

Eric_Hirsch_621_Assignment_4

Predicting Insurance Claims

Eric Hirsch

4/7/2022

Contents

1. Data Exploration	1
A. Summary Statistics	1
B. Distributions	3
C. Multicollinearity	5
2. Data Preparation	6
A. Create Dummy Variables	6
B. Address Missing Values	6
3. Predict TARGET_FLAG	8
A. Explore relationships	8
B. Create Models	9
4. Select model	14
4. Predict TARGET_AMT	15
A. Explore Relationships	15
B. Create models	15
4. Select model	20
5. Conclusion	21

We examine records of car insurance customers to build two predictive models: one for whether the customer would have crashed, and second, the \$ amount paid for the crash.

The main issue in the dataset are outliers. Without transformation, the distribution of residuals is not normal, and there are too many influential points to create reliable models.

1. Data Exploration

A. Summary Statistics We first examine the data. The dataset consists of 8161 observations and 26 variables (including two target variables, TARGET_FLAG and TARGET_AMT). 14 of the predictor variables are numeric. Approximately 27% of customers had an accident - the rest did not. TARGET_AMT appears to be highly skewed. There is a large degree of missing values.

```

##      INDEX      TARGET_FLAG      TARGET_AMT      KIDSDRIV
## Min.      :    1  Min.      :0.0000  Min.      :    0  Min.      :0.0000
## 1st Qu.: 2559  1st Qu.:0.0000  1st Qu.:    0  1st Qu.:0.0000
## Median : 5133  Median :0.0000  Median :    0  Median :0.0000
## Mean   : 5152  Mean   :0.2638  Mean   : 1504  Mean   :0.1711
## 3rd Qu.: 7745  3rd Qu.:1.0000  3rd Qu.: 1036  3rd Qu.:0.0000
## Max.   :10302  Max.   :1.0000  Max.   :107586  Max.   :4.0000
##
##      AGE      HOMEKIDS      YOJ      INCOME
## Min.      :16.00  Min.      :0.0000  Min.      : 0.0  Min.      :    0
## 1st Qu.:39.00  1st Qu.:0.0000  1st Qu.: 9.0  1st Qu.: 28097
## Median :45.00  Median :0.0000  Median :11.0  Median : 54028
## Mean   :44.79  Mean   :0.7212  Mean   :10.5  Mean   : 61898
## 3rd Qu.:51.00  3rd Qu.:1.0000  3rd Qu.:13.0  3rd Qu.: 85986
## Max.   :81.00  Max.   :5.0000  Max.   :23.0  Max.   :367030
## NA's      :6      NA's      :454  NA's      :445
##      PARENT1      HOME_VAL      MSTATUS      SEX
## Length:8161      Min.      :    0  Length:8161      Length:8161
## Class :character  1st Qu.:    0  Class :character  Class :character
## Mode  :character  Median :161160  Mode  :character  Mode  :character
##                      Mean   :154867
##                      3rd Qu.:238724
##                      Max.   :885282
##                      NA's    :464
##      EDUCATION      JOB      TRAVTIME      CAR_USE
## Length:8161      Length:8161      Min.      : 5.00  Length:8161
## Class :character  Class :character  1st Qu.: 22.00  Class :character
## Mode  :character  Mode  :character  Median : 33.00  Mode  :character
##                      Mean   : 33.49
##                      3rd Qu.: 44.00
##                      Max.   :142.00
##
##      BLUEBOOK      TIF      CAR_TYPE      RED_CAR
## Min.      : 1500  Min.      : 1.000  Length:8161      Length:8161
## 1st Qu.: 9280  1st Qu.: 1.000  Class :character  Class :character
## Median :14440  Median : 4.000  Mode  :character  Mode  :character
## Mean   :15710  Mean   : 5.351
## 3rd Qu.:20850  3rd Qu.: 7.000
## Max.   :69740  Max.   :25.000
##
##      OLDCLAIM      CLM_FREQ      REVOKED      MVR_PTS
## Min.      :    0  Min.      :0.0000  Length:8161      Min.      : 0.000
## 1st Qu.:    0  1st Qu.:0.0000  Class :character  1st Qu.: 0.000
## Median :    0  Median :0.0000  Mode  :character  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  Length:8161
## 1st Qu.: 1.000  Class :character
## Median : 8.000  Mode  :character
## Mean   : 8.328
## 3rd Qu.:12.000

```

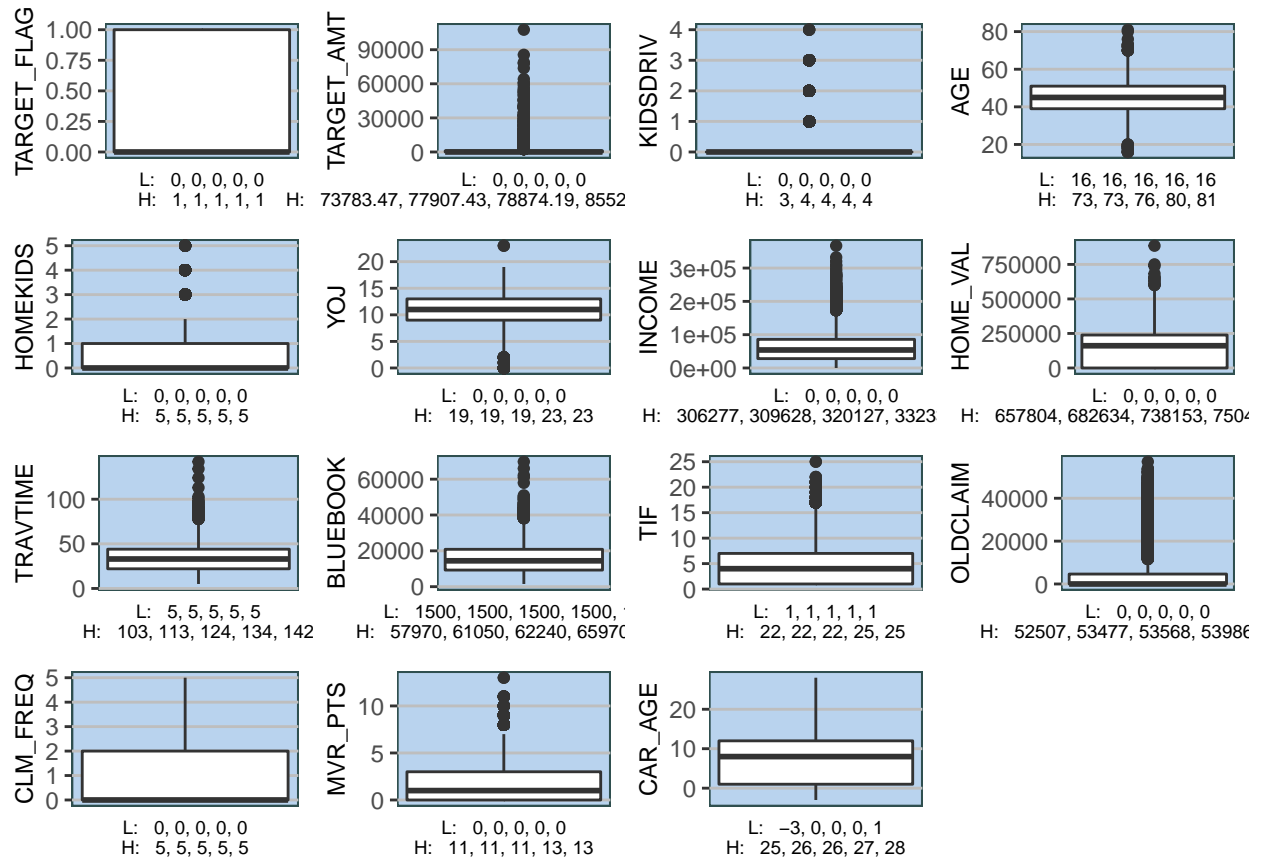
```
## Max.      :28.000
## NA's      :510
```

```
## 'data.frame':      8161 obs. of  26 variables:
## $ INDEX      : int   1 2 4 5 6 7 8 11 12 13 ...
## $ TARGET_FLAG: int   0 0 0 0 0 1 0 1 1 0 ...
## $ TARGET_AMT : num   0 0 0 0 0 ...
## $ KIDSDRIV   : int   0 0 0 0 0 0 0 1 0 0 ...
## $ AGE        : int  60 43 35 51 50 34 54 37 34 50 ...
## $ HOMEKIDS   : int   0 0 1 0 0 1 0 2 0 0 ...
## $ YOJ        : int  11 11 10 14 NA 12 NA NA 10 7 ...
## $ INCOME     : num  67349 91449 16039 NA 114986 ...
## $ PARENT1    : chr   "No" "No" "No" "No" ...
## $ HOME_VAL   : num   0 257252 124191 306251 243925 ...
## $ MSTATUS    : chr   "z_No" "z_No" "Yes" "Yes" ...
## $ SEX        : chr   "M" "M" "z_F" "M" ...
## $ EDUCATION  : chr   "PhD" "z_High School" "z_High School" "<High School" ...
## $ JOB        : chr   "Professional" "z_Blue Collar" "Clerical" "z_Blue Collar" ...
## $ TRAVTIME   : int  14 22 5 32 36 46 33 44 34 48 ...
## $ CAR_USE    : chr   "Private" "Commercial" "Private" "Private" ...
## $ BLUEBOOK   : num  14230 14940 4010 15440 18000 ...
## $ TIF        : int  11 1 4 7 1 1 1 1 1 7 ...
## $ CAR_TYPE   : chr   "Minivan" "Minivan" "z_SUV" "Minivan" ...
## $ RED_CAR    : chr   "yes" "yes" "no" "yes" ...
## $ OLDCLAIM   : num  4461 0 38690 0 19217 ...
## $ CLM_FREQ   : int   2 0 2 0 2 0 0 1 0 0 ...
## $ REVOKED    : chr   "No" "No" "No" "No" ...
## $ MVR_PTS    : int   3 0 3 0 3 0 0 10 0 1 ...
## $ CAR_AGE    : int  18 1 10 6 17 7 1 7 1 17 ...
## $ URBANICITY : chr   "Highly Urban/ Urban" "Highly Urban/ Urban" "Highly Urban/ Urban" "Highly Urban/ Urban"
```

