BAX 452 Machine Learning

An Analysis for Car Crash and Implication for Municipal Management

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Executive Summary

This report aims to analyze the Car Crash Dataset provided by the City of Cary in North Carolina, to identify factors that contribute to car crashes and to gain municipal management insights. The car crash dataset includes information such as the severity of the car crash, time, road condition, and traffic control condition. We analyzed the dataset by EDA and a series of ML methods. It is worth mentioning that the focus of our analysis is not to predict the severity of future car crashes, but to identify and interpret how and why different factors contribute to car crashes and provide insights for municipal management.

Here are some key findings for our analysis:

- Interaction road feature, signal and stop traffic control, and curve road add to the Crash Score.
- Daytime has the highest Crash_Score, followed by late-early and overnight.
- The relative impact for interaction is lower for signal stop, and the relative impact for the work area is higher for late early.

Here are the suggestions based on our findings:

- The intersection has complex traffic conditions as well as a significantly higher Crash_Score. Thus, municipal management should consider signal and stop, two-way protected median, and lighting as traffic control and road management practice.
- Time of day largely affects the Crash_Score. Thus, municipal management could try different practices for different times, especially in the work area during rush hour.
- Municipal management should provide better lighting during night and more road management for other roads.
- It is of equal importance to improving the road condition as well as to raising awareness for safety. Municipal management could consider adding more signs and slogans as reminders.

Introduction

The traffic accident is a top ten cause of death. Statistics show that every year, there are approximately 1.37 billion people die due to traffic accidents, which accounts for about 2.2% of all the death. It has always been a focus of municipal management. However, there is no systematic and scientific way to analyze traffic accidents. In order to address this issue, the City of Cary in North Carolina provided a Car Crash Dataset, which records all of the car crashes in 2014 – 2019 and includes the severity of accidents and a series of factors could contribute to accidents, for example, time, road condition, and traffic control condition. We will use a series of techniques to develop predictive ML models and to investigate how different factors affect car crashes. Traditionally, municipal management tends to apply qualitative rather than quantitative analysis, as a result, our analysis will be the first and one of a kind. Hopefully, data analytics could identify and interpret factors that are overlooked or underestimated by traditional methods.

Data Characteristics

The dataset is provided by the Department of Transportation in the City of Cary in North Carolina, and it includes information for all of the car crashes in 2014 – 2019 with 14 dimensions and 23137 observations. The dependent variable Crash_Score is a numeric variable, which measures the extent of the car crashes, based on a series of factors, such as the number of vehicles involved, and the number of injuries or fatalities. The distributions of Crash_Score and the log of Crash_Score, it is shown that the distribution of the Crash_Score is right-skewed, with a median of 5.660, and a max of 53.070, which indicate that most car crashes are slight car crashes and a small proportion are severe car crashes. The log of Crash_Score is left-skewed (Figure 1).

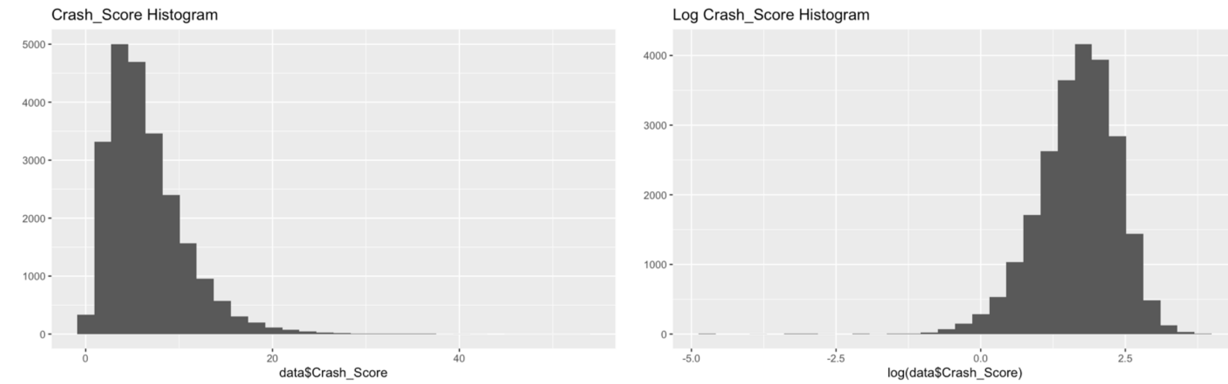


Figure 1 Crash_Score Histogram and the log of Crash_Score Histogram

Most of the independent variables are categorical variables, including year, month, time, road conditions, traffic control conditions, and weather. Here are some findings according to the EDA of independent variables (Appendix 1, 2, 3):

- There is no significant change over the years (from 2014-2019), nor significant change over the year (from Jan. to Dec.), in other words, no seasonality for car crashes.
- The crash score is affected by the time of the day, the median score is higher during the daytime (8 am to 8 pm), the median score is significantly lower for time 1 (midnight to 4 am), and relatively lower for time 2 (4 am to 8 am) and time 6 (8 pm to midnight).
- For the road feature, none traffic control has most car crashes, and the intersection has a significantly higher median score.
- For the road character, the straight level has a significantly higher median score.
- For the road class, the state highway has the most car crashes as well as the highest score.
- Surprisingly, for light, daylight has the highest median score, followed by dusk and down, and then dark light and dark not light.
- For the weather, rain and snow have a relatively higher median score, other has the lowest median score.

- Surprisingly, for the traffic control, signal and stop sign have the highest median score none has the lowest median score.
- None work area has more car crashes, while the work area has a higher median score.

We fitted a model with the unprocessed dataset, the in-sample R2 is relatively high, but the out-of-sample R2 is low. It seems that the model tends to overfit. Based on our observations, we decided to do a feature transformation and to combine some levels of the factors. Feature transformation could reduce the complexity of the model and prevent overfitting. Here is the process (Table 1):

Feature	Levels with Transformation
Time_of_Day	DAYTIME, OVERNIGHT, LATE-EARLY
Rd_Feature	INTERSECTION, OTHER
Rd_Character	STRAIGHT, CURVE
Rd_Surface	ASPHALT, OTHER
Weather	CLEAR-CLOUDY, RAIN-SNOW, OTHER
Traffic_Control	SIGNAL-STOP, OTHER

Table 1: Feature Transformation

Model Selection, Evaluation, and Interpretation

We used a series of techniques to select and evaluate generalized linear models (GLMs), and then interpret the model by the coefficients of variables. Although the predictive performance is not the main focus of our model, we used RMSE and out-of-sample R2 as the main performance metrics for us to select and evaluate models. The RMSE indicates how well the model can predict dependent variables in new datasets, and the out-of-sample R2 indicates how well the independent variables can interpret the variation for dependent variables in new datasets. We chose these metrics because we want the model to generalize insights, rather than overfit our dataset. Additionally, we applied 10-fold cross-validation, to utilize the dataset better and to provide performance metrics more accurately.

Model 0: GLM with the unprocessed dataset

$glm(Crash\_Score \sim ., gaussian(), data\ =\ data)$

As we mentioned, we fitted a model with the unprocessed dataset, and the in-sample R2 is significantly lower than the out-of-sample R2, indicating overfit. As a result, we did feature transformation and reduced the level of factors (Appendix 5).

Model 1: GLM with the processed dataset

$glm(Crash\_Score \sim ., gaussian(), data\ =\ data2)$

$glm(Crash\_Score \sim ., Gamma(log = "link"), data\ =\ data2)$

We fitted a model with the dataset after feature transformation, and both the RMSE and out-of-sample R2 are improved. Then, we benchmarked the performance for different distribution functions and link functions. As we mentioned, the distribution of Crash_Score is skewed, and Gamma distribution could be a better choice. After we investigated the visualizations (Figure 2, 3), it seems that with Gamma distribution and log link, the residuals have zero means and constant variables, and there are normal distributions for most residuals but not for extremes. As a result, we chose the model with Gamma distribution and log link, but we will also use Gaussian distribution for interpretation and intuition.

