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Research Article

Application of the CRITIC-TOPSIS Decision-Making Method for Green Supplier Selection in the Supply Chain of the Automotive Parts Manufacturing Industry

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ABSTRACT

This study aims to apply the CRITIC-TOPSIS decision-making method for selecting environmentally friendly suppliers in the automotive parts manufacturing supply chain. Eight evaluation criteria were employed: health and safety, sustainable product design, ISO 14001 certification, renewable resource utilization, green packaging, quality, cost, and delivery. Data were collected from five experts representing production, quality, and management divisions. The CRITIC analysis revealed that cost had the highest weight 0.33, followed by delivery 0.15, while environmental and quality-related criteria had relatively similar weights 0.08-0.10. The supplier ranking using TOPSIS indicated that Supplier D (A_4) was the most suitable option ($C_i^* = 0.983$), followed by Suppliers A and C, whereas Suppliers B and E exhibited more limitations. The findings suggest that integrating the CRITICTOPSIS method can enhance supplier selection decisions, ensuring alignment with both economic and environmental objectives of the automotive industry.

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1. Introduction

One of the major industries influencing the growth of the world economy and the creation of intricate supply chains that cover everything from the sourcing of raw materials to manufacturing and distribution is the automotive sector. Thailand's automotive parts industry is a vital source of production for international manufacturing networks and export endeavors [1]. Because it directly affects product quality, cost, delivery time, and the industry's overall competitiveness, choosing a supplier is therefore a crucial process. Today's supplier selection problems, however, extend beyond conventional economic considerations like cost and quality. Under the frameworks of Sustainable Supply Chain Management (SSCM) and Green Supplier Selection (GSS), environmental and social factors are becoming more and more important [2]. In addition to more conventional criteria like quality, cost, and delivery, modern supplier evaluation takes into account environmental certifications like ISO 14001, the use of renewable resources, environmentally friendly packaging, and labor health and safety [3]. Combining these disparate criteria makes supplier selection a complex Multi-Criteria Decision Making (MCDM) problem [4].

To deal with these complexities, a variety of Multi-Criteria Decision-Making (MCDM) approaches have been used. The CRITIC (Criteria Importance Through Intercriteria Correlation) method, created by Diakoulaki et al. (1995), is one of the well-known strategies. It stresses the objective calculation of criterion weights by taking into account both the variance of each criterion and the correlation between them. This approach reduces decision-makers' subjective bias and more accurately captures the inherent significance of data-driven information Diakoulaki et al., in 1995 [5]. In contrast, Hwang and Yoon in 1981 [6] developed the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method, which ranks suppliers in a methodical and logical manner by comparing alternatives with an ideal solution and taking into account both positive and negative ideal points. Because it combines the advantages of both approaches objective data-based weighting and ranking based on proximity to the ideal solution the integration of CRITICTOPSIS has been widely acknowledged in studies on green supplier selection within the automotive parts manufacturing supply chain [3, 4]. In addition to aligning with business goals, the combined approach helps organizations choose suppliers that meet corporate social responsibility and environmental sustainability standards.

Therefore, the application of the CRITIC-TOPSIS decision-making method for the selection of environmentally friendly suppliers within the supply chain for the manufacturing of automotive parts is the main focus of this study. Eight criteria form the basis of the evaluation: quality, cost, delivery, use of renewable resources, sustainable product design, ISO 14001 certification, health and safety, and environmentally friendly packaging. These criteria are intended to improve the efficacy of supplier selection choices in the highly competitive automotive sector by taking into account both contemporary economic and environmental factors [7–14].

