

Automobile Imports-85 Dataset

Statistical Methods Project Overview

March 23, 2025

- In this project, we are exploring the **Automobile Imports-85 Dataset**.
- The dataset contains various attributes of automobiles including technical specifications, performance metrics, and price.
- Our goals:
 - Provide a comprehensive overview of the dataset.
 - Understand the theoretical aspects of the methods we plan to use.
 - Propose analyses based on hypothesis testing and predictive modeling.

General Description of the Dataset

- The dataset is sourced from the UCI Machine Learning Repository.
- It contains **205** instances representing different automobiles. Some records are incomplete.
- The attributes include both categorical and numerical variables.

Examples include:

- **Symboling**: A risk rating for the automobile (ranging from -3 for very safe to +3 for very risky).
- **Normalized Losses**: A normalized measure of the insurance losses, which indicates repair costs.
- **Make**: The manufacturer of the automobile (e.g., alfa-romero, audi, bmw).
- **Fuel Type** and **Aspiration**: Attributes describing the fuel used and engine aspiration (e.g., standard, turbo).
- **Engine Size** and **Horsepower**: Key performance metrics.
- **Price**: Often used as a target variable for regression modeling.

Detailed Summary of Attributes

- **Symboling:**

- Risk factor with values typically ranging from -3 (low risk) to +3 (high risk).

- **Normalized Losses:**

- Represents relative insurance losses; higher values imply higher repair/maintenance costs.

- **Make:**

- The car manufacturer, which may influence design, performance, and pricing.

- **Fuel Type and Aspiration:**

- Fuel type (e.g., gas, diesel) and whether the engine is naturally aspirated or turbocharged.

- **Engine Attributes:**

- Includes engine size (in cubic centimeters), horsepower, and other performance metrics.

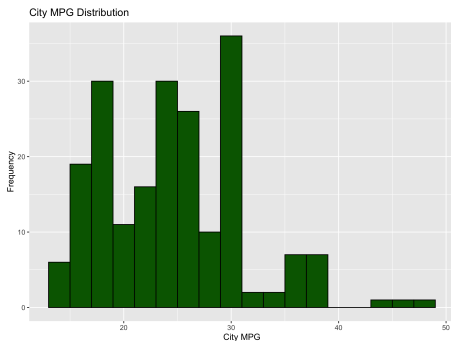
- **Performance Metrics:**

- Such as city and highway MPG, which reflect fuel efficiency.

- **Price:**

- A key continuous variable often used for regression analysis.

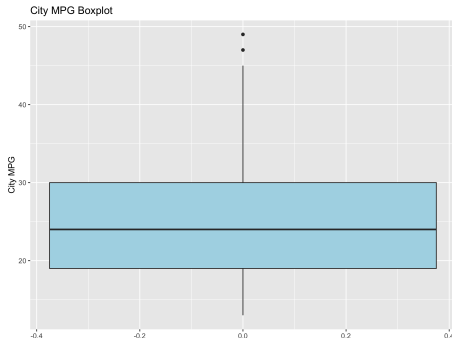
City MPG: Histogram



Interpretation:

- The histogram shows most vehicles have city MPG in the 20–30 range.
- A few cars achieve higher city MPG (over 40), indicating exceptional fuel efficiency.
- This distribution helps us spot the central tendency and potential outliers.

City MPG: Boxplot



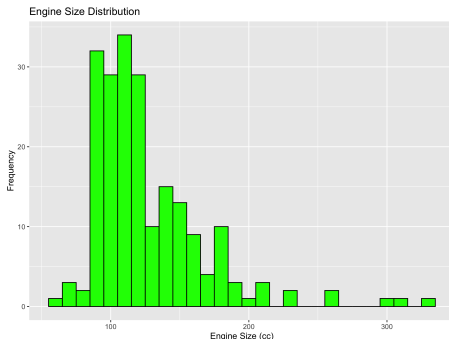
Interpretation:

- The median city MPG is around mid-20s.
- Outliers appear in the upper range (above 40 MPG).
- This visualization complements the histogram by showing data spread and outliers.

