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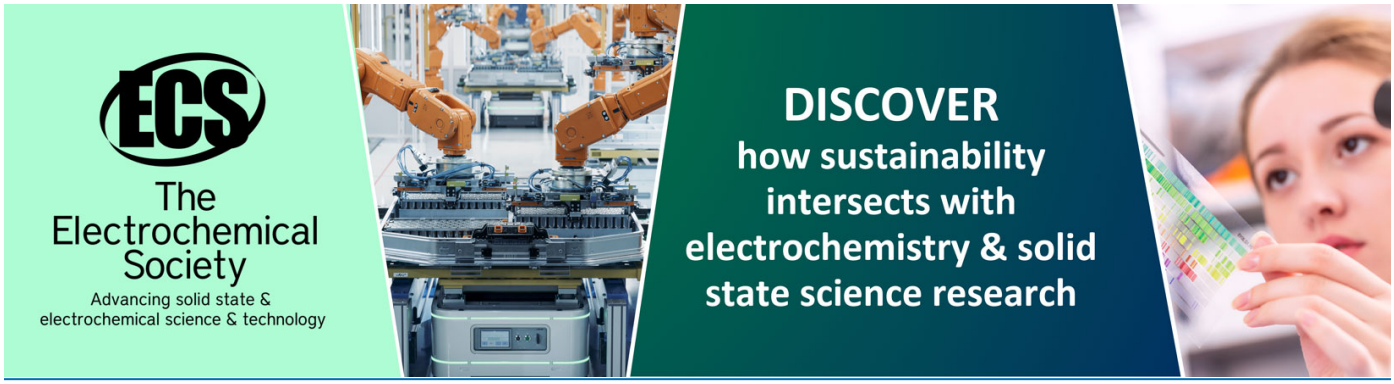

Multi-Criteria Engine Selection for Unique Purpose using AHP

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Abstract

In this automotive world the selection of a vehicle based on engine plays a major role, in which all the parameters of the engine need to be considered. The engine selection for three purposes has been considered in this paper. Most influencing 10 parameters of each purpose have been shortlisted with the help of experts in the respective field. Then the parameters are ranked with the help of Analytical Hierarchy Process (AHP). It helps to prioritise the parameters while selecting an engine for specific purpose. In AHP the relative matrix is formed by using pairwise comparison with the help of experts then the relative matrix is squared and eigen vector is found. The eigen vector is used to rank the parameters and is reported as per the priority for the respective purpose. The method proposed in this paper can be used as a decision-making tool while selecting an engine for a specific purpose.

Keywords: Engine selection; Engine parameters; AHP

1.Introduction

Engine is a power producing device which categorized based on their type of ignition as Compression Ignition (CI) and Spark Ignition (SI). In SI engine, combustion is initiated by the spark, then flame propagates throughout the combustion chamber. SI engine uses petrol as fuel and works based on Otto cycle. SI engines are mostly widely used in light motor vehicles such as scooters, motorcycles, cars etc. In CI engine, combustion of fuel takes place by the absorption of heat and auto ignition temperature of the fuel. CI engine uses diesel as fuel and works on Diesel cycle. CI engines are mostly used in heavy duty vehicles or applications such as buses, trucks, railways, ships etc. Turbochargers and superchargers are known as forced induction systems to boost the existing power. A turbocharger uses the exhaust gas heat energy to increase the boost pressure thereby power. A supercharger takes power from the engine and supplies boost pressure to the engine inlet. Superchargers are effective in boosting the engine power at lower speeds than turbocharger. However, the turbocharger performance is good at higher engine speeds. Turbochargers are quieter whereas superchargers are more reliable and easy to maintain. The vehicle's exhaust system or after treatment system is designed to take care of toxic emissions from the vehicle. It reduces the emissions thereby protecting the environment and helps in keep the air clean. Also the exhaust system significantly reduces the amount of noise the engine produces. The engine that one chooses can be based on lot of factors, including pricing, fuel economy, acceleration and sometimes even equipment and features. Commercially engine size is usually categorized in three ways: power rating, displacement and the number of cylinders. A car with more power and a larger engine will offer better power characteristics than a car with less power with smaller engine and usually costs more. As a result, if a person is interested in fuel economy, he might want to consider a car with a smaller engine, but if performance is the key then he may instead appreciate more power. Based on this, three objectives are considered which is for personal use, race and commercial use. There is a need for more speed and performance for racing, performance and fuel economy for personal use and more displacement and power is required to carry the load for commercial use. So selection of the right engine plays a crucial role.