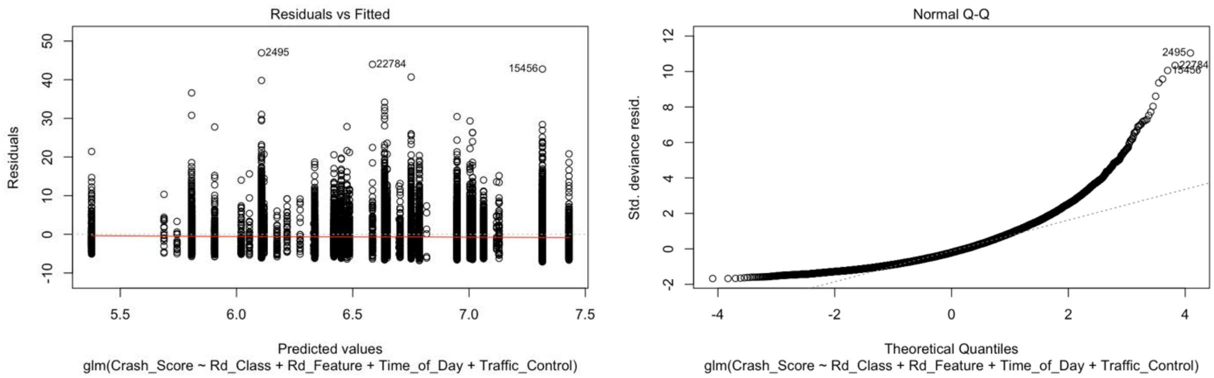


Figure 2: Visualization for GLM with Gaussian Distribution

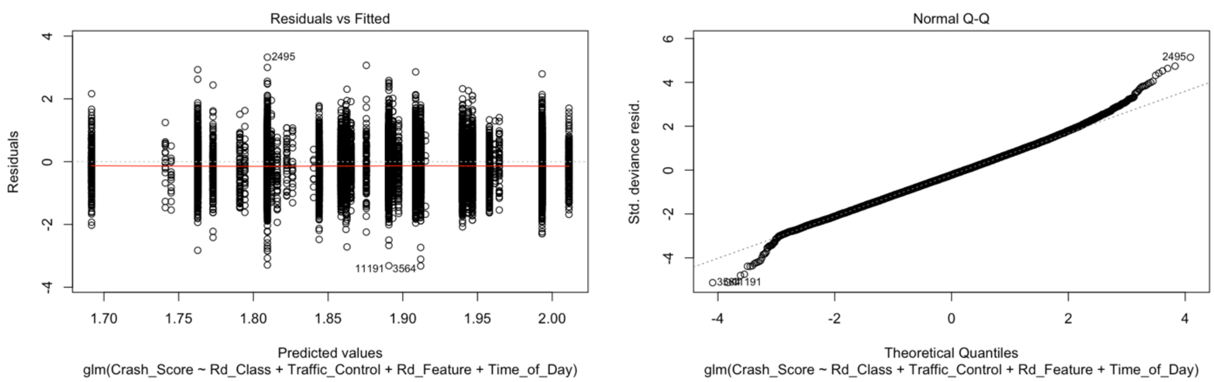


Figure 3: Visualization for GLM with Gamma Distribution and Log Link

Model 2: GLM with feature selection

$$glm(Crash\_Score \sim Rd\_Class + Traffic\_Control + Rd\_Feature + Time\_of\_Day, gaussian(), data = data2)$$

$$glm(Crash\_Score \sim Rd\_Class + Traffic\_Control + Rd\_Feature + Time\_of\_Day, Gamma(link = "log"), data = data2)$$

After feature transformation and model selection, the in-sample R2 is still significantly higher than the out-of-sample R2. This is when we consider a feature selection to reduce the complexity of the model and prevent overfitting. We chose BIC forward selection and LASSO regression. The former starts with no variables in the model and adds the variable that gives the most statistically significant improvement of the fit. The latter starts with all the variables in the model and shrinks the parameters with the penalty. Additionally, let us emphasize the focus of the analysis, to identify and interpret the key factors that contribute to car crashes. With this goal, we chose BIC over AIC for and the penalty is greater for each additional parameter; we also chose LASSO over ridge, for it could shrink the parameters of the useless variables to zero.

Although BIC forward selection and LASSO regression not significantly improve the model performance, it helps us identify key factors, including Rd_Class, Traffic_Control. Rd_Feature, and Time_of_Day. Here are some findings (Appendix 7):

- Interaction road feature adds to Crash_Score by approximately 0.36.
- Signal and stop traffic control add to Crash_Score by approximately 0.31.
- Daytime has the highest Crash_Score, followed by late-early, 0.30 lower, and overnight, 0.73 lower.

Model 3: GLM with interaction

$x_{train} = model.matrix(Crash\_Score \sim . + (.)\^{}2, trainData2)$

$y_{train} = trainData2\$Crash\_Score$

$glmnet(x\_train, y\_train, "gaussian", lambda\ =\ lasso.lam.min, alpha\ =\ 1)$

The GLM without interaction provides similar insights as EDA. We want to further improve the model and extract more insights from the dataset, so we decided to take interaction into consideration. Car crashes are complicated and different factors affect each other. In the following interaction plots, it is shown that there are interactions between factors (Figure 4).

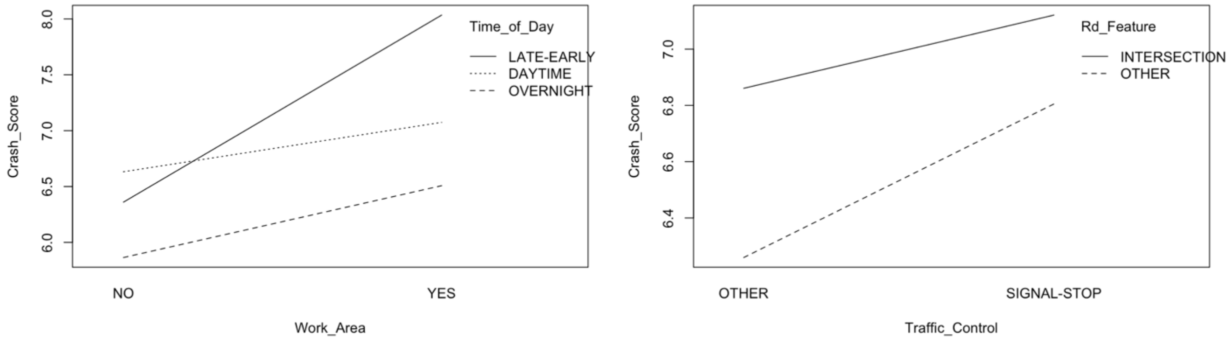


Figure 4: Interaction for different factors

To achieve this, we included all the variables and interactions and applied high dimension LASSO regression. Additionally, we used 10-fold cross-validation, to determine the penalty parameter, lambda, with minimum MSE (Figure 5).

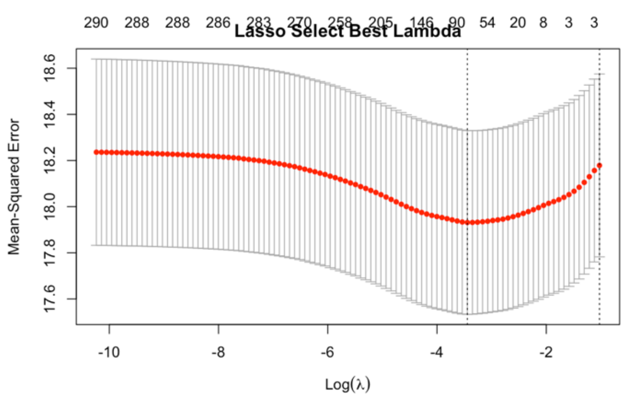


Figure 5: Selection for Lambda

With the high dimension LASSO regression, the in-sample R2 is significantly improved, and the out-of-sample R2 is further improved (Appendix 8). It helps us investigate how a single factor contributes to car crashes as well as how multiple factors interact, which provides insights that could be overlooked or underestimated by traditional methods. Here are some findings (Appendix 8):

- Although interaction, signal and stop both add to Crash_Score, the relative impact for interaction is lower for signal stop.

- The relative impact for the work area is higher for late early.
- The relative impact for light is higher during overnight.
- Road class and road condition interacts with each other. The ice, snow, slush road condition has relative high impact on other road than US and state highway.

Recommendation

Based on findings in Model 2 (Appendix 7) and Model 3 (Appendix 8), the following suggestions could be provided to the municipal management:

- The intersection has complex traffic conditions as well as a significantly higher Crash_Score. As a result, municipal management needs to pay additional attention to the intersection. Here are some recommended practices, signal and stop reduce the relative impact of the intersection, besides, two-way protected median and lighting could be considered.
- Time of day largely affects the Crash_Score, the highest is daytime, followed by late early and overnight. Municipal management could try different practices for different times. Additionally, time of day interacts with many factors. For example, more attention is needed in the work area during the rush hour.
- Bad lighting could largely contribute to Crash_Score during the night, and bad weather could largely contribute to Crash_Score for other roads than US and state highway. For example, there are more snowplows on highways than other roads during extreme weather. Thus, municipal management should provide better lighting during night and more road management for other roads.
- It seems surprising that curve road has a lower Crash_Score than straight road, as people are more cautious during curve road. Thus, it is of equal importance to improving the road condition

as well as to raising awareness for safety. Municipal management could consider adding more signs and slogans as reminders.

