

From the above study, it is found that many papers used only one method, don't consider absolute reference of the criteria, and past data for their research. They used a few criteria and sub-criteria for their research. In this research, adequate criteria are selected for getting a best result. We will use AHP and CRITIC method for weighted the criteria then PROMETHEE method is used for aggregating these criteria to rank the supplier and select the best supplier. The methods are performed by a MCDM aid software named Visual PROMETHEE.

3. Methods

3.1 Criteria

The criteria were selected from reviewing the literature review. The criteria were primarily divided into four categories like economic, environmental, social and service & communicational. Economic criteria refer to the ability for the supplier to supply the product economically. Price (C1), quality (C2), technical capacity (C3), production capacity (C4) and flexibility & delivery (C5) are the sub-criterion in this section. More the economic value gives more acceptable of the suppliers. Environmental criteria refer to how the supplier supply the product to the industry with less pollution in the environment. Environmental management system (C6), waste management (C7), resource consumption (C8), green packaging and labeling (C9) are the sub-criteria in this section. The supplier should also consider environmental impact to supply the product. Social criteria refer to the supplier should also consider the sociological factors to supply the product. Health & safety (C10), employment practices (C11), right of stock holder (C12), information disclosure (C13) are the sub-criteria in this section. Service & Communicational criteria plays a great impact to ensure the continual flow of resources and goods through the supply chain. Geographical location (C14), replenishment lead time (C15), reliability (C16), vehicles capacity (C17), risk management (C18), alternative transportation (C19), and storage capacity (C20) are the sub-criteria in this section.

3.2 Structural Framework of the Proposed Research

This research was carried out using a three-phase process. At first phase, the criteria were selected from literature review and a survey questionnaire was prepared based on the criteria. Then a survey report was prepared by surveying from the expertise people. The weights of the criterion have been assessed in the second phase using AHP & CRITIC method. Finally, the third phase concluded with the application of the PROMETHEE method to rank the suppliers in accordance with the criterion and weight. The structural framework for choosing sustainable suppliers is presented in Figure 1.

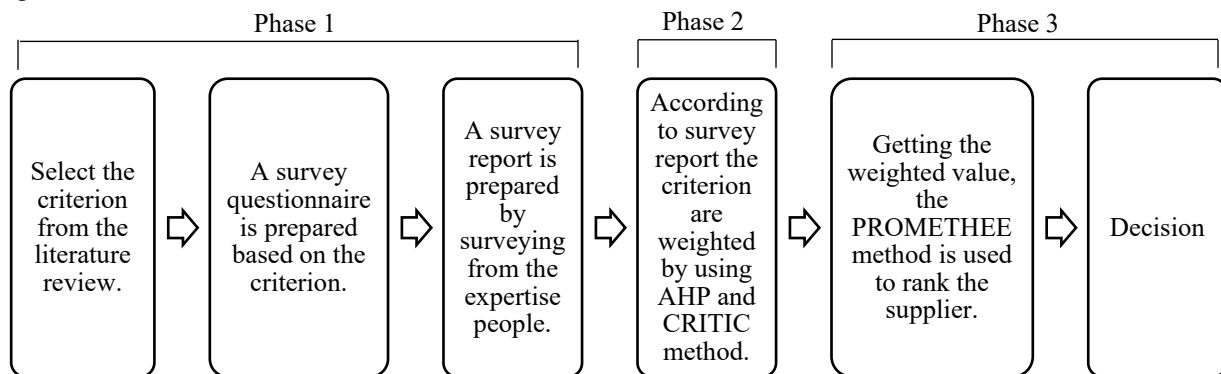


Figure 1. Structural framework of the proposed research.

3.2 AHP Method

AHP means Analytic Hierarchy Process which solves complex decision problem. It uses math and psychology. The steps for AHP method are given below:

Step 1: At first, the goal, criteria, and sub-criteria were selected for the research.

