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Research on the Comprehensive Development Index of the New Energy Vehicle Market Based on Principal Component Analysis

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Abstract: The rapid development of the new energy vehicle industry highlights its strategic value for economic and energy transformation, but existing research lacks systematic quantitative tools to assess market health. This paper proposes the New Energy Vehicle Market Development Index (NEVMDI), which integrates three dimensions—government policy, corporate innovation, and consumer demand—and uses principal component analysis to construct a dynamic assessment system to quantify the development level of China's new energy vehicle market from 2017 to 2024. The results show that the NEVMDI index increased from -2.33 to 3.74, with 2021 marking a critical turning point, reflecting the market's transition from policy dependence to market-driven growth. Policy precision, technological iteration, and demand segmentation are the core drivers of the index's improvement, while regional imbalances and infrastructure bottlenecks remain the primary constraints. This study provides a scientific tool for assessing market health and offers data support for policy optimization and industrial upgrading.

Keywords: New Energy Vehicle Market, Comprehensive Development Index, Principal Component Analysis, Market Health.

1. Introduction

The new energy vehicle industry, as a core pillar for China to achieve its carbon neutrality goals and high-quality economic development, has demonstrated strong economic driving effects. By 2024, the market penetration rate is expected to reach 47.8%, with significant growth in industrial added value in some regions[1]. Existing research suffers from three key shortcomings: 1) Limited research dimensions, with studies primarily focusing on policy[2], technology[3], or consumer behavior[4], lacking quantitative tools to integrate the synergistic effects of these three areas; 2) Lack of a systematic quantitative framework, such as scholars primarily conducting qualitative analyses of charging infrastructure differences[5]; 3) Insufficient analysis of market dynamics and inflection points. This study addresses these shortcomings by constructing the New Energy Vehicle Market Development Index (NEVMDI), integrating government, enterprise, and consumer dimensions, and employing Principal Component Analysis (PCA) to quantify market health from 2017 to 2024. Research objectives include: constructing a scientific NEVMDI indicator system, quantifying market development trajectories, analyzing the causes of the 2021 turning point and policy impacts, and providing data support for policy optimization and industrial upgrading.

This paper constructs the New Energy Vehicle Market Comprehensive Development Index (NEVMDI), integrating data from three dimensions: government, enterprises, and consumers. Using principal component analysis, it dynamically assesses market health to reveal market evolution patterns and provide a basis for policy design. Research objectives include: establishing a scientifically reasonable NEVMDI indicator system, quantifying the market development trajectory from 2017 to 2024, and analyzing driving factors and policy implications[2].

2. Construction of a Comprehensive Development Index for the New Energy Vehicle Market

2.1. Selection of indicator factors

The government is the core driving force behind the development of the new energy vehicle market. Through subsidies, regulations, and infrastructure planning, the government directly shapes the market foundation. China's "double credit" policy and dynamic adjustments to fiscal subsidies directly influence corporate R&D directions and market supply structures. Infrastructure coverage improves market penetration by reducing user costs, significantly alleviating "range anxiety." Local policies activate emerging markets through regionally differentiated designs, achieving significant regional industrial value-added growth. The government dimension serves as the foundational support for the market's transition from "policy-driven" to "market-driven," with its metric selection directly impacting the quantitative assessment of policy effectiveness and the design of optimization pathways[3].

Corporate innovation is the core of market supply capacity, with technological innovation and supply chain management determining product competitiveness and industrial security levels. Technical indicators such as battery energy density and intelligent driving penetration rates reflect product iteration speed; leading companies form a "Matthew effect" through technological barriers and economies of scale, while emerging brands continuously disrupt the market with differentiated positioning. Corporate cost control and global expansion directly impact profitability quality. Therefore, the corporate dimension reveals the dynamic evolution path of the market supply structure.

Consumer demand is the ultimate driver of market structure optimization, with user behavior and experience feedback determining demand segmentation and market expansion

boundaries. Price sensitivity and regional penetration differences reflect the spatio-temporal distribution characteristics of demand, with the rise of low-price markets complementing high-net-worth users' preference for “high-price vehicle purchases.” User satisfaction and negative feedback quantify the constraints on market expansion posed by infrastructure imbalances and winter range degradation. The consumer dimension balances demand segmentation and experience feedback, representing the underlying logic of the market's transition from “policy-driven” to “demand-driven.”

