1. Background

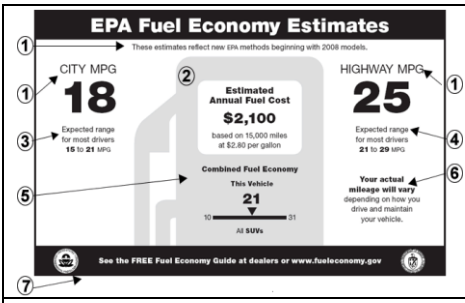
Fuel economy improvement has become a top priority for vehicle manufacturers worldwide due to factors like rising fuel prices, unpredictable long-term fossil fuel availability, the threat of climatic changes, and a growing understanding that auto emissions are harmful to both the environment and public health. The automotive business is currently faced with two major challenges: increased fuel efficiency and emission control. To save fuel, manufacturers have made vehicles running on different fuel types over the years.

Fuel economy is frequently calculated based on how far a car can go with a certain amount of fuel. (Or the inverse). In the USA, gasoline efficiency is expressed in vehicle miles per gallon. In the United States, the government-mandated CAFE (corporate Average Fuel Economy) standard, which is a sales-weighted average fuel economy, controls average fuel economy (expressed in miles per US gallon or mpg). The CAFE standard for passenger cars increased from 18 mpg in 1978 to the current 27.5 mpg. By 2025, it is intended to achieve 54.5 miles. (Mallik, 2020)

Following the oil crisis of the 1970s, the United States was the first country to establish fuel economy standards for passenger vehicles. When gasoline prices began to rise in the United States in 2007, SUV sales began to fall. In response, vehicle manufacturers began to produce crossover vehicles. By 2012, automakers had introduced 120 zero-emission HEV, PHEV, and EV models to the market. The pressure to improve fuel efficiency has persisted and will become even more pressing for future vehicles.

The EPA (United States Environmental Protection Agency) is in charge of providing the fuel economy data used on all new cars and light trucks' fuel economy labels (or window stickers). Since the mid-1970s, all new light duty cars and trucks have had fuel economy labels displayed on the window sticker, as required by the Energy Policy and Conservation Act. By making this information easily accessible via the label, consumers were able to make more informed decisions about fuel efficiency when purchasing a new vehicle. (EPA, 2022)

The important information seen in the label of an EV are fuel type, fuel economy (MPGe), how much you save in fuel cost in next five years, driving range in city, highway, annual fuel cost, charging time, fuel economy and greenhouse gas rating, smog rating.



vehicles beginning with 2008 models	Electric Vehicle Label

Figure from Fuel Economy Label Examples (EPA United States Government, 2022)

1.1 Summary of two papers

Due to the rise in fuel price in 1970s, US first CAFÉ standards was set in 1975. The history of fuel economy over the model years for different classes of vehicles is available in the EPA website. EPA is considering a value of 47 to 62mpg by the year 2025. The research on the fuel economy analysis and visualization was found abundant in the earlier years and less papers in the recent years.

According to the research conducted by Djordje T. PETROVIĆ et.al, replacing fossil fuel vehicles with Electric vehicles can reduce CO2 emissions. It is also found that low weight EC vehicles can reduce CO2 emissions better. (PETROVIĆ, PEŠIĆ, PETROVIĆ, & MIJAILOVIĆ, 2020). The factors affecting the fuel economy of US vehicles are vehicle type, fuel prices, CAFE standards, average vehicle weight, and engine horsepower. CAFE standards have a positive impact on fuel economy. (Gautam, 2010)

In an attempt to decide which is the best vehicle choice by a buyer, a technique of categorising vehicles using a weighted score calculated field is explained by Sharan Kumar. An interactive dash board is provided to select a vehicle and decide is it a good choice. The visualizations use bar charts, pie charts to represent the facts. The colour codes used in the research is following information visualisation goals to an extent. Stresses the use of good colors for the human brain to determine patterns and trends. (Sharan Kumar, July-2020)

Three well-known multivariate visualization techniques like Trellis display, Parallel coordinates, Pixel based visualization and their associated perception tasks different data exploration purposes is defined by Yan Liu. Each technique's benefits and drawbacks are discussed. It is widely assumed that visualization tools can aid in the

discovery of hidden patterns and relationships between variables. In response to the needs of handling complex datasets in various fields, there has recently been a huge rise in interest in developing tools for visualizing multivariate data. Lots of practices in evaluating visualization techniques have involved only administering them on a few datasets and examining the resulting patterns. However, such an approach provides little insight into the underlying perception issues that determine their effectiveness in revealing information to end users. A visualization fails if the decoding fails, regardless of how clever the information is chosen or how technically impressive the encoding is. (Yan, 2011)