Step 2: Then a pair-wise comparison matrix was created by the survey analysis. It used Saaty's scale for comparing two criteria Saaty (2008). Then a normalized pair wise matrix was created by dividing each value of the pair-wise matrix by the sum of the column values for each criterion.

Step 3: The criteria weight was calculated by average value of each row value in normalized pair-wise matrix. Then each criteria weight was multiplied by each value of the normalized pair-wise matrix.

Step 4: Then the weighted sum value was calculated by the sum of each row in pair-wise matrix was calculated.

Step 5: Then the maximum Eigen value denoted as λ_{\max} was calculated by averaging the divided value of weighted sum value and criteria weight. Using Eq. (3.1) to find out Consistency Index (C. I.).

$$C. I. = \frac{\lambda_{\max} - n}{n - 1} \quad (3.1)$$

Where, n = no of criteria

Step 6: Using Eq. (3.2) to find out Consistency Ratio (C. R.) and check if it is below 10% or not. If it is below 10% then it is accepted otherwise is rejected. R. I. means Random Index number which was obtained by Random Index table provided by the www.spicelogic.com.

$$C. R. = \frac{C.I.}{R.I.} \quad (3.2)$$

3.3 CRITIC Method

CRITIC means CRiteria Importance Through Inter-criteria Correlation. It is a MCDM tool that use to determine the weighted of the criteria. The steps of this method are given below:

Step 1: The several criteria, sub-criteria and goals were selected for the research.

Step 2: Best and worst criteria was selected from the criterion and using Eq. (3.3) for creating normalize decision matrix.

$$\bar{X}_{i,j} = \frac{X_{i,j} - X_j^{\text{worst}}}{X_j^{\text{best}} - X_j^{\text{worst}}} \quad (3.3)$$

Where, i, j = row and column number.

Step 3: Using Eq. (3.4) to calculate the standard deviation denoted as σ then a $n \times n$ linear correlation matrix was created.

$$\sigma_j = \sqrt{\frac{(X_{i,j} - \bar{X}_j)^2}{n - 1}} \quad (3.4)$$

where, \bar{X}_j = mean value of the matrix, n = number of linguistic variables.

Step 4: Measure of conflict was determined by subtracting one to the value in step 3. Then the quantity of information in relation for each criterion was determined by the Eq. (3.5).

$$C_j = \sigma_j \times \sum_{k=1}^n (1 - r_{j,k}) \quad (3.5)$$

Where, C_j = quantity of the information, k = 1, 2, 3,..... n.

Step 5: Using Eq. (3.6) to find weighted criteria.

$$w_j = \frac{C_j}{\sum_{k=1}^n C_j} \quad (3.6)$$

Where, w_j = weighted criteria

3.4 PROMETHEE I & II Method

PROMETHEE means Preference Ranking Organization Method for Enrichment Evaluation. It is also a multi-criteria decision analysis method. It is used for ranking the suppliers. The steps are given below:

PROMETHEE I

Step 1: At first, the sub-criteria weight was found out from the AHP and CRITIC method.

Step 2: Beneficial and non-beneficial criteria were selected from the respective criterion then normalized evaluation matrix was created using the Eq. (3.7) & Eq. (3.8)

$$R_{i,j} = \frac{[x_{i,j} - \min(x_{i,j})]}{[\max(x_{i,j}) - \min(x_{i,j})]} \quad (\text{for beneficial criteria}) \quad (3.7)$$

$$R_{i,j} = \frac{[\max(x_{i,j}) - x_{i,j}]}{[\max(x_{i,j}) - \min(x_{i,j})]} \quad (\text{for non-beneficial criteria}) \quad (3.8)$$

Where, x = value of criteria, i, j = number of rows and column, R = range value which below between 0 and 1.

Step 3: The difference between each alternative to the other alternative was calculated then find out the preference function to check the difference was less than or equal to zero or not. If it was less than or equal to zero then it taken as zero otherwise it was same as the range value in step 2.

