NYC Flights

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The NYC Flights dataset gives the data on all the flights that departed New York's airports (i.e. JFK, LGA or EWR) in 2013. The combined the data about the flights and the weather gives the information about the scheduled and actual date and time of departure,origin and destination airports, scheduled and actual date and time of arrival, and time difference between actual and scheduled time of departure and arrival. It also gives the data about the weather condition at that time.
Number of observation n=336776
Number of variables p=29

Classes created for k-NN - Class 1: If the flight was on time Class 2: If the flight arrived late than the scheduled time.

Features in a dataset (columns) are the variables which give us information based on which analysis can be performed.
Two features used for this model, p_1=wind_speed time and p_2=distance

For the purpose of plotting, observations with the values 'NA' are removed and 150 observations are sampled randomly.

```
# Load standard libraries
library(tidyverse)
library(nycflights13)
library(ggplot2)
library(MASS)
library(class)
library(dplyr)
library(gmodels)
```

```
# Joining the flight and weather data
flights_weather <- left_join(flights, weather)
```

```
## Joining, by = c("year", "month", "day", "origin", "hour", "time_hour")
```

```
# Removing the NA values
weather_flight <- na.omit(flights_weather)
```

```
summary(weather_flight)
```

```
##       year          month             day           dep_time    sched_dep_time
##  Min.   :2013   Min.   : 1.000   Min.   : 1.00   Min.   :   1   Min.   : 500
##  1st Qu.:2013   1st Qu.: 3.000   1st Qu.: 8.00   1st Qu.:1125   1st Qu.:1120
##  Median :2013   Median : 5.000   Median :15.00   Median :1448   Median :1442
##  Mean   :2013   Mean   : 5.919   Mean   :15.36   Mean   :1410   Mean   :1397
##  3rd Qu.:2013   3rd Qu.: 9.000   3rd Qu.:23.00   3rd Qu.:1717   3rd Qu.:1700
```

```
##  Max.   :2013   Max.   :12.000   Max.   :31.00   Max.   :2400   Max.   :2359
##    dep_delay          arr_time    sched_arr_time   arr_delay
##  Min.   :-23.00   Min.   :   1   Min.   :   1   Min.   :-74.000
##  1st Qu.: -5.00   1st Qu.:1311   1st Qu.:1325   1st Qu.:-16.000
##  Median : -1.00   Median :1640   Median :1645   Median : -4.000
##  Mean   : 12.29   Mean   :1588   Mean   :1608   Mean   :  7.287
##  3rd Qu.: 11.00   3rd Qu.:1925   3rd Qu.:1921   3rd Qu.: 14.000
##  Max.   :797.00   Max.   :2400   Max.   :2359   Max.   :783.000
##    carrier              flight       tailnum             origin
##  Length:72734       Min.   :   1   Length:72734       Length:72734
##  Class :character   1st Qu.: 605   Class :character   Class :character
##  Mode  :character   Median :1552   Mode  :character   Mode  :character
##                     Mean   :2016
##                     3rd Qu.:3547
##                     Max.   :6181
##      dest              air_time        distance         hour
##  Length:72734       Min.   : 21.0   Min.   :  80   Min.   : 5.00
##  Class :character   1st Qu.: 83.0   1st Qu.: 502   1st Qu.:11.00
##  Mode  :character   Median :128.0   Median : 828   Median :14.00
##                     Mean   :148.7   Mean   :1021   Mean   :13.71
##                     3rd Qu.:184.0   3rd Qu.:1372   3rd Qu.:17.00
##                     Max.   :695.0   Max.   :4983   Max.   :23.00
##      minute        time_hour                       temp            dewp
##  Min.   : 0.00   Min.   :2013-01-01 05:00:00   Min.   : 12.02   Min.   :-9.94
##  1st Qu.:10.00   1st Qu.:2013-03-14 17:00:00   1st Qu.: 37.94   1st Qu.:17.06
##  Median :29.00   Median :2013-05-26 09:00:00   Median : 51.08   Median :28.94
##  Mean   :26.66   Mean   :2013-06-13 17:47:28   Mean   : 53.62   Mean   :32.50
##  3rd Qu.:45.00   3rd Qu.:2013-09-19 16:00:00   3rd Qu.: 68.00   3rd Qu.:48.92
##  Max.   :59.00   Max.   :2013-12-30 18:00:00   Max.   :100.04   Max.   :75.02
##      humid          wind_dir       wind_speed       wind_gust
##  Min.   :13.95   Min.   : 10.0   Min.   : 4.603   Min.   :16.11
##  1st Qu.:35.80   1st Qu.:220.0   1st Qu.:12.659   1st Qu.:20.71
##  Median :44.16   Median :280.0   Median :16.111   Median :24.17
##  Mean   :46.75   Mean   :253.9   Mean   :16.523   Mean   :24.91
##  3rd Qu.:54.77   3rd Qu.:310.0   3rd Qu.:19.563   3rd Qu.:27.62
##  Max.   :96.85   Max.   :360.0   Max.   :39.127   Max.   :66.75
##      precip            pressure          visib
##  Min.   :0.000000   Min.   : 983.8   Min.   : 0.120
##  1st Qu.:0.000000   1st Qu.:1010.8   1st Qu.:10.000
##  Median :0.000000   Median :1015.4   Median :10.000
##  Mean   :0.001352   Mean   :1015.6   Mean   : 9.803
##  3rd Qu.:0.000000   3rd Qu.:1020.4   3rd Qu.:10.000
##  Max.   :0.530000   Max.   :1040.4   Max.   :10.000
```

```
str(weather_flight)
```

