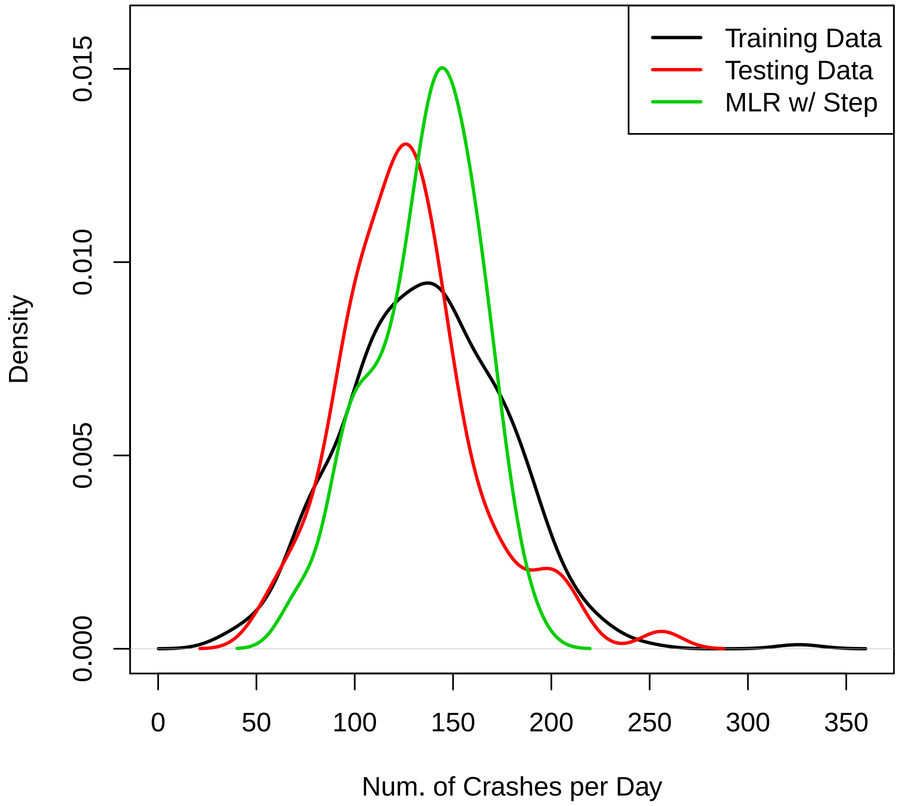
# Regression Analysis
for
Kelowna Weather-Crash Project

Contents

1 Predicting Number of Crashes

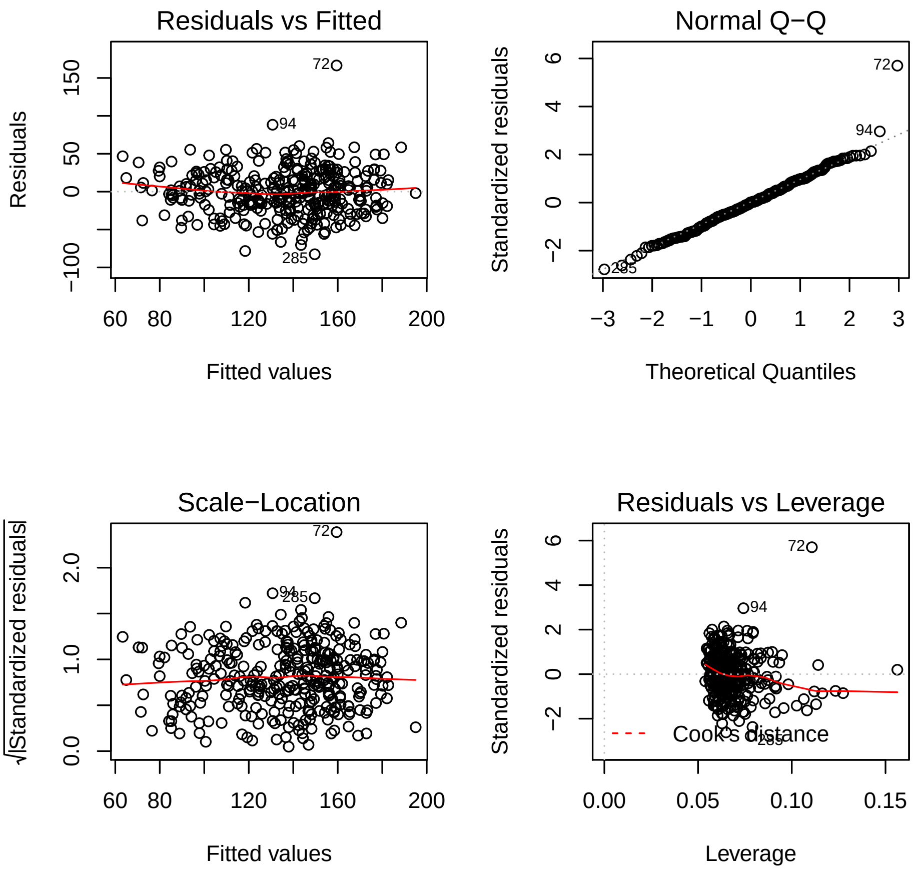
1.1 Multiple Linear Regression

```
With backwards and forward selection using 'step()':

Call:
lm(formula = crashes ~ month + day + relhum + precip + wind.dir + 
    wind.spd + visibility, data = train, x = TRUE, y = TRUE)

Residuals:
    Min      1Q  Median      3Q     Max 
-82.657 -17.998   0.226  19.747 166.522 

Coefficients:
               Estimate Std. Error t value Pr(>|t|)    
(Intercept)    248.3339    39.4690   6.292 1.06e-09 ***
monthAUGUST     21.4353     9.7515   2.198 0.028671 *  
monthDECEMBER   40.8051    11.7764   3.465 0.000604 ***
monthFEBRUARY   41.5961    10.6586   3.903 0.000117 ***
monthJANUARY    57.8888    12.1759   4.754 3.04e-06 ***
monthJULY       30.3272     9.1724   3.306 0.001055 ** 
monthJUNE       26.1346     8.5632   3.052 0.002468 ** 
monthMARCH      13.7881     8.8537   1.557 0.120403    
monthMAY        18.7967     8.4966   2.212 0.027670 *  
monthNOVEMBER   35.4994    11.1850   3.174 0.001654 ** 
monthOCTOBER    35.2250     9.7665   3.607 0.000361 ***
monthSEPTEMBER  23.1569     8.6477   2.678 0.007801 ** 
dayMONDAY      -24.6982     6.3687  -3.878 0.000128 ***
daySATURDAY    -44.2414     6.3844  -6.930 2.41e-11 ***
daySUNDAY      -64.2965     6.3471 -10.130  < 2e-16 ***
dayTHURSDAY     -8.4554     6.3670  -1.328 0.185142    
dayTUESDAY      -9.6025     6.3569  -1.511 0.131908    
dayWEDNESDAY    -9.2981     6.3458  -1.465 0.143858    
relhum          -0.8501     0.3610  -2.355 0.019151 *  
precip           0.9424     0.4563   2.065 0.039718 *  
wind.dir         1.9817     0.9429   2.102 0.036376 *  
wind.spd        -2.6151     1.0352  -2.526 0.012023 *  
visibility      -5.0721     1.6142  -3.142 0.001838 ** 
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 30.97 on 313 degrees of freedom
Multiple R-squared:  0.4441,	Adjusted R-squared:  0.405 
F-statistic: 11.37 on 22 and 313 DF,  p-value: < 2.2e-16

MLR MSE: 990.7888
```



```
Consistent Model Specification Test
Parametric null model: lm(formula = crashes ~ month + day + temp + relhum +
                          precip + wind.dir + wind.spd + visibility + pressure,
                          data = train, x = TRUE, y = TRUE)
Number of regressors: 9
IID Bootstrap (399 replications)

Test Statistic 'Jn': 2.125212        P Value: 0.0075188 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Null of correct specification is rejected at the 1% level
```

