

Analysis of India's Air Quality Index using R

Project Report



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Course: Statistical Methods
using R (SC - 612)

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Index

Sr. No	Particulars	Page No.
1	Problem Definition	03
2	Project Description	03
3	Methodology and Data Cleaning	03
4	Code and Analysis with Inference	04 - 20
5	Conclusion	21
6	References	21

❖ Problem Definition:

The air quality index (AQI) is an index for reporting air quality on a daily basis. It is a measure of how air pollution affects one's health within a short time period. The purpose of the AQI is to help people know how the local air quality impacts their health. The higher the AQI value, the greater the level of air pollution and the greater the health concerns.

❖ Project Description:

In this project, we have analyzed the Air Quality Index of a few selected states and their cities to gain inference on the various factors affecting the Air Quality of any given region.

Analyzing the exact Air Pollutant’s like “NO₂”, “PM_{2.5}”, “PM₁₀”, “CO”, “CO₂”, “Benzene”, “O₃”, “Xylene”, “Toluene”, etc. by using various statistical methods like:

- a. Normality Test
- b. Summary Statistic
- c. Correlation
- d. Linear Regression
- e. Multiple Linear Regression

And a few Visualization techniques like Bar Plot, Pie Chart, Scatter Plot, etc.

to analyze the given dataset.

❖ Methodology and Data Cleaning:

We acquired this dataset from Kaggle.com. This data consisted of 15 columns and around 10,000 rows.

We performed data cleaning in R Studio & MS Excel and removed Null values along with unwanted rows and columns.

Further we performed various above mentioned statistical tools on this data to get reliable inferences.

We have taken the AQI Range and AQI Status by using the scale:

0 – 50 – Good	50 – 100 – Satisfactory
100 – 200 – Moderate	200 – 300 – Poor
300 – 400 – Very Poor	More than 400 -- Severe

❖ Code and Analysis:

➤ **Phase - 1: Importing the csv file into R studio:**

```
getwd()

## [1] "E:/DA-IICT/Study/Sem 1/R Project/Indian_Air_Pollution_Data"

AQI_data = read.csv('AQIdatasetmain.csv')
```

getwd() : – To get or set Working directory.

read.csv() : – To read the comma separated value files.

➤ **Phase - 2: To see the content that the data holds:**

```
head(AQI_data)

##      StationId      City PM2.5  PM10  NO  NO2  NOx  NH3  CO  S
02
## 1 Andhra_Pradesh Amaravati 71.36 115.75 1.75 20.65 12.40 12.19 0.10 10.
76
## 2 Andhra_Pradesh Amaravati 81.40 124.50 1.44 20.50 12.08 10.72 0.12 15.
24
## 3 Andhra_Pradesh Amaravati 78.32 129.06 1.26 26.00 14.85 10.28 0.14 26.
96
## 4 Andhra_Pradesh Amaravati 73.96 113.56 4.58 19.29 13.97 10.95 0.10 13.
90
## 5 Andhra_Pradesh Amaravati 89.90 140.20 7.71 26.19 19.87 13.12 0.10 19.
37
## 6 Andhra_Pradesh Amaravati 87.14 130.52 0.97 21.31 12.12 14.36 0.15 11.
41
##      03 Benzene Toluene Xylene AQI AQI_Bucket
## 1 109.26  0.17   5.92  0.10 132  Moderate
## 2 127.09  0.20   6.50  0.06 184  Moderate
## 3 117.44  0.22   7.95  0.08 197  Moderate
## 4 123.80  0.17   2.85  0.04 191  Moderate
## 5 128.73  0.25   2.79  0.07 191  Moderate
## 6 114.80  0.23   3.82  0.04 227    Poor
```

head(data) : – Return the first parts of the matrix, table or dataframe

- **Normality Check: To check whether the data follows normal distribution.**

For Normality check, we use Shapiro-Wilk test on all the columns in our data.

Shapiro Test:

```
apply(AQI_data[,c(3:14)],2,shapiro.test)

## $PM2.5
##
##  Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.72028, p-value = 1.398e-11
##
##
## $PM10
##
##  Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.88156, p-value = 9.438e-07
##
##
## $NO
##
##  Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.7365, p-value = 3.39e-11
##
##
## $NO2
##
##  Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.92744, p-value = 0.0001137
##
##
## $NOx
##
##  Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.77378, p-value = 3.015e-10
##
##
## $NH3
##
##  Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.92673, p-value = 0.0001045
```

```
##
## $CO
##
## Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.36576, p-value < 2.2e-16
##
##
## $SO2
##
## Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.78091, p-value = 4.704e-10
##
##
## $O3
##
## Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.75265, p-value = 8.505e-11
##
##
## $Benzene
##
## Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.87525, p-value = 5.322e-07
##
##
## $Toluene
##
## Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.74148, p-value = 4.482e-11
##
##
## $Xylene
##
## Shapiro-Wilk normality test
##
## data:  newX[, i]
## W = 0.83072, p-value = 1.418e-08
```

For Normality check, if P-value is > Alpha (0.05), then we can say that the data follows normal distribution.

But here, for all the columns P-value < Alpha (0.05). So, we conclude that our data is not normal.

