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Modelling Transport Energy Demand in Ghana: The Policy Implication on Ghanaian Economy

Jonathan Annan[1], Yarhands Dissou Arthur[2*] and Emmanuel Quanah[1]

[1]Department of Information Systems and Decision Sciences, Kwame Nkrumah University of Science and Technology, Ghana.
[2]Department of Mechanical Technology Education, College of Technology Education, University of Education, Winneba, Kumasi Campus, P.O Box 1277, Ghana.

Authors' contributions

This work was carried out in collaboration with all authors. The teamwork lead by author JA and produced this manuscript as part of his PhD thesis. Author JA started the initial write up and provided the needed guideline for author YDA in the data preparation and statistical analysis to help generate the needed results while author EQ assisted in the discussion and reading through the write-up. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The study aims at modeling automotive energy demand in Ghana as well as predicting the long term energy demand and its implication on the Ghanaian economy.
Research Design: The research design deployed in order to achieve the aim was explanatory.
Research Duration: The research form part of bigger research work which got started in 2012 and ended 2015
Research Methodology: The study used secondary data of fuel demand collected from the ministry of energy, through Ghana statistical service. Descriptive statistics and inferential statistical methods were deployed. Various descriptive charts were used in the preliminary stages of the modeling and further modeling techniques such as quadratic, linear, logarithmic, cubic and

**Corresponding author: E-mail: 1277.day1981boy@yahoo.com, day1981boy@yahoo.com;*

exponential models were the modeling techniques used. The mean absolute deviation was also adopted.
Research Findings: The result of the study reveals that the cubic model best predict the demand for both gasoline but the PMS best predicted by quadratic model in Ghana with p-value < 0.05. The plot of the forecast value further revealed exponential future demand for automotive energy in Ghana.
Conclusion: The cubic model best fit the automotive energy demand in Ghana with exponential future automotive energy demand. The nation should put policies in place to ensure resilient public transportation system which will translate into a reduction in private car demand for fuel.
Implication on Ghanaian Economy: The exponential demand for automotive energy will mean that the nation will need more funds in order to import such energy this will further put much pressure on the cedi since demand for the fuel will demand foreign currency for its importation.

Keywords: Energy demand; transport energy; Ghanaian economy; modeling.

1. INTRODUCTION

The concept of sustainability, by and large, is gaining acceptance by all policy makers and is viewed by many stakeholders in policies formulation as the solution to economic growth in a country, being developed or developing. Energy use in the transportation sector includes energy consumed in moving people and goods by road, rail, air, water, and pipeline. Transportation systems are essential for trade and economic competitiveness in an increasingly globalized world, as well as for enhancing standards of living. Trade and economic activity are the most significant factors determining demand for freight transportation. A more complex set of determinants—including travel behaviour, land use patterns, and urbanization which all affect the demand for passenger transportation, along with macroeconomic and fuel market impacts [1].

Energy plays a vital role in the economic activities of any country. In the same vein, transport which is responsible for the mobility of passengers and the movement of freight is also of equal importance to the growth of every economy. One form of energy which is of greater use is crude oil [2]. Once extracted from the ground, refineries covert crude oil into products that we can use, mainly fuel for transportation which is non- renewable [3]. According to [2] most of the oil that had been and is currently produced is conventional oil. [4] Throws more light on oil when he states that less than 1 percent of the continents and continental shelves contain oil that is easily accessible. Ghanaians' drive to own a car is uncontrollable, and almost all the vehicles are fuel dependent and with the dependent nature of these cars on only PMS and gasoline. The world's oil demand increased from 1020 million tonnes of oil equivalent (mtoe) in 1973 to 2162 mtoe in 2007 an increase of 45% in 1973 to 61% in 2007 [5]. Furthermore, worldwide energy use in the transportation sector increased by 77% from 1971 to 1993, currently about fifty percent of the world's oil is consumed in the transportation sector [6]. From the above, it suffices to reason that consumption rate in the transport sector is expected to increase since Ghana has just attained middle income status and is bent on improving its socio-economic development to raise the living standards of its citizens. In the same way the world is now facing a twin challenge of energy shortage and environmental deterioration as a result of over dependence on fossil energy. The study is therefore sought to examine the effect of traffic congestion on fuel consumption as well as forecasting automobile fuel consumption in Ghana. The purpose being that fuel consumption predictions have become an increasingly important tool for energy planning with primary aim of enabling policy makers develop appropriate pricing and taxation systems and helping decide future investment and decisions on oil reserves to improve energy security in Ghana.