B. Distributions We examine distributions of numeric variables through boxplots and histograms:

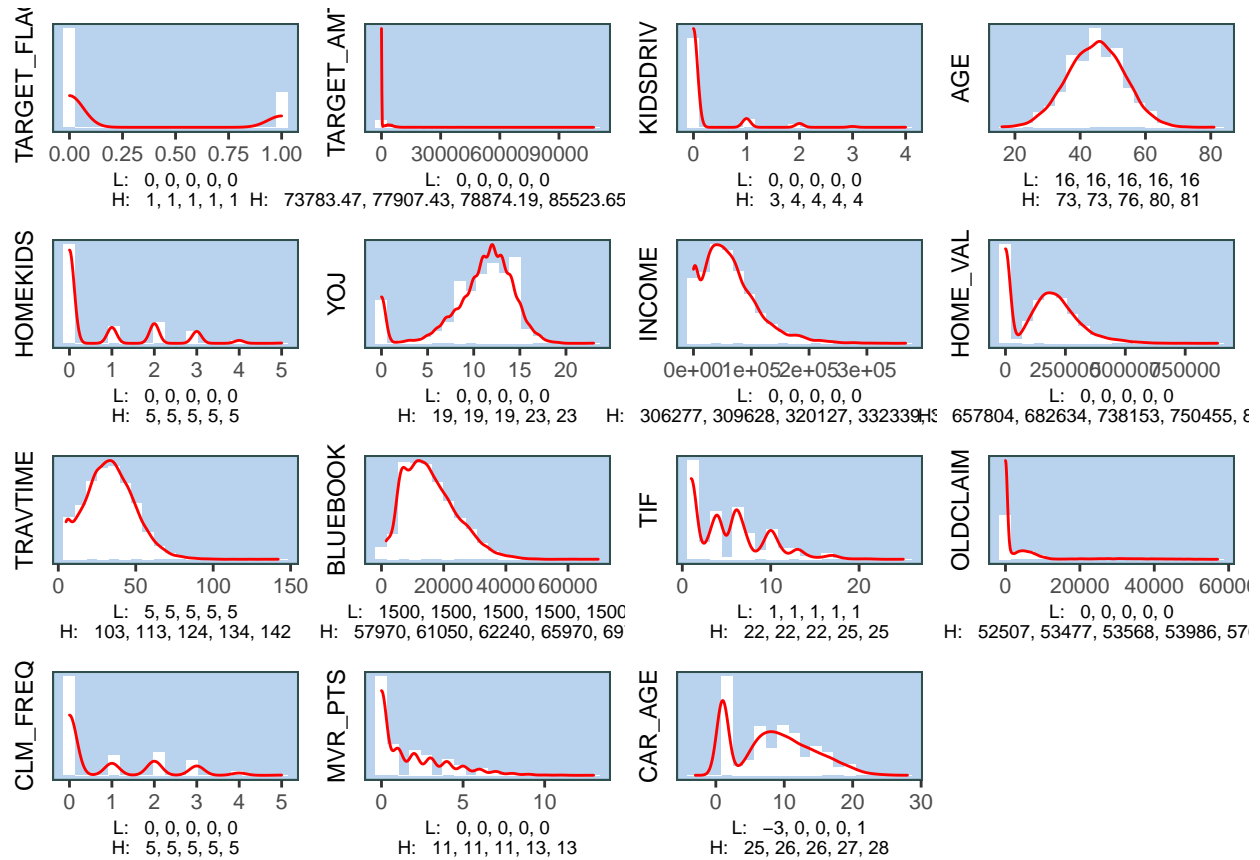
1. Boxplots

The boxplots show significant skewness and outliers.



