonia and nitrogen emission total kept going down, and pollution control was well handled. Hence, this index made a relatively big contribution rate to the overall green development level of the city's new energy vehicle industry.

3.2.5 Comparison of green development level for the new energy vehicle industry between Chongqing City and three neighboring provinces

Chongqing City is located in southwest China including 3 other provinces—Yunnan, Guizhou and Sichuan. According to the above method we calculated the index weights and green development indexes of new energy vehicles from 2016 to 2022. The index weights are shown in Tables 3.5 and 3.6, and the green development indexes are noted in Table 10.

Table 10

Green Development Indexes of New Energy Vehicles in Chongqing and Other Southwest China Provinces

Comprehensive evaluation indexes for the green development of new energy vehicles	2016	2017	2018	2019	2020	2021	2022
Yunnan	0.3811	0.4455	0.4025	0.3144	0.3288	0.3195	0.3290
Guizhou	0.6655	0.5170	0.5894	0.4343	0.3100	0.2125	0.3001
Chongqing	0.4805	0.5887	0.5456	0.7055	0.8336	0.8927	0.9539
Sichuan	0.4883	0.5407	0.5501	0.6201	0.5924	0.4969	0.4061
Comprehensive resource use indexes	2016	2017	2018	2019	2020	2021	2022
Yunnan	0.2071	0.1820	0.1918	0.2111	0.1717	0.1569	0.1696
Guizhou	0.1948	0.1675	0.1241	0.0983	0.0625	0.0560	0.0582
Chongqing	0.2093	0.2609	0.2377	0.2456	0.3221	0.2949	0.2916
Sichuan	0.1223	0.1617	0.2033	0.2253	0.2046	0.1867	0.1837
Pollution control index	2016	2017	2018	2019	2020	2021	2022
Yunnan	0.1411	0.2385	0.1880	0.0919	0.1466	0.1513	0.1431
Guizhou	0.2077	0.1308	0.3133	0.2046	0.1192	0.0782	0.1461

Chongqing	0.1715	0.1588	0.1392	0.2457	0.3065	0.3757	0.2857
Sichuan	0.1161	0.1457	0.0883	0.0749	0.0453	0.0156	0.0000
Economy and society index	2016	2017	2018	2019	2020	2021	2022
Yunnan	0.0329	0.0250	0.0227	0.0114	0.0105	0.0114	0.0162
Guizhou	0.2630	0.2186	0.1520	0.1315	0.1284	0.0784	0.0958
Chongqing	0.0997	0.1689	0.1686	0.2142	0.2050	0.2222	0.3765
Sichuan	0.2500	0.2332	0.2585	0.3199	0.3425	0.2946	0.2224

The comprehensive indexes for the green development of new energy vehicles in Chongqing and Yunnan, Guizhou and Sichuan are presented below.

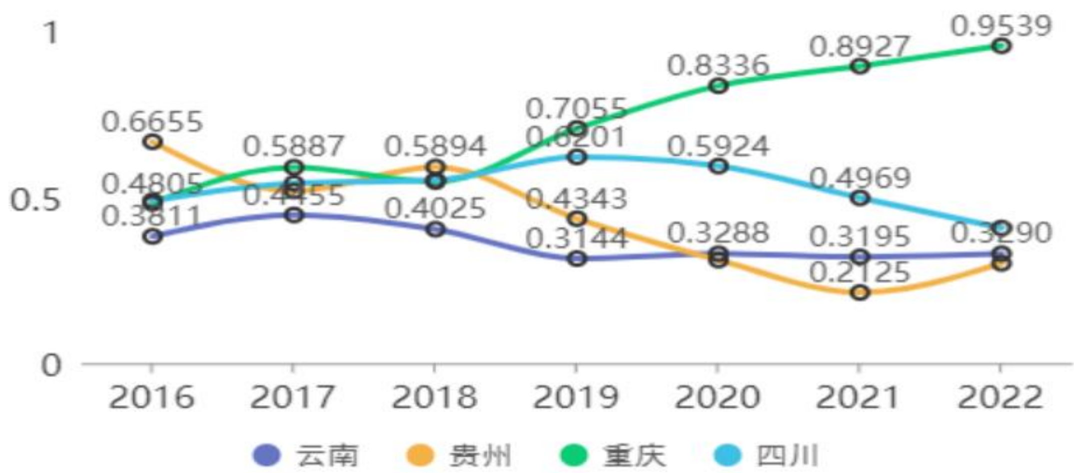

Figure 1. Comprehensive index change trend of the green development of new energy vehicles in southwest China

