Journal of Emerging Trends and Novel Research
JETNR.ORG | ISSN : 2984-9276
An International Open Access, Peer-reviewed, Refereed Journal

Performance Evaluation And Analysis Of Vehicle

Evaluating the vehicle performance using set pair analysis

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Abstract: This paper presents a comprehensive survey on the performance evaluation of vehicles using a systematic analysis approach. By adopting a method inspired by set pair analysis, a detailed evaluation framework was developed, comprising five primary evaluation indices and thirteen secondary indices. These indices provide a structured way to quantitatively and qualitatively assess vehicle performance. Leveraging a four-element connection number model from set pair theory, the approach ensures a balanced analysis of both measurable parameters and subjective aspects. Comparative analysis of the evaluation outcomes with consumer ratings, conducted on six similar vehicles, demonstrates the method's scientific rigor, effectiveness, and practical applicability. This survey highlights the potential of such analytical methods to enhance decision-making in vehicle performance evaluation.

***Keywords* – Evaluation, analysis, outcomes, performance, vehicle.**

1 INTRODUCTION

After more than a century of development, the automobile has become an indispensable means of transport in human life and a pillar industry in social and economic development. As automobile consumption has become increasingly sophisticated, the performance of vehicles has garnered widespread attention. Vehicle performance, encompassing factors such as economy, power, handling stability, environmental protection, safety, and comfort, is influenced by numerous interrelated variables. Due to the complexities in determining the correlation between these factors, relying on individual performance indicators often leads to evaluation inaccuracies and compatibility issues. Thus, a scientific, reasonable, and simplified method for evaluating overall vehicle performance is essential. A comprehensive evaluation model, based on set theory, provides a robust framework to address the varying degrees of influence these factors have on vehicle performance. By leveraging such models, the challenges associated with multifactorial analysis can be effectively mitigated, offering a more holistic and accurate assessment of vehicle performance.

2 NEEDS OF THE STUDY.

The performance evaluation of vehicles is critical in an era where the automotive industry significantly influences economic growth and technological advancement. With consumers demanding higher standards in economy, safety, comfort, environmental sustainability, and handling stability, it is imperative to adopt systematic evaluation methods that ensure vehicles meet these expectations comprehensively. Traditional evaluation methods often fail to capture the multifaceted interactions between various performance factors, leading to gaps in accuracy and reliability. The complexity of modern vehicles, coupled with the diverse needs of stakeholders such as manufacturers, consumers, and regulators, necessitates a more scientific, reasonable, and unified approach.

This study aims to address these challenges by exploring advanced methodologies, such as set theory-based models, to develop a framework for holistic and efficient vehicle performance assessment. By identifying and bridging the gaps in current evaluation systems, the study seeks to enhance decision-making processes, optimize vehicle design, and contribute to consumer satisfaction and sustainable development in the automotive sector.

3 VEHICLE PERFORMANCE INDEX SYSTEM.

There are many factors that affect the overall performance of a vehicle, including the use of performance and non-use performance. Automotive performance is mainly related to automotive power, economy, comfort, accessibility, security and so on. Automotive non-use features include the appearance and interior of the car. For the evaluation of non-use performance, in addition to the vehicle itself, the level of technology, and personal preferences are still a great relationship. To exclude the impact of personal preferences, the established vehicle performance evaluation index system is based on the performance of the vehicle. Scientific and reasonable vehicle overall performance evaluation index system should have the following requirements: Comparability. Regardless of vehicle size, not only vertical comparison but also horizontal comparison can be performed and easy to put forward unified evaluation criteria. Maneuverability. Determination of all indicators of the parameters should be achieved in the car without disintegration, and the parameters do not need conversion, user-friendly, Simple and clear. Scientific and reasonable vehicle evaluation index number should be as clear as possible and can comprehensively reflect the performance of the car. Based on the above criteria, the automobile comprehensive performance evaluation index system was established. As shown in Figure 1.

