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Selection of Karanja Biodiesel Blend for Engine Performance by using TOPSIS and VIKOR Method

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Abstract*: Demand for energy is increasing due to the development of industries, expanding urbanization, and population growth which further increases the use of fossil fuel in large amount. This also affects an environmental pollution and engine sector too. In internal combustion (IC) engines, alternative fuel blends has one of the most important decision for balancing a number of opinions and criteria for making different strategic decision by an engine expert. Choice of alternative sources of suitable blending of biodiesel and biodiesel plays an important role in engine sector. In this paper, discuss the Multi Criteria Decision Making (MCDM) techniques is used for selecting the best alternative blend of Karanja methyl ester biodiesel to fulfil the demand in IC engine sector. Optimization was done by using of VIKOR (Visekriterijimsko Kompromisno Rangiranje) and TOPSIS (technique for order performance by similarity to ideal solution) techniques. The parameter considered for optimization includes brake thermal energy, brake specific fuel consumption at different load at different compression ratio as input. Emission parameters as carbon mono oxide un burnt hydrocarbon, carbon di-oxide, oxygen and oxides of nitrogen was also determined. A productive examination of the procedure and positioning of choices can be accomplished for enhancement blends choice through TOPSIS and VIKOR techniques. Starting with normalized and weighted normalized decision matrix, positive and negative ideal solution, the distance of alternative from positive and negative ideal solution was calculated and closeness coefficient of alternative in the form of ranking of alternative was done. It was found that a mix B75 was the most appropriate blend for Karanja biodiesel for best use in CI engine without influencing the emission and performance parameters.

Keywords : **Biodiesel, Diesel Engine, TOPSIS, VIKOR..**

I. INTRODUCTION

Compression ignition (CI) engine plays an important role in many fields including automobiles, marine propulsion, industrial, domestic needs [1]. With increasing demand of transportation and population, the demand for energy is also increasing. For both developed and growing economies, the demand for energy is also growing rapidly [2-4]. Efforts are on top to discover the alternative sources of energy to fulfil the demand of it for the future generation. It is estimated that by the year 2035, 0.7% per capita, consumption of energy will also increase [5-7]. In the meantime, several studies have revealed that the growing consumption of fossil fuel will lead to the exhaustion of crude oil reserves somewhere between 2050 and 2075 [6, 8]. Therefore, there is a pressing need to replace the energy supply system of fossil fuel fully or at least partly with the other renewable alternative fuel. The alternative fuels/ Bio-fuels are one of renewable source to fulfil the world energy demand [9, 10]. Bio-fuel is the plausible alternative for fossil fuels as it is less pollutant, renewable, and having similar properties to diesel fuel. It also reduces the greenhouse gas emission and environmental disaster comparative to crude oil which leaves massive carbon footprints [6]. World-wide researchers are exploring hard in search of alternative fuels for diesel engines. Without making any physical change in existing diesel engines, different kind of biodiesels and their blends are tested as an alternative fuel for it. The American Society for Testing and Material (ASTM) characterizes that biodiesel can be created by the mono-alkyl esters of long-chain fatty acids derived from the sustainable lipid feedstock, including creature oil, vegetable oil, waste oil, and so forth [11-12]. The development of yields for biodiesel production form food grains poses a threat to food security and also contributes to a decline in soil richness [13]. Though utilization of the biodiesel in CI engine can decrease the hydrocarbon (HC), carbon monoxides (CO) and smoke emission, it will also increase the oxides of nitrogen (NOX), because of 10% content of oxygen (O_2) present in biodiesel that causes NO_X formation. These are few disadvantages of biodiesel, such as higher atomic weight, high viscosity, low volatility, high pour point contrasted to diesel. This leads to incomplete combustion and responsible poor atomization [14, 15]. Numerous researchers and specialists examined several biodiesel and its blends. In a study, Sahoo et. al. [2] investigated Karanja, Polanga and Jatropha based biodiesel and their 20 and 50% (by vol.) blends were considered at different loads (0, 50 and 100%) and reported that Pongamia oil blended with 50% (B50 blend) diesel gave the maximum power output. Bajpai et al. [15] tested different blends of Karanja Oil (KO) and diesel fuel (5%, 10%, 15% and 20%) in a single cylinder direct injection (DI), CI engine at different loads (0%, 20%, 40%, 60%, 80%, and 100%) and constant speed. Highest BTE is observed for 10% KO blend at 60% load.

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The review of relevant literature clearly indicates that the researchers are working sincerely to discover the appropriate option of diesel without any physical modifications in the existing diesel engine.