2. LITERATURE REVIEW

2.1 Introduction

In the transport and fuel energy literature, many studies have concentrated on automobile petrol demand, with the argument that cars represent a major consumer and petrol is the key source for the current passenger car fleet [7] Subsequently, with the current rate of consumption, global proven oil reserves would be depleted in 42 years [8] However, [7] compared the effectiveness of different forecasting models on fuel demand forecasts. The reason-being that, most of the researchers typically only examined the theoretical differences without actually undertaking an empirical comparison of the practical usefulness in forecasting fuel demand.

2.2 Transportation and Energy Demand

The petroleum energy demand problem has become a major issue across the globe in recent times and the need to address this problem has become imperative [9]. The relationship between transport and energy is a direct one even though the degree of the dependency varies with a particular mode. Passengers and high value goods can be transported by rapid but energy-intensive mode [10]. Shapiro et al. [11] affirmed that the role of transportation in a nation's fuel consumption as is essential for the socio-economic development of a nation; therefore effort should be made to manage its use to ensure efficiency, principally in the transport sector. Globalization has also intensified transport activities and that transportation is accounting for a growing share of the total amount of energy spent for human activities [12]. The argument continues that energy consumption has a strong correlation with the level of economic development and that among the developed countries, transportation now accounts for between 20% and 25% of the total energy being consumed. Road transportation alone is consuming on the average, 85% of the total energy used by the transport sector in developed countries. In the land transport sector, passenger transportation accounts for 60% to 73% of the fuel energy consumption [13]. Again, population rise and improved lifestyle have also influenced the demand for fuel energy [12] and [13]. World energy consumption in the transportation sector increases by an average of 1.1 per cent per year. The transportation sector accounts for the largest share (63 per cent) of the total growth in world consumption of petroleum and other liquid fuels from 2010 to 2040. Transportation energy consumption in Africa grows by 0.8 percent per year, from 3.8 quadrillion Btu in 2010 to 4.8 quadrillion Btu in 2040 [1].

2.3 Fuel Economy

Due to high oil prices and climate change policy, governments are finding new strategies to improve fuel economy. This will contribute to air quality and energy security. According to [14], fuel economy can be seen from two angles – the use of new car, as it consumes less fuel as compared to old cars and On-road fuel economy which is also influenced by driver behavior. According to [15] 70 mph speed limit set on motorways in the UK is exceeded by 57% of drivers. In the same vein 30 mph speed limit set on urban roads is also exceeded by 58% of drivers. Again, optimal speed for fuel economy lies between 55 and 60 mph [16] However, optimal speed for fuel economy is also set at 62 mph [17] explains that not driving at optimal speed on most frequently used roads causes unnecessary increase in fuel consumption. Since urban roads, motorways and minor urban roads account for almost 60% of the total distance driven. It has been shown that driving at high speed increases consumption [18]. It is now clear that car speed levels and fuel consumption are the focus of energy policy design of which [1] recommended an enforcement of speed limits.

2.4 Forecasting Fuel Demand in Ghana

Ghana's demand for fuel is increasing almost every day and the ownership of private vehicles has increased over the past decades. The influence underlying the consumption of fuel for transportation activities have received a great deal of attention in Ghana and world at large [9]. Several authors' attempts to determine the key influences on PMS and gasoline consumption and quite a lot of these studies examined that fuel demand existed in view of predicting future demand for fuel [9,19].

2.5 Automobile Fuel Demand in Ghana

The total number of road transport vehicles in Ghana is estimated to be over 2.5 million with greater percentage being passenger cars [20]. A significant characteristic of automobile usage in Ghana is highly dependent on either PMS or gasoline as primary source of combustion in Ghana. Over the period of 1999 to 2012 approximately 11 billion and 15 billion of litres of PMS and gasoline was consumed respectively [20]. The research of automobile fuel consumption is of a great concern and have attracted a lot of attention over the past four decade through the use of many econometric studies to examine the demand for automobile fuel [9]. The greatest concern has been to analyzed effect of fuel consumption resulting from fuel energy insecurity threats [21]. Just as Australians fuel demand response to price decrease which is not significantly different from zero in the short run, petrol demand would remain at the same level given decrease in price in the short run and this scenario exist in Ghana [22]. Investigated by [23] into energy demand and also reported on the risen concern over oil security.

