Data Analysis Project

DA-6833

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# 1. Summary/Abstract

The primary goal of this research project is to develop a predictive model to estimate medical insurance costs for individuals based on their health-related and personal attributes. This model will help in understanding the key factors influencing insurance charges and assist insurance companies in pricing policies more accurately.

# 2. Introduction

## 2.1 General Background Information

### 2.1.1 Importance of Predictive Modeling in Insurance

Predictive modeling plays a vital role in the insurance industry. Accurate predictions of insurance costs enable companies to:

* Assess risk more effectively.
* Set premiums that reflect the actual risk associated with individual policyholders.
* Enhance customer satisfaction by offering personalized and fair pricing.

On the consumer side, individuals can benefit from understanding the factors that influence their insurance costs, allowing them to make informed choices about their health and financial planning.

## 2.2 Description of data and data source

The dataset used for this analysis is sourced from Kaggle. The dataset comprises 2.7K rows and 7 columns and contains the following features:

* **Age**: Age of the individual.
* **Sex**: Gender of the individual (male/female).
* **BMI (Body Mass Index)**: A measure of body fat based on height and weight.
* **Children**: Number of children/dependents covered by the insurance plan.
* **Smoker**: Smoking status of the individual (yes/no).
* **Region**: Geographical region in the US where the individual resides (northeast, southeast, southwest, northwest).
* **Charges**: Medical insurance costs billed by the insurance company (target variable).

## 2.3 Questions/Hypotheses to be addressed

The primary question we aim to answer using the “Medical Insurance Cost Prediction” dataset is:

**“What are the key factors influencing medical insurance costs, and how accurately can we predict these costs based on individuals’ demographic and health-related attributes?”**

### 2.3.1 Outcomes of Interest

The main outcome of interest in this analysis is:

* **Medical Insurance Costs (charges)**: The amount billed by the insurance company for an individual’s medical insurance.

### 2.3.2 Specific Predictors

The specific predictors (independent variables) we will focus on include:

* **Age**: How age influences insurance costs.
* **Sex**: The impact of gender on insurance costs.
* **BMI (Body Mass Index)**: The relationship between BMI and insurance costs.
* **Children**: How the number of dependents affects insurance costs.
* **Smoker**: The effect of smoking status on insurance costs.
* **Region**: Regional differences in insurance costs within the US.

### 2.3.3 Relations/Patterns of Interest

I am looking for several key relationships and patterns in the data, including:

1. **Age and Insurance Costs**:Investigating whether older individuals tend to have higher medical insurance costs.
2. **Gender Differences**:Analyzing whether there is a significant difference in insurance costs between males and females.
3. **BMI and Insurance Costs**:Exploring the relationship between an individual’s BMI and their medical insurance costs.Identifying any nonlinear patterns where very high or very low BMI values might correlate with higher insurance costs.
4. **Impact of Smoking**:Assessing how smoking status (yes/no) affects insurance costs.Quantifying the cost difference between smokers and non-smokers.
5. **Number of Children**: Examining whether having more dependents (children) increases insurance costs.
6. **Regional Variations**: Identifying differences in insurance costs across different regions in the US (northeast, southeast, southwest, northwest).

# 3. Methods

The methods used to clean, process and analyze the are as follows:

* **Data Cleaning and Preprocessing:**
  + Load the data
  + Convert categorical variable
  + Identify missing values
  + Find Outliers
* **Exploratory Data Analysis:**
  + Summarize the data
  + Visualize the data
* **Model building and Analysis Approach:**
  + Train-Test split the data
  + Linear Regression Model
  + Random Forest Model
  + Model Evaluation

## 3.1 Data import and cleaning

The dataset used in this analysis is sourced from Kaggle. The dataset was downloaded directly from Kaggle website. It can be accessed at the following URL: [Medical Insurance Cost Prediction](https://www.kaggle.com/datasets/rahulvyasm/medical-insurance-cost-prediction).