In brief, different input parameters including load, compression ratio (CR), a blend of fuels are varied and the performance and emission characteristics of the engine are observed. It is observed that multiple performance parameters were studied under number of diverse frameworks. There is a need for a systematic approach to ascertain the number of experiments in order to cover the entire domain of input parameters.

In the present study, Karanja oil methyl ester as biodiesel is chosen to examine the better engine performance along with minimum exhaust emission characteristics by implementing TOPSIS (technique for order performance by similarity to ideal solution) and VIKOR (Visekriterijimsko Kompromisno Rangiranje) approach is proposed as a hybrid of Multi-Criteria Decision Making (MCDM) techniques for assessing and choosing the optimal fuel blends for CI engine.

Remaining portion of paper is divided into seven sections. Section 2 explain the literature review, section 3 provided the methodology of MCDM techniques followed in VIKOR and TOPSIS method. Section 4 describes the method for the selection of the best blend. The experimental procedure adopted is explained in section 5. Results are explained in section 6 and finally section 7 gives the conclusion the paper.

II. LITERATURE REVIEW

MCDM is a part of operational research shows managing choice issue under the nearness of factor and criteria. It gives advanced technique sensible instruments that are arranged towards the help of the leader in confronting complex genuine choice [16]. MCDM techniques applied in automobile sector have been used in the previous couple of decades. A few application regions connected by Maheswari al. [17] used nonlinear regression analysis on 13% blend of biodiesel with the 24°bTDC injection timing. Shi et al. [18] proposed, NSGA (non dominated sorting genetic algorithm) for solving the minimum value of NOx emission and BSFC on single cylinder SI (spark ignition) engine. Josc et al. [19] applied a MOPSO (multi objective particle swarm optimization) and NSGA method for reduction of emission on SI engine. Some other experiments are presented in table [1].

Table- I: Review

Author	Techniques	Application	Study reason
Chen zheng et.al[20]	ANN & Minitab software	Performance and emission	Analyzed of diesel engine parameters
Win et al [21]	Taguchi method by Minitab	Injection system	Analysed diesel engine parameter like noise, emission
Ganapathy et.al [22]	Taguchi method	Injection timing	Select the performance and emission of Jatropha Biodiesel
Vijaykumar et.al [23]	Evaluation of numerical model	Performance and emission	Performance and emission of biofulled IC engine
Pandian et.al [24]	Response surface methodology	Effect of injection system	Select the blend of Pongamia biodiesel
Bharathiraj a et al [25]	Lab view software	Performance and emission	Characteristics of ethanol fumigation
Balafoutis et al [26]	AHP & TOPSIS	Injection timing	Select the best blend of sunflower oil
Sakthivel et al. [27]	GRA & TOPSIS	Different load condition	Selection of best blend of fish oil
Akbari et al. [28]	Genetic algorithm	Production	Production of biodiesel
Etghani et al. [29]	ANN	Direct injection	Performance of castor oil biodiesel
Liu et al. [30]	Genetic algorithm	Optimization	NOx conversion efficiency
Gaikwad et al. [31]	ANP, TOPSIS & VIKOR	Direct injection	Best suitable blend
Mohammad hasani et al. [32]	ANN	Emission	Reduce NOx emission
Lotfan et al. [33]	ANN	Modelling analyse	Reduce CO NOx emission from dual fuel engines

From the literature review, it can be found out a large amount of work has been done by to improve the performance and emission characteristics of biodiesel by using different MCDM techniques. Hence, the main objective of this present paper proposed a MCDM technique for determine the optimum blend. In this paper, discuss the two MCDM techniques, i.e. TOPSIS & VIKOR are used to evaluating the best blend and this technique can be solved by Excel software sheet.

III. METHODOLOGY

In order to fulfil the requirement of data can be adopted from the paper "Optimization of Performance and Emission characteristics of a diesel engine with biodiesel [34]. In CI engine, performance and emission characteristics of Karanja biodiesel and diesel based on the three essential issues to be explicit, a blend of fuel, load and compression ratio were considered. Division of each factor is given in five levels as shown in table (2). Brake power (BP), Brake specific fuel (BSFC), and Brake thermal efficiency (BTE) are the three factors come out from the characteristics of engine performance.

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Remaining five factors come out from the characteristics of engine emission such as, CO, CO_2, NO_X, HC and O_2. ASTM tested the properties of Diesel and Karanja biodiesel are presented in table (3).

