DATA 621 - Homework 4

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Problem Statement and Goals

In this report, we generate two different models; a multiple linear regression model and a binary logistic regression model. The multiple linear regression model contains a target variable called `TARGET_AMT`, which is the amount of money it will cost if the person crashes their car. The binary logistic regression model target variable, `TARGET_FLAG` consists of 0's and 1's. 1 represents that the person was in a car crash, and zero indicates that the person was not in a car crash. The analysis detailed in this report shows the testing of several models from which a best multiple linear regression model and a best binary logistic regression model were selected based on model performance and various metrics.

Data Exploration

The following is a summary of the variables provided within the data to generate the binary logistic regression and multiple linear regression models.

Variable Name	Definition	Theoretical Effect
INDEX	Identification Variable (do not use)	None
TARGET_FLAG	Was Car in a crash? 1=YES 0=NO	None
TARGET_AMT	If car was in a crash, what was the cost	None
AGE	Age of Driver	Very young people tend to be risky. Maybe very old people also.
BLUEBOOK	Value of Vehicle	Unknown effect on probability of collision, but probably effect the payout if there is a crash
CAR_AGE	Vehicle Age	Unknown effect on probability of collision, but probably effect the payout if there is a crash
CAR_TYPE	Type of Car	Unknown effect on probability of collision, but probably effect the payout if there is a crash
CAR_USE	Vehicle Use	Commercial vehicles are driven more, so might increase probability of collision
CLM_FREQ	# Claims (Past 5 Years)	The more claims you filed in the past, the more you are likely to file in the future

Variable Name	Definition	Theoretical Effect
EDUCATION	Max Education Level	Unknown effect, but in theory more educated people tend to drive more safely
HOMEKIDS	# Children at Home	Unknown effect
HOME_VAL	Home Value	In theory, home owners tend to drive more responsibly
INCOME	Income	In theory, rich people tend to get into fewer crashes
JOB	Job Category	In theory, white collar jobs tend to be safer
KIDSDRIV	# Driving Children	When teenagers drive your car, you are more likely to get into crashes
MSTATUS	Marital Status	In theory, married people drive more safely
MVR_PTS	Motor Vehicle Record Points	If you get lots of traffic tickets, you tend to get into more crashes
OLDCLAIM	Total Claims (Past 5 Years)	If your total payout over the past five years was high, this suggests future payouts will be high
PARENT1	Single Parent	Unknown effect
RED_CAR	A Red Car	Urban legend says that red cars (especially red sports cars) are more risky. Is that true?
REVOKED	License Revoked (Past 7 Years)	If your license was revoked in the past 7 years, you probably are a more risky driver.
SEX	Gender	Urban legend says that women have less crashes then men. Is that true?
TIF	Time in Force	People who have been customers for a long time are usually more safe.
TRAVTIME	Distance to Work	Long drives to work usually suggest greater risk
URBANICITY	Home/Work Area	Unknown
YOJ	Years on Job	People who stay at a job for a long time are usually more safe

Table 1: Variables in the dataset

A summary of the variables is shown below. The `INDEX` variable has been removed. The summary below reveals that `AGE`, `VOJ`, `INCOME`, `HOME_VAL`, and `CAR_AGE` have missing values.

```
 TARGET_FLAG   TARGET_AMT        KIDSDRIV           AGE           HOMEKIDS
 0:6008      Min.   :     0   Min.   :0.0000   Min.   :16.00   Min.   :0.0000
 1:2153      1st Qu.:     0   1st Qu.:0.0000   1st Qu.:39.00   1st Qu.:0.0000
             Median :     0   Median :0.0000   Median :45.00   Median :0.0000
             Mean   :  1504   Mean   :0.1711   Mean   :44.79   Mean   :0.7212
             3rd Qu.:  1036   3rd Qu.:0.0000   3rd Qu.:51.00   3rd Qu.:1.0000
             Max.   :107586   Max.   :4.0000   Max.   :81.00   Max.   :5.0000
                                               NA's   :6
      YOJ           INCOME       PARENT1       HOME_VAL      MSTATUS
```

```
Min.   : 0.0   Min.   :     0   No :7084   Min.   :     0   No :3267
1st Qu.: 9.0   1st Qu.: 28097   Yes:1077   1st Qu.:     0   Yes:4894
Median :11.0   Median : 54028              Median :161160
Mean   :10.5   Mean   : 61898              Mean   :154867
3rd Qu.:13.0   3rd Qu.: 85986              3rd Qu.:238724
Max.   :23.0   Max.   :367030              Max.   :885282
NA's   :454    NA's   :445                 NA's   :464
SEX             EDUCATION              JOB         TRAVTIME
F:4375   <High School:1203   Blue Collar :1825   Min.   :  5.00
M:3786   Bachelors   :2242   Clerical    :1271   1st Qu.: 22.00
         High School :2330   Professional:1117   Median : 33.00
         Masters     :1658   Manager     : 988   Mean   : 33.49
         PhD         : 728   Lawyer      : 835   3rd Qu.: 44.00
                             Student     : 712   Max.   :142.00
                             (Other)     :1413
      CAR_USE        BLUEBOOK          TIF             CAR_TYPE
Commercial:3029   Min.   : 1500   Min.   : 1.000   Minivan    :2145
Private   :5132   1st Qu.: 9280   1st Qu.: 1.000   Panel Truck: 676
                  Median :14440   Median : 4.000   Pickup     :1389
                  Mean   :15710   Mean   : 5.351   Sports Car : 907
                  3rd Qu.:20850   3rd Qu.: 7.000   SUV        :2294
                  Max.   :69740   Max.   :25.000   Van        : 750

RED_CAR       OLDCLAIM        CLM_FREQ      REVOKED       MVR_PTS
no :5783   Min.   :    0   Min.   :0.0000   No :7161   Min.   : 0.000
yes:2378   1st Qu.:    0   1st Qu.:0.0000   Yes:1000   1st Qu.: 0.000
           Median :    0   Median :0.0000              Median : 1.000
           Mean   : 4037   Mean   :0.7986              Mean   : 1.696
           3rd Qu.: 4636   3rd Qu.:2.0000              3rd Qu.: 3.000
           Max.   :57037   Max.   :5.0000              Max.   :13.000

   CAR_AGE                  URBANICITY
Min.   :-3.000   Highly Rural/ Rural:1669
1st Qu.: 1.000   Highly Urban/ Urban:6492
Median : 8.000
Mean   : 8.328
3rd Qu.:12.000
Max.   :28.000
NA's   :510
```