Step 4: The aggregate preference function was calculated by using Eq. (3.9).

$$\Pi(a, b) = \frac{\sum_{j=1}^n w_j \times P_j(a,b)}{\sum_{j=1}^n w_j} \quad (3.9)$$

Where, w_j = weighted criteria

Step 5: The leaving and entering value denoted as $\varphi^+(a)$ and $\varphi^-(a)$ was calculated by summing the row and column on the matrix. Then compare one alternative to the other alternatives using three condition and developed a ranking model.

Condition 1: Alternatives a was preferred over alternatives b, aPb
 aPb if: $\varphi^+(a) > \varphi^+(b)$ and $\varphi^-(a) < \varphi^-(b)$; or $\varphi^+(a) > \varphi^+(b)$ and $\varphi^-(a) = \varphi^-(b)$;
 or $\varphi^+(a) = \varphi^+(b)$ and $\varphi^-(a) < \varphi^-(b)$.

Condition 2: Indifferent situation, aIb
 aIb if: $\varphi^+(a) = \varphi^+(b)$ and $\varphi^-(a) = \varphi^-(b)$.

Condition 3: Incomparable situation, aRb
 aRb if: $\varphi^+(a) > \varphi^+(b)$ and $\varphi^-(a) > \varphi^-(b)$; $\varphi^+(a) < \varphi^+(b)$ and $\varphi^-(a) < \varphi^-(b)$.

PROMETHEE II

Step 1 to Step 4: Same as PROMETHEE I method.

Step 5: The leaving and entering value denoted as $\varphi^+(a)$ and $\varphi^-(a)$ was calculated by averaging the row and column on the matrix. Then net out ranking value was calculated by subtracting the leaving and entering value. Denote the net out ranking value as descending order as 1, 2, 3,..... n.

4. Data Collection

The data was collected primarily about the importance of the criterion in case of supplier selection from the expertise of the supply chain department through survey questionnaire and personal interview. The alternative supplier's performance with respect to criteria was collected primarily from a manufacturing company. The linguistic scale was used to evaluate the importance of the criteria in case of supplier selection and the alternative supplier's performance with respect to criteria.

5. Results and Discussion

In this research visual PROMETHEE a MCDM aid software was used to rank and visualized the effective supplier. Visual PROMETHEE naturally follow the PROMETHEE I & II method to show the effective result. It shown the result as PROMETHEE I partial ranking, PROMETHEE II complete ranking, PROMETHEE network, PROMETHEE flow table and action profile. The weighted criteria obtained from AHP and CRITIC method put in visual PROMETHEE software to find out the rank of the effective supplier. The weighted criteria are shown at Table 1.

Table 1. Weighted criteria of AHP & CRITIC method.

Criteria	AHP method	CRITIC method
C1	0.086	0.052
C2	0.146	0.067
C3	0.055	0.043
C4	0.060	0.038
C5	0.082	0.056
C6	0.012	0.035
C7	0.017	0.041
C8	0.014	0.088
C9	0.012	0.037
C10	0.024	0.038
C11	0.008	0.048
C12	0.016	0.036
C13	0.024	0.063
C14	0.088	0.090
C15	0.120	0.055
C16	0.113	0.059
C17	0.034	0.041
C18	0.034	0.035
C19	0.019	0.037
C20	0.037	0.040

5.1: Integrated AHP-PROMETHEE Method

In PROMETHEE I partial ranking at Figure 2, supplier 5 is preferred in all other suppliers. Supplier 1 & 2 shown the indifferent situation as a result it intersects to one another. On the other hand, in PROMETHEE II complete ranking at Figure 3, supplier 5 is preferred than other suppliers, supplier 1 and 2 are closely related.