Table 2: Factors and Levels of the engine*

Design Factor	Levels				
	1	***2***	***3***	***4***	***5***
Load in Kg	4	8	12	16	20
Blend	B0	B25	B50	B75	B100
Compression Ratio	14:1	15:1	16:1	17:1	18:1

*[adopted from ref.34]

Table 3: Property of fuel*

Property	***Diesel***	***Karanja Biodiesel***	***ASTM standard***
Specific Gravity	0.824	0.880	D3142-05
Density (gm/cc)	0.717	0.766	D1298
API Gravity	40.24	29.3	D4052
Ash content (%)	0.060	0.094	D874
Cetane No.	48	56.61	D613
Viscosity (cSt)	4.2	32.3	D 2171
Calorific Value (kcal/kg)	10056.2	8095.24	D 5453-93
Pour Point (°C)	15	4	D 5949
Flash Point (°C)	66	190	D 6450
Fire Point (°C)	72	395	D3828
Carbon Residue (%)	0.080	0.530	D 189
Water Content (%)	0.07	1.66	D 2709
Ash content	0.060	0.094	D874

*[adopted from ref.34]

A. *TOPSIS Method*

This technique was discovered by Hwany and Yoon in 1981. Main objective of this technique, proved that the best method for selecting the best alternative blends and addressing the rank priority. By TOPSIS method, to obtain the solution of closest and farthest from ideal and non ideal solution [35, 36, and 37]:

Step 1: By the help of the equation to calculate the normalization of decision matrix:

$$\overline{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}} \qquad j = 1, 2, 3\ldots n, \quad i = 1, 2, 3\ldots n \qquad (1)$$

Step 2: Constructed the weighted normalized matrix: In normalized decision matrix can be multiplied by associate weight Wi and to get results:

$$V_{ij} = X_{ij} * W_i \qquad j = 1, 2, 3\ldots n, \quad i = 1, 2, 3\ldots n \qquad (2)$$

Step 3: Calculate the ideal solution of most Ai* and least Ai - preferable alternative:

Ai* = {v1*…vi*} = {(max vij |i Є I′)}, (min vij |i Є I”)} (3)

Ai⁻ = {v1-,….vi-} = {(min vij |i Є I′)}, (max vij |i Є I”)} (4)

Step 4: By the help of n-criteria Euclidean distance equation to calculated the separation measurement of each alternatives:

$$D_i^+ = \left[\sum_{j=1}^{n} \left(V_{ij} - V_j^+\right)^2\right]^{0.5} \qquad j = 1, 2, 3\ldots.n \qquad (5)$$

$$D_i^- = \left[\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2\right]^{0.5} \qquad j = 1, 2, 3\ldots.n \qquad (6)$$

Step 5: Determined the relative closeness of each alternative:

$$CC_j = \frac{D_i^-}{D_i^+ + D_i^-} \qquad (7)$$

Step 6: Rank preference: arrangement of alternatives in decreasing order of CCj.

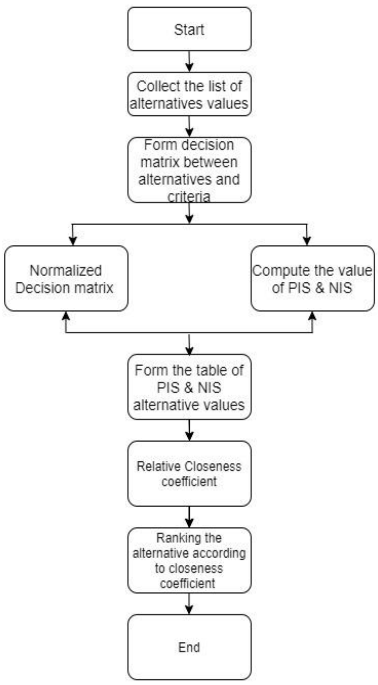

Fig 1: TOPSIS flow chart

B. VIKOR Method

This method is created by Opricovic (1998) to solve the problem with commensurable and conflicting criteria. The main focused of this method to selecting and rank priority for best alternatives with commensurable and conflicting criteria [35, 37].

Step 1: Unify the normalized decision matrix for alternatives X_{ij}

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}} \qquad j = 1, 2, 3\ldots n, \quad i = 1, 2, 3\ldots n \qquad (8)$$

Step 2: calculated the best (fi*) and worst (fi-) values for every n-criteria function by this equation:

$$f_i^* = \max_j f_{ij}, \qquad f_i^- = \min_j f_{ij} \qquad j = 1, 2, 3,\ldots n \qquad (9)$$

Step 3: For each alternatives to calculate the utility Si and Ri regret value from this equation (10) & (11).

$$S_i = \left[\sum_{i=1}^{m} w_i \left(f^*_i - f_{ij} \right) / \left(f^*_i - f_i^- \right) \right] \qquad (10)$$

$$R_i = \max \left[w_i \left(f^*_i - f_{ij} \right) / \left(f^*_i - f_i^- \right) \right] \qquad (11)$$

where w_i represent the weight of the ith criterion.