City MPG

- Mean: 25.21951
- Median: 24
- Variance: 42.79962
- Standard Deviation: 6.542142

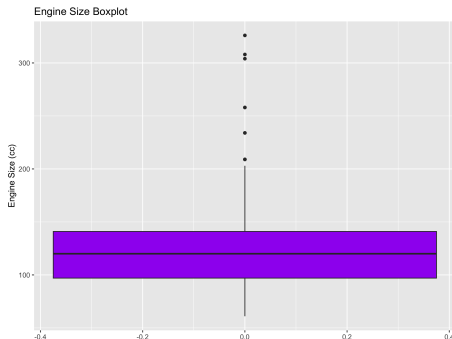
Engine Size: Histogram



Interpretation:

- Distribution centers around 100–150 cc for many vehicles.
- A smaller number of cars have significantly larger engines (above 200 cc).
- Helps identify how engine sizes cluster or spread across the dataset.

Engine Size: Boxplot



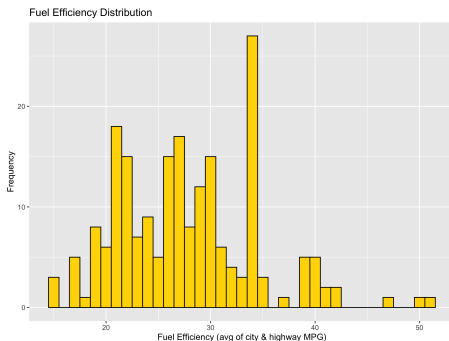
Interpretation:

- The boxplot indicates a median near 120 cc.
- The whiskers show the typical range, while any dots above the top whisker highlight very large engine sizes.
- Quickly reveals presence of potential outliers or skew in engine sizes.

Engine Size

- Mean: 126.9073
- Median: 120
- Variance: 1734.114
- Standard Deviation: 41.64269

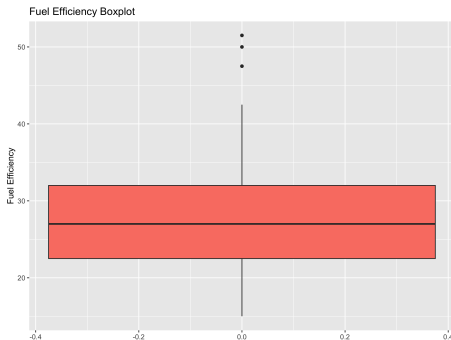
Fuel Efficiency: Histogram



Interpretation:

- Fuel efficiency (mean of city and highway MPG) often clusters in the mid-to-high 20s.
- Fewer vehicles demonstrate extremely high combined MPG (above 40).
- Reflects how well cars balance city vs. highway performance on average.

Fuel Efficiency: Boxplot



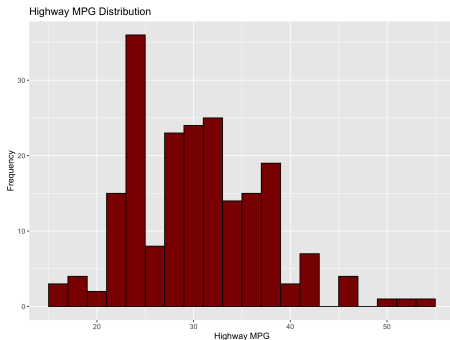
Interpretation:

- The median combined MPG is in the upper 20s.
- Outliers surpassing 40 indicate vehicles with notable overall efficiency.
- This helps identify the typical range vs. exceptional performers.

Fuel Efficiency (Average of City & Highway MPG)

- Mean: 27.98537
- Median: 27
- Variance: 44.43606
- Standard Deviation: 6.666038

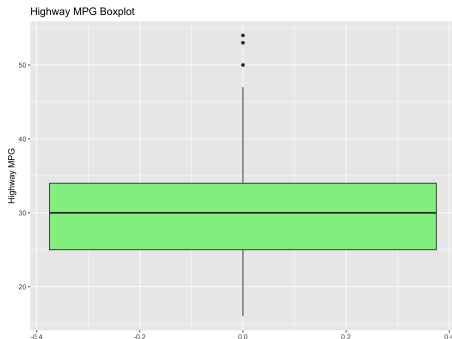
Highway MPG: Histogram



Interpretation:

- Most cars achieve highway MPG in the high 20s to low 30s.
- A small set of vehicles have very high highway MPG (above 40).
- Reflects general trends in fuel efficiency for open-road driving.

