Application of Multi Attributes Decision Making Methods For Selection of Blends of Ethanol with Petrol for SI engine

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Abstract- *The rapid growth of automobile industries leads to numerous vehicles on the road which consumes ample amount of fuel and hence rapid decrease in natural fuel. Therefore, need of finding out a suitable alternative fuel is required. India and other agricultural countries produces sugarcane in a considerable quantity and ethanol is a byproduct of sugarcane industry. Blending of ethanol with petrol can save tremendous amount of petrol. The present work, carried out experimentation on SI engine using different blends of ethanol with petrol such as E5, E8, E10 and E12 and the various engine performance parameters like brake thermal efficiency, volumetric efficiency, air to fuel ratio and heat given by exhaust were recorded. The different multi attributes decision making methods like technique of order preference by similarity to ideal solution (TOPSIS), compromise ranking method (VIKOR), modified similarity based method (Deng's Method) were used to find the rank of the blends. It is found that blend E10 is the best alternative with petrol.*

Keywords- Blending, TOPSIS, VIKOR, Deng's Method, etc.

I. INTRODUCTION

In this era of industrialization, manufacturing sector plays a very important role in the economic growth of a country and optimal inputs form the basis of competitive environment. Optimization is a decision making procedure used to obtain the best possible solution of a given problem not only in the manufacturing industry but also in day-to-day decisive life. In past few year varieties of vehicles with fewer prices made flood of vehicles on the road. This simultaneously results in depletion of petrol sources. Petrol is a non-renewable energy source hence it is required to find a secondary energy source. But there is no alternative source which can drive engine on its own energy. Hence there is need of mixing of primary and secondary energy sources. Mixing of ethanol with petrol can save considerable amount of petrol.

Researcher used various MADM methods for selection problems of different industrial and daily applications. Gupta et al. [1] showed that an AHP model of manufacturing sustainability through different manufacturing practices to achieve competiveness in the market. Kamble and Rao [2] explained that selection procedure of cricket players from a set of six level players in complex situations using analytical hierarchy process and it helps to rank the players. Wanke et al. [3] proposed that the performance assessment of Asian airlines using TOPSIS, to compute efficiency and increases the discriminatory power of the analysis against the efficient frontier. Sengul et al. [4] showed that the development of the multi criteria decision support framework for ranking renewable energy supply systems in Turkey. Saeedpoor and Vafadarnikjoo [5] proposed that an integrated multi-criteria renewable energy planning using an integrated fuzzy VIKOR-AHP methodology in order to determine the best renewable energy alternative and prioritize alternative energy production sites. Darji and Rao [6] proposed that Selection of best alternative among multiple alternatives is a tough task for decision makers in many industrial situations. This paper explores the applicability and capability of an outranking method known as Evaluation of Mixed Data (EVAMIX) method. Ataei E. [7] studied the application of TOPSIS and Fuzzy TOPSIS Method for plant layout Design. Khorshidi R., Hassani A. [8] proposed the Comparative analysis between TOPSIS and PSI method of materials selection to achieve a desirable combination of strength and workability in Al/SiC composite. Zhang Z. [9] studied the approach to multi attribute group decision making and its application to project risk assessment. Lamta M. [10] found out the Ranking of alternatives with ordered weighted averaging operators. Hashemi S.S et al. [11] proposed the Decision Making with unknown data Development of ELECTRE Method Based on Black Numbers. Stanujkic D. et al. [12] studied Extension of ratio system part of moora method for solving decision-making problems with interval data.