2. Literature review

A crucial component of sustainable supply chain management is green supplier selection (GSS), which emphasizes the necessity for businesses to assess suppliers based on social and environmental standards in addition to more conventional ones like price and quality. Due to this change in emphasis, Multi-Criteria Decision-Making (MCDM) techniques are now widely used, allowing for the systematic assessment of suppliers in relation to several sustainability-focused criteria. Because it can provide objective criteria weights and identify options that are closest to an ideal solution, the combined application of the TOPSIS ranking method and the CRITIC weighting technique has gained widespread acceptance for the selection of green suppliers. Through the use of distance-to-ideal for ranking (TOPSIS) and actual data variability for weighting (CRITIC), the integrated CRITIC-TOPSIS approach helps guarantee that chosen suppliers fulfill sustainability and business objectives. The effectiveness of the CRITIC-TOPSIS approach in sustainable supplier selection contexts has been shown in a number of important studies. In order to assess sustainable supply chain risks, [3] developed an integrated fuzzy TOPSIS-CRITIC model. They demonstrated how fuzzy logic and CRITIC-TOPSIS can be used to prioritize options and manage uncertainty in sustainability criteria. Similar to this, [4] extended the method to take into account several objectives and uncertainty at once by creating a multi-objective stochastic CRITIC-TOPSIS framework for sustainable decision-making. According to both studies, supplier selection decisions that combine TOPSIS for ranking and CRITIC for objective weighting are in line with both environmental responsibility and economic performance. The application of CRITIC-TOPSIS for assessments with a sustainability focus is still being validated and improved by recent research. For example, [2] used fuzzy MCDM techniques to handle ambiguity in expert judgments and proposed a fuzzy-based green supplier selection model that takes social and environmental factors into account. This work reinforced that fuzzy logic can be used in conjunction with CRITIC-TOPSIS to better address subjectivity in green criteria, highlighting the significance of

incorporating qualitative sustainability criteria in supplier evaluation. Refining the weighting scheme can improve the accuracy of sustainability assessments, according to [8] application of an improved CRITIC-TOPSIS method to rank companies by corporate social responsibility performance. Furthermore, [9] confirmed the method's adaptability in multi-criteria supply chain decisions beyond supplier selection by using CRITIC-TOPSIS to prioritize critical spare parts in agricultural machinery. In conclusion, research continuously emphasizes CRITIC-TOPSIS as a strong tool for making decisions that impartially assesses factors and finds the best suppliers for intricate sustainability specifications. This integrated approach improves the rigor of sustainable supplier selection decisions by striking a balance between economic and environmental objectives [3, 4]. Researchers have further enhanced the approach by creating multi-objective or improved-weighting variants to address various sustainability contexts [4, 8] and by adding fuzzy logic to manage uncertainty [2, 3]. CRITIC-TOPSIS provides a tried-and-true, methodical way to assess and choose suppliers in line with sustainability objectives as businesses place a greater emphasis on green supply chain management.

3. Research Methodology

Prior to data analysis using statistical methods and Multi-Criteria Decision-Making (MCDM) techniques, this study first identified the research problem, objectives, and evaluation criteria. In particular, the TOPSIS method was used to rank the suppliers' suitability, and the CRITIC method was used to determine the weights of the criteria [15, 16]. Figure 1 shows the steps in the methodology.