Wohlgemuth [6] used times series analysis to forecast energy demand and concluded that the lower price elasticity of traffic compared to fuel price elasticity is that changes in fuel prices are more effective in reducing fuel use than in curbing congestion. [24] determined fuel price based on estimated sectorial energy and transport demand using pumping prices and established that if fuel prices increases linearly, the marginal cost will slightly decrease from current trend but will increase if demand increases exponentially. Hirsch et al. [2] projected transport energy consumption using log linear regression model and feed forward neural network models with the national gross domestic product, population and number of registered vehicles as independent variables.

3. RESEARCH METHODOLOGY

The work by [25] applied the theory of Bayesian linear regression and Markov Chain Monte Carlo method (MCMC) to establish a demand-forecast model of petrol and diesel. In their study a final comparison between the predicted results from autoregressive integrated moving average models (ARIMA) and others is made to assess our task. The use of wavelet-neural-network-based forecast model by [26] was developed for energy demand in China. Their simulation result reveals that the nonlinear forecasting model is more reasonable and has higher precision than other multiple regressions models. Many traditional methods analysis have been used to forecast fuel demand. Among these methods are time series, regression, econometric, ARIMA. Computing techniques such as fuzzy logic, genetic algorithm, and neural networks are being extensively used for demand side management [27]. In this study Quadratic Trend model was used in forecasting automobile fuel consumption in Ghana for the next fifteen years. Secondary data was obtained from National Petroleum Authority (NPA), Driving and Vehicle Licensing Authority (DVLA), and Ghana Statistical Service [28]. A multivariate data analysis was employed including descriptive analysis, and Quadratic Trend model. Quadratic Trend model was used to access the secondary data, in doing so; we described not only the theoretical elements of the various models, but also the set of practical consideration that defines the appeal of specific models. The results of the work were tested to ascertain accuracy of the forecast model by measuring forecast errors from the data used. In total five simple forecast models are built, namely a linear trend model, quadratic trend model, cubic trend model, logarithm trend model and exponential trend models.

3.1 Simple Methods for Forecasting Automobile Fuel Demand

Many econometric models have proven to be very sophisticated with modeling fuel demand but there are other simpler methods that are available for use in demand forecasting.

These simpler statistical approaches typically provide a straight forward means of directly calculating forecasts and include such models as the linear trend model, the quadratic trend model, cubic trend model, logarithmic trend model and the exponential trend model.

These models analyze trend of time series data and make forecasts based on the observed trends. The independent variable (*x*) is the time period code and the first observation is assigned a code value *x* = 0. Then followed by the time period codes 1, 2, and 3, n. The observed data value is the dependent variable (*y*).

The method of least-squares is used to compute the values of the coefficients. The forecast of the dependent variable are achieved by substituting the corresponding time period code value into different forms of trend equations. These are examples of some models:

$$y_t = \beta_0 + \beta_1 x_t + \varepsilon_t \text{ - - linear} \tag{3.1}$$

Where x_t is the time period code?

β_0 Is a constant

β_1 is the unknown coefficient

ε_t Is the random error term

A quadratic trend model is a polynomial of order two. It is given by

$$y_t = \beta_0 + \beta_1 x_t + \beta_t x_t^2 + \varepsilon_t \text{ - quadratic} \tag{3.2}$$

Where x_t is the time period code?

β_0 is a constant

β_1 and β_2 are the unknown coefficients

ε_t is the random error term.

An exponential trend model is given as

$$y_t = \beta_0 \beta_1^{x^t} \varepsilon_t \text{ ....}$$

$$\log y_t = \log \beta_0 + x_t \log \beta_1 + \log \varepsilon_t$$

Where x_t is the time period code

β_0 is a constant

β_1 is the unknown coefficients

ε_t is the random error term.

The research question addressed here is which of the simpler forecast methods provide the best forecast with minimum MAD.

The Mean Absolute Deviation (MAD) technique is defined as in equation

$$MAD = \frac{\sum_{i=1}^{n} |y_t - f_t|}{n} \tag{3.3}$$

Where y_t is the actual observation in time period t and f_t is the forecast in time period t. According to [28], the Mean Absolute Deviation (MAD) is an effective measure of the average of the absolute difference between the actual observations and the predicted variable in the time series.