Table 10 and Figure 1 indicate that in terms of overall level the overall level of green development indexes for new energy vehicles in southwest China varied much from 2016 to 2022. Comparatively, as Chongqing is an important auto-producing base in China, its new energy vehicle industry was much better developed than that in Yunnan, Guizhou and Sichuan; the overall level of the green development indexes of new energy vehicle industry in Chongqing moved upward from 2016 to 2022.Although the city's comprehensive index of green development of new energy vehicles was lower by 0.185 than that of Guizhou in 2016 and even lower by 0.0078 than that of Sichuan, after 6 years' development, by 2022 the city's comprehensive index of green development of new energy vehicle industry surpassed that of Guizhou and Sichuan—0.6538 higher than that of Guizhou and 0.5478 higher than that of Sichuan. From 2016 to 2022 the comprehensive index of green development of Sichuan's new energy vehicles generally moved upward except for one or two years (lowered by 0.0955 from 2020 to 2021, and by 0.0908 from 2021 to 2022).

The analysis of level-2 indexes indicates that according to the comprehensive resource use index in Table 3.9, we were able to draw a change trend figure for the comprehensive resource use index of new energy vehicles in southwest China as in Figure 2.

Figure 2. Change trend for the comprehensive resource use index of new energy vehicles in southwest China.

The analysis of change trend of the comprehensive resource use index indicates that this index went upward generally in Sichuan. The change curve of this index for Chongqing lies above the other three provinces, meaning that from 2016 to 2022 the city's index of comprehensive use of new energy vehicles was higher than that of the other three provinces and showed an overall rising trend. In 2016 this index for Chongqing was higher by 0.087 than that for Sichuan, the province with the lowest rate that year; in 2022 this index for Chongqing was higher by 0.1079 than that for Sichuan and by 0.2334 than that for Guizhou, the province with the lowest rate that year and hence the discrepancy kept widening.

According to the pollution control indexes of Table 10 we drew a change trend figure for the pollution control indexes in Chongqing and 3 other provinces, as in Figure 3.

Figure 3. Change trend for the pollution control indexes of new energy vehicles in southwest China.

The combination of Table 11 and Figure 3 indicates that from 2016 to 2022 the city's pollution control index dropped slightly in 2017 and 2018 (0.0127 and 0.0323 respectively) but generally it was increased by 0.1142 or 66.59%. This index for Guizhou fluctuated most, changing from 0.2077 in 2016 to 0.1461 in 2022, a decline of 29.66%. In 2016 this index for Chongqing City was higher by 0.0554 than that for Sichuan, and by 2022 it reached 0.2857; hence, the discrepancy was bigger.

According to the economy and society index of Table3.10 we drew a change trend figure for the economy and society index in Chongqing and three other provinces as in Figure 4.

Figure 4. Change trend for the economy and society index of new energy vehicles in southwest China.

Figure 4 and Table 5 indicate that the change trend for southwest China's economy and society index varied in a dynamic way. From 2016 to 2022 Chongqing's economy and society index for new energy vehicles went up evidently: from 0.0997 in 2016 to 0.3765 in 2022, an increase of 277.63%. From 2016 to 2022 this index for Sichuan, except for one or two years when it dropped somehow, went up generally: from 0.2500 in 2016 to the peak value of 0.3425 in 2020, an increase of 37%; after 2020 it started to drop: by 2022 it was lowered to 0.222 mostly because of the Covid-19 pandemic and the 30% decrease of subsidies to the purchase of new energy vehicles in 2022 as over 2021. The economy and society index for Yunnan went down, a decrease of 50.76% in 2022 as over 2021; that for Guizhou went down even further, from 0.2630 in 2021 to 0.0958 in 2022, a decrease of 63.58%.

