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Selection of Optimum Biodiesel for Rural Electrification Using Hybrid MCDM Technique

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Abstract: For rural electrification, biodiesel is regarded as one of the major source. The power generated from the diesel power plant depends upon the fuel used. The characteristics and properties of biodiesel varied with respect to the raw materials. Due to the conflicting attributes of the parameters, selecting suitable bodiesel is a cumbersome work. An application of Multi-Criteria Decision-Making (MCDM) technique for selecting a suitable biodiesel for a diesel power generator is shown in this study. Fuzzy Analytic Hierarchy Process (FAHP) is integrated with VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) to analyze the various properties of each fuel and rank them, which is validated by the FAHP-PROMETHEE (Preference Ranking Organization method for Enrichment of Evaluations). This study focuses on seven alternative fuels with seven evaluation criteria. The result shows that Pongamia is the best alternative among the selected alternatives.

Key words: Biodiesel, power generation, MCDM, FAHP, VIKOR, PROMETHEE

INTRODUCTION

Now a days with increase in the population of the world, rapid development of technology and increase in the standard of living, consumption of energy has also increased. In remote areas, some villages are still out of reach from electricity because provide grid connection is impossible. In the world, nearly two billion people that have no access to electricity (Sebitosi and Pillay, 2005). To provide the electricity for remote locations, off grid distributed generating system is the best alternative (Cherni *et al*., 2007). Utilization of locally available energy resource is the way to provide reliable electricity using distributed generating system. In remote locations, diesel generators are used to provide the power supply. In such locations, the feed stocks of non edible oil crops are widely available. In the past decade researches were made on the use of plants oils and fats as a sustainable energy source (Martini and Schell, 2012). Biodiesel is environment-friendly which can be manufactured from both edible and non-edible oils (Demirbas, 2008). For biodiesel production non-edible oil is the reliable feed stock (Balat, 2011; Demirbas, 2008). For the production of biodiesel, over 350 oil crops were determined to be possible sources. Biodiesel is highly degradable, minimal toxic and can be used in different applications without modifications (Martini and Schell, 2012).

Research gap: Use of biodiesel as a source for power generation is gradually increased in the past few decades. Voltage regulation and frequency of groundnut oil biodiesel are similar to diesel (Eevera and Pazhanichamy, 2013). Merve cetinkaya et.al, have identified improvement in performance and emission characteristics when used the waste cooking oil for power generation. Biodiesels of cotton seed and palm oils give better electrical efficiency (Eevera and Pazhanichamy, 2013).

The overall efficiency of Jatropha and Karanj biodiesel was enhanced by blending of diesel. The fuel consumption of soya bean biodiesel is less when compared to castor oil biodiesel (Prasad *et al*., 2010). Emissions such as CO, SO_2, CxHy were reduced by use of the blend of soybean biodiesel. Waste-edible-oil biodiesel was used to reduce the emission of PM, elemental/organic carbon and PAH. Rapeseed methyl ester was used as a fuel for an electric generator by Kennedy and the emission characteristics were also observed.

From the past studies, there is no research focus on the selection of fuel using MCDM tools. Hybrid MCDM models developed for evaluating

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and selecting optimum fuel to operate the diesel power generator are described in the present study.

MATERIALS AND METHODS

Biodiesel preparation: Non-edible oils are extracted from the seeds or kernels of Pongamia, Jatropha, Cotton, Neem, linseed, Mahua and Meusa Ferra. About 68-80% oil can be extracted from seeds using a screw press. The extracted oil is further filtered and degummed to remove dirt and other inert materials. The problems related to crude oils such as high viscosity, low volatility and polyunsaturation are overcome using transestrification process. Because of it being economical and simple, transesterification is considered to be one of the best methods of the various approaches. High purity and higher yield of biodiesel were achieved with the help of this method in a short time (Kalbande *et al*., 2008). The extracted oil is heated to a temperature of 60°C. Then, for every 1 L of oil, the mixture of 150ml of methanol and 7gm of NaOH was added to heated oil and stirred for 90 min at a speed of 750 rpm. The mixture is then kept for about 30 min without interruption. The bottom layer is occupied by Now the glycerol and the top layer contains biodiesel. The biodiesel is then moved to washing compartment. Washing of biodiesel is categorized by 4 washes using water at the temperature of 50 °C. Firstly with 150 mL of acetic acid and second with 75 mL of acetic acid. Third and fourth washes are done with hot water alone. To remove the moisture content, the washed fuel is heated up to 110°C. Finally, the extracted bio diesel is filtered with 5micron filter. The above process takes 8 h. The various properties of prepared alternative biodiesel are listed in Table 1.