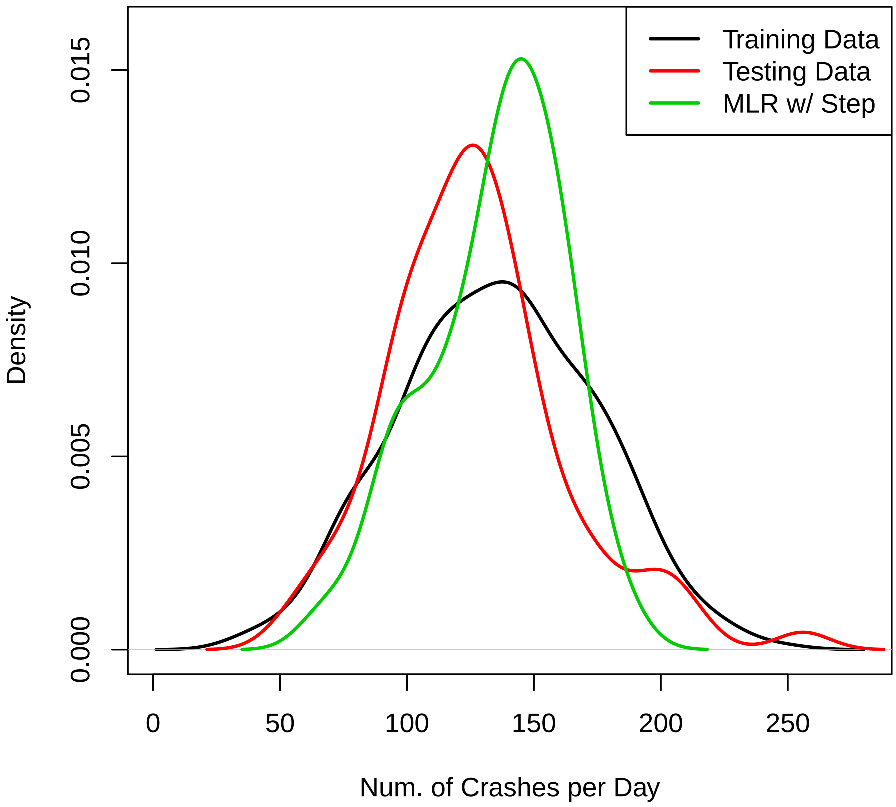
MLR Model Diagnostics:



```
Point 72:

                   linker    month      day     temp relhum precip wind.dir
72 2017 NOVEMBER THURSDAY NOVEMBER THURSDAY 3.244167   88.5   18.7 19.20085
   wind.spd visibility pressure crashes victims parked HWY97 HARVEY HWY33
72 11.43333   13.09917 95.80075     326     147     70    33     10    21
   GORDON year
72     14 2017
```

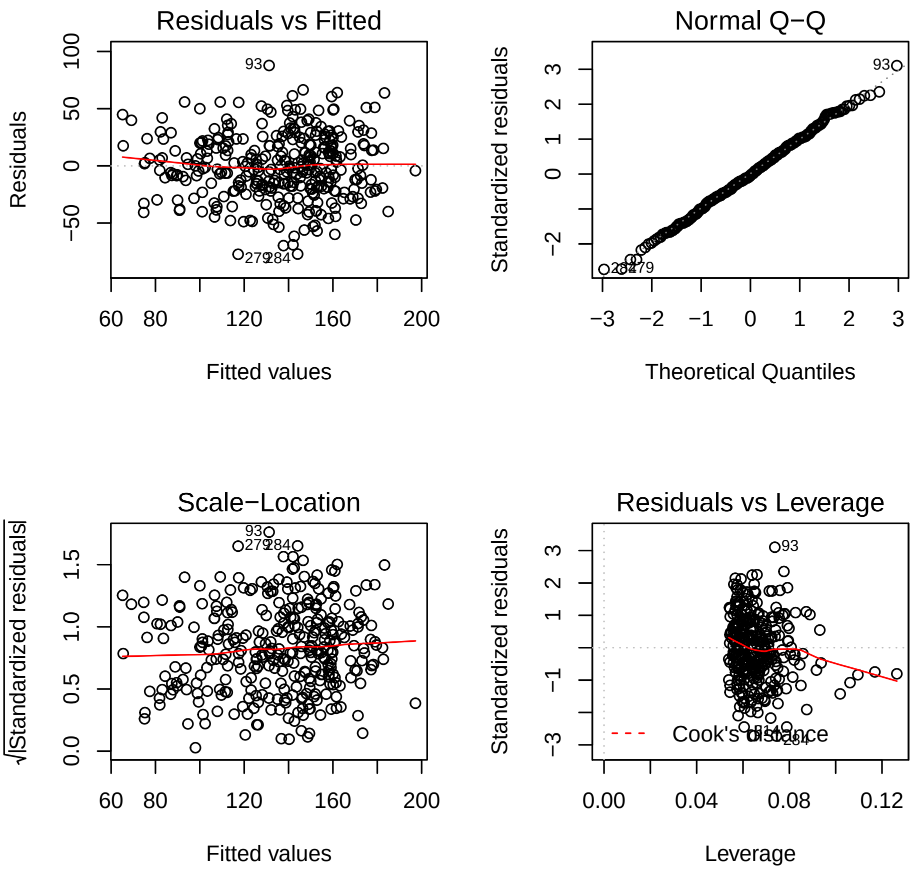
1.2 MLR Outliers Removed

```
With backwards and forward selection using 'step()':

Call:
lm(formula = crashes ~ month + day + relhum + wind.dir + wind.spd +
    visibility, data = train, x = TRUE, y = TRUE)

Residuals:
    Min      1Q  Median      3Q     Max
-77.259 -18.539  -1.277  19.245  87.761

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)    226.0928    36.2392   6.239 1.43e-09 ***
monthAUGUST     22.8495     9.2334   2.475 0.013866 *
monthDECEMBER   34.9678    10.6659   3.278 0.001161 **
monthFEBRUARY   35.5950     9.4245   3.777 0.000190 ***
monthJANUARY    51.1036    10.7197   4.767 2.87e-06 ***
monthJULY       33.1438     8.5406   3.881 0.000127 ***
monthJUNE       28.8859     8.0154   3.604 0.000365 ***
monthMARCH      11.2022     8.2851   1.352 0.177321
monthMAY        22.0047     7.8938   2.788 0.005635 **
monthNOVEMBER   22.9119    10.2012   2.246 0.025401 *
monthOCTOBER    30.8668     9.0629   3.406 0.000746 ***
monthSEPTEMBER  21.7934     8.1734   2.666 0.008066 **
dayMONDAY      -25.1623     6.0412  -4.165 4.03e-05 ***
daySATURDAY    -44.6592     6.0515  -7.380 1.44e-12 ***
daySUNDAY      -64.3616     6.0213 -10.689  < 2e-16 ***
dayTHURSDAY    -12.4378     6.0778  -2.046 0.041549 *
dayTUESDAY      -9.8105     6.0302  -1.627 0.104769
dayWEDNESDAY    -9.6708     6.0203  -1.606 0.109202
relhum          -0.5819     0.2980  -1.953 0.051731 .
wind.dir         2.1891     0.8938   2.449 0.014864 *
wind.spd        -3.2337     0.9844  -3.285 0.001136 **
visibility      -4.3765     1.5345  -2.852 0.004632 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 29.38 on 313 degrees of freedom
Multiple R-squared:  0.4638,	Adjusted R-squared:  0.4278
F-statistic: 12.89 on 21 and 313 DF,  p-value: < 2.2e-16

MLR MSE: 1029.308
```