Furthermore, although it is a relatively comprehensive dataset with a large number of dimensions and observations, there are two major limitations. Firstly, Crash_Score is abstract. It is stated that Crash_Score is related to the extent of the car crash. However, it is not intuitive when we illustrate the effect of a variable as “Interaction road feature added to Crash_Score by approximately 0.36”. What is an increase of 0.36 supposed to mean? What are the differences between Crash_Scores of 1, 5, and 10? Answers to these questions will help us better analyze the car crash issue. Secondly, as we mentioned, car crashes are complicated, there are various factors, even incidents, could contribute to traffic accidents. As a result, more dimensions for the dataset could be helpful for our analysis. For example, work and non-work areas could be an overgeneralized concept. If geospatial data is included in our dataset, we could analyze which area needs additional attention and provide customized traffic control practices for different areas.

Conclusion

By analyzing the Car Crash Dataset provided by the City of Cary in North Carolina, our report successfully identified and interpreted how different factors and interactions affect the severity of traffic accidents. Firstly, we applied EDA and gained initial insights from the dataset. Secondly, we used methods such as feature transformation, feature selection, and model selection to improve model performance and prevent overfitting. Then, we applied high dimension LASSO regression to investigate the interaction and extract further insights from the dataset. Finally, we provided several suggestions for municipal management. Furthermore, if we have a better understanding of the Crash_Score and more dimensions in the dataset, we will be able to generate more insights.

References

Road Safety Facts, https://www.asirt.org/safe-travel/road-safety-facts/

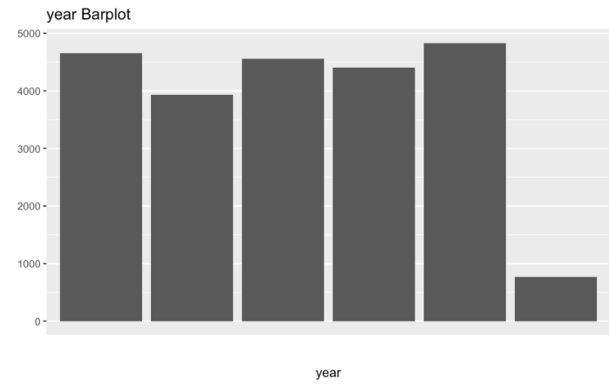
Appendix

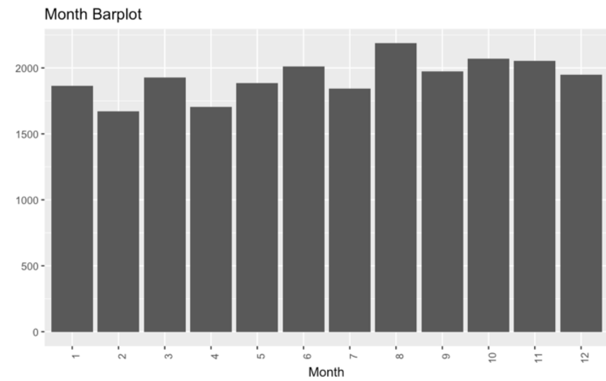
Appendix 1: Summary of Dataset

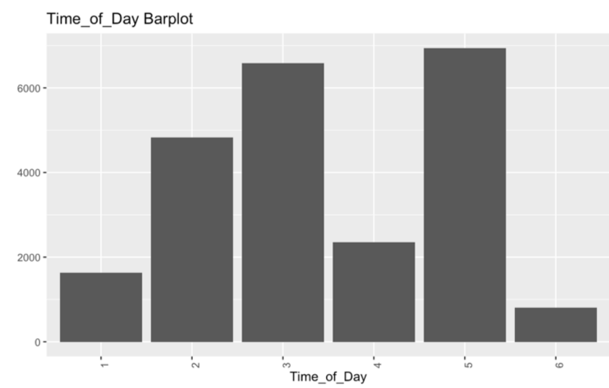
```
  Crash_Score        year        Month       Time_of_Day        Rd_Feature
Rd_Character
 Min.   : 0.010   Min.   :2014   Min.   : 1.00   Min.   :1.000   NONE        :13025   STRAIGHT-
LEVEL:18215
 1st Qu.: 3.540   1st Qu.:2015   1st Qu.: 3.00   1st Qu.:3.000   DRIVEWAY    : 2373
CURVE-GRADE   :  643
 Median : 5.660   Median :2016   Median : 7.00   Median :4.000   INTERSECTION: 6702
CURVE-LEVEL   :  725
 Mean   : 6.567   Mean   :2016   Mean   : 6.56   Mean   :4.034   OTHER       :  259   CURVE-
OTHER   :  239
 3rd Qu.: 8.600   3rd Qu.:2017   3rd Qu.:10.00   3rd Qu.:5.000   RAMP        :  778
OTHER         :   13
 Max.   :53.070   Max.   :2019   Max.   :12.00   Max.   :6.000                        STRAIGHT-
GRADE: 2622
                                                                  STRAIGHT-OTHER:  680
     Rd_Class                 Rd_Configuration           Rd_Surface          Rd_Conditions
 STATE HWY:10603   TWO-WAY-NO-MEDIAN          :12076   SMOOTH ASPHALT  :20007
DRY           :19262
 OTHER     : 9960   ONE-WAY                   : 1496   COARSE ASPHALT  : 1997   ICE-SNOW-
SLUSH:  322
 US HWY    : 2574   TWO-WAY-PROTECTED-MEDIAN  : 2627   CONCRETE        :  692
OTHER         :  134
                   TWO-WAY-UNPROTECTED-MEDIAN: 6882   GROOVED CONCRETE:  371
WET           : 3419
                   UNKNOWN                   :   56   OTHER           :   70


         Light          Weather        Traffic_Control  Work_Area
 DAYLIGHT     :18262   CLEAR :17393   NONE      :14028   NO :22823
 DARK-LIT     : 3219   CLOUDY: 3234   OTHER     :  228   YES:  314
 DARK-NOT-LIT:  708   OTHER :   85   SIGNAL    : 6352
```

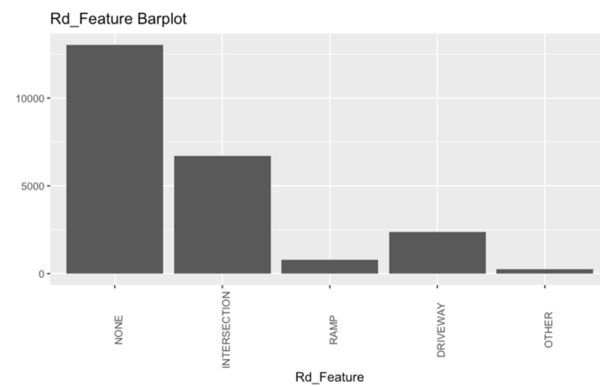
```
DAWN      : 140   RAIN  : 2230   STOP-SIGN: 2269
DUSK      : 602   SNOW  : 195    YIELD    : 260
OTHER     : 206
```

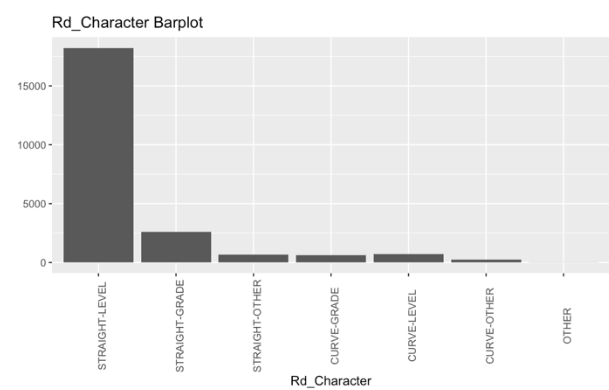
Appendix2: EDA Bar Plot for the Count of Observations