➤ **Phase - 3: To know the Summary Statistic of data (mean, median and Quantile):**

```
# Moderate , Poor , Satisfactory, Very Poor, Severe, Good
summary(AQI_data)
```

```
##      StationId      City      PM2.5      PM10
## Length:87      Length:87      Min.   : 11.04      Min.   : 18.03
## Class :character Class :character 1st Qu.: 26.41      1st Qu.: 70.61
## Mode  :character Mode  :character Median : 64.01      Median :107.73
##                                     Mean  : 73.51      Mean  :126.63
##                                     3rd Qu.: 90.66      3rd Qu.:179.50
##                                     Max.   :412.34      Max.   :404.52
```

```
##      NO      NO2      NOx      NH3
## Min.   : 0.570      Min.   : 3.13      Min.   : 2.18      Min.   : 2.77
## 1st Qu.: 3.615      1st Qu.:12.73      1st Qu.: 14.29      1st Qu.:12.12
## Median : 7.250      Median :19.87      Median : 18.21      Median :14.36
## Mean   :13.867      Mean   :24.25      Mean   : 28.75      Mean   :17.51
## 3rd Qu.:15.985      3rd Qu.:32.09      3rd Qu.: 34.78      3rd Qu.:22.60
## Max.   :78.090      Max.   :66.23      Max.   :112.44      Max.   :41.78
```

```
##      CO      SO2      O3      Benzene
## Min.   : 0.100      Min.   : 3.390      Min.   : 1.31      Min.   : 0.010
## 1st Qu.: 0.575      1st Qu.: 9.315      1st Qu.: 18.39      1st Qu.: 0.580
## Median : 0.850      Median :12.500      Median : 26.34      Median : 2.940
## Mean   : 1.785      Mean   :15.611      Mean   : 33.49      Mean   : 3.871
## 3rd Qu.: 1.130      3rd Qu.:18.995      3rd Qu.: 36.52      3rd Qu.: 6.270
## Max.   :27.140      Max.   :79.470      Max.   :128.73      Max.   :12.450
```

```
##      Toluene      Xylene      AQI      AQI_Bucket
## Min.   : 0.040      Min.   : 0.000      Min.   : 28.0      Length:87
## 1st Qu.: 1.520      1st Qu.: 0.575      1st Qu.: 95.0      Class :character
## Median : 2.850      Median : 5.060      Median :136.0      Mode  :character
## Mean   : 6.290      Mean   : 6.136      Mean   :178.6
## 3rd Qu.: 9.975      3rd Qu.: 7.680      3rd Qu.:227.0
## Max.   :41.200      Max.   :25.660      Max.   :653.0
```