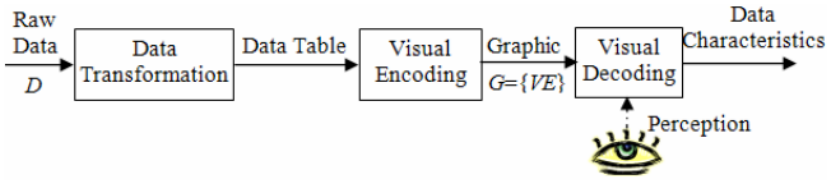


Fig. 1. Conceptual Model of the Data Visualization Process

Figure from (Yan, 2011)

1.2 Motivation of your visualization

The US vehicles data was analysed, researched and visualized by many in the earlier 2000s. Majority of the researches have been conducted for analysing the fuel economy of Gasoline vehicles and what are the factors affecting the fuel efficiency of them. These researchers have used the then graphical techniques like bar chart, pie chart, stacked bar charts to explain the dependencies and trends. Much interactive visualization techniques were not found in the studies. Most of the studies have aimed at predicting the mpg values for the next years also.

With the latest dataset, the interesting observation was the rise of Electric and Hybrid vehicles from 2008 onwards and its rise in demand and manufacturers whose produce only electric vehicles. Much visualization and analysis work are not found on the trends of electric vehicles. So, I was interested to do research on the factors to be considered by a person opting electric vehicle. How will a buyer get a better insight on the choice of electric cars as 'green cars' to environment and sustainability.

The older research papers helped me to identify the target variable and the correlations and how to visualize the attributes interactively using markers, filters and channels and dashboards.

The visualizations should be understandable and through effective colours, shapes and representations, one can easily interpret facts rather than figures. The visualisation should not be complex. The project use Tibco Spotfire as the tool for effective types of charts for the research.

2. Data

The dataset is available on the United States Environmental Protection Agency official website. The dataset contains 46024 rows and 83 columns related to all features of vehicles of all model years from 1984 to 2024. They have standardised the mpg values for the year 2024 also, but In the visualisations vehicles only till 2023 is represented. The data columns are described in the site. (Fuel Economy Web Services).

URL:

https://www.fueleconomy.gov/feg/epadata/vehicles.csv
(Updated: Wednesday March 01 2023)

3. One research question (or hypothesis)

The majority of motor vehicles worldwide is reigned by gasoline as compared to other sources — gasoline, hydrogen, propane, ethanol, and electric batteries, which are recharged from other external sources based on electricity and biodiesel. In general, many factors contribute to the profits of a new car model, such as engine type, mileage, fuel efficiency, emissions and many others. When a customer buys a new car, they consider these factors and make a decision. So, if we examine how these are prioritized, the results may be the best input for investors and automobile companies.

This project aims to examine the fuel efficiency of electric cars of single fuel type and dual fuel type over time in the United States which answers to the research question **are electric cars a better choice for sustainability and saving fuel cost?**

To get the answer of the research question, some sub questions were formulated and visualized. The final result was concluded on these insights.

1. What is the trend of electric vehicle presence in the market over the model years for different fuel type engines?
2. What are the details of each make of EV vehicle and the detailed data of each model (combined fuel efficiency, range, in city and highway)

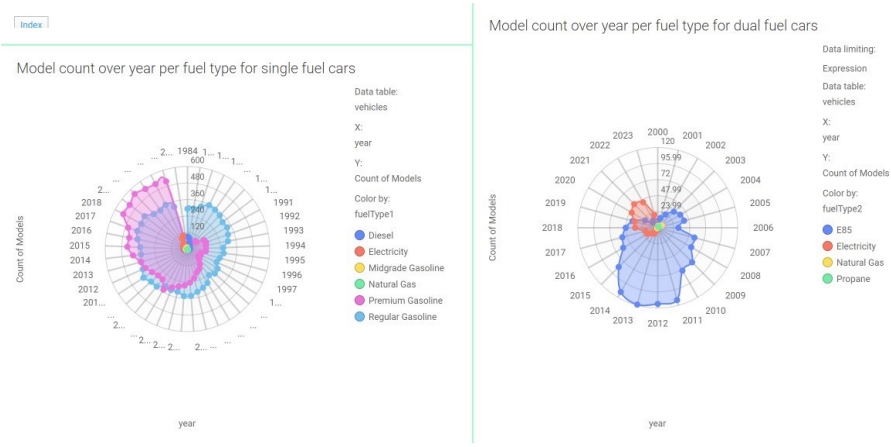
3. Which class of EVs are available the most and which company makes it?
4. Which fuel type have less or zero emissions over model years?
5. What are the parameters that affect the fuel cost saving in different fuel types, especially EVs?