The objective is to prioritise the parameters when selecting an engine using a Multi Criteria Decision Making (MCDM) technique. In today's society the technology as well as the complexity of selecting a product has increased. The decision maker is stressed and overloaded in selecting a particular product by considering all the factors. In this case the decision maker must select an engine for different objectives by considering all the criteria. To find a solution for this complexity an effective tool is required and is found to be Analytical Hierarchy Process (AHP). The AHP is a decision aiding method developed by Saaty (1980) which is used in business, government, social studies, R&D, defence and other domains involving decisions in which choice, prioritization or forecasting is needed. The AHP provides a means of decomposing the problem into a hierarchy of sub-problems which can

more easily be comprehended and subjectively evaluated. Here the AHP is used to find the criteria priorities in selecting an engine for different purposes. The AHP process has a specific flow chart which collects the information and helps the decision maker to select the suitable criteria for the selected objective by comparing each criterion with its eigen vector. So any problem with any type of complexity can be solved by using AHP process which is easy and consume less time with reasonable accuracy (Anbuudayasankar et al., 2018; Mohanavelu et al., 2017; Koganti et al., 2019). In prioritising the parameters for the respective usage Relative importance matrix and squared matrix are computed with the help of the survey from the respondents.

2. Methodology

The objective is to select an engine for three purposes namely Personal, Race and Commercial usage.
12 Engine Parameters have been short listed out of which 10 parameters have been selected from a brainstorming session by a group of 5 experts in respective fields. Using AHP tool the parameters have been ranked for each purpose. The methodology is represented in figure 1.

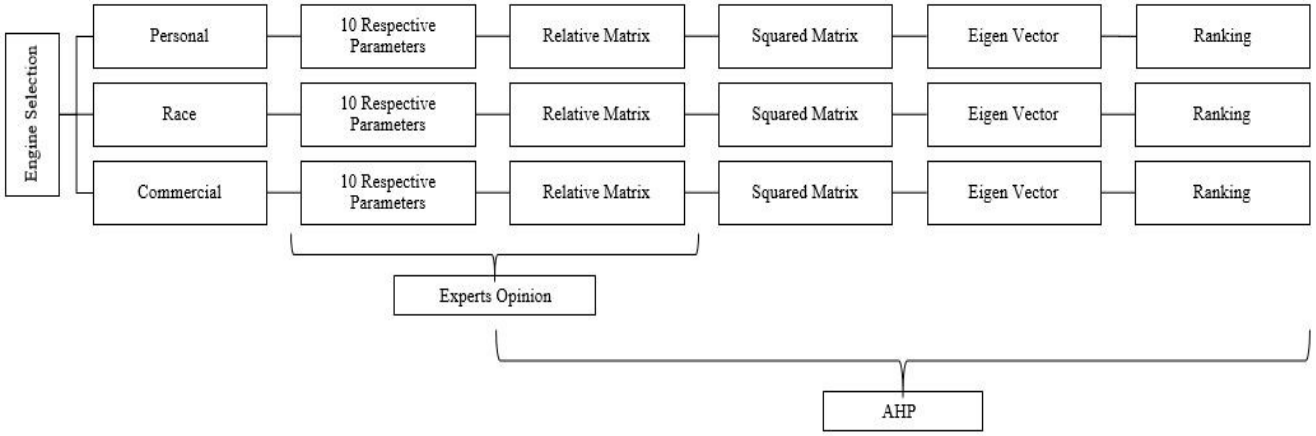

Figure1. Methodology

3. Engine Parameters

To select a suitable engine for a particular objective all the characteristics of the engine must be considered, so 12 common parameters of an engine for any objective is selected and listed below.

- Basic Design
- Size
- Working Cycle
- Cooling System
- Torque and Power
- Fuel
- Mileage
- Engine cylinder and its orientation
- Chargers
- Maintenance frequency
- Method of control
- Noise

From the above 12 parameters, top 10 prominent parameters for each of the three objectives has been selected by the respondents in order to get a clear vision. Description and literature review of the parameters are presented in table 1.