Highway MPG: Boxplot



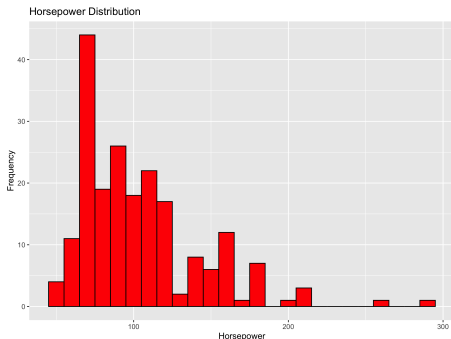
Interpretation:

- Median highway MPG around 30.
- Outliers are above 45 MPG, showing highly efficient models.
- This boxplot contrasts city vs. highway distributions, revealing how highway MPG tends to be higher overall.

Highway MPG

- Mean: 30.75122
- Median: 30
- Variance: 47.4231
- Standard Deviation: 6.886443

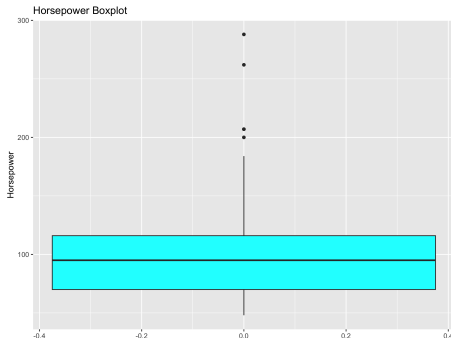
Horsepower: Histogram



Interpretation:

- The horsepower distribution is centered around 80–120 HP for many cars.
- Some vehicles reach 150+ HP, reflecting higher-performance models.
- Highlights the variety of power outputs in the dataset.

Horsepower: Boxplot



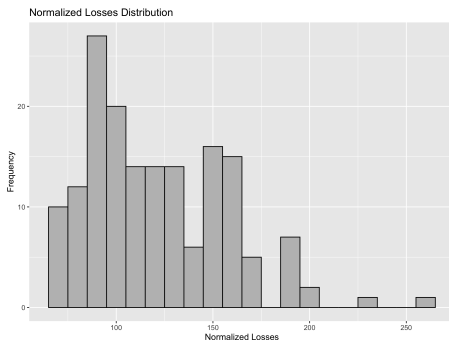
Interpretation:

- Median horsepower near 95 HP.
- Whiskers show typical range, with outliers above 160 HP.
- This reveals a skew towards lower horsepower but with some high-end performance cars.

Horsepower

- Mean: 104.2562
- Median: 95
- Variance: 1577.231
- Standard Deviation: 39.71437

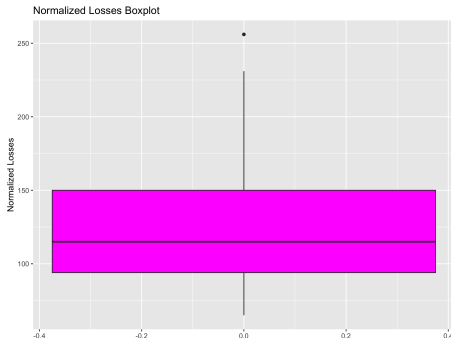
Normalized Losses: Histogram



Interpretation:

- The majority of normalized losses fall between approximately 80 and 150.
- A secondary cluster exists in the 150–200 range, with a few extremely high values over 200.
- Reflects varying insurance repair costs, indicating certain cars may be costlier to insure.

Normalized Losses: Boxplot



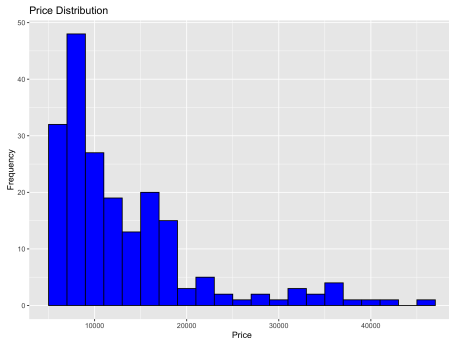
Interpretation:

- The boxplot indicates the median near 115.
- One outlier above 250 suggests a notably higher insurance loss estimate.
- Highlights the spread and skew in repair cost risk for different vehicles.

