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Using MCDM Methods in the Automotive Industry: A Review

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Abstract

In the automobile sector, choosing the best car necessitates weighing a number of factors, including cost, fuel economy, performance, safety, and environmental impact. In order to solve complicated situations that need the simultaneous evaluation of multiple conflicting aspects, multi-criteria decision-making (MCDM) procedures are essential. Among the various MCDM approaches, the technique for order preference by similarity to ideal solution (TOPSIS) and multi-objective optimization on the basis of ratio analysis (MOORA) are widely recognized for their straightforward structure and reliable outcomes. The application of the TOPSIS approach in the automobile industry to determine the best car alternatives based on several performance parameters is the main topic of this study. The process involves creating a decision matrix, normalizing the data, and identifying ideal and non-ideal reference solutions. Next, options are ranked based on how near they are to the optimal answer. Through objective and quantitative analysis, TOPSIS helps consumers and industry professionals choose the best car by facilitating systematic comparisons between various vehicles and helping decision-makers achieve a balanced evaluation of diverse attributes. Rapid technical breakthroughs, strict environmental restrictions, and changing customer expectations present the automotive sector with increasingly complicated decision-making issues. It is necessary to simultaneously assess several, frequently contradictory factors to choose the best vehicle designs, suppliers, materials, powertrain technology, and consumer car options. By offering organized, transparent, and quantitative frameworks for decision support, MCDM techniques have become powerful analytical tools to tackle these issues. With a focus on popular approaches like TOPSIS, MOORA, analytic hierarchy process (AHP), VIKOR, and their hybrid integrations, this review paper provides a thorough overview of the implementation of MCDM techniques in the automotive industry.

Keywords: Automotive industry, MCDM, MOORA, preference ranking organization method for enrichment evaluation (PROMETHEE), TOPSIS

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INTRODUCTION

The automotive industry is a large and rapidly evolving field that involves the development, production, promotion, and distribution of motor vehicles worldwide.

It has significantly contributed to economic growth and technological advancement worldwide. In contrast, multi-criteria decision-making (MCDM) approaches provide systematic frameworks for handling decision problems that require the simultaneous assessment of several, often conflicting, criteria. Here is how these two domains can intersect and complement each other.

AUTOMOBILE INDUSTRY

Key Aspects

1. Market trends
2. Technology
3. Environmental concerns
4. Customer preferences
5. Global supply chain

Applications of MCDM in the Automobile Industry

1. *Supplier selection:* Suppliers are selected based on criteria such as cost, quality, delivery performance, and environmental compliance.
2. *Vehicle design:* Deciding on materials, engine types (electric, hybrid, or ICE), and features.
3. *Market strategy:* Analyzing consumer preferences, market trends, and regional demands.
4. *Sustainability practices:* Prioritizing green initiatives and compliance with environmental regulations.
5. *Manufacturing decisions:* Optimizing production processes and technology investments.

Multi-Criteria Decision-Making Method

MCDM methods are used in various domains, including engineering, business, environmental planning, and supply chain management, to aid in making informed decisions.

Key Features of MCDM Methods

1. *Multiple criteria:* Decisions involve more than one criterion, which can be quantitative (e.g., cost and efficiency) or qualitative (e.g., aesthetics and user satisfaction).
2. *Conflict of objectives:* Criteria often have trade-offs; for example, higher quality might imply higher cost.
3. *Preference modeling:* MCDM methods incorporate decision-makers' preferences by assigning weights or priorities to different criteria, such as safety, cost, fuel efficiency, and environmental impact.
4. *Structured framework:* MCDM provides a systematic and transparent framework for evaluating alternatives such as vehicle designs, materials, and suppliers.

Steps in an MCDM Process

1. Define the problem
2. Establish criteria
3. Assign weights
4. Evaluate alternatives
5. Apply the MCDM method
6. Validate and select

Technique for Order Preference by Similarity to Ideal Solution

The technique for order preference by similarity to ideal solution (TOPSIS) compares each alternative to an ideal alternative, which has the best score for each criterion. The geometric distance between each option and the optimal option is then determined using this procedure. The option closest to the ideal solution and furthest from the negative perfect solution is selected.