Table1. Parameter, description and Literature

S.No.	Parameters	Description	Literature
1	Basic Design (Reciprocating and Rotary Engine)	A reciprocating engine uses one or more reciprocating piston to convert pressure into a rotating motion. In rotary engine, cylinder rotates around the crankshaft to produce power.	• Mostafavi et al., (2018) • MacDonald et al., (2017) • Su et al., (2017) • Andruskiewicz et al., (2017)
2	Size (Displacement, Bore and Stroke)	It is the swept volume of all the cylinder.	• Altin et al., (2009) • Hao et al., (2006) • Hyvonen et al., (2006) • Tsuchida et al., (2007)
3	Working Cycle (Two Stroke / Four Stroke)	Number of working stroke.	• Shu et al., (2013) • Zhang et al., (2011) • Conklin and Szybist (2010) • Zhao et al., (2002)
4	Cooling System	The mode in which heat generated by the engine is dissipated to continue the cycle.	• Sidik et al., (2015) • Xin (2011) • Samek et al., (2010) • Mollenhauer and Tschoke (2010)
5	Torque and Power	The maximum power and torque that an engine can produce.	• Saulnier and Guilain (2009) • Bharadwaja and Srihari (2015) • Çinar et al., (2005) • Heywood and Welling (2009)
6	Fuel	The type of fuel required to produce power.	• Nwufo et al., (2017) • Shu (2017) • Srihari and Thirumalini (2017) • Pregelj et al., (2015)
7	Mileage	The distance travelled by the vehicle per unit fuel.	• Panwar (2011) • Xin (2011) • Mollenhauer and Tschoke (2010) • Rakopoulos et al., (2011)
8	Engine Cylinder and its orientation	It describes the orientation of the cylinder (V-type, Inline 4, flat)	• Lin et al., (2018) • Hassan (2017) • Bennett et al., (2017) • Yar et al., (2018)
9	Chargers	Engine power enhancer.	• Chiong et al., (2012) • Zhang (2010) • Hu (2000) • Kirk et al., (2008)
10	Maintenance Frequency	The time period in which the engine to be serviced.	• Wang et al (2010) • Cascales and Lamata (2009) • Youngk (2000) • Kleeman and Lamont (2005)
11	Method of control	Metering of fuel to control the speed and torque.	• Acharya and Prasad (2016) • Sim and Sitohang (2014) • Mallik et al., (2011) • Kong et al., (2007)
12	Noise	The unpleasant sound produced by the engine during the operating cycle.	• Macías et al., (2018) • Isranuri et al., (2018) • Doty et al., (2018) • Sidhu et al., (2018)

4. Engine Selection for Personal Vehicle

Personal Vehicle may include cars used by families, working professionals etc., for their own commuting. The engine requirement for these kinds of vehicles are expected to have some unique features and plays an important role in the selection process. Here ten most suitable parameters are ranked using AHP.

4.1. Relative importance matrix

Initially parameters are rated using pairwise comparison. The relative importance of one parameter over another is given by the below rating

1 equal 3 moderate 5 strong 7 very strong 9 extreme

Thus, relative importance matrix is obtained. The parameters of engine selection chosen for personal usage vehicle are as follows and the corresponding relative importance matrix is presented in table 2.

P1-Mileage; P2-Torque and Power; P3-Fuel; P4-Size; P5-Cooling System; P6-Maintenance frequency; P7-Method of control; P8–Noise; P9–Chargers; P10-Working Cycle.

Table 2. Relative importance matrix for Engine Selection of Personal Vehicle

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	1	5	3	3	5	2	2	7	3	5
P2	1/5	1	3	1	3	5	5	5	1	4
P3	1/3	1/3	1	3	8	5	1	5	2	3
P4	1/3	1	1/3	1	6	8	5	3	8	6
P5	1/5	1/3	1/8	1/6	1	8	9	9	7	5
P6	1/2	1/5	1/5	1/8	1/8	1	5	3	8	4
P7	1/2	1/5	1	1/5	1/9	1/5	1	8	7	8
P8	1/7	1/5	1/5	1/3	1/9	1/3	1/8	1	7	4
P9	1/3	1	1/2	1/8	1/7	1/8	1/7	1/7	1	8
P10	1/5	1/4	1/3	1/6	1/5	1/4	1/8	1/4	1/8	1

4.2. Squared matrix

In relative importance matrix, it indicates only the pairwise comparison of each parameter with respect to the other. By squaring the matrix, the relative importance value obtained for each parameter includes the comparison of all the 9 parameters and squared matrix for engine selection of personal vehicle is presented in table 3.