2. Histograms

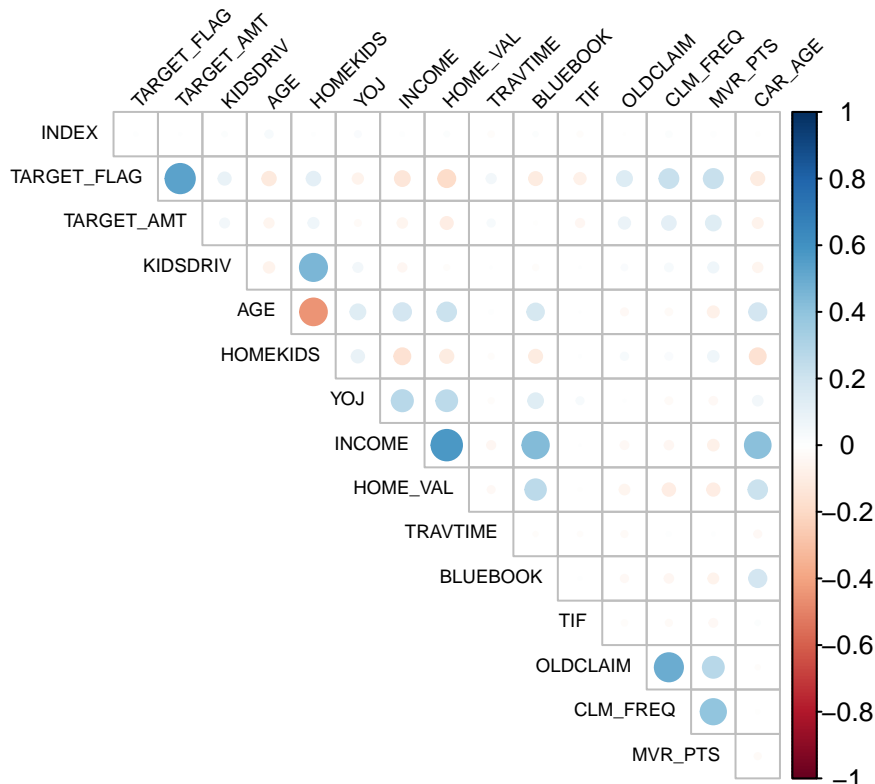
We can see from the histograms a number of opportunities to perform log and other transformations.



Many of the variables are highly skewed, particularly TARGET_AMT. The level of outliers is very high.

C. Multicollinearity The chart below shows multicollinearity for numerical variables only. There are no surprises here - older people tend not to have children at home, income and home value are related, etc. Multicollinearity does not present offhand as a major issue.

Heatmap for Multicollinearity Analysis



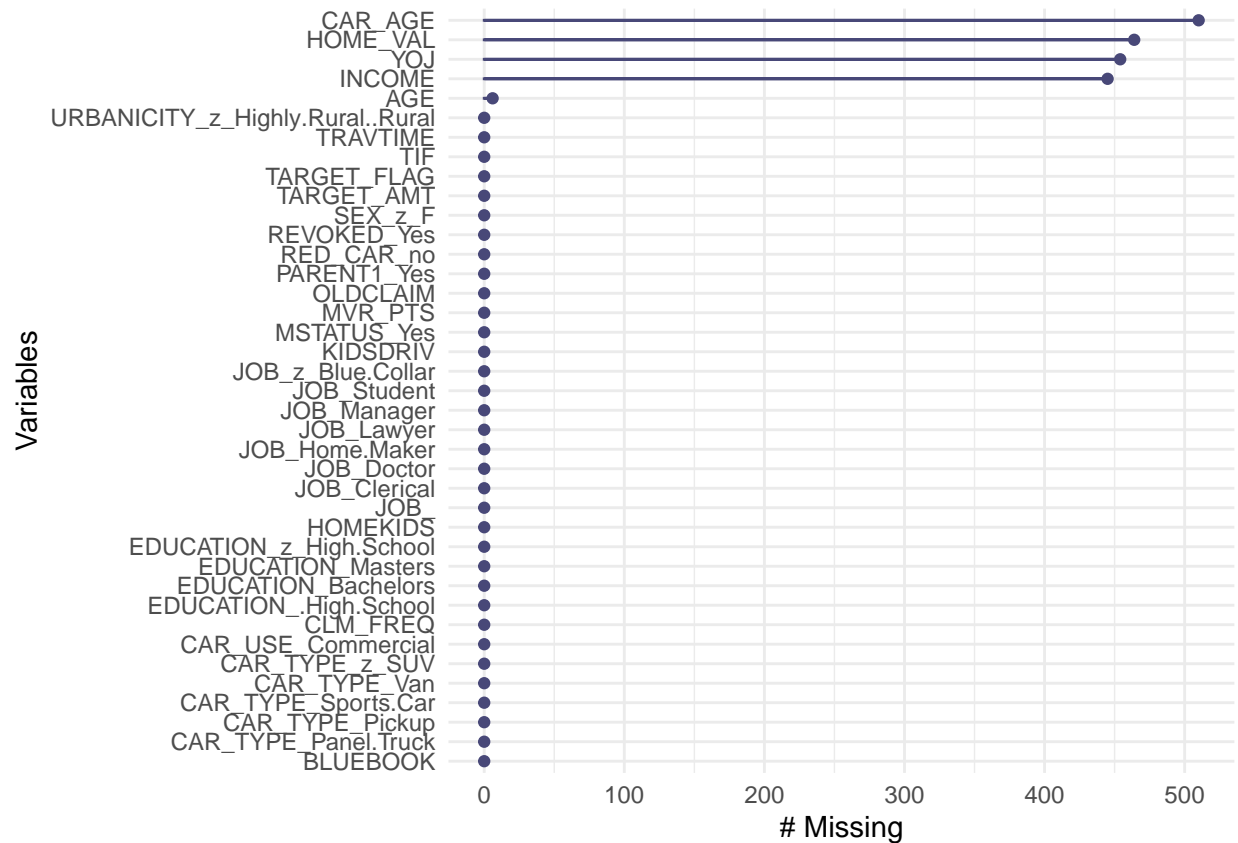
2. Data Preparation

A. Create Dummy Variables We create dummy variables from the character variables in the database.

B. Address Missing Values We consider the missing values. Over 20% of the records have missing values.

We disregard missing values in character columns because these NAs were isolated out in their own columns when we dummified the data. We convert the 0s in INCOME and HOME_VAL to NA since 0 is implausible. We create flags to track the NAs for the columns with the most significant NAs - INCOME, HOME_VAL, CAR_AGE, and YOJ. Finally we use MICE to populate the missing values.

```
## [[1]]
```