Advantages of TOPSIS

1. Simultaneously, it considers the finest and worst options.
2. Simple to comprehend and intuitive.
3. Effectively manages numerous criteria and big datasets.
4. Both helpful and non-beneficial criteria can be included.

Disadvantages of TOPSIS
1. Requires exact weights for the criteria, which could lead to subjectivity.
2. The normalization technique and weights have an impact on the outcomes.
3. Assumes linear preferences, which could not always be the case.

Multi-Objective Optimization Based on Ratio Analysis

Since its introduction by Brauers and Zavadskas in 2006, multi-objective optimization based on ratio analysis (MOORA) has been well known for its ease of use, adaptability, and efficiency in assessing options based on various factors.

Key Features

The MOORA technique is employed when judgments must be made while considering competing factors, including cost, quality, and performance.

This ratio-based method converts difficult decision-making issues into more straightforward mathematical representations for assessment and comparison.

This method focuses on normalizing decision data to eliminate the influence of different measurement units among criteria, ensuring that each criterion contributes equally to the evaluation process. It distinguishes between
- *Beneficial criteria:* Factors to be maximized (e.g., profit, efficiency).
- *Non-beneficial criteria:* Factors to be minimized (e.g., cost and waste).

The alternatives are ranked based on their aggregated performance scores, allowing decision-makers to select the optimal option.

Importance of the MOORA Method
1. *Simplicity:* It is computationally straightforward and easy to implement.
2. *Flexibility:* Can tackle both quantitative and qualitative data.
3. *Versatility:* Applicable to various fields such as engineering, finance, management, healthcare, and environmental studies.
4. *Accuracy:* Provides a clear and reliable ranking of alternatives based on objective analysis.

The MOORA method is particularly useful in real-world problems, where decision-makers must balance competing objectives to arrive at the best possible solution.

Analytic Hierarchy Process

It is used to solve complex problems involving multiple criteria by breaking them down into hierarchies and assigning priorities to each element. The analytic hierarchy process (AHP) is widely recognized for its ability to combine qualitative and quantitative data to derive consistent and logical decisions.

Key Features

A hierarchy-based approach structures the decision problem into levels, typically comprising:
- The goal (overall objective).
- Criteria (factors affecting the decision).
- Sub-criteria (optional, more specific factors).

Alternatives (options to be evaluated).

Pairwise comparisons: Evaluates elements pairwise to determine their relative importance using a scale (e.g., Saaty's 1–9 scale).

Consistency check: Verifies the consistency of judgments to ensure reliability in decision making.

Here, we applied a literature review for the use of the automobile sector using the MCDM method.

LITERATURE REVIEW

From the literature review, we observed that AHP, PROMETHEE, and GRE (gray relational evaluation) methods, supported by MCDM methods, had been applied. However, there is limited research on TOPSIS and MOORA methods. Therefore, we used only the TOPSIS method. The following are the papers based on MCDM used in the automotive industry (Table 1).

Table 1. Literature review table.

