1893FuelEcononmyAnalysisforVehicularEfficiency.pdf

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Fuel Econonmy Analysis for Vehicular Efficiency

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Abstract—Fuel economy standards in United States would require new vehicles to achieve at least 34.1 miles per gallon on average by 2020. Significant enhancements to existing vehicular system are required to achieve this target. New vehicles must have better engine, drive-type, transmission, and fuel type combination so as to increase the number of vehicle with greater average mileage achieved. These changes will not only increase average mileage, but also reduce fuel usage, and thus reducing its corresponding production energy demands as well. Using XGBoost and Random Forest classifier, a prediction model is proposed to compute Green-House score and combined average mileage, owing to vehicle specific performance parameters.

Keywords—*Vehiular Efficiency; Fuel Economy; Green-House score; Vehicle Mileage; Random Forest; XGBoost*

I. INTRODUCTION

Keeping environmental issues in mind, fuel efficiency is the major factor which buyers look upon to decide which vehicle to purchase, especially when fuel prices are sky rocketing. Since, fuel efficiency is regularly monitored by federal and state governments of U.S. to minimize the impact of vehicle, to the environment. In U.S. fuel efficiency, measured in terms of distance travelled per amount of gasoline used. The standard unit of measuring in the U.S. is miles per gallon or MPG. The Environmental Protection Agency (EPA) requires automakers to report MPG ratings for city driving, highway driving, and combined.

The MPG rating and fuel economy of a vehicle depends on various attributes. In this paper, we used data as provided by U.S. government, to describe factors affecting a vehicle's MPG rating and created a model to predict MPG and greenhouse score based on various vehicle attributes. The goal is to find and study some of these attributes and to determine their effect upon fuel efficiency. The combined miles per gallon reflects fuel efficiency and is our response variable - in other words, we described, tested, and modelled the relationships between combined MPG and the rest of the variables. We hypothesized that the following factors may affect a vehicle's fuel efficiency. These factors were tested and presented in the analyses part of this report.

By using vehicle attributes that are fixed in the medium run, such as vehicular dimensions, power train architecture, and drive type, effects of factors like fuel prices, car prices and maintenance can be accounted for. Various omitted variable bias's also have a significant role to play in behavior pattern of customers, in purchasing any particular model of vehicle.

For instance, certain vehicular characteristics are known to have strong correlation with each other:

- vehicle size and fuel economy
- fuel economy and vehicle power

However, often such parameters are negatively correlated, and hence the tradeoff must be suitably balanced. Due to these factors being strongly associated, including these parameters in the regression analysis may lead to unsatisfactory, inconsistent results because of collinearity. As a result, the findings of regression model would also be difficult to interpret as whole. Taking the case of model having variable cost (in $) per mile and distance (in miles) per gallon in regression, we find that the coefficient of cost per mile is negatively related. This further directs to the fact that people will less likely chose a vehicle that has higher cost per mile value, all other parameters being same. Same is the case for MPG, which is also negatively correlated, that everyone would prefer to buy vehicles with higher mpg.

The automotive industry consumes up to 75% of petrol/crude oil all over the world, thereby resulting in one of the most significant origin of greenhouse gas. In order to achieve maximum fuel efficiency and least greenhouse gas emission, our research is conducted with vehicle specific parameters. Specifically, our work proposal considers the change in parameter owing to vehicle class and transmission type over yearly results to track maximum savings in terms of fuel consumptions.

II. RELATED WORK

In more recent studies, the issue of correlation between choice of vehicle by customers and technological decisions of manufacturers, are discussed in innovative methods. One way to is to not only incorporate the customers decision making on new vehicle purchases, but rather also factors like, for how long to have the car, how many miles are expected to be driven, whether buying used cars is on option or not. Apparently, often the manufacturers use the same engine model or slightly enhanced model for on various car model. Hence, it becomes important to develop an instrument for analyzing fuel economy. The reason being that various vehicles using the same engine in different vehicle classes tend to have similar fuel usage stats and thus similar mileage.