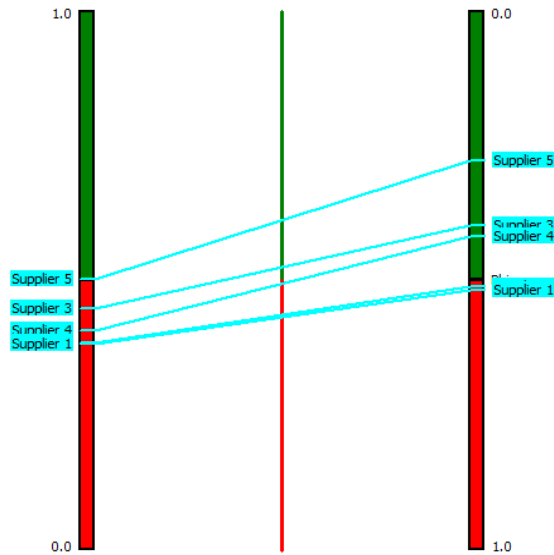


Figure 2. PROMETHEE I partial ranking.

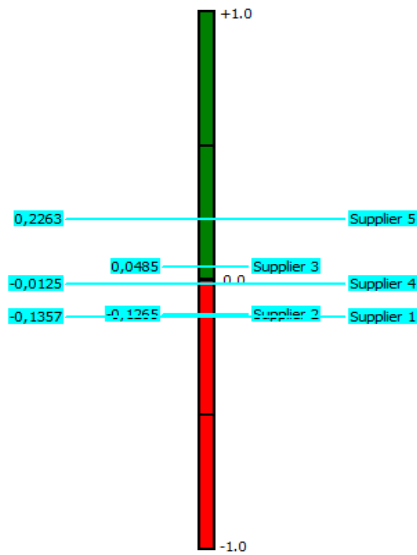


Figure 3. PROMETHEE II complete ranking.

In PROMETHEE network at Figure 4, it represents the alternative display of PROMETHEE I method. Here the alternatives are represented by the node and preference are represented by the arrays. Here, supplier 5 is most preference than other suppliers, then supplier 3, then supplier 4, then supplier 2 or 1 is preferable.

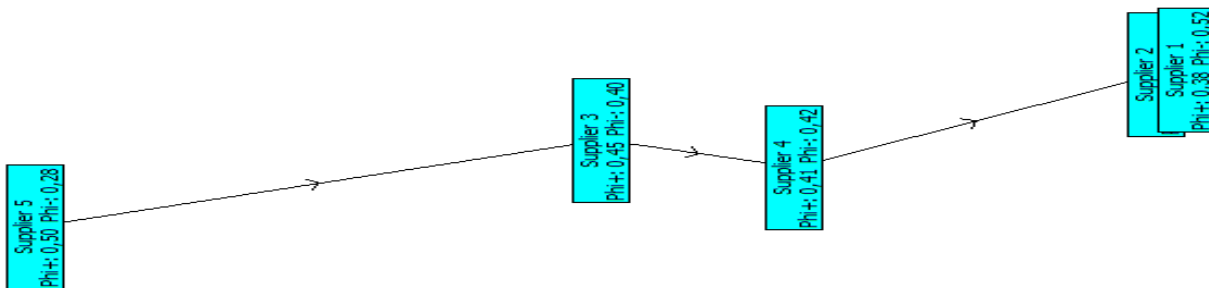


Figure 4. PROMETHEE network.

In PROMETHEE flow table at Table 2, it represents the rank value of the PROMETHEE II complete ranking. Supplier 5 has rank value 1, supplier 3 has rank value 2, supplier 4 has rank value 3, supplier 2 has rank value 4, and supplier 1 has rank value 5. The PROMETHEE II demonstrates supplier 5 outperforms alternative options. This present that supplier 5 is the most suitable supplier under the current conditions.

Table 2. PROMETHEE flow table.