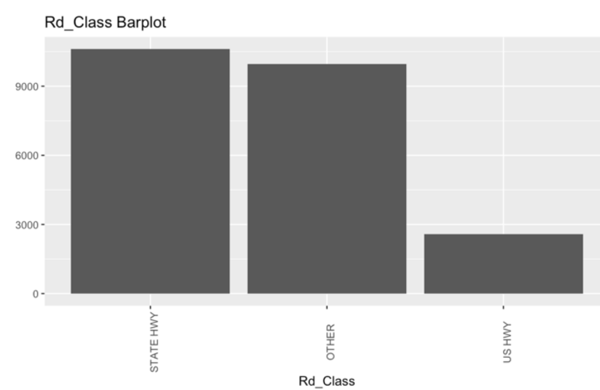


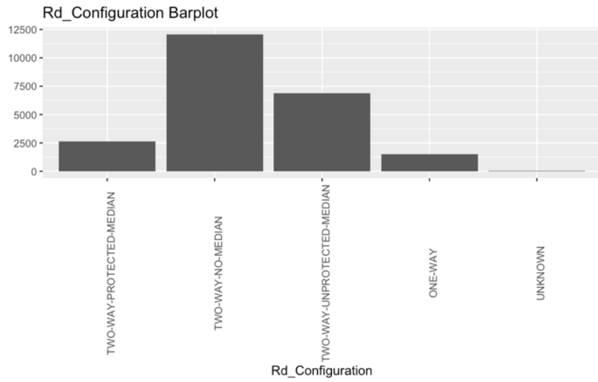


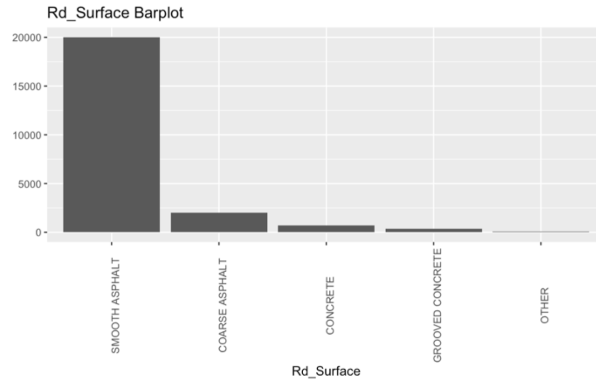


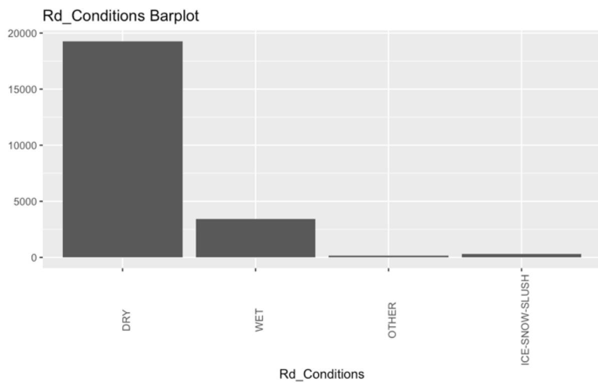


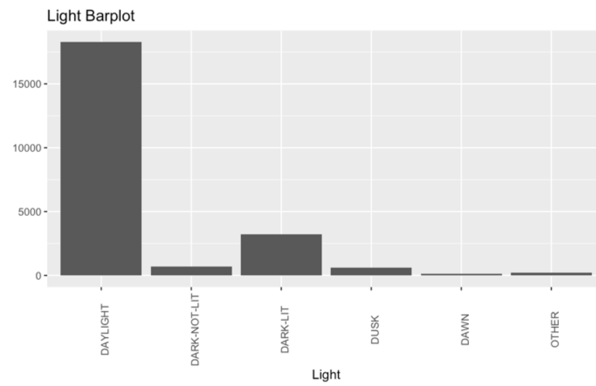


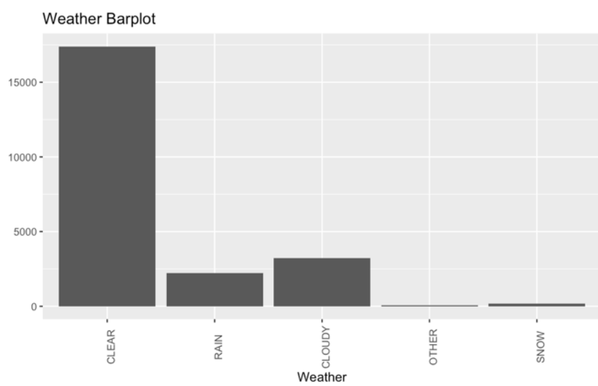


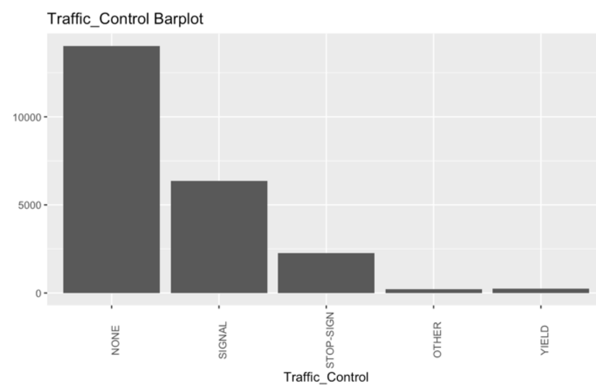

Rd_Configuration Barplot
12500
10000
7500
5000
2500
0
TWO-WAY-PROTECTED-MEDIAN
TWO-WAY-NO-MEDIAN
TWO-WAY-UNPROTECTED-MEDIAN
ONE-WAY
UNKNOWN
Rd_Configuration

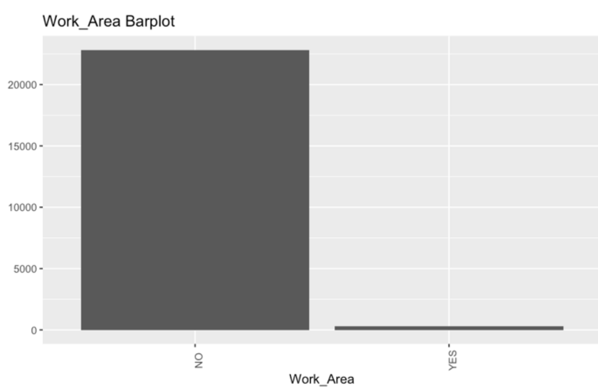

Rd_Surface Barplot
20000
15000
10000
5000
0
SMOOTH ASPHALT
COARSE ASPHALT
CONCRETE
GROOVED CONCRETE
OTHER
Rd_Surface


Rd_Conditions Barplot
20000
15000
10000
5000
0
DRY
WET
OTHER
ICE-SNOW-SLUSH
Rd_Conditions

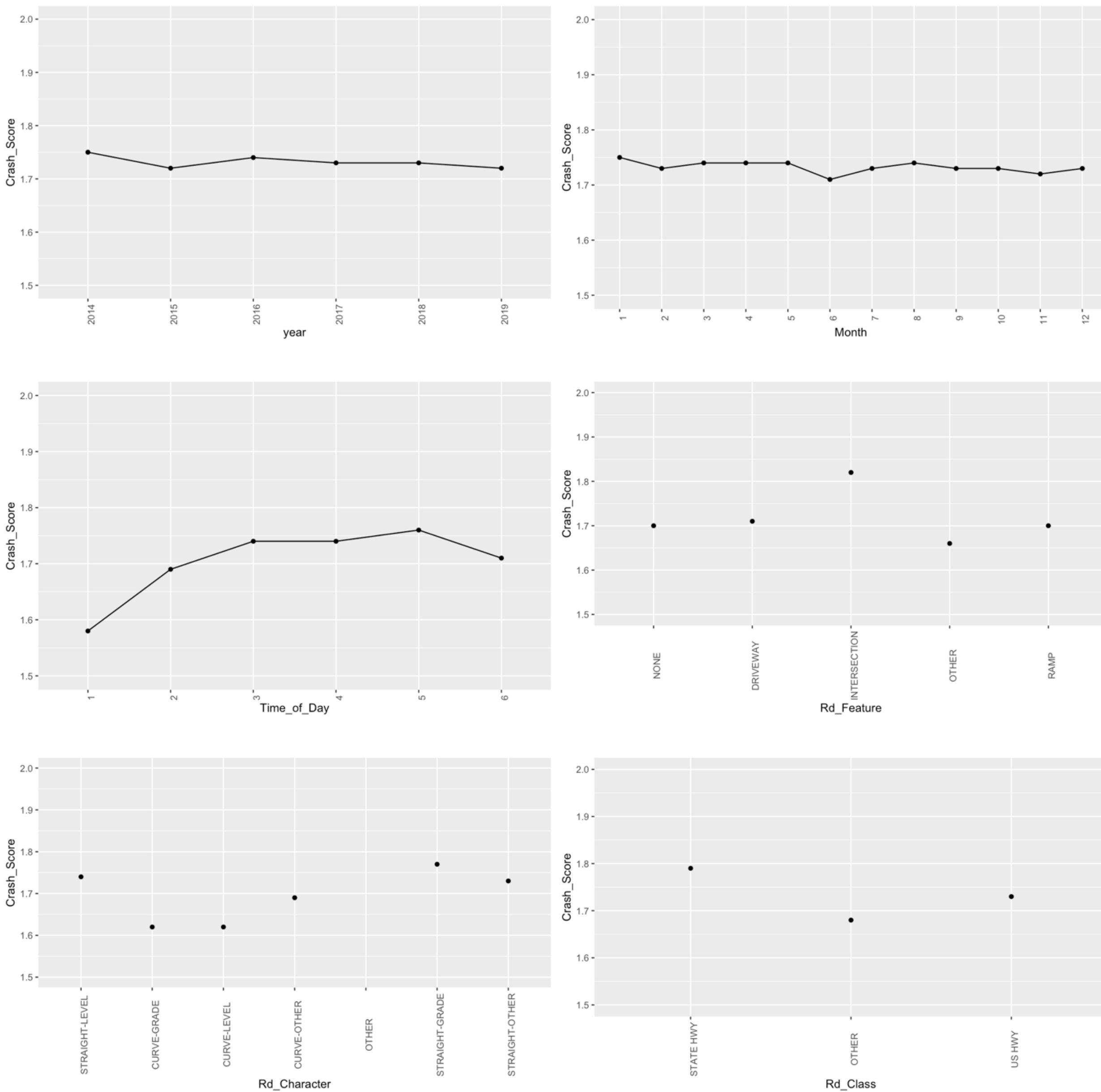

Light Barplot
15000
10000
5000
0
DAYLIGHT
DARK-NOT-LIT
DARK-LIT
DUSK
DAWN
OTHER
Light