Table 3. Squared matrix for engine selection of personal vehicle

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	10	22.11	29.59	25.02	69.67	112.35	103.92	131.67	155.62	158
P2	9.18	10	16.14	16.18	39.67	61.19	71.66	112.54	148.1	127
P3	8.31	12.95	10	11.90	38.84	103.2	117.61	119.03	167.7	131
P4	12.97	18.47	18.61	10	23.56	75.83	112.26	135.64	181.41	196.66
P5	13.68	15.32	19.47	9.15	10	26.95	63.77	120.44	207.14	209.7
P6	7.56	13.73	13.49	6.23	8.53	10	15.96	55.14	76.47	129.27
P7	6.63	14.11	11.98	10.01	16.03	15.43	10	30.7	78.67	112.85
P8	3.88	9.64	6.57	3.52	6.99	8.40	7.56	10	22.51	71
P9	2.85	6.08	7.92	5.19	11.34	12.63	10	15.29	10	26.84
P10	0.92	2.09	2.38	2.37	5.90	6.87	6.16	8.88	9.12	10

For finding out eigen vector the relative matrix is squared, then all elements in each row are added separately. Now weightage for each parameter is resulted as eigen vector.

Table 4. Eigen vector values of engine parameters

Parameters	Eigen Vector
Mileage	0.178316
Torque and Power	0.133346
Fuel	0.15708
Size	0.171224
Cooling System	0.151647
Maintenance Frequency	0.073338
Method of control	0.066805
Noise	0.032725
Chargers	0.023587
Working cycle	0.011931

The eigen vector for different engine parameters has been found and represented in table 4. It is used to priorities the parameters for the selection of personal usage vehicle. Mileage is found to top among the other parameters.

5. Engine Selection for Race car

Race cars are vehicles used in sports events. Using AHP the best applicable engine for a race car can be chosen in a short span of time without any hassles.

5.1. Relative importance matrix

The parameters chosen for race car engine are as follows and relative importance matrix for engine selection of race car is presented in table 5.
R1-Torque and Power; R2-Size; R3-Basic Design; R4-Engine cylinder and its orientation; R5-Working Cycle; R6–Chargers; R7-Cooling System; R8-Fuel; R9–Noise; R10-Method of control.

Table 5. Relative importance matrix for Engine Selection of Race car

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R1	1	1	3	5	1	2	5	2	3	2
R2	1	1	5	2	2	2	3	3	3	5
R3	1/3	1/5	1	1	8	5	5	8	6	5
R4	1/5	1/2	1	1	8	2	4	3	3	2
R5	1	1/2	1/8	1/8	1	2	3	4	3	5
R6	1/2	1/2	1/5	1/2	1/2	1	3	3	8	4
R7	1/5	1/3	1/5	1/4	1/3	1/3	1	3	4	3
R8	1/2	1/3	1/8	1/3	1/4	1/3	1/3	1	3	1
R9	1/3	1/3	1/6	1/3	1/3	1/8	1/4	1/3	1	3
R10	1/2	1/5	1/5	1/2	1/5	1/4	1/3	1	1/3	1

5.2. Squared matrix

Squared matrix for engine selection of race car is presented in table 6.

Table 6. Squared matrix for engine selection of race car

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R1	10	10.33	18.67	20.04	72.56	36.20	59.08	74	87.66	73
R2	12.66	10	18.12	20.5	65.75	42.62	59.41	83	89.6	80
R3	2.06	15.06	10	15.98	33.9	35.4	61.1	89.26	126.2	114.66
R4	14.53	10.13	8.57	10	29.68	29.60	47.91	68.9	79.76	83.9
R5	9.66	7.42	8.87	12.95	10	11.83	23.37	33.87	53.29	45.37
R6	8.93	7.50	8.07	11.17	13.31	10	18.83	29.26	45.53	52
R7	5.68	4.26	4.66	6.40	7.98	6.15	10	16.41	25.21	27.56
R8	3.42	2.96	4.61	5.73	6.81	4.86	8.95	10	15.33	18.54
R9	3.23	2.22	4.09	4.94	6.49	4.69	7.81	10.12	10	13.08
R10	2.36	1.97	3.72	4.77	7.49	4.78	8.53	9.36	12.4	10

Eigen vector is found by squaring the relative matrix and is presented in table 7. Eigen vector helps in prioritising the parameters.