Normalized Losses

- Mean: 122
- Median: 115
- Variance: 1256.147
- Standard Deviation: 35.44217

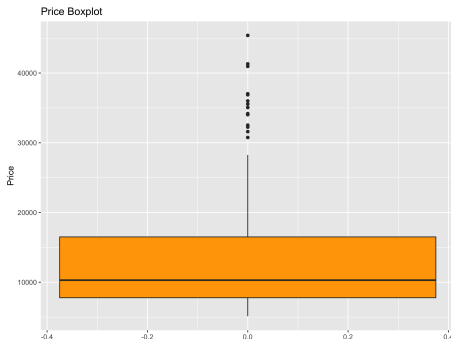
Price: Histogram



Interpretation:

- Most cars range from \$5,000 to \$15,000, peaking near \$10,000.
- A handful of luxury or high-performance vehicles exceed \$30,000.
- Strongly right-skewed distribution, typical for car prices in a diverse dataset.

Price: Boxplot



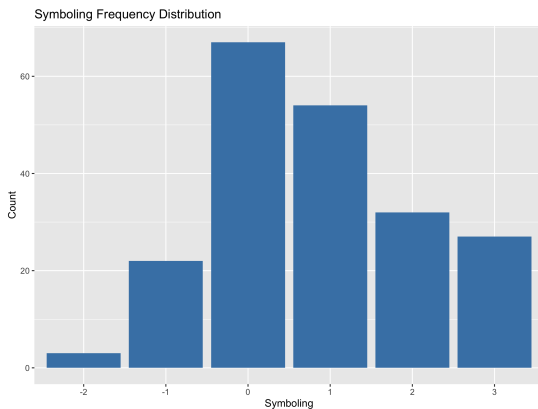
Interpretation:

- Median price is around \$10,000.
- Many outliers exceed \$20,000, reflecting expensive, possibly luxury models.
- Conveys both the typical price range and a significant tail for high-end cars.

Price

- Mean: 13207.13
- Median: 10295
- Variance: 63155863
- Standard Deviation: 7947.066

Symboling Frequency



Interpretation:

- Symboling **0** and **1** are the most common risk ratings.
- Fewer cars exhibit negative symboling (safer) or higher positive symboling (riskier).
- Indicates that moderate risk levels dominate the dataset.

Symboling

- Mean: 0.8341463
- Median: 1
- Variance: 1.550789
- Standard Deviation: 1.245307

Frequency Distribution:

- -2: 3
- -1: 22
- 0: 67
- 1: 54
- 2: 32
- 3: 27

Expected Relationship: Engine Size, Horsepower, and Price

Hypothesis: Larger engine sizes and higher horsepower values will correlate with higher prices.

- **Engineering Rationale:**

- Bigger engines and more horsepower often require more expensive manufacturing.
- Performance-oriented vehicles (e.g., sports cars) typically have higher retail prices.

- **Market Dynamics:**

- Consumers often pay a premium for powerful or luxury vehicles.
- Insurance costs, maintenance, and brand positioning can also elevate final price.

Expected Relationship: Fuel Type, Aspiration, and MPG

Hypothesis: Fuel type (gas vs. diesel) and aspiration (turbo vs. standard) will influence fuel efficiency and performance metrics.

- **Fuel Type:**

- Diesel engines often have higher fuel economy but may sacrifice acceleration.
- Gas engines can offer quicker acceleration, but potentially lower MPG.

- **Aspiration:**

- Turbocharged engines deliver more power for a given engine size.
- However, they can also consume more fuel if driven aggressively.

- **Outcome for City/Highway MPG:**

- We expect to see differences in both city and highway MPG across these categories.

Expected Relationship: Symboling, Insurance, and Other Categorical Factors

Hypothesis: Symboling (risk rating) correlates with repair costs, and other categorical attributes may show dependencies.

- **Symboling and Costs:**

- Higher symboling (2 or 3) could imply higher insurance costs or risk of accidents.
- Lower symboling (-2 or -1) indicates safer cars with reduced repair/maintenance costs.

- **Body Style, Drive Wheels, etc.:**

- These categorical attributes may show associations via chi-square tests.
- Example: Body style (sedan, hatchback, convertible) vs. price range or fuel type.

- **Statistical Exploration:**

- Conducting chi-square tests can reveal dependencies among categories (e.g., *Fuel Type* vs. *Make*).

