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Multi criteria decision making approach for selection of biodiesel blend using AHP-TOPSIS analysis

Multi criteria decision making approach for selection of biodiesel blend using AHP-TOPSIS analysis

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Abstract. Due to globalization, the demand for fossil fuels has exponentially raised and pollution level in ozone also increased. This causes awareness, leading the researchers to study about various renewable energy sources. In that extensive research, bio-diesel blends form a small part of business and are playing a vital role in developing an alternative fuel for automotive usage, which will be more efficient, balanced, and less pollutant. This research study deals with the use of a multi criteria decision making techniques called Analytic Hierarchy Process (AHP) and TOPSIS to analyse and rank the different blends of biodiesel from the engine performance data. For acquiring data, for ranking the biofuel, a 4-stroke test engine was fuelled with Pungam oil biodiesel and operated at various engine rpm and torques. The Analytic Hierarchy Process (AHP) is basically to analyse the performance and emission of the IC engine. Here, separate models are developed for emission characteristics. To rank the best fuel blend, the biodiesel blend percentage and engine load conditions are used as the input data, while the exhaust emissions parameters such as NOx, smoke, CO_2, HC, etc. are considered as the output. From the comparison of results of the AHP-TOPSIS method, the B20 blend is the best option for low engine loads while B80 shows up as the best option at high engine loads.

Keywords— MCDM, Jatropha oil, AHP, TOPSIS, IC Engines.

1. Introduction

The world is running on oil and gas, and is constantly developing in various fields by using these resources in their daily operations. In that manner, these fuels have become the blood of many production industries and they have been used for various purposes. Right now, the level of fossil fuels on earth is rapidly reducing and several journals and surveys are reporting that total fuel reserves will exhaust in the next fifty years. By the next five to ten years the world should switch to alternative resources from conventional fuels. Researchers have started to find alternatives for these problems and are developing new solutions that would be the driving force for generations to come. Much research has been done for alternative fuels and in such researches, diesel with bio-oil blends has attracted many researchers, as it holds enormous merits and gives positive outputs. Biodiesel is a renewable fuel and assures energy safety. It is an eco-friendly fuel as it is decomposable and a 100 percent natural fuel that holds properties similar to that of diesel. Biofuels will ensure lesser pollution level and reduce global warming. Such biofuels are produced from vegetables, plants, from a variety of seeds and few animal fats. Biofuels, using waste cooking oil is also another field of research. Thus, there are wide options for producing biodiesel blend, ranging from very low-grade quality waste cooking oil to high grade oil. Soybean, rapeseed, Pungam, Jatropha and Palm oil are the major feedstock for biodiesel

production. The Pungam oil biodiesel has higher density and calorific value among other biofuels listed above.

Biofuels contain oxygen levels up to 10–45%, while fossil fuels have none, and hence the chemical properties of biofuel are different from fossil-fuels. It was noted that HC and CO emissions have reduced but NOx emissions increased by using biodiesel blends [1]. Considering a combined pollution index to measure the overall air pollution, it was shown that transportation sector is the third largest cause of air pollution following industry and power sectors [2]. Further NOx and particulate emissions are found more toxic than CO or CO2 emissions. Various cost effective strategies are adapted to deal with NOx and soot emissions, such as the reduction of compression ratio in the engine to ensure effective combustion [3].

In this paper, we have tried to use a biodiesel blend with Pungam oil, to examine the performance and engine emission parameters. The IC engine was operated with this biofuel blend at a constant speed of 1500 rpm at various loads. The results from the engine test are recorded and found with high variability, because we changed the biodiesel blend for same set of different load conditions. We considered emission gas substances like NOx, smoke etc. as parameters for output reference and calculated the best biodiesel blend. The blend which is producing a lower amount of NOx, UBHC and CO2 among others is typically considered as the best one. In this project, we have tried to overcome the difficulties in biodiesel blend selection through a multi-criteria decision-making (MCDM) technique for evaluating and suggesting the best blend.

2. Experimental Procedure

The diesel engine used in this experiment is a high speed, 4-stroke, vertical and air-cooled type. The loading is done by means of an electrical eddy current dynamometer. Engine specifications are mentioned below in Table 1. The set-up is equipped for measuring fuel consumption, air intake. An AVL415 Smoke measuring meter is kept for measuring the % opacity of exhaust smoke. A five-gas analyzer is used to obtain the exhaust gas levels of CO2, CO, HC, NOx, and O2 [4].