Nowadays, quite a few different vehicle manufacturers have started adjusting vehicular parameters as and when

required to meet both consumer's demands and other keep in pace with other manufacturers' automobile strategies. Similar papers on vehicular demand which also call for not using discrete choice models, also contend with endogeneity matters. For example, model of new and old vehicles, indicate that more number of new, more fuel-efficient vehicles will be sold in coming years where prices of gasoline are expected to rise, as supply diminishes slowly.

In the research work contributed by authors in [3] by, Gloria Helfand and Ann Wolverton, the paper looks at what all are the possible reasons to why there is gap in the price consumers are willing to pay, and the price being demanded by the producers. The reason is the additional cost of buying fuels, and the expected fuel savings that result is an important underlying determinant of the overall cost of national fuel economy standards. In paper [4], researchers mainly focused on the non-renewable energy and slowly increasing renewable energy in the industry, and it is essential to hike energy efficiency in order to meet energy needs in automotive industry. Energy regulation in automotive industry plays an important role in increasing fuel efficiency and decreasing greenhouse gases.

Further, work done researchers in the paper [5], mainly focused on that vehicular data in which vehicle uses higher energy per unit distance traveled and also emits greenhouse gases and other harmful pollutants. Their work helps us to better understand the effect of aggressive driving on the automotive industry in past few years. They examine that the fuel economy value of hybrid vehicles are better than the conventional gasoline vehicles. In yet another research, in [6], limiting consumption of gasoline and reassessing the standards and looking at what all future options we have like electric vehicles (EVs), hybrid electric vehicles (HEVs), etc. Climate change is now becoming a global issue, and thus worldwide should be to curb greenhouse gas emissions. This must be done by developing countries, as part of a greater effort to promote sustainable development.

III. PROPOSED METHODOLOGY

Our study examines the hybrid/non-hybrid passenger vehicles in U.S., which consists around 300 million cars on road. We have collected data for following years 2011 - 2018, from the www.fueleconomy.gov website and collected them using R program. After fetching vehicle parametric dataset [2] a model of MPG and greenhouse has been created. In this, we have developed the model using the following approach:

- Situation analysis is being used to determine what all technologies changes can adopted and plausible changes that can be done in vehicle parameters and sales are required, to meet directed fuel economy goals by 2020.

- Using different automotive material for manufacturing cars, based on different vehicle class sales and vehicle class's sales expectations, is being monitored and regulated keeping in mind of future vehicle scenarios.

The outputs of the model are the Green house score and combined MPG in each scenario. These are the important factors associated with environment, which are being affected (figure 1).
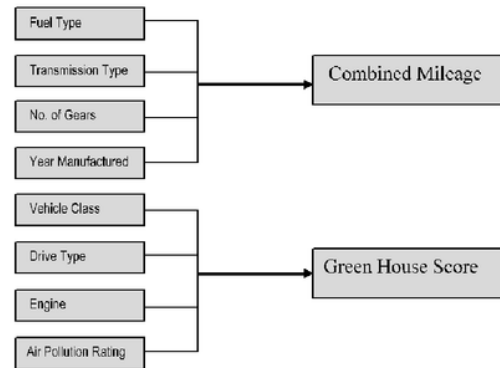

Figure 1. Proposed Model Overview

The factors associated with car such as weight, design specification, aerodynamic efficiency, etc. are not included in our analysis. Also, the mileage of plug-in hybrids and electric vehicle is not a viable option for this study, due to different mileage unit.

- *Methodical Framework*

Random forest is an ensemble learning method that used in various data science problems like regression, classification. The selection of single hyper-parameter tree from multiple decision trees at the time of training will result the best model of Random Forest. Random Forest gives the class that is mode of the other classes or mean prediction of the single tree. It chooses the best model from various decision tree and avoid over fitting up to some extent. Random forest is similar to bootstrap algorithm which contains various decision trees with different variables at root node. If our dataset consists 5000 observations with complete population along with 20 variables then random forest tries to build a different model with different size of sample and having different variables at root node. Initially, random forest begins with random stratified sample of 1000 observation and 10 anonymous initial variables at root node to build a predictive model. The whole process will repeat up to n times (n estimators) and then it will make a final prediction on each observation of validation dataset. Final prediction is a result of each prediction of every decision tree. The final prediction is the mean of each prediction of decision tree.