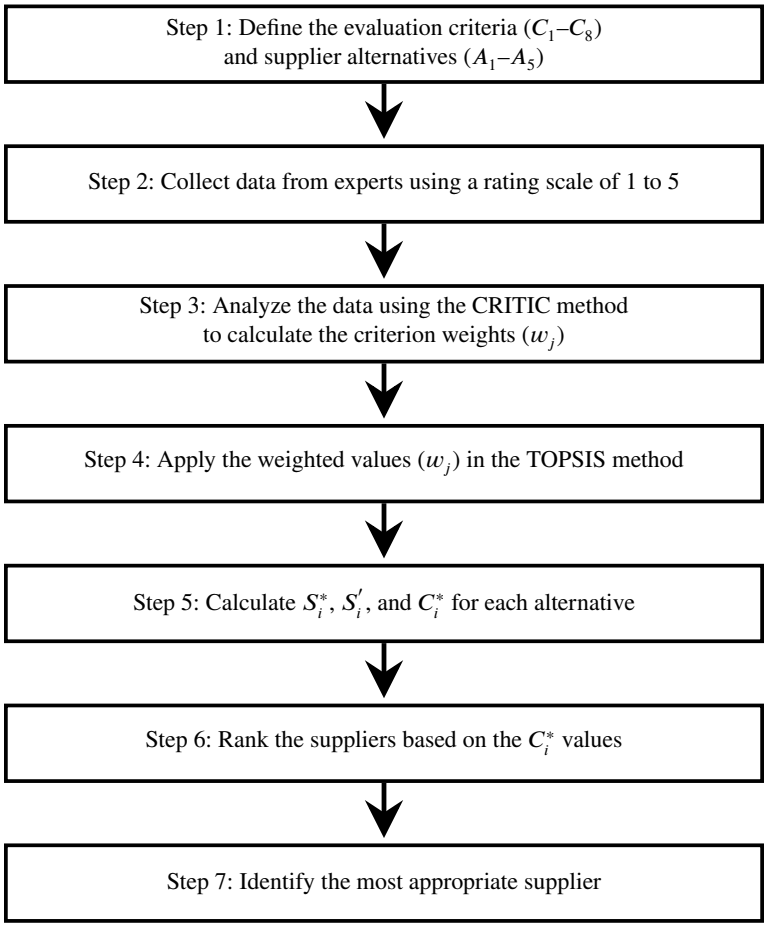


Figure 1: Flowchart of the CRITIC–TOPSIS methodology.

3.1. CRITIC Weighting Technique

The CRITIC method (Criteria Importance Through Inter-criteria Correlation) is an objective weighting technique used to determine the importance of various evaluation criteria. Originally proposed by Diakoulaki et al. in 1995 [5], the CRITIC method accounts for both the degree of conflict and contrast among the criteria within the decision-making structure. It analyzes the interrelationships between criteria to detect inconsistencies and redundancies. This process involves evaluating the decision matrix in conjunction with the standard deviation of each criterion (normalized by column), along with the correlation coefficients between each pair of columns, to determine the discriminative power of each criterion. In this study, the implementation of the CRITIC method is divided into six procedural steps [5, 17].
Step 1: Construct the decision matrix representing the performance of all alternatives

$$\begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix}. \tag{3.1}$$

Step 2: Data Normalization
For benefit-type criteria, where a higher value indicates better performance, normalization is performed to standardize the data across criteria. If criterion j is a benefit-type criterion, higher values are preferred.

$$x_{ij}^{T} = \frac{x_{ij} - x_j^{-}}{x_j^{*} - x_j^{-}}, \quad \text{if } j \in B. \tag{3.2}$$

If criterion j is a benefit-type criterion, where higher values are preferred, normalization is applied to reflect the desirability of higher performance values.

$$x_{ij}^{T} = \frac{x_{ij} - x_j^{*}}{x_j^{-} - x_j^{*}}, \quad \text{if } j \in NB. \tag{3.3}$$

Step 3: Calculation of Standard Deviation

$$S_j = \sqrt{\frac{1}{m-1} \sum_{i=1}^{m} \left(x_{ij} - \bar{x}_j\right)^2}. \tag{3.4}$$

Step 4: Calculation of Correlation Coefficients

$$R = \left[r_{jk}\right]_{m \times n}. \tag{3.5}$$

$$r_{jk} = \frac{\sum_{i=1}^{m} \left(x_{ij} - \bar{x}_j\right)\left(x_{ik} - \bar{x}_k\right)}{\sqrt{\sum_{i=1}^{m} \left(x_{ij} - \bar{x}_j\right)^2 \sum_{i=1}^{m} \left(x_{ik} - \bar{x}_k\right)^2}}. \tag{3.6}$$

