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Measuring the Dependence of Fuel Efficiency of Automobiles on Different Factors

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Abstract: The purpose of this paper is to develop a multiple regression model for measuring the miles per gallon (Efficiency) by using different independent variables. How much the efficiency in terms of miles per gallon is dependent on engine displacement, horsepower, vehicle weight, model year, number of cylinders, and filters? Which is the most important variable for increasing the efficiency of automobiles? The answers of these questions are the objectives of this paper. The results indicate that model year has positive effect on efficiency of vehicle while horse power, vehicle weight, and filters have negative impact on vehicle’s efficiency. Results also specify that vehicle weight has the maximum impact on miles per gallon while horsepower has the minimum impact.

Keywords: Fuel Efficiency, Engine displacement, Horsepower, Vehicle weight, Model year, Automobile industry.

I. INTRODUCTION

Among the most regulated consumer products is automobile industry. Safety and fuel economy are most important regulations affecting this industry. Government-mandated design standards must be fulfilled for safety requirements like air bags and seat belts. For fuel economy there are diversified interventions from government ranging from fuel economy standards for corporate fleets, gasoline taxes designed for energy conversation, and for low-mileage cars a gas guzzler tax (Dreyfus, & Viscusi, 1995).

Over the past decade there has been significant advancement in the structures and material technologies deployed in automobiles. For the achievement of weight savings, improved materials are necessary without sacrificing cost, performance, and manufacturability of the vehicles. Further development is needed to meet the cost requirements of automobiles industry by using advance lightweight materials. Vehicle structure and manufacturing process along with their design depends heavily on simulation, providing good model for lightweight material. There are many examples of computational techniques used to develop alloys, processes, and integrated structural/material designs for reducing vechicle weight and increasing efficiency with the usage of Integrated Computational Materials Engineering (National Research Council, 2008).

II. OBJECTIVES OF THE STUDY

The purpose of this paper is to develop a multiple regression model for measuring the miles per gallon (Efficiency) by using different independent variables. How much the efficiency in terms of miles per gallon is dependent on engine displacement, horsepower, vehicle weight, model year, number of cylinders, and filters? Which is the most important variable for increasing the efficiency of automobiles? The answers of these questions are the objectives of this paper.

Research Questions

- How much the efficiency in terms of miles per gallon is dependent on engine displacement, horsepower, vehicle weight, model year, number of cylinders, and filters?
- Which is the most important variable for increasing the efficiency of automobiles?

III. LITERATURE REVIEW

Many technologies such as engine displacement, model year, horsepower, vehicle weight, advance combustion can increase the efficiency of vehicles by decreasing transportation energy consumption. Widespread usage of lightweight materials for automobiles in association with new technology is strongly related with performance, efficiency and cost (Joost, 2012).

In automobile fuel consumption, horsepower is an important factor. On average current automobiles are double in horsepower than the early 1980s. Progressive people are determining their vehicle needs on the basis of fuel consumption rather than vehicle speed and time. This diversion in thinking pattern can save environment, fuel and money (EPA 2012). The speed at which energy is converted is called power or the rate of doing work. Torque tells how much work an engine can do while the horsepower explains that how quickly the work can be performed. For each application there is a strong need for the vehicle designers to optimize torque and horsepower. For example the horsepower ratings are similar for today's performance cars and farm tractors. While, this power rating for performance car is with lower torque and higher RPM and for farm tractor it is with low RPM and high torque. In automobiles high level of horsepower is useful only for high-speed racing but for family automobiles the usage of high horsepower consumes more fuel (Papahristodoulou, 1997; Abdelmalek, 1994).

In the automobile market government has been an active participant through direct product quality regulation for many years. There regulatory requirements of the government change many characteristics of the newly manufactured vehicles (e.g. miles per gallon) by achieving their objectives via improving fuel efficiency (Berkovec, 1985). Because of the impact of energy consumption and fuel efficiency the debate of small vs large cars has gained significance importance (Blomqvist, & Haessel, 1978).

IV. METHODOLOGY

We conduct this study under Positivist Paradigm by using Quantitative research methodology. The data file contains eight different variables. Among them, miles per gallon is taken as the dependent variable and six of the other variables are taken as independent variables for this analysis. The independent variables include: engine displacement, horsepower, vehicle weight, model year, number of cylinders, and filters. Multiple regression model is used to check the dependency of miles per gallon (Efficiency) on independent variables.

V. ANALYSIS

There are certain assumptions of regression analysis which must be satisfied before doing this analysis. These assumptions include Normality, Multicollinearity, Auto- correlation and Heteroscedasticity.

1. Normality:

Almost all statistical tests necessitate that data should be normal. So in data analysis, our first step is to check the normality of the data. In order to satisfy the normality assumption, we test the normality of residuals. We performed the Shapiro-Wilk test to check that either normality exists or not.