Gadakh V. S. [13] proposed the application of MOORA method for parametric optimization of milling process. Athawale V. M. and Chakraborti S. [14] studied Facility location Selection using PROMETHEE Method. Lotfi F. H. and Fallahnejad R. [15] proposed Impressive Shannon's entropy and multi attribute decision making. Popovic G. et al. [16] studied investment project selection by applying copras method and imprecise data. Chatterjee, Mondal P. and

Chakraborty S. [17] studied comparative study of preference dominance based approaches for selection of industrial robots. Stanujkic D. et al. [18] proposed extension of ratio system part of moora method for solving decision-making problems with interval data. Ermatita and Hartati S. [19] studied ELECTRE methods in solving group decision support system. Turskis Z. et al. [20] studied the novel method for multiple criteria analysis grey additive ratio assessment method. Pastijn H. and Leysen J [21] proposed constructing an outranking relation with ORESTE.

II. PROBLEM DEFINITION

Experiment were carried on four stroke, three cylinder diesel engine having bore diameter 68.5mm, stroke 72mm, piston displacement 790 cm and compression ratio 9:2:1 with different blends of ethanol with petrol (E5, E8, E10 and E12) are used in the engine to compare brake thermal efficiency (BTE), volumetric efficiency (VLE), air fuel ratio (A/F ratio) and heat given by exhaust (EH). The following results were found out.

Table 1 Blends of ethanol with different attributes

Sr. no.	Alternatives	Attributes			
		BTE (%)	VLE (%)	A/F ratio	EH (%)
1	E5	29.03	36.1	21.8	8.9
2	E8	43.26	21.9	19.7	9.4
3	E10	36.41	36.1	27.3	18.5
4	E12	19.08	33.5	13.3	7.7

III. MULTI ATTRIBUTES DECISION MAKING METHODS

3.1TOPSIS

This method [3] follows the concept that the chosen alternative should have the shortest Euclidean distance from the positive ideal solution and farthest from the negative ideal solution. TOPSIS thus gives the solution that is not only closest to hypothetically best, that is also the farthest from the hypothetically worst. The main procedure of the TOPSIS method for selection of the best alternative from among those available is described below,

Step 1: Determine the objective and evaluation attributes.

Step 2: Find out the relative importance of different attributes with respect to the goal. Construct a pair wise comparison matrix using a scale of relative importance. An attribute compared with it is always assigned the value 1, so the main diagonal entries of the pair wise comparison matrix are all 1. Assuming M attributes, the pair-wise comparison of attribute i with attribute j yields a square matrix $B_{M \times M}$ where, a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, $b_{ij} = 1$ when i = j and b_{ji}. Find the relative normalized weight (w_j) of each attribute by calculating the geometric mean of i^{th} row and normalizing the geometric means of rows in the comparison matrix.

The geometric mean method is used to find out the relative normalized weights of the attributes because of its simplicity and easiness to find out the maximum Eigen value and to reduce the inconsistency in solution.

$$GM_j = [\Pi b_{ij}]^{1/M}$$

$$W_j = GM / \Sigma\, GM_j$$

- Calculate matrices A3 and A4 such that A3 = A1 x A2 and A4=A3 /A2,
  Where, A2 = $[w_1, w_2 \dots w_j]^T$ and A1= Decision matrix
- Find out the maximum Eigen value λ_{max} (average of matrix A4).
- Calculate the consistency index CI = (λ_{max} - M)/ (M - 1). The smaller the value of CI, the smaller is the deviation from the consistency and M is matrix size.
- Obtain the random index (RI) for the number of attributes used in decision making.
- Calculate the consistency ratio, CR = CI/RI. Usually, a CR of 0.1 or less is considered as acceptable as it reflects an informed judgment that could be attributed to the knowledge of the analyst about the problem under study.

Step 3: Construct the normalized decision matrix.

$$r_{ij}= x_{ij}/ (\Sigma x^2_{ij}) \text{ for } i=1\dots m;\ j = 1\dots n$$

Step 4: Construct the weighted normalized decision matrix. Assume we have a set of weights for each criteria w_j for j = 1.....n. Multiply each column of the normalized decision matrix by its associated weight.

$$V_{ij}= wj_{*}r_{ij}$$

Step 5: Determine positive ideal and negative-ideal solutions.