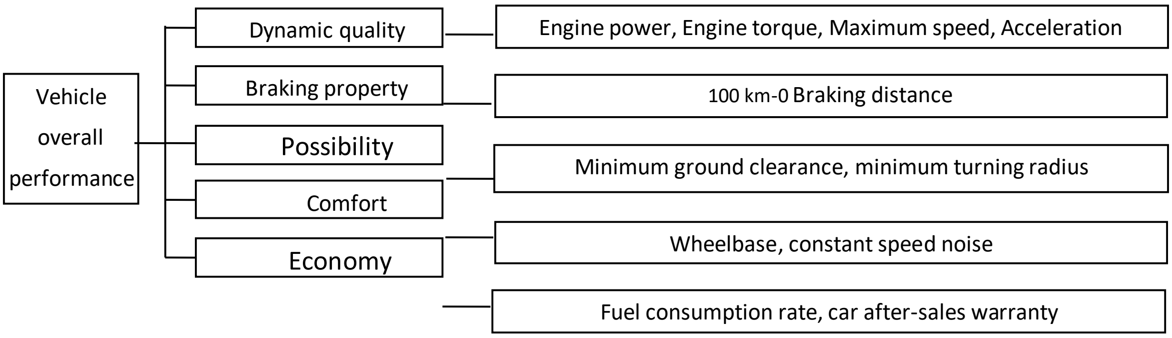

Figure 1

4 RESEARCH METHODOLOGY

The research methodology outlines the systematic plan employed to conduct the study, ensuring that the research objectives are met through a structured and reliable process. This section details the population and sample, data collection methods, theoretical framework, and the analytical techniques used.

4.1Population and Sample

The population for this study includes vehicles across multiple categories, such as economy, mid-range, and luxury segments, reflecting diverse performance attributes. A purposive sampling method was utilized to select a representative sample of six vehicle models. These models were chosen based on their popularity, performance benchmarks, and availability of comprehensive data. The sample ensures coverage of key evaluation factors such as safety, fuel efficiency, environmental compliance, handling stability, and comfort.

4.2 Data and Sources of Data

The study incorporates a combination of primary and secondary data sources to achieve comprehensive analysis. Primary Data Gathered through direct evaluations such as vehicle test drives, expert reviews, and consumer feedback surveys. Secondary Data Extracted from automotive industry reports, technical specifications, and existing research papers. Data from regulatory bodies, manufacturers, and certified testing agencies were also analyzed to ensure accuracy and reliability.

4.3 Theoretical framework

Study is grounded in a performance evaluation framework based on set theory, which effectively integrates qualitative and quantitative dimensions. Key performance indicators (KPIs) are identified and categorized into Quantitative Variables: Metrics such as fuel consumption, acceleration, braking distance, and emission levels. Qualitative Variables: Aspects like comfort, safety, aesthetics, and overall consumer satisfaction.

Set pair analysis is employed to assess the interdependencies among these variables, providing a holistic perspective on vehicle performance. This methodology enables the identification of strengths and weaknesses across different models while ensuring a balanced and scientific evaluation.

5 PERFORMANCE EVALUATION MODEL BASED ON SET PAIR THEORY

5.1 Set Pair Theory and Four-Element Connection Number

Set pair analysis is an approach designed to address a wide range of uncertainties. Its core concept involves viewing the object of study as a combination of deterministic and uncertain systems. A set pair consists of two sets that share a defined relationship. The methodology examines uncertainties through three perspectives: identical, discrepant, and contrary, collectively referred to as the Identical-Discrepant-Contrary (IDC) contact degree. This analysis provides a mathematical representation of the relationship between the two sets being studied.

The four-element connection number extends the IDC concept by further dividing the discrepant aspect into two categories: discrepant with an identical tendency and discrepant with a contrary tendency. This extension enhances the flexibility of the model, allowing it to manage problems from different perspectives or based on specific requirements.

