"Modeling of Determinants of Petroleum Consumption of Vehicles in Ghana"

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Abstract

Petroleum consumption of vehicles is always a concern of many prospective car buyers, yet many seem clueless about its determinants. This paper determined the main predictors of petroleum use of vehicles from six predictor variables, and also developed a statistical model for predicting petroleum consumption. Data was gathered from seven automobile companies in Accra, Ghana on 121 common vehicles in the country. Statistical analyses used included Pearson's correlation and Best Subsets Regression, where the Mallow's C_p and adjusted R-square helped to determine the most adequate and plausible regression model. Key findings showed that weight, width, and horsepower were significantly negatively correlated with petroleum use of vehicles. However, the best regression model for prediction involved only weight and horsepower of a vehicle. The study bears implications for prospective vehicle buyers, sellers and Government.

Keywords: vehicles, petroleum consumption, predictors, model.

1. Introduction

Generally, vehicles are indispensable means of transportation among people all over the world (UITP, 2010). The importance of vehicles in today's world is now understood by everyone. The development of vehicles has enormous effects on people's way of life throughout the world which probably may be an indication that cars have created greater and more rapid changes in the society. According to Agyemang-Bonsu et al. (2010), the last decade witnessed progressive increase in number of vehicles in Ghana, especially in major cities like Accra, Tema and Kumasi. This, they said, "presents greater challenge to urban authorities, particularly; increased traffic congestion could seriously deteriorate air quality leading to climatic variability and related health problems."

The use of vehicles is dependent on the availability of petroleum products to fuel them. This dependency poses a challenging energy and environmental problems since the transport sector is responsible for 63% of the total petroleum consumption in Ghana (Energy Foundation, 2009). According to USEIA (2011), petroleum consumption in the country has witnessed an astronomical increase from year 2000 as the number of registered vehicles increased nearly by 121% between years 2000 and 2009 (DVLA, 2010).

Undoubtedly, petroleum price is the most influential factor in determining prices of many products in Ghana's economy. Economists have postulated that a rise in petroleum price will result in a higher inflation. Also, transportation fares change as the price of crude oil changes on the international market. Recently, the Government of Ghana has recently constituted a committee to hedge against the prices of petroleum products in order to stabilise the economy as far as inflation is concerned.

Statistics have it that majority of Ghanaians are far below the middle income status (GSS, 2009) and as result would be expected to use vehicles that will economise the use of petrol. However, different types of vehicles are seen on our roads including those that are known to have high fuel consumption rates. No wonder, there is frequent shortage of petroleum products in the country. According to Ankomah (2012), "some motorists in Accra are calling on government to quickly attend to the apparent fuel shortage which has hit the nation's capital, Accra." Clearly, these high fuel consuming vehicles pose serious economic security threat to the country since government must continue to import large volume of crude oil to meet the growing demand.

Many Ghanaians hold the belief that it is only 4-wheel vehicles and long vans that consume more fuel, seemingly clueless of other factors (variables) such as the horsepower, weight, width and cargo volume of vehicles that influence their fuel consumption. To Shi (2007), the weight, tire width, 4-wheel drive and engine displacement have positive impacts on fuel cost. Interactions such as weight and tire width, 4-wheel drive and horsepower, as well as 4-wheel drive and displacement also have positive impacts on fuel cost. He again identified that fuel economy benefit of turbo cargo engines depends on their interaction with displacement and weight respectively.

2. Data and Methods

The data was obtained from reputable car distributors in Accra, Ghana. Notable among them were the Toyota Ghana Limited, Mechanical Lloyd Limited, Silver Star Limited., Japan Motors, African Automobile Limited, KIA Motors, Auto Parts Limited. The study employed the Pearson's correlation, multiple regression and Best Subsets Regression where the Mallow's C_p and adjusted R-square helped to determine the most adequate and plausible regression model for predicting petrol consumption of vehicles using the MINITAB statistical software. According to Bowerman and O'Connell (1997) and Hocking (1976), in comparing regression models, one can use the *C* statistic (also called the Mallow's C_p), the adjusted-R^2 and the standard error. The Mallow's C_p rewards low bias and also small errors, which is akin to rewarding goodness of fit and simplicity respectively. By the Mallow's C_p, a smaller value indicates that a model is better. Typically, a model is looked upon favourably if its C_p value is closed to or below its number of predictor variables as shown in Figure 1 below.