Step 4: Determined the value of VIKOR index:

$$Q_i = v\,(S_i - S^*) / (S^- - S^*) + (1-v)\,(R_i - R^*) / (R^- - R_i) \qquad (12)$$

Where S^* = mini S_i, R^* = mini R_i, R^- = maxi Rand v is represented as weight of the strategy of the majority of criteria, here v = 0.5.

Step 5: Rank priority:

Select the smallest value of best alternative value by VIKOR method. A' is the compromise solution for alternative. Rank priority followed by two satisfies condition:

C1 Acceptable advantage: Q (A") – Q (A') ≥DQ

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

C2 Acceptable stability: Alternative A′ represent the best ranked of alternative by R and S. According to decision-making process, compromise solution is stable with "voting by majority rule" v≈0.5, or with veto (v<0.5). Here, v represents the strategy of weighted decision making. According to compromise solution, if one condition is not satisfied which consist is:

• A′, A"…., AN alternatives, if C1condition is not satisfied; AN give the relation Q (AN) – Q (A') < DQ for maximum N, or

• A′ and A" an alternative, only C2 condition not satisfied.

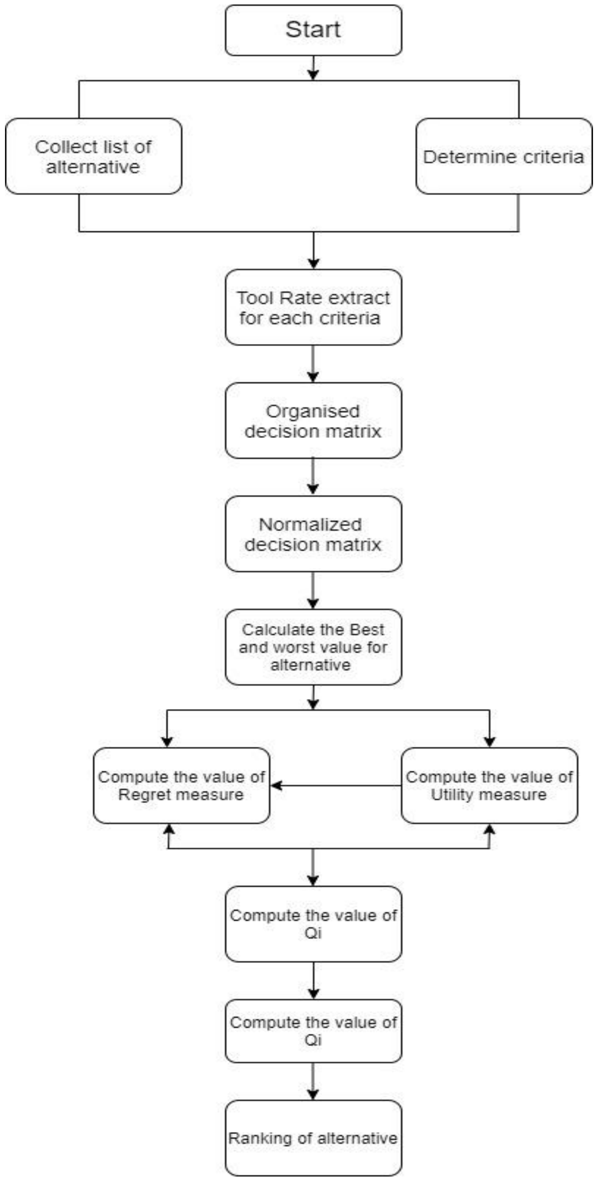

Fig 2: Flow chart of Vikor Method

IV. METHOD FOR SELECTING A BEST BLEND

In this investigation, the specialists have utilized the writing study to recognize the assessment criteria for the chose of the best blend (4). The criteria are organized in a progressive structure as appeared in fig (3). The collective choice-making strategies allow incorporating the suppositions of various IC engine assembling and motor specialists in the basic leadership process. The distinguished criteria are portrayed beneath [35]:

1. NOx: Formation of nitrogen oxides in engine due to ignition delay, flame temperature and the substance of nitrogen and oxygen available in the reaction mixture.

2. Smoke: Molecular structure of the biodiesel, smoke emission depends on the content of oxygen due to the thermal cracking process; smoke emission is generated with long-chain of HC molecules in an oxygen incomplete combustion environment.