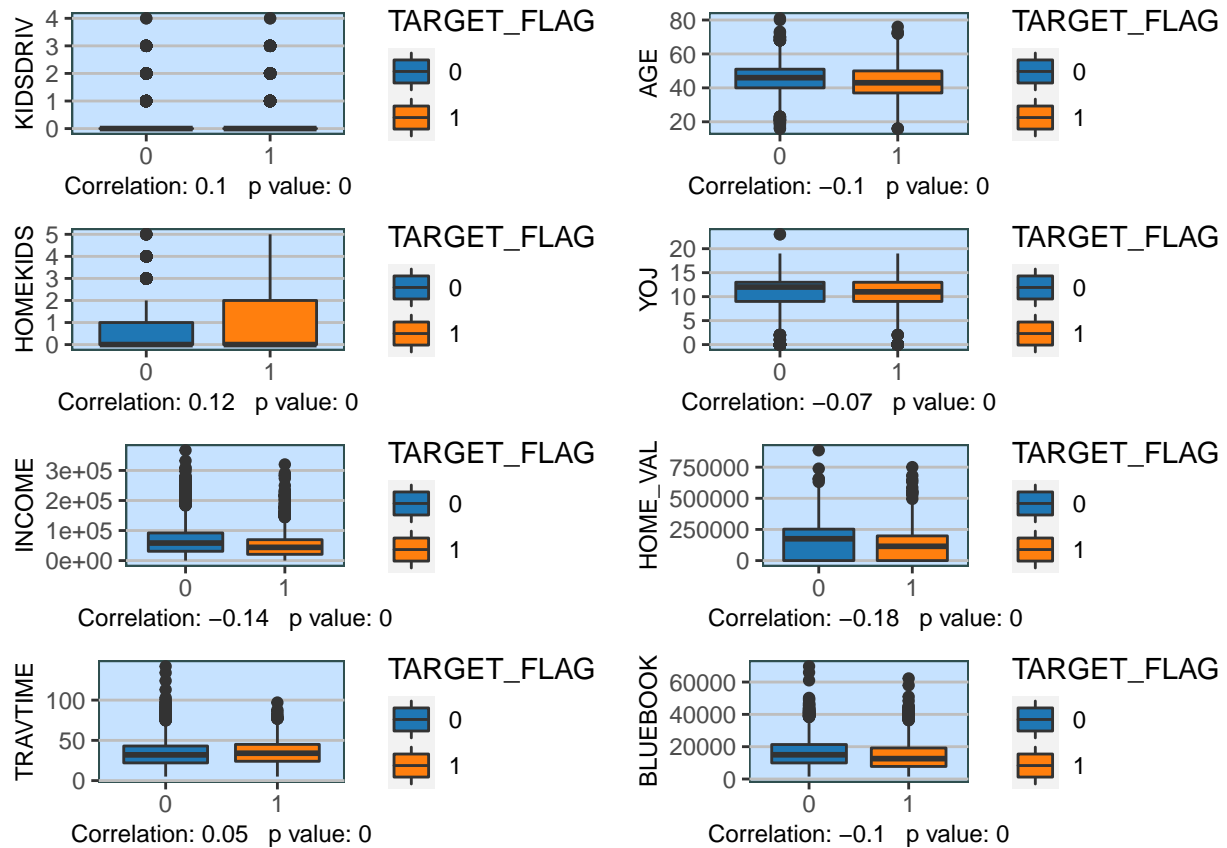
####. C. Perform Transformations

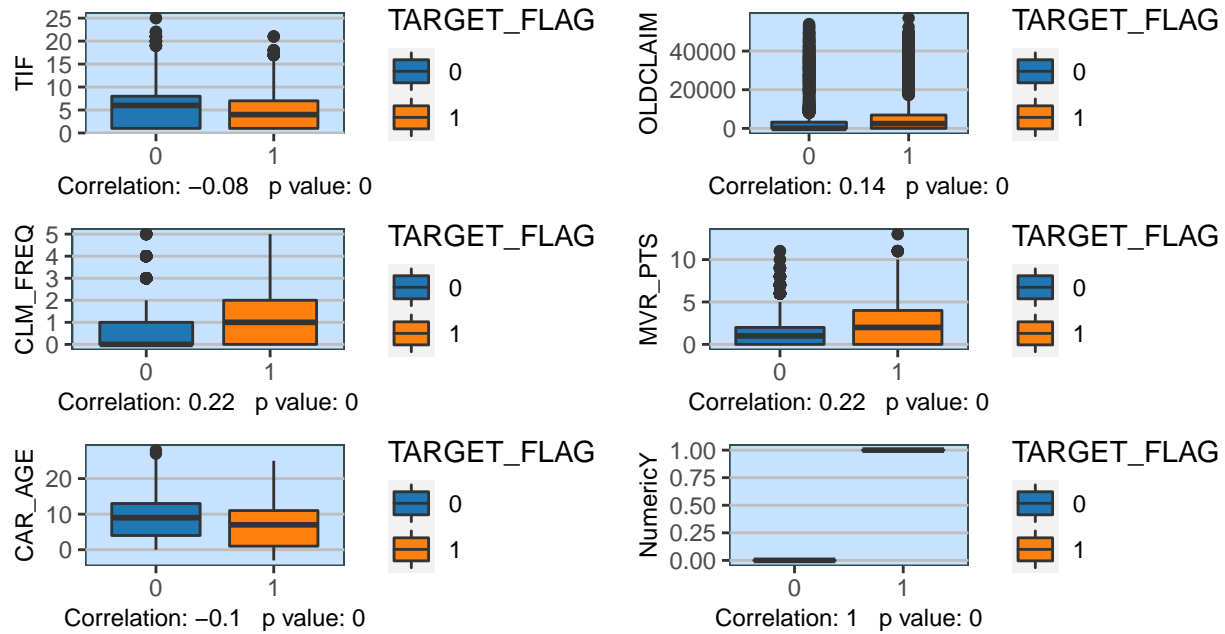
We perform log and other transformations, as well as add an interaction term, to the analysis. These transformations are based on an examination of the distributions of the independent variables. They include:

```
ageSquared
yojSquared
income_log
homeval_log
travtime_log
bluebook_log
carage_log
oldclaim_log
clm_freq_log
mvr_pts_log
tif_log
kidsdriv_log
homekids_log
inter (interaction term = KIDSDRIV*AGE
```

3. Predict TARGET_FLAG

A. Explore relationships We can see from the boxplots run on the original numeric variables against TARGET_FLAG that the correlations are quite low.





B. Create Models

Create Model 1 - a base model with the original numeric variables.

```
##
## Call:
## glm(formula = fla, family = "binomial", data = df)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.0236  -0.7694  -0.5736   0.9104   2.6679
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.351e-01  2.109e-01  -2.063  0.03910 *
## KIDSDRIV     2.484e-01  6.211e-02   3.999  6.35e-05 ***
## AGE         -1.042e-02  4.047e-03  -2.574  0.01006 *
## HOMEKIDS     7.194e-02  3.355e-02   2.144  0.03204 *
## YOJ         -5.932e-03  7.734e-03  -0.767  0.44309
## INCOME      -2.767e-07  9.289e-07  -0.298  0.76576
## HOME_VAL    -2.502e-06  2.932e-07  -8.532  < 2e-16 ***
## TRAVTIME     7.828e-03  1.885e-03   4.153  3.28e-05 ***
## BLUEBOOK    -1.260e-05  4.135e-06  -3.047  0.00231 **
## TIF         -4.439e-02  7.604e-03  -5.838  5.29e-09 ***
```

```
## OLDCLAIM      6.626e-06  3.501e-06   1.893  0.05842 .
## CLM_FREQ      2.683e-01  2.866e-02   9.361  < 2e-16 ***
## MVRPTS        1.397e-01  1.410e-02   9.910  < 2e-16 ***
## CAR_AGE       -2.387e-02  5.987e-03  -3.987  6.68e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
## Null deviance: 7445.1 on 6447 degrees of freedom
## Residual deviance: 6674.3 on 6434 degrees of freedom
## (1713 observations deleted due to missingness)
## AIC: 6702.3
##
## Number of Fisher Scoring iterations: 4

## [[1]]
## (Intercept)      KIDSDRIV      AGE      HOMEKIDS      YOJ
## -4.350637e-01  2.484120e-01 -1.041761e-02  7.193553e-02 -5.931651e-03
## INCOME      HOME_VAL      TRAVTIME      BLUEBOOK      TIF
## -2.767441e-07 -2.501621e-06  7.828270e-03 -1.259763e-05 -4.438976e-02
## OLDCLAIM      CLM_FREQ      MVRPTS      CAR_AGE
## 6.626042e-06  2.682667e-01  1.397392e-01 -2.387229e-02
##
## [[2]]
## [1] 0
##
## [[3]]
## [1] 0
```

Most of the predictors are significant. This may in part be due to the fact that there are over 8,000 predictions. The model has an AIC of 6702. Almost 20% of the records are missing so the model is not necessarily reliable.

We run the model 100 times at a 80/20 split. The base model has an accuracy of .748, an AIC of 5266 and an AUC of .716.