Fahp method: AHP (analytic hierarchy process) was developed by Saaty. Laarhoven and Pedrycz was developed FAHP by applying fuzzy logic principles in AHP to eliminate the uncertainty during pairwise comparison process (Brans *et al*., 1986). The steps involved in FAHP method are as follows:

Step 1: The problem is structured using a hierarchy.

Step 2: The pairwise comparison matrix A is formed by expert using the triangular fuzzy membership function.
Let C= {Cj | j =1, 2, ..., n |} be a set of criteria. The result of the pairwise comparison on "n" criteria can be summarized in an (n x n) evaluation matrix A in which every element $a_{i\,j}$ (I, j = 1, 2, ..., n) is the quotient of the weights of the criteria as shown:

Table 1: Fuel properties

	Calorific value $kJkg^{-1}$	Viscosity $mm^2\ sec^{-1}$	Density $kg\ m^{-3}$	Cetane number	Flash point °C	Cloud point °C	Pour point °C
Pongamia	43475	5.07	928.0	65.0	210	3.5	-3
Jatropha	40999	4.92	878.0	51.8	170	8.0	-2
Cotton seed	39403	4.58	878.6	52.6	204	14.0	5
Neem	39867	5.213	839.0	46.0	76	18.0	2
Linseed	36867	5.30	910.0	54.0	155	-3.6	-9
Mahua	39415	4.94	920.0	51.0	131	4.0	7
Meusa Ferra	39654	6.20	890.0	54.0	112	16.0	3

Table 2: Random Consistency Index (RCI)

No	RCI
1	0
2	0
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.40
9	1.45
10	1.49

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, a_{ii} = 1, a_{ji} = 1/a_{ij}$$

$$a_{ij} \neq 0 \tag{1}$$

Step 3: To normalize and find the relative weights of each matrix:

$$A_W = \lambda_{max} W \tag{2}$$

The consistency is defined by the relation between the entries of A: $a_{ij} \times a_{jk} \times = a_{jk}$ The Consistency Index (CI) is:

$$CI = (\lambda_{max} - n)/(n-1) \tag{3}$$

Step 4: To find the CR value for each square matrix:

$$CR = CI/RCI \tag{4}$$

The RCI value is chosen from Table 2 which depends on the matrix order.

Vikor method: VIKOR was developed by Opricovic to solve MCDM problems with conflicting and non-commensurable criteria (Dyer *et al*., 1992). Opricovic and Tzeng, reported that the VIKOR gives a maximum group utility and minimum individual regret of the opponent as compared to topsis. This method focuses on ranking from set of alternatives and determines the compromise solution obtained with the initial weights for a problem with conflicting criteria.

Assuming that each alternative is computed according to each criterion function, the compromise ranking is performed through comparing the measure of closeness to the ideal alternative. The various alternatives are denoted as A_1, A_2 ….A_m. For alternative A_j, the rating of the ith aspect is denoted by f_{ij}, i.e f_{ij} is the value of ith criterion function for the alternative a_j; n is the number of criteria. Development of VIKOR is started with the following form of LP- metric:

$$L_{pj} = \left\{ \sum_{i=1}^{n} \left[w_i \left(f_i^* - f_{ij} \right) \Big/ \left(f_i^* - f_i^- \right) \right]^p \right\}^{1/p}$$
$$1 \le p \le \infty, j = 1, 2, ..., J$$

In the VIKOR method L1, j (as Sj) and L_∞, j (as Rj) are used to formulate ranking measure. The results are obtained by minj Sj is with the maximum group utility (I_gmajority_rule) and the answer obtained by min Rj is with a minimum individual regret of the "gopponent"h. The compromise ranking algorithm of VIKOR encompass the following steps.

