Data Management and Visualization - Assignment 3

Ömer Faruk Durmuş

2025-01-20

1. Introduction

Fuel efficiency holds significant importance due to its environmental, economic, and industrial implications. Environmentally, improved fuel efficiency reduces greenhouse gas emissions and mitigates climate change by lowering the consumption of fossil fuels, a primary contributor to CO emissions ("Global Energy Review: CO2 Emissions," n.d.). Economically, it decreases fuel expenditures for consumers, which is particularly critical during periods of high oil prices. Fuel-efficient vehicles are thus more appealing to cost-conscious buyers, contributing to market demand ("Global Energy Review: CO2 Emissions," n.d.) . From an industry perspective, regulatory pressures such as the European Union's CO emission standards for new cars have incentivized manufacturers to invest in advanced technologies to enhance fuel economy ("CO Emission Performance Standards," n.d.). Consequently, fuel efficiency aligns with global sustainability goals, economic efficiency, and industrial innovation, making it a cornerstone of modern transportation policies and practices. Therefore, understanding the tendencies, changes, and continuities in fuel efficiency provides significant implications for the industry, governments, and the public.

This report builds on this argument by following this structure: first, the purpose of the study and the dataset will be introduced; then, the empirical results, along with their implications, will be discussed; next, recommendations will be made; and finally, concluding remarks will be provided.

2. Methodology

2.1 Research Objectives and Data

The aim of this report is to examine the changes in fuel efficiency against different features of automobiles, including by manufacturer, type of fuel, cylinder, and size of the engine, among many others. This analysis is using the 'cars' dataset with 25,469 observations and 11 variables that include make, model, year, fuel type, engine size, cylinder count, and miles per gallon (MPG) for highway and city driving. The variation in the observation of makes, years, and technical features represented in this dataset is very broad and needed to effectively illustrate temporal changes and trends.

2.2 Data preparation and analyses

Firstly, an overview was taken by having a glimpse into the summary statistics to understand what data 'cars' dataset contains. I applied the summary function and viewed mean, median, minimum, maximum value, and the types of the observations.

Cleaning the data by removing NA values and categorizing variables was the next step. After reviewing and cleaning the data, I wanted to see the trend of fuel efficiency over time, adding more meaningful variables into the analysis. The variables include the number of cylinders, usage context either city or highway, size of the engine, fuel types, make, and year.

In developing the analysis, I categorized the fuel types into two major groups-regular and premium. Other influential variables will involve the context of usage. Therefore, I will involve MPG variables that will contrast the city and highway fuel efficiency of regular and premium fuel types over time.