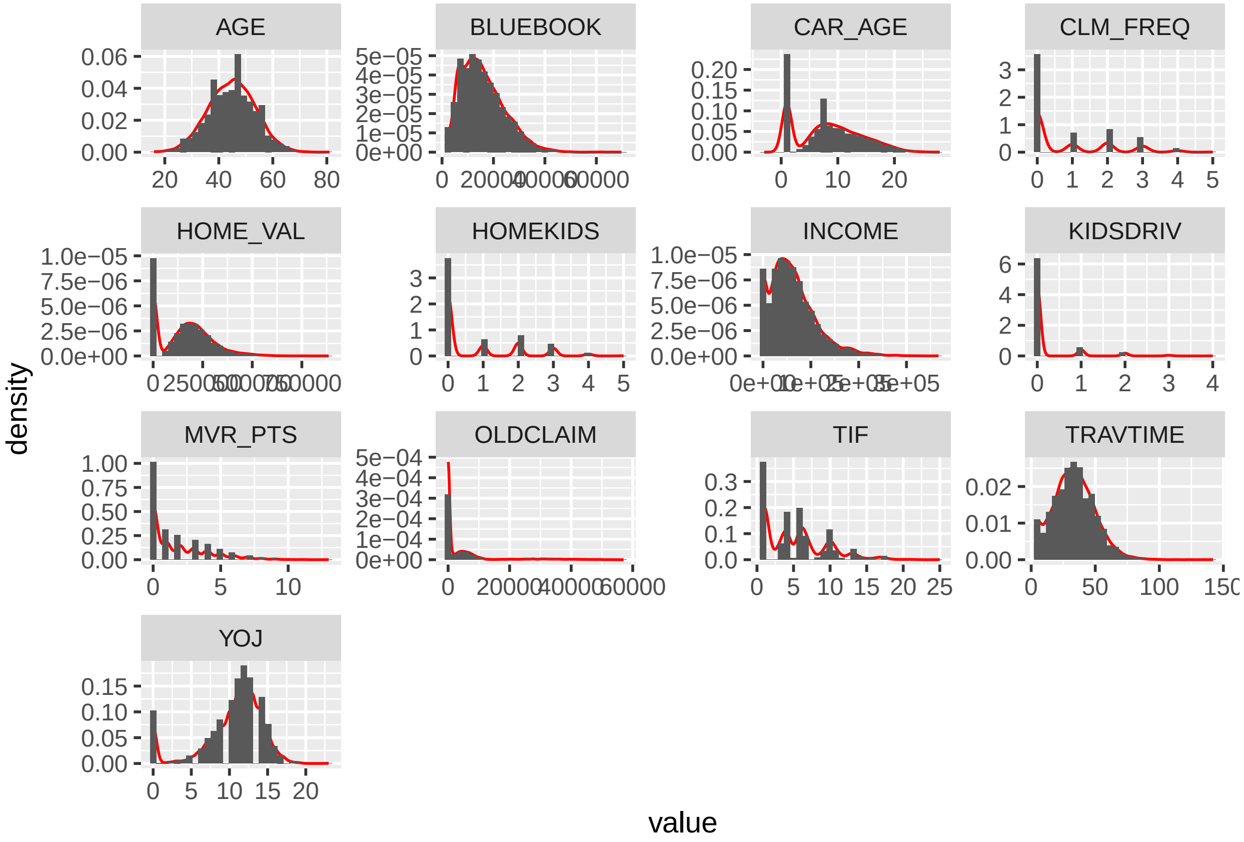


Figure 1: Histograms for all of the variables.

The density plots above show that `BLUEBOOK`, `INCOME`, and `TRAVTIME` could be transformed in order to fit the normal distribution assumption of a linear regression model. The variables with a bimodal distribution were dealt with and an explanation of the process is provided in the "Dealing with Bimodal Variables" section.

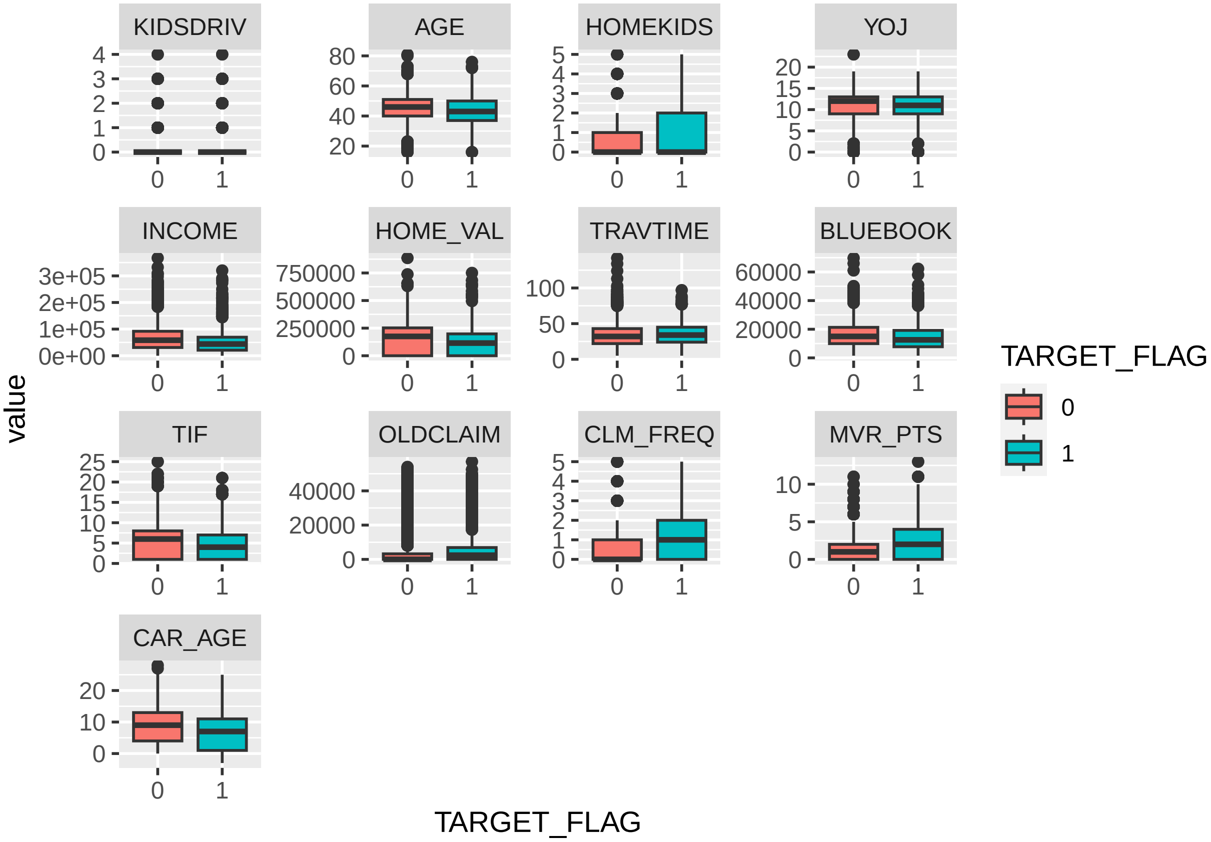


Figure 2: Boxplots for the dataset

We can see some findings that support the theoretical effects for some of the variables using the boxplots in Figure 2. It seems that younger cars are more likely to get into crashes as opposed to older cars as shown in the `CAR_AGE` boxplot. The theoretical effect of the `CLM_FREQ` (The more claims you filed in the past, the more you are likely to file in the future) is supported by the `CLM_FREQ` boxplot. The theoretical effect of `MVR_PTS` (If you get lots of traffic tickets, you tend to get into more crashes) is supported by the `MVR_PTS` boxplot. It would also seem that the theoretical effects of `INCOME` and `TIF` are also supported by the data.

Examining Feature Multicollinearity

Finally, it is imperative to understand which features are correlated with each other in order to address and avoid multicollinearity within our models. By using a correlation plot, we can visualize the relationships between certain features. The correlation plot is only able to determine the correlation for continuous variables. There are methodologies to determine correlations for categorical variables (tetrachoric correlation). However there is only one binary predictor variable which is why the multicollinearity will only be considered for the continuous variables.

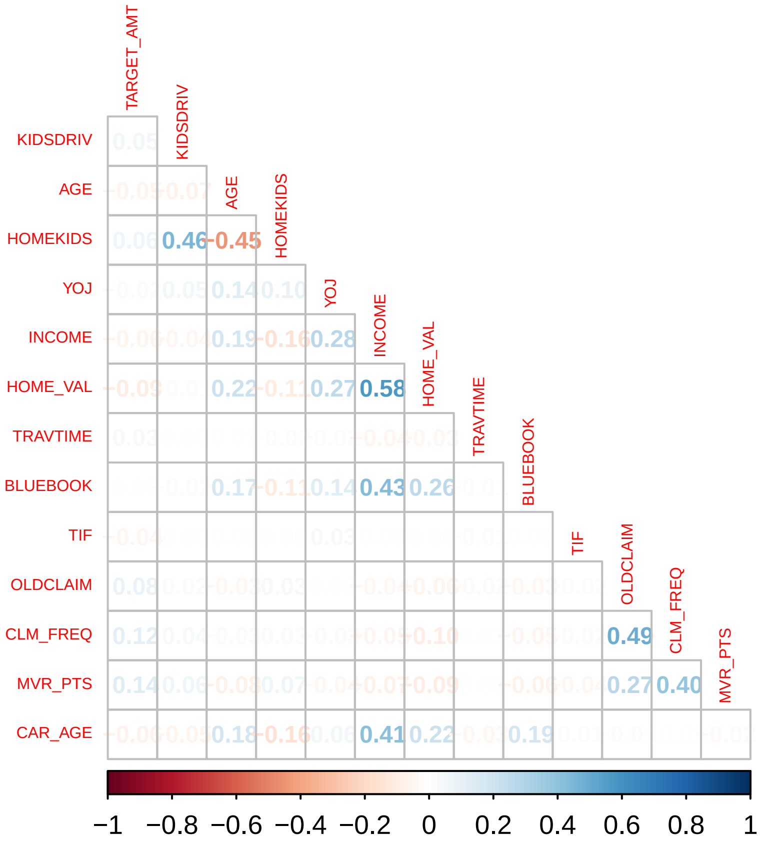


Figure 3: Multicollinearity plot for continuous predictor variables

The figure above shows that there isn't much multicollinearity between the variables. There is a moderately positive correlation of 0.58 between `INCOME` and `HOME_VAL`.