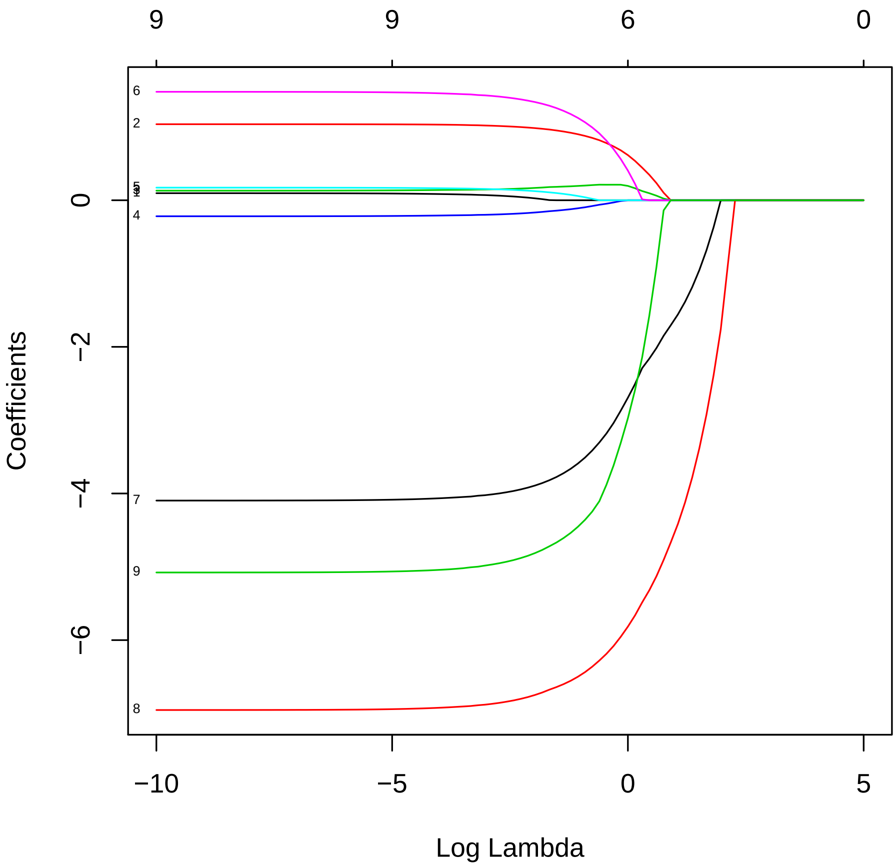


```
Consistent Model Specification Test
Parametric null model: lm(formula = crashes ~ month + day + relhum + wind.dir +
                          wind.spd + visibility, data = train, x = TRUE, y =
                          TRUE)
Number of regressors: 9
IID Bootstrap (399 replications)

Test Statistic ‘Jn’: 1.956675       P Value: 0.0075188 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Null of correct specification is rejected at the 1% level
```

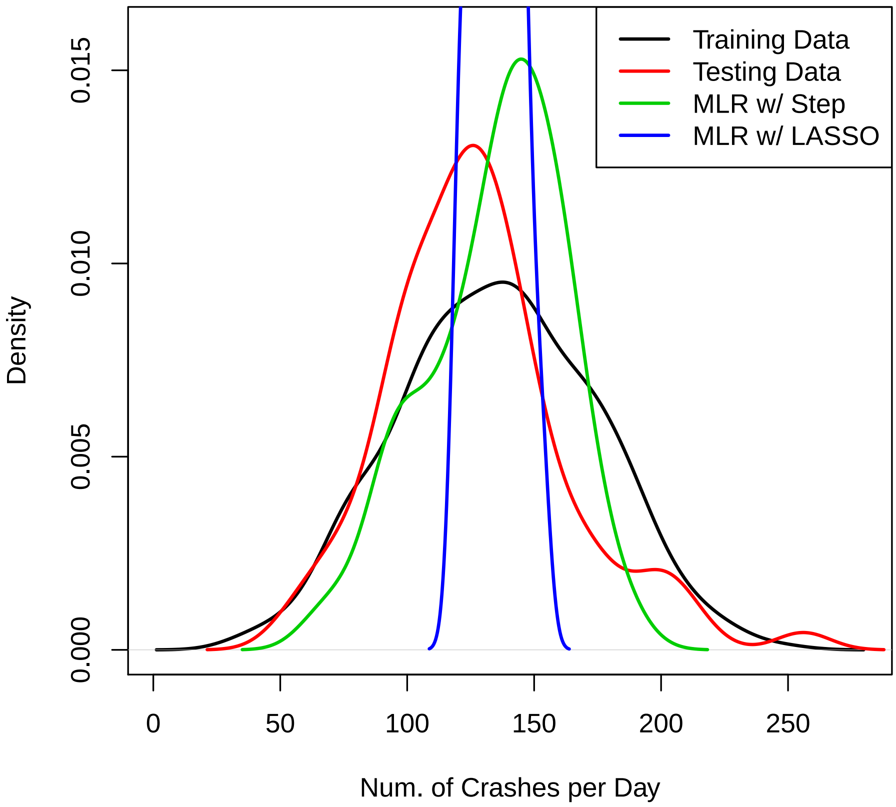
MLR Model Diagnostics:



1.3 LASSO Variable Selection



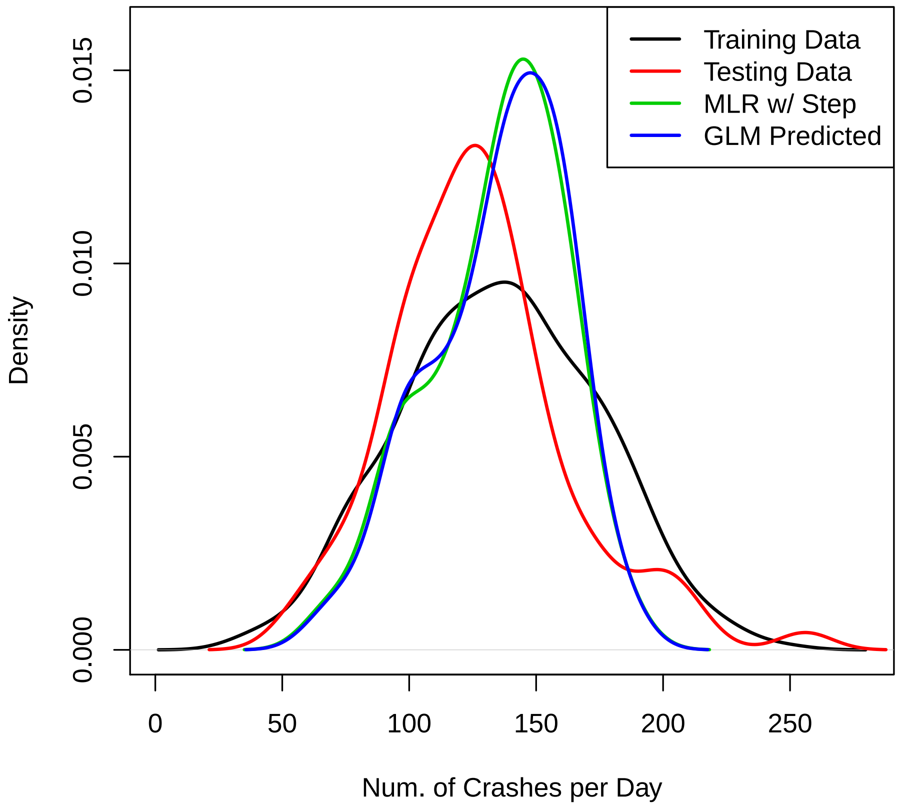
```
Value of lambda that results in the lowest MSE: 1.833195

10 x 1 sparse Matrix of class "dgCMatrix"
                      s0
(Intercept) 316.42924787
month          .
day            0.23352977
temp           0.06176113
relhum         .
precip         .
wind.dir       .
wind.spd      -2.01652421
visibility    -5.12835456
pressure      -0.91108125

MLR w/ LASSO MSE: 1334.424
```



This is clearly a terrible fit.....