Positive ideal solution is the maximum value for the beneficial attributes while minimum value for the non-beneficial attributes.

Negative ideal solution is the minimum value for the beneficial attributes while maximum value for the non-beneficial attributes.

Step 6: Calculate the separation measure.

Positive separation measures is calculated as

$$S_i^+ = [\sum (V_j^+ - V_{ij})^2]^{1/2}$$

Negative separation measures is calculated as

$$S_i^- = [\sum (V_j^- - V_{ij})^2]^{1/2}$$

Step 7: Calculate the relative closeness to the ideal solution.

$$P_i = S_i^- / (S_i^- + S_i^+)$$

Step 8: Rank the alternatives in descending order of P_i. The first rank obtained is closest to idealsolution.

3.2 VIKOR

The VIKOR method [5] was developed as a multi-criteria decision-making method to solve discrete decision problems with non-commensurable and conflicting criteria. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria, is to help decision makers reach the final destination.

The main procedure of the VIKOR method is described below,

Step 1: to determine objective, and to calculate best and worst values of all attributes.

Best value for beneficial attribute is maximum value while minimum for non-beneficial attributes. Worst value is the minimum value for beneficial while maximum value for the non-beneficial attributes.

Step 2: Calculate the optimal and inferior solution of schemes comprehensive evaluation.

$$E_i = \sum_{j=1}^{M} w_j (((m_{ij})_{max} - (m_{ij})) / ((m_{ij})_{max} - (m_{ij})_{min}))$$

F_i =Max of

$$\sum_{j=1}^{M} w_j (((m_{ij})_{max} - (m_{ij})) / ((m_{ij})_{max} - (m_{ij})_{min}))$$

Step 3: Calculate the value of interests ratio brought by scheme.

$$P = (v (E-E_{min}) / (E_{max}-E_{min})) + ((1-v)*(F-F_{min}) / (F_{max}-F_{min}))$$

Step 4: Arrange the alternatives in the ascending order according to values of interest ratio.

After the alternatives are arranged according to ranks, the first alternative is the best solution and is closest to the ideal solution and the last alternative is the worst solution and is closest to negative ideal solution.

3.3 Deng's Similarity Based Method

The stepwise solution for Deng's Similarity Method is as follows.

Step 1: Find out the relative importance of different attributes with respect to the goal. Construct a pair wise comparison matrix using a scale of relative importance. This step is explained above in AHP method solution (step1).

Step 2: Normalize the decision matrix through Euclidean normalization.

$$r_{ij} = x_{ij} / (\Sigma x^2_{ij}) \qquad \text{for } i=1\ldots m;\ j = 1\ldots n$$

Step 3: Construct the weighted normalized decision matrix. Assume we have a set of weights for each criteria w_j for j = 1.....n. Multiply each column of the normalized decision matrix by its associated weight.

$$V_{ij} = w_{j*\ rij.}$$

Step 4: Determine positive ideal and negative-ideal solutions.
Positive ideal solution is the maximum value for the beneficial attributes while minimum value for the non-beneficial attributes.

Negative ideal solution is the minimum value for the beneficial attributes while maximum value for the non-beneficial attributes.

Step 5: Conflict index between alternative and PIS and NIS:
Deng (2007) introduced the concept of alternative gradient to represent the conflict of alternative in multiple criteria analysis problem.

The degree of conflict between alternative (A_i) and I^+ (I^-) is determined by:

$$COS\theta_i^+ = (\Sigma\, y_{ij} * I^+) / [\Sigma\, y_{ij}^2 * \Sigma\, (I_j^+)^2]^{1/2}$$
$$COS\theta_i^- = (\Sigma\, y_{ij} * I^-) / [\Sigma\, y_{ij}^2 * \Sigma\, (I_j^-)^2]^{1/2}$$

For j = 1, 2 ...m.