Step 5: Calculation of the Information Content for Each Criterion (C_j)

$$H_j = S_j \sum_{k=1}^{m} \left(1 - r_{jk}\right). \tag{3.7}$$

Step 6: Calculation of the Criterion Weights (w_j)

$$w_j = \frac{H_j}{\sum_{k=1}^{m} H_k}. \tag{3.8}$$

3.2. Ranking Using the TOPSIS Technique

The ranking process using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is applied after the weights of the evaluation criteria have been determined. This technique analyzes the proximity of each alternative to the ideal solution by comparing it to both the best (positive ideal) and worst (negative ideal) possible options. The TOPSIS approach offers a systematic framework for evaluating and ranking alternatives, making it an effective Multi-Criteria Decision-Making (MCDM) tool for complex decision problems. The procedure consists of six steps as outlined by Hajduk and Jelonek in 2021 [18].

Step 1: Construct the Decision Matrix

In this step, the decision matrix is created, where x_{ij} represents the numerical data corresponding to the performance of alternative i with respect to criterion j. Here, A denotes the set of alternatives and f represents the set of evaluation criteria, as illustrated in Equation (3.9)

$$\begin{matrix} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} f_1 & f_2 & f_3 & \cdots f_n \\ x_{11} & x_{12} & x_{13} & \cdots x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots x_{2n} \\ \vdots & \vdots & \vdots & \ddots \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots x_{mn} \end{bmatrix}. \tag{3.9}$$

Step 2: Construct the Normalized Decision Matrix

In this step, the decision matrix is normalized by calculating each value r_{ij}, as shown in Equation (3.10). The purpose of normalization is to transform criteria measured in different units into a dimensionless form, allowing for direct comparison across all evaluation factors.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad \forall i = 1, \ldots, m, \ \forall j = 1, \ldots, n. \tag{3.10}$$

Step 3: Construct the Weighted Normalized Decision Matrix

Using the criterion weights w_j, obtained from prior data analysis, and the normalized decision matrix values r_{ij}, the weighted normalized decision matrix is constructed by calculating v_{ij}, as shown in Equation (3.11). This step integrates the relative importance of each criterion into the normalized performance scores.

$$v_{ij} = w_j r_{ij}. \tag{3.11}$$

Step 4: Determine the Positive and Negative Ideal Solutions

Based on the weighted normalized decision matrix v_{ij}, the positive ideal solution A (representing the best possible performance) and the negative ideal solution A' (representing the worst possible performance) are calculated, as shown in Equations (3.12) and (3.13), respectively. Here, J represents the set of benefit-type criteria (the more, the better), while J' represents the set of cost-type criteria (the less, the better).

$$A^* = \left\{ v_1^*, \ldots, v_n^* \right\}, \quad \text{where } v_j^* = \begin{cases} \max(v_{ij}), & \text{if } j \in J, \\ \min(v_{ij}), & \text{if } j \in J'. \end{cases} \tag{3.12}$$

$$A' = \left\{ v_1', \ldots, v_n' \right\}, \quad \text{where } v_j' = \begin{cases} \min(v_{ij}), & \text{if } j \in J, \\ \max(v_{ij}), & \text{if } j \in J'. \end{cases} \tag{3.13}$$

Step 5: Calculate the Separation Measures for Each Alternative

In this step, the separation measures for each alternative iii are computed. The separation from the positive ideal solution is denoted as S_i^*, and the separation from the negative ideal solution is denoted as S_i', as presented in Equations (3.14) and (3.15), respectively. These values reflect how far each alternative is from the ideal and anti-ideal scenarios.