Step 1: The purpose of normalizing the performance matrix is to unify the unit of matrix entries. The determination of normalized values of alternatives x_{ij} is the numerical score of alternative j on criterion i. The corresponding normalized value f_{ij} is defined as follows:

$$r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{m} x_{ij}^2}, i = 1, 2, ..., m; j = 1, 2, ..., n \quad (5)$$

Step 2: Determine the best f_i^* and the worst f $_i^*$values for each criterion functions, i = 1, 2, ..., n:

$$f_i^* = \max_j f_{ij} \quad (6)$$

Step 3: The utility measure and the regret measure for each maintenance alternative are given as:

$$S_j = \sum_{i=1}^{n} w_i (f_i^* - f_{ij}) / (f_i^* - f_i^j) \quad (7)$$

$$R_j = \max_i \left[w_i (f_i^* - f_{ij}) / (f_i^* - f_i^j) \right] \quad (8)$$

where, S_i and R_i represent the utility measure and the regret measure, respectively and w_j is the weight of the j^{th} criterion.

Step 4: Calculate the VIKOR index:

$$Q_j = v(S_j - S^*) / (S^- - S^*) + (1 - v)$$
$$(R_j - R^*) / (R^- - R^*) \quad (9)$$

where $S^* = \min_j S_j$, $S^- = \max_j S_j$, $RE^* = \min_j R_j$, $R^- \max_j R_j$ and υ is introduced as weight of the strategy of "the majority of criteria" (or "the maximum group utility"), here V = 0.5.

Step 5: Rank the order of preference. The alternative with the smallest VIKOR value is determined to be the best value. Propose as a compromise solution the alternative A' which is ranked the best by the measure Q (Minimum) if the following two conditions are satisfied:
C1. Acceptable advantage:

$$Q(A'') - Q(A') \ge DQ$$

where, "A" is the alternative with second position in the ranking list by Q; DQ = 1/(m - 1); m is the number of alternatives.

C2; acceptable stability in decision making: Alternative A' must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be "voting by majority rule" (when v>0.5 is needed), or "by consensus" v ≅0.5, or "with veto" (v<0.5). Here, v is the weight of the decision making strategy "the majority of criteria" (or "the maximum group utility"). If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

- Alternatives A' and A" if only condition C2 is not satisfied, or
- Alternatives A', A",.., $A^{(M)}$ if condition C1 is not satisfied; $A^{(M)}$ is determined by the relation $Q(A^{(M)})$-Q(A)<DQ or maximum M (the positions of these alternatives are "in closeness")

PROMETHEE methodology: The preference function-based outranking method was developed by Brans *et al.* (1986). It is a special type of MCDM tools that can provide a ranking order of the alternatives. The PROMETHEE method which was further extended by Brans *et al.* (1986) and named as PROMETHEE II. PROMETHEE I method can provide a partial ordering of the decision alternatives whereas PROMETHEE II method can derive the full ranking of the alternatives. It is suitable for almost any kind of application having multiple criteria and various alternatives when the designer needs to choose a most appropriate alternative. The procedural steps involved in PROMETHEE II are enlisted below:

Step 1: First of all, a committee of decision makers is formed; fuzzy rating of each criterion can be represented as TFN with membership function.

Step 2: The appropriate crisp score is chosen for evaluating the alternatives.

Step 3: Based on the questionnaire, the suitable crisp score is assigned for alternative biodiesels by the decision maker. Then the decision matrix is formed.

Step 4: Normalize the decision matrix using the Eq. 10:

$$R_{ij} = \left[X_{ij} - \min X_{ij}\right] / \left[\max X_{ij} - \min X_{ij}\right] \quad (i=1,2,...,n : j=1,2,.....,m) \tag{10}$$

Where X_{ij} is the performance measure of ith alternative with respect to jth criterion. For non-beneficial criteria, Eq. 10 can be rewritten as follows:

$$R_{ij} = \left[X_{ij} - \min X_{ij}\right] / \left[\max X_{ij} - \min X_{ij}\right] \tag{11}$$

Step 5: Calculate the evaluative differences of i^{th} alternative with respect to otheralternatives. This step involves the calculation of differences in criteria valuesbetween different alternatives pair-wise.

Step 6: Calculate the preference function $P_j(i, I')$ It may be very tough for decision makers to select the suitable preference function for each criterion by Brans *et al.* (1986) proposal. In order to reducethe overburden of decision makers, the simplified preference function model by Brins and Vinke (2002) is implemented here:

$$p_j(i,i') = 0 \text{ if } R_{ij} \le Ri'j \tag{12}$$

$$p_j(i,i') = R_{ij} - Ri'j \text{ if } R_{ij} > Ri'j \tag{13}$$

Step 7: Calculate the aggregated preference function taking the criteria weights intoaccount.Aggregated preference function:

$$\pi(i,i') = \left[\sum_{j=1}^{m}[W_j \times P_j(i,i')] / \sum_{j=1}^{m}[W_j]\right] \tag{14}$$

where, Wj is the relative importance (weight) of j th criterion.