NA exploration

As can be seen below, some of the columns have missing values. Contextually, this can be possible because not every metric must have a value- for example it is possible that an entire season can be played without a batter being hit by the pitch. However it is less likely that an entire season can be played without any strikeouts by batters. We did some research and came up with ways to address each of these issues- more on that later.

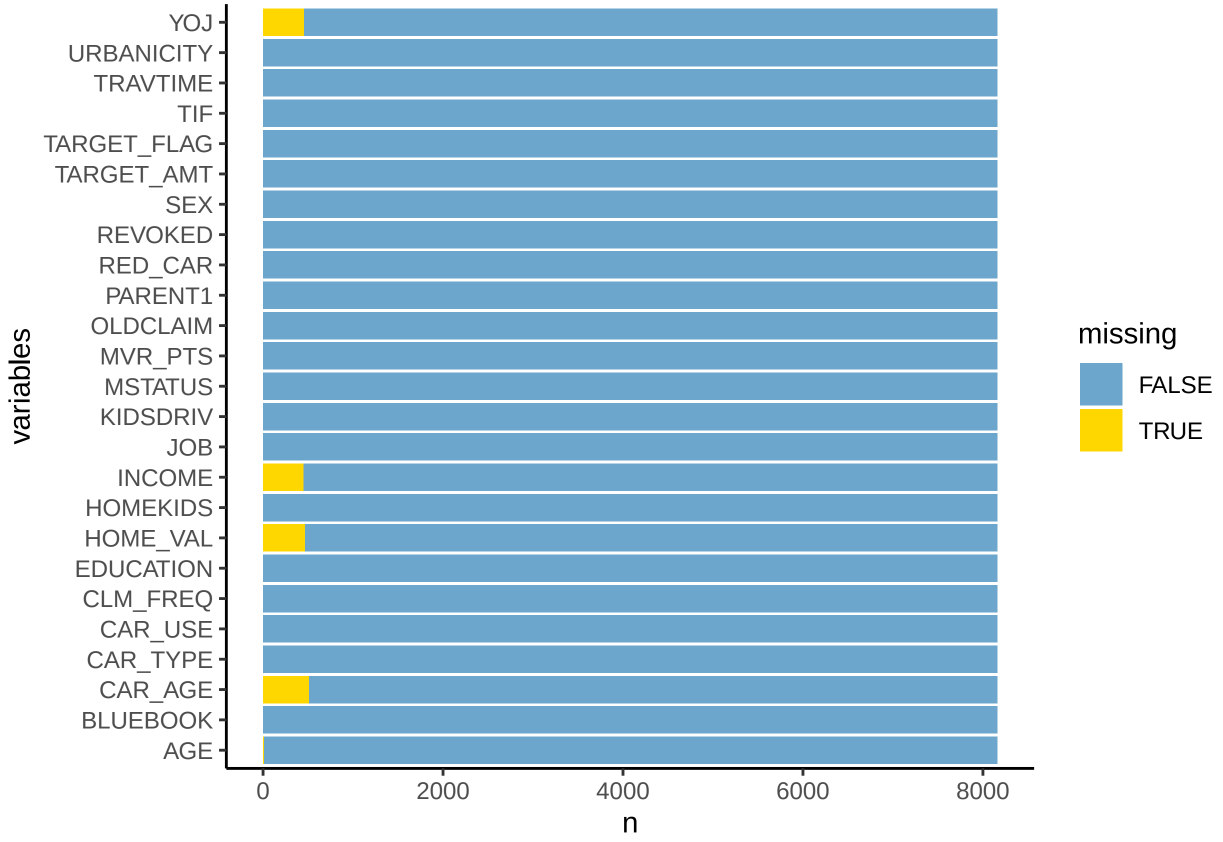


Figure 4: Barplot of number of missing values for each predictor.

The barplot above shows that `YOJ`, `INCOME`, `HOME_VAL`, `AGE`, and `CAR_AGE` were missing some data values. However, the amount of missing data for each variable is less than 10%. Therefore, imputing can be done on the missing data.

Data Preparation

Dealing with Missing Values

In general, imputations by the means/medians is acceptable if the missing values only account for 5% of the sample. Peng et al.(2006) However, should the degree of missing values exceed 20% then using these simple imputation approaches will result in an artificial reduction in variability due to the fact that values are being imputed at the center of the variable's distribution.

Our team decided to employ another technique to handle the missing values: Multiple Regression Imputation using the MICE package.

The MICE package in R implements a methodology where each incomplete variable is imputed by a separate model. Alice points out that plausible values are drawn from a distribution specifically designed for each missing datapoint. Many imputation methods can be used within the package. The one that was selected for the data being analyzed in this report is PMM (Predictive Mean Matching), which is used for quantitative data.

Van Buuren explains that PMM works by selecting values from the observed/already existing data that would most likely belong to the variable in the observation with the missing value. The advantage of this is that it selects values that must exist from the observed data, so no negative values will be used to impute missing data.Not only that, it circumvents the shrinking of errors by using multiple regression models. The variability between the different imputed values gives a wider, but more correct standard error. Uncertainty is inherent in imputation which is why having multiple imputed values is important. Not only that. Marshall et al. 2010 points out that:

"Another simulation study that addressed skewed data concluded that predictive mean matching 'may be the preferred approach provided that less than 50% of the cases have missing data…'

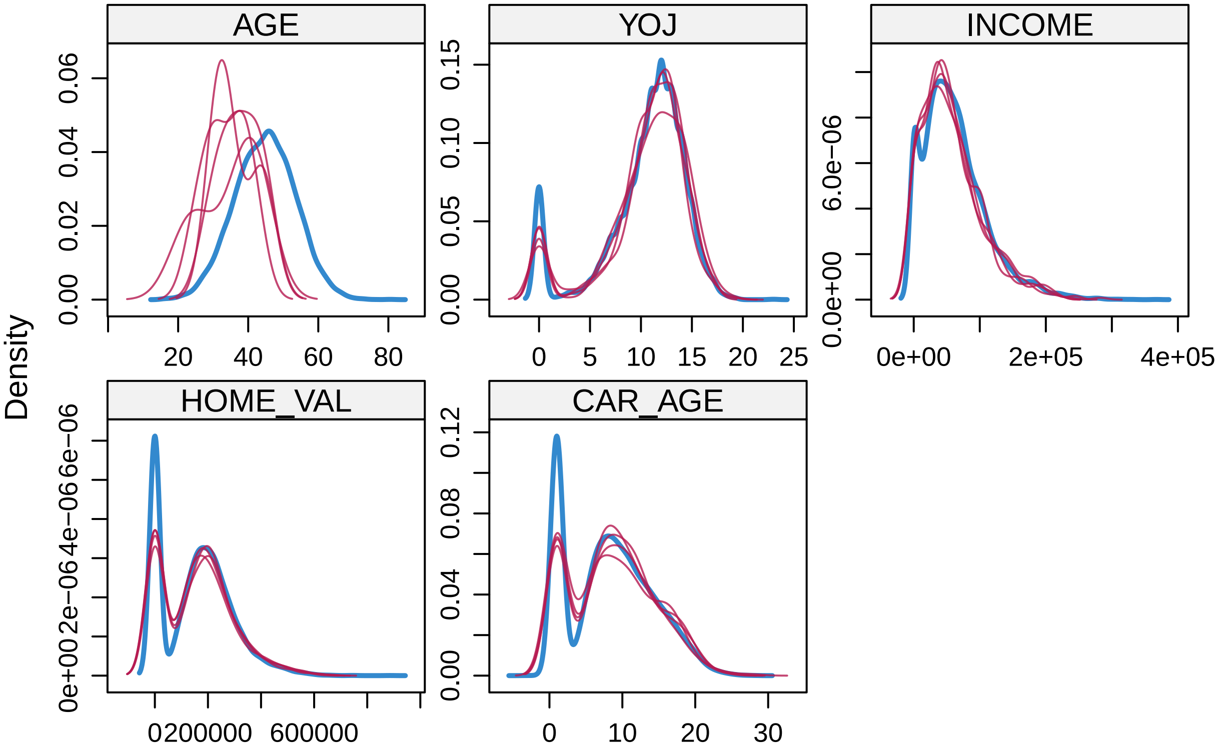


Figure 5: Density plots for variables containing missing data. The number of multiple imputations was set to 4. Each of the red lines represents the distribution for each imputation.