Step 6: calculating the degree of similarity of the alternative between each alternative and the PIS and NIS:

Based on the degree of the Conflict between the alternative and the PIS and NIS, the degree of similarity of the alternative between alternative (A_i) and I^+ (I^-) can be calculated as follows:

$$S_i^+ = [COS\,(\theta_i^+) * (A_i)] / (I_j^+)$$
$$S_i^- = [COS\,(\theta_i^-) * (A_i)] / (I_j^-)$$

Step 7: Calculating overall performance index for each alternative across all criteria:

$$P_i = S_i^+ / (Si^+ + S_i^-)$$

Step 8: ranking the alternatives in the descending order of the performance index.

IV. SOLUTION USING MULTIPLE ATTRIBUTE DECISION MAKING METHODS

4.1 TOPSIS method

Step 1: Construct normalized decision matrix.

$r_{ij}= x_{ij}/ (\Sigma x^2_{ij})^{1/2}$ for i = 1, …, m; j = 1, …, n

$r_{ij}= 29.03/(29.03^2{}_{+}43.26^2+36.41^2+19.08^2)^{1/2}=0.4374$

Table 4 Normalized decision matrix.

Sr. No.	Material	BTE	VLE	A/F	EH
1	E5	0.4374	0.5565	0.5159	0.3731
2	E8	0.6519	0.3376	0.4662	0.3940
3	E10	0.5487	0.5565	0.6461	0.7755
4	E12	0.2875	0.5164	0.3148	0.3228

Step 2: Construct the weighted normalized decision matrix. Initially we have calculated weight for each attribute. Multiply each column of the normalized decision matrix by its associated weight. An element of the new matrix is vij= $w_j * r_{ij}$.

Step 3: Determine positive ideal and negative-ideal solutions and also determine the separation measures.

Negative separation measures:

$S_i^- = [\sum (V_j^- - V_{ij})^2]^{1/2}$

$S_1^+=0.0928$, $S_2^+=0.1025$, $S_3^+=0.0599$, $S_4^+=0.2100$

Positive separation measures:

$S_i^+= [\sum (V_j^+ - V_{ij})^2]^{1/2}$

$S_1^-=0.1613$, $S_2^-=0.1361$, $S_3^-=0.1994$, $S_4^-=0.0542$

Step 4: Calculate the relative closeness to the ideal solution. $P_i = S_i^-/ (S_i^- + S_i^+)$ and rank the alternative in descending order of P_i.

Table 5 Relative Closeness

P_i	Values	Rank
P_1	0.6348	2
P_2	0.5704	3
P_3	0.7692	1
P_4	0.2052	4

Hence the order of selection of Blends of Ethanol is **2-3-1-4** by TOPSIS.

4.2 Solution by VIKOR

Step 1: To determine objective, and to calculate best and worst values of all attributes.

Table 6 Best and Worst Values

Attributes	Best Value	Worst Value
BTE	43.26	19.08
VLE	36.1	21.9
A/F	27.3	13.3
EH	7.7	18.5

Step 2: Calculate the optimal and inferior solution of schemes comprehensive evaluation.

$E_i=\sum_{j=1}^{M} w_j ((m_{ij})_{max} - (m_{ij})) / ((m_{ij})_{max} - (m_{ij})_{min})$

$=\sum W_{ij}((m_{ij})max-(m_{ij}))/((m_{ij})max-(m_{ij})_{min})$

Table 7 Optimal Solution and Inferior Solution

E1	0.3896	F1	0.2215
E2	0.3797	F2	0.3061
E3	0.1924	F3	0.1178
E4	0.8373	F4	0.5639

E min= 0.1924 E max=0.8373

F min=0.1178 F max=0.5639

F_i =Maximum of

$\sum_{j=1}^{M} w_j ((m_{ij})_{max} - (m_{ij})) / ((m_{ij})_{max} - (m_{ij})_{min})$

Step 3 Calculate the value of interests ratio brought by scheme, P_i.