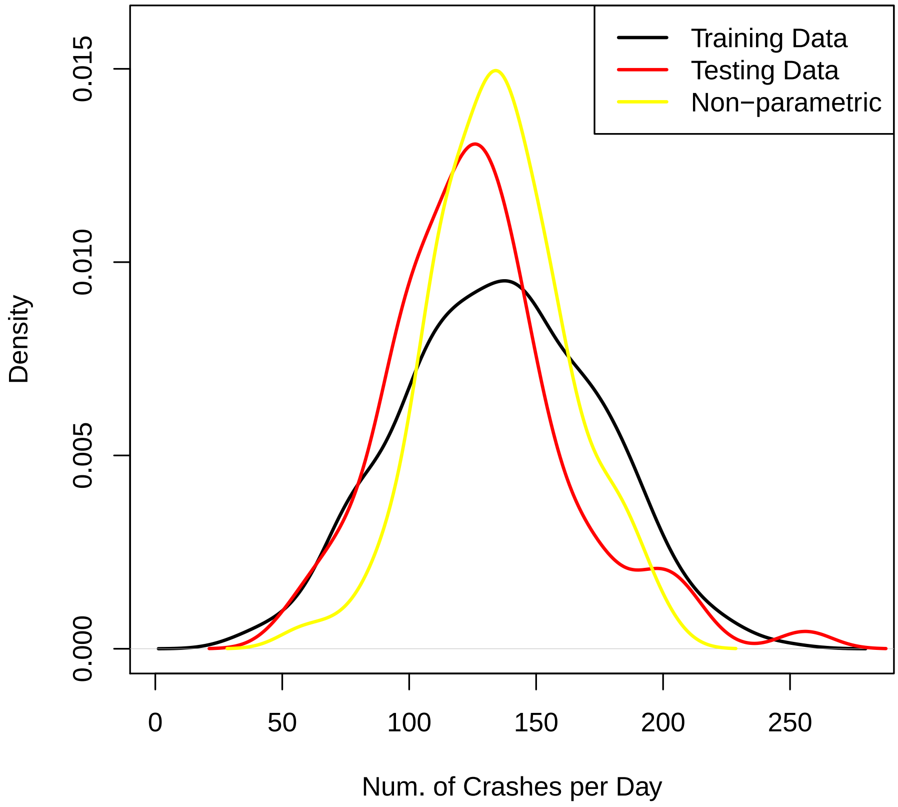
1.4 Generalized Linear Model

```
Call:
glm(formula = crashes ~ month + day + temp + relhum + precip +
    wind.dir + wind.spd + visibility + pressure, family = gaussian(link = "identity"),
    data = train)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-79.335  -18.853   -0.679   19.692   88.901

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)    791.9625   565.5173   1.400 0.162387
monthAUGUST     28.1143    14.2525   1.973 0.049431 *
monthDECEMBER   38.0453    13.6585   2.785 0.005674 **
monthFEBRUARY   34.8072    14.6491   2.376 0.018106 *
monthJANUARY    52.9286    14.6668   3.609 0.000359 ***
monthJULY       38.2162    14.7552   2.590 0.010050 *
monthJUNE       31.9660    11.8956   2.687 0.007594 **
monthMARCH      10.5997     9.7818   1.084 0.279377
monthMAY        23.4757    10.4261   2.252 0.025046 *
monthNOVEMBER   25.7166    11.7240   2.193 0.029014 *
monthOCTOBER    34.9887     9.5613   3.659 0.000297 ***
monthSEPTEMBER  26.9859    10.7824   2.503 0.012837 *
dayMONDAY      -24.3617     6.1856  -3.938 0.000101 ***
daySATURDAY    -44.0734     6.0752  -7.255 3.25e-12 ***
daySUNDAY      -63.9712     6.0884 -10.507  < 2e-16 ***
dayTHURSDAY    -12.5281     6.1086  -2.051 0.041118 *
dayTUESDAY      -9.7347     6.1057  -1.594 0.111870
dayWEDNESDAY    -9.6339     6.0622  -1.589 0.113041
temp            -0.5824     1.0183  -0.572 0.567779
relhum          -0.8393     0.3532  -2.376 0.018089 *
precip           0.4340     0.4469   0.971 0.332244
wind.dir         2.1701     0.8995   2.413 0.016416 *
wind.spd        -3.5396     1.0086  -3.510 0.000515 ***
visibility      -4.1926     1.5441  -2.715 0.006993 **
pressure        -5.6648     5.8171  -0.974 0.330908
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 865.032)

    Null deviance: 503970  on 334  degrees of freedom
Residual deviance: 268160  on 310  degrees of freedom
AIC: 3242.2

Number of Fisher Scoring iterations: 2

GLM MSE: 974.3266
```


Training Data
Testing Data
MLR w/ Step
GLM Predicted
Density
0.000
0.005
0.010
0.015
0
50
100
150
200
250
Num. of Crashes per Day

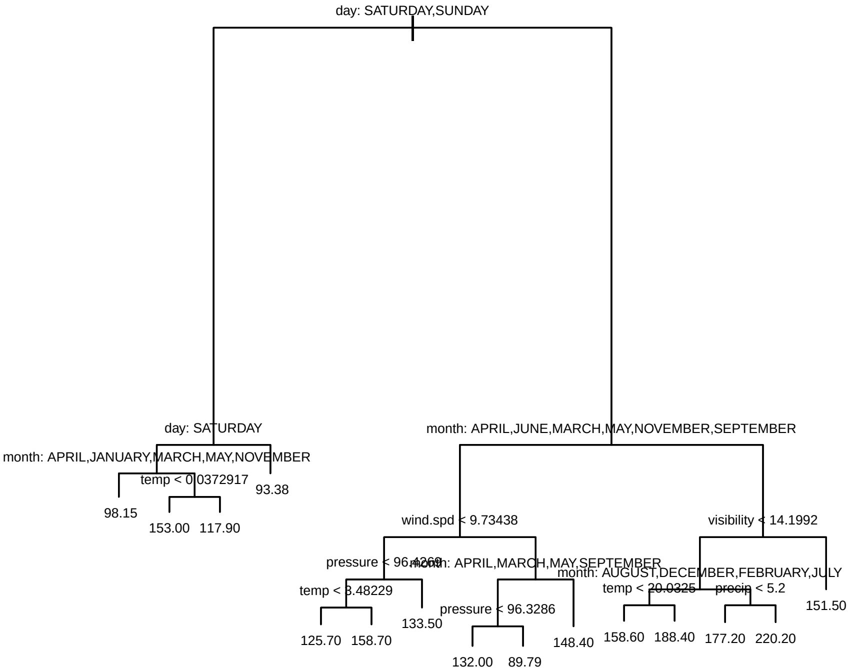
1.5 Non-parametric Approach

```
Kernel Regression Significance Test
Type I Test with IID Bootstrap (399 replications, Pivot = TRUE, joint = FALSE)
Explanatory variables tested for significance:
month (1), day (2), temp (3), relhum (4), precip (5), wind.dir (6), wind.spd (7), visibility

                 month       day     temp   relhum  precip wind.dir wind.spd
Bandwidth(s): 0.916666 0.4419936 9.705523 12.39832 6428386 20379937 14.35713
              visibility pressure
Bandwidth(s):    6167572  6886070

Individual Significance Tests
P Value:
month      0.0075188 **
day        < 2.22e-16 ***
temp       0.0175439 *
relhum     0.6892231
precip     0.2706767
wind.dir   0.0350877 *
wind.spd   < 2.22e-16 ***
visibility 0.0100251 *
pressure   0.1027569
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Non-parametric MSE: 1203.843
```