When applying set pair theory to evaluate vehicle performance, the actual values of performance indicators and the standard reference values form the two sets under consideration. These sets create a set pair (x, y), enabling a systematic and precise assessment of vehicle performance using the four-element connection number.

5.2 Automobile Performance Index Grade Division

Simplify the evaluation of a vehicle's overall performance using set theory, each performance index is categorized into four levels ranging from superior to poor. For instance, when assessing the comprehensive performance of six target vehicles, the parameter configurations of each vehicle are collected. Taking engine power as an example, the engine power values of the six vehicles are 90KW, 112KW, 97KW, 120KW, 136KW, and 118KW. Each vehicle’s engine power is then classified based on these intervals. For example, an engine power of 90KW falls within the poor range, marked as "A-," while other values are categorized into excellent ("A++"), good ("A+"), medium ("A"), or poor ("A-") levels.

This grading approach is also applied to other performance indicators. Notably, for indicators like fuel consumption rate, the grading principle differs, with the smallest parameter value corresponding to the highest grade (A++), unlike other indicators where larger values typically signify higher performance. This method ensures a structured and accurate classification of vehicle performance metrics from these values, 136KW is identified as the maximum, representing the optimal value, while 90KW is the minimum, denoting the poorest value. This creates a parameter range [90, 136]. Using the four-element connection number theory, this range is divided into four intervals.

6 EXAMPLE CALCULATION

There are 6 cars to be evaluated as q1, q2, q3, q4, q5 and q6 respectively. Applying the vehicle performance evaluation model based on set theory, the vehicle performance of the six cars is evaluated comprehensively and the evaluation results are obtained.

6.1 Determine the Weight of Evaluation Index

The process begins with establishing a multi-level analysis structural model comprising three layers: the target layer, the criterion layer, and the index layer. The vehicle's overall performance (A) serves as the target layer, while dynamic quality (B1), brake property (B2), possibility (B3), comfort (B4), and economy (B5) form the criterion layer. The index layer includes 13 car performance evaluation indicators (C1-C13), such as engine power, engine torque, maximum speed, acceleration, braking distance, minimum ground clearance, minimum turning radius, approach angle, departure angle, wheelbase, constant speed noise, fuel consumption, and car after-sales warranty.

Weights are calculated using the Analytical Hierarchy Process (AHP), which involves constructing a judgment matrix and performing consistency checks to ensure reliability. For the target layer to criterion layer analysis, weights are calculated and normalized, yielding results such as ω_1 = {0.18, 0.25, 0.121, 0.056, 0.393}. Similarly, for the criterion layer to index layer analysis, a B-C judgment matrix is constructed, and the calculation results are summarized in Table I.

Table I The weights calculation results

B1	ω	B2	ω	B3	ω	B4	ω	B5	ω
C1	0.282	C5	1	C6	0.311	C10	0.529	C12	0.607
C2	0.266			C7	0.211	C11	0.471	C13	0.393
C3	0.189			C8	0.239				
C4	0.263			C9	0.239				

6.2 Collect Performance Parameters of the Cars to be Evaluated and Classify the Indexes

Based on the established vehicle performance evaluation index system, the parameter table is obtained according to the collected vehicle technical condition parameters, as shown in Table II.

Table II Collected automotive technical performance data

Performance	q1	q2	q3	q4	q5	q6
Engine power /kw	120	165	135	130	125	242
Engine torque /N•m	246	350	270	259	280	475
Maximum speed /km/h	192	230	202	190	197	209
Acceleration / s	15.06	7.080	8.080	13.77	7.900	7.500
100km-0 Braking distance /m	43.79	39.92	38.52	43.54	39.4	39.92
Minimum ground clearance /mm	220	170	185	235	180	201
Minimum turning radius /m	5.8	5.9	5.9	5.7	6.2	5.75
Departure angle / degree	25	23	22	25	28	23
Fuel consumption rate /L	13	11.3	7.6	12.4	9.4	8.5
Car after-sales warranty /year	3	3	3	5	3	3

According to the establishment of the index classification rules to evaluate each grade of two indicators. The results are shown in Table III.