XGBoost is an advanced algorithm that has recently been using in various data science challenges. XGBoost is best for its high accuracy and performance. It is an enhancement of boosted decision trees. XGBoost is an ensemble of decision trees where in weighted combinations of predictors is taken. XGBoost works on the same lines of Random Forest, but there is a difference in working procedures. The similarities are that the features extracted in both the cases is completely random in nature. Steps that are algorithmic carried out throughout the process, includes learning of a regression independent variables, calculation of residuals, and prediction of residuals. Parameters mentioned below is used for calculating error rate.

```
In [42]: from xgboost import XGBClassifier
         #Train the model
         XGBOOST = XGBClassifier(base_score=0.5, colsample_bylevel=1, colsample_bytree=0.8,
             gamma=0, learning_rate=0.1, max_delta_step=0, max_depth=5,
             min_child_weight=3, missing=None, n_estimators=500, nthread=-1,
             objective='binary:logistic', reg_alpha=0, reg_lambda=1,
             scale_pos_weight=1, seed=0, silent=True, subsample=0.8)

         XGBOOST.fit(x_train,y)

Out[42]: XGBClassifier(base_score=0.5, colsample_bylevel=1, colsample_bytree=0.8,
             gamma=0, learning_rate=0.1, max_delta_step=0, max_depth=5,
             min_child_weight=3, missing=None, n_estimators=500, nthread=-1,
             objective='binary:logistic', reg_alpha=0, reg_lambda=1,
             scale_pos_weight=1, seed=0, silent=True, subsample=0.8)

In [ ]: #SAVING MODEL

In [43]: import pickle

         with open('XGBOOST.pkl', 'wb') as fid:
             pickle.dump(XGBOOST, fid,2)
```

Figure 2. XGBoost Model to Predict Combined MPG

Error in prediction is given by:

$$J = (z, \hat{z}) = X(z[i] - \hat{z}[i])^2 \qquad (1)$$

$\hat{z}$ can be adjusted to reduce the error, by using the following formula:

$$z[i] = z[i] + \alpha f[i] \qquad (2)$$
$$f[i] \approx \nabla J (z, \hat{z}) \qquad (3)$$

Each learner estimates the gradient of the loss function. Gradient Descent is used to take sequence of steps to re-duce sum of predictors weighted by step size α.

- *Flowchart*

We started by collecting data for different years, and applied various data processing methods as per the data requirement. Various steps applied:
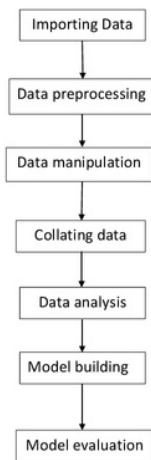

Figure 3: System Work Flow Model & Flowchart

- First we removed some of the unnecessary columns such as Sales Area, Standards, and Standard Description, under hood ID's and source file names.

- Then separated transmission type and number of transmissions from the transmission column, substituting CVT transmission for a '1' in transmission type variable.
- Removed hydrogen and electricity operated cars as we are interested in gas based cars (including hybrids) or vehicles with an MPG rating.
- Took only MPG of gasoline engines from the hybrid fuel cars, such that we compare similar fuel type i.e. gas and thus keeping the response variable in Miles per Gallon.
- For duplicate entries we took a mean of numerical variables to gauge the average values of our variable of interest (Combined MPG)

Figure 4. Predictive Model for Greenhouse Score

This was performed on data for years from 2011 - 2018, and finally collated them to make one single data file. Next step was to create a predictive model. We created a model and trained it on the dataset. Thus, a model was successfully created to predict Green House Score and let user evaluate his vehicle.

