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From AHP to DEA: A Comparative Study of MCDM Approaches for Automotive Supplier Sustainability

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Abstract

The automotive industry is playing a crucial role in global economy. But it is also contributing largely to environmental challenges we are facing today. This industry is facing a growing pressure to adopt sustainable practices. Selecting a sustainable supplier to meet the sustainability goals is a very critical decision which directly affects company's performance, long term competitiveness and operational efficiency. In this paper, a widely used Multi-Criteria Decision Making (MCDM) technique, Analytic Hierarchy Process (AHP) is applied to evaluate and select sustainable suppliers in the automotive sector. Five criteria are used to assess three supplier alternatives and the results are evaluated. Besides this, the paper discusses and compares other MCDM methods, such as TOPSIS, VIKOR, Fuzzy AHP and DEA. Findings indicate that AHP is showing better result in transparency and consistency for expert-driven decisions. TOPSIS and VIKOR is exceling in ranking large datasets and can balance trade-offs well. Fuzzy AHP can capture uncertainty in human judgement where DEA can benchmark efficiency using quantitative data. These findings can contribute to both academia and industry to structure a framework for sustainable supplier selection by using appropriate MCDM techniques. MCDM by using hybrid AI integration is recently being followed.

Keywords
MCDM, AHP, TOPSIS, VIKOR, Fuzzy AHP

1. Introduction
To maintain a competitive position, selecting potential supplier is acknowledged as one of the most critical decisions in an organization which is directly linked to profitability and cash flow. As automotive industry is a major contributor in world's economy and by revenue, its turnover is equivalent to the sixth largest economy of the world, ((Masoumi et al., 2019)) choosing a sustainable supplier is even more critical for any automotive company. In many industries, the cost of materials and components constitute of around 70 percent of the cost of production. Selecting proper supplier could save a company tons of money, for instance, Jose Ignacio Lopez de Arriortua, head of General Motors' worldwide purchasing reduced General Motors' annual expenditure on parts and components around 50 billion US

dollar(Ghobadian et al., 2016). Companies who value the rising concern of the customers regarding carbon footprint and environmental change are getting acknowledged. To keep the competitive edge, business organizations are re-framing their policies to improve environmental scores in every aspect, from procurement to finished goods. (Kaur & Singh, 2018). To make this happen, co-ordination among all the members are required to make the supply chain sustainable, robust and resilient (Barrosa et al., 2019). Adding a "Green" component in supply chain means making an environmentally-conscious mindset and implementing Green Purchasing + Green Manufacturing/Materials Management + Green Distribution/Marketing + Reverse Logistics. Performance measurement has become more challenging as it's difficult to attribute performance results to one entity within the chain due to lack of standard performance measurement systems (Hervani et al., 2005). It is more difficult to choose Green suppliers than conventional suppliers as the consistency and contradictory standards of environment has to be considered and this makes it an Multi-criteria Decision making problem(MCDM)(Gupta & Vijayvargy, 2021). Here, we will be using the Analytical Hierarchy process (AHP) method to identify the Green supplier for our automobile industry. Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by Prof. Thomas L. Saaty in his book "Principia Mathematica Decernendi". Mathematically, this method is based on a solution of eigenvalue problem. In short, it is a method to derive ratio scales from paired comparisons. Through this method, various factors, even subjective opinions can be translated into measurable numeric relations (Goepel, 2018). In this paper, 5 criteria is taken as sample to select a sustainable supplier among 3 alternatives. AHP tools from Spicelogic is used, though the method is simpler enough to implement in excel. For other MCDM methods, tools from onlineoutput, Decision Radar and Fuzzy AHP are used.

2. Literature Review

The automotive industry produces a lot of greenhouse gases. It also wastes a lot of resources and makes a lot of trash. For this reason, it is important to incorporate sustainability considerations into its supply chain (Govindan et al., 2013; Vijaya et al., 2025a). Initially, Green Supply Chain Management (GSCM) was employed solely for compliance. Now, it helps businesses get ahead of their rivals. This is true for initiatives such as electric cars, recycling, and new laws like the EU Green Deal and net-zero goals (Handoyo, 2024a; Jain et al., 2024a; Mohsin et al., 2025a). Recent research shows that green supply chain management (GSCM) is becoming more important in the car industry. New technology, like the Internet of Things (IoT) and big data, helps companies check their sustainability in real time. These tools also help companies follow raw materials from start to finish, including recycling (Dang et al., 2022a). In Vietnam, COVID-19 disruptions made car companies pick stronger and greener suppliers. To help recover the economy and lower emissions, companies used special decision models called fuzzy AHP-VIKOR (Xie et al., 2022). In Morocco, car companies used other decision methods, such as fuzzy AHP-TOPSIS-WASPAS, to focus on health, safety, and getting ISO 14001 certification. These methods made picking suppliers 25% faster and helped companies create more eco-friendly designs (Tronnebati et al., 2024). Since 2019, there have been more studies about these decision models. About 81% of them use fuzzy logic to deal with unclear expert opinions when choosing suppliers (Khulud et al., 2023a; Rajendran et al., 2024). Some frameworks, like BWM-SAW-TOPSIS, help companies choose the right number of suppliers and avoid problems if they rely too much on just a few suppliers (Darvazeh et al., 2022). Recent studies talk about the importance of circular economy ideas, but car companies do not use them much yet.

SSS, or sustainable supplier selection, is now the most important part of GSCM. This is because suppliers are responsible for 60–80% of a vehicle's social and environmental effects (Khulud et al., 2023a; Štreimikienė et al., 2024a). Suppliers have a significant impact on pollution and people's lives.Recent reviews list five main criteria for supplier selection. Green suppliers draw from environmental, economic, social, operational, and innovation factors that studies outline well (Ghosh et al., 2023; Karakoç et al., 2024; Wu et al., 2023). Environmental checks watch carbon sent into the air, while economic ones track money spent. Workers' rights and community impacts drive the social side since they hit people right away. Quality and on-time delivery run operations smoothly. Innovation sparks new tech and green solutions. Car makers push these harder as they roll out electric and self-driving vehicles (Khulud et al., 2023a; Vijaya et al., 2025b).

MCDM methods shape supplier decisions (Chakraborty et al., 2025). AHP, TOPSIS, VIKOR, Fuzzy AHP, and DEA stand out most—they each rank suppliers uniquely (Karakoç et al., 2024; Štreimikienė et al., 2024a). Hybrid one's pair fuzzy logic with classic tools. Their use climbed about 40% since 2019.This is because hybrid methods are better at dealing with unclear language and expert opinions that aren't always clear (Çalik et al., 2023; Khulud et al., 2023a). Numerous studies exist regarding the utilization of these methods. But not many of them compare them directly. Fewer than 15% of the papers examine various MCDM methods on an identical dataset (Mohammed et al., 2023; (Khulud et al., 2023a; Rajendran et al., 2024). In car supply chains, even fewer studies use DEA with ranking methods like

AHP, TOPSIS, or VIKOR. Studies also don't often look at how stable the rankings are when the weights change. They don't often think about how hard the methods are to use or how easy they are for managers to understand (Chakraborty et al., 2025; Karakoç et al., 2024). Current researches have some clear gaps in this field. There is a need for a study that compares AHP, TOPSIS, VIKOR, Fuzzy AHP, and DEA to find which method works best for selecting green suppliers in the automotive industry. Such research should test both the theoretical strength and the practical use of these methods. The present study aims to fill this gap.