Rank	Action	ϕ	ϕ^+	ϕ^-
1	Supplier 5	0.2263	0.5028	0.2765
2	Supplier 3	0.0485	0.4467	0.3982
3	Supplier 4	-0.0125	0.4058	0.4183
4	Supplier 2	-0.1265	0.3842	0.5108
5	Supplier 1	-0.1358	0.3815	0.5172

In action profile, it displayed a graphical representation of the selected action's single-criteria net flow score. Positive score represented the good feature and negative score represented the bad feature. In supplier 1 at Figure 5, price, delivery and flexibility, resource consumption, information disclosures, reliability, vehicle capability, risk management represented good features. On the other hand, quality, technical capacity, production capacity, environmental management system, waste management, green packaging & labeling, health & safety, employment practice, right of stock holder, geographical location, replenishment lead time, alternative transportation and storage capacity represented bad features.

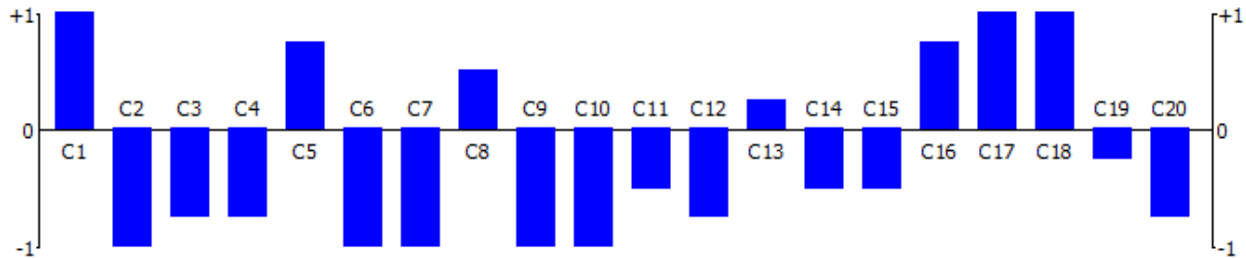


Figure 5. Action profile of supplier 1.

In supplier 2 at Figure 6, price, production capacity, waste management, resource consumption, health & safety, right of stock holder, information disclosures, geographical location, and alternative transportation represented good features. On the other hand, quality, technical capacity, delivery & flexibility, environmental management system, green packaging & labeling, employment practice, replenishment lead time, reliability, storage capacity represented bad features. Vehicle capacity and risk management represented neutral feature.

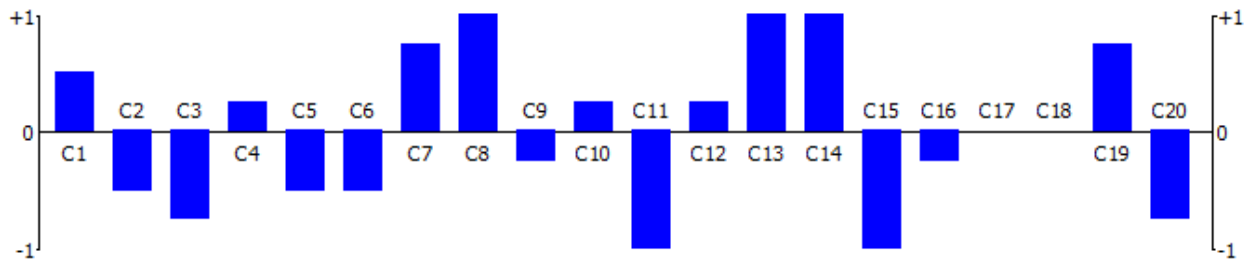


Figure 6. Action profile of supplier 2.

In supplier 3 at Figure 7, quality, technical capacity, production capacity, environmental management system, green packaging & labeling, right of stock holder, geographical location, replenishment lead time, risk management and storage capacity represented good features. On the other hand, waste management, resource consumption, health & safety, information disclosures, reliability, vehicle capacity and alternative transportation represented bad features. Price, delivery & flexibility, employment practice represented neutral feature.