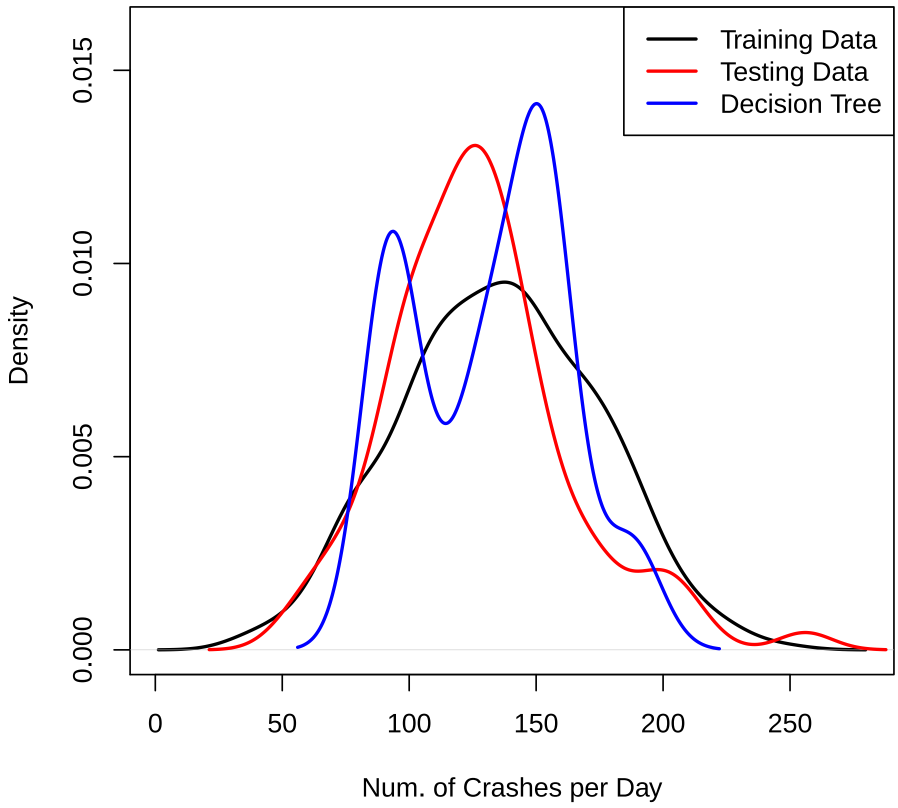

Training Data
Testing Data
Non−parametric
Density
0.000
0.005
0.010
0.015
0
50
100
150
200
250
Num. of Crashes per Day

1.6 Decision Tree

```
Regression tree:
tree(formula = crashes ~ month + day + temp + relhum + precip +
    wind.dir + wind.spd + visibility + pressure, data = train)
Variables actually used in tree construction:
[1] "day"        "month"      "temp"       "wind.spd"   "pressure"
[6] "visibility" "precip"
Number of terminal nodes:  15
Residual mean deviance:  705.1 = 225600 / 320
Distribution of residuals:
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
-65.0000 -17.4200   0.1304   0.0000  17.5900  66.0000
```

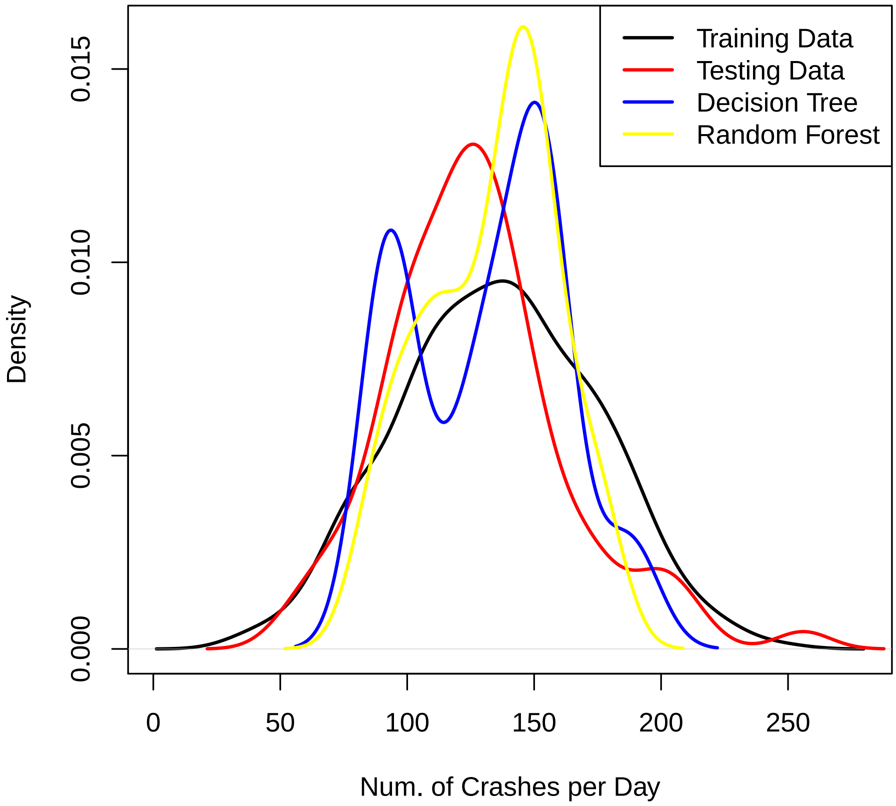


```
Decision Tree MSE: 1164.874
```


Training Data
Testing Data
Decision Tree
Density
0.000
0.005
0.010
0.015
0
50
100
150
200
250
Num. of Crashes per Day

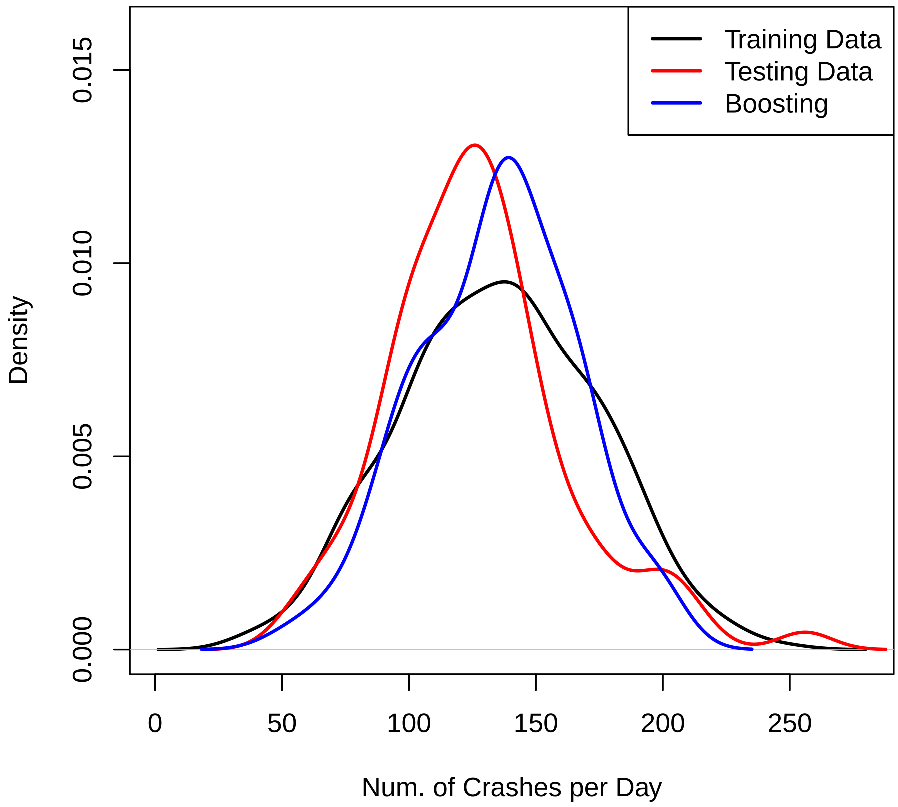
1.7 Random Forest

```
Call:
 randomForest(formula = crashes ~ month + day + temp + relhum +      precip + wind.dir + wir
               Type of random forest: regression
                     Number of trees: 500
No. of variables tried at each split: 3

          Mean of squared residuals: 837.889
                    % Var explained: 44.3

Random Forest MSE: 1017.569
```



1.8 Boosting

```
Distribution not specified, assuming gaussian ...

                    var   rel.inf
month             month 37.449966
day                 day 13.487334
wind.dir       wind.dir 10.802975
wind.spd       wind.spd  8.292799
visibility visibility  7.510607
pressure       pressure  6.772252
temp               temp  5.864595
relhum           relhum  5.223828
precip           precip  4.595645

Boosting MSE: 1052.224
```