4. FINDINGS OF AUTOMOBILE FUEL DEMAND

This section examines the findings of the study, thus, forecasting automobile fuel consumption in Ghana. The following sub-sessions present analyse and discuss the demand for automobile fuel in Ghana.

4.1 Pattern of National Fuel Demand/ Consumption

The study used data collected within 10-year period: 1999 – 2009. The average yearly consumption levels were 727,338,937 and 950,477,745 litres for PMS and gasoline respectively. The lowest quantity demanded occurred in the year 1999 (605,810,210) and 2000 (790,695,840) litres for PMS and gasoline respectively while the highest demand was recorded in 2009 for both PMS and gasoline, each amounting to 929,472,159 and 1,326,952,821 litres respectively. By comparison, it can be said that, in all cases (in terms of yearly demand), the demand for gasoline has been higher than PMS. Possible reasons that may account for this observation is the growing emergence of private and passenger vehicles that use gasoline instead of PMS. In addition, traditionally, almost all heavy duty vehicles are powered by gasoline and they consume more fuel per distance compared to small vehicles that use PMS.

The trend analysis over the same period is presented in Fig. 1. Taken the base year to be 1999, by percentage wise, it can be seen that, the demand for both PMS and gasoline has been rising steadily between 1999 and 2009. The demand for gasoline has increased by 61.6% while that of PMS has been 53.4% from 1999 to 2009. It is also seen that the growth levels have not been consistent, while gasoline recorded decreasing levels between 1999 and 2001 that of PMS rose up. In conclusion, the demand for both products seems to experience irregular growth levels, which may have been possibly caused by other economic factors that exhibited during the respective years. For instance, in periods where GDP or income levels rise, people's travel needs tend to increase which consequently increases fuel consumption. Notwithstanding this, this observation could be also coincidental [29].

Data by [30] for the same period was furthered explored to ascertain which periods within the years was fuel been consumed most. This analysis was performed on month by month basis. On the average, from 1999 to 2009, fuel consumed in each month amounts to 871,271,266.6 litres and 666,727,359.0 litres for gasoline and PMS respectively. Similarly, the data also indicate that, gasoline is being consumed more than PMS per each month.

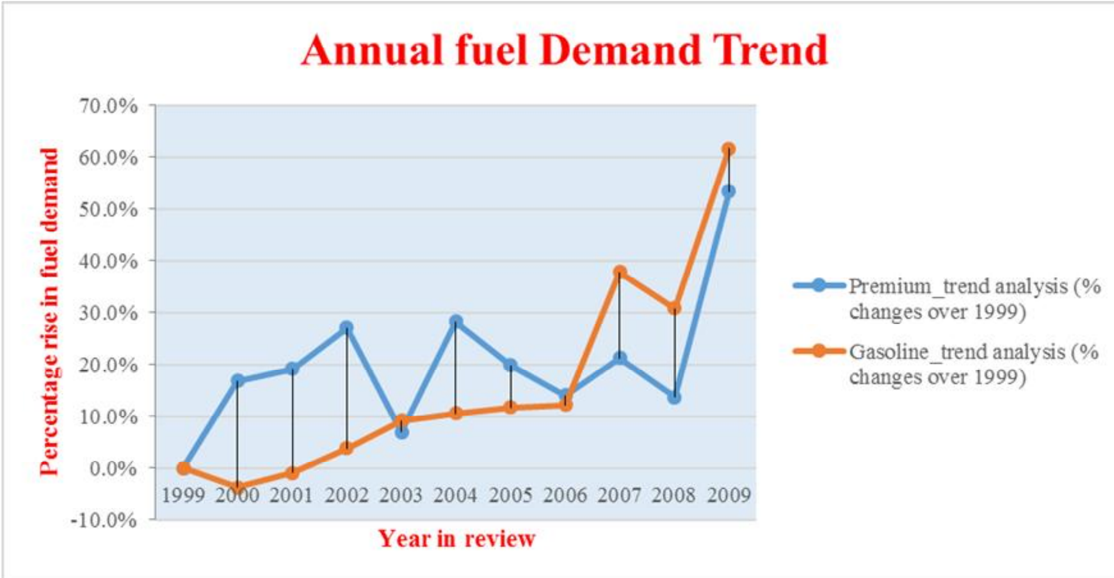

Fig. 1. Annual fuel consumption – trend
Source: (Ghana statistical service, 2011)