Table 1. Engine Specification

Make	Kirloskar
Orientation	Vertical
Cycle	4 strokes
Rated Power	4.4 kW
Rated Speed	1500 rpm
Type Of Dynamometer	Eddy current dynamometer
Bore Diameter	87.5 mm
Stroke Length	110 mm
Cooling System	Air Cooling
Cubic Capacity	0.661 litres
Ignition System	Compression Ignition
Compression Ratio	17.5 : 1
Coefficient of discharge	0.6
Orifice diameter	13.6 mm
Lub. Oil Capacity	4 litres

The experiment was carried out at room temperature, 30°C. The injection pressure in the intake manifold was kept at 200 bar and injection timing were setup with 23° before TDC. In the present study, we are experimenting with six different types of biofuels (Diesel-B0, B20, B40, B60, B80 and B100) which were tested at a constant speed of 1500 rpm with five distinctive engine loads i.e., 0%, 25%, 50%, 75%, and 100% of load. The diesel fuel in the blend is the ultra-low sulphur diesel which we get from petrol stations, whereas the biofuel was extracted using pungam leaves.

Engine performance lies in the efficient conversion of the chemical energy into the required mechanical work. The performance parameters of an IC engine are normally Specific fuel consumption, Specific power output, Exhaust smoke and other emissions.

3. Method

3.1 Analytical Hierarchy Process (AHP)

AHP is a MCDM method, designed hierarchically for decision making at various levels, with each level containing a finite number of elements. It is one of the widely used techniques for decision making because it is better, comfortable and easy for analysis. The AHP helps in achieving both objective and subjective calculations giving a useful mechanism for correcting the consistency measures. The results of AHP are prioritized rankings or prioritized weights to each alternative or variable [5].

In AHP, there is a system of decision-making techniques that help the decision-maker. The application and importance of MCDM has widely increased in the last few years. Few examples of AHP being efficient are its use in the decision making of the transportation of fuels [6]. AHP with TOPSIS was combinedly used to examine vehicle concepts utilizing alternate fuel for public transportation [7]. There are many applications where AHP has been applied to find better results, obtained by ranking the solutions from the best to the worst solution [8-11].

The different steps involved in the AHP method are given below.

Step 1: Initially, it simplifies the complex MCDM into a hierarchy structure of criteria to evaluate potential alternatives. Using AHP, they are arranged in the mentioned structure similar to a family tree. It has three levels, the overall goals at the top, defined multi-criteria in the centre, and the decision alternatives at the lower level.

Step 2: Using the fuzzy technique, the crisp matrix A1 is formed, representing lower and upper bound range of the importance of the evaluation criteria, which is available in the form of preferences of the decision-maker. The intensity of importance is ranging from 1 to 9. 1 is referred to equal importance, 3 is referred to moderate, 5 is referred to essentially strong over the other, 7 is to very strong, 9 is to the extreme importance and even no's like 2,4,6,8 are intermediate values between adjacent judgments which is listed in Table 2.

Table 2. Intensity of Importance

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over the other	Experience and judgement favours one activity over the other
5	Essentially strong over the other	Experience and judgement strongly favours one activity over the other
7	Very strong importance	Activity is strongly favoured and its dominance is demonstrated in practice
9	Extreme importance	The favouring of one activity over the other is of the highest possible order
2,4,6,8	Intermediate value	When compromise is needed

Step 3: The pair-wise comparison matrix, A1, mentioned in Step 2 is an (nxn) matrix, where n is the number of criteria. The priority vector, A2 is then determined to finally calculate the average weight matrix. The geometric mean of each row of A1 matrix, representing the relative importance of each criteria against others, gives the priority vector A2.

The relative weights are given by the eigen vector (A2) corresponding to the eigen value (λmax), as

$$[A1] \, [A2] = [\lambda max] \, [A2].$$

The consistency index(CI) is calculated from λmax obtained from average weight matrix.

$$CI = (\lambda max - n) / (n - 1).$$

The input's consistency ratio (CR) is calculated to check the pairwise comparison matrix consistency and CR having a value of less than 0.1 is good. The CR is given as,

$$CR = CI / RCI, \text{ where RCI is the random consistency index.}$$

A number of iterations are performed which depends on the matrix order to obtain the CI. The random indices are listed from 0 to 9 in the below Table 3. According to the intensity, the acceptable CR value varies within the matrix. On the contrary, if the CR value is likely to be more than value of acceptance, inconsistency occurred in the weight matrix, and evaluation is reattempted and improved.