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^* \right)^2}, \quad \forall i = 1, \ldots, m. \tag{3.14}$$

$$S_i' = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j'\right)^2}, \quad \forall i = 1, \ldots, m. \tag{3.15}$$

Step 6: Calculate the Relative Closeness to the Ideal Solution
In this final step, the relative closeness of each alternative i to the ideal solution is calculated and denoted as C_i^*, as shown in Equation (3.16). The value of C_i^* ranges between 0 and 1, where a value of 0 indicates the worst-performing alternative and a value of 1 represents the best-performing alternative. The interpretation of C_i^* is further explained in Equation (3.17).

$$C_i^* = \frac{S_i'}{S_i^* + S_i'}. \tag{3.16}$$

$$C_i^* = \begin{cases} 1, & \text{if } A_i = A^*, \\ 0, & \text{if } A_i = A'. \end{cases} \tag{3.17}$$

Based on the relative closeness to the ideal solution C_i^* for each alternative, the alternatives are ranked accordingly. The alternative with the C_i^* value closest to 1 is considered the most preferred option or the best solution [19, 20].

4. Results

The evaluation process began with the identification of eight criteria: health and safety (C_1), sustainable product design (C_2), ISO 14001 certification (C_3), use of renewable resources (C_4), environmentally friendly packaging (C_5), quality (C_6), cost (C_7), and delivery performance (C_8). Five supplier alternatives were considered: Supplier A (A_1), Supplier B (A_2), Supplier C (A_3), Supplier D (A_4), and Supplier E (A_5). Expert evaluations were conducted by five professionals: two from the production department, two from the quality assurance department, and one from the management team, all with more than 10 years of industry experience. The experts rated each supplier on a 5-point Likert scale (1–5) [2, 21].

4.1. Results of the CRITIC Weighting Technique

4.1.1. The resulting decision matrix illustrates the performance outcomes of all supplier alternatives

Constructing the decision matrix is a critical step in the Multi-Criteria Decision-Making (MCDM) process. Its purpose is to systematically collect and organize expert judgment into a tabular format that reflects the performance evaluation of each supplier under all predefined criteria. In this study, five supplier alternatives (A1-A5) were assessed across eight evaluation criteria encompassing economic, quality, and environmental dimensions. The performance scores were provided by five experts, consisting of two from the production department, two from the quality assurance department, and one from the management team. The resulting matrix is presented in Table 1.

Table 1
Results of the Constructed Decision Matrix.

Alternatives / Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	4.60	4.30	5.00	4.20	4.50	4.80	4.10	4.70
A_2	3.80	3.50	4.20	3.60	3.70	4.00	4.50	4.00
A_3	4.20	4.40	4.50	3.90	4.10	4.40	4.00	4.20
A_4	4.90	4.80	4.90	4.70	4.60	4.90	3.70	3.80
A_5	3.70	3.90	3.50	3.30	3.60	3.80	4.80	3.90

Based on Table 1, the results from the constructed decision matrix reveal that the average scores of each supplier across the evaluation criteria vary significantly. For instance, the criteria related to health and safety (C_1) and quality

(C_6) generally received high scores across most suppliers, reflecting a strong emphasis on product safety standards and quality performance. In contrast, criteria such as cost (C_7) and delivery (C_8) exhibited more pronounced score differences among suppliers, indicating variations in cost competitiveness and logistical efficiency.

The construction of this decision matrix enables a systematic overview of each suppliers performance under a unified set of criteria. It serves as a critical foundation for the subsequent steps, namely, data normalization to eliminate unit inconsistencies and the computation of criterion weights using the CRITIC method. These steps precede the supplier ranking process using the TOPSIS technique, which ultimately identifies the most suitable supplier in terms of both economic and environmental performance.

4.1.2. Results of Data Normalization

Table 2
Normalized Decision Matrix.

Alternatives / Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.75	0.62	1.00	0.64	0.90	0.91	0.36	1.00
A_2	0.08	0.00	0.47	0.21	0.10	0.18	0.73	0.22
A_3	0.42	0.69	0.67	0.43	0.50	0.55	0.27	0.44
A_4	1.00	1.00	0.93	1.00	1.00	1.00	0.00	0.00
A_5	0.00	0.31	0.00	0.00	0.00	0.00	1.00	0.11

4.1.3. Results of Correlation Coefficient Calculation

Table 3
Correlation Coefficient Calculation.