Table 7. Eigen vector values of engine parameters

Parameters	Eigen Vector
Torque and Power	0.178983
Size	0.186785
Basic design	0.195306
Engine cylinder and its orientation	0.14852
Working Cycle	0.084015
Chargers	0.079347
Cooling system	0.044332
Fuel	0.031495
Noise	0.025858
Method of Control	0.025359

The eigen vector for different engine parameters has been found and it is used to prioritize the parameters for the selection of race car. Basic design is found to top among the other parameters.

6. Engine Selection for Commercial Vehicle

Commercial vehicles are heavy duty vehicles used solely for the purpose of transportation of freight. Using AHP the best applicable engine for a commercial vehicle can be chosen in a short span of time without any hassles.

6.1. Relative importance matrix

The parameters chosen for commercial vehicle engine are as follows and the corresponding relative importance matrix for engine selection presented in table 8.
C1-Torque and Power; C2-Size; C3-Fuel; C4–Mileage; C5-Working Cycle; C6–Chargers; C7-Maintenance frequency; C8-Method of control; C9-Cooling System; C10-Engine cylinder and its orientation.

Table 8. Relative importance matrix for Engine Selection of Commercial Vehicle

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	1	1	3	5	3	5	3	3	2	3
C2	1	1	1	2	5	3	4	9	3	3
C3	1/3	1	1	4	2	5	3	2	3	6
C4	1/5	1/2	1/4	1	2	3	5	1	5	6
C5	1/3	1/5	1/2	1/2	1	2	6	2	3	3
C6	1/5	1/3	1/5	1/3	1/2	1	6	5	7	3
C7	1/3	1/4	1/3	1/5	1/6	1/6	1	4	3	5
C8	1/3	1/9	1/2	1	1/2	1/5	1/4	1	8	9
C9	1/2	1/3	1/3	1/5	1/3	1/7	1/3	1/8	1	3
C10	1/3	1/3	1/6	1/6	1/3	1/3	1/5	1/9	1/3	1

6.2. Squared matrix

Squared matrix for engine selection of commercial vehicle is presented in table 9

Table 9. Squared matrix for engine selection of commercial vehicle

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	10	12.5	14.41	31.6	33.16	51.38	94.41	69.85	118.33	129
C2	11.83	10	15.9	27.4	27.66	35.89	76.25	66.97	141.33	161
C3	9.3	10.37	10	18.53	25	33.99	76.5	60.57	96.33	103
C4	8.75	7.87	8.03	10	14.1	17.49	47.26	48.42	63.31	79.6
C5	6.7	5.87	7.22	10.03	10	13.09	32.3	43.27	59.6	76.6
C6	9.2	6.72	9	11.48	11.16	10	23.78	40.80	77.5	108.3
C7	5.65	4.46	5.91	9.47	8.4	8.24	10.66	14.65	43.63	60.95
C8	8.43	7.45	6.90	9.35	11.36	13.08	18.3	10.8	28.15	55.68
C9	2.77	2.81	3.41	5.80	6.08	7.79	9.38	8.93	9.33	15.92
C10	1.5	1.57	2.18	3.9	4.35	5.44	8.44	8.58	9.15	10.8

After the relative importance matrix is squared eigen vector is obtained by finding the weightage of each parameter.

Table 10. Eigen vector values of engine parameters

Parameters	Eigen Vector
Torque and Power	0.192739
Size	0.196013
Fuel	0.151418
Mileage	0.104053
Working Cycle	0.090348
Chargers	0.105115
Maintenance frequency	0.058719
Method of control	0.057859
Cooling system	0.024652
Engine cylinder and its orientation	0.019085

The eigen vector for different engine parameters has been found and it is used to prioritise the parameters for the selection of commercial usage vehicle. Size is found to top among the other parameters. Eigen vector of the parameters is represented in table 10.