The methods used to clean, process and analyze the are as follows:

* **Data Cleaning and Preprocessing:**
  + Load the data (can be found in processingcode2.R)
  + Convert categorical variable (can be found in processingcode2.R)
  + Identify missing values (can be found in processingcode2.R)
  + Find Outlier (can be found in eda2.R)
* **Exploratory Data Analysis:**
  + Summarize the data (can be found in eda2.R)
  + Visualize the data (can be found in eda2.R)
* **Model building and Analysis Approach: *(Have not started yet)***
  + Train-Test split the data
  + Linear Regression Model
  + Random Forest Model
  + Model Evaluation

## 3.2 Statistical analysis

The data will be built and analyzed as follows:

* **Model building and Analysis Approach: *(Have not started yet)***
  + Train-Test split the data
  + Linear Regression Model
  + Random Forest Model
  + Model Evaluation

# 4. Results

## 4.1 Exploratory/Descriptive analysis

[Table 1](#tbl-summarytable) shows a summary of the data.

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| Table 1: Data summary table.   |  | age | sex | bmi | children | smoker | region | charges | | --- | --- | --- | --- | --- | --- | --- | --- | |  | Min. :18.00 | female:1366 | Min. :15.96 | Min. :0.000 | no :2208 | northeast:658 | Min. : 1122 | |  | 1st Qu.:26.00 | male :1406 | 1st Qu.:26.22 | 1st Qu.:0.000 | yes: 564 | northwest:664 | 1st Qu.: 4688 | |  | Median :39.00 | NA | Median :30.45 | Median :1.000 | NA | southeast:766 | Median : 9333 | |  | Mean :39.11 | NA | Mean :30.70 | Mean :1.102 | NA | southwest:684 | Mean :13261 | |  | 3rd Qu.:51.00 | NA | 3rd Qu.:34.77 | 3rd Qu.:2.000 | NA | NA | 3rd Qu.:16578 | |  | Max. :64.00 | NA | Max. :53.13 | Max. :5.000 | NA | NA | Max. :63770 | |

[Figure 1](#fig-outliers-bmi) shows the outliers in BMI

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| Figure 1: BMI Outliers |

[Figure 2](#fig-outliers-charges) shows the outliers in charges

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| Figure 2: Charges Outliers |

[Figure 3](#fig-charges) shows histogram of insurance charges

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| Figure 3: Distribution of Insurance charges |

[Figure 4](#fig-smoking) shows box plot of insurance charges by smoking status

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| Figure 4: Insurance Charges by smoking status. |

[Figure 5](#fig-region) shows box plot of insurance charges by region

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| Figure 5: Insurance Charges by Region. |

[Figure 6](#fig-age) shows scatter plot of insurance charges by age

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| Figure 6: Insurance Charges by Age. |

[Figure 7](#fig-bmi) shows scatter plot of insurance by BMI

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| Figure 7: Insurance Charges by BMI. |

**?@fig-children** shows bar graph of average insurance charges by number of children

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| Figure 8: Average Insurance Charges by Number of Children. |

## 4.2 Basic statistical analysis

[Table 2](#tbl-resulttable1) shows a simple model with one predictor using linear regression analysis.