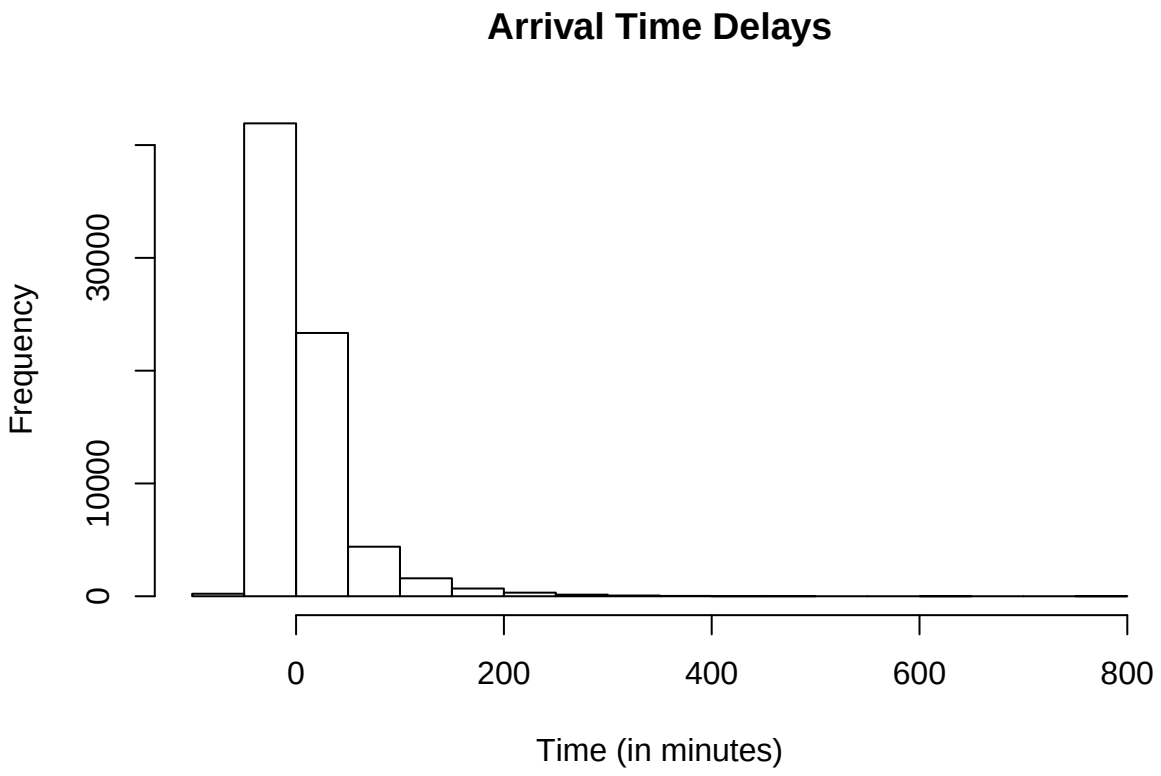
```
## Classes 'tbl_df', 'tbl' and 'data.frame':    72734 obs. of  28 variables:
##  $ year          : int  2013 2013 2013 2013 2013 2013 2013 2013 2013 2013 ...
##  $ month         : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ day           : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ dep_time      : int  533 554 557 558 559 600 600 602 602 623 ...
##  $ sched_dep_time: int  529 600 600 600 600 600 600 610 605 610 ...
##  $ dep_delay     : num  4 -6 -3 -2 -1 0 0 -8 -3 13 ...
##  $ arr_time      : int  850 812 709 753 941 851 837 812 821 920 ...
##  $ sched_arr_time: int  830 837 723 745 910 858 825 820 805 915 ...
```

```
##  $ arr_delay     : num  20 -25 -14 8 31 -7 12 -8 16 5 ...
##  $ carrier       : chr  "UA" "DL" "EV" "AA" ...
##  $ flight        : int  1714 461 5708 301 707 371 4650 1919 4401 1837 ...
##  $ tailnum       : chr  "N24211" "N668DN" "N829AS" "N3ALAA" ...
##  $ origin        : chr  "LGA" "LGA" "LGA" "LGA" ...
##  $ dest          : chr  "IAH" "ATL" "IAD" "ORD" ...
##  $ air_time      : num  227 116 53 138 257 152 134 170 105 153 ...
##  $ distance      : num  1416 762 229 733 1389 ...
##  $ hour          : num  5 6 6 6 6 6 6 6 6 6 ...
##  $ minute        : num  29 0 0 0 0 0 0 10 5 10 ...
##  $ time_hour     : POSIXct, format: "2013-01-01 05:00:00" "2013-01-01 06:00:00" ...
##  $ temp          : num  39.9 39.9 39.9 39.9 39.9 ...
##  $ dewp          : num  25 25 25 25 25 ...
##  $ humid         : num  54.8 54.8 54.8 54.8 54.8 ...
##  $ wind_dir      : num  250 260 260 260 260 260 260 260 260 260 ...
##  $ wind_speed    : num  15 16.1 16.1 16.1 16.1 ...
##  $ wind_gust     : num  21.9 23 23 23 23 ...
##  $ precip        : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ pressure      : num  1011 1012 1012 1012 1012 ...
##  $ visib         : num  10 10 10 10 10 10 10 10 10 10 ...
##  - attr(*, "na.action")= 'omit' Named int  1 3 4 6 7 9 11 12 13 14 ...
##   ..- attr(*, "names")= chr  "1" "3" "4" "6" ...
```

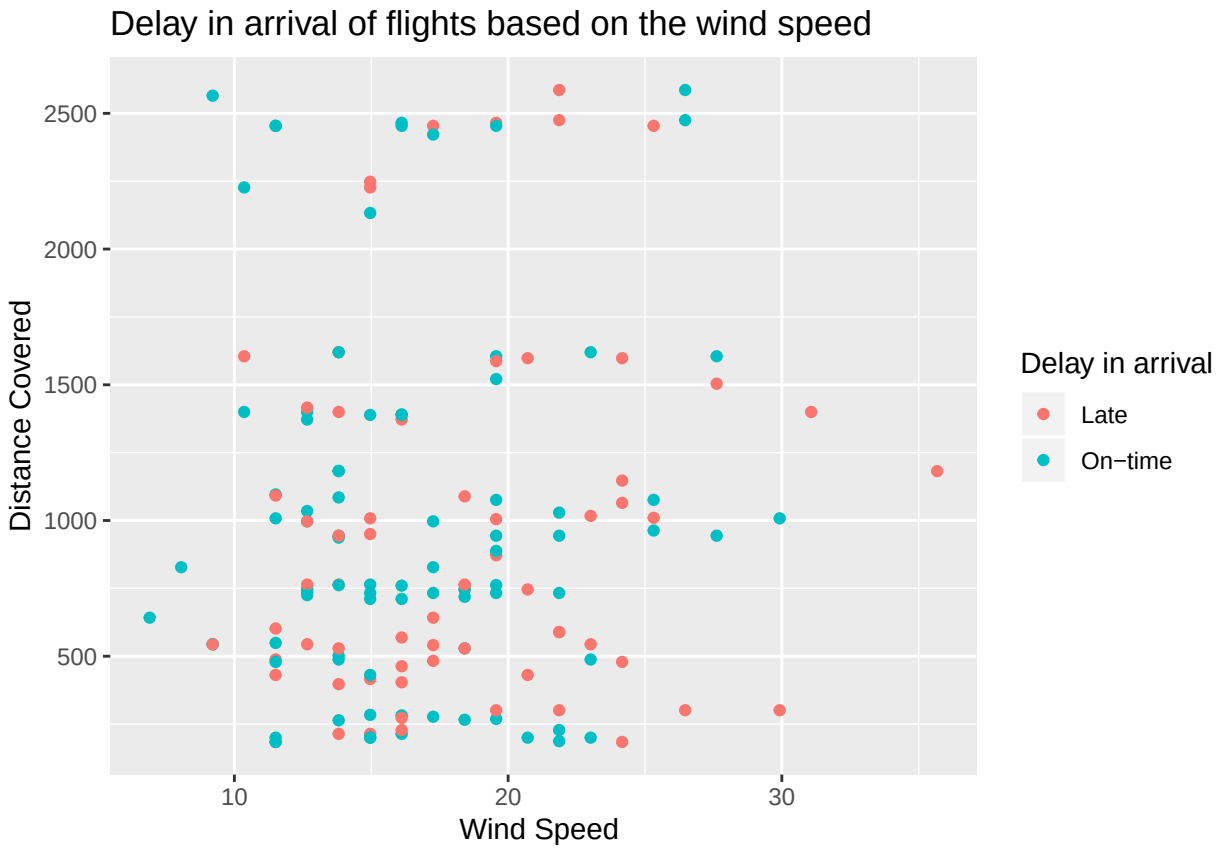
```
head(weather_flight)
```

```
## # A tibble: 6 x 28
##    year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>
## 1  2013     1     1      533            529         4      850            830
## 2  2013     1     1      554            600        -6      812            837
## 3  2013     1     1      557            600        -3      709            723
## 4  2013     1     1      558            600        -2      753            745
## 5  2013     1     1      559            600        -1      941            910
## 6  2013     1     1      600            600         0      851            858
## # ... with 20 more variables: arr_delay <dbl>, carrier <chr>, flight <int>,
## #   tailnum <chr>, origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>,
## #   hour <dbl>, minute <dbl>, time_hour <dttm>, temp <dbl>, dewp <dbl>,
## #   humid <dbl>, wind_dir <dbl>, wind_speed <dbl>, wind_gust <dbl>,
## #   precip <dbl>, pressure <dbl>, visib <dbl>
```

```
hist(weather_flight$arr_delay, main = "Arrival Time Delays", xlab = "Time (in minutes)")
```