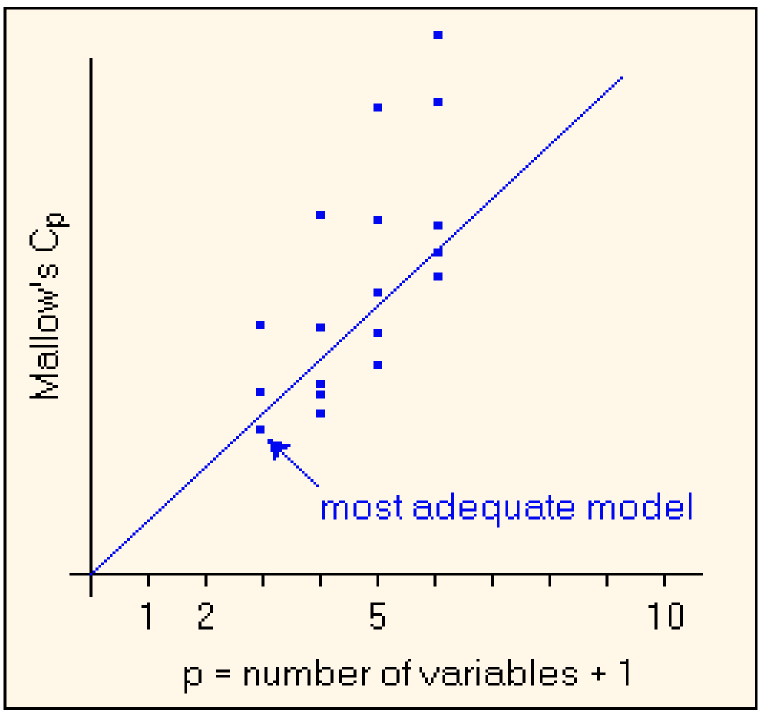

Fig. 1: A plot of Mallow's C_p and *p* variables

2.1 Variable Definition

The variables of interest in this study are as follows:

1. Petroleum use (PU) is measured in km/litre.
2. Drive type (D) has three main categories. Namely: All-wheel, Front-wheel and Rear-wheel drives.
3. Horsepower (HP) reflects the relative size and power of the standard engine. It is measured in horsepower (hp).
4. Weight indicates how heavy a car is. Its unit of measurement is kilogramme (kg).
5. Length is an indication of a car's size. It is measured in centimetre (cm).

6. Cargo volume indicates a car's loading capacity. The standard unit of measurement is cubic centimetre (cm^3).
7. Width is an indication of the car's size. It is measured in centimetre (cm).

3. Results and Discussion

This section first analyses the correlation between petroleum use and other explanatory variables such as drive type, horsepower, weight, cargo volume and width of a vehicle. It then proceeds to discuss the multiple regression and best subsets regression analyses.

3.1 Correlation Analysis

Table 1 gives the correlation coefficients between petroleum consumption/use, drive type, horsepower, weight, cargo volume and width of a vehicle.

Table 1: Correlation Analysis

	Petrol use (km/litre)	Drive type	Horsepower	Weight	Cargo volume	Width
Drive type (D)	-0.362					
	(0.000)					
Horsepower (Hp)	-0.593	0.328				
	(0.000)	(0.000)				
Weight (Wg)	-0.782	0.430	0.673			
	(0.000)	(0.000)	(0.000)			
Cargo volume (C)	-0.570	0.175	0.296	0.716		
	(0.000)	(0.054)	(0.000)	(0.000)		
Width (W)	-0.627	0.138	0.660	0.780	0.546	
	(0.000)	(0.130)	(0.000)	(0.000)	(0.000)	
Length (L)	-0.516	-0.056	0.648	0.634	0.395	0.825
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Bracketed figures are p-values.

The correlation matrix shows the relationship between variables and the strength of the relationship. It also helps in identifying multicollinearity among the explanatory variables. From Table 1, there is no evidence of multicollinearity and hence all the variables can be incorporated in the regression model. Also from Table 1, all predictor variables were negatively and significantly correlated with the dependent variable (petroleum use) at 5% significance level; implying that all the predictors might be important in the prediction of petroleum consumption in a vehicle. Specifically, the highest correlation of -0.782 was realised between weight and petroleum use. This means that the heavier a car, the higher its petroleum consumption and vice versa.

Also, horsepower had a significant relationship of -0.593 with petroleum use; implying that the bigger a car's engine, the higher its consumption rate. Drive type of a vehicle was, however, moderately correlated with petroleum consumption. The implication is that drive type of a vehicle might not be a key determinant of petroleum use. This is, however, contrary to the general notion that drive type is the main predictor of fuel consumption of vehicles.