Therefore, the cross-validation of indicators across the three dimensions of government, enterprises, and consumers forms the “iron triangle” of NEV market development: policy support builds the market foundation, enterprise innovation provides supply momentum, and consumer choices determine structural optimization. This paper will construct the NEVMDI comprehensive evaluation index from these three aspects.

2.2. Collection of indicator data

This paper is based on market policy, industry, and consumption data for new energy vehicles from 2017 to 2024. It constructs a NEVMDI index system comprising three dimensions: government, enterprise, and consumer. Table 1 shows the data sources for this section.

Table 1 Data sources

Data Type	Data sources
Production Volume (10,000 units)	China Association of Automobile Manufacturers (CAAM), National Bureau of Statistics
Sales Volume (10,000 units)	China Association of Automobile Manufacturers (CAAM), China Passenger Car Association (CPCA)
Number of Public Charging Stations(piece)	China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA), National Energy Administration
Number of Shared Private Charging Stations(piece)	Local government reports, third-party platforms (Star Charge, Teli)
Number of Battery Swapping Stations(piece)	Automaker financial reports, China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA)
Subsidy Amount (100 million yuan)	Ministry of Finance, Ministry of Industry and Information Technology (MIIT)
Number of Subsidies (10,000 units)	Ministry of Industry and Information Technology (MIIT)
Penetration Rate (Percentage)	China Association of Automobile Manufacturers (CAAM), China Passenger Car Association (CPCA)

2.3. Data Feature Analysis

2.3.1. Time Series Analysis of New Energy Vehicle Sales

Consumer behavior analysis is a core component of new energy vehicle market research, with its importance manifesting in two key areas: first, consumer choices directly influence market demand structure and market expansion boundaries. For instance, changes in price sensitivity, brand preferences, and product functionality requirements directly impact corporate R&D directions and government subsidy strategies; Second, consumer behavior data serves as a critical indicator for assessing market maturity and predicting future trends, such as penetration rate segmentation, regional differences, and consumption upgrade trends, providing empirical evidence for supply chain optimization and infrastructure planning.

This paper uses Python as a data analysis tool to conduct consumer behavior research through a systematic process: first, multi-source data (including sales volume, price, and manufacturer information) from 2017 to 2024 is cleaned and standardized, with outliers removed and data formats unified; second, time series analysis is used to track the evolution of price range distribution, brand market share, and vehicle model demand structure; finally, visualization technology is combined to intuitively present changes in consumer preferences. The entire analysis process is data-driven, ensuring the objectivity and interpretability of conclusions, and providing scientific basis for market strategy optimization and policy design. The specific analysis results are as follows.

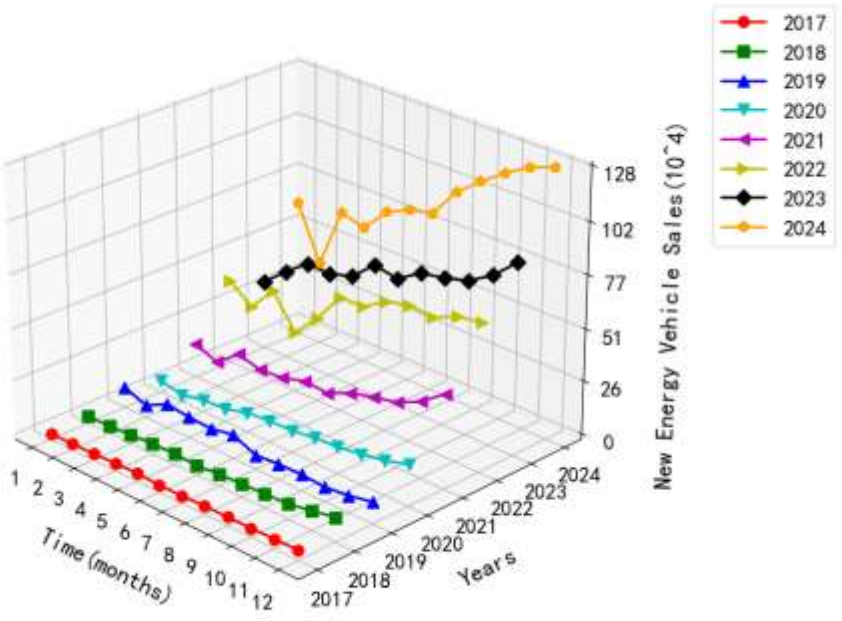


Figure 1: Three-dimensional trend chart of new energy vehicle sales from 2017 to 2024

As shown in Figure 1, consumer behavior trends from 2017 to 2024 indicate that sales volumes remained relatively stable and at a low level during the early period (2017-2018). However, volatility intensified starting in 2019, with sales volumes temporarily declining in 2020-2021 due to external shocks such as the pandemic. A turning point occurred in 2022, with market demand beginning to recover steadily, leading to explosive growth in 2023-2024. In particular, consumption in 2024 far exceeded previous peaks, confirming the significant recovery of market confidence and demand. This time-series change not only reflects the recovery of the economic environment and the effects of policy stimulus but also highlights the shift in consumer preferences from caution to optimism. Driven by improvements in technological maturity and increased product diversity, the market has entered a phase of high-speed growth.