4.Visualization results.

4.1 Visualization

1. What is the trend of electric vehicle presence in the market over the model years for different fuel type engines?

year wise model count



Premium Gasoline and Diesel vehicle models are still highly produced from 1984 to 2023 for single fuel type engines. Electricity vehicle models count is 31 in 2016 and in the year 2023 the number of models has increased to 103.

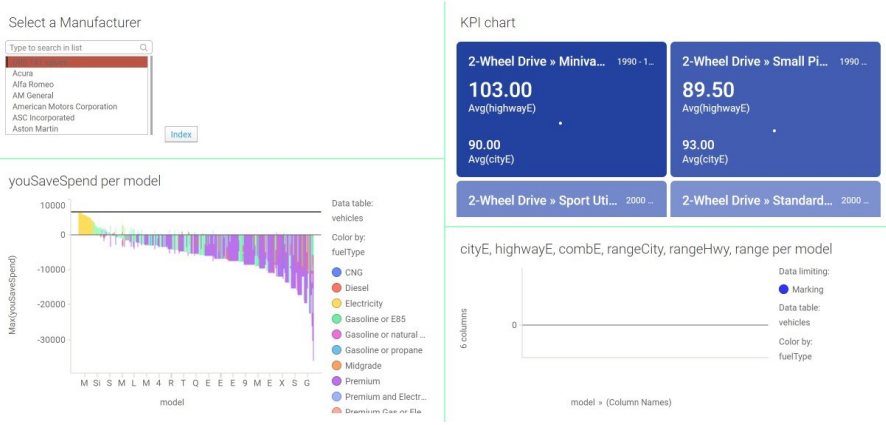
In 2014, electricity was the fuel type in dual fuel type vehicles with 10 models. It was higher in 2021, with 50 and can see a decrease to 20 in 2023.

In electric vehicles, single fuel type engines are produced more by manufacturers.

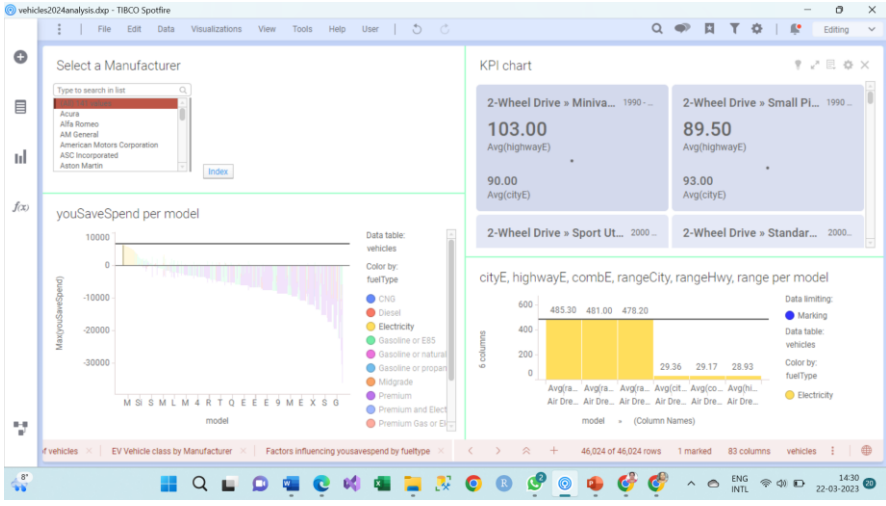
2. What are the details of each make of EV vehicle and the detailed data of each model (combined fuel efficiency, range, in city and highway)

When all manufactures are selected from the dropdown, the youSaveSpend model visualization shows all models as bars in the sorted order of youSaveSpend values. The yellow color bars are on the top with highest saving values. The yellow color represents the electricity fuel type. The KPI displays summary of highway and city energy consumption trends of each manufacturer models.