Step 8: Determine the leaving and entering outranking flows as follows: Leaving (or positive) flow for ith alternative:

$$\phi^{+}(i) = \frac{1}{n-1}\sum_{i=1}^{n}\pi(i,i') \quad (i \ne i)' \tag{15}$$

Entering (or negative) flow for ith alternative:

$$\phi^{-}(i) = \frac{1}{n-1}\sum_{i=1}^{n}\pi(i,i') \quad (i \ne i)' \tag{16}$$

where, n is the number of alternatives. Here, each alternative faces (n-1) number of other alternatives. The leaving flow expresses how much an alternative dominates the other alternatives, while the entering flow denotes how much an alternative is dominated by the other alternatives.

Step 9: Calculate the net outranking flow for each alternative. The net outranking flow is computed through the difference between leaving flow and entering flow of each alternative.

Step 10: Determine the ranking of all the considered alternatives depending on the values of $\varphi(i)$.The higher value of $\varphi(i)$, the better is the alternative. Thus, the best alternative is the one having the highest $\varphi(i)$ value.

Proposed methodology: The flow chart of proposed model is shown in Fig. 1, it consists of three stages. In the first stage, alternative fuels are determined and evaluating criteria are identified. The criteria weights are computed using FAHP in the second stage. The fuel ranks are determined using alternatives using VIKOR and PROMETHEE method in the last stage with FAHP computation criteria weights.

Criteria for selecting an optimum fuel: Various evaluation criteria such as calorific value, density, viscosity, cetane number, flash point, cloud point and pour point are identified through literature and experts (Fig. 1).

Computation of criteria weights using FAHP: The decision hierarchy is formed using the evaluation criteria and the alternate biodiesel are shown in Fig. 2.