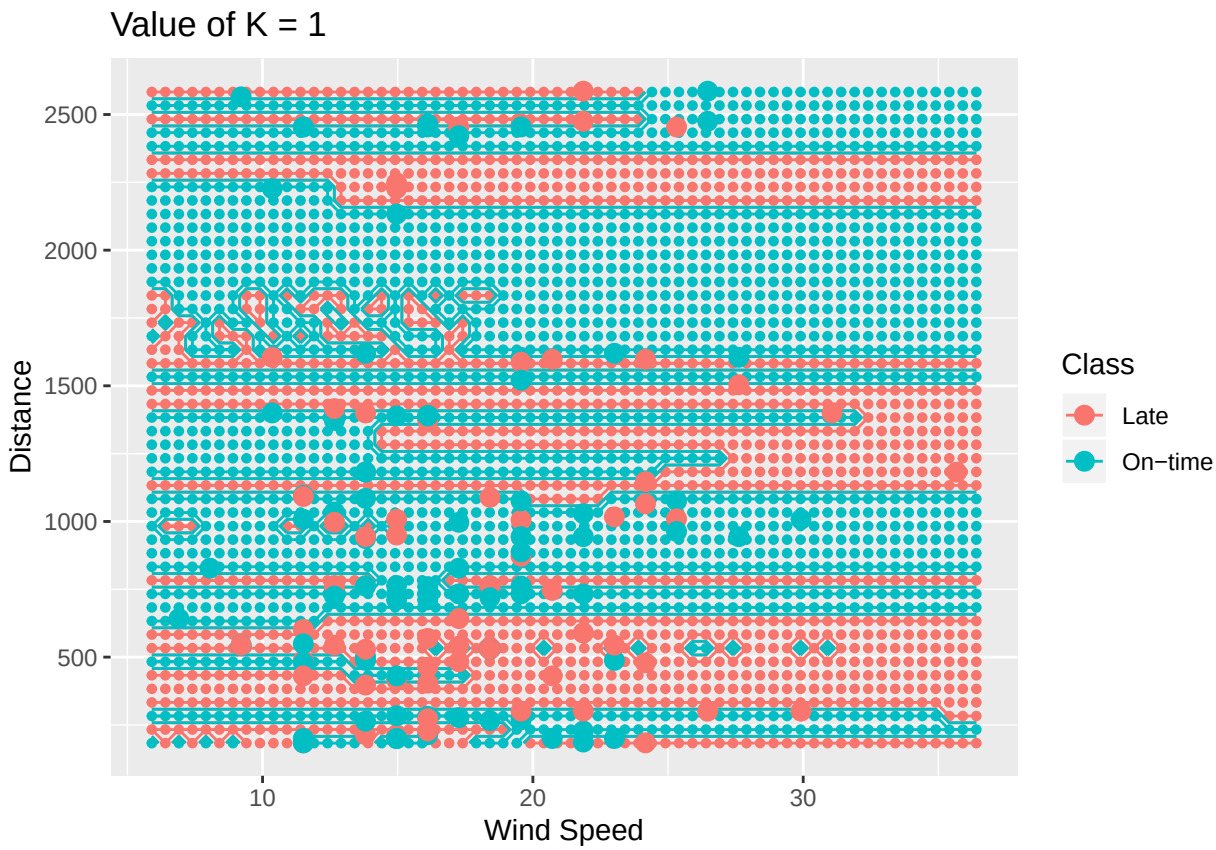


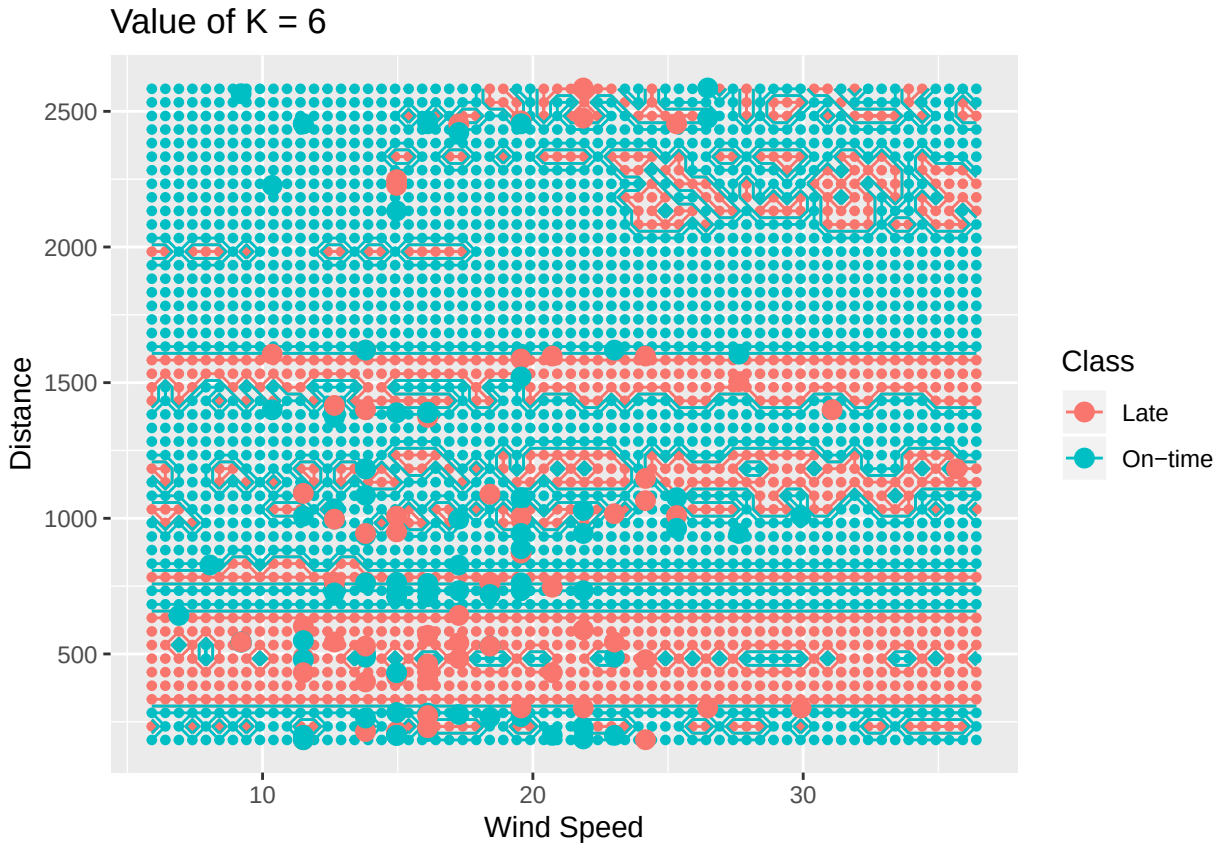

```
# Adding another column in the data frame, 'Class'
weather_flight$Class <- ifelse(weather_flight$arr_delay <=0,"On-time",
                               ifelse
                               (weather_flight$arr_delay >0,"Late",NA))

# Randomly sampling 150 observations
set.seed(3)
weather_flight_rand <- sample(1:nrow(weather_flight),size = 150, replace = FALSE)
weather_flight_rand_df <- weather_flight[weather_flight_rand,]

# Plotting the graph between distance and wind speed
gg <- ggplot(weather_flight_rand_df, aes(weather_flight_rand_df$wind_speed, weather_flight_rand_df$dista
print(gg)
```