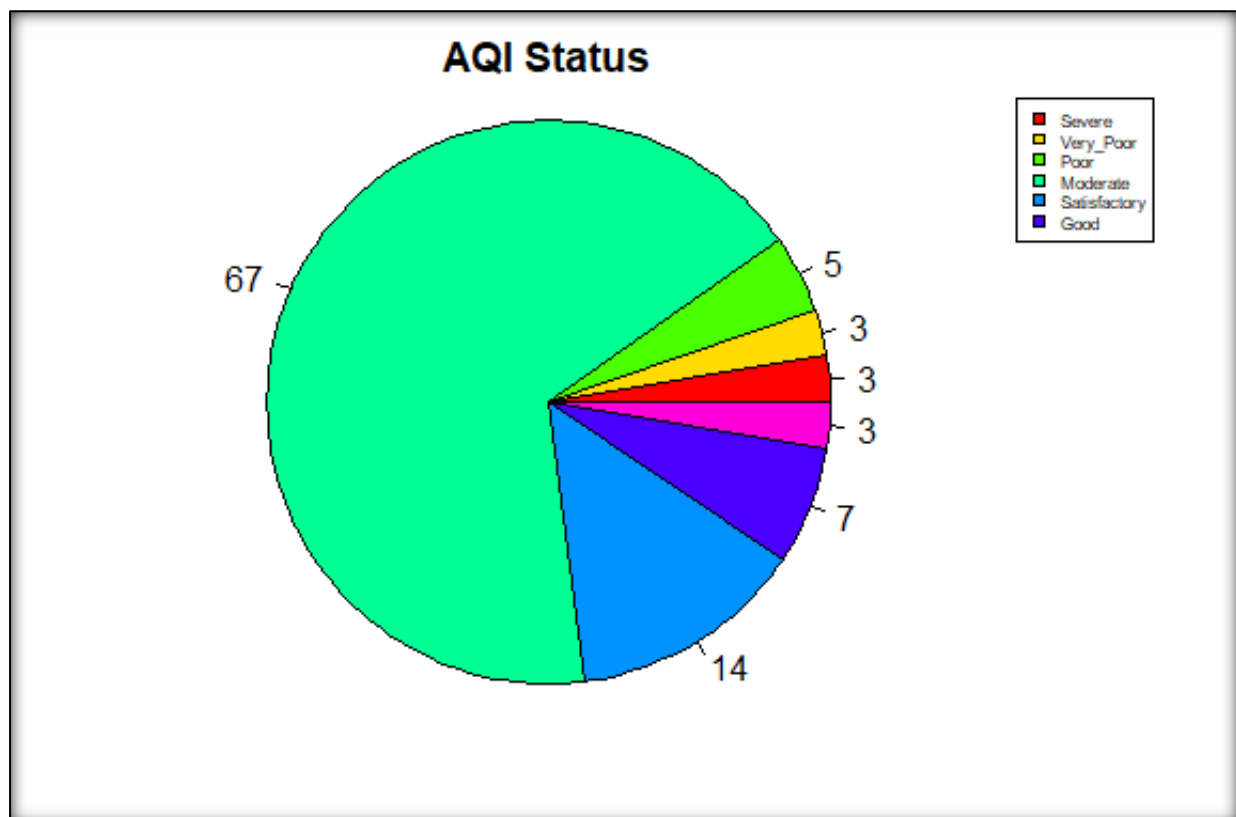
➤ Phase - 4: Checking the Air Quality Status:

```
#Moderate,Very Poor,Poor , Severe , Good, Satisfactory
#Average = mean(AQI_data$AQI)
moderate = length(which(AQI_data$AQI_Bucket == 'Moderate'))
VeryPoor = length(which(AQI_data$AQI_Bucket == 'Very_Poor'))
Poor = length(which(AQI_data$AQI_Bucket == 'Poor'))
Severe = length(which(AQI_data$AQI_Bucket == 'Severe'))
Satisfactory = length(which(AQI_data$AQI_Bucket == 'Satisfactory'))
Good = length(which(AQI_data$AQI_Bucket == 'Good'))

pie_chart = cbind(Severe,VeryPoor,Poor,moderate,Satisfactory,Good)
percentage = round(100*pie_chart/sum(pie_chart))

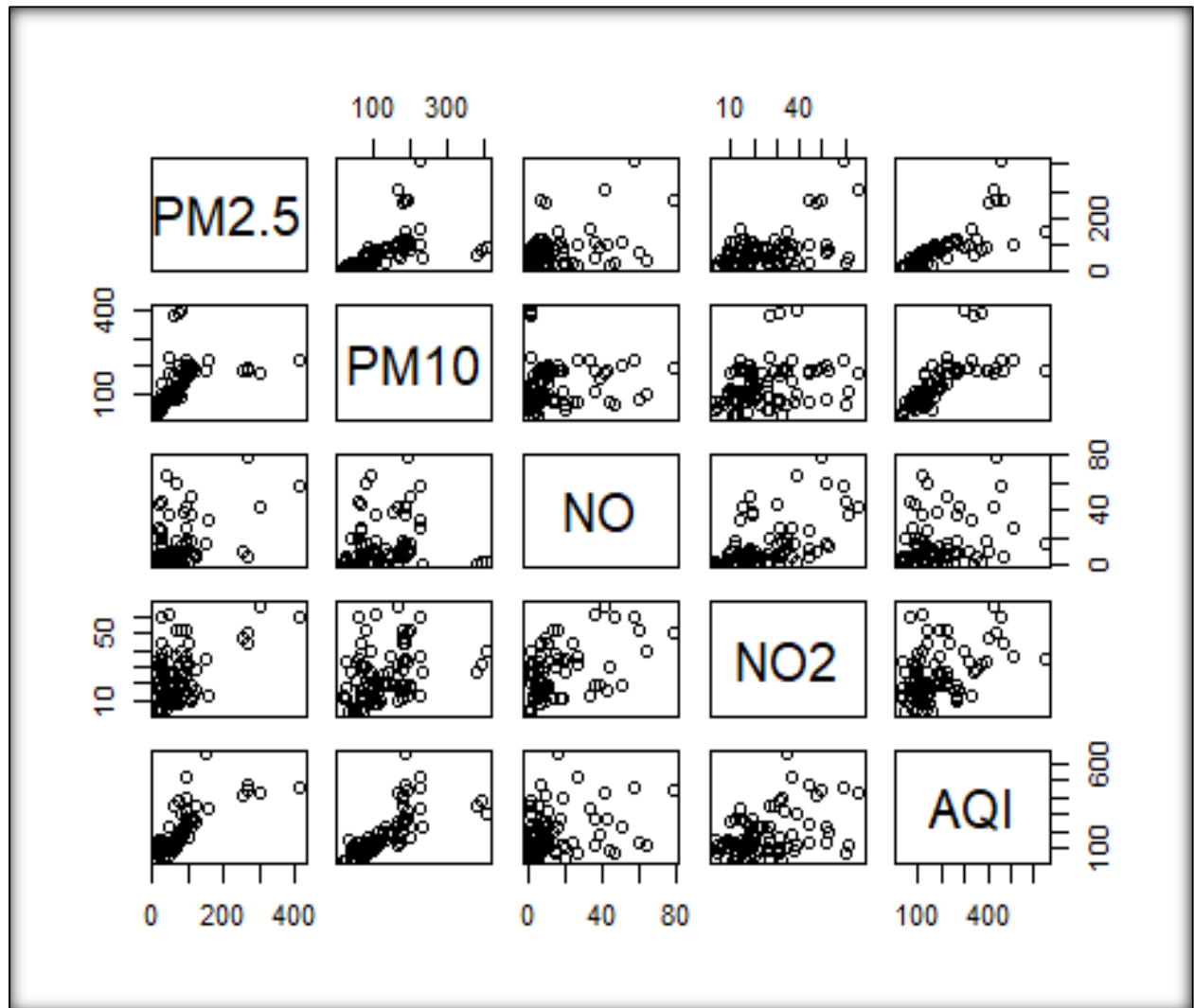
pie(pie_chart,labels = percentage,col = rainbow(length(pie_chart)),main =
"AQI Status",radius = 1)

legend("topright",c("Severe","Very_Poor","Poor","Average","Moderate","Sati
sfactory","Good"),cex = 0.5,fill = rainbow(length(pie_chart)))
```