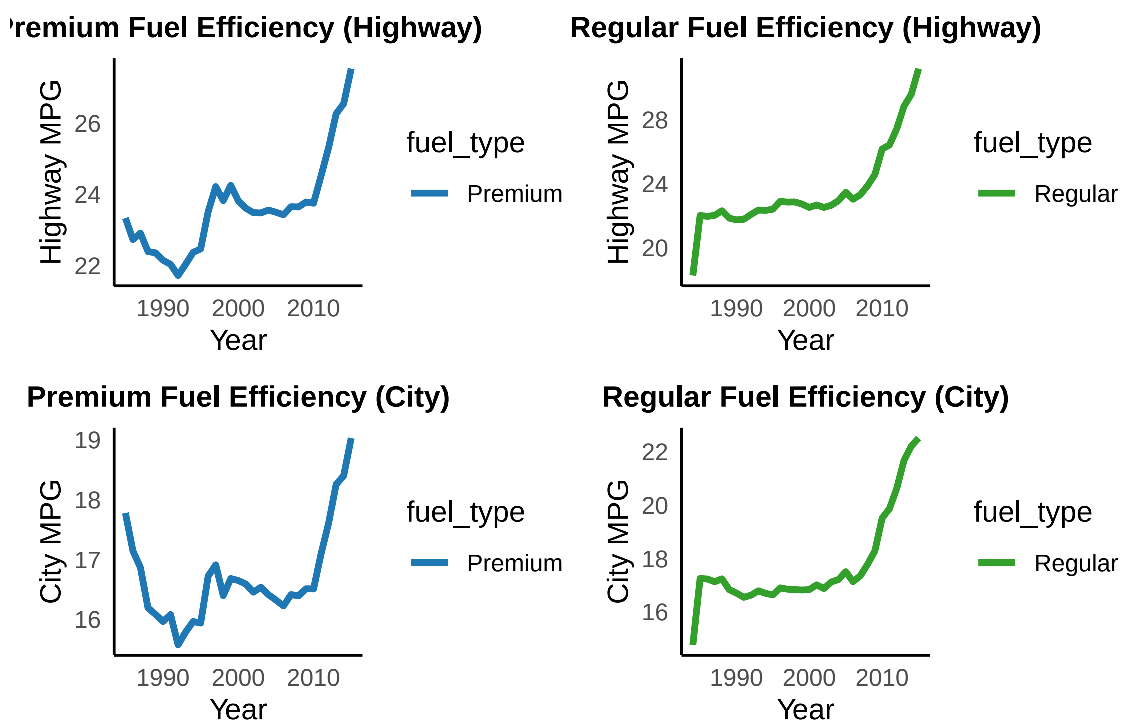
Next I visualized the average fuel efficiency rates of both highway and city driving by different makes over the year 2000. This was when the European Union and the United States placed regulations on fuel efficiency and carbon emissions. I did this by filtering data starting in the year 2000, then grouping makes based on the mean efficiency for city and highway driving.

Thirdly, fuel efficiency was analyzed, classed by vehicle cylinder categories-4, 6, and 8 cylinders operating in highways and city environments. Different histograms, which visually estimate the spread over such classes of vehicle cylinder categories, were plotted. Such a process also helped delineate mileage and consumption patter to show how the increment in the size of the motor, in terms of the number of cylinders, affected the fuel efficiency both on highways and in cities. In the fourth analysis, I considered the trend of engine size and fuel efficiency represented in MPG, by fuel type, namely regular and premium, and by usage context, namely highway and city, over time.

Next, I did some analysis of the MPG over time for selected makes and fuel types. First, I filtered data starting from the year 2000 and then grouped makes by their mean efficiency values for both city and highway driving. In the final analysis, I focused on fuel efficiency for four makes—Honda, Mercedes-Benz, Volvo, and Nissan—comparing their highway MPG. These makes were selected because of their countries of origin: Honda and Nissan are from Japan, Volvo from Sweden, and Mercedes-Benz from Germany. This allows for the making of predictions about differences in fuel efficiency between Asian and European manufacturers.