- *Current Production Situation*

While evaluating all possible area of impacts, fuel efficiency of vehicles can have, it is important to understand how changes in real time technologies could bring about a change in the number of vehicles and types of vehicles being purchased. Exploring this factual question need the use of models that analyze the consumer's choices of vehicles.
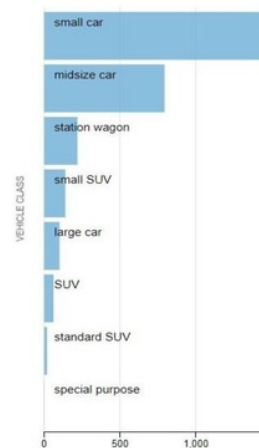

Figure 5. Vehicle Distribution over Vehicle Class Type

The factful studies are spending less time on analyzing how efficient is the production rate of the latest vehicles in the market. It is commonly assumed that vehicle manufacturers often, exploit any and every chance they have, to increase their profit marg[2] Although, our analysis show that it separates the practicality of low cost manufacturing opportunities to increase fuel economy and the non-fulfillment of the market to invest in such development may not be entirely due to ambiguity in customers decision making process.

Over the years many vehicles with different fuel type launched in market. Gasoline based cars continue to dominate market share over the years. But slowly and steadily, the electric vehicles are increasing and taking market share from Gasoline cars due to being more cost effective in long term.
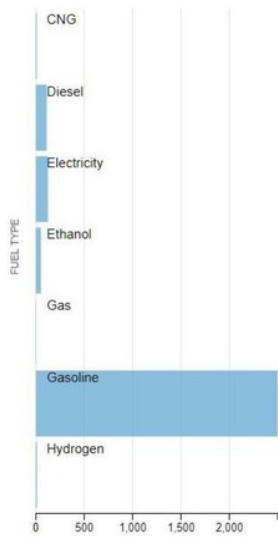
Figure 6. Vehicle Distribution over Fuel Type

As previously mentioned, several analyses show that recent improvements being done in engine efficiency, have resulted into improvement of various vehicle parameters, like power, chassis' weight and acceleration, rather than improved fuel mileage. Car manufactures are maximizing sell profits by constantly improving small and minor details of vehicle parameter and launching cars as new model, rather they should launch new models only where both fuel economy and other vehicular parameters are improved significantly.

III . PREDICTIVE MODEL OUTCOMES

Using the model build we predicted the values of Greenhouse Score, for each fuel type and keeping other predictor variables fixed at values in Figure 7. The result we found were interesting, and are detailed in the figure 8. Using the model build we also predicted the values of Greenhouse Score, for each transmission type and keeping other predictor variables fixed at values in Figure 9.

Figure 7. Input Values for Other Variables
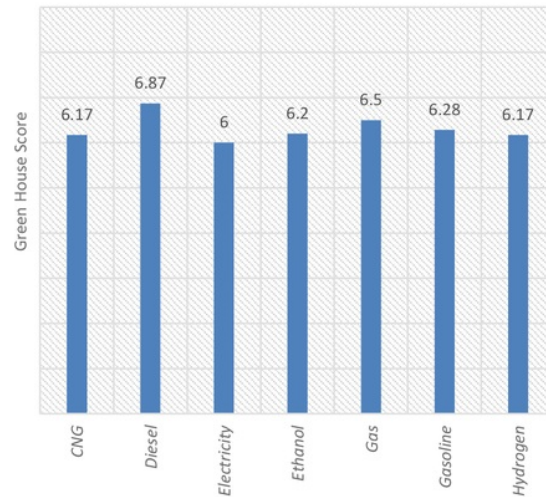
Figure 8. Greenhouse Score over Fuel Type

Figure 9. Input Values for Other Variables
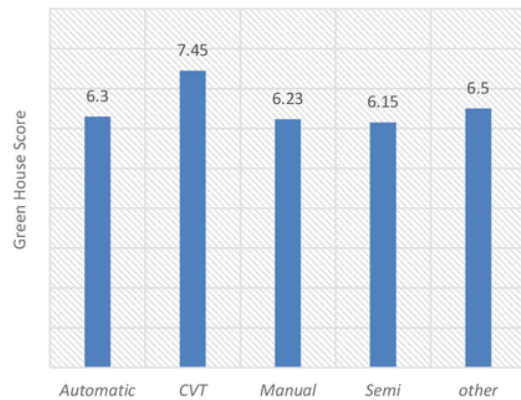
Figure 10. Greenhouse Score over Transmission Type

Figure 12. Predicted MPG for Different Fuel Types

Figure 10 shows the Green House score for different class of vehicles. After our analysis, we have gathered enough information to deduce the vehicles (in passenger category) fuel usage and the impact it has on environment under the various circumstances. Results have been projected for years up to 2020, keeping in mind the changes required to meet the 2018 targets. Under the diverse situations, we expect no drastic deviations in growth, rather changes will happen linearly, as seen from 2011 up to 2018 and will continue in similar fashion now onwards.