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3. Brake Thermal Efficiency: Thermal input of the fuel is the main function of the engine can describe the brake power. BTE shows that evaluate how efficient the energy of fuel converted into mechanical energy.
4. CO_2: The burning efficiency of fuel inside the combustion chamber is indicated by the CO_2 emission of diesel engine. Most of the conversion of carbon into carbon dioxides shows good combustion.
5. CO: CO emission depends on the matter of oxygen, carbon and the ability of combustion fuel to form
CO, present of carbon in the fuel is oxidized with oxygen present in the air and to form CO.
6. Hydrocarbon (HC): In the presence of oxygen, take part of hydrocarbon in combustion reaction and remaining part of hydrocarbon comes out in form of unburned HC.
7. Exhaust gas temperature: After the combustion in cylinder, the mixing of the fuel at accurate temperature. It is important parameters to analyze the emission values and indicates combustion efficiency.
8. Ignition delay: It is the difference between the time interval of injection and combustion process start in the diesel engine. Ignition delay can be created by vaporization, atomization, mixing of fuel in air and the reaction due pre-combustion.
9. Combustion duration: Combustion duration can determine the heat release data by the whole process of combustion from starting point to ending point.

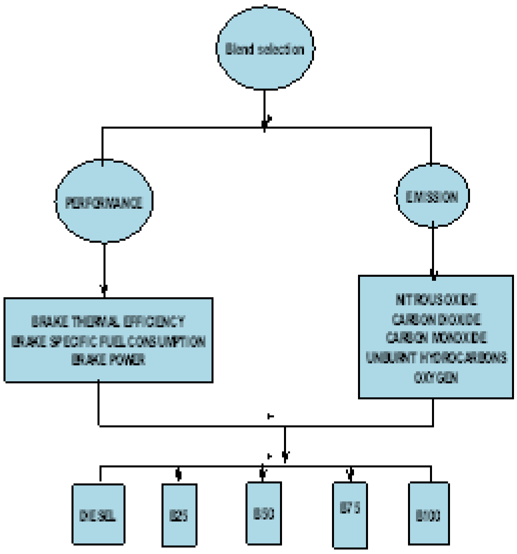

Fig 3: Decision hierarchy

V. EXPERIMENTAL PROCEDURE

A. TOPSIS computations

The proposed of this TOPSIS technique for selects the best alternative blend. Consideration emission and performance characteristics of engine at 20% load at 14 CR and apply the TOPSIS method. In TOPSIS method, firstly to calculated the normalized matrix on experimental reading of emission and engine performance at 14, 15, 16, 17and 18 CR using the equation (1) from table (4). After the calculation normalized decision matrix reading are put in table (5). Considering the weighted criteria and to compute in weighted normalized decision matrix by using the equation (2) and represent in table (6).

After the matrix of weighted normalized is formed ideal and non ideal solution for alternative by using the equation (3-4) and tabulated in table form (7-8).

$A^* = \{0.020, 0.018, 0.019, 0.018, 0.038\} = \{0.020\}$

$A^- = \{0.020, 0.018, 0.019, 0.018, 0.038\} = \{0.018\}$

Then also compute the each criterion by using the equation (5-6) to determine the value of alternative distance from ideal and non ideal solution and tabulate in (9-10).

Di*= [(0.020 - 0.020)^2 + (0.1002 - 0.0754)^2 + (0.0281 - 0.0422)^2 + (0.003 - 0.0006)^2 + (0.0029 - 0.0006)^2 + (0.0038 - 0.0030)^2+ (0.0023-0.0023)^2+(0.0010 - 0.0009)^2]^0.5 = 0.029

Di- = [(0.020 - 0.0186)^2+ (0.1002 - 0.1009)^2 + (0.0281 - 0.0281)^2 + (0.003 - 0.0034)^2 + (0.0029 - 0.0036)^2+ (0.0038 - 0.0038)^2+ (0.0023-0.005)^2+ (0.0010 - 0.0049)^2]^0.5 = 0.004

Then find the coefficient of closeness for each alternative with respect to positive and negative ideal solution by apply the equation (7). Lastly, calculate the rank priority of every closeness coefficient alternatives.

CC1* = 0.126 CC2*= 0.142 CC3*= 0.744

CC4*= 0.921 CC5* = 0.345

Similarly the procedure is followed for selecting the best alternative blend value at 40%, 60%, 80%, and 100% load. Results and rank of every alternative of closeness coefficient are presented in tabulated (11).

B. VIKOR computations

Utilization of this VIKOR technique for selects the best alternative blend. Performance and emission characteristics of engine at 20% load at 14 CR are considered to demonstrate the computational procedure for VIKOR method:
Step 1: In VIKOR method, to calculate the normalized decision matrix by help of TOPSIS table (5).
Step 2: After the calculation of normalized matrix, to calculate the best f* and worst fi^- value by using the equation (9).