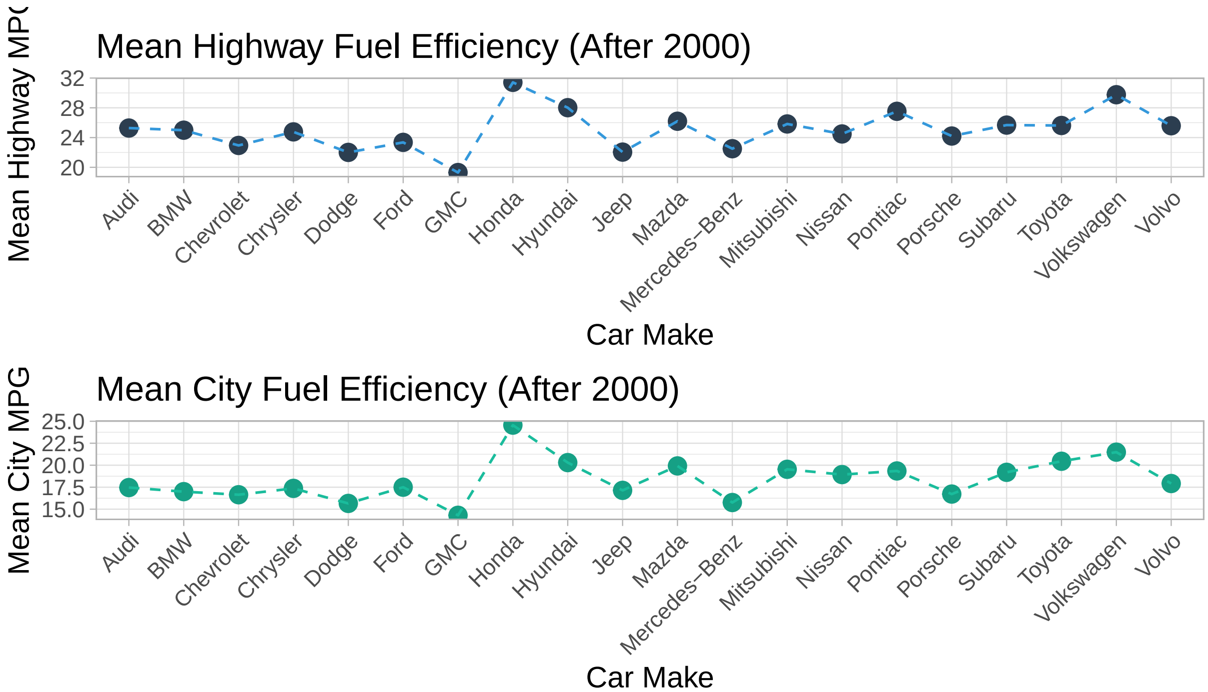
3. Empirical Results

Visualization 1: Change in Fuel Efficiency



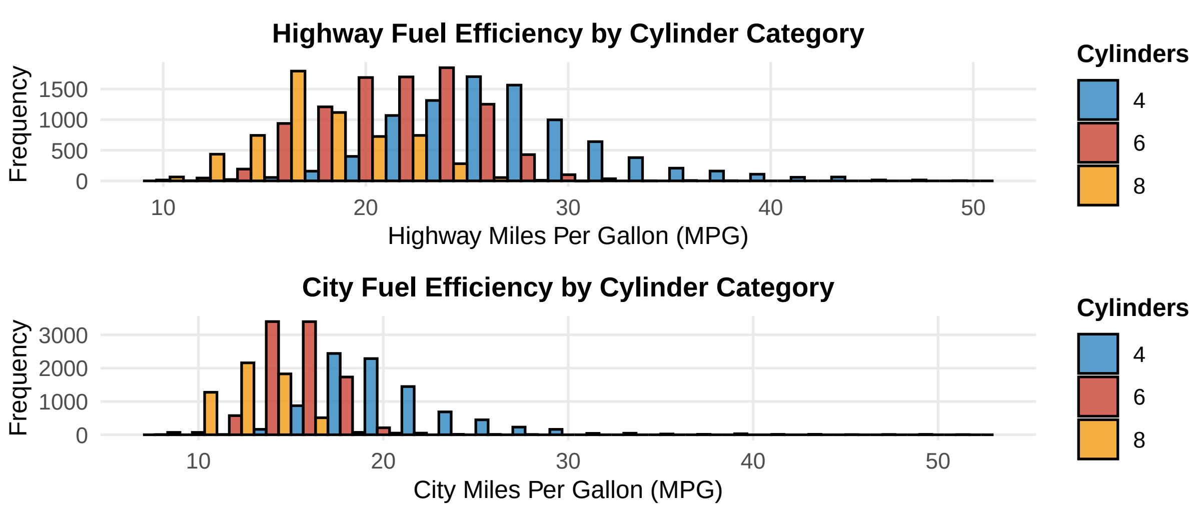
The graph indicates that the fuel efficiency of premium fuel in both highway and city usage kept falling until the 1990s. During the 2000s, there was a steep upward curve, which continued with minor increases after the 2010s. In the case of regular fuel efficiency, it has also represented a little positive slope even though there are several ups and downs. This category of fuel also faces a growth after 2010 in both usages. A significant upward trend is observed after 2010 for both of the fuel types. This could be an indication that technological advancements and improvements in quality have led to better fuel efficiency. Optimal improvement in fuel efficiency could potentially be attained through systemic regulations, research and development funding, subsidies, and tax cuts. With the increase in fuel quality, the number of emissions would reduce, therefore clearing the atmospheric environment and helping to prevent ozone layer depletion.