1.9 Regression Summary

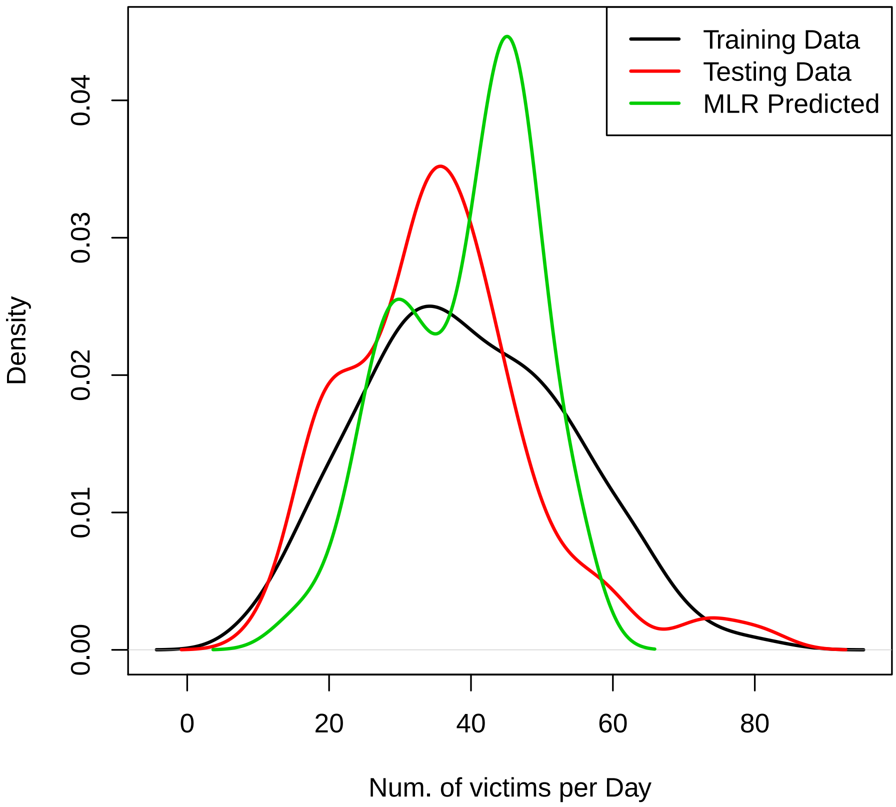
```
All model MSEs:

      MLR      GLM       NP     Tree       RF Boosting 
 1029.308 974.3266 1203.843 1164.874 1017.569 1052.224 
```

Winner: GLM!

2 Predicting Number of Victims

2.1 Multiple Linear Regression

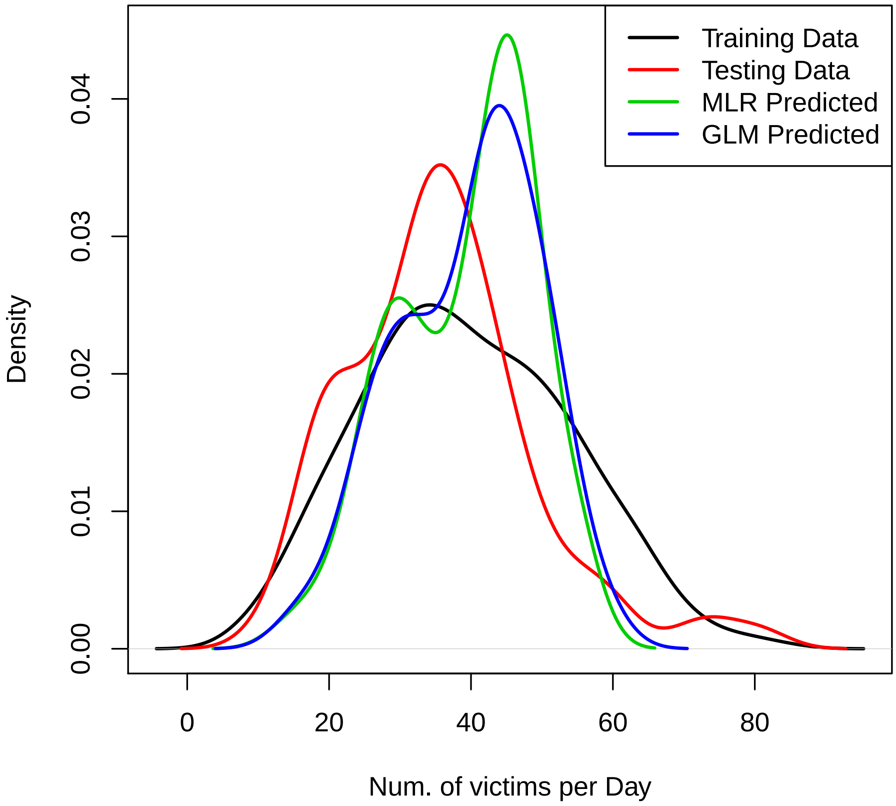
```
Call:
lm(formula = victims ~ month + day + wind.spd, data = train,
    x = TRUE, y = TRUE)

Residuals:
    Min      1Q  Median      3Q     Max
-28.201  -6.864   0.272   6.680  37.935

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     48.3371     4.1058  11.773  < 2e-16 ***
monthAUGUST     11.2373     3.0844   3.643 0.000314 ***
monthDECEMBER   10.2125     3.2096   3.182 0.001609 **
monthFEBRUARY    7.8671     3.0711   2.562 0.010882 *
monthJANUARY     9.2144     3.1289   2.945 0.003470 **
monthJULY       12.3294     3.0452   4.049 6.48e-05 ***
monthJUNE        9.2431     3.0452   3.035 0.002603 **
monthMARCH       1.0384     3.0717   0.338 0.735536
monthMAY         6.1042     3.0446   2.005 0.045825 *
monthNOVEMBER    5.1081     3.1965   1.598 0.111040
monthOCTOBER     9.9902     3.1395   3.182 0.001608 **
monthSEPTEMBER  10.5302     3.0902   3.408 0.000740 ***
dayMONDAY      -12.5839     2.3256  -5.411 1.24e-07 ***
daySATURDAY    -21.8174     2.3350  -9.344  < 2e-16 ***
daySUNDAY      -25.5786     2.3266 -10.994  < 2e-16 ***
dayTHURSDAY     -7.6391     2.3499  -3.251 0.001275 **
dayTUESDAY      -6.6192     2.3290  -2.842 0.004773 **
dayWEDNESDAY    -7.3388     2.3275  -3.153 0.001771 **
wind.spd        -0.5891     0.3222  -1.828 0.068447 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 11.39 on 316 degrees of freedom
Multiple R-squared:  0.4259,        Adjusted R-squared:  0.3932
F-statistic: 13.02 on 18 and 316 DF,  p-value: < 2.2e-16

MLR MSE: 153.6082
```



```
Consistent Model Specification Test
Parametric null model: lm(formula = crashes ~ month + day + temp + relhum +
                          precip + wind.dir + wind.spd + visibility + pressure,
                          data = train, x = TRUE, y = TRUE)
Number of regressors: 9
IID Bootstrap (399 replications)

Test Statistic ‘Jn’: 2.125212        P Value: 0.0075188 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Null of correct specification is rejected at the 1% level
```