ManufacturewiseModelkeydetails

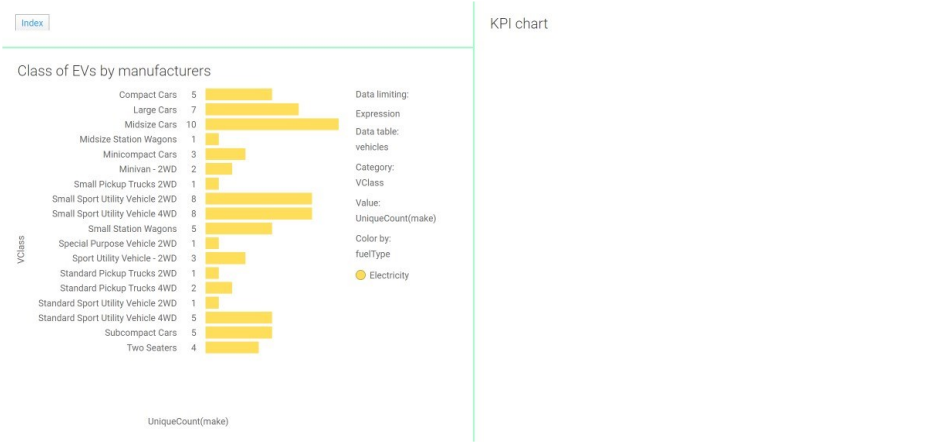


On selecting a model, its city, highway and combined energy consumptions and the range of the vehicle in city, highway and combined is displayed as yellow bars.

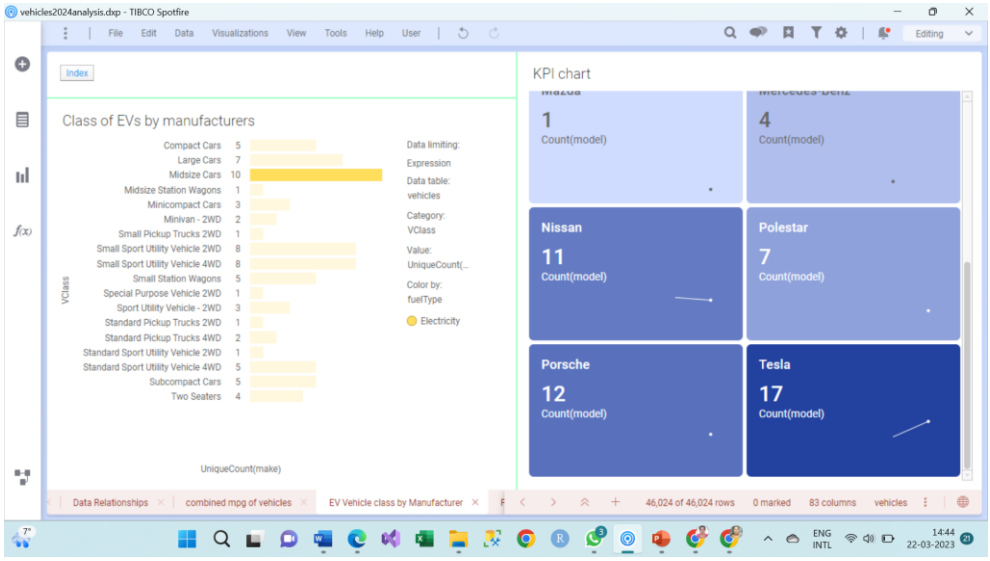


3. Which class of EVs are available the most and which company makes it?

EV Vehicle class by Manufacturer



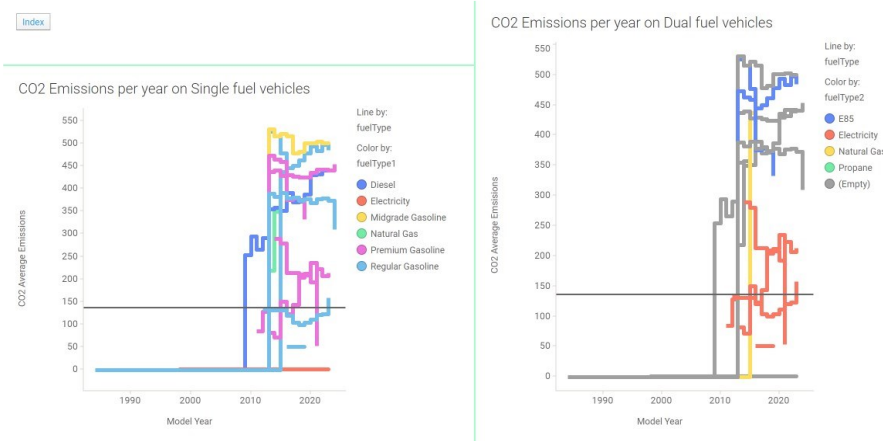
In EVs Midsize cars available in highest number is visible from this scrollable bar chart. On selecting the vehicle class bar we will get the company manufacturing more models.