$P= (v (E- E_{min}) / (E_{max}- E_{min})) + ((1-v) (F - F_{min}) / (F_{max}- F_{min}))$, Where, v=0.5

Table 8 Interest Ratio

Interest Ratio	RANK
0.2691	2
0.3563	3
0.0000	1
1.0000	4

Hence, the order of selection of Blends of Ethanol is **2-3-1-4** by VIKOR.

4.3 Solution by Deng's Method:

Step 1: Construct normalized decision matrix.

$r_{ij}= x_{ij}/ (\Sigma x^2_{ij})^{1/2}$ for i = 1, …, m; j = 1, …, n

$r_{ij}= 29.03/(29.03^2{}_{+}43.26^2+36.41^2+19.08^2)^{1/2}=0.4374$

Table 9 Normalized decision matrix.

Sr. No.	Material	BTE	VLE	A/F	EH
1	E5	0.4374	0.5565	0.5159	0.3731
2	E8	0.6519	0.3376	0.4662	0.3940
3	E10	0.5487	0.5565	0.6461	0.7755
4	E12	0.2875	0.5164	0.3148	0.3228

Step 2: Construct the weighted normalized decision matrix. Initially we have calculated weight for each attribute. Multiply each column of the normalized decision matrix by its associated weight. An element of the new matrix is

$v_{ij}= w_j * r_{ij}$.

The positive ideal solution is as follow

BTE=0.1716, VLE=0.0306, A/F=0.3643, EH=0.0380

The negative ideal solution is as follow

BTE=0.0757, VLE=0.0186, A/F=0.1775, EH=0.0914

Calculate conflict Index ($COS\theta^+$)

$$COS\theta_i^+= (\Sigma y_{ij} * I^+)/ [\Sigma y_{ij}^2 * \Sigma (I_j^+)^2]^{1/2}$$

$$COS\theta_i^- = (\Sigma y_{ij} * I^-)/ [\Sigma y_{ij}^2 * \Sigma (I_j^-)^2]^{1/2}$$

Table 10 Conflict Index (+) ve

$COS\theta_1^+$	0.99680
$COS\theta_2^+$	0.98915
$COS\theta_3^+$	0.98908
$COS\theta_4^+$	0.99206

Table 11 Conflict Index (-) ve

$COS\theta_1^-$	0.95459
$COS\theta_2^-$	0.94293
$COS\theta_3^-$	0.97717
$COS\theta_4^-$	0.96832

Step 3: Calculating The Degree Of Similarity Of The Alternative Between Each Alternative And The PIS And NIS:

$S_i^+ = [COS (\theta_i^+) * (A_i)] / (I_j^+)$

$S_1^+=0.7801$, $S_2^+=0.7751$, $S_3^+=0.9840$, $S_4^+=0.4860$

And

$S_i^- = [COS (\theta_i^-) * (A_i)] / (I_j^-)$

$S_1^-=0.7072$, $S_2^-=0.7150$, $S_3^-=0.5434$, $S_4^-=1.1137$

Step 4: Calculating Overall Performance Index for Each Alternative across All Criteria:

$P_i = S_i^+/ (Si^+ + S_i^-)$

Table 12 Performance Index

P_i	Rank
0.5245	2
0.5202	3
0.6442	1
0.3038	4

Hence rank by Deng's method is **2-3-1-4**.

V. RESULT AND DISCUSSION

The selection of blends of ethanol with petrol having four attributes and four alternatives has been solved by using TOPSIS, VIKOR and Deng's similarity methods and it has been observed that the rank is same for three methods i.e.2-3-1-4.So it can be concluded from this study that the blend E10 is the best alternative with petrol. E5 is the second best where as E8 and E12 are third and fourth best alternative respectively.

REFERENCES

[1] Gupta S., Dangayach G.S., Singh A.K., Rao P.N., "Analytic hierarchy process model for evaluating sustainable manufacturing practices in Indian electrical panel industries", XVIII annual international conference of the society of operations management, Procedia - Social and Behavioral Sciences, 2015, 189, pp.208-216.