Table 3. Random Consistency Index

N	1	2	3	4	5	6	7	8	9
RCI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45

3.2 TOPSIS method

The TOPSIS is comparatively fast and eases the systematic fundamental procedure. It is acclaimed as the best decision-maker whose predictions lies closest to the non-ideal and ideal solutions [12]. Such positive and negative ideal solutions were computed by the overall alternatives. The positive ideals maximize the benefits and reduce the cost. On the other hand, the negative ideal solutions have increased the cost and reduce the benefits. MCDM technique predicted good results when TOPSIS is used [13]. The combined approach of TOPSIS and AHP to find and rank the data gives the finest result [14-16]. The TOPSIS has several steps to be followed.

Step 1: Normalized decision matrix is created by converting various complex units among different criteria into local measuring units to access the comparisons across the criteria. If Xij is an evaluating matrix X of alternative j under such evaluation criteria i, the normalized decision matrix X could be calculated by,

$$X = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mm} \end{bmatrix}$$

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$$

Step 2: Weighted normalized decision matrix is calculated by multiplying associated weight w_i, with normalized decision matrix Xij to get the result,

$$a_{ij} = w_i \, r_{ij} = W_i \, \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$$

Step 3: Positive and Negative Ideal solution is calculated by the formula given below for d*1 using the maximum preferable alternatives and minimum preferable alternatives, respectively.

$$a_i^* = \begin{bmatrix} \text{Max } a_{ij} \text{ for} & j=1\ldots\ldots..k \\ \text{Min } a_{ij} \text{ for} & j=k+1\ldots\ldots.n \end{bmatrix}$$

$$d^*_1 = d\,(A_1, A^*) = \sqrt{\sum_{j=1}^{n}\left(a_{ij} - a_i^*\right)^2}$$

$$a_i^o = \begin{bmatrix} \text{Min } a_{ij} \text{ for} \quad j=1\ldots\ldots\ldots k \\ \\ \text{Max } a_{ij} \text{ for} \quad j=k+1\ldots\ldots n \end{bmatrix}$$

$$d^0_1 = d\,(A_1, A^o) = \sqrt{\sum_{j=1}^{n}\left(a_{ij} - a_i^0\right)^2}$$

Step 4: Relative closeness to the ideal solution is calculated by comparing the relative closeness of 'i' alternatives, with ideal solution, 'd',

$$D_1^* = \frac{d_1^o}{d_1^* + d_1^o}$$

Step 5: Ranking is done by sorting the set of preferences accordingly to the descending order.

3.3 Criteria of best biodiesel blend selection
The criteria for selection of best biodiesel blend are identified by doing the literature study in the area of blend selection. This study helps us to find the various parameters and expert opinions to be considered in the selection process [17- 20]. The decision-making techniques will pave the way to find the best blend. The selected criteria to evaluate a biodiesel blend based on emission characteristics are given below. The pollutants listed below are known to give rise to varying levels of toxicity in air. NOx, particulate matter and HC emissions are highly toxic compared to CO. The search for the best biodiesel blend should result in reducing the more toxic emission constituents.

NOx: Oxides of nitrogen are produced when there is a high peak combustion temperature, delay in ignition, and amount of nitrogen and oxygen in the air-fuel mixture is changed or altered.

CO2: Carbon dioxide is generally emitted from all biofuels while burning it. The amount of CO_2 will be reduced if combustion is good while increased emission will occur when the combustion is poor.

Smoke: Smoke emission occurs mainly because of the oxygen content in the biodiesel molecules. Smoke emission happens because of the thermal cracking of huge polymeric chain of HC molecule in O2 deficient environment during combustion.

CO: The carbon monoxide emitted in air depends on the oxygen content in the air-fuel mixture. The carbon present in the biofuel is mixed and oxidized with O2 during combustion and forms CO.

HC: Hydro Carbons are basically present in the fuel that take part in the combustion process and reacts with the oxygen present in the air-fuel mixture and the remaining HC will be exhausted as unburned HC.