2.3.2. Comparison and analysis of annual sales of new energy vehicles by different manufacturers

From 2017 to 2024, the new energy vehicle market has shown a significant growth trend, with BYD and Tesla China standing out in terms of sales performance: BYD has established its market dominance with sales of 3.039 million vehicles in 2024, far surpassing other manufacturers; Tesla China has grown from 458,000 vehicles in 2021 to 657,000 vehicles in 2024, with a stable annual growth rate. In contrast, early-leading companies such as SAIC-GM-Wuling and Geely New Energy have seen their market shares gradually shrink due to competitive pressure, while emerging brands like Li Auto and GAC Aion have rapidly risen to prominence by leveraging technological advantages or market positioning. This has created a competitive landscape where "leading companies maintain their dominance while emerging brands accelerate their catch-up efforts," with the overall industry characterized by both increasing concentration and dynamic competition.

Consumer behavior exhibits the following characteristics: In the early years (2017-2019), consumers preferred domestic traditional automakers (such as BYD, SAIC Group, and BAIC New Energy) and favored economical models; After 2020, with the surge in low-cost models like the Wuling Hongguang MINI EV, consumer demand for cost-effectiveness and short-distance commuting significantly increased; Starting in 2021, Tesla's sales in China surged, indicating a preference for brand technical capabilities and international image in the high-end market; after 2022, BYD became the mainstream choice through its full-industry-chain layout and expansion of its model portfolio, reflecting consumers' emphasis on reliable supply chains and diverse product combinations; simultaneously, brands like Li Auto and GAC Aion have captured niche markets through extended-range technology or differentiated positioning, indicating growing consumer demand for technological innovation and personalized options. Overall, consumers have shifted from early scattered choices to concentrated support for leading brands, while continuing to focus on technological innovation and cost-effectiveness balance, driving the market toward a "technology-driven + brand concentration" direction. Relevant visualizations are shown in Figure 2.