Create Model 2 - a model with missing values addressed and all of the transformed and added variables included.

```
##
## Call:
## glm(formula = fla, family = "binomial", data = df)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.7164  -0.6978  -0.3849   0.5989   3.0770
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    9.370e+00  3.577e+00   2.620 0.008796 **
## KIDSDRIV     -1.031e+00  5.121e-01  -2.013 0.044160 *
## AGE         -1.962e-01  2.646e-02  -7.416 1.21e-13 ***
```

## HOMEKIDS	-2.136e-01	1.537e-01	-1.390	0.164430	
## YOJ	-7.017e-02	3.271e-02	-2.145	0.031931	*
## INCOME	-1.059e-05	3.245e-06	-3.263	0.001101	**
## HOME_VAL	4.376e-06	2.282e-06	1.917	0.055225	.
## TRAVTIME	4.900e-03	5.456e-03	0.898	0.369170	
## BLUEBOOK	4.828e-06	1.092e-05	0.442	0.658465	
## TIF	-7.933e-03	2.344e-02	-0.338	0.735042	
## OLDCLAIM	-2.782e-05	5.608e-06	-4.961	7.00e-07	***
## CLM_FREQ	1.874e-01	2.635e-01	0.711	0.476965	
## MVR_PTS	1.133e-01	4.321e-02	2.622	0.008736	**
## CAR_AGE	8.331e-03	1.965e-02	0.424	0.671562	
## PARENT1_Yes	2.036e-01	1.217e-01	1.673	0.094244	.
## MSTATUS_Yes	-6.146e-01	8.769e-02	-7.009	2.40e-12	***
## SEX_z_F	-4.600e-02	1.135e-01	-0.405	0.685361	
## EDUCATION_.High.School	1.776e-01	2.212e-01	0.803	0.421930	
## EDUCATION_Bachelors	-1.565e-01	1.875e-01	-0.835	0.403714	
## EDUCATION_Masters	-5.231e-02	1.559e-01	-0.336	0.737231	
## EDUCATION_z_High.School	2.258e-01	2.033e-01	1.111	0.266763	
## JOB_	-1.751e-01	1.797e-01	-0.974	0.330022	
## JOB_Clerical	2.385e-01	1.274e-01	1.872	0.061239	.
## JOB_Doctor	-5.960e-01	2.775e-01	-2.148	0.031718	*
## JOB_Home.Maker	-1.446e-01	1.759e-01	-0.822	0.411063	
## JOB_Lawyer	-5.107e-02	1.694e-01	-0.301	0.763081	
## JOB_Manager	-7.251e-01	1.333e-01	-5.439	5.36e-08	***
## JOB_Student	-2.660e-01	1.775e-01	-1.498	0.134063	
## JOB_z_Blue.Collar	2.029e-01	1.212e-01	1.674	0.094202	.
## CAR_USE_Commercial	7.684e-01	9.299e-02	8.263	< 2e-16	***
## CAR_TYPE_Panel.Truck	5.206e-01	1.672e-01	3.113	0.001852	**
## CAR_TYPE_Pickup	5.876e-01	1.019e-01	5.765	8.17e-09	***
## CAR_TYPE_Sports.Car	8.974e-01	1.325e-01	6.772	1.27e-11	***
## CAR_TYPE_Van	6.546e-01	1.281e-01	5.110	3.22e-07	***
## CAR_TYPE_z_SUV	7.259e-01	1.130e-01	6.422	1.35e-10	***
## RED_CAR_no	3.971e-02	8.747e-02	0.454	0.649852	
## REVOKED_Yes	9.685e-01	9.406e-02	10.297	< 2e-16	***
## URBANICITY_z_Highly.Rural..Rural	-2.369e+00	1.143e-01	-20.735	< 2e-16	***
## YOJ_NA	-5.498e-02	1.282e-01	-0.429	0.668095	
## INCOME_NA	-1.351e-01	1.274e-01	-1.061	0.288885	
## CAR_AGE_NA	-1.530e-01	1.193e-01	-1.283	0.199554	
## HOME_VAL_NA	-2.590e-01	7.785e-02	-3.327	0.000878	***
## ageSquared	2.107e-03	2.908e-04	7.245	4.33e-13	***
## yojSquared	3.284e-03	1.750e-03	1.876	0.060595	.
## income_log	-5.300e-02	6.199e-02	-0.855	0.392558	
## homeval_log	-2.485e-01	3.413e-01	-0.728	0.466634	
## travtime_log	2.947e-01	1.542e-01	1.911	0.055958	.
## bluebook_log	-3.583e-01	1.246e-01	-2.877	0.004015	**
## carage_log	-8.735e-02	1.221e-01	-0.716	0.474288	
## oldclaim_log	9.244e-02	4.254e-02	2.173	0.029783	*
## clm_freq_log	-4.504e-01	7.973e-01	-0.565	0.572122	
## mvr_pts_log	-7.221e-02	1.293e-01	-0.558	0.576596	
## tif_log	-2.875e-01	1.344e-01	-2.138	0.032482	*
## kidsdriv_log	1.452e+00	6.156e-01	2.359	0.018334	*
## homekids_log	4.649e-01	3.446e-01	1.349	0.177373	
## inter	1.652e-02	8.421e-03	1.962	0.049747	*
## ---					

```

## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##    Null deviance: 9415.3  on 8159  degrees of freedom
## Residual deviance: 7156.9  on 8104  degrees of freedom
##    (1 observation deleted due to missingness)
## AIC: 7268.9
##
## Number of Fisher Scoring iterations: 5

## [[1]]
##              (Intercept)              KIDSDRIV
##              9.370156e+00             -1.030672e+00
##              AGE              HOMEKIDS
##             -1.962298e-01             -2.136347e-01
##              YOJ              INCOME
##             -7.016521e-02             -1.059150e-05
##              HOME_VAL              TRAVTIME
##              4.375603e-06              4.899993e-03
##              BLUEBOOK              TIF
##              4.827554e-06             -7.932672e-03
##              OLDCLAIM              CLM_FREQ
##             -2.782041e-05              1.873694e-01
##              MVR PTS              CAR_AGE
##              1.132953e-01              8.331462e-03
##              PARENT1_Yes              MSTATUS_Yes
##              2.035901e-01             -6.146059e-01
##              SEX_z_F              EDUCATION_.High.School
##             -4.600387e-02              1.776204e-01
##              EDUCATION_Bachelors              EDUCATION_Masters
##             -1.565376e-01             -5.231392e-02
##              EDUCATION_z_High.School              JOB_
##              2.257944e-01             -1.750627e-01
##              JOB_Clerical              JOB_Doctor
##              2.385014e-01             -5.960141e-01
##              JOB_Home.Maker              JOB_Lawyer
##             -1.446106e-01             -5.107468e-02
##              JOB_Manager              JOB_Student
##             -7.251163e-01             -2.659940e-01
##              JOB_z_Blue.Collar              CAR_USE_Commercial
##              2.028571e-01              7.683794e-01
##              CAR_TYPE_Panel.Truck              CAR_TYPE_Pickup
##              5.205814e-01              5.875796e-01
##              CAR_TYPE_Sports.Car              CAR_TYPE_Van
##              8.974411e-01              6.545880e-01
##              CAR_TYPE_z_SUV              RED_CAR_no
##              7.259328e-01              3.970691e-02
##              REVOKED_Yes URBANICITY_z_Highly.Rural..Rural
##              9.684759e-01             -2.369379e+00
##              YOJ_NA              INCOME_NA
##             -5.497836e-02             -1.350652e-01
##              CAR_AGE_NA              HOME_VAL_NA
##             -1.529934e-01             -2.590234e-01

```

```
##          ageSquared          yojSquared
##      2.106869e-03      3.283852e-03
##      income_log      homeval_log
##     -5.299784e-02     -2.484832e-01
##      travtime_log      bluebook_log
##      2.946639e-01     -3.583411e-01
##      carage_log      oldclaim_log
##     -8.734651e-02      9.244048e-02
##      clm_freq_log      mvr_pts_log
##     -4.504258e-01     -7.221226e-02
##      tif_log      kidsdriv_log
##     -2.874765e-01      1.451993e+00
##      homekids_log      inter
##      4.648545e-01      1.652350e-02
##
## [[2]]
## [1] 0
##
## [[3]]
## [1] 0
```

In the “kitchen sink” model many of the predictors are not significant. This model risks overprediction. AIC has increased to 7269.