The blue lines for each of the graphs above represent the distributions the non-missing data for each of the variables while the red lines represent the distributions for the imputed data. Note that the distributions for the imputed data for each of the iterations closely matches the distributions for the non-missing data, which is ideal. If the distributions did not match so well, than another imputing method would have had to have been used.

Feature Manipulation based on Multicollinearity Plot

There is a significant amount of observations for `INCOME` with a value of 0. Therefore, we reasoned that we could create a new dummy variable based on the `INCOME`, called `EMPLOYMENT`, where 0 was unemployed and any positive value for income would be employed. Then, we could effectively be rid of the `INCOME` variable while still having some sort of distinction that represents this variable that does not have a high correlation with any of the other variables.

Dealing with Bimodal Variables

Bimodal distributions in data are interesting, in that they represent features which actually contain multiple (2) inherent systems resulting in separated distributional peaks. While a Box-Cox transformation could have been undertaken in order to transform the bimodal variables to a normal distribution. However, this throws away important information that is inherent in the bimodal variable itself. The fact that the variable is bimodal in the first place is essentially ignored, and the predicted values in the linear multiple regression model will not reflect this bimodality.

For variables that displayed bimodality, new variables were created; `bi_CAR_AGE`, `bi_CLM_FREQ`, `bi_HOME_VAL`, `bi_KIDSDRIV`, `bi_YOJ`. For many of these variables, there are a significant number of 0 values, which results in the bimodal distributions shown above, so 0 will represent observations with a value of 0 and 1 will represent any observations with a value greater than 0. For `CAR_AGE`, many cars are 1 years old, so 0 represents observations where the `CAR_AGE` is 1, while 1 represents any observations with a value greater than 1.

Box-Cox Transformation for Skewed Variables

Based on the previous distribution plot (using histograms) we noticed that a select group of columns exhibited non-normal skew. In order to address this skewness and attempt to normalize these features for future modeling, we will employ box-cox transformations. Because some of these values include 0, we will need to replace any zero values with infintesimmaly small, non-zero values.

The λ's that were used to transform the skewed variables are shown on Table 2.

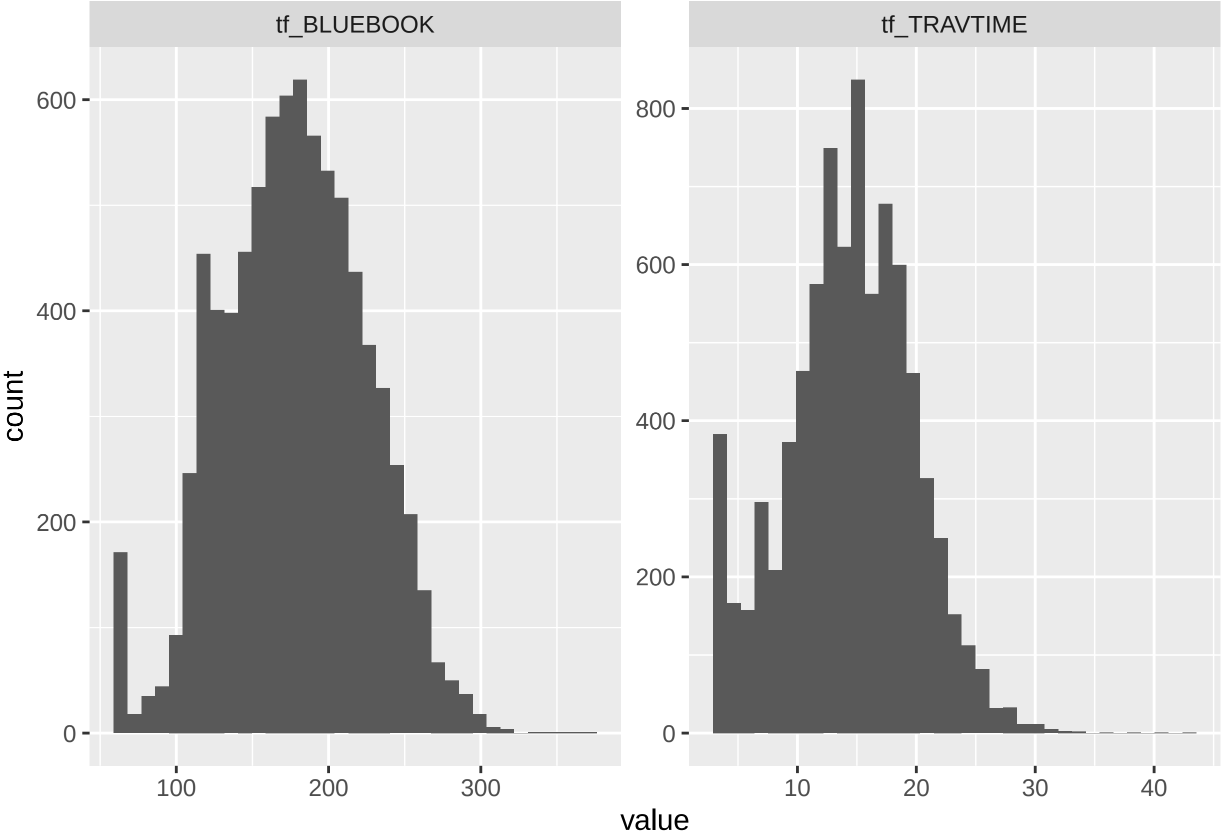


Figure 6: Histograms for transformed variables.

Column Name	λ
BLUEBOOK	0.461
TRAVTIME	0.687

Table 2: λ's for skewed variables.

Split Data Into Testing and Training

The data was into testing and training subsets such that 60% of it will be used to train, and 40% to test. The first row shows the split for the testing data while the second row shows the split for the training data.

```
   0    1 
1202  431 
```

```
   0    1 
4806 1722 
```