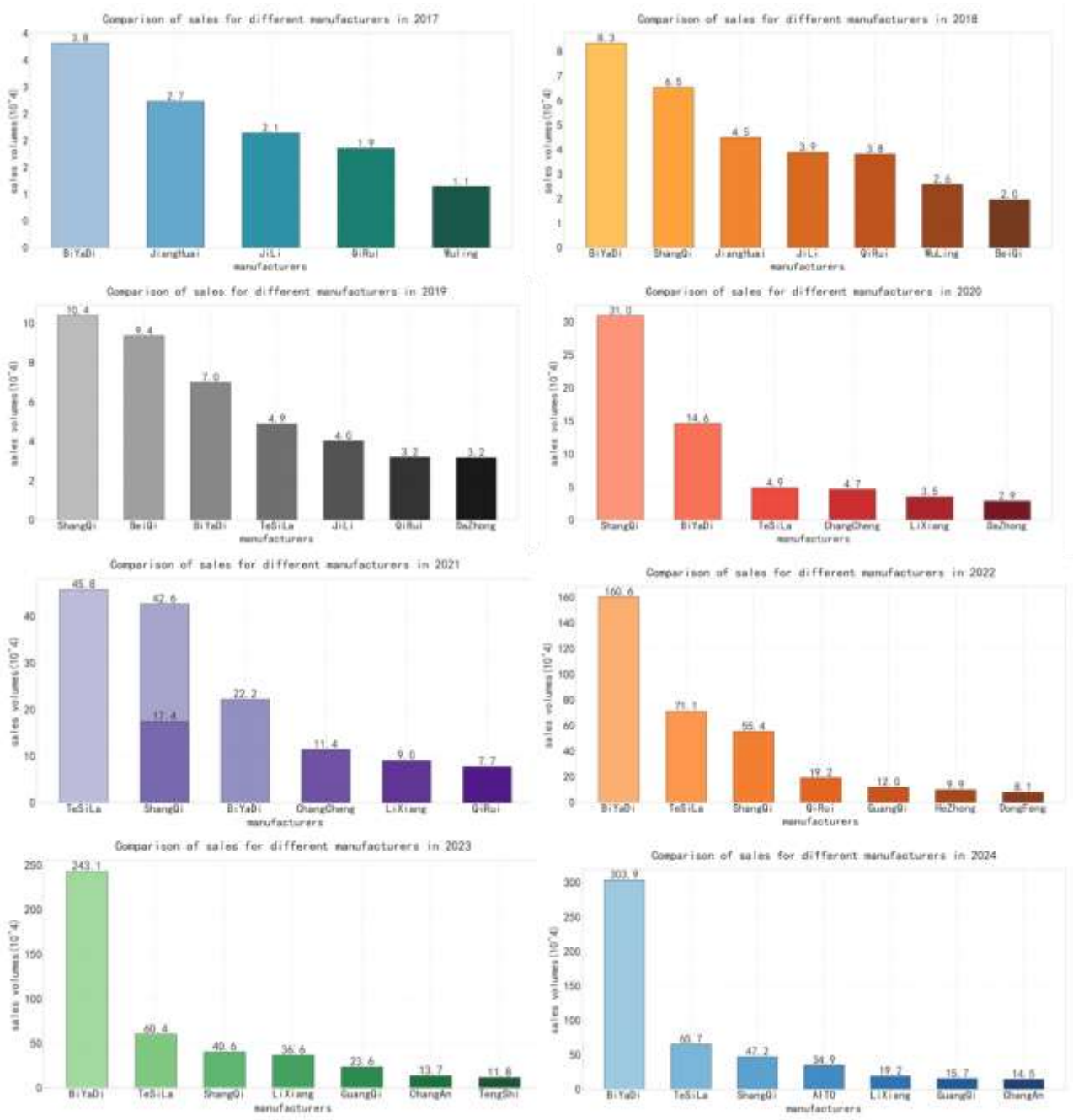


Figure 2 Comparison of sales figures for new energy vehicle manufacturers from 2017 to 2024

At the same time, based on time series analysis of sales volumes from different manufacturers, this paper obtained the brand concentration for each year from 2017 to 2024. Brand concentration is defined as an indicator of the degree of market share concentration of leading companies in a specific market, and is usually quantified by calculating the proportion of sales of the top three manufacturers in the total market sales, i.e., CR_3. The formula is:

$$CR_3 = \frac{\sum Top\ three\ manufacturers\ by\ sales\ volume}{\sum total\ market\ sales} \quad (1)$$

2.3.3. Time Series Analysis of Price Acceptance for New Energy Vehicles

In price segmentation analysis, this paper introduces the PSI index (Price Segmentation Index) as a core indicator for measuring the degree of market premiumization. Its essence lies in quantifying the market penetration rate of high-priced vehicles (>200,000 CNY) in a specific year. This index reflects consumers' willingness to pay for premium products and the evolving trends in market structure through systematic price interval segmentation and sales share calculations. First, based on price sensitivity and actual market distribution characteristics, vehicle prices are divided into four groups: low-priced (<50,000 yuan), mid-low priced (50,000–100,000 yuan), mid-high priced (100,000–200,000 yuan), and high-priced (>200,000 yuan). Next, for the target year's sales data, the annual total sales volume of all vehicle

models is calculated, and the total sales volume of models within the "high-priced (>200,000 yuan)" price range is calculated separately. Through the formula:

$$PSI = \frac{Total\ sales\ in\ the\ high\ price\ range}{total\ market\ sales} \quad (2)$$

Convert the sales share of high-priced models into a percentage to form the PSI index. This index tracks time series data and clearly reveals the dynamic changes in market structure from "low-price dominance" to "high-end upgrading," providing quantitative evidence for the market. Table 2 shows the PSI index calculation results for 2017-2024.

Table 2 Statistical Table of PSI Index for New Energy Vehicles from 2017 to 2024

year	PSI index
2017	0.3163
2018	0.3009
2019	0.2510
2020	0.3404
2021	0.4299
2022	0.3646
2023	0.3962
2024	0.3879

2.4. Determination of the comprehensive development index

This paper uses annual data from 10 indicators over an 8-year period from 2017 to 2024. Using Python software and principal component analysis, the first, second, and third principal components were selected based on their cumulative contribution rates to construct a comprehensive index for quantifying the health of the new energy vehicle market—the NEVMDI index.