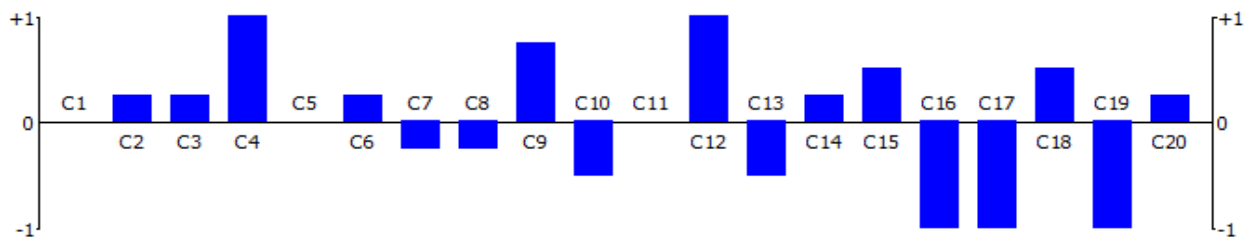


Figure 7. Action profile of supplier 3.

In supplier 4 at Figure 8, quality, technical capacity, production capacity, environmental management system, health & safety, employment practice, information disclosures, replenishment lead time, alternative transportation and storage capacity represented good features. On the other hand, price, delivery & flexibility, waste

management, resource consumption, green packaging & labeling, right of stock holder, geographical location, reliability, risk management represented bad features. Vehicle capacity represented neutral features.

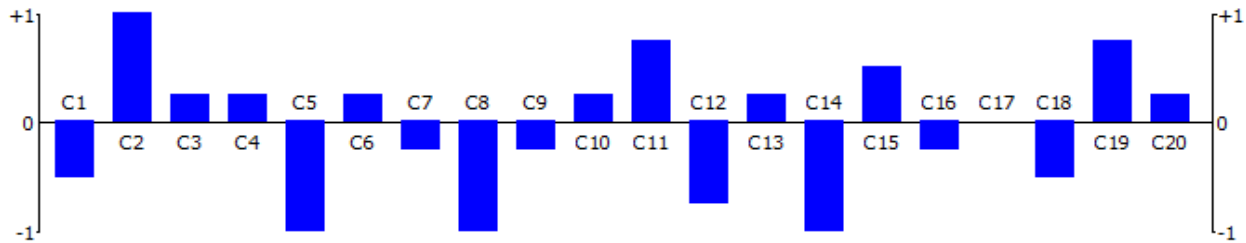


Figure 8. Action profile of supplier 4.

In supplier 5 at Figure 9, quality, technical capacity, delivery & flexibility, environmental management system, waste management, green packaging & labeling, health & safety, employment practice, right of stock holder, geographical location, replenishment lead time, reliability, and storage capacity represented good features. On the other hand, price, production capacity, resource consumption, information disclosures, risk management, alternative transportation represented bad features. Vehicle capacity represented neutral feature.

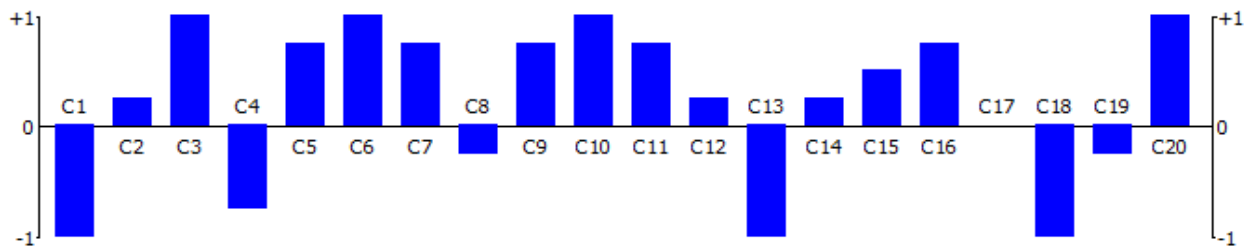


Figure 9. Action profile of supplier 5.

5.2 Integrated CRITIC-PROMETHEE Method

PROMETHEE I partial ranking at Figure 10, supplier 5 is most preferred than another supplier, supplier 1 & 4 shown incomparable situation. On the other hand, in PROMETHEE II complete ranking at Figure 11, supplier 5 is most preferred, supplier 1 & 4 is closely related.