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4 Decision hierarchy

The decision hierarchy diagram is created by using evaluation criteria and alternatives and is shown in Fig.1. It consists of the objective of the problem, i.e., to select the best biodiesel blend based on the collected engine emission data. At second level in the decision hierarchy, the evaluation criteria to

select the best solution is presented, which is nothing but the various engine emission parameters that are to be reduced. The third level of decision hierarchy presents the alternative solutions, i.e., six different biodiesel blends.
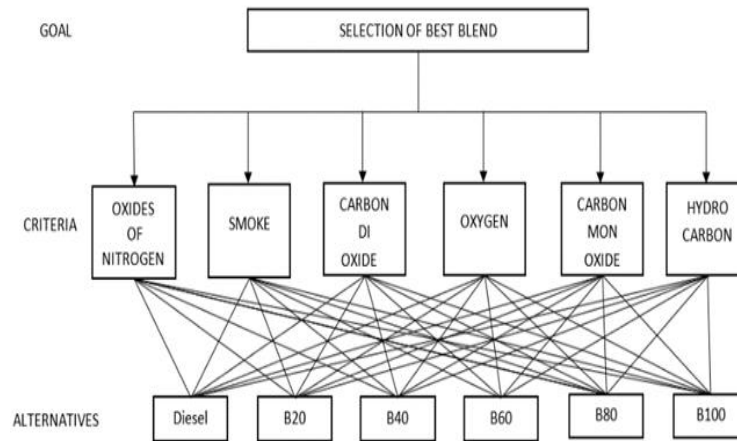

Figure 1. Decision hierarchy

5 AHP Computation

Once the decision hierarchy is constructed, the following comparisons such as pair-wise comparison will require the criteria to determine their relative weights. In this process, every criterion is being matched and compared with the nine-point scale. The AHP comparison of 6 criteria is shown in the Table 4. Here, the HC and CO are assigned the highest decision criterion compared to others.

Table 4. Pairwise weighted matrix of criteria

A1 matrix						
	NOx	Smoke	CO2	O2	CO	HC
NOx	1	3	3	3	5	5
Smoke	(1/3)	1	3	3	5	5
CO2	(1/3)	(1/3)	1	3	3	5
O2	(1/3)	(1/3)	(1/3)	1	3	5
CO	(1/5)	(1/5)	(1/3)	(1.3)	1	3
HC	(1/5)	(1/5)	(1/5)	(1/5)	(1/3)	1

5.1 Weights of criteria normalization

Accordingly, to the weights of each criterion is obtained by calculating the geometric mean of corresponding row. This calculation is given in the below Table 5.

By multiplying the A1*A2 matrices we get the A3 matrix of criteria weights in Table 6.

5.2 Average matrix

The average matrix calculates the average weights of the criteria. This is done by dividing the A3 matrix by A2 matrix as shown in Table 7.

The λmax value is the mean vale obtained from Table 7 and as n=6, the consistency index is calculated as

$$CI = (\lambda max-n) / (n-1) = 0.108995.$$

From Table 3, RCI = 1.25. So, the consistency ratio, CR = CI/RCI = 0.0872. As the CR value is less than 0.1, we move forward with the analysis.

Table 5. The weights of criteria

A2 matrix	
NOx	0.37082599
Smoke	0.25668578
CO2	0.16317707
O2	0.11295130
CO	0.06076506
HC	0.03559520
Sum	1

Table 6. A3 matrix

A3 matrix	
A1*A2 matrix	
NOx	2.4511
Smoke	1.6905
CO2	1.0715
O2	0.7368
CO	0.3851
HC	0.2366

Table 7. A4 average weight matrix

A4 = A3/A2 matrix	
NOx	6.609845881
Smoke	6.585873191
CO2	6.566486292
O2	6.523165085
CO	6.337523701
HC	6.646964389
λmax	6.544976423

6   Technique For Order Preference by Similarity of Ideal Solution (TOPSIS) Computation

TOPSIS computation is used for the selection of the best biodiesel blend. The emission characteristics of the IC engine under 0 to 100 % load condition are taken to perform the TOPSIS computation. The procedure starts with the normalization of the experimental data of emission and using it in the equation. The AHP criteria weights are accepted and computed with the weighted normalized decision matrix using those equations.

6.1 Normalized decision matrix
The normalized decision matrix is obtained by adding each value of the squared matrix and adding all the values in the column followed by square root of the obtained value. Then, we divide it with all individual values in the respective column. The matrix is given in Table 8.

6.2 Weighted normalization matrix
The weighted normalization matrix is obtained by multiplying the normalized matrix with the A2 matrix. This weighted normalized matrix is given in Table 9.

6.3 Positive ideal solution and Negative ideal solution
The positive ideal solution is calculated by taking the weighted decision matrix and negating each column vector by its corresponding minimum value and then taking the square of the obtained value. To find the total positive ideal solution for each blend, the values of each row in the matrix are added and the total square root of it is taken. For the negative ideal solution instead of computing with the minimum value, the maximum value is used to calculate the values of the matrix.

