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Selection of Fuel by Using Analytical Hierarchy Process

Asilata M. Damle, Dr. I. P. Keswani

Abstract
Selection of fuel is a very important and critical decision one has to make. Various criteria are to be considered while selecting a fuel. Some of important criteria are Fuel Economy, Availability of fuel, Pollution from vehicle, Maintenance of the vehicle. Selection of best fuel is a complex situation. It needs a multi-criteria analysis.
Earlier, the solution to the problem were found by applying classical numerical methods which took into account only technical and economic merits of the various alternatives. By applying multi-criteria tools, it is possible to obtain more realistic results.
This paper gives a systematic analysis for selection of fuel by using Analytical Hierarchy Process (AHP).
This is a multi-criteria decision making process. By using AHP we can select the fuel by comparing various factors in a mathematical model. This is a scientific method to find out the best fuel by making pairwise comparisons.
Key words: AHP - Analytical Hierarchy Process; LPG- Liquefied Petroleum Gas; MS- Motor Spirit or Petrol; HSD- High speed Diesel; CNG- Compressed Natural Gas

I. Introduction

The technological development of vehicles with new alternative fuels is considered in this paper.

Various types of available fuels are considered such as Motor Spirit (MS, Petrol), High Speed Diesel (HSD), Liquefied Petroleum Gas (LPG) and Compressed natural Gas (CNG).

The levels of liquid fuels MS and HSD are depleting. Whereas, Natural gas is abundantly available. This has transformed the situation towards use of gaseous fuels LPG and CNG in motor vehicles.

Moreover, it has been established that the emission from gaseous fuels is very less compared to liquid fuels. This is basically due to the fact that gaseous fuels contain less number of Carbon atoms.

Thus, the world has to move in the direction of controlling hazardous emissions from automobiles to achieve environment protection. Hazardous emissions from automobiles is taking toll on living being in form of pollution.

Therefore alternate gaseous fuels will replace the liquid fuels over the period of time. All the countries are taking initiative to control the pollution by adopting use of gaseous fuels. Many countries including India are setting up Liquefied natural Gas (LNG) terminals and laying piping network across the country to make use of Natural gas. Gaseous fuels are equally compatible with liquid fuels. Gaseous fuels are being implemented in many applications such as Manufacturing, Electrical Power Generation, Domestic consumption, Automotive use.

II. Literature Review:

The concept of AHP was developed by an American mathematician, Thomas L. Saaty from the university of Pittsburgh (saaty 2008) The objective of this method is, from the set of available alternative quantifies relative priorities and stresses the importance of judgements of a decision maker and also provides consistency in comparing the alternatives for decision making.

AHP is a methodological approach useful in making complex decisions (e.g., multi-criteria decisions) based on variables that do not have exact numerical consequences .AHP structures criteria of multiple options into a system hierarchy, by assigning relative values to all criteria, compares alternatives for each particular criterion and defines average importance of all alternatives It breaks the problem in a definite sequence from the large to the smaller and smaller and in this way one is able to connect to paired comparative judgements. Generally the hierarchyy has three levels. Problems where complex decision making is involved AHP are a structured technique. The goal is to identify one out of several possible decisions AHP method offers meaningful and rational framework for structuring problems presentation and quantification of elements that make a problem.

Steps of AHP

Step 1: To develop the criteria hierarchy: The user of AHP breaks the entire problem into a hierarchy structure such that each alternative could be observed separately. All the elements of the structure is linked in relationship with different aspects of solution to the problem irrespective of their importance.

Step 2: Compare the criteria pairwise AHP allocates weights to the criteria that have been selected in the hierarchy The person who is expert in the field

systematically carries out pairwise comparison at every hierarchic level and for every level of the hierarchy Due to such comparison at a time the focus is only on two criteria and to find as to which criteria is having more weight over the other and helps find out the difference in them in terms of importance

step 3: Assign numeric value to a criteria at each level of hierarchy The comparisons are expressed in terms of numeric value is derived which helps the elements to be compared are in rational and consistent way which are otherwise unmeasurable This methodology of comparing the elements at each level of hierarchy and assigning weight based on the importance of one over the other distinguish AHP from other decision making process.

Step 4 Calculate the overall priorities of criteria and subcriteria and compare alternatives.

Selecting the best fuel using AHP is taken from Mr. Saaty's work.

Mr. Saaty is the founder of AHP process.

Mr. Saaty has decided the scale that the available values for the pairwise comparisons are members of the set (9, 8, 7, 6, 5, 4, 3, 2)

Scale of relatives importance's according to Mr. Saaty (1980)

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
3	Weak Importance of one over another	Experience and Judgment slightly favour one activity over another
5	Essential or Strong Importance	Experience and Judgment strongly favour one activity over another
7	Demonstrated Importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute Importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Intensity of Importance	**Definition**	**Explanation**
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocal of above non zero	If activity i has one of the above non zero numbers assigned to it when compared with activity j then j has the reciprocal value when compared with i	

Pairwise comparisons:

1- Equal 2 - Weak
3- Moderate 4- Moderate plus
5- Strong 6- Strong plus
7- Very strong 8- Very very strong
9- Extreme

Now, the above principle put forth by Mr. Saaty is used to determine the best fuel among the available alternatives.

III. Computation

Here 3 important criteria are considered which are:

1. Fuel Economy
2. Pick up of vehicle
3. Pollution from vehicle

We have to put these criteria in a hierarchy of relative importance.