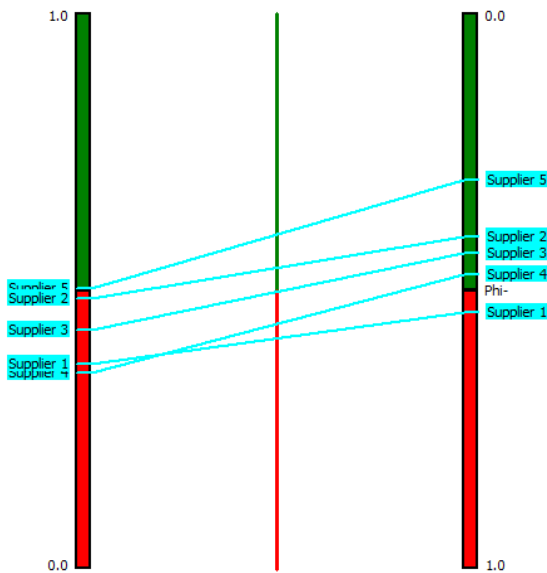


Figure 10. PROMETHEE I partial ranking.

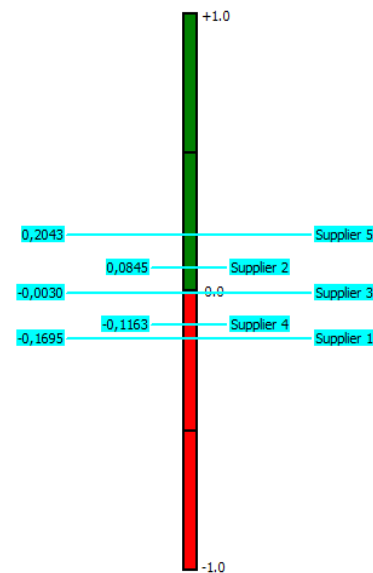


Figure 11. PROMETHEE II complete ranking.

In PROMETHEE network at Figure 12, supplier 5 is most preferred, then supplier 2, then supplier 3, then supplier 4 or 1.

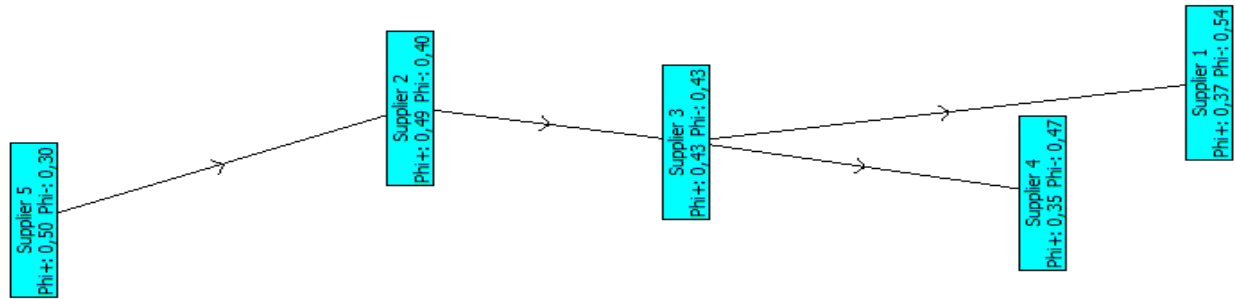


Figure 12. PROMETHEE network.

In PROMETHEE flow table at Table 3, supplier 5 has rank 1, supplier 2 has rank 2, supplier 3 has rank 3, supplier 4 has rank 4 and supplier 1 has rank 5. The PROMETHEE II demonstrates that supplier 5 outperforms alternative options. This shows that supplier 5 is the most suitable supplier under the current conditions.

Table 3. PROMETHEE flow table.