For calculating the individual values of the positive and negative ideal solution matrix the following computation is performed and squared, respectively. Table 10 shows the Positive ideal solution matrix and Table 11 shows Negative ideal solution matrix.

$a^{*}_{1} = \{\ 0.148,\ 0.1416,\ 0.1584,\ 0.135,\ 0.151,\ 0.169\} - \{0.135\}$

$a^{o}_{1} = \{\ 0.148,\ 0.1416,\ 0.1584,\ 0.135,\ 0.151,\ 0.169\} - \{0.169\}$

For computing the whole matrix, the current formula is used,

$$d^{*}_{1} = \sqrt{\begin{array}{l}(0.148 - 0.135)^2 + (0.141 - 0.135)^2 + (0.158 - 0.135)^2 \\ + (0.135 - 0.135)^2 + (0.151 - 0.135)^2 + (0.169 - 0.135)^2\end{array}} = 0.0129$$

$$d^{o}_{1} = \sqrt{\begin{array}{l}(0.148 - 0.169)^2 + (0.141 - 0.169)^2 + (0.158 - 0.169)^2 \\ + (0.135 - 0.169)^2 + (0.151 - 0.169)^2 + (0.169 - 0.169)^2\end{array}} = 0.0945$$

The closeness coefficients of the alternatives with respect to the ideal solution is given using the mentioned equation below, and from the calculated values the ranking is done by giving the least rank to the maximum value.

$D_{1}^{*} = \dfrac{0.0945}{0.0129 + 0.0945} = 0.87925$;

$D_{2}^{*} = \dfrac{0.0961}{0.0097 + 0.0961} = 0.9081$

$D_{3}^{*} = \dfrac{0.0445}{0.0549 + 0.0445} = 0.44736$;

$D_{4}^{*} = \dfrac{0.04192}{0.0699 + 0.04192} = 0.3749$

$D_{5}^{*} = \dfrac{0.01882}{0.093 + 0.01882} = 0.16773$;

$D_{6}^{*} = \dfrac{0.0098}{0.0935 + 0.0098} = 0.0955$

Table 8. Normalized Decision Matrix							
Load(%)	Blends	NOx(ppm)	Smoke(%)	CO_2(%)	O_2(%)	CO(%)	HC(ppm)
0%	Diesel	0.400096	0.187511	0.396434	0.406369	0.394055	0.379468
	B 20	0.381909	0.187511	0.396434	0.405662	0.394055	0.491076
	B 40	0.427375	0.379487	0.396434	0.403542	0.394055	0.53572
	B 60	0.366754	0.459849	0.396434	0.409196	0.394055	0.26786
	B 80	0.409189	0.544675	0.430906	0.419326	0.472866	0.379468
	B 100	0.457685	0.526817	0.430906	0.405191	0.394055	0.334825
25%	Diesel	0.418605	0.355693	0.429755	0.400407	0.421076	0.47036
	B 20	0.370071	0.397685	0.405198	0.407333	0.421076	0.517396
	B 40	0.421639	0.444617	0.392919	0.408359	0.421076	0.517396
	B 60	0.380688	0.459437	0.405198	0.411437	0.336861	0.329252
	B 80	0.395855	0.392745	0.39783	0.410667	0.421076	0.23518
	B 100	0.456522	0.390275	0.417476	0.41118	0.421076	0.282216
50%	Diesel	0.411195	0.311316	0.418047	0.411505	0.303046	0.51367
	B 20	0.366576	0.467906	0.243051	0.403542	0.404061	0.533426
	B 40	0.407696	0.417573	0.42777	0.405533	0.404061	0.474156
	B 60	0.400697	0.411981	0.437492	0.410936	0.404061	0.296348
	B 80	0.461939	0.443672	0.42777	0.412074	0.404061	0.316104
	B 100	0.395448	0.378426	0.456936	0.405817	0.505076	0.197565
75%	Diesel	0.402367	0.24674	0.395529	0.412339	0.389249	0.493913
	B 20	0.359492	0.529944	0.415988	0.402023	0.467099	0.474156
	B 40	0.412921	0.488618	0.395529	0.412339	0.3114	0.474156
	B 60	0.381919	0.384088	0.429626	0.396032	0.467099	0.375374
	B 80	0.398409	0.339116	0.415988	0.407347	0.467099	0.355617
	B 100	0.4835	0.396243	0.395529	0.418995	0.3114	0.197565
100%	Diesel	0.389601	0.457889	0.399185	0.405605	0.43352	0.512672
	B 20	0.399787	0.445011	0.425797	0.383236	0.464486	0.485689
	B 40	0.444986	0.39636	0.38854	0.430507	0.144507	0.418232
	B 60	0.395331	0.413531	0.40983	0.409404	0.43352	0.350775
	B 80	0.406153	0.36488	0.420475	0.402651	0.402554	0.350775
	B 100	0.411246	0.362018	0.404507	0.416579	0.474807	0.283319