Build Models

Binary Logistic Regression Model with Original Variables

```
Call:
glm(formula = TARGET_FLAG ~ ., family = binomial(link = "logit"), 
    data = original_train_no_target_amt)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-2.4277  -0.7086  -0.3954   0.6203   3.1819  

Coefficients:
                                Estimate Std. Error z value Pr(>|z|)    
(Intercept)                   -1.973e+00  5.286e-01  -3.733 0.000189 ***
KIDSDRIV                       2.189e-01  1.373e-01   1.594 0.110912    
AGE                           -5.668e-03  4.590e-03  -1.235 0.216890    
HOMEKIDS                       2.281e-02  4.243e-02   0.538 0.590909    
YOJ                            2.059e-02  1.359e-02   1.515 0.129760    
PARENT1Yes                     3.938e-01  1.242e-01   3.170 0.001523 ** 
HOME_VAL                      -1.240e-06  5.466e-07  -2.269 0.023289 *  
MSTATUSYes                    -3.250e-01  9.920e-02  -3.277 0.001051 ** 
SEXM                           1.582e-01  1.247e-01   1.269 0.204489    
EDUCATIONBachelors            -4.013e-01  1.306e-01  -3.072 0.002128 ** 
EDUCATIONHigh School          -2.952e-02  1.075e-01  -0.275 0.783623    
EDUCATIONMasters              -3.444e-01  2.063e-01  -1.670 0.094981 .  
EDUCATIONPhD                  -3.548e-01  2.415e-01  -1.469 0.141857    
JOBBlue Collar                 4.464e-01  2.076e-01   2.150 0.031554 *  
JOBClerical                    5.857e-01  2.186e-01   2.680 0.007368 ** 
JOBDoctor                     -3.209e-01  2.940e-01  -1.091 0.275165    
JOBHome Maker                  3.189e-01  2.401e-01   1.328 0.184098    
JOBLawyer                      3.097e-01  1.893e-01   1.636 0.101936    
JOBManager                    -4.536e-01  1.924e-01  -2.357 0.018419 *  
JOBProfessional                2.475e-01  2.000e-01   1.238 0.215807    
JOBStudent                     1.859e-01  2.460e-01   0.756 0.449863    
TRAVTIME                      -2.167e-02  1.947e-02  -1.113 0.265651    
CAR_USEPrivate                -7.367e-01  1.032e-01  -7.140 9.35e-13 ***
BLUEBOOK                       4.036e-05  2.198e-05   1.836 0.066352 .  
TIF                           -4.863e-02  8.267e-03  -5.883 4.03e-09 ***
CAR_TYPEPanel Truck            3.875e-01  1.863e-01   2.080 0.037517 *  
CAR_TYPEPickup                 5.476e-01  1.120e-01   4.889 1.01e-06 ***
```

```
CAR_TYPESports Car             1.041e+00  1.447e-01   7.198 6.11e-13 ***
CAR_TYPESUV                    8.011e-01  1.244e-01   6.441 1.19e-10 ***
CAR_TYPEVan                    6.429e-01  1.413e-01   4.549 5.39e-06 ***
RED_CARyes                    -5.252e-02  9.669e-02  -0.543 0.587050    
OLDCLAIM                      -2.374e-05  4.712e-06  -5.038 4.69e-07 ***
CLM_FREQ                       6.644e-02  4.973e-02   1.336 0.181483    
REVOKEDYes                     9.804e-01  1.032e-01   9.495  < 2e-16 ***
MVR_PTS                        9.301e-02  1.581e-02   5.883 4.02e-09 ***
CAR_AGE                        3.058e-03  1.220e-02   0.251 0.802027    
URBANICITYHighly Urban/ Urban  2.330e+00  1.289e-01  18.070  < 2e-16 ***
EMPLOYMENT1                   -7.136e-01  3.098e-01  -2.303 0.021281 *  
bi_CAR_AGE1                   -1.041e-01  1.205e-01  -0.864 0.387484    
bi_CLM_FREQ1                   5.972e-01  1.361e-01   4.387 1.15e-05 ***
bi_HOME_VAL1                  -1.178e-01  1.466e-01  -0.804 0.421567    
bi_KIDSDRIV1                   3.300e-01  2.170e-01   1.521 0.128360    
bi_YOJ1                       -6.203e-02  3.425e-01  -0.181 0.856262    
tf_BLUEBOOK                   -1.092e-02  3.669e-03  -2.975 0.002929 ** 
tf_TRAVTIME                    1.042e-01  5.684e-02   1.834 0.066683 .  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 7533.1  on 6527  degrees of freedom
Residual deviance: 5818.0  on 6483  degrees of freedom
AIC: 5908

Number of Fisher Scoring iterations: 5
```

```
Setting levels: control = 0, case = 1

Setting direction: controls < cases
```

Confusion Matrix for Binary Logistic Regression Model with Original Variables

The confusion matrix for the binary logistic regression model with original variables is provided below.

```
      Predicted
Actual    0    1
     0 1119   83
     1  249  182
```

Step-AIC Binary Logistic Regression Model

```

Call:
glm(formula = TARGET_FLAG ~ KIDSDRIV + YOJ + PARENT1 + HOME_VAL + 
    MSTATUS + EDUCATION + JOB + CAR_USE + BLUEBOOK + TIF + CAR_TYPE + 
    OLDCLAIM + REVOKED + MVR_PTS + URBANICITY + EMPLOYMENT + 
    bi_CLM_FREQ + bi_KIDSDRIV + tf_BLUEBOOK + tf_TRAVTIME, family = binomial(link = "logit"), 
    data = original_train_no_target_amt)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-2.4416  -0.7139  -0.3948   0.6362   3.1713  
```

```
Coefficients:
                                Estimate Std. Error z value Pr(>|z|)
(Intercept)                   -1.978e+00  4.569e-01  -4.329 1.50e-05 ***
KIDSDRIV                       2.336e-01  1.341e-01   1.742 0.081595 .
YOJ                            1.895e-02  1.178e-02   1.608 0.107858
PARENT1Yes                     4.665e-01  1.070e-01   4.361 1.29e-05 ***
HOME_VAL                      -1.615e-06  3.539e-07  -4.565 5.00e-06 ***
MSTATUSYes                    -3.264e-01  9.083e-02  -3.594 0.000326 ***
EDUCATIONBachelors            -4.207e-01  1.216e-01  -3.460 0.000540 ***
EDUCATIONHigh School          -2.625e-02  1.067e-01  -0.246 0.805678
EDUCATIONMasters              -3.533e-01  1.795e-01  -1.968 0.049101 *
EDUCATIONPhD                  -3.612e-01  2.172e-01  -1.663 0.096324 .
JOBBlue Collar                 4.352e-01  2.072e-01   2.101 0.035648 *
JOBClerical                    5.710e-01  2.172e-01   2.629 0.008565 **
JOBDoctor                     -3.356e-01  2.933e-01  -1.144 0.252528
JOBHome Maker                  2.438e-01  2.335e-01   1.044 0.296575
JOBLawyer                      2.766e-01  1.887e-01   1.466 0.142560
JOBManager                    -4.763e-01  1.918e-01  -2.483 0.013022 *
JOBProfessional                2.269e-01  1.994e-01   1.138 0.255136
JOBStudent                     2.023e-01  2.428e-01   0.833 0.404756
CAR_USEPrivate                -7.305e-01  1.029e-01  -7.102 1.23e-12 ***
BLUEBOOK                       3.745e-05  2.142e-05   1.748 0.080474 .
TIF                           -4.819e-02  8.245e-03  -5.844 5.09e-09 ***
CAR_TYPEPanel Truck            4.675e-01  1.738e-01   2.691 0.007126 **
CAR_TYPEPickup                 5.408e-01  1.117e-01   4.843 1.28e-06 ***
CAR_TYPESports Car             9.453e-01  1.200e-01   7.875 3.41e-15 ***
CAR_TYPESUV                    7.106e-01  9.576e-02   7.420 1.17e-13 ***
CAR_TYPEVan                    6.836e-01  1.372e-01   4.984 6.22e-07 ***
OLDCLAIM                      -2.382e-05  4.698e-06  -5.070 3.97e-07 ***
REVOKEDYes                     9.827e-01  1.031e-01   9.535  < 2e-16 ***
MVR_PTS                        9.336e-02  1.576e-02   5.923 3.16e-09 ***
URBANICITYHighly Urban/ Urban  2.342e+00  1.287e-01  18.197  < 2e-16 ***
EMPLOYMENT1                   -7.599e-01  1.935e-01  -3.928 8.55e-05 ***
bi_CLM_FREQ1                   7.357e-01  8.797e-02   8.363  < 2e-16 ***
bi_KIDSDRIV1                   3.303e-01  2.166e-01   1.525 0.127193
tf_BLUEBOOK                   -1.093e-02  3.639e-03  -3.003 0.002675 **
tf_TRAVTIME                    4.141e-02  6.217e-03   6.661 2.72e-11 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 7533.1  on 6527  degrees of freedom
Residual deviance: 5826.5  on 6493  degrees of freedom
AIC: 5896.5

Number of Fisher Scoring iterations: 5

Setting levels: control = 0, case = 1

Setting direction: controls < cases
```

Confusion Matrix for Step-AIC Binary Logistic Regression Model

The confusion matrix for the Step-AIC binary logistic regression model with original variables is provided below.

```
      Predicted
Actual    0    1
     0 1121   81
     1  251  180
```