4 Conclusions and Countermeasures

4.1 Research Conclusions

This dissertation constructed the index evaluation systems and analysis framework for the green level of Chongqing City's new energy vehicle industry development, and proposed some measures and ways for the development of the city's new energy vehicle industry.

The main research conclusions are rendered below.

The first job is that we constructed the index systems and analysis framework for the green development level of new energy vehicle industry. The evaluation index systems consist of 1 level-e index (comprehensive index for the green development of new energy vehicle industry), 3 level-2 indexes (comprehensive resource use, pollution control, and economy and society), and 10 level-3 indexes.

The second job is that we constructed the analysis framework for the evaluation of the green development level of Chongqing City's new energy vehicle industry. From four dimensions, namely, comprehensive index, comprehensive resource use index, pollution control index, and economy and society index, by means of comparative research and Matlab software we fully evaluated and studies the discrepancies and change trends of the green development level regarding the new energy vehicle industry from 2016 to 2022 in Chongqing City, Yunnan Province, Guizhou Province and Sichuan Province, and drew the major conclusions as presented below.

First, the city's green development of new energy vehicle industry moved upward. The "economy and society" index made the greatest contribution to the city's green development level of new energy vehicle industry; the "pollution control" index made a relatively big contribution to the city's green development level of new energy vehicle industry. Comparatively speaking, the "comprehensive resource use" index made the smallest contribution to the green development of the city's new energy vehicle industry and should be further studied and strengthened.

Second, the overall level of green development for new energy vehicles in southwest China varied much from 2016 to 2022. Comparatively, the green development level of Chongqing's new energy vehicle industry was much higher than that of the other three provinces: it moved upward from 2016 to 2022. The green development of Yunnan and Guizhou' new energy vehicles went down overall, particularly evidently in Guizhou; the green development of Sichuan's new energy vehicles went upward smoothly though not greatly.

Third, we found that in terms of level-2 index contribution to the green development level of new energy vehicles, the level-2 index contribution varied from province to province in a dynamic way. The comprehensive resource use index made the smallest contribution in Chongqing regarding the three level-2 indexes, only 17.39%; it also made the smallest contribution in Sichuan, -74.82%; it made the biggest contribution in Yunnan, accounting for 71.98%; it was ranked No.2 in Guizhou following the economy and society index, accounting for 37.38%. The pollution control index contribution was ranked No.2 in Chongqing; it made the biggest contribution in Sichuan, 141.24%; it made the smallest contribution in Yunnan, -3.84%; it made the smallest contribution in Guizhou, 16.86%. The economy and society index made a 58.48% contribution in Chongqing (the biggest contribution), and a 45.76% contribution in Guizhou (the biggest contribution); it made a 32.05% contribution in Yunnan and a 33.58% contribution in Sichuan (ranked No.2).

Fourth, from the angle of level-2 index change trend analysis concerning the comprehensive resource use index, the index change curve went upward overall in Chongqing City, meaning that from 2016 to 2022 the comprehensive use index for the city's new energy vehicle industry was higher than that of the other 3 provinces, showing that its new energy vehicle industry took the lead in comprehensive resource use in southwest China; this index went upward generally in Sichuan despite relatively smooth; this index had some fluctuations in Yunnan, but overall it went downward; this index went downward evidently in Guizhou.

Fifth, from the analysis of pollution control index change trend, it was found that this index, despite slight fluctuations, went upward in Chongqing and became strong; this index fluctuated most in Guizhou, with big ups and downs, but generally it went downward; this index went up slightly in Sichuan, but then it went down all the way; this index first went upward from 2016 to 2017, and then went downward from 2017 to 2019, but from 2019 to 2022 it went up smoothly.

Sixth, from the analysis of economy and society index change trend, it was found that Chongqing's economy and society index regarding the new energy vehicle industry went upward evidently, indicating that in the process of developing new energy vehicles much attention was paid to the leading role of this index for the green development level of new energy vehicle industry; this index fluctuated slightly in Sichuan, but generally it went upward, and meanwhile from 2016 to 2021 this index of Sichuan was above Chongqing, indicating that the development level of this index was higher than that of Chongqing; this index went down sharply in Guizhou; this index went down smoothly in Yunnan.