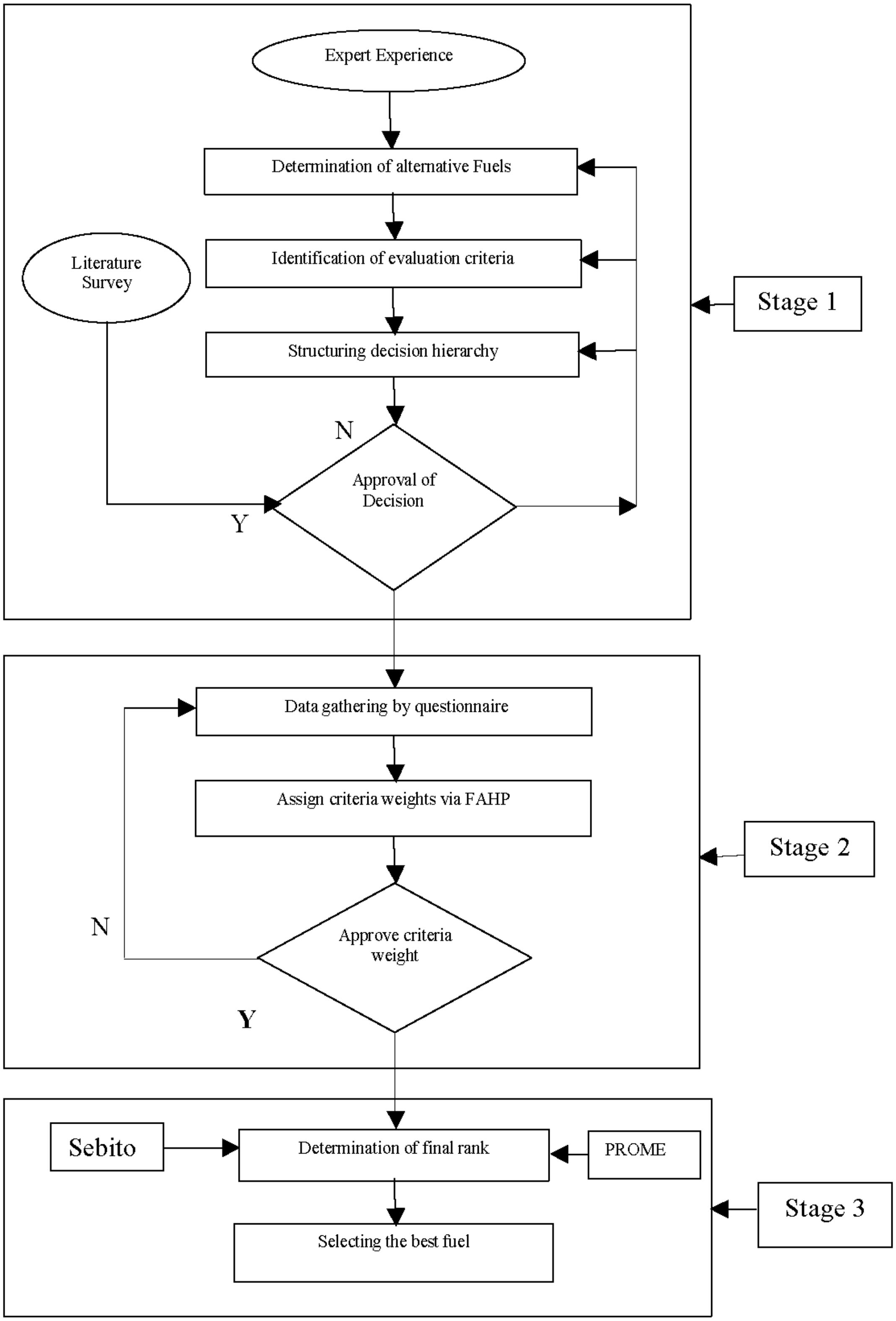

Fig. 1: Flow chart of the proposed model for fuel selection

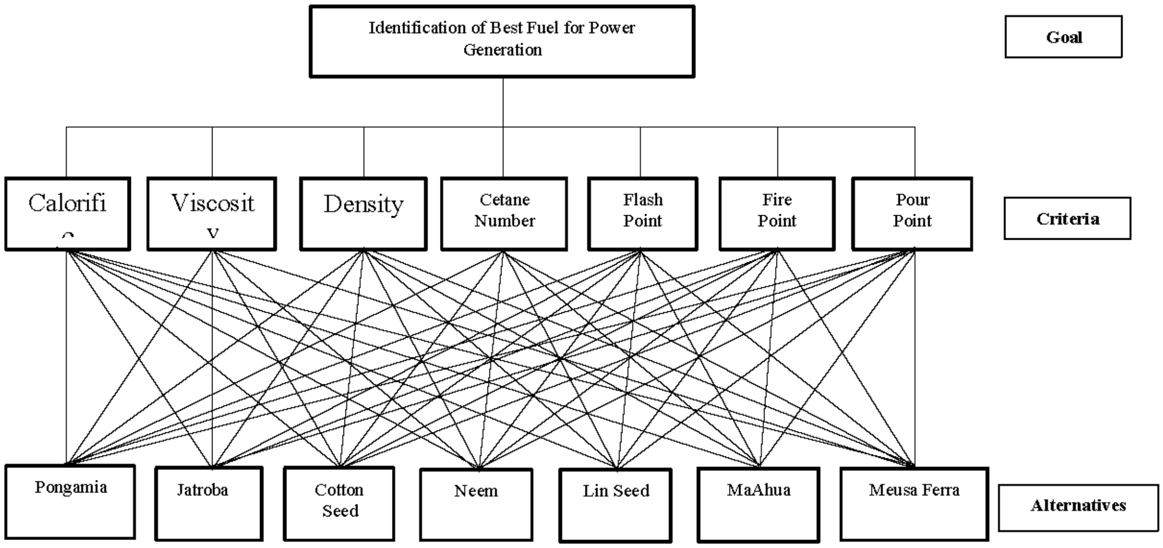

Fig. 2: Decision hierarchy of fuel selection

Table 3: Membership function of fuzzy numbers

Scale of importance	Triangular Fuzzy Number (TFN) (L, M, U)	Reciprocal of TFN (1/L,1/M, 1/U)
Just equal	(1, 1, 1)	(1, 1, 1)
Equal importance	(1, 1, 3)	(0.33, 1, 1)
Moderate	(1, 3, 5)	(0.20, 0.33, 1)
Strong importance	(3, 5, 7)	(0.14, 0.20, 0.33)
Very strong importance	(5, 7, 9)	(0.11, 0.14, 0.20)
Extremely preferred	(7, 9, 9)	(0.11, 0.11, 0.14)