Multiple Linear Regression Model with Original Variables

```

Call:
lm(formula = TARGET_AMT ~ ., data = original_train_no_target_flag)

Residuals:
   Min     1Q Median     3Q    Max 
 -6122  -1731   -758    383 103578 

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)    
(Intercept)                   -1.035e+03  9.389e+02  -1.102 0.270306    
KIDSDRIV                      -2.131e+02  2.666e+02  -0.799 0.424235    
AGE                            6.765e+00  8.199e+00   0.825 0.409327    
HOMEKIDS                       9.948e+01  7.672e+01   1.297 0.194804    
YOJ                            8.655e+00  2.358e+01   0.367 0.713527    
PARENT1Yes                     6.643e+02  2.331e+02   2.849 0.004395 ** 
HOME_VAL                      -1.326e-03  9.005e-04  -1.473 0.140806    
MSTATUSYes                    -4.208e+02  1.746e+02  -2.411 0.015953 *  
SEXM                           3.526e+02  2.096e+02   1.682 0.092521 .  
EDUCATIONBachelors            -4.672e+02  2.373e+02  -1.969 0.048972 *  
EDUCATIONHigh School          -2.185e+02  1.986e+02  -1.100 0.271312    
EDUCATIONMasters              -1.432e+02  3.527e+02  -0.406 0.684856    
EDUCATIONPhD                  -1.521e+01  4.111e+02  -0.037 0.970497    
JOBBlue Collar                 3.979e+02  3.677e+02   1.082 0.279223    
JOBClerical                    5.630e+02  3.877e+02   1.452 0.146492    
JOBDoctor                     -4.532e+02  4.652e+02  -0.974 0.329982    
JOBHome Maker                  5.003e+02  4.229e+02   1.183 0.236858    
JOBLawyer                      3.994e+02  3.390e+02   1.178 0.238724    
JOBManager                    -5.411e+02  3.307e+02  -1.636 0.101841    
JOBProfessional                4.261e+02  3.529e+02   1.208 0.227252    
JOBStudent                     3.026e+02  4.398e+02   0.688 0.491432    
TRAVTIME                      -8.385e+00  3.223e+01  -0.260 0.794775    
CAR_USEPrivate                -8.551e+02  1.883e+02  -4.541 5.69e-06 ***
BLUEBOOK                      -1.745e-02  3.776e-02  -0.462 0.644096    
TIF                           -4.595e+01  1.410e+01  -3.259 0.001123 ** 
CAR_TYPEPanel Truck            3.053e+02  3.262e+02   0.936 0.349320    
CAR_TYPEPickup                 3.410e+02  1.946e+02   1.752 0.079750 .  
CAR_TYPESports Car             8.628e+02  2.480e+02   3.479 0.000507 ***
CAR_TYPESUV                    7.592e+02  2.051e+02   3.701 0.000216 ***
CAR_TYPEVan                    3.924e+02  2.449e+02   1.602 0.109204    
RED_CARyes                     2.414e+01  1.710e+02   0.141 0.887760    
OLDCLAIM                      -1.662e-02  9.096e-03  -1.827 0.067734 .  
CLM_FREQ                       1.041e+02  1.013e+02   1.028 0.304105    
```

```
REVOKEDYes                      6.170e+02  2.005e+02   3.078 0.002093 **
MVR_PTS                         1.857e+02  3.081e+01   6.027 1.76e-09 ***
CAR_AGE                        -3.576e+01  2.075e+01  -1.724 0.084831 .
URBANICITYHighly Urban/ Urban  1.670e+03  1.624e+02  10.283  < 2e-16 ***
EMPLOYMENT1                    -8.873e+02  5.458e+02  -1.626 0.104070
bi_CAR_AGE1                     1.362e+02  2.138e+02   0.637 0.523994
bi_CLM_FREQ1                    2.563e+02  2.702e+02   0.949 0.342846
bi_HOME_VAL1                    1.268e+02  2.587e+02   0.490 0.623971
bi_KIDSDRIV1                    9.308e+02  4.197e+02   2.218 0.026605 *
bi_YOJ1                         4.712e+02  6.054e+02   0.778 0.436442
tf_BLUEBOOK                     4.971e+00  6.455e+00   0.770 0.441217
tf_TRAVTIME                     6.028e+01  9.394e+01   0.642 0.521102
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4658 on 6483 degrees of freedom
Multiple R-squared:  0.07341,   Adjusted R-squared:  0.06713
F-statistic: 11.67 on 44 and 6483 DF,  p-value: < 2.2e-16
```

Step-AIC Multiple Linear Regression Model

```
Call:
lm(formula = TARGET_AMT ~ PARENT1 + HOME_VAL + MSTATUS + SEX +
    JOB + CAR_USE + TIF + CAR_TYPE + OLDCLAIM + CLM_FREQ + REVOKED +
    MVR_PTS + CAR_AGE + URBANICITY + EMPLOYMENT + bi_KIDSDRIV +
    tf_TRAVTIME, data = original_train_no_target_flag)

Residuals:
   Min     1Q Median     3Q    Max
 -6253  -1733   -771    335 103540

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    -4.485e+00  5.295e+02  -0.008 0.993242
PARENT1Yes                      7.673e+02  2.039e+02   3.762 0.000170 ***
HOME_VAL                       -1.052e-03  5.966e-04  -1.764 0.077810 .
MSTATUSYes                     -3.213e+02  1.564e+02  -2.055 0.039932 *
SEXM                            2.913e+02  1.667e+02   1.748 0.080522 .
JOBBlue Collar                  2.868e+02  3.025e+02   0.948 0.343066
JOBClerical                     4.688e+02  3.264e+02   1.436 0.150999
JOBDoctor                      -3.842e+02  4.256e+02  -0.903 0.366691
JOBHome Maker                   2.998e+02  3.838e+02   0.781 0.434837
JOBLawyer                       3.539e+02  3.280e+02   1.079 0.280718
JOBManager                     -7.279e+02  3.062e+02  -2.377 0.017488 *
JOBProfessional                 1.619e+02  3.032e+02   0.534 0.593342
JOBStudent                      1.048e+02  3.815e+02   0.275 0.783478
CAR_USEPrivate                 -7.628e+02  1.789e+02  -4.263 2.04e-05 ***
TIF                            -4.476e+01  1.406e+01  -3.184 0.001461 **
CAR_TYPEPanel Truck             4.907e+02  2.857e+02   1.718 0.085933 .
CAR_TYPEPickup                  3.621e+02  1.915e+02   1.891 0.058725 .
CAR_TYPESports Car              7.843e+02  2.320e+02   3.380 0.000730 ***
CAR_TYPESUV                     7.012e+02  1.886e+02   3.718 0.000202 ***
CAR_TYPEVan                     4.907e+02  2.368e+02   2.072 0.038292 *
```

```
OLDCLAIM                     -1.314e-02  8.509e-03  -1.544 0.122649    
CLM_FREQ                      1.793e+02  6.337e+01   2.829 0.004688 ** 
REVOKEDYes                    5.837e+02  1.981e+02   2.946 0.003229 ** 
MVR_PTS                       1.905e+02  2.974e+01   6.406 1.60e-10 ***
CAR_AGE                      -3.094e+01  1.259e+01  -2.457 0.014050 *  
URBANICITYHighly Urban/ Urban  1.694e+03  1.603e+02  10.573  < 2e-16 ***
EMPLOYMENT1                  -3.937e+02  2.777e+02  -1.418 0.156290    
bi_KIDSDRIV1                  7.462e+02  1.855e+02   4.023 5.82e-05 ***
tf_TRAVTIME                   3.551e+01  1.080e+01   3.288 0.001014 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4657 on 6499 degrees of freedom
Multiple R-squared:  0.07155,   Adjusted R-squared:  0.06755 
F-statistic: 17.89 on 28 and 6499 DF,  p-value: < 2.2e-16
```