We run the model 100 times at a 80/20 split. The kitchen sink model has an accuracy of .79, an AIC of 5723 and an AUC of .815. Despite possible overprediction, this model offers significant improvement.

Create Model 3 - Use backward elimination to choose the best model: We use backward elimination to achieve a better fit and lower AIC.

```
##
## Call:
## glm(formula = fla, family = "binomial", data = df)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -2.5304  -0.7393  -0.4235   0.7285   2.8625
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    -9.854e-01  1.277e-01  -7.716 1.20e-14 ***
## INCOME         -7.501e-06  7.651e-07  -9.805 < 2e-16 ***
## TRAVTIME        1.395e-02  1.837e-03   7.594 3.11e-14 ***
## BLUEBOOK       -1.321e-05  4.388e-06  -3.010 0.00261 **
## TIF            -5.591e-02  7.193e-03  -7.773 7.69e-15 ***
## OLDCLAIM       -4.926e-06  3.875e-06  -1.271 0.20362
## PARENT1_Yes     7.579e-01  8.255e-02   9.181 < 2e-16 ***
## SEX_z_F        -2.041e-01  8.798e-02  -2.319 0.02038 *
## JOB_Manager    -8.476e-01  1.041e-01  -8.139 4.00e-16 ***
## CAR_USE_Commercial  9.257e-01  6.478e-02  14.291 < 2e-16 ***
## CAR_TYPE_Pickup   3.612e-01  8.695e-02   4.155 3.26e-05 ***
## CAR_TYPE_Sports.Car  9.408e-01  1.232e-01   7.639 2.19e-14 ***
## CAR_TYPE_z_SUV    6.999e-01  1.049e-01   6.671 2.54e-11 ***
```

```

## URBANICITY_z_Highly.Rural..Rural -2.342e+00 1.119e-01 -20.933 < 2e-16 ***
## HOME_VAL_NA -4.871e-01 6.124e-02 -7.954 1.80e-15 ***
## oldclaim_log 7.761e-02 8.507e-03 9.123 < 2e-16 ***
## inter 9.684e-03 1.208e-03 8.018 1.08e-15 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
## Null deviance: 9418.0 on 8160 degrees of freedom
## Residual deviance: 7553.3 on 8144 degrees of freedom
## AIC: 7587.3
##
## Number of Fisher Scoring iterations: 5

## [[1]]
## (Intercept) INCOME
## -9.853727e-01 -7.501381e-06
## TRAVTIME BLUEBOOK
## 1.395330e-02 -1.320759e-05
## TIF OLDCLAIM
## -5.590842e-02 -4.925857e-06
## PARENT1_Yes SEX_z_F
## 7.579452e-01 -2.040512e-01
## JOB_Manager CAR_USE_Commercial
## -8.475772e-01 9.257383e-01
## CAR_TYPE_Pickup CAR_TYPE_Sports.Car
## 3.612426e-01 9.407812e-01
## CAR_TYPE_z_SUV URBANICITY_z_Highly.Rural..Rural
## 6.999295e-01 -2.341684e+00
## HOME_VAL_NA oldclaim_log
## -4.870927e-01 7.760677e-02
## inter
## 9.684202e-03
##
## [[2]]
## [1] 0
##
## [[3]]
## [1] 0

```

The refined model has an AIC of 7587. This is not an improvement.

We run the model 100 times at a 80/20 split. The refined model has an accuracy of .77, an AIC of 5805 and an AUC of .79. Despite lower AIC, this model does not predict the data as well. Again, the AIC does not fall and the model does not predict as well.

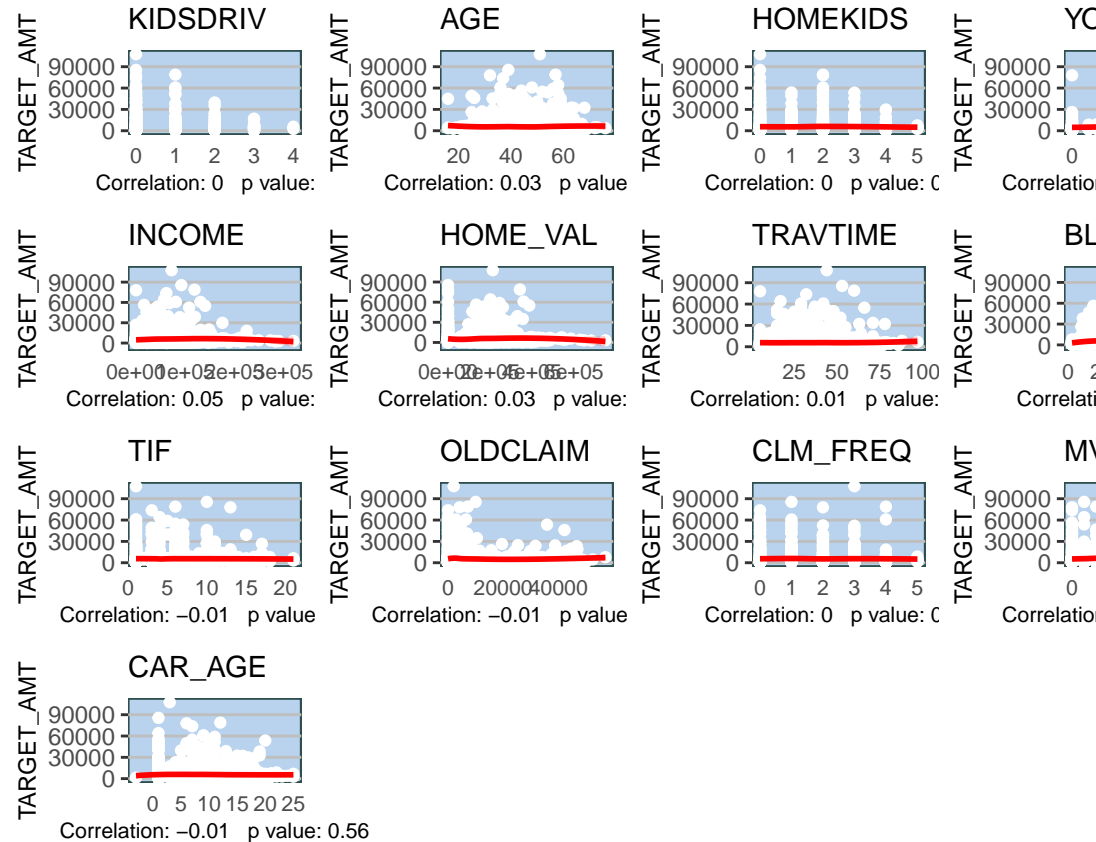
4. Select model Below is a table of results:

	Base Model	Kitchen Sink Model	Refined Model
Accuracy	0.748	0.790	0.770
AIC	5266.000	5723.000	5805.000

	Base Model	Kitchen Sink Model	Refined Model
AUC	0.716	0.815	0.795

Despite the apparent superior predictability of the second model, we choose the third. This model has a lower AIC and is more interpretable and coherent than the second model.