Alternatives / Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	1.00	0.88	0.90	0.98	0.99	0.99	-0.92	0.23
A_2	0.88	1.00	0.66	0.84	0.86	0.83	-0.86	0.05
A_3	0.90	0.66	1.00	0.90	0.93	0.95	-0.89	0.48
A_4	0.98	0.84	0.90	1.00	0.96	0.96	-0.94	0.11
A_5	0.99	0.86	0.93	0.96	1.00	1.00	-0.91	0.36

4.1.4. Results of Standard Deviation Calculation

Table 4
Standard Deviation Calculation.

Standard Deviation	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
SD_j	0.43	0.38	0.40	0.39	0.45	0.44	0.39	0.40

4.1.5. Results of Calculation of the Coefficient for Each Criterion (C_j)

Table 5
Information Content Calculation for Each Criterion (C_j).

C_j Coefficient	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_j	1.26	1.43	1.24	1.23	1.28	1.24	4.94	2.19

4.1.6. Results of Weight Calculation (w_j)

Table 6
Calculation of Criterion Weights (w_j).

Weights of Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
w_j	0.09	0.10	0.08	0.08	0.09	0.08	0.33	0.15

According to Table 6, the criterion weights (w_j) calculated using the CRITIC method reflect both the variability of the data and the interrelationships among criteria. The results illustrate the relative importance of each criterion in the supplier selection process. Among them, the cost criterion (C_7) received the highest weight of 0.33, indicating that cost exerts the most significant influence on decision-making in the context of automotive parts manufacturing–an industry characterized by intense competition and a strong emphasis on cost control to enhance competitiveness.

The second-highest weight was assigned to the delivery criterion (C_8), with a value of 0.15, highlighting the importance of timely and reliable delivery. Disruptions in delivery schedules can directly affect production lines and lead to hidden operational costs. Other criteria, including health and safety ($C_1 = 0.09$), sustainable product design ($C_2 = 0.10$), ISO 14001 certification ($C_3 = 0.08$), use of renewable resources ($C_4 = 0.08$), environmentally friendly packaging ($C_5 = 0.09$), and quality ($C_6 = 0.08$), received relatively similar weights ranging from 0.08 to 0.10.

Although these criteria carry slightly lower weights, they remain essential for consideration, as they reflect long-term sustainability, environmental standards, and organizational safety. In summary, the analysis indicates that economic factors–namely, cost and delivery–continue to be the most critical determinants in supplier selection decisions. Nevertheless, environmental and social factors play a necessary complementary role in fostering sustainable supply chain management. Thus, the application of the CRITIC method supports not only business-driven objectives but also broader responsibilities related to environmental and social governance.

4.2. Results of the CRITIC Weighting Technique

The TOPSIS analysis began with the scaling of the initial decision matrix, as shown in Table 7. Subsequently, the scaled matrix was transformed into a weighted normalized decision matrix by incorporating the criterion weights derived from the CRITIC method, as presented in Table 8. The next step involved calculating the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS), which were then used to compute the separation measures from the ideal solution (S_i^*) and from the anti-ideal solution ($S_i^{'}$). Finally, the relative closeness to the ideal solution (C_i^*) was calculated for each alternative. These results are summarized in Table 9 and organized by criterion.

Table 7
Scaled Decision Matrix.

Alternatives / Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	4.60	4.30	5.00	4.20	4.50	4.80	4.10	4.70
A_2	3.80	3.50	4.20	3.60	3.70	4.00	4.50	4.00
A_3	4.20	4.40	4.50	3.90	4.10	4.40	4.00	4.20
A_4	4.90	4.80	4.90	4.70	4.60	4.90	3.70	3.80
A_5	3.70	3.90	3.50	3.30	3.60	3.80	4.80	3.90
Sum	9.54	9.40	9.96	8.88	9.21	9.84	9.48	9.24

Table 8
Normalized Weighted Decision Matrix.