Table 9. Weighted Normalized Decision Matrix							
Load(%)	Blends	NOx(ppm)	Smoke(%)	CO_2(%)	O_2(%)	CO(%)	HC(ppm)
0%	Diesel	0.148363426	0.048126628	0.064688894	0.045899401	0.023944764	0.013507204
	B 20	0.141619634	0.048126628	0.064688894	0.045819576	0.023944764	0.017479911
	B 40	0.158479114	0.097399127	0.064688894	0.045580101	0.023944764	0.019068994
	B 60	0.135999807	0.118024825	0.064688894	0.046218701	0.023944764	0.009534497
	B 80	0.151735322	0.139796394	0.070314015	0.04736286	0.028733717	0.013507204
	B 100	0.169718768	0.135212906	0.070314015	0.045766359	0.023944764	0.011918121
25%	Diesel	0.155227235	0.091292238	0.070126126	0.04522598	0.025586681	0.016742527
	B 20	0.137229874	0.102069794	0.066118919	0.046008236	0.025586681	0.018416779
	B 40	0.15635207	0.114115298	0.064115315	0.046124126	0.025586681	0.018416779
	B 60	0.141166797	0.117919141	0.066118919	0.046471795	0.020469345	0.011719769
	B 80	0.146790972	0.100801846	0.064916757	0.046384878	0.025586681	0.008371263
	B 100	0.169287673	0.100167873	0.068122522	0.046442823	0.025586681	0.010045516
50%	Diesel	0.152479498	0.079902331	0.068215736	0.046479474	0.018414576	0.018284117
	B 20	0.13593385	0.120092725	0.039660311	0.045580078	0.024552768	0.018987353
	B 40	0.1511818	0.107174384	0.069802148	0.045804927	0.024552768	0.016877647
	B 60	0.148586404	0.105739013	0.07138856	0.046415231	0.024552768	0.010548529
	B 80	0.171296117	0.113872783	0.069802148	0.046543716	0.024552768	0.011251765
	B 100	0.146639857	0.097126785	0.074561385	0.045837048	0.03069096	0.007032353
75%	Diesel	0.149205621	0.063328288	0.064541256	0.046573729	0.023652744	0.017580882
	B 20	0.133306662	0.136015436	0.067879596	0.045408446	0.028383293	0.016877647
	B 40	0.153119211	0.125408727	0.064541256	0.046573729	0.018922195	0.016877647
	B 60	0.141623041	0.098579995	0.070105157	0.04473183	0.028383293	0.01336147
	B 80	0.147738025	0.0870374	0.067879596	0.046009882	0.028383293	0.012658235
	B 100	0.179291345	0.101699615	0.064541256	0.047325524	0.018922195	0.007032353
100%	Diesel	0.144471889	0.117521714	0.065137765	0.045813139	0.026342835	0.018248597
	B 20	0.148248932	0.114216416	0.069480283	0.043286504	0.028224466	0.017288145
	B 40	0.165009559	0.101729734	0.063400758	0.048625809	0.008780945	0.014887014
	B 60	0.146596475	0.106136798	0.066874772	0.04624219	0.026342835	0.012485882
	B 80	0.150609584	0.093650116	0.068611779	0.045479433	0.024461204	0.012485882
	B 100	0.152498105	0.092915605	0.066006269	0.047052621	0.028851677	0.010084751