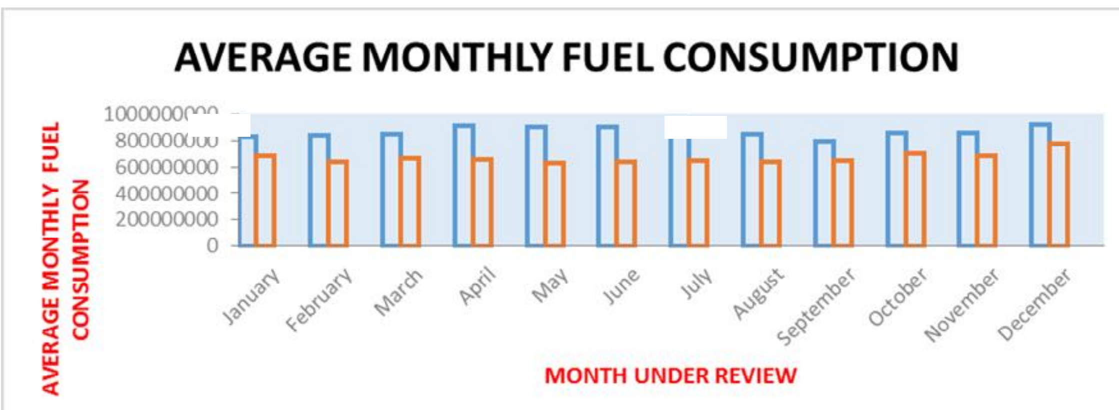

Fig. 2. Monthly fuel consumption – 1999 to 2009
Source: (Ghana statistical service, 2011)

While the demand for PMS peaks during December and January only, gasoline has other peak periods in April, May, June, and July. In Ghana, people traveling needs also increase during certain festive periods, such as Christmas (December), New year (January), and Easter (April), which may account for these observations. One particular factor that could affect the increasing demand for gasoline between May and July will be harvest season. Between May and July is the peak period for harvesting major farm produces (e.g. maize, rice, yam, fruits, vegetables, and other crops) in Ghana. This period is often related to increasing demand for heavy duty vehicle and trucks for carting farm produce to the cities and other market centres. Other related trading activities also emerge during this same period and increases the demand for gasoline.

4.1.1 Forecasting the demand for automobile fuel

In forecasting future automobile fuel consumption in Ghana, the researcher adopted various forecasting methods. These forecasts were made for both PMS and gasoline consumption. These models were fitted and the results are found to be very interesting.