S.N.	Paper title	Name of the journal(s)	MCDM methods	Publication year
1	A hybrid MCDM approach for evaluating an automobile purchase model	International Journal of Information and Decision Science	PROMETHEE ; GRE	2013 [1]
2	Using the analytic hierarchy process (AHP) to improve human performance: an application of multiple criteria decision-making problem	Journal of Intelligent Manufacturing,	AHP	2004 [2]
3	Facility location selection using the PROMETHEE II method	International Conference on Industrial Engineering and Operations Management	PROMETHEE	2010 [3]
4	PROMETHEE: a comprehensive literature review on methodologies and applications	European Journal of Operational Research	PROMETHEE	2010 [4]
5	The lean improvement of the chemical emissions of motor vehicles based on preference ranking: a PROMETHEE uncertainty analysis	Omega International Journal of Management Science	PROMETHEE	2008 [5]
6	Performance evaluation of international airports in the region of East Asia	Proceedings of Eastern Asia Society for Transportation Studies	AHP	2003 [6]
7	A survey and optimization-based evaluation of development strategies for the air cargo industry	International Journal of Production Economics	TOPSIS	2007 [7]
8	Evaluating attack helicopters by AHP based on linguistic variable weight	European Journal of Operational Research	AHP	1999 [8]
9	Decision making in equipment selection: an integrated approach with AHP and PROMETHEE	Journal of Intelligent Manufacturing	AHP; PROMETHEE	2008 [9]
10	Multi-criteria analysis of alternative-fuel buses for public transportation	Energy Policy	AHP; TOPSIS	2005 [10]
11	A Closer Look at Drawbacks of Minimizing Weighted Sums of Objectives for Pareto Set Generation in Multi-Criteria Optimization Problems	Structural Optimization	WSM	1997 [11]
12	Interactive selection model for vendor selection process: an analytical hierarchy process approach	International Journal of Production Research	AHP	2003 [12]
13	An AHP multi-criteria suitability evaluation of technological diversification in the automotive industry	International Journal of Production Research	AHP	2012 [13]
14	Industrial competitiveness analysis: Using the analytic hierarchy process	The Journal of High Technology Management Research	AHP	2006 [14]
15	An AHP based prioritization model for risk evaluation factors in the automotive industry	International Journal of the Analytic Hierarchy Process	AHP	2018 [15]
16	Using the MCDM Technique-TOPSIS for selecting small passenger car	Pal Arch's Journal of Archaeology	TOPSIS	2020 [16]

17	Combining the AHP and TOPSIS to Evaluate Car Selection	Association for Computing Machinery	AHP; TOPSIS	2020 [17]
18	An analytic hierarchy process approach with a novel framework for luxury car selection	8th International Management Conference	AHP	2012 [18]
19	Application of Fuzzy TOPSIS Algorithm for Selecting Best Family Car	International Conference on Decision Aid Sciences and Application	FUZZY TOPSIS	2020 [19]
20	Investigating car purchasing decision-making process using Multi-Objective Optimization Ratio Analysis based Analytical Hierarchy Process Model	Journal of Contemporary Issues in Business and Government	AHP	2021 [20]
21	Development of a new hybrid multi-criteria decision-making method for a car selection scenario	Facta Universitatis	AHP	2020 [21]
22	Assessment and Comparison of Various MCDM Approaches in the Selection of Manufacturing Process	Advances in Materials Science and Engineering	AHP	2020 [22]
23	Selection of Car Using Fuzzy AHP and Fuzzy TOPSIS Method by MCDM Approach	International Research Journal of Engineering and Technology (IRJET)	FUZZY AHP	2023 [23]
24	A state-of-the-art survey of TOPSIS applications	Expert System Applications	TOPSIS	2012 [24]
25	Multi-attribute optimization of EDM process parameters for machining of SiC and B_4C particle reinforced Al 6061 metal matrix composite adopting TOPSIS method	International Journal of Advanced. Technology & Engineering	TOPSIS	2021 [25]

CONCLUSION

This review highlights the significant role of MCDM methods in addressing complex decision-making challenges in the automotive industry, such as in the automobile sector. From material selection and supplier evaluation to vehicle design optimization and technology adoption, MCDM tools offer a structured framework for balancing multiple, conflicting criteria. Methods such as AHP, TOPSIS, VIKOR, and PROMETHEE have been widely applied, each demonstrating strengths depending on the context and data requirements. The integration of MCDM with modern tools, such as fuzzy logic, machine learning, and sustainability metrics, is becoming increasingly relevant as industries move toward smarter, greener, and more cost-efficient solutions. Overall, the application of MCDM techniques contributes to enhanced transparency, rationality, and objectivity in the strategic and operational decisions in the automotive sector.

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