Table 4: Pairwise comparison matrix for FAHP

Variables	Calorific value	Viscosity	Density	Cetane number	Flash point	Fire point	Pour point
Calorific value	1,1,1	1,1,3	3,5,7	1,3,5	5,7,9	5,7,9	7,9,9
Viscosity	0.333,1,1	1,1,1	1,1,3	1,3,5	5,7,9	5,7,9	7,9,9
Density	0.143,0.2,0.333	0.333,1,1	1,1,1	1,1,3	3,5,7	3,5,7	5,7,9
Cetane number	0.200,0.333,1	0.2,0.333,1	0.333,1,1	1,1,1	1,1,3	1,1,3	5,7,9
Flash point	0.111,0.143,0.2	0.111,0.143,0.2	0.143,0.2,0.333	0.333,1,1	1,1,1	1,1,3	5,7,9
Fire point	0.111,0.143,0.2	0.111,0.143,0.2	0.143,0.2,0.333	0.333,1,1	0.333,1,1	1,1,1	1,3,5
Pour point	0.111,0.111,0.143	0.111,0.111,0.143	0.111,0.143,0.2	0.111,0.143,0.2	0.111,0.143,0.2	0.2,0.333,1	1,1,1

The decision hierarchy structure comprises three levels: first level, selection of optimum fuel; second level, the criteria; and third level, the alternate biodiesels. The expert team then forms the pair-wise comparison matrix using triangular fuzzy scales from Table 3, shown in Table 4. Then using Eq. 3 and 4, the individual weights, CI and CR are evaluated. Table 5 shows the calculated CI, CR and weights of the criterion. The calculated weight is consistent as the CR is less than the predefined value 0.1.

VIKOR computations: The first step is to develop the normalization matrix by normalizing the fuel performance parameters using Eq. 5 and is tabulated in Table 6. The best (f_j^*) and the worst (f_j^-) values of the each criterion are calculated by using Eq. 6.

$$Fi^* = \text{Maxi } fij = 0.50326$$

$$Fi^- = \text{Mini } fij = 0.18213$$

The values of utility measure and regret measure are tabulated in Table 7 using Eq. 7 and 8. Finally, using Eq. 9, the VIKOR Index value is calculated. On the basis of the VIKOR Index value, the ranks are assigned to the alternatives. Table 8 shows the obtained results.

PROMETHEE computations: PROMETHEE is a function based method, in which linguistic variables and crisp scores is defined and then each alternative is rated with their corresponding crisp scores. Then Eq. 10 and 11 are used to compute normalization matrix, which is shown in Table 9. The preference functions for all the alternatives are calculated using Eq. 12 and 13 which are shown in Table 10. Table 11 exhibits the aggregated preference function values for all paired alternatives as calculated

Table 5: Crisp weights of FAHP

Variables	FAHP CrispWeights
C1	0.3426
C2	0.2610
C3	0.1614
C4	0.1064
C5	0.0603
C6	0.0472
C7	0.0211

CI = 0.1120; RCI = 1.350; CR = CI/RCI = 0.0830

Table 6: Normalized decision matrix for FAHP-VIKOR

Alternative	Calorific value	Viscosity	Density	Cetane number	Flash point	Cloud point	Pour point
Pongamia	0.4108	0.3688	0.3930	0.4571	0.5033	0.1179	-0.2230
Jatropha	0.3874	0.3579	0.3719	0.3642	0.4074	0.2695	-0.1487
Cotton seed	0.3724	0.3331	0.3721	0.3699	0.4889	0.4716	0.3716
Neem	0.3767	0.3792	0.3554	0.3235	0.1821	0.6064	0.1487
Linseed	0.3484	0.3855	0.3854	0.3797	0.3715	-0.1213	-0.6690
Mahua	0.3725	0.3593	0.3897	0.3586	0.3139	0.1347	0.5203
Meusa Ferra	0.3747	0.4510	0.3770	0.3797	0.2684	0.5390	0.2230

Table 7: S_i and R_i values of alternatives

Alternatives	S_i	R_i
Pongamia	0.2269	0.1820
Jatropha	0.5509	0.2062
Cotton seed	0.6452	0.2610
Neem	0.6808	0.1871
Linseed	0.6749	0.3426
Mahua	0.5725	0.2105
Meusa Ferra	0.3823	0.1981