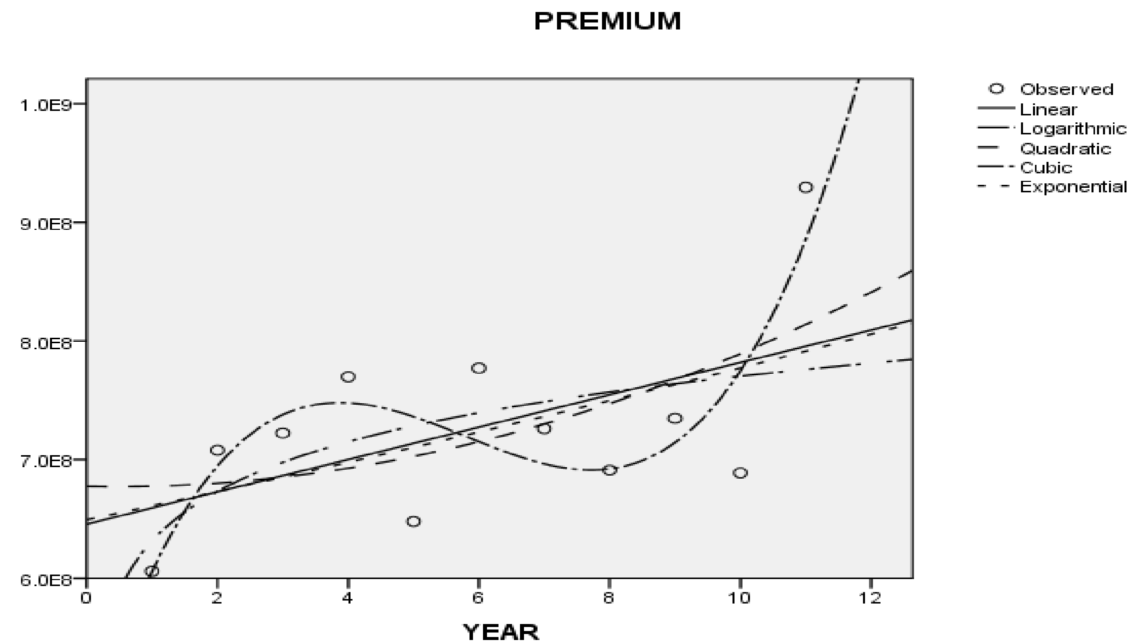

Fig. 3a. Demand forecast for PMS fuel energy
Source: (Field study, 2014)

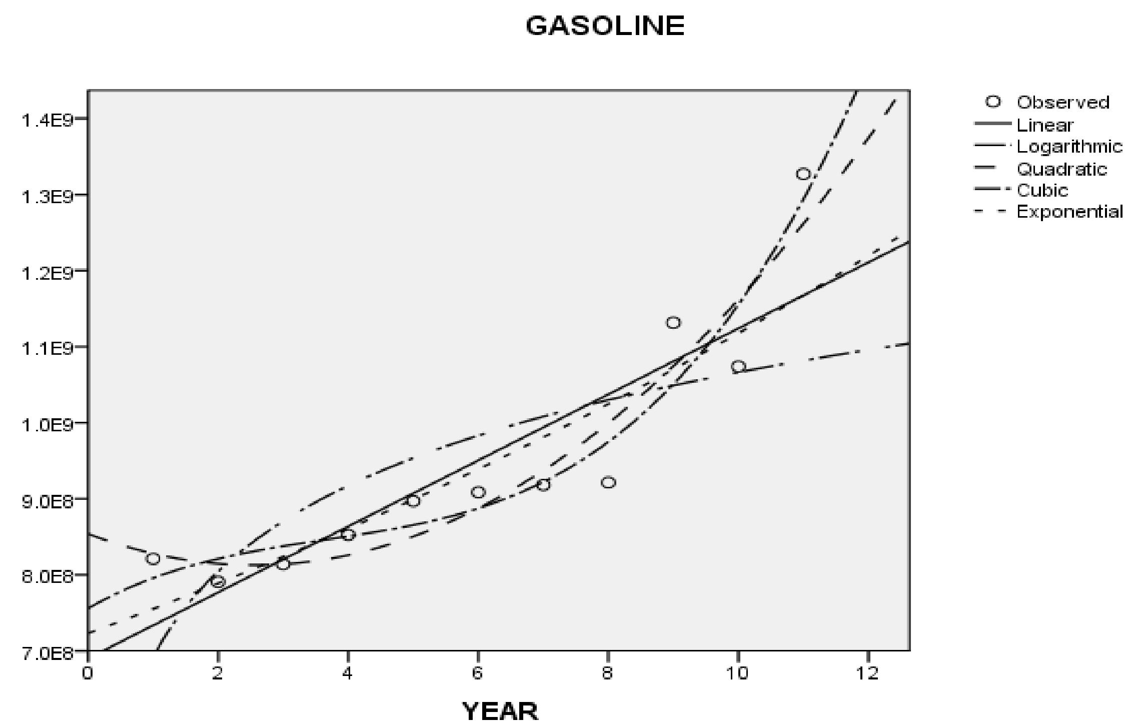

Fig. 3b. Demand forecast for gasoline fuel energy
Source: (Field study, 2014)