Tesla produced the highest models of midsize cars over the model years. The arrow line indicates increase in production over years.

4. Which fuel type have less or zero emissions over model years?

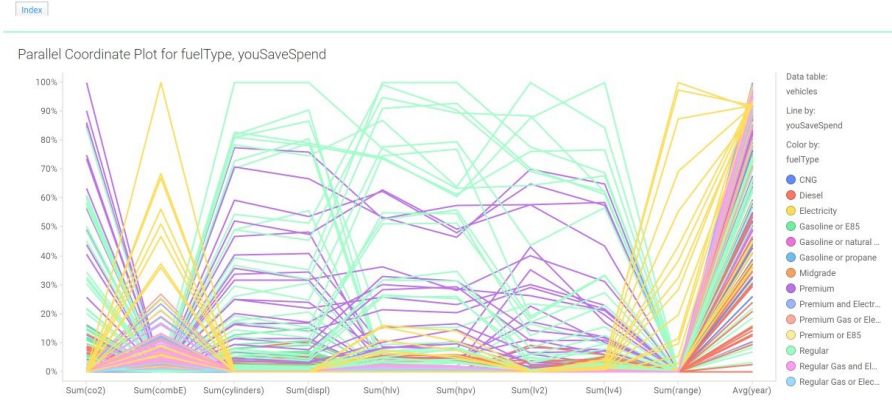
CO2 emission trends in vehicles



CO2 emissions for EVs are zero over all model years.

5. Which electric vehicles have the high youSaveSpend by fuel type and what are factors influencing it?

Factors influencing yousavespend by fueltype



The fuel cost saving relationship to different variables like combE, hlv (hatchback luggage volume),hpv(hatchback passenger volume), range,cylinders, diplacemet are visible from the parallel coordinate plot

4.2 Data analysis (What, Why, How)

What:

The data of US fuel economy was acquired from the source and analysed. Did the exploratory analysis of the data. It was found that the dataset consists of numerical and categorical data. youSaveSpend column was taken as the target variable, which could determine the best vehicle in terms of fuel economy. Checked for empty values, missing values and did the data transformations. The cylinders and displacement columns had empty values and it was replaced by zero. Since the research question on electric cars, only the data of such cars were filtered in many of the visualizations.

DataTable

Index | Vehicle spread over Model Year

vehicles

barrels08	barrelsA08	charge120	charge240	city08	city08U	cityA08	cityA08U	cityCD	cityE	cityUF	co2
10.63	0.00	0.00	0.00	25	0.00	0	0.00	0.00	0.00	0.00	-1
27.05	0.00	0.00	0.00	10	0.00	0	0.00	0.00	0.00	0.00	-1
16.53	0.00	0.00	0.00	16	0.00	0	0.00	0.00	0.00	0.00	-1
16.53	0.00	0.00	0.00	16	0.00	0	0.00	0.00	0.00	0.00	-1
16.53	0.00	0.00	0.00	16	0.00	0	0.00	0.00	0.00	0.00	-1
14.17	0.00	0.00	0.00	18	0.00	0	0.00	0.00	0.00	0.00	-1
14.88	0.00	0.00	0.00	18	0.00	0	0.00	0.00	0.00	0.00	-1
13.52	0.00	0.00	0.00	19	0.00	0	0.00	0.00	0.00	0.00	-1
13.52	0.00	0.00	0.00	19	0.00	0	0.00	0.00	0.00	0.00	-1
12.94	0.00	0.00	0.00	19	0.00	0	0.00	0.00	0.00	0.00	-1
12.40	0.00	0.00	0.00	21	0.00	0	0.00	0.00	0.00	0.00	-1
14.17	0.00	0.00	0.00	18	0.00	0	0.00	0.00	0.00	0.00	-1
19.83	0.00	0.00	0.00	14	0.00	0	0.00	0.00	0.00	0.00	-1
14.17	0.00	0.00	0.00	18	0.00	0	0.00	0.00	0.00	0.00	-1
12.94	0.00	0.00	0.00	21	0.00	0	0.00	0.00	0.00	0.00	-1
11.44	0.00	0.00	0.00	23	0.00	0	0.00	0.00	0.00	0.00	-1
12.94	0.00	0.00	0.00	21	0.00	0	0.00	0.00	0.00	0.00	-1
11.90	0.00	0.00	0.00	22	0.00	0	0.00	0.00	0.00	0.00	-1
14.17	0.00	0.00	0.00	18	0.00	0	0.00	0.00	0.00	0.00	-1
14.88	0.00	0.00	0.00	17	0.00	0	0.00	0.00	0.00	0.00	-1
13.52	0.00	0.00	0.00	19	0.00	0	0.00	0.00	0.00	0.00	-1
12.94	0.00	0.00	0.00	19	0.00	0	0.00	0.00	0.00	0.00	-1
12.40	0.00	0.00	0.00	21	0.00	0	0.00	0.00	0.00	0.00	-1