Parsed Step-AIC Multiple Linear Regression Model

In this model, we selected the variables from the original Step-AIC Model that had p-values that were less than 0.05.

```
Call:
lm(formula = TARGET_AMT ~ PARENT1 + MSTATUS + JOB + CAR_USE + 
    TIF + CAR_TYPE + CLM_FREQ + MVR_PTS + CAR_AGE + URBANICITY + 
    bi_KIDSDRIV + tf_TRAVTIME, data = original_train_no_target_flag)

Residuals:
   Min     1Q Median     3Q    Max 
 -5777  -1728   -777    338 103635 

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)    
(Intercept)                    -333.30     432.62  -0.770 0.441077    
PARENT1Yes                      760.23     203.85   3.729 0.000194 ***
MSTATUSYes                     -469.46     137.50  -3.414 0.000643 ***
JOBBlue Collar                  359.24     300.01   1.197 0.231173    
JOBClerical                     577.97     320.89   1.801 0.071728 .  
JOBDoctor                      -416.16     425.36  -0.978 0.327926    
JOBHome Maker                   553.57     352.70   1.570 0.116576    
JOBLawyer                       387.28     328.01   1.181 0.237767    
JOBManager                     -714.36     306.05  -2.334 0.019621 *  
JOBProfessional                 192.81     302.85   0.637 0.524367    
JOBStudent                      530.98     342.05   1.552 0.120630    
CAR_USEPrivate                 -749.20     178.88  -4.188 2.85e-05 ***
TIF                             -45.71      14.06  -3.251 0.001157 ** 
CAR_TYPEPanel Truck             553.79     280.90   1.971 0.048715 *  
CAR_TYPEPickup                  388.20     191.55   2.027 0.042741 *  
CAR_TYPESports Car              617.53     207.97   2.969 0.002996 ** 
CAR_TYPESUV                     544.39     158.81   3.428 0.000612 ***
CAR_TYPEVan                     543.40     234.50   2.317 0.020516 *  
CLM_FREQ                        145.00      56.15   2.583 0.009829 ** 
MVR_PTS                         191.92      29.62   6.479 9.91e-11 ***
CAR_AGE                         -33.16      12.59  -2.634 0.008460 ** 
URBANICITYHighly Urban/ Urban  1723.57     159.76  10.789  < 2e-16 ***
```

```
bi_KIDSDRIV1                    756.44     185.49   4.078 4.59e-05 ***
tf_TRAVTIME                      36.38      10.80   3.367 0.000763 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4662 on 6504 degrees of freedom
Multiple R-squared:  0.06895,   Adjusted R-squared:  0.06566
F-statistic: 20.94 on 23 and 6504 DF,  p-value: < 2.2e-16
```

Model Selection

Binary Logistic Regression Models

Model	Precision	Recall	AIC	AUC	F-score	Accuracy	Error
Simple Log Reg	0.69	0.42	5908.03	0.82	0.523	0.8	0.2
Step AIC Log Reg	0.69	0.42	5896.48	0.82	0.52	0.8	0.2

Table 3: Model metrics for binary logistic regression models

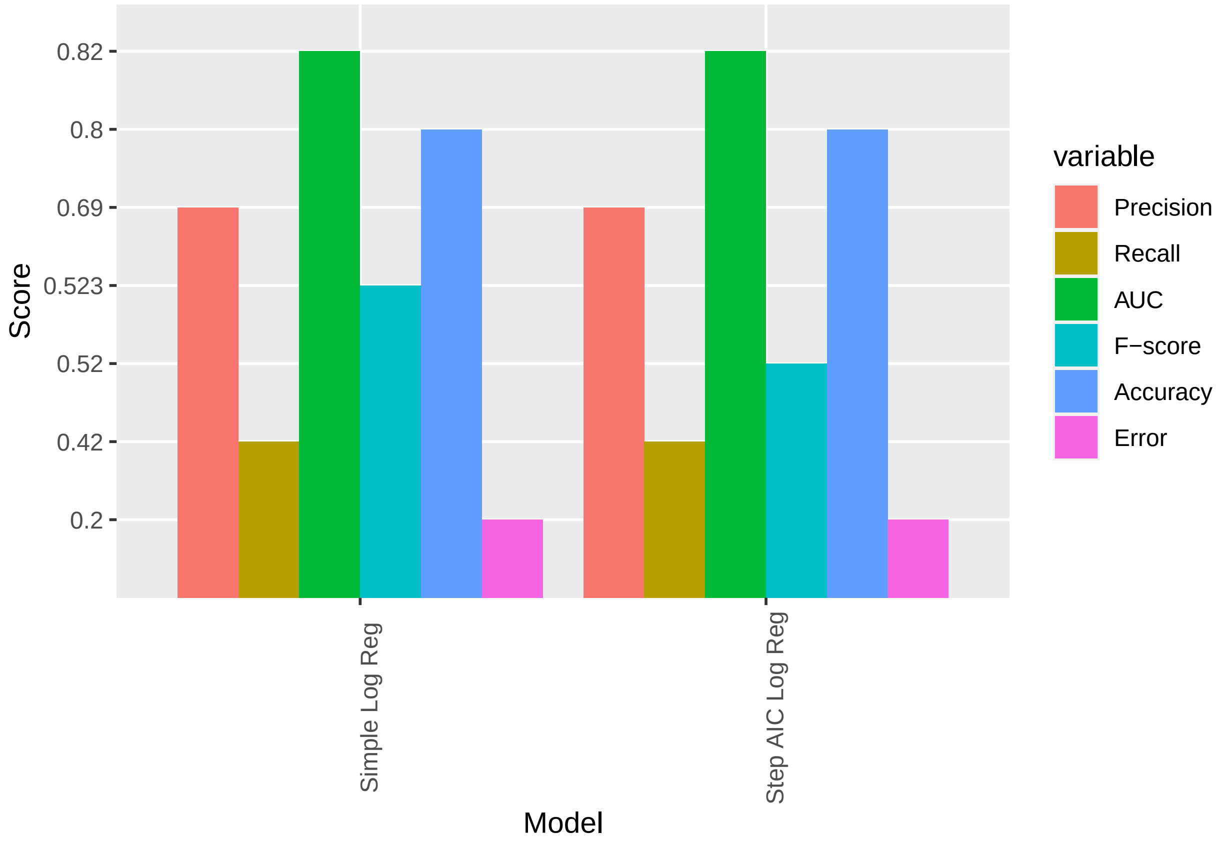


Figure 7: Bar chart of metrics for binary logistic regression models

For this assignment, we will be choosing the Simple Log Reg for our binary logistic regression model. Between the two models, the simple binary logistic regression model has a higher f-score than the Step-AIC Logistic Regression model.

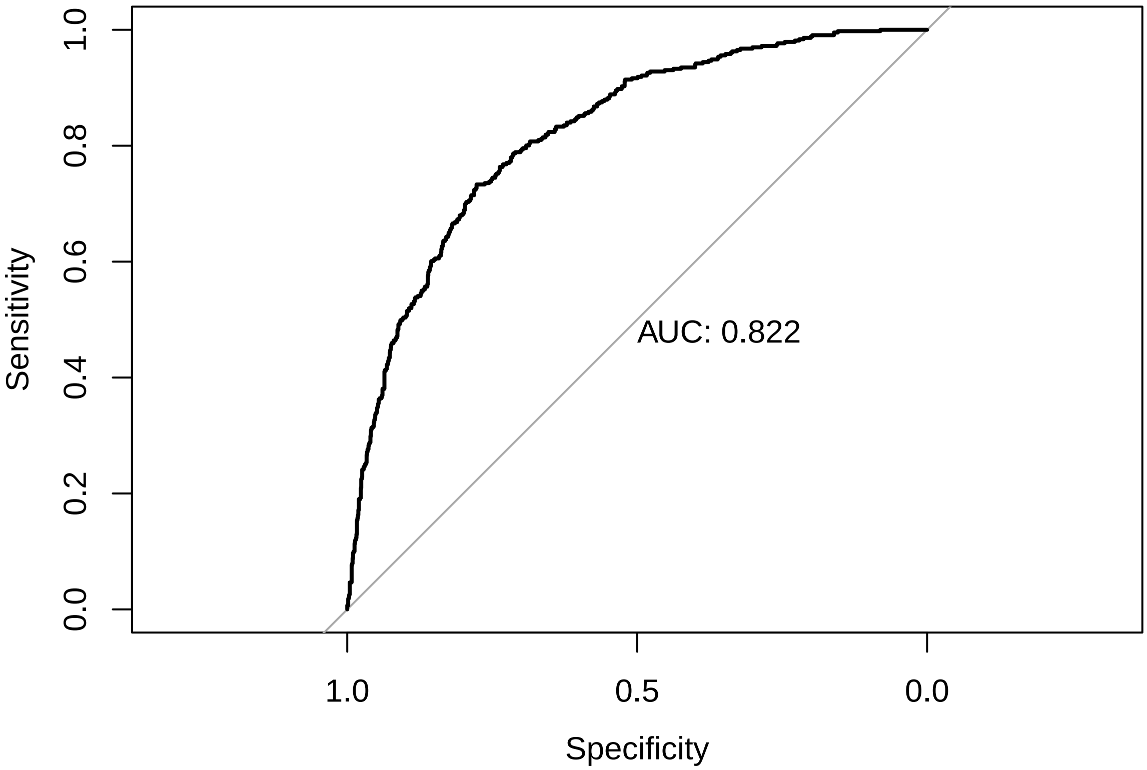


Figure 8: ROC Curve for selected model (Simple Model)

As we see on Figure 8, our model performs really well with an AUC of 0.822.