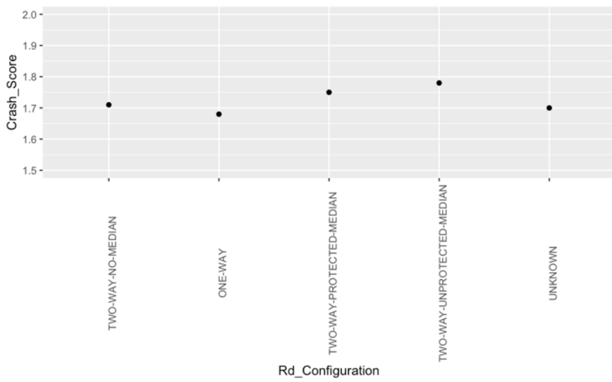

Weather Barplot
15000
10000
5000
0
CLEAR
RAIN
CLOUDY
OTHER
SNOW
Weather

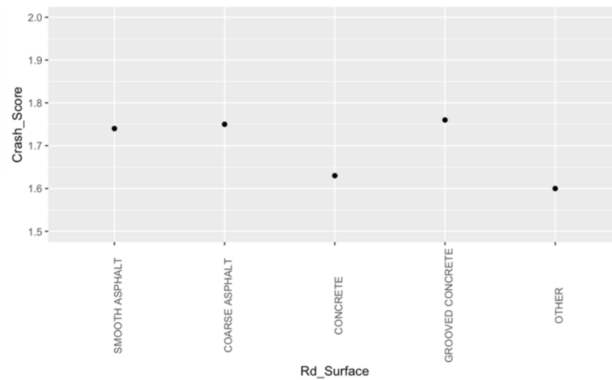

Traffic_Control Barplot
10000
5000
0
NONE
SIGNAL
STOP-SIGN
OTHER
YIELD
Traffic_Control

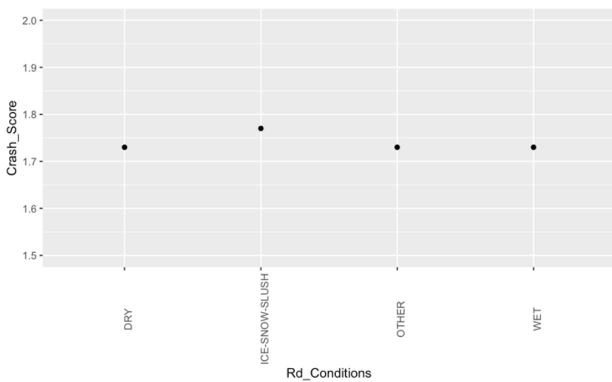

Work_Area Barplot
20000
15000
10000
5000
0
NO
YES
Work_Area

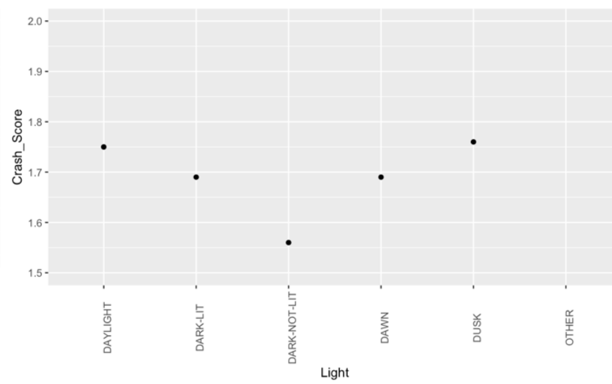
Appendix 3: EDA Line Plot and Scatter Plot for the Median of Crash_Score

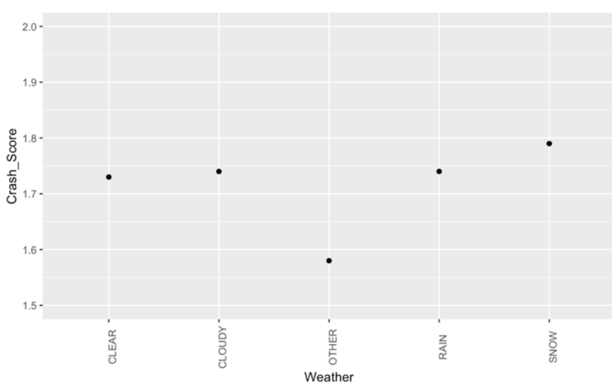


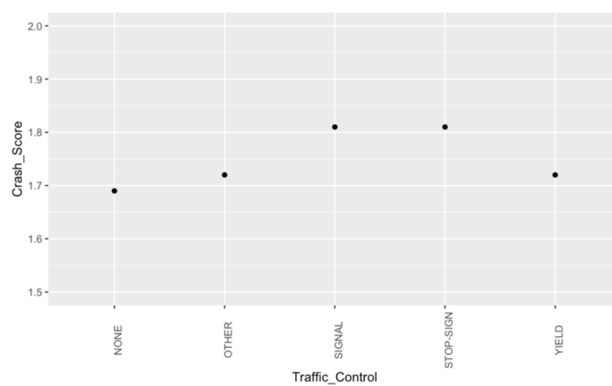


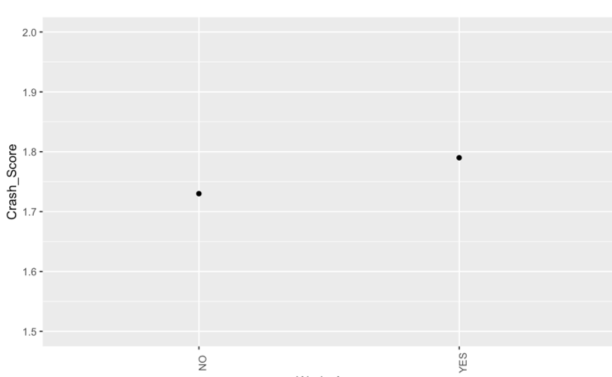












Appendix 4: Summary of Dataset with Feature Transformation

```
Crash_Score        year        Month         Time_of_Day         Rd_Feature
Rd_Character
 Min.   : 0.010   Min.   :2014   Min.   : 1.00   DAYTIME   :18345   OTHER      :16435
STRAIGHT:21517
 1st Qu.: 3.540   1st Qu.:2015   1st Qu.: 3.00   OVERNIGHT :  808   INTERSECTION: 6702
CURVE   : 1620
 Median : 5.660   Median :2016   Median : 7.00   LATE-EARLY: 3984
 Mean   : 6.567   Mean   :2016   Mean   : 6.56
 3rd Qu.: 8.600   3rd Qu.:2017   3rd Qu.:10.00
 Max.   :53.070   Max.   :2019   Max.   :12.00
    Rd_Class                  Rd_Configuration   Rd_Surface         Rd_Conditions          Light
 STATE HWY:10603   TWO-WAY-NO-MEDIAN        :12076   ASPHALT:22004
DRY          :19262   DAYLIGHT    :18262
 OTHER    : 9960   ONE-WAY                  : 1496   OTHER  : 1133   ICE-SNOW-SLUSH:  322
DARK-LIT    : 3219
 US HWY   : 2574   TWO-WAY-PROTECTED-MEDIAN  : 2627                OTHER        :  134
DARK-NOT-LIT:  708
              TWO-WAY-UNPROTECTED-MEDIAN: 6882                WET          : 3419
DAWN       :  140
              UNKNOWN                :   56                              DUSK       :  602
                                                                     OTHER      :  206
       Weather        Traffic_Control  Work_Area
 CLEAR-CLOUDY:20627   OTHER      :14516   NO :22823
 OTHER       :   85   SIGNAL-STOP: 8621   YES:  314
 RAIN-SNOW   : 2425
```