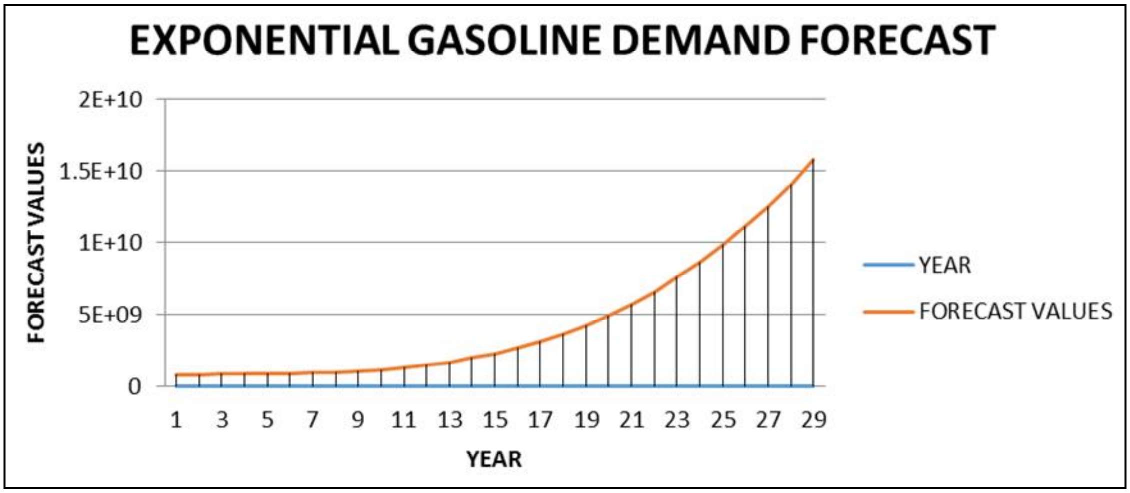

Fig. 4. Graph of cubic trend model forecast values for gasoline
Source: (Field study, 2014)

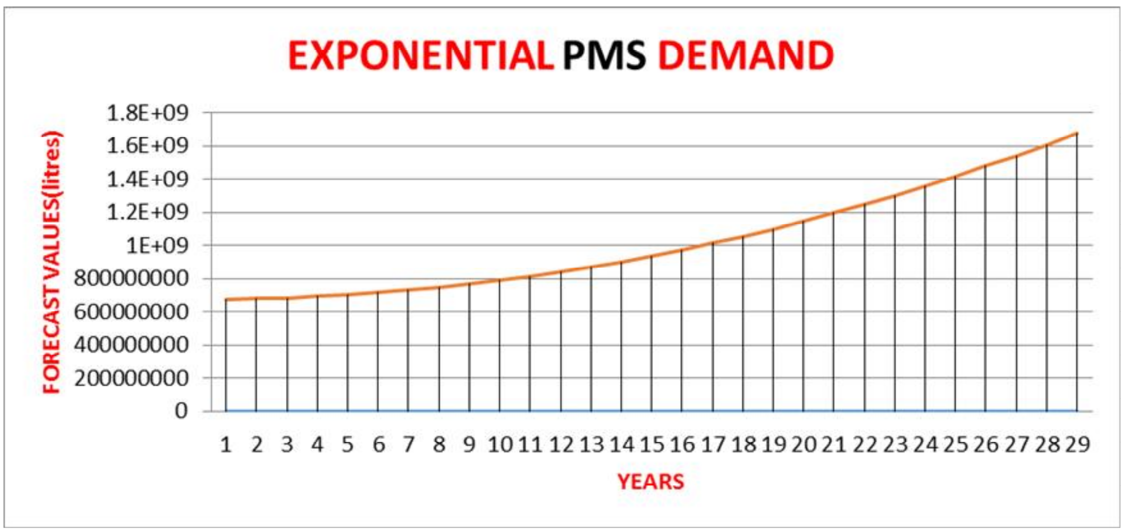

Fig. 5. Graphs of quadratic trend model forecast values for PMS
Source: (Field study, 2014)

The examination of the models for the PMS and gasoline in Table 1 reveals that the cubic models have the best r^2 value of 0.666 with the quadratic model with 0.313 r^2 values. The forecast values produced by these models were further subjected to Mean Absolute Deviation (MAD) analysis and were found that, although the cubic model has the best r^2 value, yet the quadratic model has the smallest MAD which is an indication that the quadratic trend model is the best model for the PMS. Hence the quadratic trend model produces a better forecast compared to the cubic. On the other hand, the cubic model best fit the gasoline since the r^2 and the Mean Absolute Deviation (MAD) values were all positive for the cubic model. The r^2 value of the PMS for the cubic model is higher than that of quadratic although the quadratic model has smaller MAD. This may be due to the fact that the r^2 value is affected by the number of predictor variables in the model. This also brings to light the fact that the r^2 value for one model is greater than the other does not necessarily mean that the model with the least r^2 is not the best model.