3. Methodology

3.1 MCDM Methods Considered

Choosing sustainable suppliers is challenging for the automotive industry. Multi-Criteria Decision Making (MCDM) methods are now essential; they help in carefully determining and ranking suppliers in a lot of different ways. The following section presents over the main MCDM methods that are used to pick sustainable suppliers in the automobile industry.

AHP – Structured Pairwise Comparison

The Analytic Hierarchy Process (AHP) is an efficient MCDM method that breaks down stressful choices into a number of criteria, sub-criteria, and choices that are ranked in order. This is done by using multiple comparisons to find priority weights (Akarte et al., 2001; Dang et al., 2022a). Because it uses a consistency ratio check to make sure that expert evaluations are consistent, it's a great tool for clearly choosing suppliers in car supply chains, where qualitative judgments, such as following sustainability requirements) are involved. are the norm (H.-S. Hwang et al., 2005; Zyoud et al., 2025). AHP turns personal choices into ratios, which makes it easier to rank sources based on how important they are. This method is especially good for finding a balance between economic and environmental goals (Partovi, 2006; Zyoud et al., 2025).

TOPSIS – Closeness to Ideal Solution

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) ranks the possibilities by considering where they are from the best and worst outcome possibilities. It emphasizes giving preference to sellers that meet the most important factors (C.-L. Hwang & Yoon, 1981). In the automotive field, it handles the pros and cons (e.g., low emissions vs. cost) well across large datasets, providing a simple ranking without assuming linear relationships (Jayant et al., 2014). It can be used to assess a number of different providers who are facing sustainability issues (Zhang, 2015).

VIKOR – Compromise Ranking Method

Multi-Criteria Optimization VIKOR creates compromise scores by looking at both the maximum group utility and the minimum individual regret. This makes it a good choice for multi-criteria supplier selection problems where there are conflicting criteria that need to be resolved (*Applications of VIKOR Method in Supplier Selection: A Meta-Regression Analysis View*, n.d.; Opricovic & Tzeng, 2004). This compromise logic works well for choosing an automotive supplier, since factors like distribution speed, quality, price, and sustainability must be balanced against each other instead of being optimized on their own (*Applications of VIKOR Method in Supplier Selection: A Meta-Regression Analysis View*, n.d.; Çalı & Balaman, 2019). By focusing on acceptable advantages and stable decisions, VIKOR also deals with quite large sets of alternatives. This helps to keep seller rankings high so that industrial supply chains can stay competitive over the years (Opricovic & Tzeng, 2004).

Fuzzy AHP – Handling Uncertainty in Judgments

Fuzzy Analytic Hierarchy Process (Fuzzy AHP) extends AHP by using triangular fuzzy numbers to represent linguistic terms in expert pairwise comparisons, allowing uncertainty and vagueness in judgments to be modelled more realistically (Huang, 2022; Suganthi, 2018). This makes it suitable for automotive (and other industrial) supplier selection problems where experts often provide qualitative assessments such as “high” or “low” sustainability risk instead of precise numerical scores (Gupta et al., 2019; Lavanpriya et al., 2022). Fuzzy AHP makes comparisons by calculating fuzzy weights and then putting them into distinct values. This approach keeps the decision-making structure in place and allows for subjective tastes, which leads to strong decisions in unpredictable circumstances (Huang, 2022; Suganthi, 2018).

DEA (Data Envelopment Analysis) – Efficiency-Based Evaluation

Data Envelopment Analysis (DEA) is a non-parametric efficiency frontier method that compares multiple input-output ratios to find an efficient frontier without needing to set weights for each parameter ahead of time (Ho et al., 2010). DEA is used in the automotive industry to measure how efficient an operation is in terms of cost, quality, and environmental performance per unit of resource. This allows for objective supplier screening and rationalization in the procurement of auto parts and components, so that multiple inputs and outputs can be handled at the same time (Sarkis & Talluri, 2002).

3.2 Criteria for Supplier Selection

To test each method, the following criteria are taken.
1. environmental performance (priority or weight = 0.303)
2. Economic performance (priority or weight = 0.129)
3. Build quality (priority or weight = 0.228)
4. operational performances. (priority or weight = 0.101)
5. Green initiatives(priority or weight = 0.238)

3.3 Comparative Framework

The methods along with case study are discussed below-

3.3.1 AHP

Steps to calculate AHP

Step 1: Define the decision hierarchy of the problem

Goals of the decision is declared, the criteria are declared afterwards, followed by alternatives.

Step 2: Giving nominal value of each level of hierarchy and creating pairwise comparison matrix.

The scale ranges from one to nine where number nine means one element is extremely more important than the other in a pairwise matrix. These nominal values can be gathered from experts' opinion on a factor or statistics based.

Each column is divided by its sum to scale values.

- Then, each row is averaged to get the priority vector w (Table 1).

Example:

- Column sums = (1.583, 4.5, 7).
- Normalize each entry by dividing by column sum.
- Average each row → $w^{\{c\}} = 0.61{,}0.23{,}0.17$).

Table 1. Importance scale table (Adapted from (Saaty, 1987))

Table 1. The fundamental scale

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining *n* numerical values to span the matrix

ı the elements being compared are closer together than indicated by the scale, one can use the scale 1.1, 1.2, …, ill finer, one can use an appropriate even finer refinement.

Step 3: Derive priority vectors (weights)

The priority vector data can be collected from subject matter experts, cross-functional teams, top management or from external stakeholders.

Compute the normalized principal eigenvector of each matrix:

(Jalaliyoon et al., 2012)

compute the principal eigenvector of the matrix:

$$A \cdot w = \lambda_{max} \cdot w$$

- Normalize w so that $\sum w_i = 1.$
- This eigenvector gives the most accurate weights.

Step 4: consistency check

Steps to calculate the consistency ratio-

1. Define the matrix for pairwise comparison
2. Define the matrix for priority vector
3. Multiply the pairwise comparison matrix with priority vector
4. Elementwise divide the multiplication result with priority vector
5. A new vector is found which will give the principal Eigenvalue by averaging the new vector
6. If n is the dimension of matrix, consistency index (CI) can be formulated as $= \frac{principle\ eigenvalue - n}{n-1}$
7. AHP calculates the consistency ratio of a matrix by comparing the CI of this matrix vs CI of a random matrix, $CR = \frac{consistancy\ index\ of\ this\ matrix}{consistancy\ index\ of\ a\ random\ matrix}$
   The CR should be below 0.1 according to (Saaty, 1987)

Step 5: Final weights

The resulting vector w gives the relative importance of criteria. These weights are then multiplied with alternative scores under each criterion to get global rankings.