Appendix 5: Performance for Model 0

GLM with Gaussian Distribution

```
 [1] "AIC"
[1] 119370.1
[1] "RMSE"
[1] 4.25114
[1] "R2"
[1] 0.0166
[1] "OOS_R2"
[1] 0.01191
```

Appendix 6: Performance for Model 1

GLM with Gaussian Distribution

```
[1] "AIC"
[1] 119369.4
[1] "RMSE"
[1] 4.25061
[1] "R2"
[1] 0.01521
[1] "OOS_R2"
[1] 0.01215
```

GLM with Gamma Distribution and Log Link

```
[1] "AIC"
[1] 111848.9
[1] "RMSE"
[1] 4.25092
[1] "R2"
[1] 0.01565
[1] "OOS_R2"
[1] 0.01201
```

Appendix 7: Performance for Model 2

GLM with BIC forward selection

```
[1] "AIC"
[1] 119385.6
[1] "RMSE"
[1] 4.25201
[1] "R2"
[1] 0.01265
[1] "OOS_R2"
[1] 0.01191
```

```
Call:
glm(formula = Crash_Score ~ Rd_Class + Rd_Feature + Time_of_Day +
    Traffic_Control, family = gaussian(), data = data2)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
```

```
-7.116  -2.990  -0.888   1.993  46.962

Coefficients:
                           Estimate Std. Error t value Pr(>|t|)
(Intercept)                 6.63688    0.05809 114.247  < 2e-16 ***
Rd_ClassOTHER              -0.52929    0.06449  -8.207 2.38e-16 ***
Rd_ClassUS HWY              0.11414    0.09647   1.183    0.237
Rd_FeatureINTERSECTION      0.36731    0.08050   4.563 5.07e-06 ***
Time_of_DayOVERNIGHT       -0.73084    0.15299  -4.777 1.79e-06 ***
Time_of_DayLATE-EARLY      -0.30067    0.07449  -4.036 5.45e-05 ***
Traffic_ControlSIGNAL-STOP  0.31143    0.07598   4.099 4.17e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 18.08283)

    Null deviance: 423606  on 23136  degrees of freedom
Residual deviance: 418256  on 23130  degrees of freedom
AIC: 132650

Number of Fisher Scoring iterations: 2
```

```
 [1] "AIC"
[1] 111874
[1] "RMSE"
[1] 4.25218
[1] "R2"
[1] 0.01285
[1] "OOS_R2"
[1] 0.01183
```

```
Call:
glm(formula = Crash_Score ~ Rd_Class + Traffic_Control + Rd_Feature +
    Time_of_Day, family = Gamma(link = "log"), data = data2)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.3222  -0.5540  -0.1431   0.2772   3.3251
```

```
Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)              1.890659   0.008845 213.758  < 2e-16 ***
Rd_ClassOTHER            -0.081263   0.009819  -8.276  < 2e-16 ***
Rd_ClassUS HWY            0.017964   0.014688   1.223    0.221
Traffic_ControlSIGNAL-STOP  0.049331   0.011569   4.264 2.02e-05 ***
Rd_FeatureINTERSECTION     0.053241   0.012257   4.344 1.41e-05 ***
Time_of_DayOVERNIGHT      -0.117649   0.023294  -5.051 4.44e-07 ***
Time_of_DayLATE-EARLY     -0.046650   0.011342  -4.113 3.92e-05 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 0.4191914)

    Null deviance: 9740.7  on 23136  degrees of freedom
Residual deviance: 9615.7  on 23130  degrees of freedom
AIC: 124303

Number of Fisher Scoring iterations: 5
```

GLM with LASSO Regression

```
[1] "RMSE"
[1] 4.38792
[1] "R2"
[1] 0.0152273
[1] "OOS_R2"
[1] 0.01172
[1] "Coefficient"
27 x 1 sparse Matrix of class "dgCMatrix"
                                          1
(Intercept)                     30.587004828
(Intercept)                      .
year                           -0.011851525
Month                           -0.001069361
Time_of_DayOVERNIGHT                  -0.376405738
Time_of_DayLATE-EARLY                 -0.125524940
Rd_FeatureINTERSECTION                 0.380489862
Rd_CharacterCURVE                   -0.245784850
Rd_ClassOTHER                      -0.505853226
```

```
Rd_ClassUS HWY                          0.133399307
Rd_ConfigurationONE-WAY                 -0.191381117
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN    0.086848286
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN -0.020658867
Rd_ConfigurationUNKNOWN                  0.154234645
Rd_SurfaceOTHER                         -0.293156710
Rd_ConditionsICE-SNOW-SLUSH               .
Rd_ConditionsOTHER                       0.432660392
Rd_ConditionsWET                        -0.073925175
LightDARK-LIT                          -0.329201985
LightDARK-NOT-LIT                       -0.492735150
LightDAWN                              -0.110753748
LightDUSK                              .
LightOTHER                             -0.663746014
WeatherOTHER                            -0.558324341
WeatherRAIN-SNOW                         0.146435986
Traffic_ControlSIGNAL-STOP               0.273934004
Work_AreaYES                            0.462645783
```