4.2 Countermeasures

Auto making is a pillar industry in Chongqing. Chongqing City is an important town of vehicle industry in China, where the foundation for development of new energy vehicle industry is strong and the space for industry transformation and upgrading is vast. The following are some suggestions for the improvement of the city's new energy vehicle industry development.

4.2.1 Improving industry development policies and creating a benign investment and financing environment

(1) To scientifically formulate the negative lists for the access of new energy vehicles and relevant industries. It is necessary to consider the construction of evaluation systems and effectively distinguish whether the new energy vehicle industry can have access from the angles of environmental impact, resource consumption, pollution control and economic and social contributions. Those industries affecting much negatively the resource environment, receiving much opposition from citizens, producing little favorable eco-environmental effects and exerting slight if any economic contributions and social benefits should be banned from entering the access list.

(2) To improve the support of relevant systems and policies. The double pressure of economic development and ecological protection may exist in some regions, where the new energy vehicle industry's access could run into trouble regarding the negative list. Hence, it is important to establish an all-watershed eco-compensation mechanism so as to ensure the west China regions can have the industry's eco-compensations from the benefit-receiving regions, and if necessary the Central Government can provide relevant fiscal resources or subsidies.

(3) To set foot on the objective proposed in Chongqing City's 14th Five-year Plan—"focusing on high-end, smart, and new energy directions, keeping observing the new directions of software-defined vehicles, chip-making vehicles and data-developing vehicles, and constructing an advanced industry ecology nationwide". The policies for the improvement of the city's industry development should be set and the policy advantages should be made use of to pool all vehicle corporations and investors together for access to the city's new energy vehicle production and sales.

4.2.2 Focusing on talent usher-in and cultivation and strengthening innovation chains for the new energy vehicle industry

(1) To make up for the shortcoming of talents. Talent is the first driving force of innovation. It is necessary to optimize the talent-gathering and incentive mechanism, and increase the usher-in of high-end and backbone talents. It is encouraged to open new energy and intelligently-connected vehicle majors in the city's universities. When it comes to ushering in talents, it is suggested to rely on the "Project of Top Talents", focusing on the recruitment and nurturing of compound talents and strategic industry development talents in the fields of intelligent connection technology, software technology, vehicle + IT + communications, and vehicle sales. Matching support policies should be issued and implemented, involving home-making subsidies, employment assistance, staff registration management, children's schooling, spouses' transfer, medical security, and self-employment incentives.

(2) To explore the establishment of multi-party cooperative research and development bases between universities, R & D institutes, the government and key corporations and spread the model "elite talent class of intelligently-connected vehicles". First, the government, leading corporations, research institutes, and upper and lower reach corporations should form a "4 parties in unity" liaison mechanism (that is, the government is responsible for organization and coordination, the leading corporations take the initiative, the research institutes push ahead the action, and the upper and lower reach corporations interact with each other) and a combined innovative entity, aiming at further developing the eco-systems for smart new energy corporations and setting up broader application scenarios. Second, efforts should be made to erect a platform for production, education, research and application, aiming at constructing key labs on new energy whole-vehicle making, key parts and key materials and combining the power of leading corporations and innovation centers for cooperative R & D breakthroughs in core technologies and industrialized application. Third, it is important to have national intelligently-connected new energy vehicle R & D platforms and the leading corporations' R & D centers land in Chongqing, and expedite the development of innovative center for intelligently-connected vehicles in Western Science City. Fourth, it is necessary to guide the cooperation between new energy vehicles and energy, transport, information and communications, big data, and artificial intelligence and integrated their innovation.