3.3.2 Case study with AHP

Each company scores differently in various criteria. Blue ocean inc. can create things at a competitive price but neglect green initiatives and scores poor on environmental performance. Whereas General automotive has the highest score in green initiatives. High sky inc. makes great quality product and is more concerned of environment but performs poor on economic aspects. Our goal is to select the best sustainable supplier among these 3 alternatives. For this, we are putting more weight on environmental performance, green initiatives rather than focusing only on economic benefits. At first, the goal is declared, followed by the criteria and alternatives. Then the comparison in pair is done. The matrix is formed. Then the software calculated the normalized matrix and created eigenvalue vector and implemented rest of the formulae. The result is shown as, High sky inc. scores more in overall aspects and sourcing from this supplier is recommended. The software also shows radar graphs and rectangular graphs to change the values to see further information. The bar graph shows how one criterion is affecting the decision as a whole. We can see, the High Sky inc. has more area in maroon, indicating the environmental performance played a critical role in recommending the company. The sensitivity analysis shows how sensitive the decision is and how it's depending on any criteria. The consistency ratio for each criterion is less than 0.1 which indicates the judgements are acceptably consistent as well as expert's comparisons are logically coherent enough to be trusted (Figure 1-10 and Table 2-16).

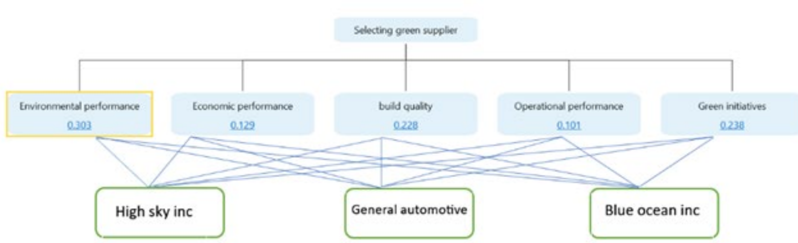

Figure 1. The hierarchy of criteria and alternatives in AHP

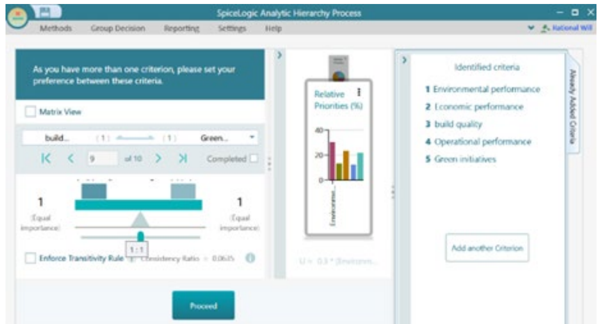

Figure 2. Implementation of AHP method using Spicelogic tool

Table 2. Final values of each category for each supplier showing local priorities.

Value

Criterion	General Automotives inc.	High Sky inc.	Blue Ocean Ltd.
Environmental performa	0.297	0.539	0.164
Economic performance	0.312	0.198	0.49
build quality	0.312	0.49	0.198
Operational performanc	0.312	0.49	0.198
Green initiatives	0.49	0.312	0.198

3.3.3 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

Principle: Ranks alternatives based on their distance to the *ideal solution* (best values for all criteria) and the *negative-ideal solution* (worst values). The best alternative is closest to the ideal and farthest from the negative-ideal. This is a Euclidean distance problem.

TOPSIS approach:

- Creating the matrix with design options and criteria
- Assigning importance to each criterion
- Entering design option data for each criterion
- Assigning goal direction (minimize or maximize)
- Computing and evaluating scores

- Strengths: Simple, efficient, widely used in supplier selection and sustainability studies.
- Limitations: Sensitive to normalization and assumes monotonic criteria.

STEP 1: Normalize the decision-matrix.

The following formula can be used to normalize.

$$r_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \qquad i = 1, \dots, m \;\; ; j = 1, \dots \;\; , n$$

STEP 2: Calculate the weighted normalized decision matrix.

According to the following formula, the normalized matrix is multiplied by the weight of the criteria.

$v_{ij}(\mathrm{x}) = w_j r_{ij}(x) \qquad i = 1, \dots, m \;\; ; j = 1, \dots \;\; , n$

The following table shows the weighted normalized decision matrix.

STEP 3: Determine the positive ideal and negative ideal solutions.

The aim of the TOPSIS method is to calculate the degree of distance of each alternative from positive and negative ideals. Therefore, in this step, the positive and negative ideal solutions are determined according to the following formulas.

$A^{+} = (v_1^{+}, v_2^{+}, \dots, v_n^{+})$

$A^{-} = (v_1^{-}, v_2^{-}, \dots, v_n^{-+})$

So that

$v_j^{+} = \{(max\ v_{ij}(x) \big| j\epsilon j_1), (min\ v_{ij}(x) \big| j\epsilon j_2)\}\ \ i = 1, \dots, m$

$v_j^{-} = \{(min\ v_{ij}(x) \big| j\epsilon j_1), (max\ v_{ij}(x) \big| j\epsilon j_2)\}\ \ i = 1, \dots, m$

where j1 and j2 denote the negative and positive criteria, respectively.

The following table shows both positive and negative ideal values.

STEP4: distance from the positive and negative ideal solutions

TOPSIS method ranks each alternative based on the relative closeness degree to the positive ideal and distance from the negative ideal. Therefore, in this step, the calculation of the distances between each alternative and the positive and negative ideal solutions is obtained by using the following formulas.

$$d_i^{+} = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^{+}(x)]^2}\ \ ,\ \ i = 1, \dots, m$$

$$d_i^{-} = \sqrt{\sum_{j=1}^{n} [v_{ij}(x) - v_j^{-}(x)]^2}\ \ ,\ \ i = 1, \dots, m$$

The following table shows the distance to the positive and negative ideal solutions

STEP 5: Calculate the relative closeness degree of alternatives to the ideal solution

In this step, the relative closeness degree of each alternative to the ideal solution is obtained by the following formula. If the relative closeness degree has value near to 1, it means that the alternative has shorter distance from the positive ideal solution and longer distance from the negative ideal solution.

$$C_i = \frac{d_i^{-}}{(d_i^{+} + d_i^{-})}\ \ ,\ \ i = 1, \dots, m$$

The following table shows the relative closeness degree of each alternative to the ideal solution and its ranking.

3.3.4 Case study with TOPSIS

The tool used for TOPSIS is Decision Radar as well as onlineoutput.com The local and global priorities are considered same for each supplier.To make the decision matrix, local priorities of each supplier under each criterion can be treated as the performance scores for TOPSIS.

Table 3. Decision matrix with previous local and global priorities.(Decision Radar)

Step 3: Decision Matrix

Fill the decision matrix values

Choice	Environmental Performance	Economic	Build quality	Operational Performance	Green initiatives
General Automotive	Value 0.297	Value 0.312	Value 0.312	Value 0.312	Value 0.49
High Sky	Value 0.539	Value 0.198	Value 0.49	Value 0.49	Value 0.312
Blue Ocean inc	Value 0.164	Value 0.49	Value 0.198	Value 0.198	Value 0.198

Table 4. Criteria weight for TOPSIS (onlineoutput tool)

Characteristics of Criteria

	name	type	weight
1	Environmental\n performance	+	0.303
2	Economic	+	0.129
3	Build Quality	+	0.228
4	Operational	+	0.101
5	Green initiatives	+	0.238

Table 5. STEP 1: Normalize the decision-matrix

The normalized matrix

	Environmental\\n performance	Economic	Build Quality	Operational	Green initiatives
General Automotive	0.466	0.508	0.508	0.508	0.798
High Sky	0.846	0.323	0.798	0.798	0.508
Blue Ocean inc	0.258	0.798	0.323	0.323	0.323

Table 6. STEP 2: Calculate the weighted normalized decision matrix

The weighted normalized matrix

	Environmental\\n performance	Economic	Build Quality	Operational	Green initiatives
General Automotive	0.141	0.066	0.116	0.051	0.226
High Sky	0.256	0.042	0.182	0.081	0.144
Blue Ocean inc	0.078	0.103	0.074	0.033	0.091

Table 7. STEP 3: Determine the positive ideal and negative ideal solutions.