Appendix 8: Performance for Model 3

High Dimension LASSO Regression

```
[1] "RMSE"
[1] 4.384924
[1] "R2"
[1] 0.02173758
[1] "OOS_R2"
[1] 0.01306927
[1] "Coefficient"
305 x 1 sparse Matrix of class "dgCMatrix"
                                                   1
(Intercept)                                     6.656291e+00
(Intercept)                                     .
year                                         .
Month                                          .
Time_of_DayOVERNIGHT                                 .
Time_of_DayLATE-EARLY                              -1.726661e-04
Rd_FeatureINTERSECTION                              2.455170e-01
Rd_CharacterCURVE                                 .
```

```
Rd_ClassOTHER                                        -4.692470e-01
Rd_ClassUS HWY                                        .
Rd_ConfigurationONE-WAY                               .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN              .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN            .
Rd_ConfigurationUNKNOWN                               .
Rd_SurfaceOTHER                                       .
Rd_ConditionsICE-SNOW-SLUSH                           .
Rd_ConditionsOTHER                                    .
Rd_ConditionsWET                                      .
LightDARK-LIT                                        -3.332283e-02
LightDARK-NOT-LIT                                    -2.983988e-01
LightDAWN                                             .
LightDUSK                                             .
LightOTHER                                           -2.987457e-01
WeatherOTHER                                          .
WeatherRAIN-SNOW                                      .
Traffic_ControlSIGNAL-STOP                            2.308190e-01
Work_AreaYES                                          .
year:Month                                            .
year:Time_of_DayOVERNIGHT                             .
year:Time_of_DayLATE-EARLY                           -8.481234e-06
year:Rd_FeatureINTERSECTION                           4.680128e-06
year:Rd_CharacterCURVE                               -3.727260e-06
year:Rd_ClassOTHER                                   -6.221184e-06
year:Rd_ClassUS HWY                                   .
year:Rd_ConfigurationONE-WAY                          .
year:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN         .
year:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN       .
year:Rd_ConfigurationUNKNOWN                          .
year:Rd_SurfaceOTHER                                  .
year:Rd_ConditionsICE-SNOW-SLUSH                      .
year:Rd_ConditionsOTHER                               .
year:Rd_ConditionsWET                                 .
year:LightDARK-LIT                                    .
year:LightDARK-NOT-LIT                                .
year:LightDAWN                                        .
year:LightDUSK                                        .
year:LightOTHER                                      -2.655948e-06
year:WeatherOTHER                                     .
```

```
year:WeatherRAIN-SNOW                                          .
year:Traffic_ControlSIGNAL-STOP                                .
year:Work_AreaYES                                              .
Month:Time_of_DayOVERNIGHT                                     .
Month:Time_of_DayLATE-EARLY                                    .
Month:Rd_FeatureINTERSECTION                                   .
Month:Rd_CharacterCURVE                                        .
Month:Rd_ClassOTHER                                  -2.266645e-03
Month:Rd_ClassUS HWY                                           .
Month:Rd_ConfigurationONE-WAY                                  .
Month:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN        2.327427e-02
Month:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN               .
Month:Rd_ConfigurationUNKNOWN                                  .
Month:Rd_SurfaceOTHER                                          .
Month:Rd_ConditionsICE-SNOW-SLUSH                              .
Month:Rd_ConditionsOTHER                                       .
Month:Rd_ConditionsWET                                         .
Month:LightDARK-LIT                                  -1.280446e-02
Month:LightDARK-NOT-LIT                                        .
Month:LightDAWN                                                .
Month:LightDUSK                                                .
Month:LightOTHER                                               .
Month:WeatherOTHER                                             .
Month:WeatherRAIN-SNOW                                         .
Month:Traffic_ControlSIGNAL-STOP                               .
Month:Work_AreaYES                                    8.479576e-03
Time_of_DayOVERNIGHT:Rd_FeatureINTERSECTION                    .
Time_of_DayLATE-EARLY:Rd_FeatureINTERSECTION                   .
Time_of_DayOVERNIGHT:Rd_CharacterCURVE                         .
Time_of_DayLATE-EARLY:Rd_CharacterCURVE              -1.498426e-01
Time_of_DayOVERNIGHT:Rd_ClassOTHER                             .
Time_of_DayLATE-EARLY:Rd_ClassOTHER                            .
Time_of_DayOVERNIGHT:Rd_ClassUS HWY                  -4.460607e-01
Time_of_DayLATE-EARLY:Rd_ClassUS HWY                  2.689500e-02
Time_of_DayOVERNIGHT:Rd_ConfigurationONE-WAY                   .
Time_of_DayLATE-EARLY:Rd_ConfigurationONE-WAY                  .
Time_of_DayOVERNIGHT:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN        -
9.214905e-01
Time_of_DayLATE-EARLY:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN       .
Time_of_DayOVERNIGHT:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN      .
```

```
Time_of_DayLATE-EARLY:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN      -
7.651017e-02
Time_of_DayOVERNIGHT:Rd_ConfigurationUNKNOWN                     .
Time_of_DayLATE-EARLY:Rd_ConfigurationUNKNOWN                    .
Time_of_DayOVERNIGHT:Rd_SurfaceOTHER                             .
Time_of_DayLATE-EARLY:Rd_SurfaceOTHER                            3.886565e-03
Time_of_DayOVERNIGHT:Rd_ConditionsICE-SNOW-SLUSH                 3.126225e-01
Time_of_DayLATE-EARLY:Rd_ConditionsICE-SNOW-SLUSH                .
Time_of_DayOVERNIGHT:Rd_ConditionsOTHER                          1.702176e+00
Time_of_DayLATE-EARLY:Rd_ConditionsOTHER                         .
Time_of_DayOVERNIGHT:Rd_ConditionsWET                            .
Time_of_DayLATE-EARLY:Rd_ConditionsWET                           -3.696563e-01
Time_of_DayOVERNIGHT:LightDARK-LIT                               -6.237493e-01
Time_of_DayLATE-EARLY:LightDARK-LIT                              -1.648334e-01
Time_of_DayOVERNIGHT:LightDARK-NOT-LIT                           -4.494685e-01
Time_of_DayLATE-EARLY:LightDARK-NOT-LIT                          .
Time_of_DayOVERNIGHT:LightDAWN                                   .
Time_of_DayLATE-EARLY:LightDAWN                                  .
Time_of_DayOVERNIGHT:LightDUSK                                   .
Time_of_DayLATE-EARLY:LightDUSK                                  .
Time_of_DayOVERNIGHT:LightOTHER                                  .
Time_of_DayLATE-EARLY:LightOTHER                                 .
Time_of_DayOVERNIGHT:WeatherOTHER                                -1.873626e+00
Time_of_DayLATE-EARLY:WeatherOTHER                               .
Time_of_DayOVERNIGHT:WeatherRAIN-SNOW                            .
Time_of_DayLATE-EARLY:WeatherRAIN-SNOW                           .
Time_of_DayOVERNIGHT:Traffic_ControlSIGNAL-STOP                  2.039222e-01
Time_of_DayLATE-EARLY:Traffic_ControlSIGNAL-STOP                 1.024350e-01
Time_of_DayOVERNIGHT:Work_AreaYES                                .
Time_of_DayLATE-EARLY:Work_AreaYES                               5.117929e-03
Rd_FeatureINTERSECTION:Rd_CharacterCURVE                         .
Rd_FeatureINTERSECTION:Rd_ClassOTHER                             .
Rd_FeatureINTERSECTION:Rd_ClassUS HWY                            1.211543e-01
Rd_FeatureINTERSECTION:Rd_ConfigurationONE-WAY                   .
Rd_FeatureINTERSECTION:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN  .
Rd_FeatureINTERSECTION:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN
1.228891e-01
Rd_FeatureINTERSECTION:Rd_ConfigurationUNKNOWN                   -5.485124e-02
Rd_FeatureINTERSECTION:Rd_SurfaceOTHER                           .
Rd_FeatureINTERSECTION:Rd_ConditionsICE-SNOW-SLUSH               .
```

```
Rd_FeatureINTERSECTION:Rd_ConditionsOTHER                    -6.401051e-01
Rd_FeatureINTERSECTION:Rd_ConditionsWET                       1.479159e-02
Rd_FeatureINTERSECTION:LightDARK-LIT                          .
Rd_FeatureINTERSECTION:LightDARK-NOT-LIT                      .
Rd_FeatureINTERSECTION:LightDAWN                              .
Rd_FeatureINTERSECTION:LightDUSK                              .
Rd_FeatureINTERSECTION:LightOTHER                            -6.385495e-01
Rd_FeatureINTERSECTION:WeatherOTHER                           .
Rd_FeatureINTERSECTION:WeatherRAIN-SNOW                       1.262507e-01
Rd_FeatureINTERSECTION:Traffic_ControlSIGNAL-STOP             .
Rd_FeatureINTERSECTION:Work_AreaYES                           .
Rd_CharacterCURVE:Rd_ClassOTHER                               .
Rd_CharacterCURVE:Rd_ClassUS HWY                             -1.126252e-01
Rd_CharacterCURVE:Rd_ConfigurationONE-WAY                     .
Rd_CharacterCURVE:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN            .
Rd_CharacterCURVE:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN          -
6.207546e-02
Rd_CharacterCURVE:Rd_ConfigurationUNKNOWN                     .
Rd_CharacterCURVE:Rd_SurfaceOTHER                             .
Rd_CharacterCURVE:Rd_ConditionsICE-SNOW-SLUSH                 .
Rd_CharacterCURVE:Rd_ConditionsOTHER                          .
Rd_CharacterCURVE:Rd_ConditionsWET                            .
Rd_CharacterCURVE:LightDARK-LIT                              -2.585268e-02
Rd_CharacterCURVE:LightDARK-NOT-LIT                           .
Rd_CharacterCURVE:LightDAWN                                   .
Rd_CharacterCURVE:LightDUSK                                   .
Rd_CharacterCURVE:LightOTHER                                  .
Rd_CharacterCURVE:WeatherOTHER                                .
Rd_CharacterCURVE:WeatherRAIN-SNOW                           -4.750677e-01
Rd_CharacterCURVE:Traffic_ControlSIGNAL-STOP                 -3.084268e-02
Rd_CharacterCURVE:Work_AreaYES                                7.838758e-01