3.2 Multiple Regression Analysis

Tables 2 and 3 are the summaries of the multiple regression results with petroleum use as the dependent variable. From Table 2, the regression model based on all predictor variables is given as follows:

$$\boldsymbol{PU = 16.931 - 0.412D - 0.006HP - 0.002Wg - 0.001L - 0.009C - 0.009W}$$

Table 2: Results of Multiple Regression Analysis

	Coefficient	Standard Error	*t*	*p*
Constant	16.931	3.737	4.531	0.000
Drive type (D)	-0.142	0.236	-0.605	0.547
Horsepower (HP)	-0.006	0.004	-1.538	0.127
Weight (Wg)	-0.002	0.000	-4.080	0.000
Length (L)	-0.001	0.018	-0.070	0.332
Cargo volume (C)	-0.009	0.009	-0.975	0.911
Width (W)	-0.009	0.078	-0.112	0.945

Table 3: ANOVA for Regression Model

Source	*df*	SS	MS	*F*	*p*
Regression	6	295.655	49.276	31.372	0.000
Residual	114	179.060	1.571		
Total	120	474.715			

R-Sq(adj) = 60.3%

The regression analysis indicates that although the model was significant, all predictor variables were not statistically significant at 5% significance level except weight. Again, these variables accounted for 60.3% of variability in petroleum consumption of vehicles studied, which is not desirable enough. The explanation here is that some variables may have been unnecessarily included in the model. For this reason, the Best Subsets regression analysis was used to determine the most adequate and plausible model.

3.4 Best Subsets Regression

The most adequate and predictive regression model is obtained via the use of the best subsets regression analysis. Table 4 gives the result from the best subsets regression analysis.

Table 4: Best Subsets Regression Analysis based on Predictors

Variables	R-sq. (Adj.)	C_p	S.E.	Drive type	Horsepower	Weight	Cargo volume	Width	Length
1	60.8	0.6	1.2460			x			
1	38.8	66.5	1.5562					x	
2	61.2	0.2	1.2381		x	x			
2	60.5	2.4	1.2499	x		x			
3	61.2	1.4	1.2393		x	x	x		
3	61.0	2.0	1.2425	x	x	x			
4	61.0	3.0	1.2426	x	x	x	x		
4	60.9	3.4	1.2445		x	x	x		x
5	60.6	5.0	1.2478	x	x	x	x	x	
5	60.6	5.0	1.2479	x	x	x	x		x
6	60.3	7.0	1.2533	x	x	x	x	x	x

From Table 4, the best subsets regression analysis reveals the following results: the most adequate model containing only one predictor is either regressing petroleum use (PU) on weight (Wg) or on the width (W) of a vehicle. On a model involving two predictors, the model must include horsepower (HP) and weight (Wg) or drive type (D) and weight (Wg). Also, a 3-variable model should have horsepower (HP), weight (Wg) and cargo volume (C) or drive type (D), horsepower (HP) and weight (Wg). In similar fashion, a four-predictor model must involve drive type (D), horsepower (HP), weight (Wg) and cargo volume (C) or horsepower (HP), weight (Wg), cargo volume (C) and length (L) of a vehicle. Furthermore, an regression model containing five determinants would include the drive type (D), horsepower (HP), weight (Wg), cargo volume (C) and width (W) or drive type (D), horsepower (HP), weight (Wg), cargo volume (C) and length (L) of a car.

In determining the best model, the adjusted R-squares and the Mallow's C_p statistics were greatly considered for the various models. A closer look at Table 4 shows that the subset containing horsepower (HP) and weight (W) was the best model. This is because it had an adjusted R-square of 61% with the lowest *C*-statistic of 0.2 and smallest standard error value of 1.2381.

It is, therefore, clear that the best regression model for predicting petroleum consumption of a vehicle must include its horsepower (HP) and weight (W). Hence, the model is given as:

$$PU = 16.700 - 0.005\ HP - 0.002Wg$$

4. Conclusions

The present study determined a model for predicting petroleum use in vehicles. Using data gathered on some 121 selected vehicles on Ghana's roads.

The study yielded some key findings. First, the weight of a vehicle had the strongest correlation with petroleum consumption, whilst drive type had the lowest. Again, all six determinants were not important in the model for predicting petroleum use in vehicles. Also, contrary to the general notion that drive type and length of a vehicle mainly determine petroleum use of a car, the study's findings disproved it. Finally, horsepower (HP) and weight (W) of a vehicle proved to be statistically important in predicting petroleum consumption in vehicles; disagreeing with Shi (2007) that weight, tire width and engine displacement of a vehicle have positive impacts on fuel cost.

Evidently, the findings above bear the implications that prospective vehicle buyers should take into account *Horsepower* and *Weight* if they intend to economise petroleum consumption of their vehicles. Also, government should be proactive in planning petroleum needs of the country by considering the types (specifications) of vehicles that are imported.

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