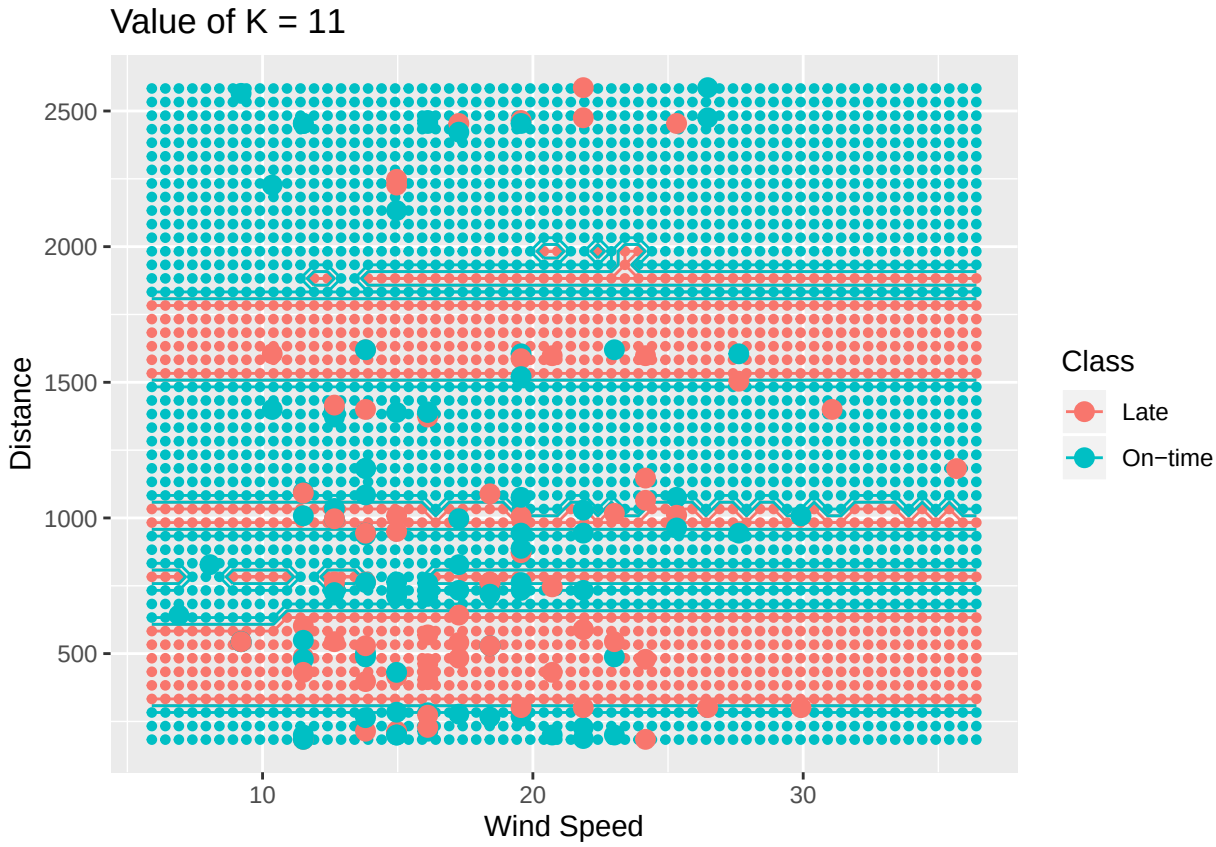


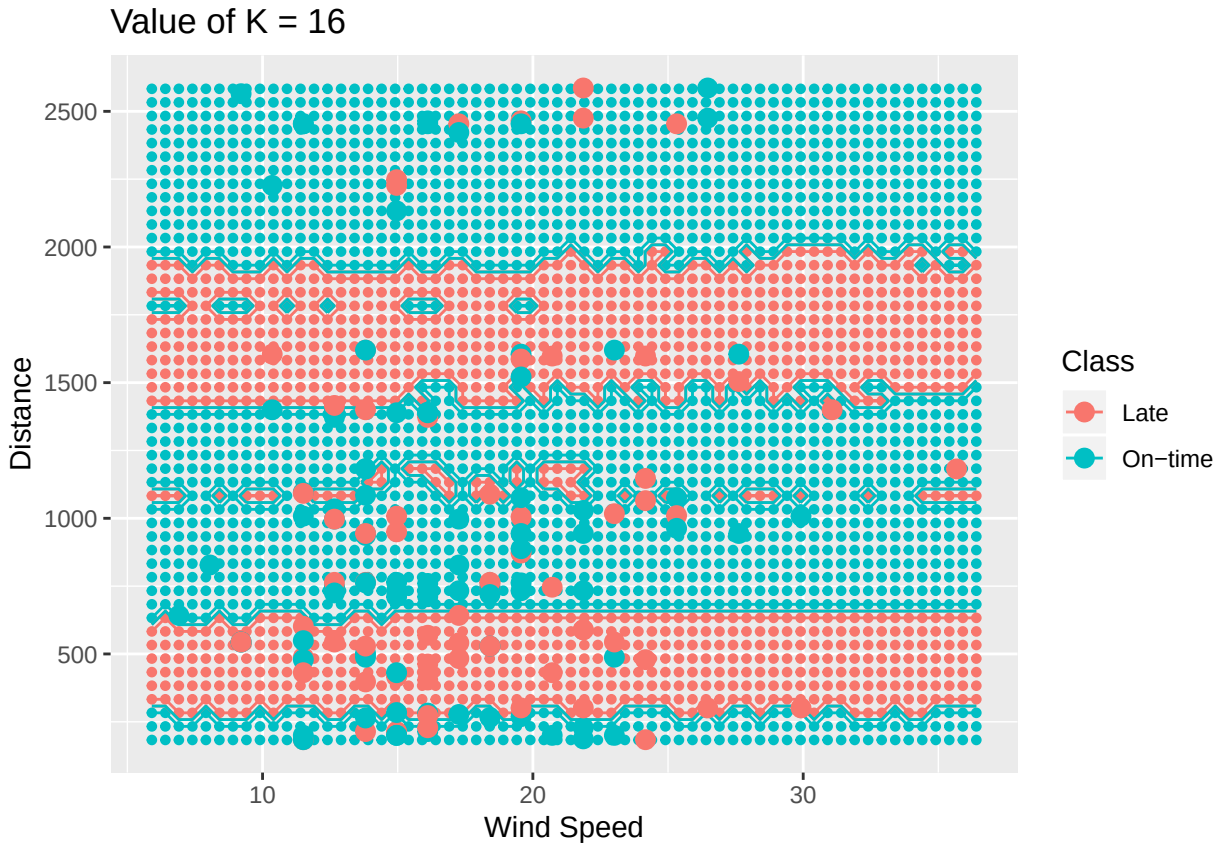

```
# Creating a function for plotting of KNN for different values of K
func_knn <- function(k){

# Training Data
train <- rbind(weather_flight_rand_df[1:150,c('wind_speed','distance')])

# Test Data
test <- expand.grid(x=seq(min(train[,1]-1), max(train[,1]+1),
                          by=0.5),
                    y=seq(min(train[,2]-1), max(train[,2]+1),
                          by=50))

cl <- factor(c(weather_flight_rand_df$Class[1:150]))

classif <- knn(train=train, test=test, cl = cl, k = k, prob = TRUE)

prob <- attr(classif, "prob")

dataf <- bind_rows(mutate(test,
                          prob=prob,
                          cls='On-time',
                          prob_cls=ifelse(classif==cls,
                                          1, 0)),
                   mutate(test,
                          prob=prob,
                          cls='Late',
                          prob_cls=ifelse(classif==cls,
```

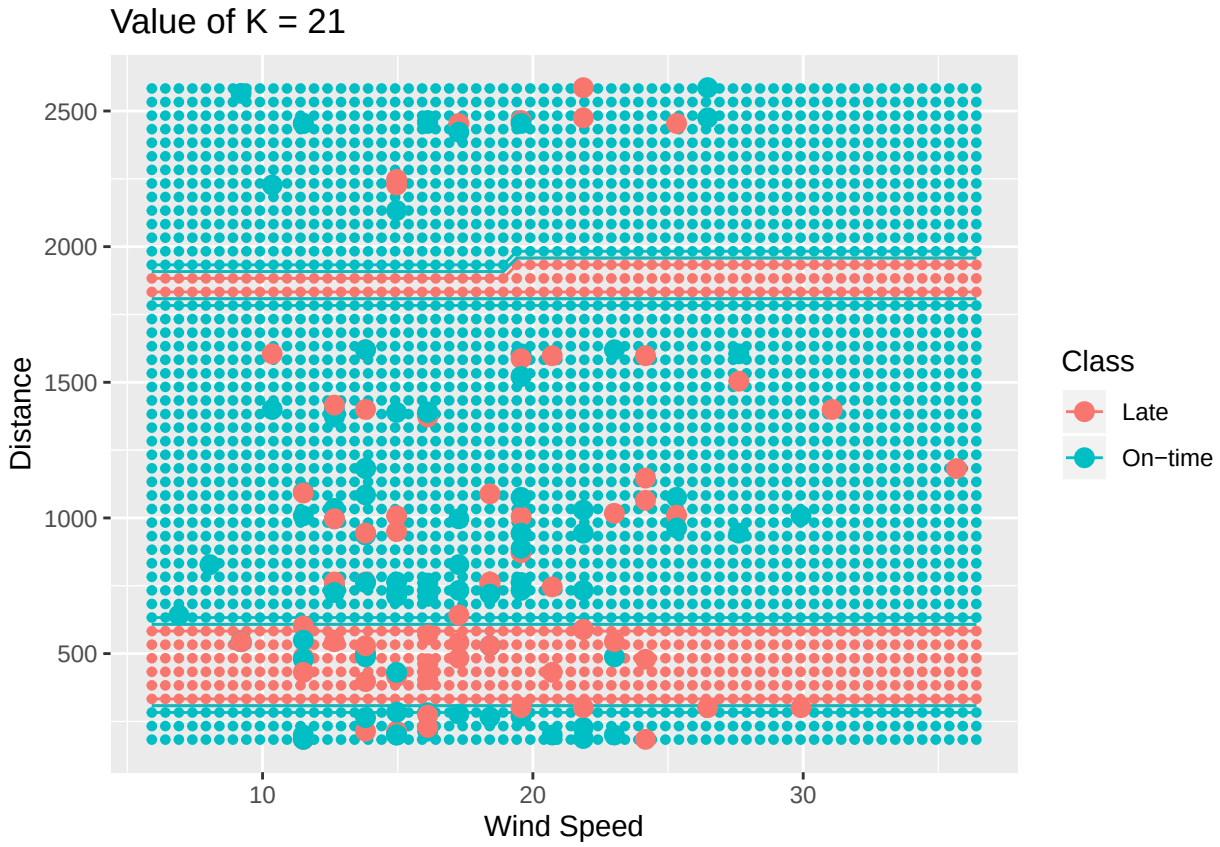
```
                                        1, 0)))
# Plotting KNN
ggp <- ggplot(dataf) + labs(x='Wind Speed', y='Distance') + ggtitle (paste("Value of K =", as.character
  geom_point(aes(x=x, y=y, col=cls),
             data = mutate(test, cls=classif),
             size=1.2) +
  geom_contour(aes(x=x, y=y, z=prob_cls, group=cls, color=cls),
               bins=2, data = dataf) +
  geom_point(aes(x=train$wind_speed, y=train$distance, col=cls), size=3, data=data.frame(x=train[,1], y=
print(ggp)
}

# Calling the function to plot KNN based on multiple values of K
for(i in seq(1, 75, 5)) {
  func_knn(i) }
```