The positive and negative ideal values

	Positive ideal	Negative ideal
Environmental\\n performance	0.256	0.078
Economic	0.103	0.042
Build Quality	0.182	0.074
Operational	0.081	0.033
Green initiatives	0.226	0.091

Table 8. STEP4: distance from the positive and negative ideal solutions

Distance to positive and negative ideal points

	Distance to positive ideal	Distance to negative ideal
General Automotive	0.141	0.158
High Sky	0.102	0.221
Blue Ocean inc	0.253	0.061

3.3.5 VIKOR

- Principle: Focuses on ranking and selecting from a set of alternatives with conflicting criteria. It identifies a *compromise solution* that balances group utility and individual regret.
- Strengths: Useful when trade-offs are necessary; highlights compromise rather than absolute best.
- Limitations: Sensitive to the choice of parameter (v) (weight of strategy of majority vs. individual).

STEP 1: Normalize the decision matrix

The following formula can be used to normalize.

$$f_{ij}(\mathrm{x}) = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad i = 1, \dots, m \ \ ; j = 1, \dots \ , n$$

STEP 2: Determine the best f_i^* and worst f_i^- benefits of each criterion

The best and worse benefits can be determined by the following formula:

If the criterion is positive, then

$$f_j^* = Max_i f_{ij} \ \ , \ \ f_j^- = Min_i f_{ij} \ \ ; \ \ j = 1,2, \dots, n$$

If the criterion is negative, then

$$f_j^* = Min_i f_{ij} \ \ , \ \ f_j^- = Max_i f_{ij} \ \ ; \ \ j = 1,2, \dots, n$$

The positive ideal solution (f^*) and negative ideal solution (f^-) can be expressed as follows:

$$f^* = \{f_1^*, f_2^*, f_3^*, \dots, f_n^*\}$$
$$f^- = \{f_1^-, f_2^-, f_3^-, \dots, f_n^-\}$$

STEP 3: Calculate the S_i and R_i values

The values S_i and R_i, representing the group utility and individual regret, respectively, can be calculated by the formulas below:

$$S_i = \sum_{j=1}^{n} w_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)}$$

$$R_i = Max_j \left[w_j \frac{\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \right]$$

Where w_j denotes the weight of the criteria.

STEP4: Calculate the value Q_i

The value Q_i, representing the VIKOR index for each alternative can be calculated by the following formula:

$$Q_i = \gamma \frac{(S_i - S^*)}{(S^- - S^*)} + (1 - \gamma) \frac{(R_i - R^*)}{(R^- - R^*)}$$

Where

$$S^* = Min_i\{S_i\} \ \ ; \ \ S^- = Max_i\{S_i\} \ \ ; \ \ R^* = Min_i\{R_i\} \ \ ; \ \ R^- = Max_i\{R_i\}$$

And γ is the maximum group utility represented by value 0.5.

STEP 5: Rank the alternatives, sorting by the S, R and Q values

Alternatives are ranked by sorting the S, R, and Q, values in decreasing order such that the best rank is assigned to the alternative with the smallest VIKOR value.

STEP 6: Propose a compromise solution

the alternative ($A^{(1)}$), which is the best ranked by the measure Q (minimum) if the following two conditions are satisfied:

Condition 1. Acceptable advantage: $Q(A^{(2)}) - Q(A^{(1)}) \geq 1/(m-1)$ where$A^{(1)}$is the alternative with first position and $A^{(2)}$is the alternative with second position in the ranking list by Q. m is number of alternatives.

Condition 2. Acceptable stability in decision making: The alternative $A^{(1)}$ must also be the best ranked by S or/and R.

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

Solution 1. Alternatives $A^{(1)}, A^{(2)}, \ldots., A^{(M)}$ if Condition 1 is not satisfied; Alternative $A^{(M)}$ is determined by $Q\left(A^{(M)}\right) - Q\left(A^{(1)}\right) < 1/(m-1)$ for maximum M (the positions of these alternatives are ‘‘in closeness’’).

Solution 2. Alternatives $A^{(1)}$ and $A^{(2)}$ if only condition 2 is not satisfied.

Solution 3. Alternative with the minimum Q value will be selected as the best Alternative if both conditions are satisfied.

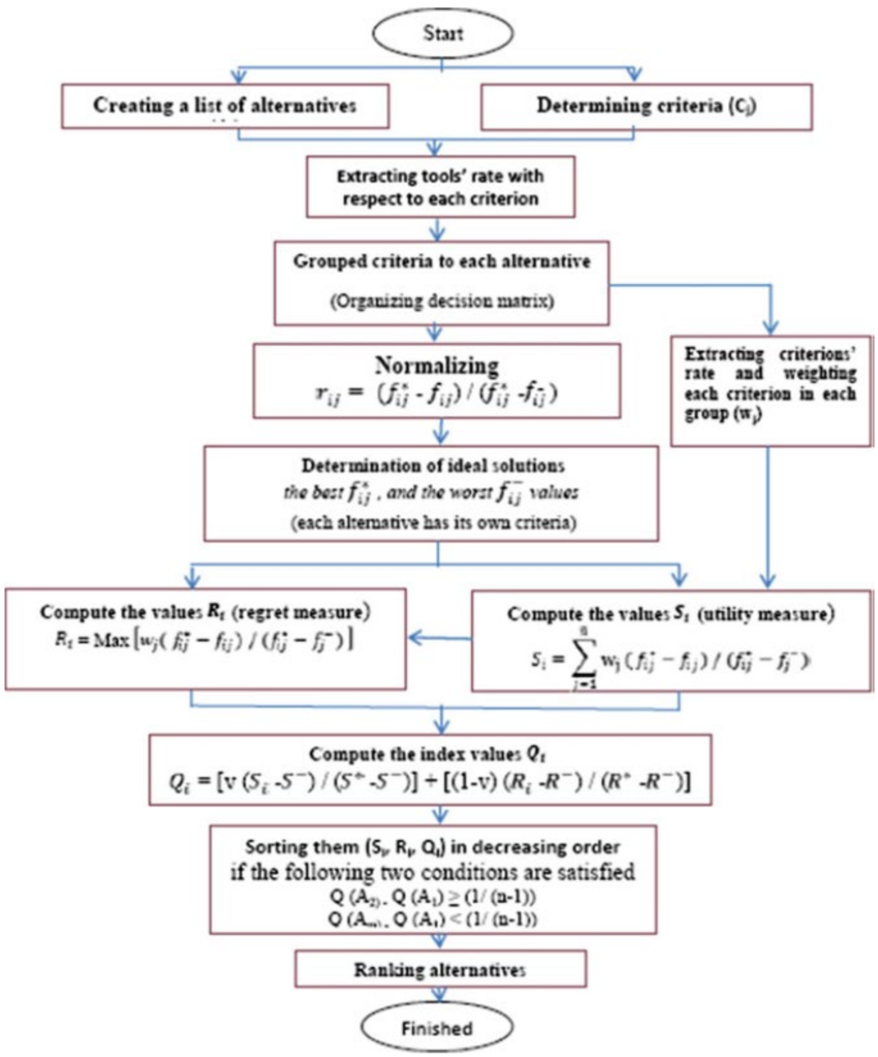

Figure 3. VIKOR method flowchart (adapted from (Anvari et al., 2014)

3.3.6 Case study with VIKOR

The tool used for VIKOR is onlineoutput.com. The VIKOR technique was first introduced by Opricovic in 1998 in order to solve multi-criteria decision making (MCDM) problems and obtain the best compromise solution. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. The main objective of the VIKOR method is to choose a solution that is closest to the ideal level in each criterion such that the alternatives are based on the particular measure of ‘‘closeness’’ to the ‘‘ideal’’ solution.