Rank	Action	φ	φ^+	φ^-
1	Supplier 5	0.2043	0.5035	0.2993
2	Supplier 2	0.0845	0.4858	0.4014
3	Supplier 3	-0.0030	0.4295	0.4325
4	Supplier 4	-0.1163	0.3534	0.4697
5	Supplier 1	-0.1695	0.3686	0.5381

The result of the action profile in integrated CRITIC-PROMETHEE method is same as the integrated AHP-PROMETHEE method.

Above all the analysis, it was clear that supplier 5 give the best result in comparing with other suppliers. The different criteria weight of AHP and CRITIC method that use in visual PROMETHEE software represented the same result. Both methods given the supplier 5 was most preferable than another supplier. The evaluation of the AHP-PROMETHEE and CRITIC-PROMETHEE techniques revealed that supplier 5 was the most sustainable supplier for the manufacturing company when all the criterion were taken into account.

5.3 Discussion

Choosing the best supplier from a number of alternatives based on a variety of criteria is a complex process. In this research, the weights of the evaluation criteria were determined using the AHP and CRITIC methods, and PROMETHEE was used to rank the sustainable suppliers. The consistency ratio of AHP method was 2.73% which is less than 10% that represents the acceptance of the process. The criteria weight was further used in visual PROMETHEE software as an input value. In PROMETHEE I partial ranking for AHP-PROMETHEE and CRITIC-PROMETHEE method supplier 5 was shown the most preferable ranked in all other suppliers. In AHP-PROMETHEE method supplier 1 and 2 was shown the indifferent situation where CRITIC-PROMETHEE method supplier 1 and 4 was shown the incomparable situation. Here the supplier 5 is most preferred then other suppliers. In PROMETHEE II complete ranking for AHP-PROMETHEE and CRITIC-PROMETHEE, the supplier 5 shown the first ranked in all other suppliers. In PROMETHEE network, it represents a visual ranking model for PROMETHEE I partial ranking. In AHP-PROMETHEE and CRITIC-PROMETHEE, supplier 5 was given the best performance by analyzing the overall network. In action profile, it represents the several bad and good features for each supplier for each criterion. By analyzing the overall suppliers, the supplier 5 has less bad feature by comparing the other suppliers. The evaluation of AHP-PROMETHEE and CRITIC-PROMETHEE methodologies recommended that supplier 5 was the most sustainable for the company when all the criteria were considered.

6. Conclusion

The purpose of this research was to develop a structural framework of sustainable supplier selection for raw materials in a manufacturing industry. For research work primarily selected five suppliers for the alternative supplier's performance with respect to criteria. Several MCDM method was applied to find out the rank of different of suppliers. AHP and CRITIC was used to find out the weighted criteria for different criterion and MCDM aid software named visual PROMETHEE was used to rank the supplier. The weighted criteria from the AHP and CRITIC methods were put into the visual PROMETHEE software to determine the rank of alternative suppliers. Both the integrated AHP-PROMETHEE and CRITIC-PROMETHEE methods give that supplier 5 is preferred over other suppliers in PROMETHEE I partial ranking, PROMETHEE II complete ranking, and achieved first rank in PROMETHEE flow table. Furthermore, supplier 5 outperforms the other suppliers in the PROMETHEE network. According to the results analysis, supplier 5 is the best alternative supplier and supplier 1 is the worst supplier for the manufacturing company. In this research, top sustainable supplier selection criteria were price, quality, resource consumption, geographical location. These criteria had a high impact on supplier 5. As a result, supplier 5 was the most sustainable supplier for the manufacturing industry.

The manufacturing sector at steel industry has been the main focus of this research. This method can be applied other sectors such as, pharmaceutical businesses, leather producers, automakers, chemical plants, and cement manufacturers, The best alternatives will be chosen by using the TOPSIS, VIKOR, MARCOS, Best-Worst, DEMATEL, and Entropy methodologies, which can be used to compare the proposed framework to other multi-criteria decision-making techniques will be employed to identify the most suitable alternatives.

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