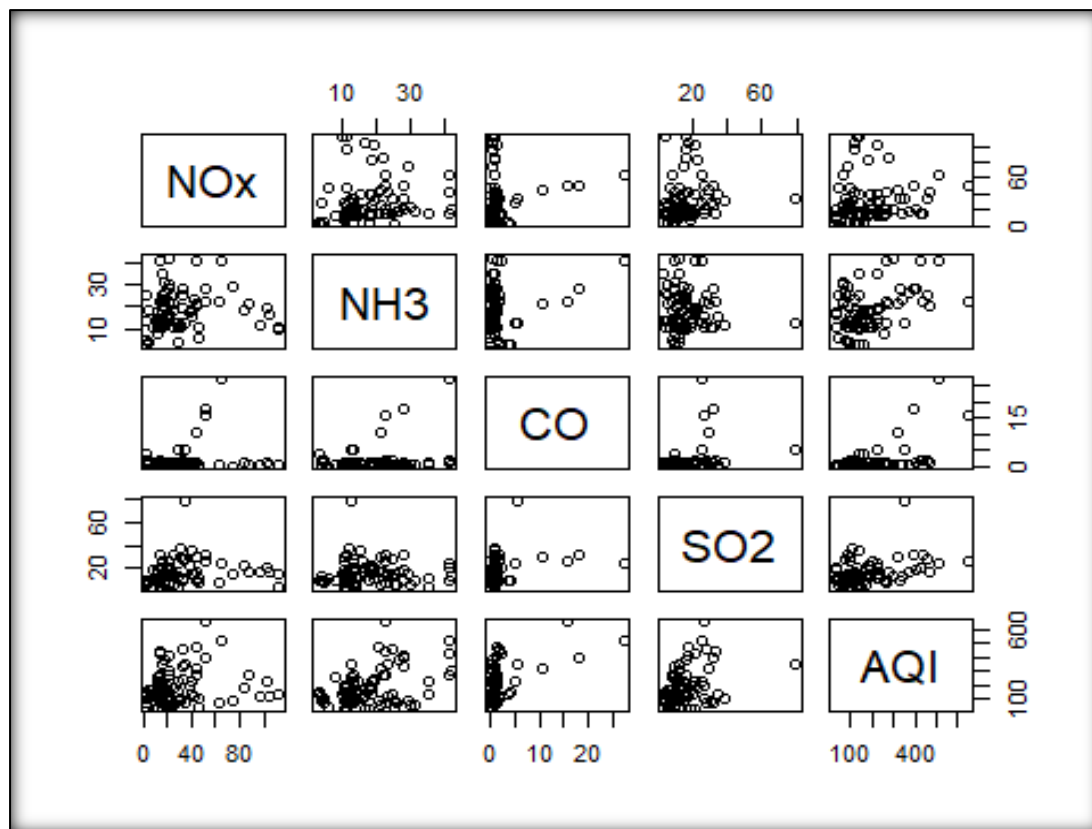


➤ **Phase - 5: Correlation between different affecting factors affecting AQI:**

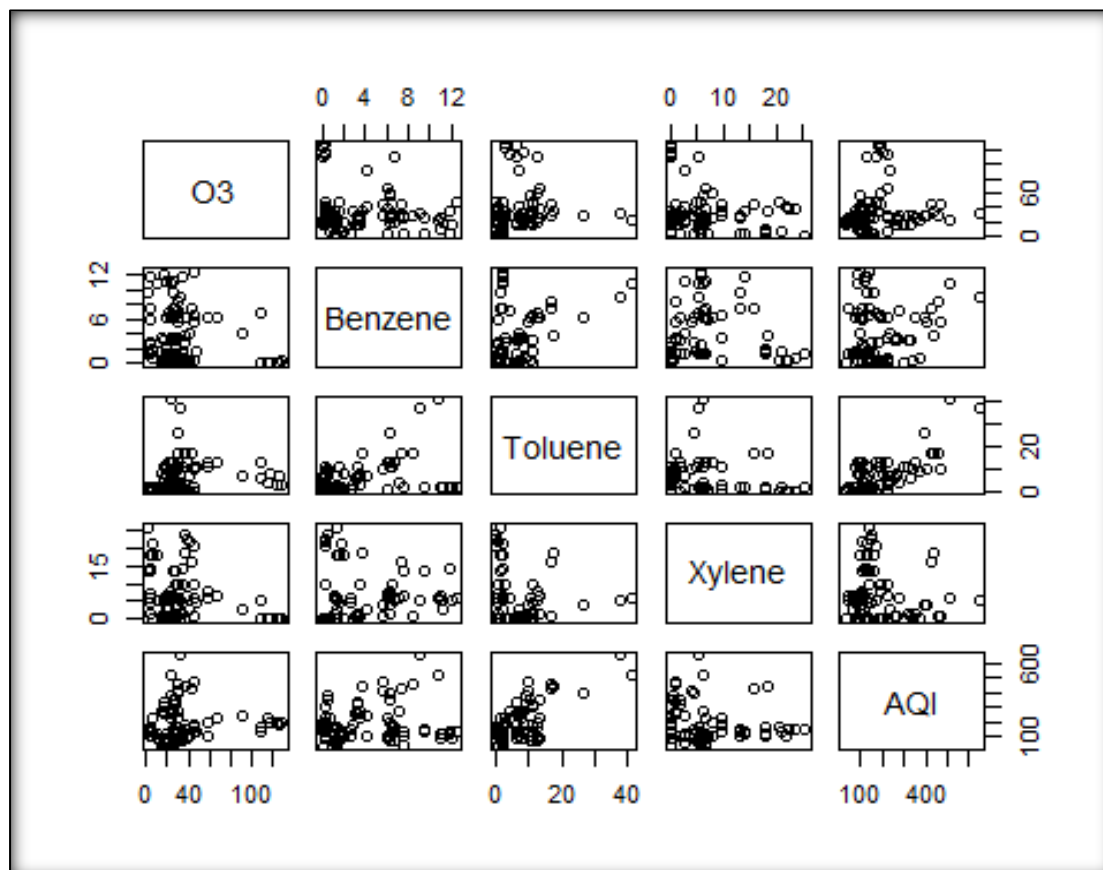
```
pairs(AQI_data[,c(3:6,15)])
```



```
pairs(AQI_data[,c(7:10,15)])
```



```
pairs(AQI_data[,c(11:15)])
```



➤ Phase - 6: Testing of Hypothesis

▪ Correlation

○ 1:

H0: Correlation between Xylene and AQI is zero.

H1: Correlation between Xylene and AQI is not zero.

```
cor.test(AQI_data$Xylene,AQI_data$AQI,method = 'spearman')

## Warning in cor.test.default(AQI_data$Xylene, AQI_data$AQI, method = "spearman"):
## Cannot compute exact p-value with ties

##
## Spearman's rank correlation rho
##
## data: AQI_data$Xylene and AQI_data$AQI
## S = 111419, p-value = 0.8879
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
## rho
## -0.01533987
```

Inference: Here, we can see that the correlation coefficient is -0.015. i.e., Weak Negative Correlation. But the P-value > Alpha (0.05) and the Correlation coefficient is very close to 0, so we cannot reject H0 and the correlation is almost equal to 0.

○ 2:

H0: Correlation between PM2.5 and AQI is zero.