Table III vehicle comprehensive performance index grade division

Performance	Indicato					
	q1	q2	q3	q4	q5	q6
Engine power /kw	A－	A	A－	A－	A－	A＋＋
Engine torque /N•m	A－	A＋	A－	A－	A－	A＋＋
Maximum speed /km/h	A－	A＋＋	A	A－	A－	A
Acceleration / s	A＋＋	A－	A－	A＋＋	A－	A－
100km-0 Braking distance /m	A＋＋	A	A－	A＋＋	A	A
Minimum ground clearance /mm	A＋＋	A－	A－	A＋＋	A－	A
Minimum turning radius /m	A－	A＋	A＋	A－	A＋＋	A－
Approach angle / degree	A＋	A－	A－	A＋＋	A－	A
Departure angle / degree	A＋＋	A＋＋	A＋＋	A＋＋	A－	A
Wheelbase /cm	A＋＋	A＋＋	A＋＋	A＋＋	A－	A
60km/h Noise /dB	A＋＋	A－	A－	A－	A＋	A＋
Fuel consumption rate /L	A－	A－	A＋＋	A－	A	A＋＋
Car after-sales warranty /year	A－	A－	A－	A＋＋	A－	A－

6.3 The Evaluation Results Discussion

The comprehensive performance score of a vehicle effectively represents how automotive consumer groups perceive and acknowledge vehicle performance. By assigning the variables I, j, and k values of 0.75, 0.5, and 0.25 respectively, the contact number is calculated.

This variable ensures comparability between consumer ratings and contact numbers by maintaining consistent dimensions:

P= (each contact number-each contact number)/each contact number

The calculation of the number of contacts, consumer ratings and P values are shown in Table IV.

Table IV Evaluation results comparison

Target vehicle	q1	q2	q3	q4	q5	q6
Contact numbers	0.580	0.432	0.494	0.683	0.405	0.618
Consumer ratings	4.47	4.31	4.32	4.45	4.17	4.43
P value	0.843	0.883	0.899	0.849	0.894	0.869

A comparative analysis of the evaluation results and consumer ratings from a Chinese domestic car website is presented in Figure 2. The PPP-value curve exhibits minimal fluctuations and remains linear for each target vehicle, signifying that the evaluation method is scientific, reliable, and has practical reference value. In contrast, the curve representing the identical characteristic degree shows significant variations, suggesting that assessing vehicle performance based solely on similarity is insufficient.

The ranking derived from the contact number curve objectively ranks the six vehicles as q4>q6>q1>q3>q2>q5. Meanwhile, the consumer rating curve reflects public perception and recognition of each vehicle's overall performance under real-world conditions. A comparison of the contact degree and consumer rating curves reveals a similar trend, indicating a general agreement between the evaluation results and consumer opinions. However, slight discrepancies exist, such as q1q1q1, which ranks third highest in consumer ratings.

This difference arises because the evaluation model focuses on vehicle performance, producing an objective conclusion, while consumer ratings are influenced by brand reputation and personal preferences. For instance, in China's auto market, German joint-venture models, such as q1q1q1, benefit from longstanding brand recognition and visibility, which significantly impact consumer scores.

7 CONCLUSIONS

The comprehensive evaluation of vehicle performance demonstrates that the performance evaluation model based on set theory considers not only the similarities but also the differences and opposing factors within the evaluation process. Practical applications of this model have shown that it integrates index information effectively, offering a more scientific and comprehensive approach compared to evaluations relying on individual indices. This method enables a more accurate and comprehensive reflection of vehicle performance, making it a valuable tool for performance analysis. Its simplicity, ease of implementation, and practical relevance further establish it as an effective and reliable approach for evaluating vehicle performance comprehensively.

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