Why:

The data relationships were mapped and found that the parameters used for gasoline cars are not dependent on the fuel economy or efficiency of electric vehicles. The youSaveSpend was the target variable and the dependencies were mapped. This enables to find the fact that electric cars are fuel economic and sustainable or not.

Data Relationships

How:

With the analysed and processed data, visualisations were created. Spider chart, KPI chart, scrollable bar chart, interactive dash board, trellises panels are some of the visualizations created for the better understanding. Good color schemes, labels, markers and index pages were used in the visualizations. To analyse the EVS, a filter fueltype=’electricity’ was applied to appropriate visualizations.

The users can navigate to the different question visualizations from the index page and navigation buttons given in each page

Index

4.3 Reflection

Conclusions

- Electric vehicles started to appear in the market from 2014 and is continuing to be efficient and available in more models from different manufacturers over the different model years, till 2023 as the spider shows in the area. It is the same for single fuel type and dual fuel type vehicles

- Electric vehicles are the best in saving fuel cost for the next five years. The highest fuel cost youSaveSpend value is 6500. All EVs have good positive youSaveSpend values. The mpg (highwayE and CityE) values of two-wheel drive are the highest.

- Midsize cars (in EVs) are more manufactured by companies over the model years. Tesla is the company that produced high number of models (17) over the years in this class of EVs.

- Are electric cars good for environment. Electric cars produce zero CO2 emission in single fuel type and less emissions in dual fuel type.

- Unlike other fuel types whose fuel efficiency depends on cylinders, displacement, engine type etc. the EVs save fuel cost and give high range. The luggage space and passenger space of 4-wheel drive might have slight influence.

  In a nutshell we can conclude that EVs produce zero emissions and can be called as green vehicles. There are many midsize electric cars available in the market which helps to save the fuel cost to the maximum in next five years. Many manufacturers like Tesla are into production of electric vehicles according to the demand of customers.

  If given more time, more comparison could be done of city and highway energy consumption, models could be generated for predicting youSaveSpend and MPGe values. Related works had concentrated more on predictions and modelling. Most of the visualizations were done with ggplot and python. Here I have used visualization tool Sportfire which enabled better perception of the data.

5.References

EPA United States Government. (2022, August 5). *Fuel Economy and Environment Label Examples*. Retrieved from Fuel Economy (EPA): https://www.epa.gov/fueleconomy/fuel-economy-and-environment-label-examples

EPA. (2022, August 5). *Fuel Economy*. Retrieved from EPA Fuel Economy: https://www.epa.gov/fueleconomy

Gautam, S. (2010, April 21). *digitalcommons.iwu.edu.* Retrieved from "What Factors Affect Average Fuel Economy of US Passenger Vehicles?": https://digitalcommons.iwu.edu/econ_honproj/104

Mallik, P. K. (2020). Materials, Design and Manufacturing for Lightweight Vehicles (Second Edition). In P. K. Mallik, *Materials, Design and Manufacturing for Lightweight Vehicles* (Second Edition ed., p. Chapter 1). Chennai: Mathew Deans, WoodHead Publishing. doi:https://doi.org/10.1016/B978-0-12-818712-8.00001-X

PETROVIĆ, D. T., PEŠIĆ, D. R., PETROVIĆ, M. M., & MIJAILOVIĆ, R. M. (2020). Electric Cars – Are They Solution to Reduce CO2 Emission. *Thermal Science, 24*(5 Part A), 2879-2889. doi:https://doi.org/10.2298/TSCI191218103P

Sharan Kumar, P. (July-2020). Data Visualization for Vehicle Selection Process. *International Journal of Engineering Research & Technology (IJERT)*, Vol. 9 Issue 07 .