Visualization 2: Average Highway and City Efficiency Across Makes



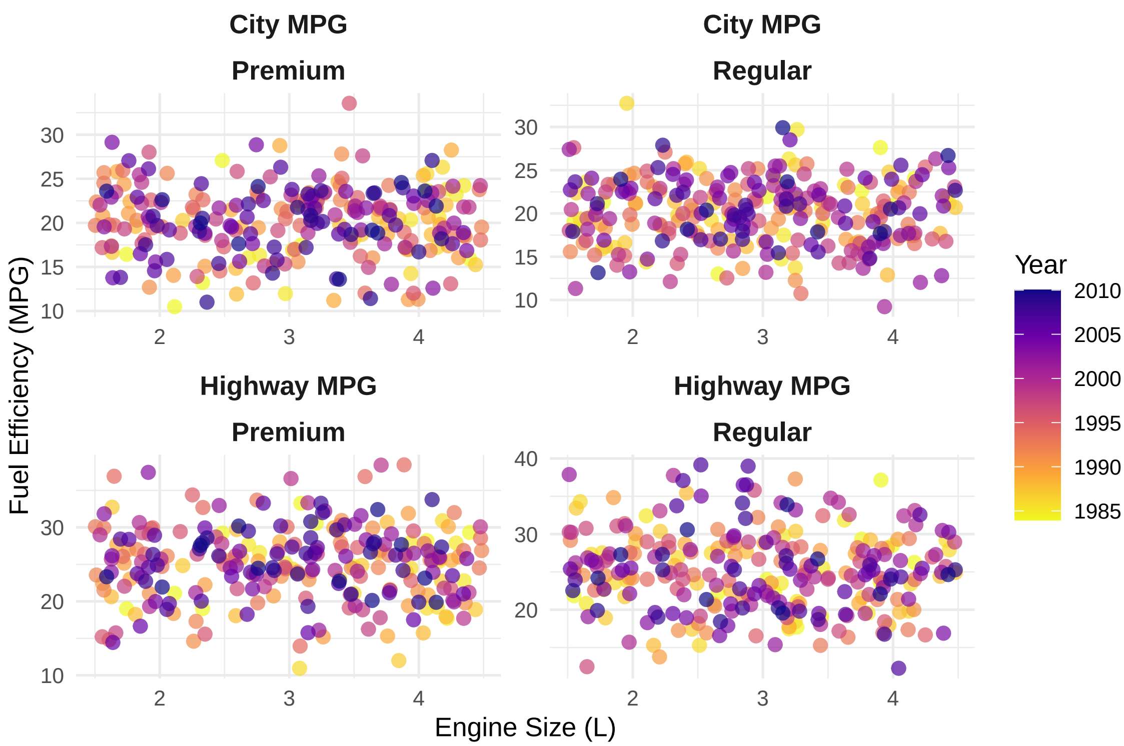
These plots reveals the average values of fuel efficiency across makes in the data set. Japanese brand Honda appears to have the highest fuel efficiency among others. It is followed by Volkswagen and Hyundai. On the other hand, the GMC, Jeep and Dodge makes presents the least fuel efficiency across all makes. This can be considered as a warning light for these brands.

Visualization 3: Fuel efficiency by Cylinders (City and Highway)