4. Predict TARGET_AMT



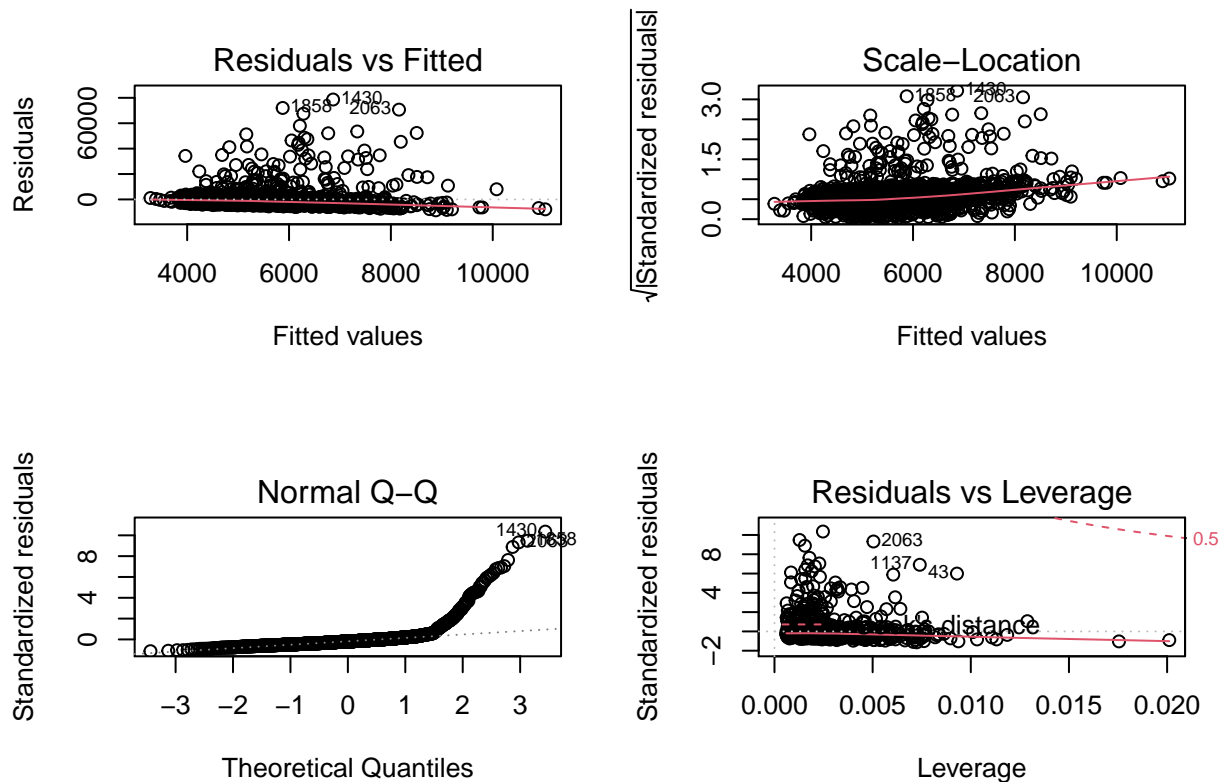
A. Explore Relationships

B. Create models

Create Model 1 - the base model with the original numeric variables.

```
##
## Call:
## lm(formula = TARGET_AMT ~ BLUEBOOK + MVR_PTS + CAR_AGE, data = df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -8566  -3086  -1519    287   78658
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept) 4021.48678 459.06110 8.760 < 2e-16 ***
## BLUEBOOK    0.12199 0.02243 5.439 6.15e-08 ***
## MVR_PTS     109.75419 70.96899 1.547 0.122
## CAR_AGE     -50.90781 34.04373 -1.495 0.135
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7605 on 1699 degrees of freedom
## Multiple R-squared:  0.01821, Adjusted R-squared:  0.01648
## F-statistic: 10.51 on 3 and 1699 DF, p-value: 7.581e-07
##
## [1] "VIF Analysis"
## BLUEBOOK MVR_PTS CAR_AGE
## 1.037901 1.005499 1.036879
```



```
## NULL
```




The base model shows a number of issues with the residuals including heteroskedasticity and particularly non-normal residuals. We cannot use this model without some transformation.