Table 9. Decision matrix of VIKOR with same criteria (onlineoutput.com tool)

Decision Matrix

	Environmental performance	Economic	Build Quality	Operational	Green initiatives
General Automotive	0.297	0.312	0.312	0.312	0.49
High Sky	0.539	0.198	0.49	0.49	0.312
Blue Ocean	0.164	0.49	0.198	0.198	0.198

- In this study there are 5 criteria and 3 alternatives that are ranked based on VIKOR method. The table below shows the type of criterion and weight assigned to each criterion.

Table 10. STEP 1: Normalize the decision matrix

Normalized Decision Matrix

	Environmental\n performance	Economic	Build Quality	Operational	Green initiatives
General Automotive	0.466	0.508	0.508	0.508	0.798
High Sky	0.846	0.323	0.798	0.798	0.508
Blue Ocean	0.258	0.798	0.323	0.323	0.323

Table 11. Calculate the S_i and R_i values

The values S and R

	R	S
General Automotive	0.196	0.475
High Sky	0.173	0.302
Blue Ocean	0.303	0.915

Table 12. STEP4: Calculate the value Q_i

The values Q

	Q
General Automotive	0.229
High Sky	0
Blue Ocean	1

3.3.7 Fuzzy AHP

Principle: Extends AHP by incorporating fuzzy set theory to handle uncertainty and vagueness in human judgments. Instead of crisp numbers, experts use fuzzy numbers (triangular or trapezoidal) to express preferences.

- Strengths: Captures ambiguity in expert opinions; more realistic for complex, uncertain environments.
- Limitations: More complex calculations; requires defuzzification.

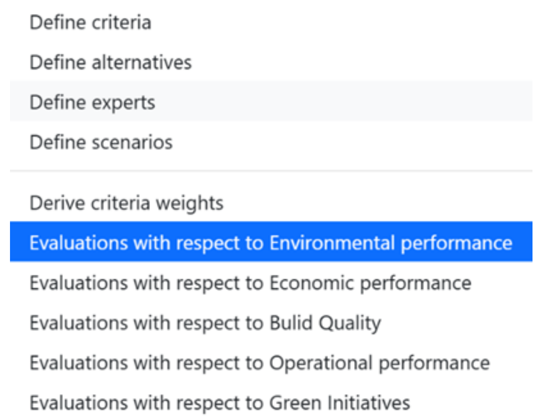

Figure 4. Steps in Fuzzy AHP

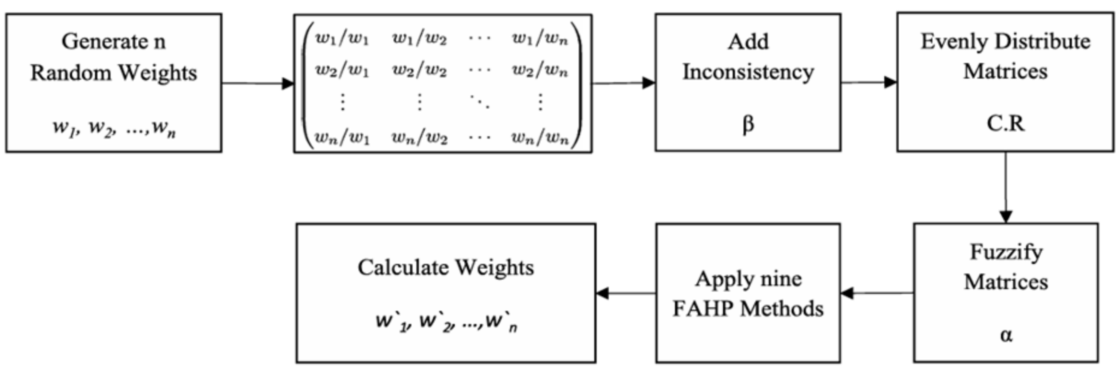

Figure 5. Fuzzy steps (adapted from Ahmed & Kilic, 2019)

Step1 : Choosing from various algorithms

In literature, various algorithms are there but arithmetic and geometric mean are popular for crisp AHP. (Ahmed & Kilic, 2019). For this, a fully consistent comparison matrix is created as like conventional AHP

Step 2: Fuzzy extent analysis

Implement fuzzy extent analysis to add fuzziness to the data according to the original FEA formula proposed by (Chang, 1996)

3.3.8 Case study with Fuzzy AHP

The tool used, Fuzzy AHP is available in online.

A 10 step method is considered where the criteria and alternatives are set. Then the pairwise comparison in a Saaty scale (Saaty, 1987) 1 to 9 is considered. Only the upper triangle of the matrix has to be filled and the lower half is automatically filled by reciprocating the upper half values. Then the pairwise comparison for each alternatives and each criterion is done. Each case, only upper half is filled. The result comes at the end.

3.3.9 DEA

- Principle: A non-parametric method that evaluates the relative efficiency of decision-making units (DMUs) by comparing multiple inputs and outputs. It constructs an efficiency frontier and measures each unit's performance relative to it.

- Strengths: Objective benchmarking; does not require predefined weights; widely used in efficiency analysis.
- Limitations: Requires quantitative data; cannot handle qualitative judgments directly.

Steps- The steps are followed according to (Charnes et al., 1978)
3.3.10 Case study with DEA
The DEA requires quantitative data to analyze. So, we created quantitative data in such a way that reflects their performance/priority vector. The tool used for this is Onlineoutput.com. The table for quantitative data according to their performance in various categories (table 2).

Table 13. Table for DEA

Supplier (DMU)	**Input1** **Cost (USD/unit)**	**Input2** **Lead time (days)**	**Output1** **First-pass yield (%)**	**Output2** **CO_2 reduction (%)**
General	12.0	5.5	89	22
High Sky	11.5	4.8	92	28
Blue Ocean	10.5	6.2	86	15

5. Results

The results of all 5 analysis are given below.

5.1 Numerical Results

5.1.1 AHP

In AHP, High Sky ranks first, followed by General automotive and Blue Ocean inc. The Bar chart shows the red portion of High sky is significant which means due to having larger score in environmental performance, the supplier High Sky is getting the deal. Though Blue Ocean performed well in Economic performance, the market is no longer interested to purchase from them as their priorities have changed.
Sensitivity Analysis
It shows how sensitive the decision is to one criterion and how it affects the supplier selection. In Green initiative, it is showing 76.25% sensitive, that means, if the variable's value changes 100 - 76 = 24% within its range of possible values, then the selected decision will be changed.