Table 8: Results of alternatives with the use of FAHP-VIKOR

Alternatives	VIKOR Index	Rank
Pongamia	0	1
Jatropha	0.4322	3
Cotton seed	0.7066	6
Neem	0.5156	5
Linseed	0.9935	7
Mahua	0.4693	4
Meusa Ferra	0.2211	2

Table 9: Normalised Decision Matrix for PROMETHEE

Alternative	Calorific value	Viscosity	Density	Cetane number	Flash point	Cloud point	Pour point
Pongamia	1.000	0.302	1.000	1.000	0.000	0.329	0.375
Jatropha	0.625	0.210	0.438	0.305	0.701	0.537	0.438
Cotton seed	0.384	0.000	0.445	0.347	0.955	0.815	0.875
Neem	0.454	0.391	0.000	0.000	0.000	0.000	0.688
Linseed	0.000	0.444	0.798	0.421	0.590	0.000	0.000
Mahua	0.386	0.222	0.910	0.263	0.410	0.352	0.000
Meusa Ferra	0.422	1.000	0.573	0.421	0.269	0.907	0.750

Table 10: Preference function for all pair of alternatives

Alternative	C1	C2	C3	C4	C5	C6	C7
p1,2	0.375	0.093	0.562	0.695	0.299	0.000	0.000
p1,3	0.616	0.302	0.555	0.653	0.045	0.000	0.000
p1,4	0.546	0.000	1.000	1.000	1.000	0.000	0.000
p1,5	1.000	0.000	0.202	0.579	0.410	0.329	0.375
p1,6	0.614	0.080	0.090	0.737	0.590	0.000	0.000
p1,7	0.578	0.000	0.427	0.579	0.731	0.000	0.000
p2,1	0.000	0.000	0.000	0.000	0.000	0.208	0.063
p2,3	0.241	0.210	0.000	0.000	0.000	0.000	0.000
p2,4	0.171	0.000	0.438	0.305	0.701	0.000	0.000
p2,5	0.625	0.000	0.000	0.000	0.112	0.537	0.438
p2,6	0.240	0.000	0.000	0.042	0.291	0.185	0.000
p2,7	0.203	0.000	0.000	0.000	0.433	0.000	0.000
p3,1	0.000	0.000	0.000	0.000	0.000	0.486	0.500
p3,2	0.000	0.000	0.007	0.042	0.254	0.278	0.438
p3,4	0.000	0.000	0.445	0.347	0.955	0.000	0.188
p3,5	0.384	0.000	0.000	0.000	0.366	0.815	0.875

Table 10: Continue

Alternative	C1	C2	C3	C4	C5	C6	C7
p3,6	0.000	0.000	0.000	0.084	0.545	0.463	0.000
p3,7	0.000	0.000	0.000	0.000	0.687	0.000	0.125
p4,1	0.000	0.088	0.000	0.000	0.000	0.671	0.313
p4,2	0.000	0.181	0.000	0.000	0.000	0.463	0.250
p4,3	0.070	0.391	0.000	0.000	0.000	0.185	0.000
p4,5	0.454	0.000	0.000	0.000	0.000	1.000	0.000
p4,6	0.068	0.169	0.000	0.000	0.000	0.648	0.000
p4,7	0.032	0.000	0.000	0.000	0.000	0.093	0.000
p5,1	0.000	0.142	0.000	0.000	0.000	0.000	0.000
p5,2	0.000	0.235	0.360	0.116	0.000	0.000	0.000
p5,3	0.000	0.444	0.353	0.074	0.000	0.000	0.000
p5,4	0.000	0.054	0.798	0.421	0.590	0.000	0.000
p5,6	0.000	0.222	0.000	0.158	0.179	0.000	0.000
p5,7	0.000	0.000	0.225	0.000	0.321	0.000	0.000
p6,1	0.000	0.000	0.000	0.000	0.000	0.023	0.625
p6,2	0.000	0.012	0.472	0.000	0.000	0.000	0.563
p6,3	0.002	0.222	0.465	0.000	0.000	0.000	0.125
p6,4	0.000	0.000	0.910	0.263	0.410	0.000	0.313
p6,5	0.386	0.000	0.112	0.000	0.000	0.352	1.000
p6,7	0.000	0.000	0.337	0.000	0.142	0.000	0.250
p7,1	0.000	0.698	0.000	0.000	0.000	0.579	0.375
p7,2	0.000	0.790	0.135	0.116	0.000	0.370	0.313
p7,3	0.038	1.000	0.128	0.074	0.000	0.093	0.000
p7,4	0.000	0.609	0.573	0.421	0.269	0.000	0.063
p7,5	0.422	0.556	0.000	0.000	0.000	0.907	0.750
p7,6	0.036	0.778	0.000	0.158	0.000	0.556	0.000