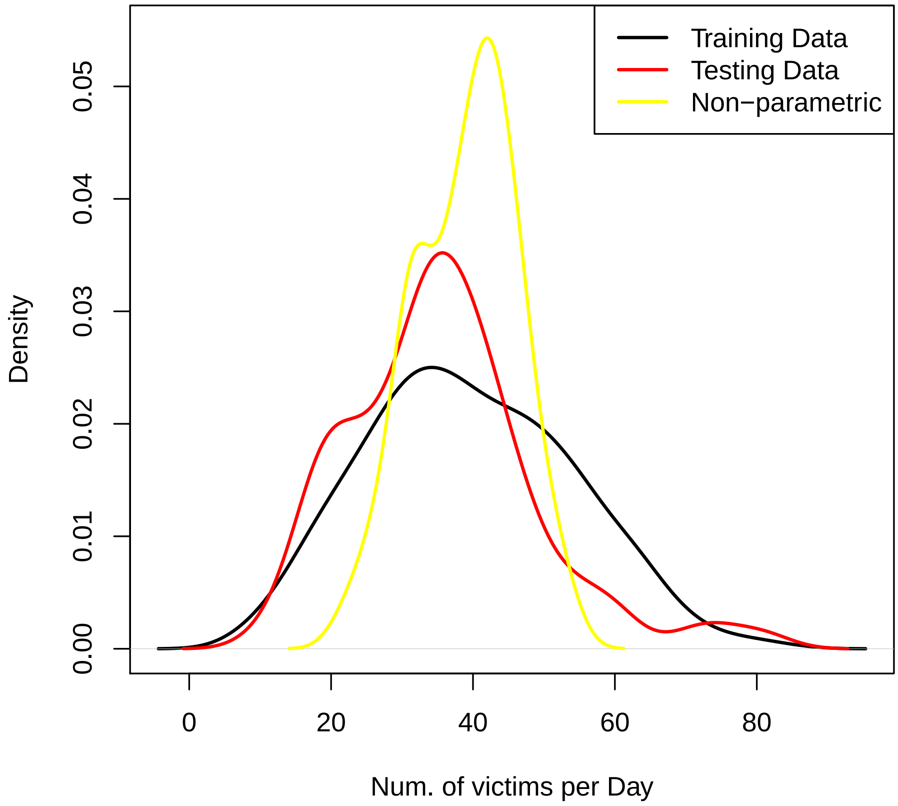
2.2 Generalized Linear Model

```
Call:
glm(formula = victims ~ month + day + temp + relhum + precip + 
    wind.dir + wind.spd + visibility + pressure, family = gaussian(link = "identity"), 
    data = train)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-29.597   -7.378    0.171    7.247   39.637  

Coefficients:
                Estimate Std. Error t value Pr(>|t|)    
(Intercept)    383.54765  218.89064   1.752 0.080722 .  
monthAUGUST     14.79288    5.51660   2.682 0.007721 ** 
monthDECEMBER   10.36465    5.28669   1.961 0.050830 .  
monthFEBRUARY    3.54993    5.67013   0.626 0.531726    
monthJANUARY     7.31513    5.67695   1.289 0.198510    
monthJULY       17.86761    5.71119   3.129 0.001924 ** 
monthJUNE       13.82776    4.60435   3.003 0.002889 ** 
monthMARCH      -0.98606    3.78617  -0.260 0.794699    
monthMAY         9.30472    4.03556   2.306 0.021788 *  
monthNOVEMBER    6.15255    4.53793   1.356 0.176147    
monthOCTOBER    12.42884    3.70083   3.358 0.000882 ***
monthSEPTEMBER  14.63639    4.17346   3.507 0.000520 ***
dayMONDAY      -12.67408    2.39423  -5.294 2.27e-07 ***
daySATURDAY    -21.74037    2.35150  -9.245  < 2e-16 ***
daySUNDAY      -25.43063    2.35661 -10.791  < 2e-16 ***
dayTHURSDAY     -7.89874    2.36442  -3.341 0.000938 ***
dayTUESDAY      -6.87792    2.36327  -2.910 0.003872 ** 
dayWEDNESDAY    -7.52565    2.34645  -3.207 0.001480 ** 
temp            -0.57623    0.39413  -1.462 0.144744    
relhum          -0.19986    0.13670  -1.462 0.144754    
precip           0.02343    0.17298   0.135 0.892338    
wind.dir         0.34939    0.34815   1.004 0.316375    
wind.spd        -0.98698    0.39037  -2.528 0.011958 *  
visibility      -0.69167    0.59765  -1.157 0.248031    
pressure        -3.21530    2.25158  -1.428 0.154294    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 129.5969)

    Null deviance: 71422  on 334  degrees of freedom
Residual deviance: 40175  on 310  degrees of freedom
AIC: 2606.3

Number of Fisher Scoring iterations: 2

GLM MSE: 142.8508
```


Training Data
Testing Data
MLR Predicted
GLM Predicted
Density
0.00
0.01
0.02
0.03
0.04
0
20
40
60
80
Num. of victims per Day

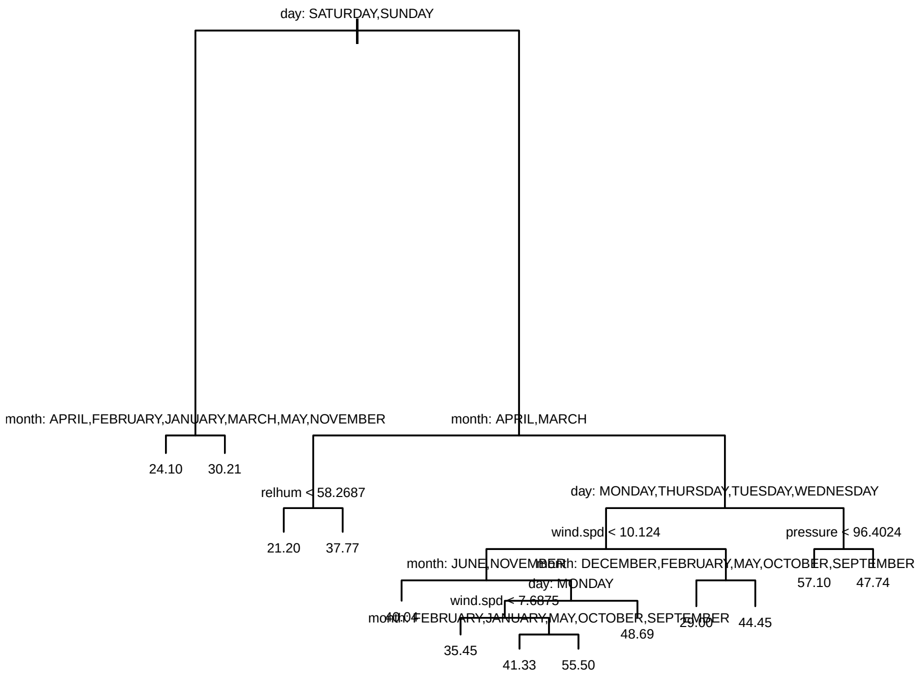
2.3 Non-parametric Approach

```
Kernel Regression Significance Test
Type I Test with IID Bootstrap (399 replications, Pivot = TRUE, joint = FALSE)
Explanatory variables tested for significance:
month (1), day (2), temp (3), relhum (4), precip (5), wind.dir (6), wind.spd (7), visibility

                 month       day     temp  relhum   precip wind.dir wind.spd
Bandwidth(s): 0.916666 0.4512622 15.01095 11.0829 9.474667  5925261 11.88198
              visibility pressure
Bandwidth(s):   52101772  3255838

Individual Significance Tests
P Value:
month      0.0025063 **
day        < 2.22e-16 ***
temp       0.0075188 **
relhum     0.7969925
precip     0.0350877 *
wind.dir   0.1679198
wind.spd   0.0050125 **
visibility 0.0225564 *
pressure   0.2080201
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Non-parametric MSE: 170.7991
```

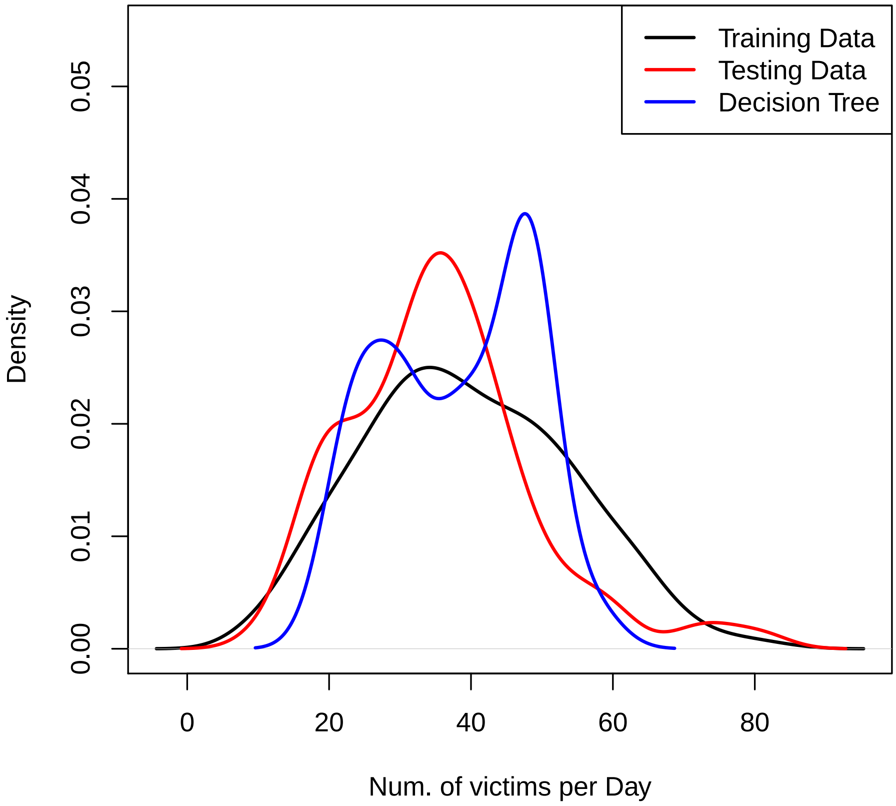

Training Data
Testing Data
Non−parametric
Density
0.00
0.01
0.02
0.03
0.04
0.05
0
20
40
60
80
Num. of victims per Day