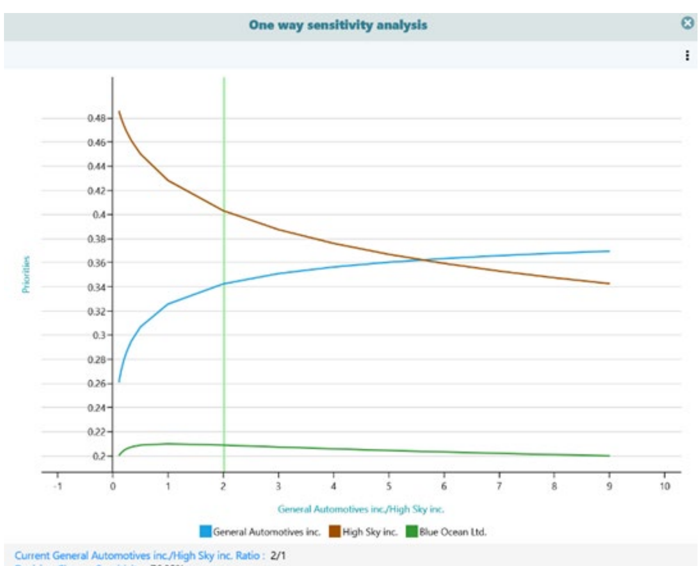

Figure 6. Sensitivity analysis AHP

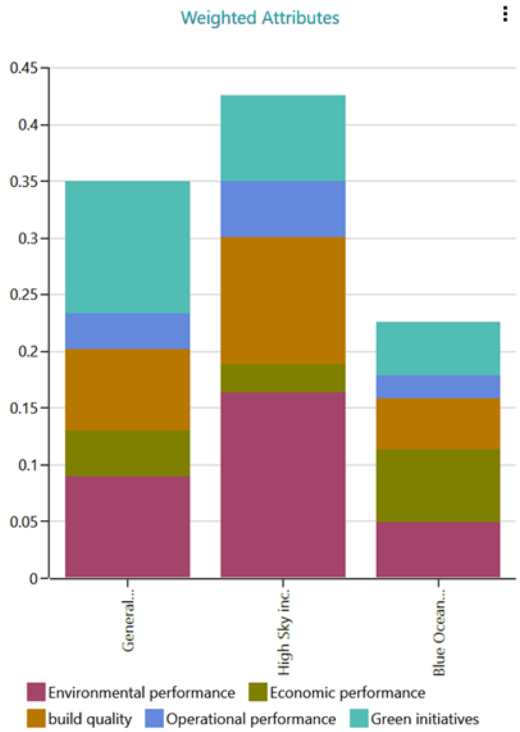

Figure 7. Bar chart of result AHP

5.1.2 TOPSIS

TOPSIS results from both analyses matched with each other. The HIGH sky ranked the 1st among all 3 alternatives, followed by General Automotive and Blue Ocean.

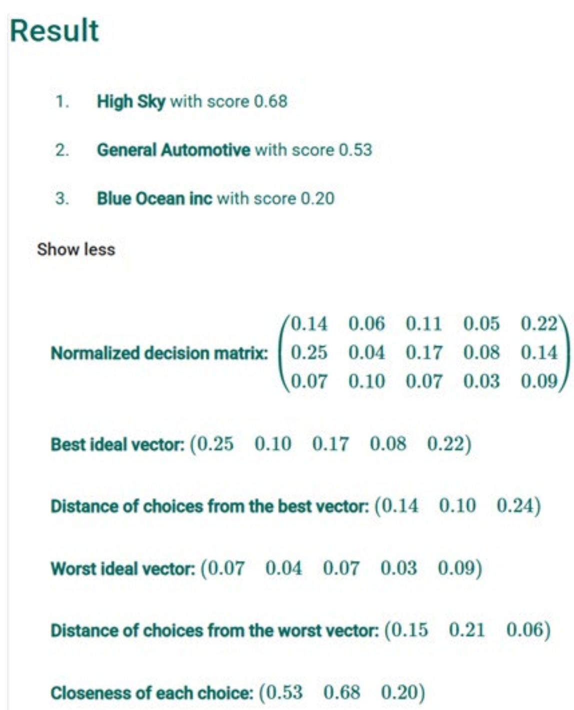

Figure 8. Result from TOPSIS(decision Radar)

Table 14. Result from TOPSIS (online output)

The ci value and ranking

	Ci	rank
General Automotive	0.528	2
High Sky	0.683	1
Blue Ocean inc	0.195	3

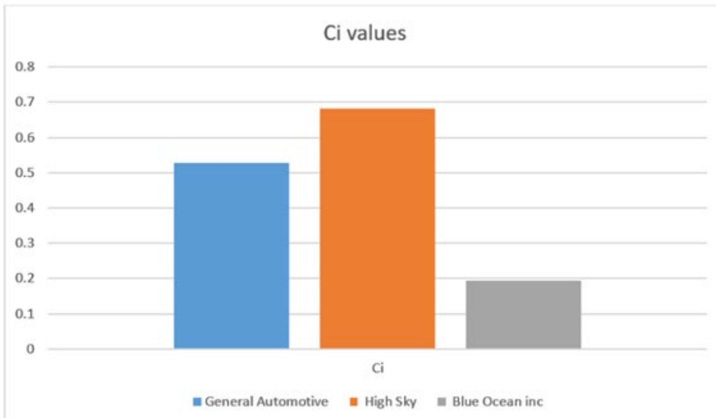

Figure 9. Result from TOPSIS, Ci values shown in bar chart (online output)

5.1.3 VIKOR

In VIKOR, High Sky ranked 1 in R value, S value and Q value.

Table 15. Result from VIKOR

result of the conditions survey

Condition 1	Non acceptance
Condition 2	-
Selected solution	Solution 1

Table 16. Result from VIKOR (onlineoutput)

The ranking list for the alternatives

	R value	Rank in R	S value	Rank in S	Q value	Rank in Q
General Automotive	0.196	2	0.475	2	0.229	2
High Sky	0.173	1	0.302	1	0	1
Blue Ocean	0.303	3	0.915	3	1	3

Therefore, High Sky,General Automotive, are selected as the final alternatives. (VIKOR)

5.1.4 Fuzzy AHP

General Automotive ranked as first as the dataset were fuzzy(in Saaty scale 1 to 9). Followed by High Sky and Blue Ocean Inc.