Table 1.1 Tests of Normality

	Shapiro-Wilk		
	Statistic	Df	Sig.
Unstandardized Residual	.957	384	.000

Before remedial measures, the significance value is .000 as shown in table 1.1 which indicates that data is not from normal distribution because for normal distribution the p value should be more than 5%. It indicates that there are some unusual observations which are affecting the normality of the data. In order to identify that which unusual observations affecting the normality of the data we checked the normal Q-Q plot. Here the points on the scatter plot that are vertically far away from the regression line are the unusual observations or outliers as shown in figure 1.1.

Figure 1.1 (a)

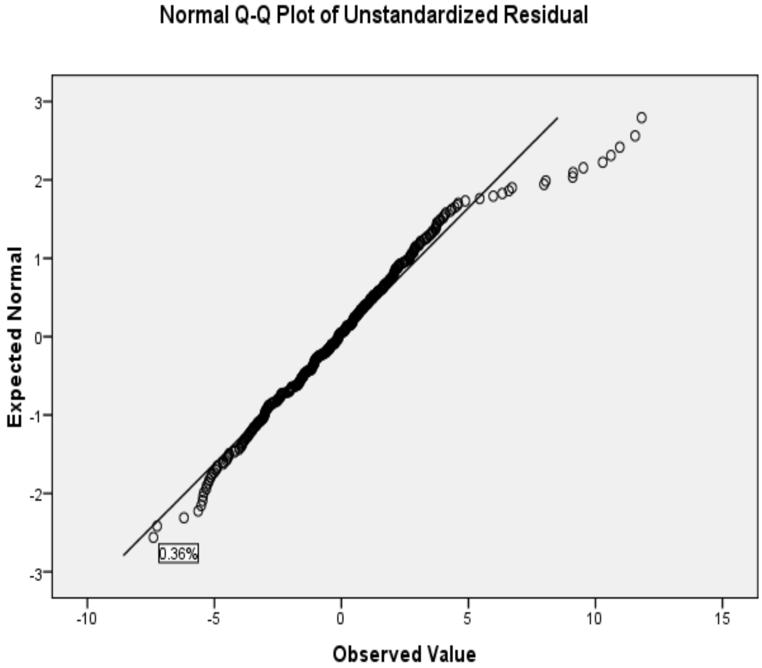
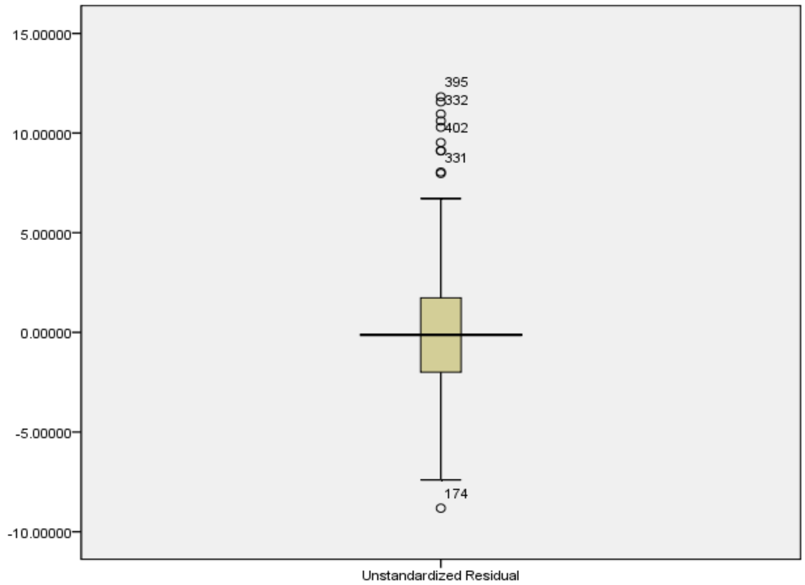


Figure 1.1 (b)



The unusual observations which are away from the regression line are 395, 332, 402, 331, 174 and others as shown in figure 1.1 (b). After taking remedial measures and deleting the outliers, the significance value in Shapiro-Wilk test become .092 which is greater than 5% level of significance as shown in table 1.2. So the data becomes normal due to this remedial measure.

Table 1.2 Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Unstandardized Residual	.993	373	.092
[			

1.Multicollinearity

It is applicable for multiple regression and not for simple regression. It means correlation among independent variables. In our model there are six independent variables and the regression will be multiple regression. Before taking remedial measures, the value of VIF for Engine displacement was 20.307 and number of cylinders was 13.698 as shown in table 1.3. These two values are not ignorable and do not satisfy the condition of multicollinearity. Therefore, these two variables must be removed in order to satisfy this assumption.

Table 1.3

Model		Sig.	Collinearity Statistics	
			Tolerance	VIF
1	(Constant)	.473		
	Engine Displacement (cu. inches)	.716	.049	20.307
	Horsepower	.289	.150	6.649
	Vehicle Weight (lbs.)	.000	.115	8.730
	Model Year (modulo 100)	.000	.820	1.219
	Number of Cylinders	.000	.073	13.698
	cylrec = 1 | cylrec = 2 (FILTER)	.000	.180	5.541

After removing these two independent variables, the VIF values of all remaining variables become less than 10 which is acceptable to satisfy the condition of multicollinearity as shown in table 1.4.