The hierarchy is given below:

A. Fuel economy is 3 times as important as Pick up of vehicle

B. Pollution is 2 times as important as Pick up of vehicle

C. Fuel economy is 2 times as important as Pollution control

Now the matrix can be derived as below:

	Economy of fuel	**Pick up of vehicle**	**Pollution control**
Economy of fuel	1/1	3/1	2/1
Pick up of vehicle	1/3	1/1	1/2
Pollution control	1/2	2/1	1/1

Now we solve for eigen vector:

1. A short computational way to obtain this ranking is to raise the pairwise matrix to powers that are successively squared each time.
2. The row sums are then calculated and normalized.
3. The computer is instructed to stop when the difference between these sums in two consecutive calculations is smaller than a prescribed value.

Converting the fractions to decimals:

1.0000	3.0000	2.0000
0.33	1.0000	0.5000
0.5000	2.0000	1.0000

Squaring the matrix:

2.99	10	5.5
0.91	2.99	1.66
1.66	5.5	3

Sum	18.49	0.5404
Sum	5.56	0.1625
Sum	10.16	0.2969
Total	34.21	1.0000

Step 2
We square the matrix obtained in step 1

1.0000	3.0000	2.0000
0.33	1.0000	0.5000
0.5000	2.0000	1.0000

with this result

27.1701	90.05000	49.5450	166.7651	0.5400
8.1974	27.1701	14.9484	50.3159	0.1629
14.9484	49.5450	27.2600	91.7534	0.2971
			308.8344	1.0000

Compute the difference of the previous computed eigen vector to this one which results

1	Fuel economy	0.0005	The most important criterion
3	Pick up of vehicle	-0.0004	The least important criterion
2	Pollution control	-0.0001	Second most important criterion

In terms of Fuel economy:

	LPG	**CNG**	**MS**	**HSD**
LPG	1/1	2/1	1/2	1/3
CNG	1/2	1/1	1/3	1/4
MS	2/1	3/1	1/1	1/2
HSD	3/1	4/1	2/1	1/1

Converting fractions to decimal we get..,

	LPG	**CNG**	**MS**	**HSD**
LPG	1.00	2.00	0.50	0.33
CNG	0.50	1.00	0.33	0.25
MS	2.00	3.00	1.00	0.50
HSD	3.00	4.00	2.00	1.00

Which results in following:

	LPG	**CNG**	**MS**	**HSD**
LPG	3.99	6.82	2.32	1.41
CNG	2.41	3.99	1.41	0.83
MS	7	12	3.99	2.41
HSD	12	20	6.82	3.99

Which results in following:

	LPG	**CNG**	**MS**	**HSD**		
LPG	LPG	6.82	2.32	1.41	10.55	0.1207
CNG	2.41	3.99	1.41	0.83	8.64	0.0989
MS	7	12	3.99	2.41	25.4	0.2906
HSD	12	20	6.82	3.99	42.81	0.4898
					87.4	1.0000

In terms of Pick-up of vehicle:

	LPG	**CNG**	**MS**	**HSD**
LPG	1/1	2/1	1/3	1/2
CNG	1/2	1/1	1/4	1/3
MS	3/1	4/1	1/1	2/1
HSD	2/1	3/1	1/2	1/1

Converting fractions to decimal we get..,

	LPG	**CNG**	**MS**	**HSD**
LPG	1.00	2.00	0.33	0.50
CNG	0.50	1.00	0.25	0.33
MS	3.00	4.00	1.00	2.00
HSD	2.00	3.00	0.50	1.00

Which gives following result:

In terms of Pollution of vehicle:

	LPG	**CNG**	**MS**	**HSD**
LPG	1/1	2/1	1/3	1/4
CNG	1/2	1/1	1/4	1/5
MS	3/1	4/1	1/1	1/2
HSD	4/1	5/1	2/1	1/1

Converting fractions to decimal we get..,

	LPG	**CNG**	**MS**	**HSD**
LPG	1.00	2.00	0.33	0.25
CNG	0.50	1.00	0.25	0.20
MS	3.00	4.00	1.00	0.50
HSD	4.00	5.00	2.00	1.00

Which results into following:

	LPG	**CNG**	**MS**	**HSD**		
LPG	3.99	6.57	1.66	1.065	13.285	0.1234
CNG	2.55	4	1.065	0.65	8.265	0.0768
MS	10	16.5	3.99	2.55	33.04	0.3069
HSD	16.5	26	6.57	4	53.07	0.4929
					107.66	1.0000

Final Matrix is as below:

	Fuel economy	**Pick up**	**Pollution**
LPG	0.1207	0.1591	0.1234
CNG	0.0989	0.0945	0.0768
MS	0.2906	0.4684	0.3069
HSD	0.4898	0.2779	0.4929

Above matrix is multiplied by the Eigen vector obtained in Step no 1, which results in following:

LPG	0.1277625
CNG	0.0915909
MS	0.3244227
HSD	0.4562239

Here we can see that HSD is the winner.

IV. Result and Conclusion

By applying AHP, it is found that Diesel is the fuel to be selected since it has the most weight-age as per above eigen vector. Obviously diesel wins since it has the highest fuel economy and fuel economy being the most important criteria selected.

If pollution control has more importance, the result will vary. Here the result also proves that liquid fuels shall prevail over Gaseous fuels for obvious reason of more energy content!

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AUTHORS

Asilata M Damle, Assistant Professor (Department of Industrial Engineering) Ramdeobaba college of Engineering and Management Nagpur.
Mobile no: 9923076669
Email:asilata_91576@yahoo.com

Dr. Ishwar. P. Keswani H.O.D.(Department of Industrial Engineering) Ramdeobaba college of Engineering and Management Nagpur.
Cell No. : 9225220122
Email Keswaniip@rknec.edu