$f^* = \{0.0668, 0.0621, 0.065, 0.0650, 0.062\} = \{0.0668\}$

$f^- = \{0.0668, 0.0621, 0.065, 0.0650, 0.062\} = \{0.0621\}$

Step 3: Calculate the value of Si and Ri by the equation (10-11). And obtained the results are tabulated (12-13).
Step 4: By equation (12) to calculate the value of VIKOR index and results outcomes are given in table (14).
Step 5: Calculate the smallest index value to select the best blend.

Table 4: Experimental value*

Experiment	Load %	Blend	CR	BP (Kw)	BSFC (gm/Kw hr)	BTE	CO (%vol)	HC (ppm/vol)	CO_2 (%vol)	O_2 (%vol)	NOx (ppm/vol)
1	20	0	14	1.223	632.784	*13.521*	0.35	58	4.8	14.2	117
2		25	15	1.138	624.431	14.207	0.36	70	4	15.03	105
3		50	16	1.2	509.584	18.029	0.17	43	3.8	15.53	218
4		75	17	1.19	474.778	20.317	0.08	17	4	15.45	400
5		100	18	1.15	599.332	17.734	0.06	11	4.2	15.36	596
6	40	0	15	2.33	365.421	23.414	0.06	25	5.6	13.64	702
7		25	16	2.26	362.915	24.445	0.07	41	5.6	13.33	726
8		50	17	2.25	345.877	26.562	0.04	37	5.4	13.71	843
9		75	18	2.342	337.708	28.564	0.05	13	6	13.51	963
10		100	14	2.442	399.555	26.601	0.21	23	5.8	13.3	247
11	60	0	16	3.403	271.75	31.485	0.01	22	7.3	11.42	1154
12		25	17	3.351	293.691	30.207	0.02	31	7.4	11.28	1316
13		50	18	3.475	271.973	33.78	0.02	39	7.2	11.5	1130
14		75	14	3.282	327.154	29.485	0.1	32	7.8	10.86	859
15		100	15	3.431	317.996	33.424	0.07	18	7.3	11.62	983
16	80	0	17	4.469	255.027	33.55	0.02	7	1.1	19.25	123
17		25	18	4.497	255.32	34.747	0.04	34	9.5	8.59	1240
18		50	14	4.319	283.192	32.442	0.08	55	9.6	8.6	1298
19		75	15	4.326	287.354	33.569	0.05	30	9.3	9.05	1337
20		100	16	4.412	299.319	35.51	0.05	21	9	9.57	1463
21	100	0	18	5.272	277.365	30.848	0.32	16	4.5	14.69	482
22		25	14	5.57	284.662	31.165	0.73	84	11.6	5.29	1209
23		50	15	5.411	287.639	31.94	0.3	65	11.3	6.06	1350
24		75	16	5.281	299.598	32.197	0.17	39	11.2	6.57	1360
25		100	17	5.539	300.61	35.357	0.12	29	11.1	6.81	1410

Table 5: Normalized decision matrix

Load	*Blend*	*BP (Kw)*	*BSFC (gm/Kwhr)*	*BTE*	*CO (%vol)*	*HC (ppm/vol)*	*CO_2 (%vol)*	*O_2 (%vol)*	*NOx (ppm/vol)*
20	B0	0.067	0.336	0.094	0.327	0.295	0.128	0.232	0.024
	B25	0.062	0.332	0.098	0.336	0.356	0.107	0.245	0.021
	B50	0.066	0.271	0.125	0.159	0.219	0.101	0.253	0.045
	B75	0.065	0.252	0.141	0.075	0.086	0.107	0.252	0.082
	B100	0.063	0.319	0.123	0.056	0.056	0.112	0.251	0.122
40	B0	0.127	0.194	0.162	0.056	0.127	0.149	0.222	0.144
	B25	0.123	0.193	0.169	0.065	0.208	0.149	0.217	0.149
	B50	0.123	0.184	0.184	0.037	0.188	0.144	0.224	0.173
	B75	0.128	0.180	0.198	0.047	0.066	0.160	0.220	0.197
	B100	0.133	0.212	0.184	0.196	0.117	0.155	0.217	0.051
60	B0	0.186	0.144	0.218	0.009	0.112	0.195	0.186	0.236
	B25	0.183	0.156	0.209	0.019	0.158	0.197	0.184	0.269
	B50	0.190	0.145	0.234	0.019	0.198	0.192	0.188	0.231
	B75	0.179	0.174	0.204	0.093	0.163	0.208	0.177	0.176
	B100	0.187	0.169	0.231	0.065	0.092	0.195	0.190	0.201
80	B0	0.244	0.136	0.232	0.019	0.036	0.029	0.314	0.025
	B25	0.246	0.136	0.241	0.037	0.173	0.253	0.140	0.254
	B50	0.236	0.151	0.225	0.075	0.280	0.256	0.140	0.266
	B75	0.236	0.153	0.233	0.047	0.153	0.248	0.148	0.274
	B100	0.241	0.159	0.246	0.047	0.107	0.240	0.156	0.299
100	B0	0.288	0.147	0.214	0.299	0.081	0.120	0.240	0.099
	B25	0.304	0.151	0.216	0.682	0.427	0.309	0.086	0.247
	B50	0.296	0.153	0.221	0.280	0.330	0.301	0.099	0.276
	B75	0.288	0.159	0.223	0.159	0.198	0.299	0.107	0.278
	B100	0.303	0.160	0.245	0.112	0.147	0.296	0.111	0.289