Alternatives / Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.48	0.46	0.50	0.47	0.49	0.49	0.43	0.51
A_2	0.40	0.37	0.42	0.41	0.40	0.41	0.47	0.43
A_3	0.44	0.47	0.45	0.44	0.45	0.45	0.42	0.45
A_4	0.51	0.51	0.49	0.53	0.50	0.50	0.39	0.41
A_5	0.39	0.41	0.35	0.37	0.39	0.39	0.51	0.42

Table 9
Weighted Decision Matrix.

Alternatives / Criteria	$C_1^{\max}$	$C_2^{\max}$	$C_3^{\max}$	$C_4^{\max}$	$C_5^{\max}$	$C_6^{\max}$	$C_7^{\min}$	$C_8^{\max}$
A_1	0.04	0.05	0.04	0.04	0.04	0.04	0.14	0.08
A_2	0.04	0.04	0.03	0.03	0.04	0.03	0.16	0.06
A_3	0.04	0.05	0.04	0.04	0.04	0.04	0.14	0.07
A_4	0.05	0.05	0.04	0.04	0.04	0.04	0.13	0.06
A_5	0.03	0.04	0.03	0.03	0.04	0.03	0.17	0.06

The data from Table 9 were used to calculate the distance of each alternative from the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS), based on Equations (3.14) and (3.15). Subsequently, the relative closeness coefficient to the ideal solution for each alternative was computed using Equations (3.16) and (3.17). The results of these calculations are presented in Table 10.

Table 10
Relative Closeness Coefficients to the Ideal Solution.

Alternatives	S_i^*	S_i'	C_i^*	Rank
A_1	0.022	0.047	0.676	2
A_2	0.052	0.017	0.252	4
A_3	0.024	0.045	0.658	3
A_4	0.001	0.067	0.983	1
A_5	0.066	0.006	0.084	5

According to Table 10, the relative closeness values (C_i^*) for each alternative in the supplier selection process were determined using the CRITIC–TOPSIS method, based on the positive ideal solution (S_i^*) and the negative ideal solution (S_i'). Supplier D (A_4) achieved the highest closeness score ($C_i^* = 0.983$), ranking first overall. This result indicates that Supplier D is the most appropriate choice when considering both economic and environmental criteria, as evidenced by the smallest positive separation ($S_i^* = 0.001$), suggesting that its performance closely aligns with the ideal solution across nearly all criteria.

Following Supplier D, Supplier A (A_1) and Supplier C (A_3) ranked second and third, with C_i^* values of 0.676 and 0.658, respectively. These two suppliers exhibited moderate distances from the ideal solution, indicating relatively strong performance, although with some areas for improvement when compared to Supplier D. Supplier B (A_2) obtained a C_i^* value of 0.252, placing it in fourth position. While Supplier B demonstrated acceptable performance in certain criteria, it lagged behind the top-ranked alternatives due to several limitations.

Finally, Supplier E (A_5) received the lowest closeness score ($C_i^* = 0.084$), ranking last among the alternatives. This outcome reflects a significant distance from the ideal solution across most criteria, despite having a relatively low negative separation ($S_i' = 0.006$) in some aspects. Overall, the results indicate that Supplier E failed to sufficiently meet the evaluation criteria.

In summary, the findings confirm that Supplier D is the most suitable choice in terms of both economic and environmental performance. Suppliers A and C emerge as secondary candidates with potential, whereas Suppliers B and E exhibit several performance gaps that may inform future improvement strategies.

Table 11
Comparison of Fuzzy TOPSIS, WASPAS, and the Proposed Method.