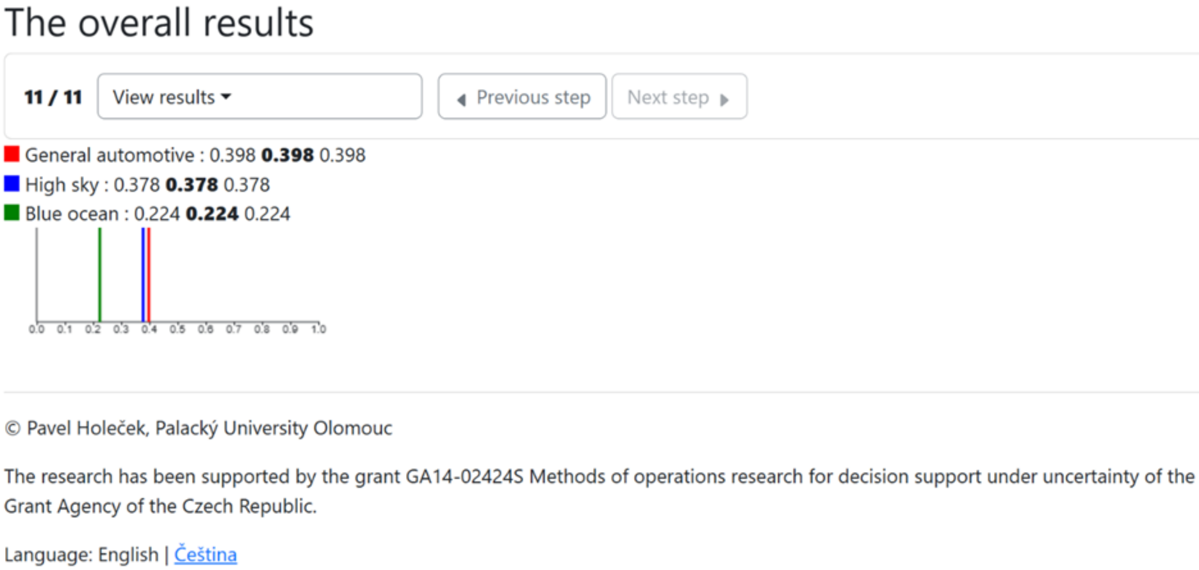

Figure 10. Fuzzy AHP result shows General Automotive scores higher.

5.1.5 DEA

The dataset were changed into 2 input and 2 output according to their previous data. The results are given in terms of efficiency, peer set, λ (Weights for Peer Units), Weights (values of the variables for the primary model), Input and Output slacks and Target Values.

Reference Set

In each linear program of DEA, the solution technique will attempt to make the efficiency of the target unit as large as possible. This search procedure will terminate when either the efficiency of the target unit or the efficiency of one or more other units is equal to one. Therefore, for an inefficient unit at least one other unit has the efficiency equal to 1 with the same weight of the target unit obtained from the solution of the model. These efficient units are known as the peer group for the inefficient unit. Table 17-22 shows the peers.

Table 17. Efficiency table (DEA)

	Efficiency	
General Automotive	0.922	Inefficient
High Sky	1	Efficient
Blue Ocean	1	Efficient

Table 18. Peer table

	First-pass yield (%)	CO_2 reduction (%)
General Automotive	89 ➔ 89	22 ➔ 24.302
High Sky	92 ➔ 92	28 ➔ 28
Blue Ocean	86 ➔ 86	15 ➔ 15

Table 19. Lambda values

	General Automotive	High Sky	Blue Ocean
General Automotive	0	0.734	0.249
High Sky	0	1	0
Blue Ocean	0	0	1

Table 20. Weights

	Peer1	Peer2
General Automotive	High Sky	Blue Ocean
High Sky	High Sky	-
Blue Ocean	Blue Ocean	-

Table 21. Inputs and target inputs

	Cost (USD/unit)	Lead time (days)
General Automotive	12 ➔ 11.063	5.5 ➔ 5.07
High Sky	11.5 ➔ 11.5	4.8 ➔ 4.8
Blue Ocean	10.5 ➔ 10.5	6.2 ➔ 6.2

Table 22. Outputs and target outputs

	Cost (USD/unit)	Lead time (days)
General Automotive	0.078	0.011
High Sky	0.087	0
Blue Ocean	0.088	0.013

6. Discussion

The AHP works better for qualitative judgements well though it has limitations of sensitivity to inconsistency. As subjective weights can be translated into numerical weights, it's dependent to experts' opinion to assign weight/priority value. Though having limitations like assuming linear trade-offs, TOPSIS can work better in simple-intuitive environment, better for managerial tasks. But when criteria conflicts with each other and the decision maker needs a balanced solution, VIKOR can come in handy as it considers compromises between maximizing overall satisfaction(group utility) and minimizing overall dissatisfaction(regret). If the experts' judgements are vague and they can't give precise numbers but can express in linguistic terms such as high, low, moderate etc, Fuzzy AHP can tolerate all this by using fuzzy numbers, thus capturing the vagueness between a range. Lastly, when the weights are not defined properly, but actual data is at hand, DEA should be used to benchmark efficiency.

7. Conclusion and Future Scope

The automotive industry faces mounting pressure to integrate sustainability into its supply chains, as suppliers account for nearly 60–80% of a vehicle's social and environmental impact(Khulud et al., 2023b; Štreimikienė et al., 2024b). Multi-Criteria Decision Making (MCDM) methods such as AHP, TOPSIS, VIKOR, Fuzzy AHP, and DEA provide structured approaches to evaluate and rank suppliers across environmental, economic, operational, social, and innovation criteria. This study highlights that while each method offers unique strengths—AHP for structured qualitative judgments, TOPSIS for intuitive closeness to ideal solutions, VIKOR for compromise rankings, Fuzzy AHP for handling uncertainty, and DEA for efficiency benchmarking—comparative analyses across identical datasets remain scarce. By applying these methods to the automotive sector, this research contributes to bridging theoretical rigor with practical usability, ensuring that supplier selection aligns with sustainability goals and regulatory frameworks such as the EU Green Deal and net-zero targets ((Handoyo, 2024b) (Jain et al., 2024b) (Mohsin et al., 2025b).

Future research should expand in several directions. First, comparative studies must incorporate sensitivity analysis to test the stability of supplier rankings under varying weight distributions, reflecting shifting industry priorities. Second, hybrid frameworks that combine DEA with ranking methods (AHP, TOPSIS, VIKOR) should be explored to capture both efficiency and preference-based evaluations. Third, greater emphasis should be placed on circular economy and innovation criteria, which remain underrepresented despite their growing relevance in electric and autonomous vehicle supply chains ((Vijaya et al., 2025c)). Fourth, studies should evaluate the managerial usability of these methods, ensuring that decision-makers can interpret results easily and apply them in practice. Finally, future work could integrate real-time data sources such as IoT and big data analytics to dynamically update supplier evaluations, making sustainable supplier selection more adaptive and responsive to disruptions ((Dang et al., 2022b)
By addressing these gaps, upcoming research can provide both methodological innovation and practical guidance, ultimately strengthening the role of Green Supply Chain Management in advancing sustainability within the automotive industry.