Table 11: Aggregate preference function

(a,b)	a1	a2	a3
b1		0.335158	0.45178
b2	0.011148		0.13749
b3	0.033498	0.043217	
b4	0.061308	0.074325	0.134741
b5	0.037053	0.131567	0.180772
b6	0.014301	0.091266	0.13632
b7	0.217268	0.264369	0.306895

a4	a5	a6	a7
0.515184	0.485037	0.359911	0.37269
0.204191	0.255542	0.112867	0.095782
0.170334	0.210474	0.063648	0.044036
	0.202699	0.09797	0.015366
0.22312		0.085602	0.055612
0.206235	0.187976		0.06823
0.313819	0.348174	0.258417	

Table 12: Leaving flow and entry flow

Variables	Leaving flow f+	Entering flow f-
Pongamia	0.31497	0.046822
Jatroba	0.102128	0.117488
Cotton	0.070651	0.1685
Neem	0.073301	0.20411
Linseed	0.089216	0.211238
Mahua	0.088041	0.122302
Meusa ferra	0.213618	0.081464

Table 13: Net outranking flows

Variable	Net outranking flow F	Rank
Pongamia	0.268148	1
Jatroba	-0.01536	3
Cotton	-0.09785	5
Neem	-0.13081	7
Linseed	-0.12202	6
Mahua	-0.03426	4
Meusa ferra	0.132153	2

using Eq. 14. The leaving and entering flows of different alternatives are computed using Eq. 15 and 16 respectively, tabulated in Table 12. The net outranking flow values of different alternatives are calculated using Eq. 17 tabulated in Table 13.

Table 14: Results of alternatives with the use of FAHP-VIKOR and FAHP-PROMETHEE methodologies

	FAHP-VIKOR		FAHP-PROMETHEE	
Alternatives	VIKOR index	Rank	Net outranking flow F	Rank
Pongamia	0.0000	1	0.268148	1
Jatroba	0.4322	3	-0.01536	3
Cotton	0.7066	6	-0.09785	5
Neem	0.5156	5	-0.13081	7
Linseed	0.9935	7	-0.12202	6
Mahua	0.4693	4	-0.03426	4
Meusa ferra	0.2211	2	0.132153	2

RESULTS AND DISCUSSION

Table 14 shows the results of the methodologies proposed here. Pongamia biodiesel which has the highest performance value and placed in first position. The priority ranking of biodiesels are pongamia>mesua ferra>jatroba>mahua>neem>cotton> linseed in FAHP-VIKOR method. To validate the results of the proposed methodology, another method FAHP PROMETHEE was applied. For both methods, the top four ranking orders are similar but the preorders are different. It is shown that Pongamia biodiesel can be selected by the decision makers to operate the diesel power generator. Few researchers are experimentally investigated the performance of pongamia fuelled power generator and reported that Pongamia biodiesel as a better alternate source of energy.

Kalbande *et al.* (2008) investigated that the performance of electrical power generator fuelled with jatroba and pongamia biodiesel and reported that the efficiency of pongamia biodiesel is high comparable to jatroba and diesel. Prasad *et al.* (2010) investigated the performance of an electrical generator fuelled with pongamia to drive agricultural pumps; the brake thermal efficiency was reported to be slightly reduced. In addition to that, emission particles such as hydrocarbon, carbon monoxide and smoke are reduced. Thus, it is clear that the proposed MCDM models are capable enough to be successfully selected as better the alternative fuel from various other alternatives.

CONCLUSION

In this study, a multicriteria decision making model is used to rank the alternate fuel for diesel power generator to operate remote areas. There are a number of parameters that are to be considered before choosing the best fuel which involves a multi-dimensional perspective. Inappropriate selection of fuel affects the environment as well as the operating cost negatively. So, the selection of opt fuel from many options needs a MCDM technique. This proposed model has been tested by many experiments on a number of applications. So the models can help the decision makers to select the best biodiesel. The top ranking results of both methods are same. This shows that when the decision-makers are consistent in an evaluation process for the two independent methods, the top ranking results will be same. The research work can be extended with more numbers of alternatives and criterion.

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