The following is the specific calculation process and results:

First, this paper starts from three dimensions: government, enterprise, and consumer, and further selects 10 indicators based on these three dimensions, as shown in the table 3.

Table 3 Factors and meanings of the comprehensive index for the new energy vehicle market

factor symbol	Factor Name
x_1	New Energy Vehicle Production (10,000 units)
x_2	Sales (10,000 units)
x_3	Number of Public Charging Stations (nationwide)
x_4	Number of Shared Private Charging Stations(piece)
x_5	Number of Battery Swapping Stations(piece)
x_6	Subsidy Amount (100 million yuan)
x_7	Number of Subsidies (10,000 units)
x_8	Penetration Rate (%)
x_9	PSI (percentage of high-priced vehicle purchases)
x_{10}	CR_3 (brand concentration)

Subsequently, this paper standardizes the data and performs principal component analysis. According to the calculation results, the cumulative contribution rate of the first three principal components reached 92.86%, as shown in the table 4, indicating that the first three principal component indicators can effectively cover the core information of the original 10 indicators. Therefore, these three principal components were selected for subsequent analysis.

Table 4 Contribution rate of principal components

principal component	variance contribution ratio （%）	Cumulative contribution rate （%）
f_1	74.13%	74.13%
f_2	12.80%	86.94%
f_3	5.92%	92.86%
f_4	4.43%	97.29%
f_5	2.35%	99.64%
f_6	0.34%	99.99%
f_7	0.01%	100.00%
f_8	0.00%	100.00%

Subsequently, the linear relationship between each principal component and the original variables was determined through the principal component loading matrix. The loading coefficients reflect the direction of contribution of the original variables to the principal components.

The index retains the core information of the original data while achieving dimension reduction by integrating the top three principal components with weighting, providing a reliable quantitative basis for comprehensive assessment of the new energy vehicle market. The quantitative results for 2017–2024 are shown in Table 5.

Table 5 NEVMDI quantification results

year	NEVMDI value
2017	-2.3346
2018	-1.8824
2019	-1.6866
2020	-1.1021
2021	0.1918
2022	0.8386
2023	2.2323
2024	3.7429

From 2017 to 2024, the NEVMDI index showed a continuous upward trend, growing from -2.33 to 3.74, with a significant average annual increase after 2021. 2021 was a critical turning point, as the index turned positive for the first time, and the growth rate accelerated thereafter, reaching a

peak of 3.74 in 2024, indicating a leap in the overall development level of the new energy vehicle market.The reasons for this turning point are as follows: First, policy support has become more targeted. In 2021, the national government introduced a long-term development plan to stabilize market expectations, while also optimizing the “double credit policy” to incentivize companies to increase R&D investment. Second, significant technological advancements have led to a substantial reduction in the cost of lithium iron phosphate batteries, driving the popularity of low-cost models; the adoption rate of intelligent driving technology has also increased, making high-end models more attractive. Third, consumer demand has diversified, with low-cost models meeting commuting needs and high-end models gaining favor among the middle class. The PSI index rose from 0.3404 to 0.4299, reflecting the market's trend toward premiumization. Finally, external factors have provided support, as post-pandemic economic recovery has unleashed consumer potential, and the rapid growth in charging station numbers has alleviated “range anxiety.” The synergistic effects of policy, technology, demand, and external factors have collectively driven 2021 to become a milestone in market development, accelerating the structural transformation of the new energy vehicle industry.

3. Conclusions

This paper systematically assesses the health and development level of China's new energy vehicle market from 2017 to 2024 by constructing a comprehensive new energy vehicle market development index (NEVMDI), providing a scientific tool for industrial research in the context of economic and energy transformation. The NEVMDI index integrates three dimensions: government policies, corporate innovation, and consumer demand. It employs principal component analysis (PCA) to extract key factors and determine their weights, enabling dynamic quantification of multi-dimensional data. The research findings show that the NEVMDI index rose from -2.33 in 2017 to 3.74 in 2024, with 2021 marking a critical turning point, signifying the market's transition from policy-dependent to market-driven growth. Policy precision, technological iteration speed, and demand segmentation are the core drivers of the index's improvement, while regional development imbalances and infrastructure bottlenecks remain the primary constraints. The NEVMDI index not only reveals the evolutionary patterns of the market but also provides data support for policy optimization, industrial upgrading, and market strategies, contributing theoretical and practical value to the sustainable development of the new energy vehicle industry.

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