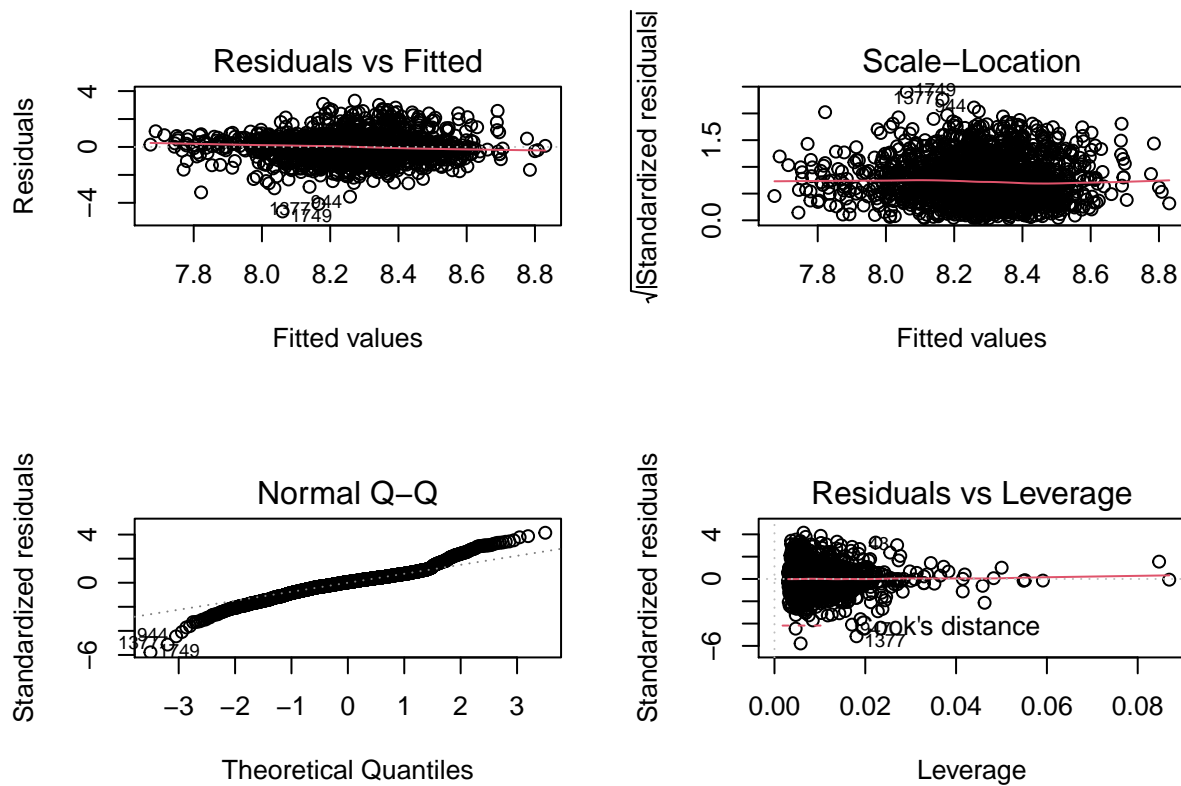
Create Model 2 - a model with missing values addressed and all of the transformed and added variables included. We also take the log of TARGET_AMT. We find the model with the highest AIC using stepAIC from the MASS package in R.

```
##
## Call:
## lm(formula = TARGET_AMT ~ KIDSDRIV + INCOME + BLUEBOOK + OLDCLAIM +
##   CLM_FREQ + CAR_AGE + MSTATUS_Yes + EDUCATION_.High.School +
##   EDUCATION_Bachelors + EDUCATION_Masters + EDUCATION_z_High.School +
##   CAR_TYPE_Panel.Truck + REVOKED_Yes + homeval_log + bluebook_log +
##   carage_log + mvr_pts_log + inter, data = df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -4.6176 -0.4021  0.0342  0.3988  3.3141
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   4.665e+00  9.932e-01   4.696 2.82e-06 ***
## KIDSDRIV      -3.378e-01  1.693e-01  -1.995  0.04616 *
## INCOME        -1.943e-06  9.973e-07  -1.949  0.05148 .
## BLUEBOOK      -1.227e-05  6.129e-06  -2.002  0.04539 *
## OLDCLAIM       4.793e-06  2.344e-06   2.045  0.04101 *
```

```

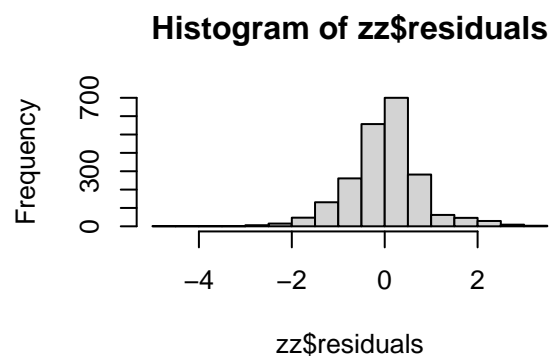
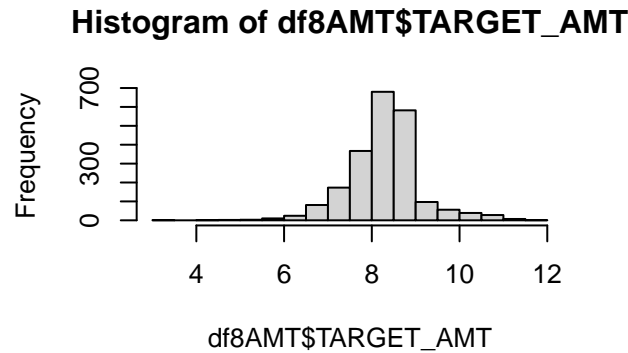
## CLM_FREQ          -3.893e-02  1.630e-02  -2.388  0.01704 *
## CAR_AGE           -2.693e-02  1.255e-02  -2.146  0.03197 *
## MSTATUS_Yes       -8.359e-02  3.493e-02  -2.393  0.01681 *
## EDUCATION_.High.School -2.633e-01  1.118e-01  -2.356  0.01855 *
## EDUCATION_Bachelors -2.908e-01  9.546e-02  -3.047  0.00234 **
## EDUCATION_Masters  -1.310e-01  9.008e-02  -1.455  0.14586
## EDUCATION_z_High.School -2.579e-01  1.034e-01  -2.493  0.01273 *
## CAR_TYPE_Panel.Truck  1.635e-01  7.864e-02   2.079  0.03777 *
## REVOKED_Yes       -9.493e-02  5.343e-02  -1.777  0.07578 .
## homeval_log        1.223e-01  8.066e-02   1.516  0.12962
## bluebook_log       2.757e-01  6.974e-02   3.953  7.96e-05 ***
## carage_log         1.483e-01  7.448e-02   1.991  0.04664 *
## mvr_pts_log        5.922e-02  2.315e-02   2.559  0.01058 *
## inter              7.489e-03  3.852e-03   1.944  0.05199 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.8011 on 2133 degrees of freedom
## Multiple R-squared:  0.03496,    Adjusted R-squared:  0.02681
## F-statistic: 4.292 on 18 and 2133 DF,  p-value: 3.959e-09
##
## [1] "VIF Analysis"
##          KIDSDRIV          INCOME          BLUEBOOK
##          37.786241          5.589714          8.678143
##          OLDCLAIM          CLM_FREQ          CAR_AGE
##          1.862833          1.388044          15.925940
##          MSTATUS_Yes EDUCATION_.High.School EDUCATION_Bachelors
##          1.022736          6.152726          5.614654
##          EDUCATION_Masters EDUCATION_z_High.School CAR_TYPE_Panel.Truck
##          3.506406          8.351117          1.573691
##          REVOKED_Yes          homeval_log          bluebook_log
##          1.562762          4.746742          7.136432
##          carage_log          mvr_pts_log          inter
##          12.705195          1.108395          37.848324

```



```
## NULL

## $breaks
## [1] 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
## [16] 10.5 11.0 11.5 12.0
##
## $counts
## [1] 1 0 1 2 3 10 24 81 173 367 680 582 97 56 39 28 7 1
##
## $density
## [1] 0.000929368 0.000000000 0.000929368 0.001858736 0.002788104 0.009293680
## [7] 0.022304833 0.075278810 0.160780669 0.341078067 0.631970260 0.540892193
## [13] 0.090148699 0.052044610 0.036245353 0.026022305 0.006505576 0.000929368
##
## $mids
## [1] 3.25 3.75 4.25 4.75 5.25 5.75 6.25 6.75 7.25 7.75 8.25 8.75
## [13] 9.25 9.75 10.25 10.75 11.25 11.75
##
## $xname
## [1] "df8AMT$TARGET_AMT"
##
## $equidist
## [1] TRUE
##
## attr(,"class")
## [1] "histogram"
```



The adjusted-R-Squared is very low, despite the number of significant variables and significance overall. The distribution of the residuals improves but the tails are still an issue. There still appear to be a large number of outliers.

Create Model 3 - a model using robust regression. If we remove a large number of outliers from the data our results improve dramatically. However, this must be true by definition as the variance will decrease when outliers are removed. A better way to discover the underlying pattern beneath the outliers (and to check that pattern against our second model) is robust regression.

4. Select model The following table summarizes the RSE and RSME when using robust regression on the base and refined models:

```
## [1] 7605.298
## [1] 2334.499
## [1] 0.8010519
## [1] 0.5732322
## [1] 0.5844755
```

	Base Model	Refined Model
Standard - Sigma	7605.000	0.800
Standard - Adj-R ²	0.035	0.239
Robust - Sigma	2334.000	0.573

It should be noted that the refined model sigma is not comparable to the base model because we have taken the log of the dependent variable. The refined model clearly outperforms the base model. In addition, the robust model clearly outperforms the standard model. We therefore choose the robust refined model.

5. Conclusion

We examined 466 records of town statistics to create a predictive model of whether crime rates were above the median or not. We used a logistic regression to do this, testing our models on an 80/20 split 100 times and taking the average accuracy and AIC.

Several enhancements to the model increased accuracy and lowered AIC. First, some predictors were transformed with the log or square to improve fit. Second, dummy variables were introduced to capture the fact that highly industrial areas appeared to operate by a different logic than mixed use areas. interaction terms to model this phenomenon did not improve the model. The final model 93% accurate.