(3) To actively create an innovation height and optimize the ecological chains. First, it is necessary to strengthen the eco-oriented corporations. Focusing on such fields as new energy whole-vehicle making, power battery and charging facilities, we should support the leading corporations like Chang'an Auto and BYD in developing innovative eco-industry chains centering on R & D, production and services. Second, we should nurture specific types of leading corporations. Efforts should be made to make up the shortcomings regarding core basic parts and components and software, and cultivate a number of innovative, quality-rated, efficient new corporations engaging in particular, precise and special manufacturing. Third, we should usher in high-end new energy vehicle brands and work at improving the penetration rate of new energy commercial vehicles. While making crucial parts like power battery, electric motor and chips, we should fix our attention at famous corporations, ushering them in collectively and prioritized, making up for the shortcoming of core, key parts-matching industry chains and supply chains. We should recruit such corporations as Huawei, Baidu, iFLYTEK and Horizon Robotics for setting up R & D centers in Chongqing in order to increase the localization rate of vehicle software. Fourth, we should enhance the cooperation of the Chengdu and Chongqing urban

economic belt, and promote business and investment of big projects and strengthen the whole-industry chains of new energy vehicles by means of Sichuan's advantages in new materials, power battery, electronic information and software, intelligently-connected vehicle testing and monitoring platforms, and information security; in Western (Chongqing) Science Town, Yongchuan and Bishan we should plan diversely and concentrated a new matching town for intelligently-connected vehicle functions, working at vehicle R & D, manufacturing and application bases; we should expedite the collective group development of hydrogen energy vehicle industry. Fifth, we should speed up the construction of charging and hydrogen-filling infrastructure facilities; it is important to establish and improve the financial services, after-sales services, second-hand transactions, power battery evaluation and testing, tier-based use, and dismantling and recycling for new energy vehicles.

(4) To take self-made brands as the hand-hold and improve then industry value chains. First, we should expand the brand influence and work harder at cultivating a number of core parts-making corporations and whole-vehicle corporations in leading the industry development and building a batch of entirely-digitalized, flexible production bases. Second, we should support core corporations to lead or participate in the national or local standard formulation and improvement concerning intelligently-connected new energy vehicles, particularly the core, significant directions like communication protocol, cloud big data, smart control, and whole-vehicle operation system. Third, we should support Chang'an Auto, Chang'an Ford and Seres in improving their brand influence, setting up their leading technological image, expanding the application scenarios of meta-universe industry in intelligently-connected new energy vehicles, involving VR, AR, MR, AI, block chain, internet of things technology, and changing the industry image.

4.2.3 Innovating the policies and environment and keeping optimizing the development ecology of new energy vehicle industry

(1) To strengthen the support of various policies. First, we should be innovative in our financial support policies. It is necessary to construct a diversified investment and financing system, and focus on support for the business and investment of new energy industry, the industrialization of big R & D project achievements, and the innovation of business model. We should make good use of policy-based financing and funds for the support to new energy corporations, and apply for special loans like "hundreds of chain and corporations" and "particular, precise, special and new"; in industrial parks we can lower the purchase costs and financing costs for the industry chain corporations through such business models as entrusted construction and purchase, increase investment in marts-making corporations, and facilitate the sustainable development of new energy corporation chain. Second, we should actively obtain the municipality-level and district-level financial subsidy support policies. In addition to electric vehicles, at present the national and city government support the development of hydrogen new energy vehicles, but the producing cost of new energy vehicles is relatively high, and there are difficulties regarding hydrogen-making, hydrogen transport and hydrogen-filling. Vehicle corporations, regardless of Shanghai Auto Group, Great Wall Auto, Beijing Auto Group, or Qingling Auto, normally start from commercial vehicles; they need large amounts of fiscal subsidies and their self-replenishing ability is poor, and thus we suggest maintaining fiscal subsidies for support and promoting the stable development of new energy corporations and industry. Third, we should implement the city's support policies and render such aids to new energy vehicles as free or reduced-charge parking, convenient go-though and lowering of electric charging expenses.

(2) To develop matching infrastructure facilities for support to the industry. Based on the new energy vehicle infrastructure construction available, while not increasing the government's debts, we should, by means of social investment and marketization, appropriately advance the infrastructure construction, innovate smart highway construction, optimize the intelligent information layout of new energy vehicles, establish and improve service systems like charging and power battery recycling, keep enhancing service ability, and promote the upgrading of new energy vehicle whole-industry value chains.

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