Table 1. Model summary demand forecast

	Model	r	r^2	F	P-value
PMS	Linear	0.54	0.294	3.751	0.085
	Logarithm	0.539	0.291	3.693	0.087
	Quadratic	0.559	0.313	1.820	0.223
	Cubic	0816	0.666	4.659	0.043
Gasoline	Linear	0.881	0.776	31.49	0.000
	Logarithm	0.742	0.550	11.01	0.009
	Quadratic	0.951	0.904	37.591	0.000
	Cubic	0.96	0.922	27.38	0.000

Source: (Field study, 2014)

Table 2. Cubic trend model forecast values for gasoline

Year	Forecast values(liters)	Year	Forecast values(liters)
1999	795700000	2014	2687290217
2000	821142826.7	2015	3143438290
2001	837674613.8	2016	3671299729
2002	850670321.7	2017	4276249495
2003	865504910.8	2018	4963662548
2004	887553341.4	2019	5738913848
2005	922190573.9	2020	6607378356
2006	974791568.7	2021	7574431032
2007	1050731286	2022	8645446836
2008	1155384687	2023	9825800729
2009	1294126731	2024	11120867672
2010	1472332379	2025	12536022624
2011	1695376591	2026	14076640546
2012	1968634328	2027	15748096399
2013	2297480550		

Table 3. Quadratic trend forecasting values for PMS

Year	Forecast values (liters)	Year	Forecast values (liters)
1999	677600000	2014	974090000
2000	680202000	2015	1013472000
2001	685256000	2016	1055306000
2002	692762000	2017	1099592000
2003	702720000	2018	1146330000
2004	715130000	2019	1195520000
2005	729992000	2020	1247162000
2006	747306000	2021	1301256000
2007	767072000	2022	1357802000
2008	789290000	2023	1416800000
2009	813960000	2024	1478250000
2010	841082000	2025	1542152000
2011	870656000	2026	1608506000
2012	902682000	2027	1677312000
2013	937160000		

Source: (Field data, 2014)

5. FINDINGS AND IMPLICATIONS

The forecasting of fuel consumption has become an important tool for energy planning of most countries. Therefore, a reliable forecasting modeling method is paramount for researchers. The study successfully concluded that the quadratic trend model is the best forecasting method for the data used in this study. This confirms the assertion of [7]. Also, the graph of the forecast figures for PMS exhibit an exponential pattern as shown in Fig. 4 and Fig 5.

This indicates that in the next fifteen (15) years, the consumption of automobile fuel will take a greater part of the nation's income and hence, the government will have to put measures in place to conserve automobile fuel energy. Finally, the study also concludes that the concept on new-car fuel economy and on-road fuel economy concepts are not known to Ghanaian drivers on our roads.

6. RECOMMENDATION

Policy measures for bringing about favorable driving behavioral changes are required for desired reduction of fuel consumed by road transport vehicles. Strategic planning and acting early are the keys to tackling the energy challenges faced by the road transport sector. Again, using alternative fuels in vehicles is a laudable idea as it will save the nation huge sums of money on importation of road transport fuel at the expense of other equally important sectors in the economy. Therefore, using alternative fuels is a laudable concept. The production of biodiesel from waste vegetable oil is recommended because it offers a triple-facet solution: economic, environmental and waste management. The new process technologies developed during the last years made it possible to produce biodiesel from recycled frying oils comparable in quality to that of virgin vegetable oil biodiesel with an added attractive advantage of being lower in price. The study recommends the introduction of hybrid car concept in the country. A hybrid car is a new technology of passenger cars which is the most efficiently used energy vehicle in road transportation. The government should have a policy to give incentives to those who patronize hybrid cars. Again government officials and other agencies should be seen to be using energy-efficient vehicles as against the land cruisers and heavy-engine-fuel consuming vehicles.

7. CONCLUSION

The study finally concluded that the quadratic trend model is the best forecasting method for the data used in this study. This confirms the assertion of [7]. The study further reveals that graph of the forecast figures for PMS and Gasoline exhibit an exponential pattern. This indicates that in the next fifteen (15) years, the consumption of automobile fuel will take a greater part of the nation's income and hence, the government will have to put measures in place to conserve automobile fuel energy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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