Table 1.4

Model		Sig.	Collinearity Statistics	
			Tolerance	VIF
1	(Constant)	.198		
	Horsepower	.338	.180	5.543
	Vehicle Weight (lbs.)	.000	.227	4.399
	Model Year (modulo 100)	.000	.835	1.198
	cylrec = 1 | cylrec = 2 (FILTER)	.000	.273	3.664

After satisfying the condition of multicollinearity and taking remedial measures, our remaining independent variables are now four instead of six. These four variables are: horsepower, vehicle weight, model year, and filter.

2. Auto-Correlation:

Auto correlation tells about the effect of one observation on another observation and there should be no auto-correlation in regression analysis. It increases the significant value in co-efficient table. If this value is greater than .05 the regression co-efficient becomes insignificant and not generalizable. Durbin-Watson test is used to check the auto correlation of the data. Before remedial measure the Durbin-Watson value is 1.244 and it is not in the ignorable limit which is 1.7-2.3 as shown in the table 1.5. So it increased the regression co-efficient value and makes it insignificant.

Table 1.5

Model	R	R Square	Adjusted R Square	**Durbin-Watson**
1	.924[a]	0.853	0.852	1.244

In corrective measures first of all we calculated the value of Rho (ρ) by following formula and its value is 0.378 by this formula.

$$\rho = 1 - \text{Durbin-Watson}/2$$

This 0.378 is the value which trickles down from first observation to the second observation and so on. After creating time series and computing new variables, we again performed the Durbin-Watson test and its value become 2.023 as shown in table 1.6.

Table 1.6

Model	R	R Square	**Durbin-Watson**
1	.885[a]	.784	2.023

Durbin-Watson value becomes 2.023 as shown in table 1.6 which falls within the ignorable range (1.7-2.3).

3. Heteroscedasticity:

Many researchers are of the view that when the first three assumptions of regression are fulfilled then the assumption of heteroscedasticity is automatically fulfilled.

4.Multiple Regression Analysis:

After fulfilling all the assumptions of regression analysis we ran the regression analysis separately in order to identify the effect of independent variables on dependent variable. In our final model dependent variable is miles per gallon and independent variables are horse power, vehicle weight, model year and filters. So there is one dependent variable and four independent variables and regression is multiple regression.

Table 1.7

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3.282	3.406		-.964	.336
	horse_new	-.006	.008	-.042	-.825	.410
	weight_new	-.007	.000	-.829	-17.531	.000
	year_new	.677	.066	.276	10.196	.000
	filter_new	-1.831	.625	-.117	-2.929	.004

The value of beta for horse_new, weight_new, year_new, and filter_new in unstandardized coefficients are -0.006, -0.007, 0.677, and -1.831 respectively. These values are non-zero which indicates that the dependence exists and year_new has positive effect on miles per gallon while all other variables have negative impact on miles per gallon. Here the value of 0.006 indicates that with every 1 unit increase in horsepower, the fuel efficiency will decrease by 0.006 mile per gallon. Similarly, the value of 0.007 indicates that with every 1 pound increase in vehicle weight, the fuel efficiency will decrease by 0.007 miles per gallon. Next, the value of 0.677 indicates that with every 1 unit increase in model year will increase the fuel efficiency by 0.677 miles per gallon. Lastly, the value of 1.831 shows that with every 1 unit increase in filter, the value of fuel efficiency will decrease by 1.831 miles per gallon.

The value of R^2 is .784 which indicates strong regression and also it fulfills the linearity assumption because its value is not in the range of 0-0.02. This value of R^2 also indicates that this model explains fuel efficiency in miles per gallon by 78.4% as shown in table 1.8.

Table 1.8

Model	R	R Square	Adjusted R Square
1	.885[a]	.784	.781

To check the independent impact of each independent variable on the miles per gallon, we can see the respective values of Beta in standardized coefficient table (table 1.7). It indicates that vehicle weight has the maximum impact (0.829) on miles per gallon while horsepower has the minimum impact (0.042). The significance values of each independent variable in coefficient table (table 1.7) shows that all other independent variables are significant except horsepower. The significance of overall model can be seen in ANOVA Table (Table 1.9) which shows that the overall model is significant (sig = 0.000). It clearly indicates that these results are not by chance or due to repeatability, however, these results are generalizable and applicable to whole population.

Table 1.9

Model		Sum of Squares	Mean Square	F	Sig.
1	Regression	8454.919	2113.730	317.460	.000[a]
	Residual	2330.391	6.658		
	Total	10785.310			

VI. CONCLUSION

The efficiency of vehicle is dependent on multiple factors including horse power, vehicle weight, model year and filters etc. The results indicate that model year has positive effect on efficiency of vehicle while horse power, vehicle weight, and filters have negative impact on vehicle's efficiency. Results also specify that vehicle weight has the maximum impact (0.829) on miles per gallon while horsepower has the minimum impact (0.042).

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