				Table 10. Positive Ideal Solution			
Load(%)	Blends	NOx(ppm)	Smoke(%)	CO_2(%)	O_2(%)	CO(%)	HC(ppm)
0%	Diesel	0.000153	0	0	1.01953E-07	0	1.57824E-05
	B 20	3.16E-05	0	0	5.73483E-08	0	6.31296E-05
	B 40	0.000505	0.002428	0	0	0	9.09066E-05
	B 60	0	0.004886	0	4.0781E-07	0	0
	B 80	0.000248	0.008403	3.1642E-05	3.17823E-06	2.29341E-05	1.57824E-05
	B 100	0.001137	0.007584	3.1642E-05	3.46922E-08	0	5.68166E-06
25%	Diesel	0.000324	0	3.61298E-05	0	2.61871E-05	7.00781E-05
	B 20	0	0.000116	4.01443E-06	6.11924E-07	2.61871E-05	0.000100912
	B 40	0.000366	0.000521	0	8.06666E-07	2.61871E-05	0.000100912
	B 60	1.55E-05	0.000709	4.01443E-06	1.55205E-06	0	1.12125E-05
	B 80	9.14E-05	9.04E-05	6.42308E-07	1.34304E-06	2.61871E-05	0
	B 100	0.001028	7.88E-05	1.60577E-05	1.48071E-06	2.61871E-05	2.80312E-06
50%	Diesel	0.000274	0	0.000815412	8.08912E-07	0	0.000126602
	B 20	0	0.001615	0	0	3.76774E-05	0.000142922
	B 40	0.000232	0.000744	0.00090853	5.0557E-08	3.76774E-05	9.69298E-05
	B 60	0.00016	0.000668	0.001006682	6.9748E-07	3.76774E-05	1.23635E-05
	B 80	0.00125	0.001154	0.00090853	9.28598E-07	3.76774E-05	1.78034E-05
	B 100	0.000115	0.000297	0.001218085	6.60337E-08	0.00015071	0
75%	Diesel	0.000253	0	0	3.39259E-06	2.23781E-05	0.000111271
	B 20	0	0.005283	1.11445E-05	4.57809E-07	8.95124E-05	9.69298E-05
	B 40	0.000393	0.003854	0	3.39259E-06	0	9.69298E-05
	B 60	6.92E-05	0.001243	3.0957E-05	0	8.95124E-05	4.00577E-05
	B 80	0.000208	0.000562	1.11445E-05	1.63342E-06	8.95124E-05	3.16506E-05
	B 100	0.002115	0.001472	0	6.72725E-06	0	0
100%	Diesel	0	0.000605	3.01719E-06	6.38389E-06	0.00030842	6.66484E-05
	B 20	1.43E-05	0.000454	3.69606E-05	0	0.000378051	5.18889E-05
	B 40	0.000422	7.77E-05	0	2.85082E-05	0	2.30617E-05
	B 60	4.51E-06	0.000175	1.20688E-05	8.73608E-06	0.00030842	5.76543E-06
	B 80	3.77E-05	5.4E-07	2.71547E-05	4.80894E-06	0.000245871	5.76543E-06
	B 100	6.44E-05	0	6.78869E-06	1.41836E-05	0.000402834	0

Table 11. Negative Ideal Solution							
Load(%)	Blends	Nox(ppm)	Smoke(%)	CO_2(%)	O_2(%)	CO(%)	HC(ppm)
0%	Diesel	0.000456051	0.008403346	3.1642E-05	2.14171E-06	2.29E-05	3.09335E-05
	B 20	0.000789561	0.008403346	3.1642E-05	2.38173E-06	2.29E-05	2.52518E-06
	B 40	0.00012633	0.001797528	3.1642E-05	3.17823E-06	2.29E-05	0
	B 60	0.001136968	0.000474001	3.1642E-05	1.3091E-06	2.29E-05	9.09066E-05
	B 80	0.000323404	0	0	0	0	3.09335E-05
	B 100	0	2.10084E-05	0	2.54882E-06	2.29E-05	5.1135E-05
25%	Diesel	0.000197696	0.000708992	0	1.55205E-06	0	2.80312E-06
	B 20	0.001027702	0.000251202	1.60577E-05	2.14887E-07	0	0
	B 40	0.00016733	1.44692E-05	3.61298E-05	1.20874E-07	0	0
	B 60	0.000790784	0	1.60577E-05	0	2.62E-05	4.485E-05
	B 80	0.000506102	0.000293002	2.71375E-05	7.55462E-09	0	0.000100912
	B 100	0	0.000315108	4.01443E-06	8.39402E-10	0	7.00781E-05
50%	Diesel	0.000354065	0.001615268	4.02673E-05	4.1271E-09	0.000151	4.9454E-07
	B 20	0.00125049	0	0.001218085	9.28598E-07	3.77E-05	0
	B 40	0.000404586	0.000166884	2.26503E-05	5.45809E-07	3.77E-05	4.45086E-06
	B 60	0.000515731	0.000206029	1.00668E-05	1.65084E-08	3.77E-05	7.12137E-05
	B 80	0	3.86877E-05	2.26503E-05	0	3.77E-05	5.98393E-05
	B 100	0.000607931	0.000527434	0	4.99379E-07	0	0.000142922
75%	Diesel	0.000905151	0.005283421	3.0957E-05	5.65196E-07	2.24E-05	0
	B 20	0.002114591	0	4.95312E-06	3.67519E-06	0	4.9454E-07
	B 40	0.000684981	0.000112502	3.0957E-05	5.65196E-07	8.95E-05	4.9454E-07
	B 60	0.001418901	0.001401412	0	6.72725E-06	0	1.78034E-05
	B 80	0.000995612	0.002398848	4.95312E-06	1.73091E-06	0	2.42325E-05
	B 100	0	0.001177576	3.0957E-05	0	8.95E-05	0.000111271
100%	Diesel	0.000421796	0	1.88575E-05	7.91111E-06	6.29E-06	0
	B 20	0.000280919	1.0925E-05	0	2.85082E-05	3.93E-07	9.22469E-07
	B 40	0	0.000249387	3.69606E-05	0	0.000403	1.13002E-05
	B 60	0.000339042	0.000129616	6.78869E-06	5.68164E-06	6.29E-06	3.32089E-05
	B 80	0.000207359	0.000569853	7.54298E-07	9.89968E-06	1.93E-05	3.32089E-05
	B 100	0.000156536	0.000605461	1.20688E-05	2.47492E-06	0	6.66484E-05