Expected Relationship: Normalized Losses and Repair Costs

Hypothesis: Higher Normalized Losses correspond to cars that potentially incur higher repair/maintenance costs, influencing overall affordability.

- **Connection to Insurance:**

- Normalized losses often reflect the average repair expense for a given model.
- Vehicles with higher normalized losses may be pricier to insure or maintain.

- **Impact on Consumer Choice:**

- Consumers might avoid models with very high expected repair costs.
- In some cases, higher performance or luxury vehicles have higher normalized losses.

- **Statistical Exploration:**

- We may see a correlation between Normalized Losses and Price or Symboling.

Expected Relationship: City MPG vs. Highway MPG

Hypothesis: Automobiles efficient in city driving often exhibit relatively higher highway MPG, but the improvement may vary by engine configuration and body style.

- **Driving Conditions:**

- City driving tends to involve stop-and-go traffic, reducing efficiency.
- Highway driving allows for steadier speeds, generally leading to better fuel economy.

- **Influencing Factors:**

- Aerodynamics, transmission design, and engine tuning can cause varying gaps between city and highway MPG.
- Some hybrid or diesel models show comparatively smaller differences between city and highway MPG.

- **Analysis Approach:**

- Correlation tests may reveal strong or moderate relationships between city and highway MPG.
- Segmenting by body style or engine type (turbo vs. non-turbo) could further clarify these patterns.

Hypothesis Testing: Detailed Overview

Our hypothesis testing will focus on evaluating associations between variables:

- **Null Hypothesis (H_0):** Assumes no association between the variables under investigation (e.g., "Engine size is independent of price").
- **Alternative Hypothesis (H_1):** Assumes there is a statistically significant association (e.g., "Engine size is associated with price").
- **Testing Procedure:**
 - For categorical variables, we will use the **Chi-square test of independence**.
 - For numerical relationships, correlation tests or regression analyses will be used.
- **Statistical Significance:**
 - A p-value less than $\alpha = 0.05$ will lead us to reject the null hypothesis.
 - Effect sizes, such as **Cramér's V**, will be computed to quantify the strength of associations.

Decision Trees will be used for classification and regression:

- **Algorithm:**

- We plan to use the CART (Classification and Regression Trees) algorithm.
- The tree splits data based on impurity measures (e.g., Gini index or information gain) for classification, and variance reduction for regression.

- **Model Building:**

- Data will be split into training and testing subsets.
- Cross-validation techniques will be used to prevent overfitting.

- **Interpretability:**

- Decision trees provide intuitive rules that help identify the most influential attributes.

Predictive Modeling: Regression Analysis

Regression Analysis will help us predict continuous outcomes such as price:

- **Linear Regression:**

- Models the relationship between one or more predictor variables and a continuous target variable.
- Assumes linearity between predictors and the target.

- **Model Evaluation:**

- Performance metrics include R-squared, RMSE (Root Mean Squared Error), and MAE (Mean Absolute Error).
- Diagnostic plots will be used to assess assumptions (e.g., normality of residuals, homoscedasticity).

- **Extensions:**

- If the linear model is insufficient, we may explore polynomial regression or regularization techniques (e.g., Ridge, Lasso).

Proposal of Analyses

Our comprehensive analysis plan includes:

① Data Cleaning and Preparation:

- Handle missing values and encode categorical variables appropriately.

② Exploratory Data Analysis (EDA):

- Compute frequency distributions and visualize each attribute using bar plots, histograms, and scatter plots.

③ Inferential Statistics and Hypothesis Testing:

- Use chi-square tests for categorical variables and correlation tests for numerical variables.
- Formulate null and alternative hypotheses (e.g., "Engine size is associated with price").

④ Predictive Modeling:

- **Decision Trees:** Build classification/regression trees using CART with cross-validation.
- **Regression Analysis:** Develop linear or polynomial regression models to predict price, evaluating model assumptions and performance.

Conclusion and Future Work

- Our study aims to identify the key factors that influence automobile characteristics and pricing.
- Future work may include:
 - Incorporating ensemble methods or other advanced modeling techniques.
 - A deeper analysis of variable interactions and model refinements.
- Our findings will be compared with established automotive market theories to validate the insights.

References



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AutoVista: Automobile Imports-85 Dataset Project. GitHub repository. Available at: <https://github.com/piotrek1459/AutoVista>