Rd_ClassOTHER:Rd_ConfigurationONE-WAY                         .
Rd_ClassUS HWY:Rd_ConfigurationONE-WAY                       -2.499031e-01
Rd_ClassOTHER:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN            1.810607e-
01
Rd_ClassUS HWY:Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN           .
Rd_ClassOTHER:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN          .
Rd_ClassUS HWY:Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN
4.558398e-01
Rd_ClassOTHER:Rd_ConfigurationUNKNOWN                         .
```

```
Rd_ClassUS HWY:Rd_ConfigurationUNKNOWN                          .
Rd_ClassOTHER:Rd_SurfaceOTHER                        -5.307316e-01
Rd_ClassUS HWY:Rd_SurfaceOTHER                          .
Rd_ClassOTHER:Rd_ConditionsICE-SNOW-SLUSH                    2.197920e-01
Rd_ClassUS HWY:Rd_ConditionsICE-SNOW-SLUSH                    .
Rd_ClassOTHER:Rd_ConditionsOTHER                          .
Rd_ClassUS HWY:Rd_ConditionsOTHER                          .
Rd_ClassOTHER:Rd_ConditionsWET                          .
Rd_ClassUS HWY:Rd_ConditionsWET                          .
Rd_ClassOTHER:LightDARK-LIT                          .
Rd_ClassUS HWY:LightDARK-LIT                          .
Rd_ClassOTHER:LightDARK-NOT-LIT                          .
Rd_ClassUS HWY:LightDARK-NOT-LIT                        -7.629586e-02
Rd_ClassOTHER:LightDAWN                          .
Rd_ClassUS HWY:LightDAWN                        -5.748051e-01
Rd_ClassOTHER:LightDUSK                          .
Rd_ClassUS HWY:LightDUSK                          .
Rd_ClassOTHER:LightOTHER                          .
Rd_ClassUS HWY:LightOTHER                          .
Rd_ClassOTHER:WeatherOTHER                          .
Rd_ClassUS HWY:WeatherOTHER                          .
Rd_ClassOTHER:WeatherRAIN-SNOW                          .
Rd_ClassUS HWY:WeatherRAIN-SNOW                          .
Rd_ClassOTHER:Traffic_ControlSIGNAL-STOP                          .
Rd_ClassUS HWY:Traffic_ControlSIGNAL-STOP                          .
Rd_ClassOTHER:Work_AreaYES                          .
Rd_ClassUS HWY:Work_AreaYES                        2.459279e-01
Rd_ConfigurationONE-WAY:Rd_SurfaceOTHER                          .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:Rd_SurfaceOTHER              .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:Rd_SurfaceOTHER            .
Rd_ConfigurationUNKNOWN:Rd_SurfaceOTHER                          .
Rd_ConfigurationONE-WAY:Rd_ConditionsICE-SNOW-SLUSH                   .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:Rd_ConditionsICE-SNOW-SLUSH    .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:Rd_ConditionsICE-SNOW-SLUSH  .
Rd_ConfigurationUNKNOWN:Rd_ConditionsICE-SNOW-SLUSH                   .
Rd_ConfigurationONE-WAY:Rd_ConditionsOTHER                          .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:Rd_ConditionsOTHER           -
1.420038e+00
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:Rd_ConditionsOTHER          .
Rd_ConfigurationUNKNOWN:Rd_ConditionsOTHER                          .
```

```
Rd_ConfigurationONE-WAY:Rd_ConditionsWET                          .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:Rd_ConditionsWET          .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:Rd_ConditionsWET         .
Rd_ConfigurationUNKNOWN:Rd_ConditionsWET                          .
Rd_ConfigurationONE-WAY:LightDARK-LIT                        -1.399179e-02
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:LightDARK-LIT            -2.227619e-
01
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:LightDARK-LIT           -3.531091e-
01
Rd_ConfigurationUNKNOWN:LightDARK-LIT                             .
Rd_ConfigurationONE-WAY:LightDARK-NOT-LIT                         .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:LightDARK-NOT-LIT          .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:LightDARK-NOT-LIT         .
Rd_ConfigurationUNKNOWN:LightDARK-NOT-LIT                         .
Rd_ConfigurationONE-WAY:LightDAWN                                 .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:LightDAWN                .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:LightDAWN               .
Rd_ConfigurationUNKNOWN:LightDAWN                                 .
Rd_ConfigurationONE-WAY:LightDUSK                            5.997676e-01
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:LightDUSK                .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:LightDUSK               .
Rd_ConfigurationUNKNOWN:LightDUSK                                 .
Rd_ConfigurationONE-WAY:LightOTHER                                .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:LightOTHER           -1.602921e+00
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:LightOTHER              .
Rd_ConfigurationUNKNOWN:LightOTHER                                .
Rd_ConfigurationONE-WAY:WeatherOTHER                         -9.420533e-01
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:WeatherOTHER              .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:WeatherOTHER            .
Rd_ConfigurationUNKNOWN:WeatherOTHER                              .
Rd_ConfigurationONE-WAY:WeatherRAIN-SNOW                          .
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:WeatherRAIN-SNOW          .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:WeatherRAIN-SNOW         .
Rd_ConfigurationUNKNOWN:WeatherRAIN-SNOW                          .
Rd_ConfigurationONE-WAY:Traffic_ControlSIGNAL-STOP           -2.499343e-01
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:Traffic_ControlSIGNAL-STOP    .
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:Traffic_ControlSIGNAL-STOP   .
Rd_ConfigurationUNKNOWN:Traffic_ControlSIGNAL-STOP                .
Rd_ConfigurationONE-WAY:Work_AreaYES                              .
```

```
Rd_ConfigurationTWO-WAY-PROTECTED-MEDIAN:Work_AreaYES               1.917471e-
01
Rd_ConfigurationTWO-WAY-UNPROTECTED-MEDIAN:Work_AreaYES             .
Rd_ConfigurationUNKNOWN:Work_AreaYES                                .
Rd_SurfaceOTHER:Rd_ConditionsICE-SNOW-SLUSH                         .
Rd_SurfaceOTHER:Rd_ConditionsOTHER                                  .
Rd_SurfaceOTHER:Rd_ConditionsWET                                   -8.372690e-02
Rd_SurfaceOTHER:LightDARK-LIT                                       .
Rd_SurfaceOTHER:LightDARK-NOT-LIT                                  -9.233593e-02
Rd_SurfaceOTHER:LightDAWN                                           .
Rd_SurfaceOTHER:LightDUSK                                          -1.428736e-01
Rd_SurfaceOTHER:LightOTHER                                          .
Rd_SurfaceOTHER:WeatherOTHER                                        .
Rd_SurfaceOTHER:WeatherRAIN-SNOW                                    .
Rd_SurfaceOTHER:Traffic_ControlSIGNAL-STOP                          .
Rd_SurfaceOTHER:Work_AreaYES                                        .
Rd_ConditionsICE-SNOW-SLUSH:LightDARK-LIT                          -3.768304e-01
Rd_ConditionsOTHER:LightDARK-LIT                                    .
Rd_ConditionsWET:LightDARK-LIT                                      .
Rd_ConditionsICE-SNOW-SLUSH:LightDARK-NOT-LIT                       1.077994e+00
Rd_ConditionsOTHER:LightDARK-NOT-LIT                                .
Rd_ConditionsWET:LightDARK-NOT-LIT                                  .
Rd_ConditionsICE-SNOW-SLUSH:LightDAWN                               .
Rd_ConditionsOTHER:LightDAWN                                        .
Rd_ConditionsWET:LightDAWN                                          .
Rd_ConditionsICE-SNOW-SLUSH:LightDUSK                               .
Rd_ConditionsOTHER:LightDUSK                                        2.736671e-01
Rd_ConditionsWET:LightDUSK                                          .
Rd_ConditionsICE-SNOW-SLUSH:LightOTHER                              .
Rd_ConditionsOTHER:LightOTHER                                       .
Rd_ConditionsWET:LightOTHER                                         .
Rd_ConditionsICE-SNOW-SLUSH:WeatherOTHER                            .
Rd_ConditionsOTHER:WeatherOTHER                                     .
Rd_ConditionsWET:WeatherOTHER                                      -2.477240e-01
Rd_ConditionsICE-SNOW-SLUSH:WeatherRAIN-SNOW                        .
Rd_ConditionsOTHER:WeatherRAIN-SNOW                                 .
Rd_ConditionsWET:WeatherRAIN-SNOW                                   6.471902e-03
Rd_ConditionsICE-SNOW-SLUSH:Traffic_ControlSIGNAL-STOP              .
Rd_ConditionsOTHER:Traffic_ControlSIGNAL-STOP                       .
Rd_ConditionsWET:Traffic_ControlSIGNAL-STOP                         .
```

```
Rd_ConditionsICE-SNOW-SLUSH:Work_AreaYES                       .
Rd_ConditionsOTHER:Work_AreaYES                                6.774153e+00
Rd_ConditionsWET:Work_AreaYES                                  .
LightDARK-LIT:WeatherOTHER                                     .
LightDARK-NOT-LIT:WeatherOTHER                                 .
LightDAWN:WeatherOTHER                                         .
LightDUSK:WeatherOTHER                                         .
LightOTHER:WeatherOTHER                                        .
LightDARK-LIT:WeatherRAIN-SNOW                                 1.776019e-01
LightDARK-NOT-LIT:WeatherRAIN-SNOW                             .
LightDAWN:WeatherRAIN-SNOW                                     .
LightDUSK:WeatherRAIN-SNOW                                     .
LightOTHER:WeatherRAIN-SNOW                                    .
LightDARK-LIT:Traffic_ControlSIGNAL-STOP                       2.205936e-01
LightDARK-NOT-LIT:Traffic_ControlSIGNAL-STOP                   .
LightDAWN:Traffic_ControlSIGNAL-STOP                           .
LightDUSK:Traffic_ControlSIGNAL-STOP                           .
LightOTHER:Traffic_ControlSIGNAL-STOP                          -2.812067e-01
LightDARK-LIT:Work_AreaYES                                     5.713643e-01
LightDARK-NOT-LIT:Work_AreaYES                                 .
LightDAWN:Work_AreaYES                                         .
LightDUSK:Work_AreaYES                                         .
LightOTHER:Work_AreaYES                                        .
WeatherOTHER:Traffic_ControlSIGNAL-STOP                        -4.918214e-02
WeatherRAIN-SNOW :Traffic_ControlSIGNAL-STOP                   5.792116e-02
WeatherOTHER:Work_AreaYES                                      .
WeatherRAIN-SNOW :Work_AreaYES                                 .
Traffic_ControlSIGNAL-STOP:Work_AreaYES                        .
```