Alternatives	Fuzzy TOPSIS	Rank	WASPAS	Rank	Proposed	Rank
A_1	0.754	2	0.939	2	0.676	2
A_2	0.199	4	0.808	4	0.252	4
A_3	0.593	3	0.898	3	0.658	3
A_4	0.875	1	0.968	1	0.983	1
A_5	0.052	5	0.772	5	0.084	5

Table 12
Correlation Coefficient Comparison Results.

Method	Fuzzy TOPSIS	WASPAS	Proposed
Fuzzy TOPSIS	1.000	1.000	1.000
WASPAS	1.000	1.000	1.000
Proposed	1.000	1.000	1.000

According to Table 12, the Spearman correlation coefficient is equal to 1.000 for all method pairs. This indicates that all three methods yield identical supplier rankings, demonstrating complete consistency across the approaches.

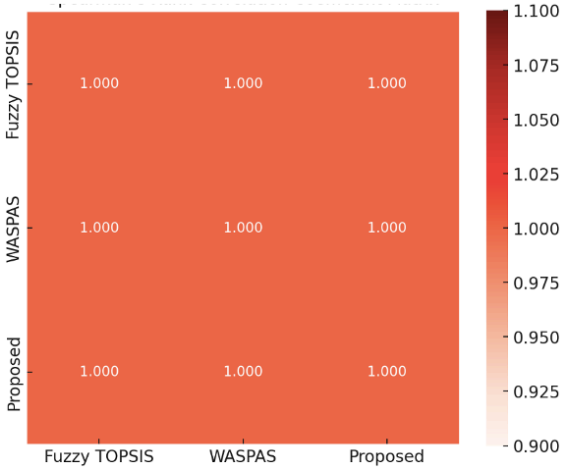


Figure 2: Spearman's Rank Correlation Coefficients.

As shown in Figure 2, the analysis reveals that the Spearmans rank correlation coefficient () among the three methods Fuzzy TOPSIS, WASPAS, and the proposed method is equal to 1.000 for all pairwise comparisons. This indicates that all three methods produce identical supplier rankings, with no discrepancies in rank positions. Statistically, a Spearmans value of 1.000 represents a perfect positive correlation, meaning that any change in ranking by one method is consistently mirrored in the other methods. This result confirms the consistency and reliability of the applied Multi-Criteria Decision-Making (MCDM) techniques.

5. Conclusions and Discussion

The application of the CRITIC–TOPSIS decision-making method proved to be effective for selecting environmentally friendly suppliers in the automotive parts manufacturing industry. The analysis revealed that the cost criterion (C_7) received the highest weight (0.33), underscoring the critical role of cost considerations in business operations. The delivery criterion (C_8) followed with a weight of 0.15, while health and safety, sustainable product design, green packaging, and quality criteria were assigned weights ranging between 0.08 and 0.10. Other criteria carried slightly lower weights, highlighting the interplay between economic and environmental factors in supplier evaluation.

The supplier ranking obtained using the TOPSIS technique indicated that Supplier D (A_4) achieved the highest relative closeness score ($C_i^* = 0.983$), ranking first overall. This result reflects its strong performance across both economic and environmental dimensions. Suppliers A (A_1) and C (A_3) followed closely, with relative closeness scores of 0.676 and 0.658, respectively. In contrast, Suppliers B (A_2) and E (A_5) scored significantly lower (0.252 and 0.084), indicating limitations in meeting the established evaluation criteria.

Overall, these findings demonstrate that integrating the CRITIC and TOPSIS methods provides a transparent and reliable analytical tool for green supplier selection in the automotive parts supply chain. The proposed approach enables organizations to make rational decisions that account for economic performance, quality, and environmental sustainability, ultimately supporting the development and advancement of a more sustainable automotive supply chain.

Author Contributions

Pariwat Nasawat: investigation, writing-original draft and software.
Prawach Chourwong: conceptualization and writing-review.
Seksan Singthanu: supervision, conceptualization and writing-review.
Methee Promsila: supervision, conceptualization and writing-review.

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