2.4 Decision Tree

```
Regression tree:
tree(formula = victims ~ month + day + temp + relhum + precip +
    wind.dir + wind.spd + visibility + pressure, data = train)
Variables actually used in tree construction:
[1] "day"      "month"    "relhum"   "wind.spd" "pressure"
Number of terminal nodes:  13
Residual mean deviance:  111.3 = 35840 / 322
Distribution of residuals:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
-23.770  -7.331  -0.686   0.000   6.606  45.230
```

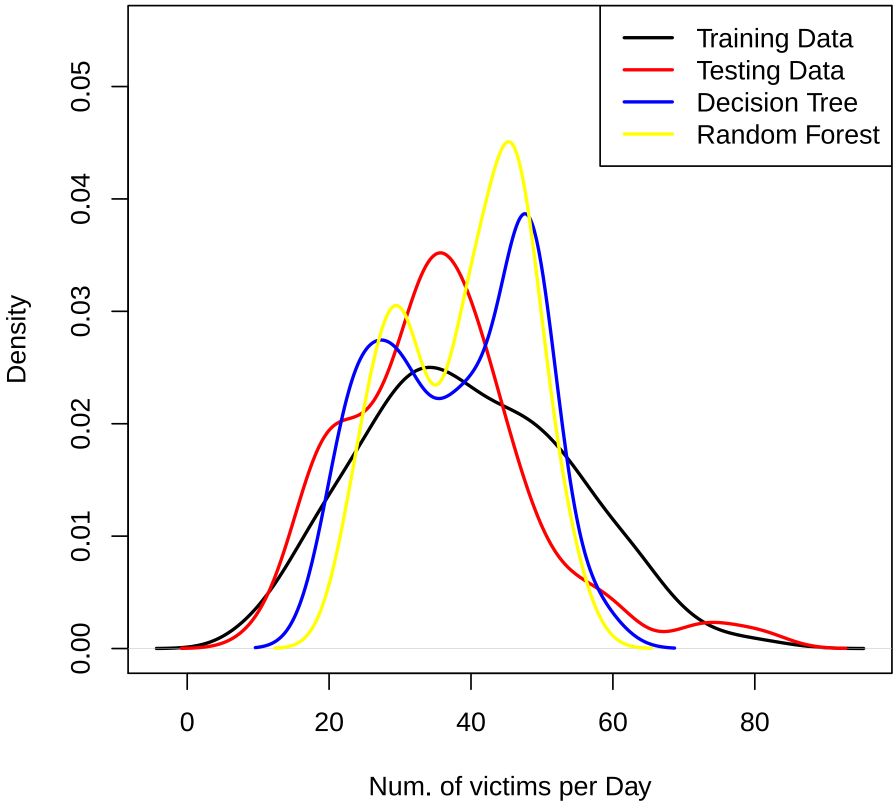


```
Decision Tree MSE: 180.8277
```


Training Data
Testing Data
Decision Tree
Density
0.00
0.01
0.02
0.03
0.04
0.05
0
20
40
60
80
Num. of victims per Day

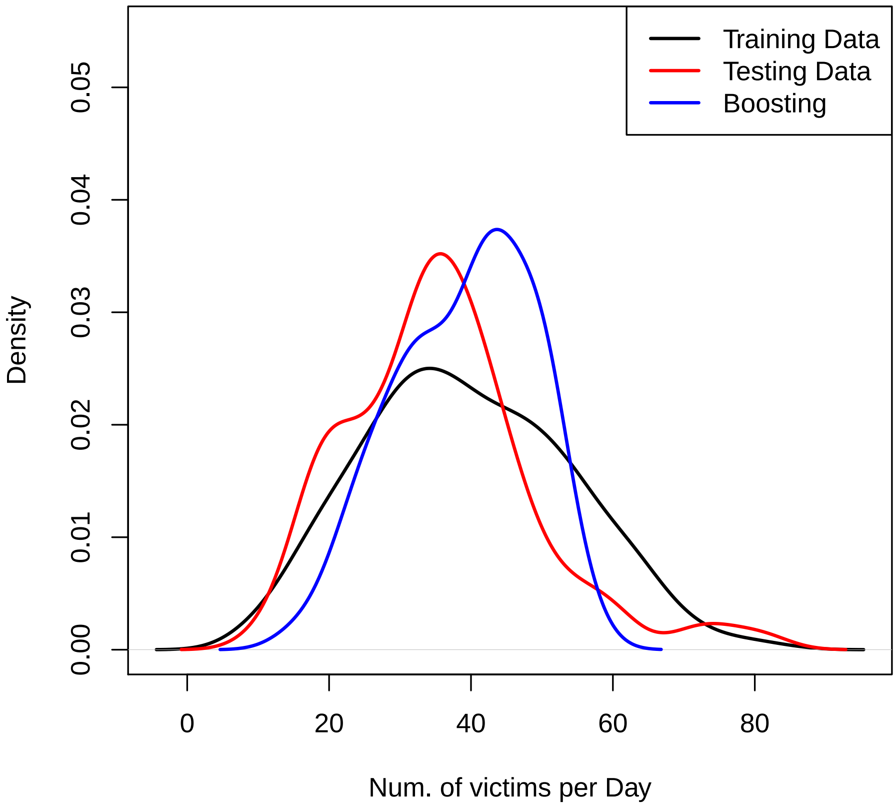
2.5 Random Forest

```
Call:
 randomForest(formula = victims ~ month + day + temp + relhum +      precip + wind.dir + wir
               Type of random forest: regression
                     Number of trees: 500
No. of variables tried at each split: 3

          Mean of squared residuals: 142.6944
                    % Var explained: 33.07

Random Forest MSE: 152.5664
```



2.6 Boosting

```
Distribution not specified, assuming gaussian ...

                   var   rel.inf
month            month 40.877423
day                day 12.957957
pressure      pressure  9.455169
wind.dir      wind.dir  9.081652
visibility visibility  6.599191
wind.spd      wind.spd  6.451126
temp              temp  5.749958
relhum          relhum  4.830842
precip          precip  3.996683

Boosting MSE: 143.6589
```



2.7 Regression Summary

```
All model MSEs:

      MLR      GLM       NP     Tree       RF Boosting 
 153.6082 142.8508 170.7991 180.8277 152.5664 143.6589 
```

Winner: GLM (again)!

3 Answering Hypotheses

3.1 Visibility on a given day will be inversely correlated with # of crashes per day.

3.2 Temperature will have a weak correlation with # of crashes per day (people drive more recklessly in the summer? also tourism = more traffic in summer).

3.3 Precipitation will be correlated with # of crashes per day.

3.4 Summer will have more crashes involving cyclists and motorcyclists.

3.5 Crash fatality will be higher on weekends when more people are driving under the influence.

3.6 Fatal, more severe crashes occur proportionately more often at nighttime, as visibility is reduced due to lack of sunlight.

3.7 Single-vehicle crashes should be more proportionally higher during adverse weather, especially snow/ice conditions.