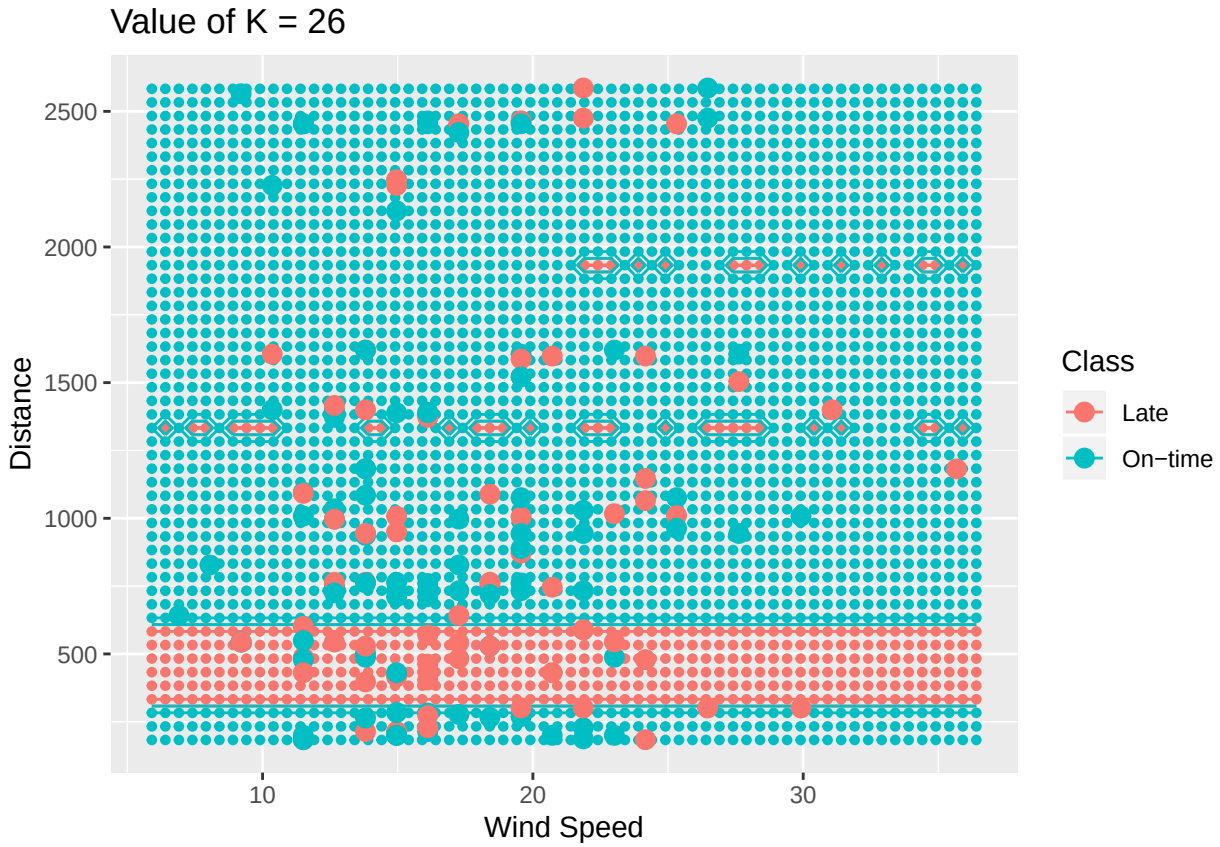


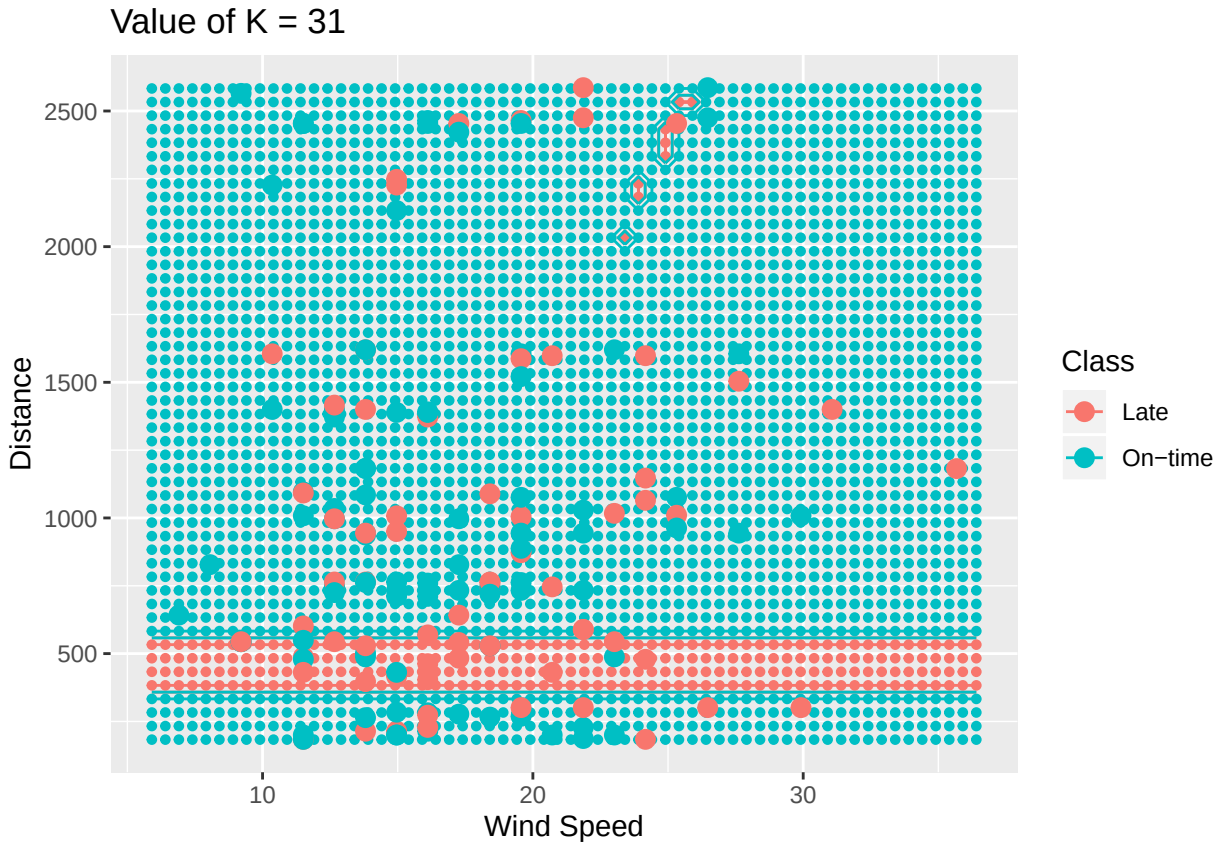

Value of K = 6
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time


Value of K = 11
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time

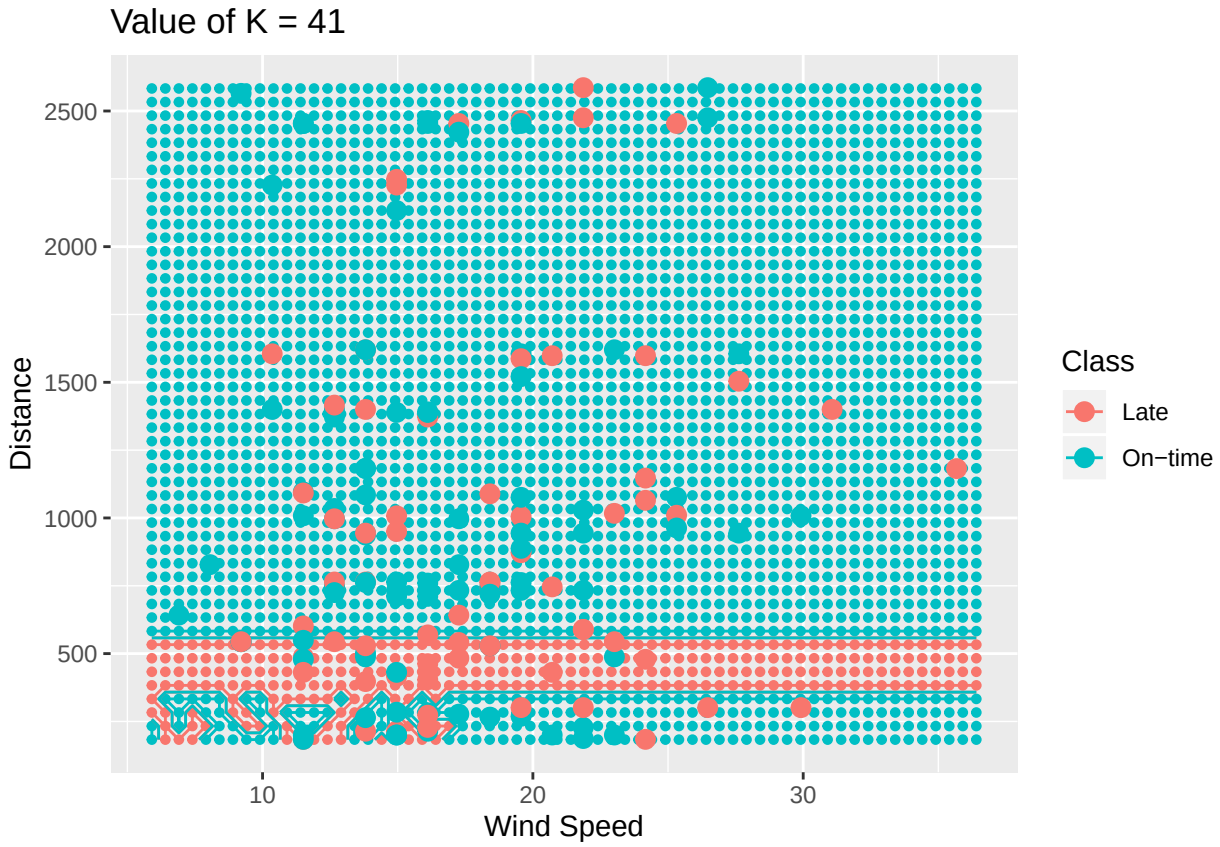

Value of K = 16
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time

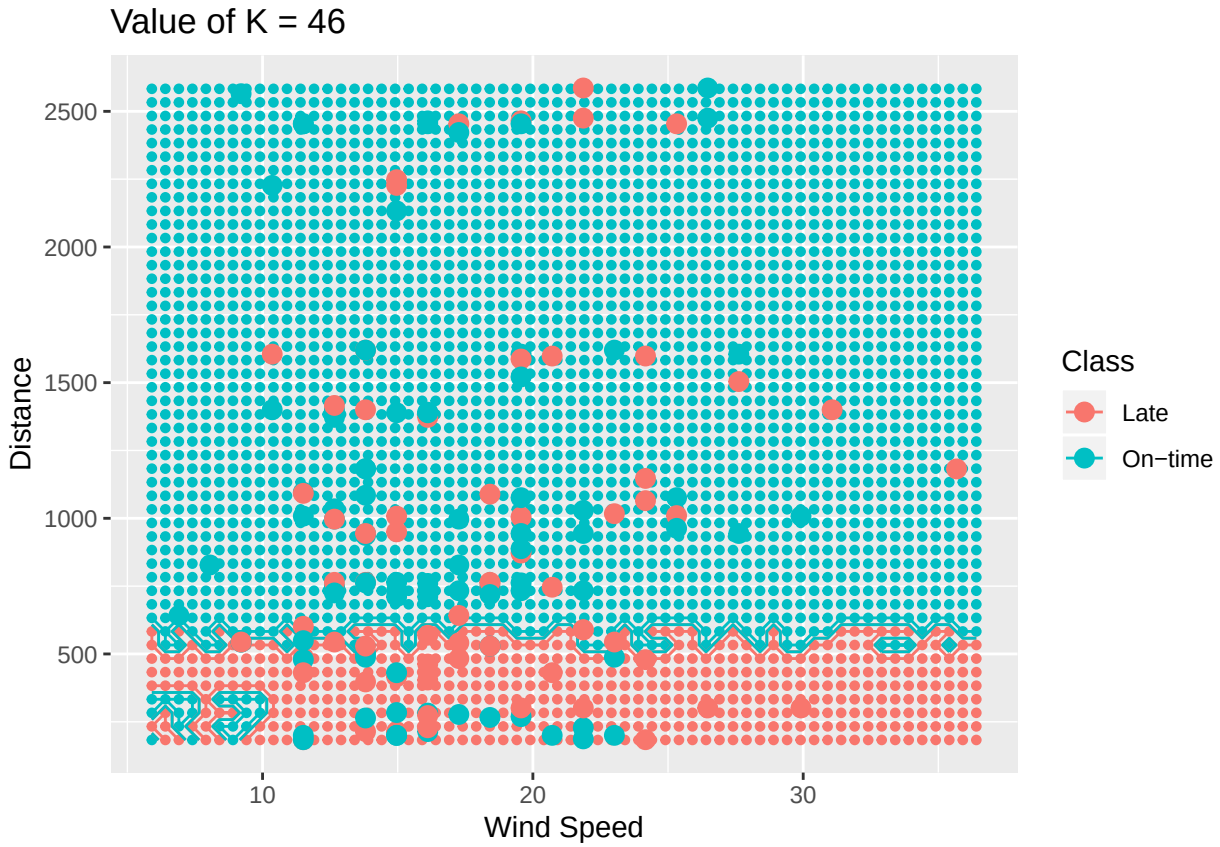

Value of K = 21
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time

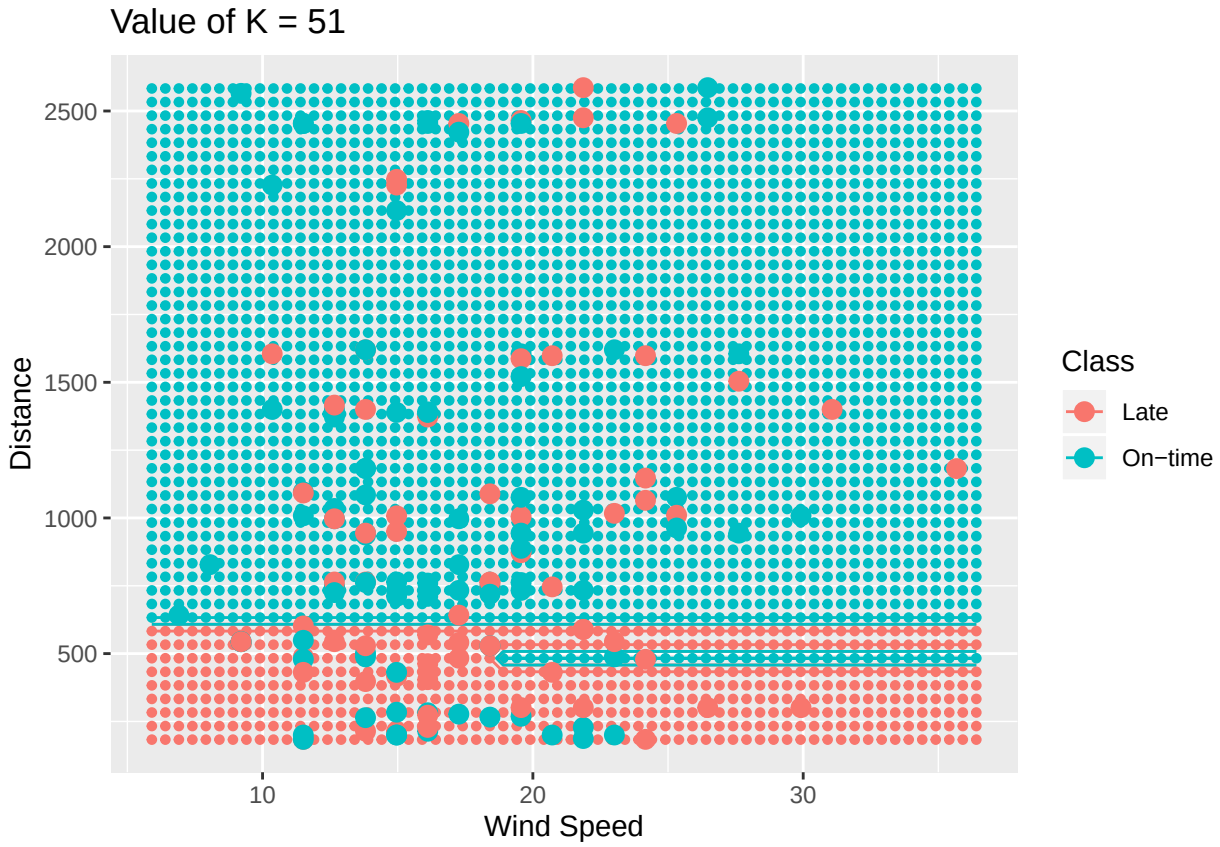

Value of K = 26
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time

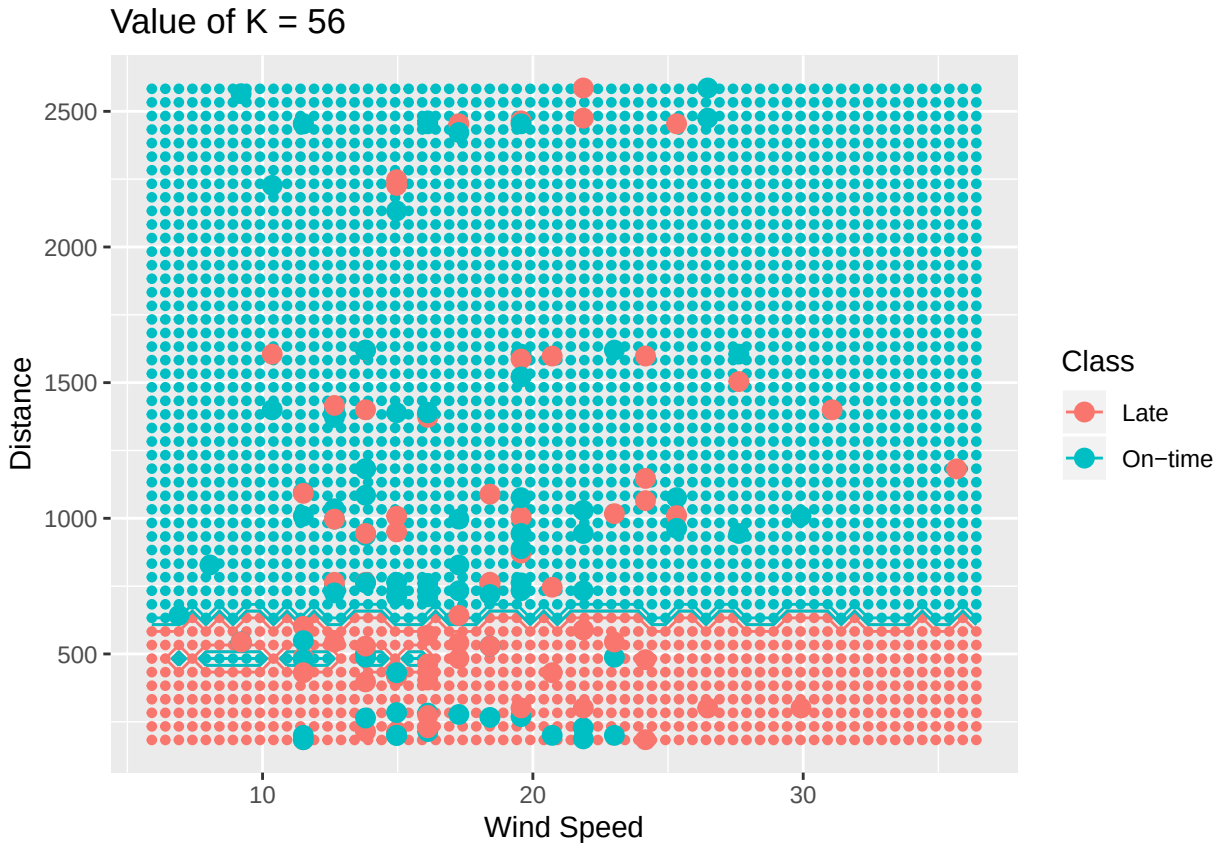

Value of K = 31
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time

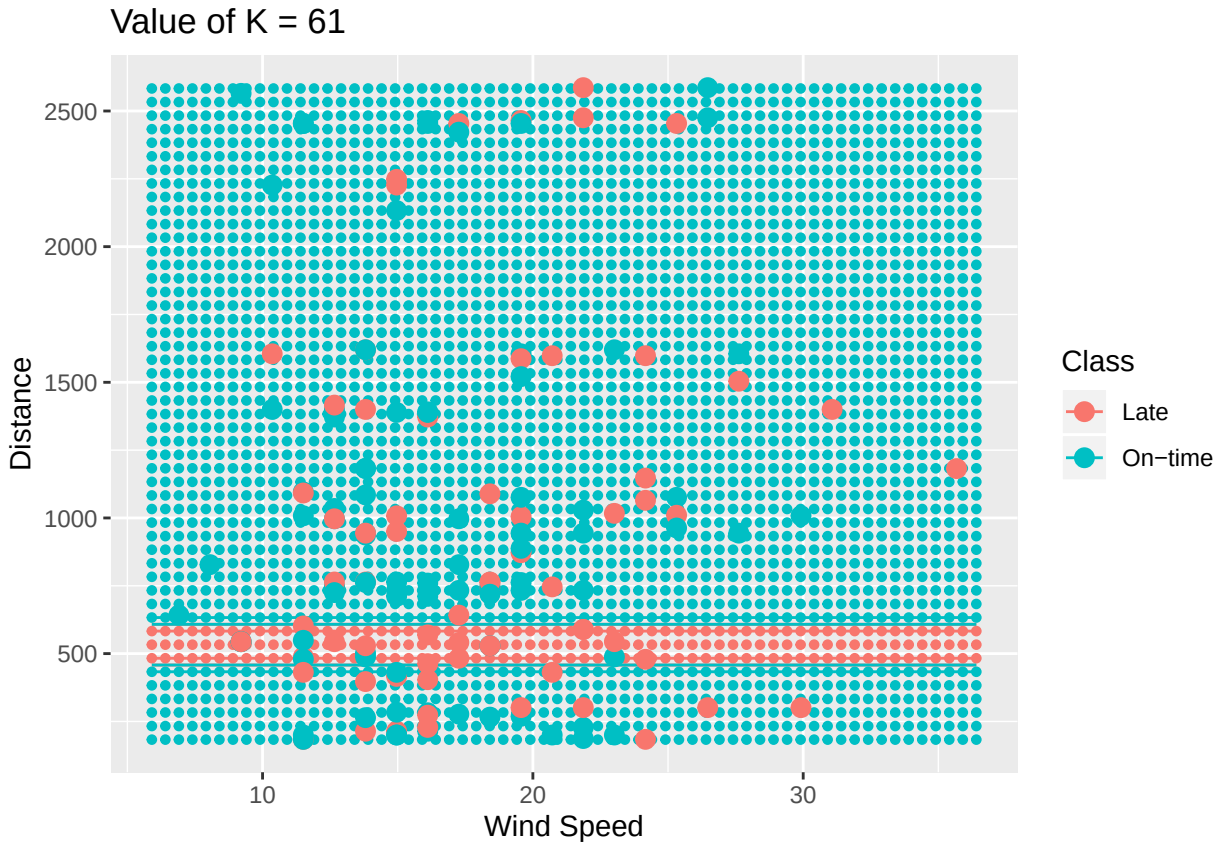

Value of K = 36
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time

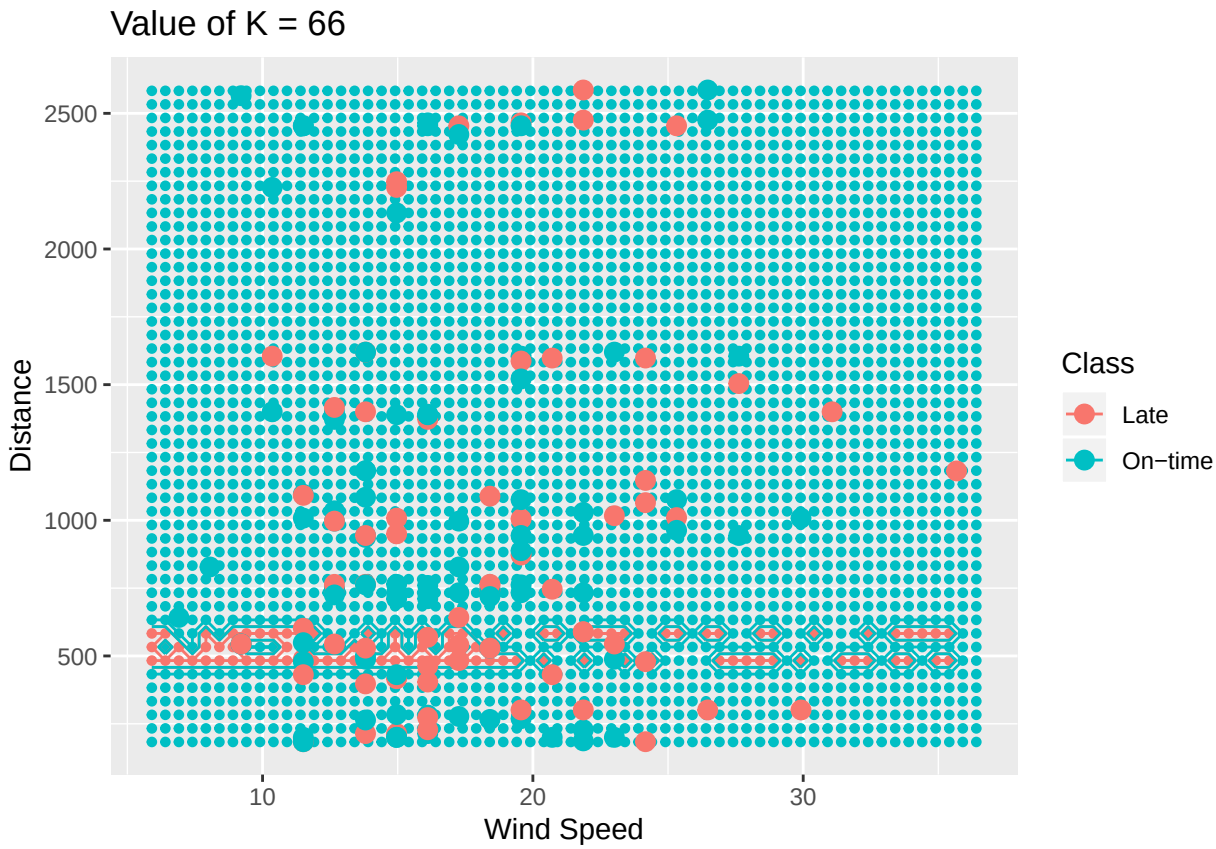

Value of K = 41
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time


Value of K = 46
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time


Value of K = 51
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time


Value of K = 56
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time


Value of K = 61
Distance
2500