References

Ahmed, F., & Kilic, K. Fuzzy Analytic Hierarchy Process: A performance analysis of various algorithms. *Fuzzy Sets and Systems*, 362, 110–128, **2019**, https://doi.org/10.1016/J.FSS.2018.08.009

Akarte, M. M., Surendra, N. V., Ravi, B., & Rangaraj, N. Web based casting supplier evaluation using analytical hierarchy process. *Journal of the Operational Research Society*, 52(5), 511–522, **2001**, https://doi.org/10.1057/PALGRAVE.JORS.2601124/METRICS

Anvari, A., Zulkifli, N., & Arghish, O. Application of a modified VIKOR method for decision-making problems in lean tool selection. *International Journal of Advanced Manufacturing Technology*, 71(5–8), 829–841, **2014**, https://doi.org/10.1007/s00170-013-5520-x

Applications of VIKOR Method in Supplier Selection: A Meta-Regression Analysis view, **n.d.**, https://isarder.org/index.php/isarder/article/view/1530/1483

Barrosa, R. de C., Sampaio, M., & Correa, J. S. Impact of the inclusion of variable CO_2 cost in the distribution network design. *Production*, 29, **2019**, https://doi.org/10.1590/0103-6513.20190065

Çalik, A., Onifade, S. T., & Alola, A. A. Evaluating Supply Resilience Performance of an Automotive Industry during Operational Shocks: A Pythagorean Fuzzy AHP-VIKOR-Based Approach. *Systems*, 11(8), **2023**, https://doi.org/10.3390/SYSTEMS11080396

Çalı, S., & Balaman, Ş. Y. A novel outranking based multi criteria group decision making methodology integrating ELECTRE and VIKOR under intuitionistic fuzzy environment. *Expert Systems with Applications*, 119, 36–50, **2019**, https://doi.org/10.1016/j.eswa.2018.10.039

Chakraborty, S., Raut, R. D., Rofin, T. M., & Chakraborty, S. Supplier selection using multi-criteria decision making methods: a comprehensive review. *OPSEARCH*, 1–62, **2025**, https://doi.org/10.1007/S12597-025-01009-6

Chang, D. Y. Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, 95(3), 649–655, **1996**, https://doi.org/10.1016/0377-2217(95)00300-2

Charnes, A., Cooper, W. W., & Rhodes, E. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429–444, **1978**, https://doi.org/10.1016/0377-2217(78)90138-8

Dang, T.-T., Nguyen, N.-A.-T., Nguyen, V.-T.-T., & Dang, L.-T.-H. A Two-Stage Multi-Criteria Supplier Selection Model for Sustainable Automotive Supply Chain under Uncertainty. *Axioms*, 11(5), **2022**, https://doi.org/10.3390/AXIOMS11050228

Darvazeh, S. S., Mooseloo, F. M., Vandchali, H. R., Tomaskova, H., & Tirkolaee, E. B. An integrated multi-criteria decision-making approach to optimize the number of leagile-sustainable suppliers in supply chains. *Environmental Science and Pollution Research*, 29(44), 66979–67001, **2022**, https://doi.org/10.1007/S11356-022-20214-0

Ghobadian, A., Stainer, A., Liu, J., & Kiss, T. A Computerised Vendor Rating System. *Developments in Logistics and Supply Chain Management*, 103–112, **2016**, https://doi.org/10.1057/9781137541253_10

Ghosh, S., Bhowmik, C., Sinha, S., Raut, R. D., Mandal, M. C., & Ray, A. An integrated multi-criteria decision-making and multivariate analysis towards sustainable procurement with application in automotive industry. *Supply Chain Analytics*, 3, 100033, **2023**, https://doi.org/10.1016/J.SCA.2023.100033

Goepel, K. Implementation of an Online Software Tool for the Analytic Hierarchy Process (AHP-OS). *International Journal of the Analytic Hierarchy Process*, 10(3), 469–487, **2018**, https://doi.org/10.13033/IJAHP.V10I3.590

Govindan, K., Azevedo, S. G., Carvalho, H., & Cruz-Machado, V. Lean, green and resilient practices influence on supply chain performance: interpretive structural modeling approach. *International Journal of Environmental Science and Technology*, 12(1), 15–34, **2013**, https://doi.org/10.1007/S13762-013-0409-7

Gupta, S., Soni, U., & Kumar, G. Green supplier selection using multi-criterion decision making under fuzzy environment: A case study in automotive industry. *Computers & Industrial Engineering*, 136, 663–680, **2019**, https://doi.org/10.1016/J.CIE.2019.07.038

Gupta, S., & Vijayvargy, L. Selection of Green Supplier in Automotive Industry: An Expert Choice Methodology. *IOP Conference Series: Earth and Environmental Science*, 795(1), 012036, **2021**, https://doi.org/10.1088/1755-1315/795/1/012036

Hervani, A. A., Helms, M. M., & Sarkis, J. Performance measurement for green supply chain management. *Benchmarking: An International Journal*, 12(4), 330–353, **2005**, https://doi.org/10.1108/14635770510609015

Ho, W., Xu, X., & Dey, P. K. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research*, 202(1), 16–24, **2010**, https://doi.org/10.1016/J.EJOR.2009.05.009

Huang, F. Low-Carbon Supplier Selection Using Fuzzy AHP and Goal Programming Approach. *Discrete Dynamics in Nature and Society*, 2022(1), 3115490, **2022**, https://doi.org/10.1155/2022/3115490

Hwang, C.-L., & Yoon, K. Methods for Multiple Attribute Decision Making, **1981**, https://doi.org/10.1007/978-3-642-48318-9_3

Hwang, H.-S., Chuang, C.-L., & Jong, M. Supplier Selection and Planning Model Using AHP, **2005**, https://doi.org/10.13033/ISAHP.Y2005.052

Jalaliyoon, N., Bakar, N., & Taherdoost, H. Accomplishment of Critical Success Factor in Organization; Using Analytic Hierarchy Process. *International Journal of Academic Research in Management*, 1, 1–9, **2012**

Jayant, A., Gupta, P., Garg, S. K., & Khan, M. TOPSIS-AHP Based Approach for Selection of Reverse Logistics Service Provider. *Procedia Engineering*, 97, 2147–2156, **2014**, https://doi.org/10.1016/J.PROENG.2014.12.458

Karakoç, Ö., Memiş, S., & Sennaroglu, B. A Review of Sustainable Supplier Selection with Decision-Making Methods from 2018 to 2022. *Sustainability*, 16(1), **2024**, https://doi.org/10.3390/SU16010125

Kaur, H., & Singh, S. P. Heuristic modeling for sustainable procurement and logistics in a supply chain using big data. *Computers & Operations Research*, 98, 301–321, **2018**, https://doi.org/10.1016/J.COR.2017.05.008

Lavanpriya, C., Muthukumaran, V., & Manoj Kumar, P. Evaluating Suppliers Using AHP in a Fuzzy Environment and Allocating Order Quantities. *Mathematical Problems in Engineering*, 2022(1), 8695983, **2022**, https://doi.org/10.1155/2022/8695983

Masoumi, S. M., Kazemi, N., & Abdul-Rashid, S. H. Sustainable Supply Chain Management in the Automotive Industry: A Process-Oriented Review. *Sustainability*, 11(14), 3945, **2019**, https://doi.org/10.3390/SU11143945

Opricovic, S., & Tzeng, G. H. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research*, 156(2), 445–455, **2004**, https://doi.org/10.1016/S0377-2217(03)00020-1

Saaty, R. W. The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling*, 9(3–5), 161–176, **1987**, https://doi.org/10.1016/0270-0255(87)90473-8

Suganthi, L. Multi expert and multi criteria evaluation of sectoral investments for sustainable development. *Sustainable Cities and Society*, 43, 144–156, **2018**, https://doi.org/10.1016/J.SCS.2018.08.022

Wu, C., Jia, Y., & Barnes, D. Criteria system construction for sustainable supplier selection. *Applied Soft Computing*, 145, 110586, **2023**, https://doi.org/10.1016/J.ASOC.2023.110586

Zyoud, S., Omair, S. M., & Jarrad, S. A. A two-stage fuzzy AHP and fuzzy synthetic evaluation technique. *Scientific Reports*, 15(1), 3736, **2025**, https://doi.org/10.1038/s41598-025-88236-5

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