Table 7: Positive ideal solution A*

Blend	BP (Kw)	BSFC (gm/Kwhr)	BTE	CO (%vol)	HC (ppm/vol)	CO_2 (%vol)	O_2 (%vol)	NOx (ppm/vol)
B0	0.0200	0.0757	0.0422	0.0006	0.0006	0.0030	0.0023	0.0009
B25	0.0400	0.0539	0.0594	0.0004	0.0007	0.0043	0.0022	0.0020
B50	0.0569	0.0433	0.0702	0.0001	0.0009	0.0058	0.0018	0.0070
B75	0.0737	0.0407	0.0738	0.0002	0.0004	0.0009	0.0014	0.0010
B100	0.0913	0.0442	0.0735	0.0011	0.0008	0.0036	0.0009	0.0039

Table 8: Negative ideal solution A?

Blend	BP (Kw)	BSFC (gm/Kwhr)	BTE	CO (%vol)	HC (ppm/vol)	CO_2 (%vol)	O_2 (%vol)	NOx (ppm/vol)
B0	0.0186	0.1009	0.0281	0.0034	0.0036	0.0038	0.0025	0.0049
B25	0.0188	0.0637	0.0487	0.0020	0.0021	0.0048	0.0022	0.0079
B50	0.0569	0.0522	0.0613	0.0009	0.0020	0.0062	0.0019	0.0108
B75	0.0737	0.0477	0.0674	0.0007	0.0028	0.0077	0.0031	0.0120
B100	0.0864	0.0479	0.0641	0.0068	0.0043	0.0093	0.0024	0.0115

Table 6: Weighted normalized decision matrix

Load	Blend	BP (Kw)	BSFC (gm/Kwhr)	BTE	CO (%vol)	HC (ppm/vol)	CO_2 (%vol)	O_2 (%vol)	NOx (ppm/vol)
20	B0	0.020	0.101	0.028	0.003	0.003	0.004	0.002	0.001
	B25	0.019	0.100	0.030	0.003	0.004	0.003	0.002	0.001
	B50	0.020	0.081	0.037	0.002	0.002	0.003	0.003	0.002
	B75	0.020	0.076	0.042	0.001	0.001	0.003	0.003	0.003
	B100	0.019	0.096	0.037	0.001	0.001	0.003	0.003	0.005
40	B0	0.038	0.058	0.049	0.001	0.001	0.004	0.002	0.006
	B25	0.037	0.058	0.051	0.001	0.002	0.004	0.002	0.006
	B50	0.037	0.055	0.055	0.000	0.002	0.004	0.002	0.007
	B75	0.038	0.054	0.059	0.000	0.001	0.005	0.002	0.008
	B100	0.040	0.064	0.055	0.002	0.001	0.005	0.002	0.002
60	B0	0.056	0.043	0.065	0.000	0.001	0.006	0.002	0.009
	B25	0.055	0.047	0.063	0.000	0.002	0.006	0.002	0.011
	B50	0.057	0.043	0.070	0.000	0.002	0.006	0.002	0.009
	B75	0.054	0.052	0.061	0.001	0.002	0.006	0.002	0.007
	B100	0.056	0.051	0.069	0.001	0.001	0.006	0.002	0.008
80	B0	0.073	0.041	0.070	0.000	0.000	0.001	0.003	0.001
	B25	0.074	0.041	0.072	0.000	0.002	0.008	0.001	0.010
	B50	0.071	0.045	0.067	0.001	0.003	0.008	0.001	0.011
	B75	0.071	0.046	0.070	0.000	0.002	0.007	0.001	0.011
	B100	0.072	0.048	0.074	0.000	0.001	0.007	0.002	0.012
100	B0	0.086	0.044	0.064	0.003	0.001	0.004	0.002	0.004
	B25	0.091	0.045	0.065	0.007	0.004	0.009	0.001	0.010
	B50	0.089	0.046	0.066	0.003	0.003	0.009	0.001	0.011
	B75	0.087	0.048	0.067	0.002	0.002	0.009	0.001	0.011
	B100	0.091	0.048	0.073	0.001	0.001	0.009	0.001	0.012