[2] Kamble A.G., Rao R.V., Kale A.V., Samant S.P., "Selection of cricket players using analytical hierarchy process", International Journal of Sports Science and Engineering, 2011, 5,pp.207-212

[3] Wanke P., Barros C. P., Chen Z., "Analysis of asian airlines efficiency with two-stage TOPSIS and MCMC generalized linear mixed models", Int. J. Production Economics 2015,169,pp.110-126

[4] Umran S , Engül , Eren M., Shiraz S. E., Gezder V., Bilal A., Sengul, " Fuzzy topsis method for ranking renewable energy supply systems in turkey", Renewable Energy 2015,75,pp.617-625

[5] Saeedpoor M., Vafadarnikjoo A., Corrigendum to "Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology," Energy 2010, 35, pp.2517-2527

[6] Darji V. P., Rao R.V., "Application of AHP / EVAMIX method for decision making in the industrial

environment",American Journal of Operations Research 2013, 03, pp.542-569

[7] Ataei E., "Application of TOPSIS and Fuzzy TOPSIS Method for plant layout Design", World applied science journal 2013, 24, pp.908-913

[8] Khorshidi R., Hassani A., "Comparative analysis between TOPSIS and PSI method of materials selection to achieve a desirable combination of strength and workability in Al/SiC composite, "Materials and Design, 2013,52 pp. 999-1010

[9] Zhang Z., "An approach to multi attribute group decision making and its application to project risk assessment," Journal of Software, 2014, 9, pp.529-534

[10] Lamta M. T., "Ranking of alternatives with ordered weighted averaging operators, "International Journal of intelligent systems, 2004, 19, pp.473-482

[11] Hashemi S.S., Hossein S., Hajiagha R., Amiri M., "Decision Making with unknown data: Development of ELECTRE Method Based on Black Numbers" INFORMATICA, 2014, 25, pp.21-36

[12] Stanujkic D., Magdalinovic N., Stojanovic S., Jovanovic R., "Extension of ratio system part of moora method for solving decision-making problems with interval data", Informatica,2012,23,pp.141-154

[13] Gadakh V. S-. "Application of MOORA method for parametric optimization of milling process", International Journal of Applied Engineering Research, Dindigul 2011, 1, pp. 743-58

[14] Athawale V. M., Chakraborti S., "Facility location Selection using PROMETHEE Method", International Conference on Industrial Engineering and Operation and Management Dhaka, Bangladesh 2010,9,pp.59-64

[15] Lotfi F. H., R. Fallahnejad R., "Impressive Shannon's entropy and multi attribute decision making", entropy ISSN, 2010, 12, pp.53-62

[16] Ermatita, Hartati S., "ELECTRE methods in solving group decision support system", International Journal of science and technology, 2011, 3, pp.40-52

[17] Popovic G., Stanujkic D., Stojanovic S., "Investment project selection by applying copras method and imprecise data", Faculty of Management Zajecar, Megatrend University Belgrade Park Suma "Kraljevica", 1995, 32, pp.50-58

[18] Chatterjee, Mondal P., Chakraborty S., "A comparative study of preference dominance based approaches for selection of industrial robots", apem-journal 2014, 9, pp.5-20

[19] Stanujkic D., Magdalinovic N., Stojanovic S., Jovanovic R., "Extension of ratio system part of moora method for solving decision-making problems with interval data", Informatica,2012,23,pp.141-154

[20] Turskis Z., Kazimieras E, Zavadskas, "A novel method for multiple criteria analysis grey additive ratio assessment method", INFORMATICA, 2010, 21, pp.597-610

[21] Pastijn H. and Leysen J, "Constructing an outranking relation with ORESTE'', math1 comput. modelling 1989, 12, pp.1225-1268