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| Table 2: Simple Models with One Predictor.   | predictor | term | estimate | std.error | statistic | p.value | | --- | --- | --- | --- | --- | --- | | age | (Intercept) | 3182.7705 | 650.44959 | 4.8931854 | 0.0000010 | | age | age | 257.7010 | 15.64837 | 16.4682290 | 0.0000000 | | bmi | (Intercept) | 1097.5183 | 1155.49870 | 0.9498222 | 0.3422855 | | bmi | bmi | 396.1993 | 36.90861 | 10.7346011 | 0.0000000 | | children | (Intercept) | 12529.1303 | 310.97832 | 40.2894006 | 0.0000000 | | children | children | 664.6262 | 189.64091 | 3.5046560 | 0.0004644 | | sex | (Intercept) | 12486.8320 | 328.19612 | 38.0468610 | 0.0000000 | | sex | sexmale | 1527.0407 | 460.82644 | 3.3137004 | 0.0009325 | | smoker | (Intercept) | 8417.8744 | 158.98688 | 52.9469743 | 0.0000000 | | smoker | smokeryes | 23805.2654 | 352.46691 | 67.5390070 | 0.0000000 | | region | (Intercept) | 13475.8747 | 472.25777 | 28.5349983 | 0.0000000 | | region | regionnorthwest | -1012.7454 | 666.36289 | -1.5198107 | 0.1286728 | | region | regionsoutheast | 1272.9030 | 643.90193 | 1.9768585 | 0.0481567 | | region | regionsouthwest | -1311.6783 | 661.49615 | -1.9828964 | 0.0474777 | |

## 4.3 Full analysis

[Table 3](#tbl-resulttable2) shows linear regression analysis charges is analyzed across all predictors.

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| Table 3: Linear Regression Analysis.   | term | estimate | std.error | statistic | p.value | | --- | --- | --- | --- | --- | | (Intercept) | -1.184037e+04 | 757.390243 | -15.6331202 | 0.0000000 | | age | 2.526119e+02 | 9.072504 | 27.8436841 | 0.0000000 | | bmi | 3.364993e+02 | 21.859169 | 15.3939664 | 0.0000000 | | children | 4.550461e+02 | 105.022395 | 4.3328479 | 0.0000154 | | sexmale | 8.252665e-01 | 255.209406 | 0.0032337 | 0.9974202 | | smokeryes | 2.415304e+04 | 317.486710 | 76.0757369 | 0.0000000 | | regionnorthwest | -2.197996e+02 | 368.749286 | -0.5960679 | 0.5511909 | | regionsoutheast | -1.020635e+03 | 369.922657 | -2.7590496 | 0.0058447 | | regionsouthwest | -7.674076e+02 | 366.387191 | -2.0945263 | 0.0363267 | |

[Figure 9](#fig-linear) helps visualize which features have a significant effect on charges.

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| Figure 9: Linear Regression Coefficients. |

[Table 4](#tbl-resulttable3) helps to capture complex interaction between features.

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| Table 4: Random Forest Analysis.   |  | Feature | Importance | | --- | --- | --- | | age | age | 41276698254 | | sex | sex | 2333500565 | | bmi | bmi | 45657041834 | | children | children | 6364617046 | | smoker | smoker | 205835757547 | | region | region | 6128386015 | |

[Figure 10](#fig-randomforest) helps visualize how each feature have a significant effect on charges.

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| Figure 10: Random Forest Feature Importance. |

# 5. Discussion

## 5.1 Summary and Interpretation

*Summarize what you did, what you found and what it means.*

## 5.2 Strengths and Limitations

*Discuss what you perceive as strengths and limitations of your analysis.*

## 5.3 Conclusions

*What are the main take-home messages?*

*Include citations in your Rmd file using bibtex, the list of references will automatically be placed at the end*

This paper (Leek & Peng, 2015) discusses types of analyses.

These papers (McKay, Ebell, Billings, et al., 2020; McKay, Ebell, Dale, Shen, & Handel, 2020) are good examples of papers published using a fully reproducible setup similar to the one shown in this template.

Note that this cited reference will show up at the end of the document, the reference formatting is determined by the CSL file specified in the YAML header. Many more style files for almost any journal [are available](https://www.zotero.org/styles). You also specify the location of your bibtex reference file in the YAML. You can call your reference file anything you like.

# 6. References

Leek, J. T., & Peng, R. D. (2015). Statistics. What is the question? *Science (New York, N.Y.)*, *347*(6228), 1314–1315. <https://doi.org/10.1126/science.aaa6146>

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