Yan, L. (2011). Multivariate Data Visualization: A Review from the Perception Aspect. *Smith, M.J., Salvendy, G. (eds) Human Interface and the Management of Information. Interacting with Information. Human Interface 2011. vol 6771*, pp. 221–230. Berlin, Heidelberg: Springer. doi:https://doi.org/10.1007/978-3-642-21793-7_26

6. Appendix

Visualizations from literature review

Fig.15 Dashboard for criteria 1&2

Criteria 2

Car Brand	category	Value	Range	Weight	Score
2017 Ford Escape	Insurance	2136	3	10	30
2017 Ford Escape	Fuel Economy	26	4	5	20
2017 Ford Escape	Resale Value	15981	3.5	7	24.5
2017 Honda CRV	Insurance	2364	2	10	20
2017 Honda CRV	Fuel Economy	28	4.5	5	22.5
2017 Honda CRV	Resale Value	16789	4	7	28
2017 Hyundai Santa Fe	Insurance	1256	3.5	10	35
2017 Hyundai Santa Fe	Fuel Economy	24	3.5	5	17.5
2017 Hyundai Santa Fe	Resale Value	21225	5	7	35
2017 Toyota Rav 4	Insurance	1405	4.5	10	45
2017 Toyota Rav 4	Fuel Economy	30	5	5	25
2017 Toyota Rav 4	Resale Value	17302	4.5	7	31.5

Fig.4 Calculated score based for criteria 2

Fig.7 Stacked bar chart for criteria 1

Figures from (Sharan Kumar, July-2020)

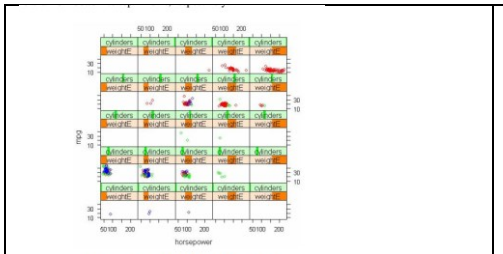


Fig. 2. Trellis display of the auto-mpg dataset

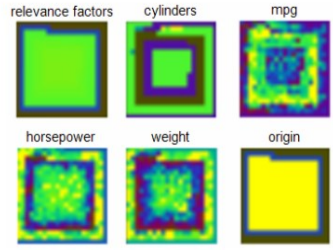


Fig. 4. Spiral pixel-based display of the auto-mpg dataset

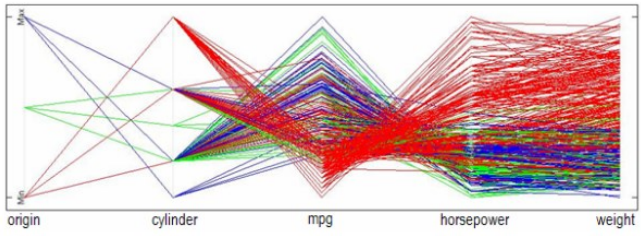


Fig. 3. Parallel coordinates of auto-mpg dataset

Figures from (Yan, 2011)

6.2 Other materials referred

1. Electric Cars: Plugged In 2, Global Market Research, Deutsche Bank, 3 November 2009
2. Understanding latent demand for hybrid and plug-in electric vehicles using large-scale longitudinal survey data of US new vehicle buyers, Energy Efficiency (2020) 13:1063–1074, https://doi.org/10.1007/s12053-020-09865-5, Rubal Dua & Kenneth White
3. The 2022 EPA Automotive Trends Report – Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975
4. Multivariate Classification of Automobiles by Use of an Automobile Characteristics Data Base, Robin Dubin, Department of Geography and Environmental Engineering, Johns Hopkins University, Baltimore David L. Greene and Connie Begovich, Oak Ridge National Laboratory, Oak Ridge, Tennessee