2000
1500
1000
500
10
20
30
Wind Speed
Class
Late
On−time




```
## Warning: Not possible to generate contour data
```

```
## Warning in grDevices::contourLines(x = sort(unique(data$x)), y =
## sort(unique(data$y)), : all z values are equal
```

```
## Warning: Not possible to generate contour data
```


```
# Function to calculate training error
func_accuracy <- function(k){

train <- rbind(weather_flight_rand_df[1:150,c('wind_speed','distance')])

cl <- factor(c(weather_flight_rand_df$Class[1:150]))

knn_accuracy <- knn(train=train, test=train, cl = cl, k = k)

data_tab <- table(knn_accuracy, cl)
matr <- as.matrix(data_tab)

# Calculating accuracy
accuracy <- sum(diag(matr))/length(cl)

# Calculating error
train_error <- (1 - accuracy)
print(paste("Training Error for K =", k, "is ", train_error))
}
for(i in seq(1, 75, 5)) {
  func_accuracy(i)
  }
```

```
## [1] "Training Error for K = 1 is  0.0533333333333333"
## [1] "Training Error for K = 6 is  0.32"
## [1] "Training Error for K = 11 is  0.38"
## [1] "Training Error for K = 16 is  0.42"
```

```
## [1] "Training Error for K = 21 is  0.38"
## [1] "Training Error for K = 26 is  0.386666666666667"
## [1] "Training Error for K = 31 is  0.4"
## [1] "Training Error for K = 36 is  0.413333333333333"
## [1] "Training Error for K = 41 is  0.413333333333333"
## [1] "Training Error for K = 46 is  0.426666666666667"
## [1] "Training Error for K = 51 is  0.406666666666667"
## [1] "Training Error for K = 56 is  0.4"
## [1] "Training Error for K = 61 is  0.406666666666667"
## [1] "Training Error for K = 66 is  0.44"
## [1] "Training Error for K = 71 is  0.44"
```

Out of all the plots, the plot with $K = 11$ neither has high bias nor high variance. (It is neither too wiggly/curvy nor does one class cover the whole plot) Considering the bias-variance trade off, when either variance or the bias is too high, test error increases. So keeping that in mind, based on the plots created in the think $K = 11$ will give the smallest expected test error.

```
summary(lm(weather_flight$arr_delay~weather_flight$temp+weather_flight$dewp+weather_flight$humid+weathe
```

```
##
## Call:
## lm(formula = weather_flight$arr_delay ~ weather_flight$temp +
##     weather_flight$dewp + weather_flight$humid + weather_flight$wind_dir +
##     weather_flight$wind_dir + weather_flight$wind_speed + weather_flight$wind_gust +
##     