7. Ranking of engine parameters for each criterion

Ranking plays a major role in selecting the engine by prioritising their parameters, so AHP helps with this. The parameters for each objective are ranked in the order of their eigen vector values and the chart is presented in figure 2.

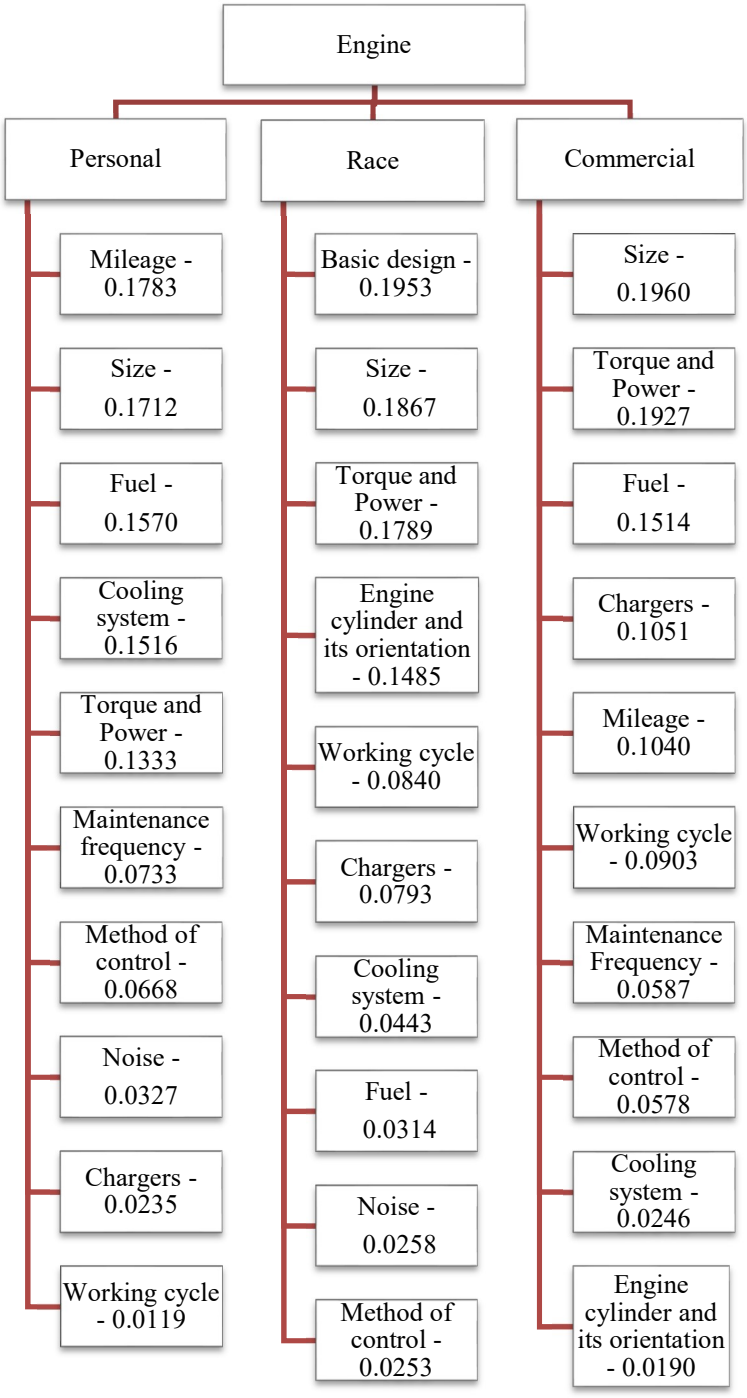

Figure 2. Ranking of parameters based on eigen vectors

8. Conclusion:

Selection of engines for three purposes namely: Personal, Race and Commercial usage has been investigated using Analytical Hierarchy Process (AHP). List of Engine parameters for each criterion has been ranked based on their relative importance. A chart has been prepared which specifies that for selecting a car for personal use mileage of the engine plays a major role, similarly for a race car it is basic design of the engine plays a prominent role and for commercial vehicle size of the engine has more influence. Though AHP is found to be an effective tool other MCDM techniques can also be used to employ decision making. Apart from engine selection other features can also be used to assess the selection of vehicles for different usages.

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