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Table 14: Value of Q_i at v = 0.5										
Blend	20% Load	Rank	40% Load	Rank	60% Load	Rank	80% Load	Rank	100% Load	Rank
B0	0.837	2	0.960	1	0.396	4	0.329	4	0.730	2
B25	1.000	1	0.946	2	0.730	2	0.000	5	0.411	4
B50	0.082	4	0.798	3	0.000	5	1.000	1	0.213	5
B75	0.039	5	0.000	5	1.000	1	0.903	2	0.938	1
B100	0.745	3	0.733	4	0.594	3	0.755	3	0.500	3

*[adopted from ref.34]

Table 9: Distance of alternative from PIS D_j*					
Blend	*20%load*	*40%load*	*60%load*	*80%load*	*100%load*
B0	0.029	0.012	0.005	0.004	0.011
B25	0.027	0.011	0.009	0.012	0.014
B50	0.008	0.007	0.002	0.015	0.012
B75	0.003	0.006	0.013	0.014	0.013
B100	0.021	0.011	0.008	0.015	0.01

Table 11: Closeness coefficient (CC_j) and ranking of alternatives										
Blend	20% Load	Rank	40% Load	Rank	60% Load	Rank	80% Load	Rank	100% Load	Rank
B0	0.126	5	0.622	5	0.646	2	0.772	1	0.513	2
B25	0.142	4	0.643	4	0.392	4	0.436	2	0.303	4
B50	0.744	2	0.741	2	0.837	5	0.234	5	0.198	5
B75	0.921	1	0.8	1	0.274	1	0.254	4	0.34	3
B100	0.345	3	0.68	3	0.54	3	0.323	3	0.55	1

Table 12: S_i values of alternatives at different load					
Blend	*20%load*	*40%load*	*60%load*	*80%load*	*100%load*
B0	0.649	0.659	0.312	0.249	0.613
B25	0.886	0.696	0.624	0.149	0.454
B50	0.277	0.508	0.044	0.876	0.597
B75	0.158	0.232	0.947	0.772	0.860
B100	0.669	0.448	0.376	0.520	0.403

Table 10: Distance of alternative from NIS D_j?					
Blend	*20%load*	*40%load*	*60%load*	*80%load*	*100%load*
B0	0.004	0.02	0.01	0.015	0.011
B25	0.005	0.019	0.006	0.009	0.006
B50	0.022	0.021	0.013	0.004	0.003
B75	0.029	0.024	0.005	0.005	0.007
B100	0.011	0.023	0.009	0.007	0.012

VI. RESULTS

Applying the approaches of TOPSIS and VIKOR methods to calculate the best alternative blend results are represented in table (15-16). Both techniques acquire the B75 blend. Even though the first ranking is comparable in both techniques; the TOPSIS has a few restrictions over the VIKOR. It requires long computation to get the PIS and NIS of the criteria and

Table 13: R_i values of alternatives at different load					
Blend	20%load	40%load	60%load	80%load	100%load
B0	0.300	0.300	0.160	0.192	0.300
B25	0.300	0.284	0.250	0.075	0.279
B50	0.101	0.300	0.024	0.300	0.227
B75	0.116	0.156	0.300	0.288	0.291
B100	0.258	0.300	0.250	0.300	0.300

division measures and closeness coefficient of the other alternatives. Increasingly computational planning is more, if the quantity of alternative and criteria increment.

Table15: Ranking of TOPSIS					
Blend	20%load	40%load	60%load	80%load	100%load
B0	2	1	4	4	2
B25	1	2	2	5	4
B50	4	3	5	1	5
B75	5	5	1	2	1
B100	3	4	3	3	3

Table16: Ranking of VIKOR					
Blend	20%load	40%load	60%load	80%load	100%load
B0	5	5	2	1	2
B25	4	4	4	2	4
B50	2	2	1	5	5
B75	1	1	5	4	3
B100	3	3	3	3	1

VII. CONCLUSION

In IC engines, selection of the best blend of biodiesel is an important issue. In a multi dimensional point of view, the best blend can be performing different number of experimental value. In this way, the MCDM techniques are essential for solving this issue. TOPSIS and VIKOR techniques are used to select the best possible candidate out of all alternative blends. It was found that B75 is the best blend which should be used in IC engine. This indicates that if design engineer use B75 blend in IC engine, the performance of engine would be better.

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