Multiple Linear Regression Models

Model	MSE	R-Squared	Adjusted R-Squared	F-Statistic
Simple Linear	16581656.19	0.073	0.067	11.67
Step-AIC Linear	16559343.49	0.072	0.068	17.89
Parsed Step-AIC Linear	16612545.4	0.069	0.066	20.94

Table 4: Model metrics for multiple linear regression models

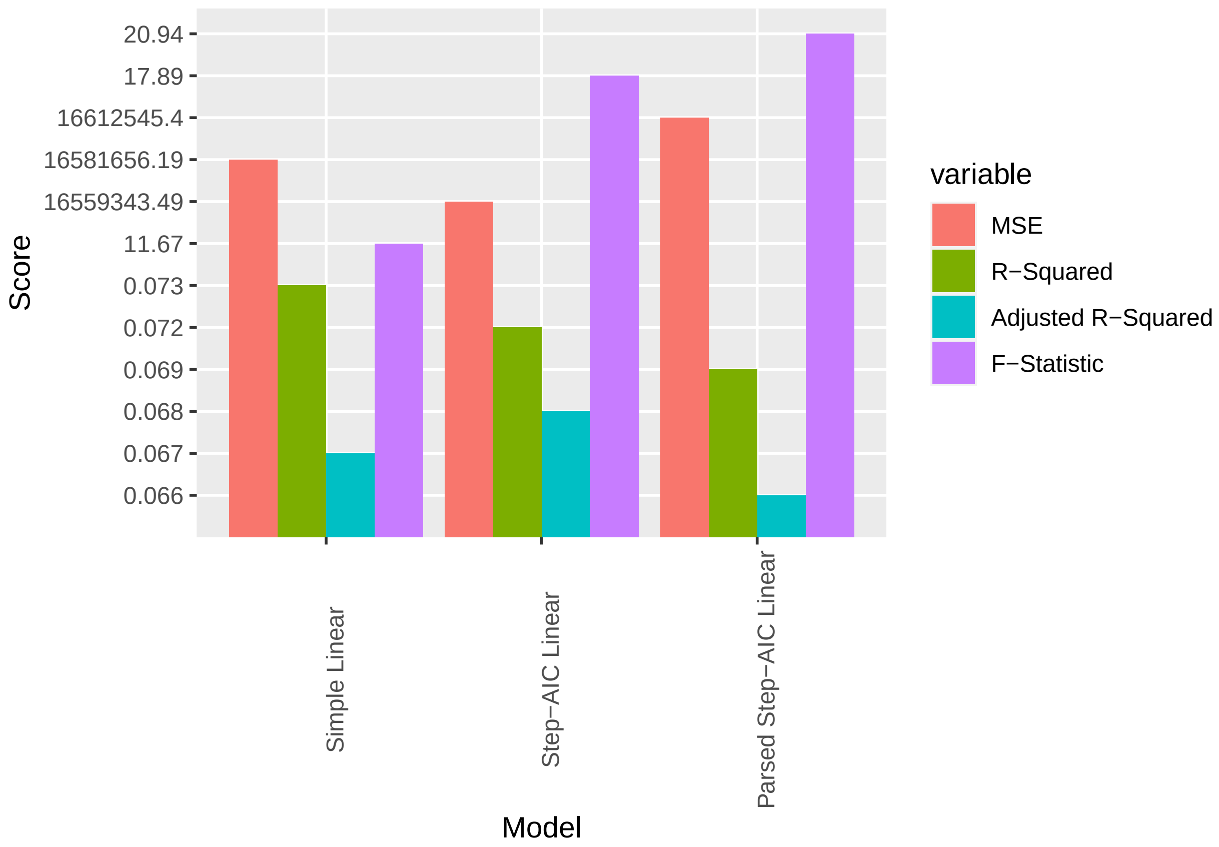
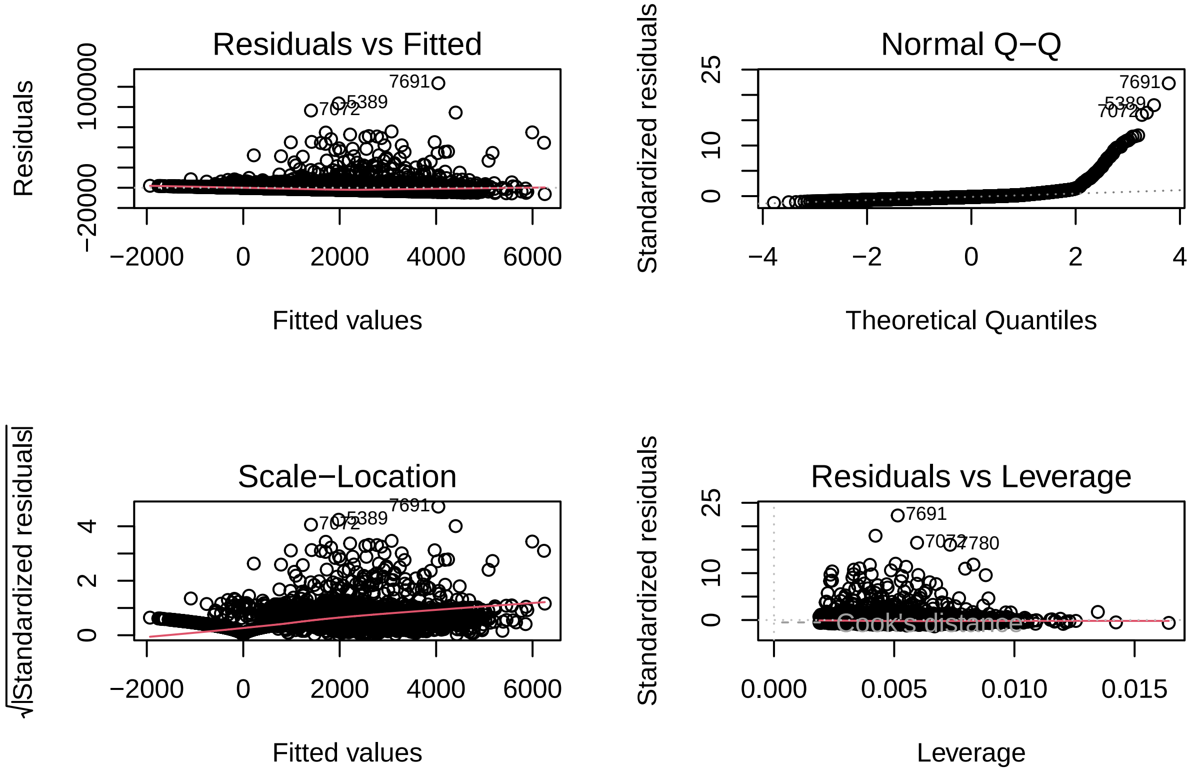


Figure 9: Metrics bar chart for multiple linear regression models

For this assignment, we will be choosing the Step-AIC Linear model for our multiple linear regression model. Between the three models, the multiple linear regression model has the highest adjusted R-squared and the lowest MSE.



Residuals vs Fitted

Normal Q−Q

Scale−Location

Residuals vs Leverage

Figure 10: Residual Plots for Step-AIC Linear Model