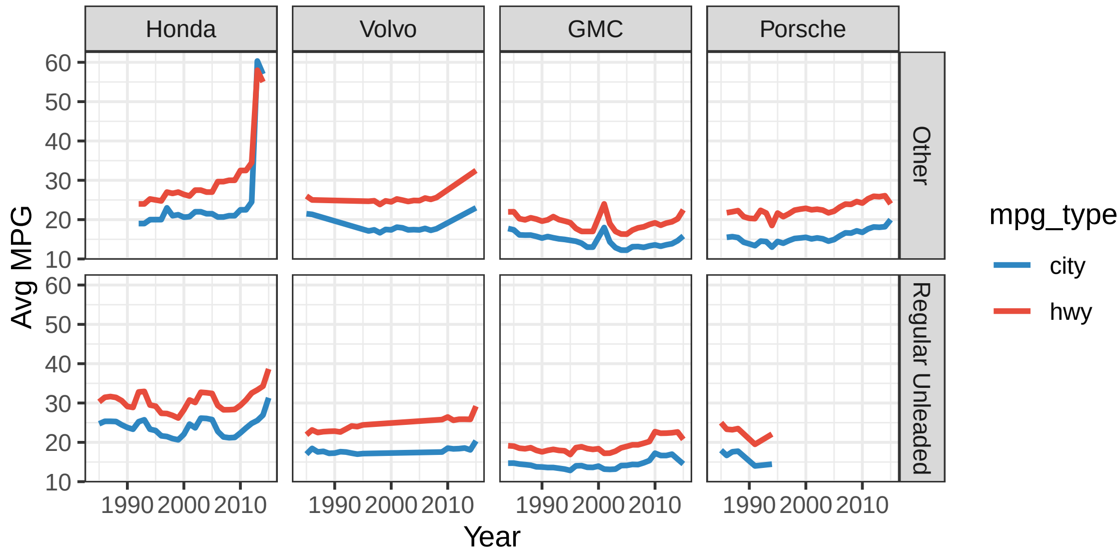
The histograms suggest a negative relation between fuel efficiency and the number of cylinders in a car engine. As the number of cylinders increase, the fuel efficiency decrease. To this end, 4-cylinder cars, which produced for ordinary use, shows better efficiency rates. 6-cylinder cars are also showing relatively stable efficiency in highways but not in the city. Since the number of the cylinder of a car addresses the power of the engine, 8-cylinder cars are failing to provide efficiency in fuel. Therefore, the International Energy Agency should encourage the public for the use of 4-cylinder cars regarding the fuel efficiency.

Visualization 4: Engine Size and Fuel Efficiency(A bad visualization example)



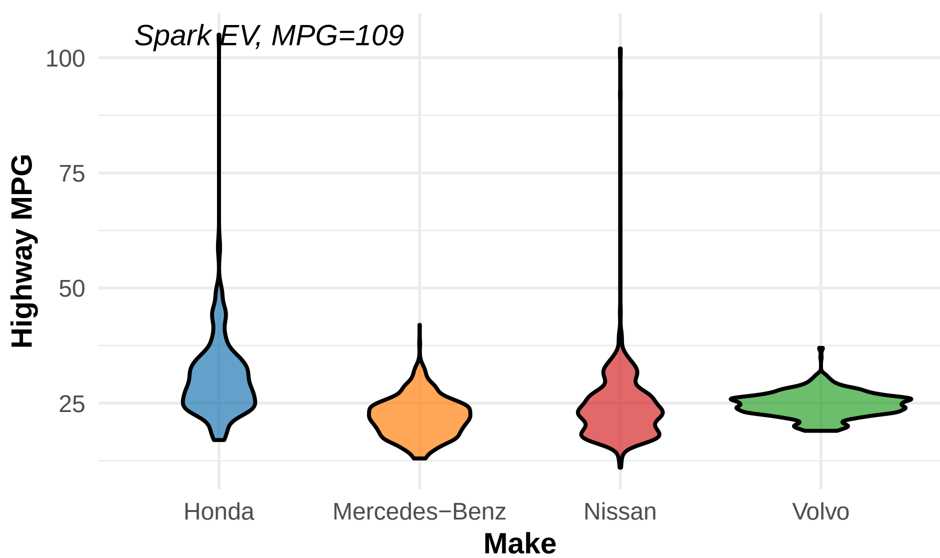
The graph illustrates a series of relationships; the relationship between the size, in liters, of an engine to fuel efficiency, in miles per gallon, for city and highway driving across different fuel types—Premium and Regular—by year, color-coded. It can be observed that across this trend, larger-size engines have lower fuel efficiency; however, the points reflecting this relationship are rather scattered, revealing marked overlap across the differing sizes of engines and different years. This dispersion suggests considerable variability in fuel efficiency that is not accounted for by variation in engine size. Also, a color gradient representing different years contributes to visual complexity without providing clear temporal patterns.