H1: Correlation between PM2.5 and AQI is not zero.

```
cor.test(AQI_data$PM2.5,AQI_data$AQI,method = 'spearman')

## Warning in cor.test.default(AQI_data$PM2.5, AQI_data$AQI, method = "spearman"):
## Cannot compute exact p-value with ties

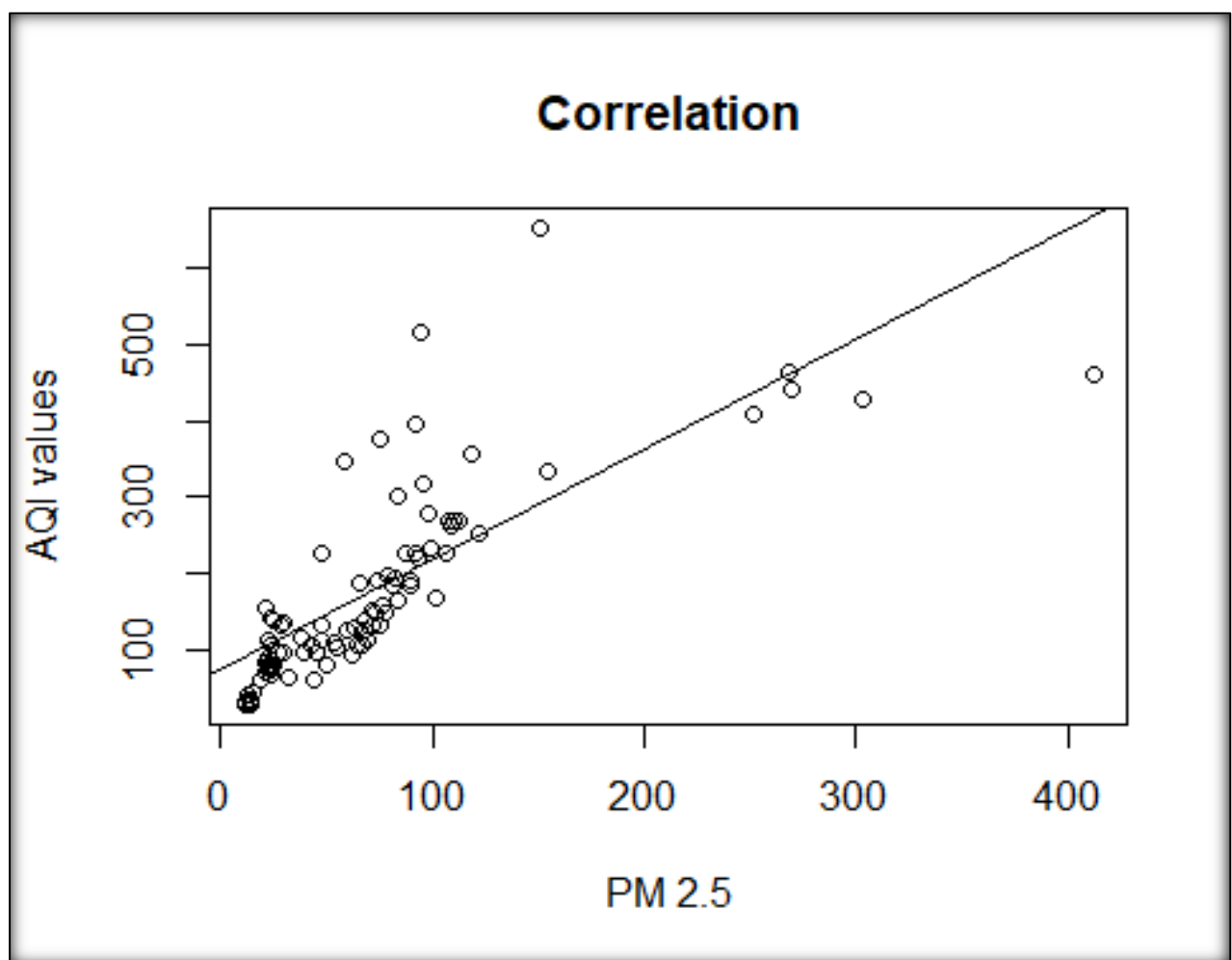
##
## Spearman's rank correlation rho
##
## data: AQI_data$PM2.5 and AQI_data$AQI
## S = 12972, p-value < 2.2e-16
## alternative hypothesis: true rho is not equal to 0
## sample estimates:
## rho
## 0.8817868
```

Inference: Here, we can see that the correlation coefficient is 0.881. i.e., Strong Positive Correlation. Also, the P-value < Alpha (0.05), so we can reject H0.

We can conclude that there is Strong Correlation between PM2.5 and AQI.

▪ **Graphical Representation:**

```
plot(x = AQI_data$PM2.5, y = AQI_data$AQI, xlab = "PM 2.5", ylab = "AQI values", main = "Correlation")
abline(lm(AQI_data$AQI~AQI_data$PM2.5))
```



Inference: We can visualize that there is positive correlation between PM2.5 and AQI, which says that AQI values are dependent on PM2.5 (Higher the PM2.5 values, higher the AQI).

We can also see that in the Trend line.

■ Phase - 7: State-wise Average AQI index:

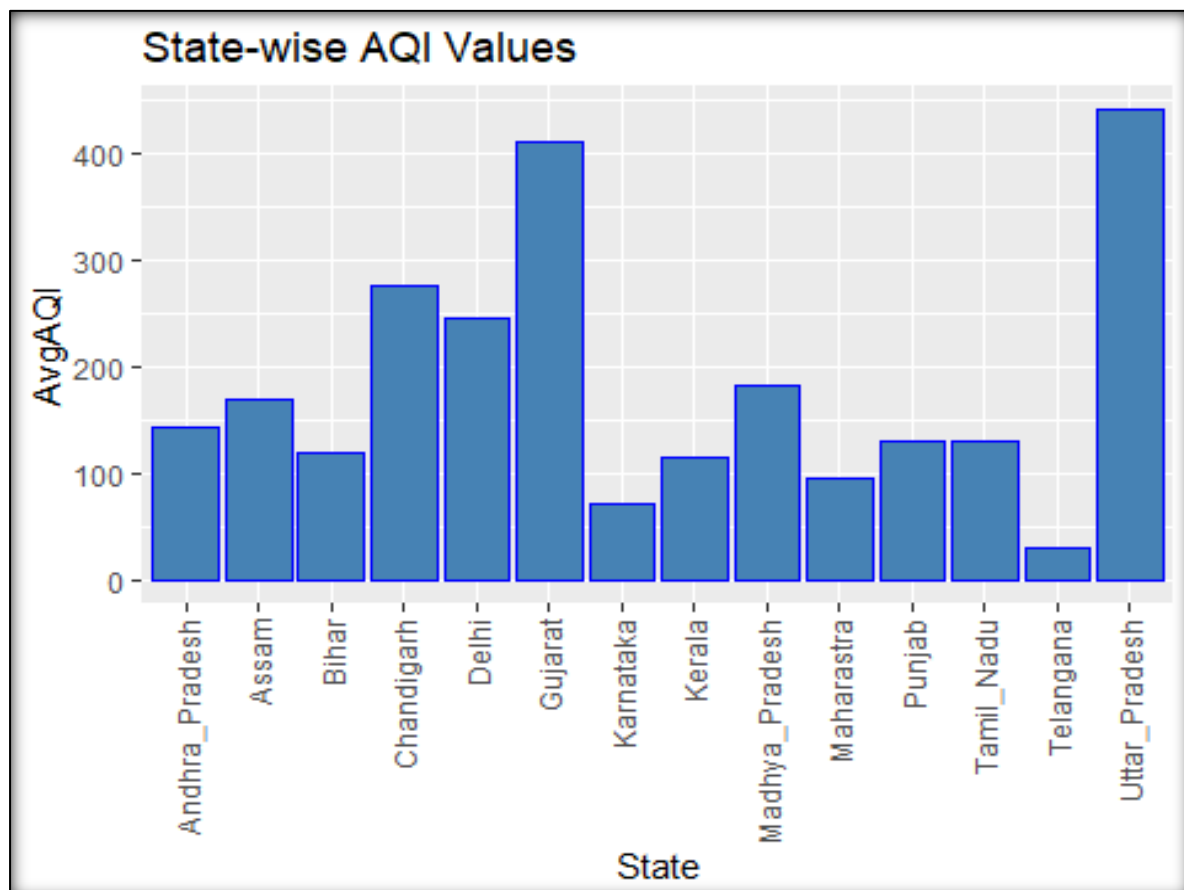
```
Lalu = aggregate(x = AQI_data$AQI,by = list(AQI_data$StationId),FUN = mean)
colnames(Lalu)[1] = "State"
colnames(Lalu)[2] = "AvgAQI"
print(Lalu)

##           State    AvgAQI
## 1 Andhra_Pradesh 142.25000
## 2           Assam 169.66667
## 3           Bihar 118.71429
## 4 Chandigarh    276.33333
## 5           Delhi 244.16667
## 6           Gujarat 410.83333
## 7           Karnataka  71.42857
## 8           Kerala 113.80000
## 9 Madhya_Pradesh 182.83333
## 10  Maharashtra  96.16667
## 11           Punjab 130.80000
## 12 Tamil_Nadu    129.80000
## 13           Telangana  30.00000
## 14 Uttar_Pradesh 439.80000

require(ggplot2)

## Loading required package: ggplot2

ggplot(Lalu,aes(x = State,y = AvgAQI)) + ggtitle("State-wise AQI Values") + geom_bar(
  stat = "identity",color = "blue", fill = "steelblue") + theme(axis.text.x = element_text(
    angle = 90,hjust = 1,vjust = 0.5))
```



➤ Phase - 8: Regression:

Ho: There is no significant relationship between the variables.

H1: There is significant relationship between the variables.

Linear Regression:

```
linear_rega= lm(AQI ~ CO,AQI_data)
summary(linear_rega)

##
## Call:
## lm(formula = AQI ~ CO, data = AQI_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -123.50  -74.59  -30.05   48.35  292.43
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  146.460     12.327   11.881 < 2e-16 ***
## CO           18.007       2.887    6.236 1.67e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 104.4 on 85 degrees of freedom
## Multiple R-squared:  0.3139, Adjusted R-squared:  0.3058
## F-statistic: 38.89 on 1 and 85 DF,  p-value: 1.672e-08

# Predicting the Value of AQI for a given CO reading:

df1 = data.frame(CO = 1.69)
predict(linear_rega,df1)

##      1
## 176.8913
```

Inference: Here, P-value (1.67e-08) < Alpha (0.001) which shows that the regression model fits properly and also has a high F-statistic (38.89).

So, we reject H0.

This shows that AQI and CO levels are highly related to each other.