In addition, some findings are highlighted in figure 11 & 12. The result shows increase in number of transmission as MPG of vehicle reduces. Although it is believed that manual transmission is more fuel efficient than automatic transmissions, during our analysis, the study showed no significant advantages of manual transmission. Instead engines with continuously variable transmission (CVT) are the more fuel efficient transmission type, which are often used in hybrid vehicles.

The results show drastic difference mileage for electric vehicle. EV seem to have at least double the mileage as compared to any other fuel type. This can also be a major reason for shift to EV. As technology gets better, the battery get more optimized, better motor engine are available, thus more reliable and better performance from cars.

Sales of electric vehicle is increasing rapidly, moreover by 2020, it is estimated the cost of electric vehicles are expected to be the same as conventional fuel powered equivalents. While this will steal revenue currently being generated from conventional fuel powered cars, it will also open new pool of opportunities for new car manufacturers in new mobility services, new electric charging infrastructure and for battery manufacturers.

Electric vehicle sales across all major regional markets are on the upswing. In 2017, in terms of sales, the US had up to 200,000 units sold. In recent times, new US policy proposals are indicating that backing for reducing greenhouse gas might not stay as stringent as they were. Despite this, the sales of electric vehicle continue to grow, by about 27%, to reach almost 200,000 units. Also, market penetration finally reached to about 1% mark.
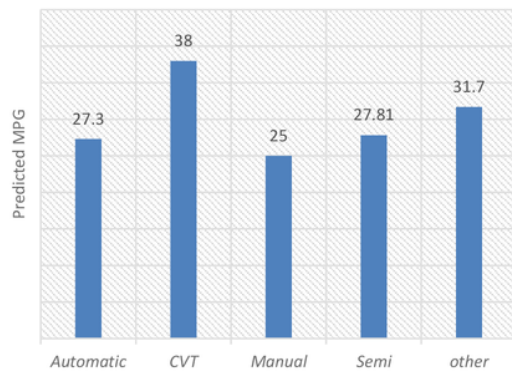

Figure 11. Predicted MPG Keeping Other Fixed

Using the predictive model build, we predicted the values of average mileage, for each fuel type and keeping other predictor variables fixed. The result was as follows.
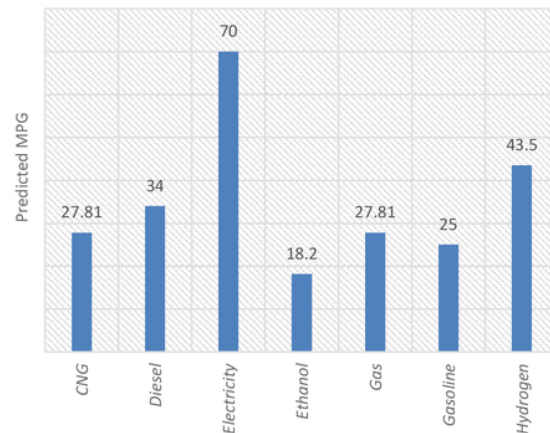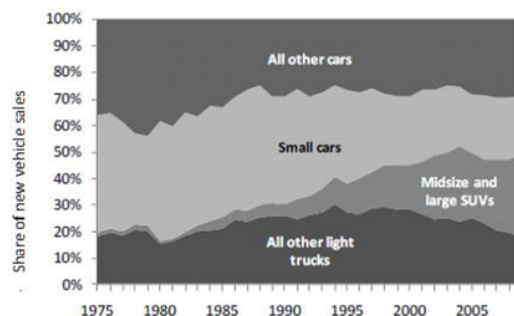