weather_flight$precip + weather_flight$pressure + weather_flight$visib,
##     data = weather_flight)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -104.41  -22.49   -9.94    8.09  738.33
##
## Coefficients:
##                              Estimate Std. Error t value Pr(>|t|)
## (Intercept)                301.057399  26.834468  11.219  < 2e-16 ***
## weather_flight$temp          0.140113   0.093587   1.497   0.1344
## weather_flight$dewp         -0.042238   0.102716  -0.411   0.6809
## weather_flight$humid         0.244938   0.057761   4.241 2.23e-05 ***
## weather_flight$wind_dir     -0.013592   0.002218  -6.129 8.92e-10 ***
## weather_flight$wind_speed   -0.118186   0.065608  -1.801   0.0716 .
## weather_flight$wind_gust     0.390119   0.056833   6.864 6.73e-12 ***
## weather_flight$precip       -9.303290  13.051536  -0.713   0.4760
## weather_flight$pressure     -0.280174   0.024806 -11.295  < 2e-16 ***
## weather_flight$visib        -3.175639   0.192232 -16.520  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 41.76 on 72724 degrees of freedom
## Multiple R-squared:  0.03219,    Adjusted R-squared:  0.03207
## F-statistic: 268.7 on 9 and 72724 DF,  p-value: < 2.2e-16
```