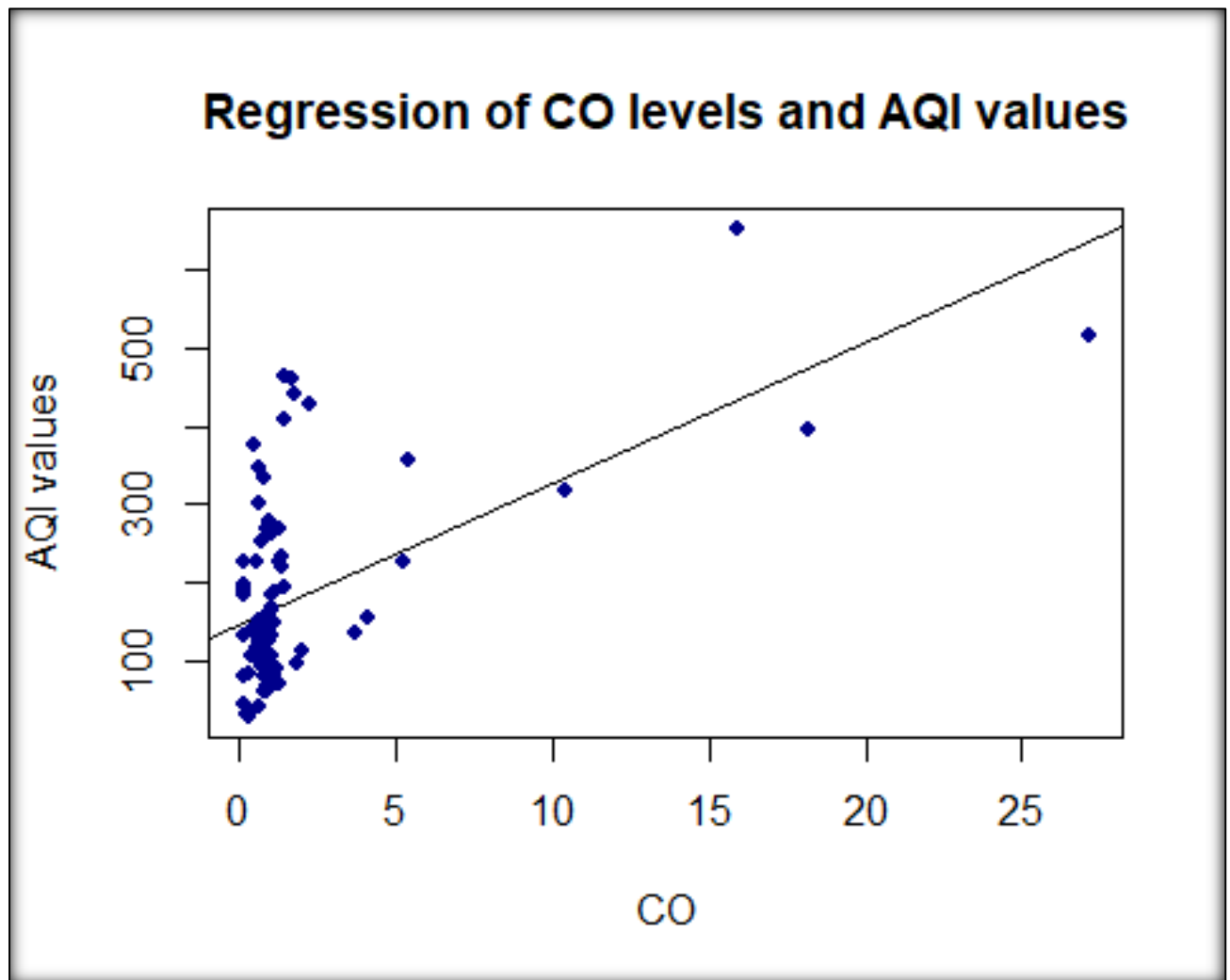
Regression Equation: $y = 146.460 + 18.007 * x$

Thereafter, we have also predicted the value of AQI for a given CO value by using the *predict()* function.

- **Graphical Representation:**

```
# Plotting scatter plot with Regression Line:
```

```
plot(x = AQI_data$CO, y = AQI_data$AQI,xlab ="CO",ylab = "AQI values",main  
= "Regression of CO levels and AQI values",abline(linear_rega),cex = 1.3,p  
ch=20,col="Dark Blue")
```



Inference: We can visualize the regression and regression line.

Multiple Regression:

```
rega = lm(AQI ~ PM2.5 + PM10 + NO + NO2 + NOx + NH3 + CO + SO2 + O3 + Benzene + Toluene + Xylene ,AQI_data)
summary(rega)

##
## Call:
## lm(formula = AQI ~ PM2.5 + PM10 + NO + NO2 + NOx + NH3 + CO +
##      SO2 + O3 + Benzene + Toluene + Xylene, data = AQI_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -106.054  -24.209    0.804   23.109  154.998
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -1.85229   17.92562  -0.103   0.9180
## PM2.5         0.93116    0.09160  10.166 1.08e-15 ***
## PM10         0.63656    0.07584   8.394 2.33e-12 ***
## NO           -0.09341    0.44768  -0.209   0.8353
## NO2          -0.53375    0.42835  -1.246   0.2167
## NOx          0.10776    0.26438   0.408   0.6847
## NH3          -0.22906    0.66572  -0.344   0.7318
## CO           9.62891    1.88765   5.101 2.52e-06 ***
## SO2           0.34155    0.50460   0.677   0.5006
## O3            0.18276    0.16717   1.093   0.2778
## Benzene       1.25150    1.50435   0.832   0.4081
## Toluene       2.21884    1.23219   1.801   0.0758 .
## Xylene       -0.14488    0.69765  -0.208   0.8361
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 38.26 on 74 degrees of freedom
## Multiple R-squared:  0.9199, Adjusted R-squared:  0.9069
## F-statistic: 70.78 on 12 and 74 DF,  p-value: < 2.2e-16

# Predicting the value of AQI:

xyz = data.frame(PM2.5=25.2,PM10=69,NO=28.5,NO2=37,NOx=24.3,NH3=21.3,CO=0.89,SO2=22.9,O3=108,Benzene=3.5,Toluene=6.9,Xylene=4)
predict(rega,xyz)

##      1
## 96.10458
```

Here, we have taken the Multiple Linear regression of AQI (dependent variable) with respect to all the other Independent variables.

We can see that there is a very high F-statistic value (70.78) and also P-value (2.2e-16) < Alpha (0.05) so we can conclude that AQI is highly dependent on all these independent variables.

After that, we have also predicted the AQI for given values of all the other variables.