Visualization 5: MPG Shift in Honda, Volvo, GMC and Porsche



This graph shows average fuel efficiency (MPG) over time for Honda, Volvo, GMC, and Porsche. Honda stands out with the best fuel efficiency, especially on highways, with a sharp rise around 2010 likely due to hybrid models. Volvo improves moderately but stays below Honda. GMC has the worst fuel efficiency across the board, while Porsche remains stable but falls behind Honda. The trends suggest a technological focus on fuel efficiency improvement by Honda, while other manufacturers exhibit smaller or negligible improvements over time.

Visualization 6: Distribution of Highway for Selected Makes



The graph shows the distribution of highway MPG (miles per gallon) for Honda, Mercedes-Benz, Nissan, and Volvo using violin plots. The key findings are:

Honda: Displays the widest range of highway MPG, with a peak value of 109, likely from the Spark EV model. This suggests Honda's strong focus on fuel-efficient vehicles, including hybrids and electric models.

Mercedes-Benz: Shows a narrower and lower range of highway MPG, indicating that their cars generally prioritize performance or luxury over fuel efficiency. Nissan: Has a wider range of highway MPG, with some models being highly efficient. However, most models fall closer to average fuel efficiency levels.

Volvo: Has the most compact distribution, indicating consistent but moderate highway MPG across its models, with no significant outliers.

In summary, Honda leads in fuel efficiency, particularly for highway driving, while Mercedes-Benz and Volvo seem to prioritize performance or luxury. Nissan strikes a balance with a variety of efficiency levels across its models.

4. Recommendations: This analysis reveals that fuel efficiency has become increasingly important. The final graphs highlight the superior fuel efficiency of Japanese brands like Honda compared to European manufacturers such as Mercedes-Benz and Volvo, reflecting Japan's focus on hybrid and electric vehicles (EVs). As fuel efficiency gains global importance, European brands risk losing market share if they continue to prioritize luxury and performance. To remain competitive, European manufacturers should invest in hybrid and EV technology, explore lightweight materials, and diversify their powertrains. Japanese manufacturers, on the other hand, should maintain their edge by expanding into luxury segments and targeting emerging markets. The International Energy Agency (IEA) could play a key role in supporting this transition by standardizing stricter fuel efficiency standards, subsidizing green technologies, fostering collaborative research and development, and educating consumers on the economic and environmental benefits of fuel-efficient vehicles to drive the shift toward sustainable transportation.

5. Conclusion: This report concludes by underlining fuel efficiency in its very core across environmental, economic, and industrial dimensions. The analysis shows a strong improvement in fuel efficiency, especially post-2010, aligning with the development of hybrid and electric vehicle technologies. Honda ranked first in highway fuel efficiency through the use of innovation with hybrid models, while GMC was consistently the lowest on all metrics of efficiency. Besides, the relationship between the size of the engine and fuel efficiency was real: the smaller the engine, the better the mileage, especially for 4-cylinder cars.

It also shows the disparities between the regular and premium variants of fuel types, each demonstrating a positive slope of efficiency over time. The European manufacturers, Mercedes-Benz and Volvo, in the category of the moderately efficient, seem to lag behind the Japanese rivals, whose hallmark has been innovations in fuel-efficient technologies. These findings really pinpoint the need for an industry-wide paradigm shift toward greener practices. Collaboration, regulation, and a focus on lightening materials along with a range of different powertrains are all significant in meeting the shifting demands of consumers and the environment. Ultimately, fostering global adoption of fuel-efficient technologies can ensure a sustainable and competitive future for the automotive industry.

References

"CO Emission Performance Standards." n.d. *European Comission*. https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en.

"Global Energy Review: CO2 Emissions." n.d. *International Energy Agency*. https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2.