7   Results and Discussion

The most prioritized ranking order is obtained for the different biodiesel blends, based on the 0%, 25%, 50%, 75%, 100% engine loads, considering six prominent emission criteria. The AHP and TOPSIS computations were carried out using MS-EXCEL spreadsheet. The time of computation will be increased if the criteria and alternatives numbers increased. The results obtained from AHP-TOPSIS ranking is mentioned in the Table 8.1 and 8.2 below. Using the relative closeness, the ranking of each alternative is done.

From the comparison of results of the AHP-TOPSIS method, the order of preference of the best blend with respect to other blends are B20>Diesel>B80>B60>B100>B40. The following result showcases the best biodiesel blend of Pungam oil is B20 at low load level and B80 at high load level. In summary, the Tables 12 and 13 provide the rank for each blend with respect to the operating load which has been taken as the input variable. Thus the MCDM technique helps identify the biodiesel blend that will result in reduction of the relatively more toxic emission constituents.

Table 12. Ideal Closeness Ranking

Blend	0% Load	Rank	25% Load	Rank	50% Load	Rank
Diesel	0.879250298	2	0.585579262	3	0.571315076	1
B20	0.908095145	1	0.695662148	1	0.541612392	2
B40	0.447361855	3	0.316762007	6	0.3596075	5
B60	0.374916141	4	0.521130261	4	0.400420209	4
B80	0.167727506	5	0.677534165	2	0.1778395956	6
B100	0.095495504	6	0.367486041	5	0.458745012	3

Blend	75% Load	Rank	100% Load	Rank
Diesel	0.800068806	1	0.404005120	5
B20	0.383645560	5	0.397113550	6
B40	0.314977017	6	0.529955873	3
B60	0.581593121	3	0.501528461	4
B80	0.660581746	2	0.617731077	1
B100	0.385081300	4	0.567879731	2

Table 13. Relative Closeness Rating

		Rank					
		Diesel	B20	B40	B60	B80	B100
	0%	2	1	3	4	5	6
	25%	3	1	6	4	2	5
Load	50%	1	2	5	4	6	3
	75%	1	5	6	3	2	4
	100%	5	6	3	4	1	2

8   Conclusion

By the right selection of biodiesel blend, we can reduce the toxic engine emission and also biodegradable in nature and thus environment friendly. Using AHP-TOPSIS method, the selection of best biodiesel blend for IC engine based on emission characteristics, has been achieved in this study. By considering the quantity of NOx, smoke, CO_2, CO, O_2 and HC in the engine exhaust as the evaluation criteria, the AHP was used to prioritize the weightage of emission criteria and TOPSIS method has been implemented to rank six different fuel blends. From the comparison of results of the AHP-TOPSIS analysis, the B20 blend is the best option for low engine loads while B80 shows up as the best option at high engine loads. The decision making methods proposed in this study will help the manufacturing industries, in research and development to analyze the fuel and to choose the best biofuel for their IC engines. The ranking method is to give the precise ranking for the alternatives that have been used. This method is found to be different from the existing selection methods. For further research and experiments, the percentage of biodiesel blend should be taken in small variations for increasing the accuracy of the blend selection.

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