Figure 13. Trend of SUV's Sales in The U.S. [1]

Vehicle launches grew rapidly in the last few years. Small sedans continue to dominate market share over the years. But slowly and steadily, the share of medium size sedans, SUVs kept increasing and take market share from small sedans. (Figure 13)
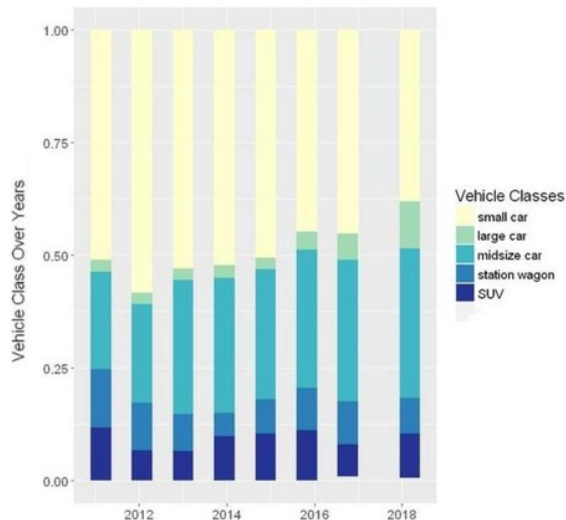

Figure 14. Class Wise Percentage over the Years

Two-wheel drive remains the more preferred drive train type over the years, but slowly more and more four-wheel drive vehicles are coming to the market in recent years. It is a trend that manufacturers are adopting four-wheel drive in their SUVs to meet the needs for various road conditions (Figure 15).
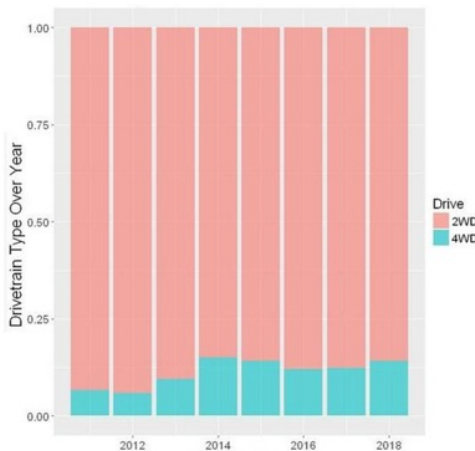

Figure 15. Share of Drive Type in SUVs

Predicted state of future vehicle sales figure are not proposed as sales estimates, but a way to discover potential in an indeterminate future. Few situations that highlight different, near future approaches for improving fuel economy are:

- *Vehicle size reduction* – SUVs are in general larger, heavier and thus less fuel-efficient vehicles of all vehicle type, yet there sales continue to increase, mainly due to luxury. Thus a need to invoke shift to smaller vehicle like small sedans, with higher mpg is required.

- *Introduction of improved, more fuel efficient engines* – Standard internal combustion engines are supposed to continue enhance in terms of fuel efficiency, with lower friction and new revolutionary techniques like direct injection. Further, by introducing more turbocharged engines, and equiping more number of gasoline, diesel, and hybrid and plugin hybrid electric vehicles wth these latest engines, fuel consumption of the upcoming vehicles can be reduced, thus reducing envirnmental impacts as well.

IV. CONCLUSION

In this research, we studied factors affecting fuel economy by analyzing different vehicle features. Our results confirm trends in fuel economy observed in the U.S. automobile industry. However, there are additional factors that were not captured in our analysis such as weight, design specification, etc. Some of the assumptions behind the statistical techniques we employed may not be valid and can be looked at in more detail in further studies. However, almost all outlined advancement in vehicles have been counterbalance by advancement in horsepower and acceleration performance of vehicles, rather than being obtain in actual fuel consumption reduction. For upcoming vehicles in this analysis, it is reckoning that this trend will move backward given more rigid fuel economy regulation. There will be some advancement in performance in upcoming vehicles in market, but not at former rates. Partially of the upcoming vehicle efficiency advancement will be devoted to improving fuel economy of vehicular market.

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