Correlation Matrix:

```
cor_matrix = cor(AQI_data[,c(3:15)],method = 'spearman')
round(cor_matrix,2)
```

```
##          PM2.5  PM10    NO   NO2   NOx   NH3   CO   SO2    O3 Benzene To
luene
## PM2.5      1.00  0.85  0.31  0.27  0.19  0.32  0.37  0.20  0.29  0.16
0.45
## PM10       0.85  1.00  0.25  0.31  0.24  0.42  0.26  0.17  0.11  0.09
0.51
## NO         0.31  0.25  1.00  0.42  0.68  0.23  0.28  0.25 -0.08  0.48
0.21
## NO2        0.27  0.31  0.42  1.00  0.57  0.29  0.17  0.57  0.36  0.24
0.58
## NOx        0.19  0.24  0.68  0.57  1.00  0.32  0.18  0.41 -0.06  0.45
0.31
## NH3        0.32  0.42  0.23  0.29  0.32  1.00  0.19  0.09 -0.03 -0.04
0.34
## CO         0.37  0.26  0.28  0.17  0.18  0.19  1.00  0.13  0.20  0.41
0.38
## SO2        0.20  0.17  0.25  0.57  0.41  0.09  0.13  1.00  0.18  0.32
0.59
## O3         0.29  0.11 -0.08  0.36 -0.06 -0.03  0.20  0.18  1.00 -0.07
0.34
## Benzene    0.16  0.09  0.48  0.24  0.45 -0.04  0.41  0.32 -0.07  1.00
0.36
## Toluene    0.45  0.51  0.21  0.58  0.31  0.34  0.38  0.59  0.34  0.36
1.00
## Xylene    -0.05 -0.05  0.33 -0.03  0.09 -0.10  0.36 -0.23 -0.05  0.48
-0.07
## AQI        0.88  0.87  0.23  0.35  0.19  0.32  0.41  0.27  0.29  0.21
0.54
##          Xylene  AQI
## PM2.5      -0.05  0.88
## PM10       -0.05  0.87
## NO         0.33  0.23
## NO2        -0.03  0.35
## NOx        0.09  0.19
## NH3        -0.10  0.32
## CO         0.36  0.41
## SO2        -0.23  0.27
## O3         -0.05  0.29
## Benzene    0.48  0.21
## Toluene    -0.07  0.54
## Xylene     1.00 -0.02
## AQI       -0.02  1.00
```

Inference: Here, we can see the correlation matrix for the data.

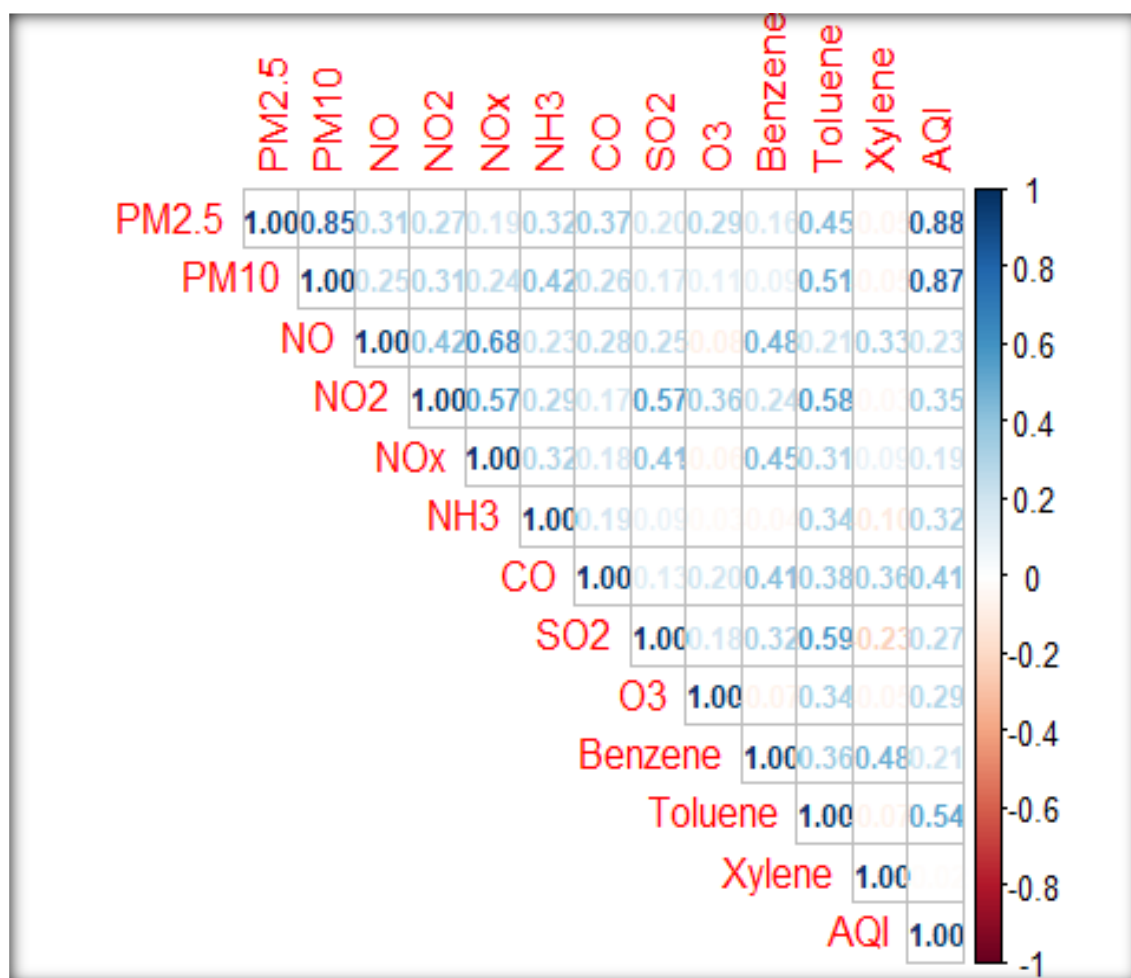
▪ **Corrplot:**

```
require(corrplot)

## Loading required package: corrplot

## corrplot 0.92 loaded

corrplot(cor(AQI_data[,c(3:15)],method = 'spearman'), method = 'number',type = 'upper',number.cex = 0.75, )
```

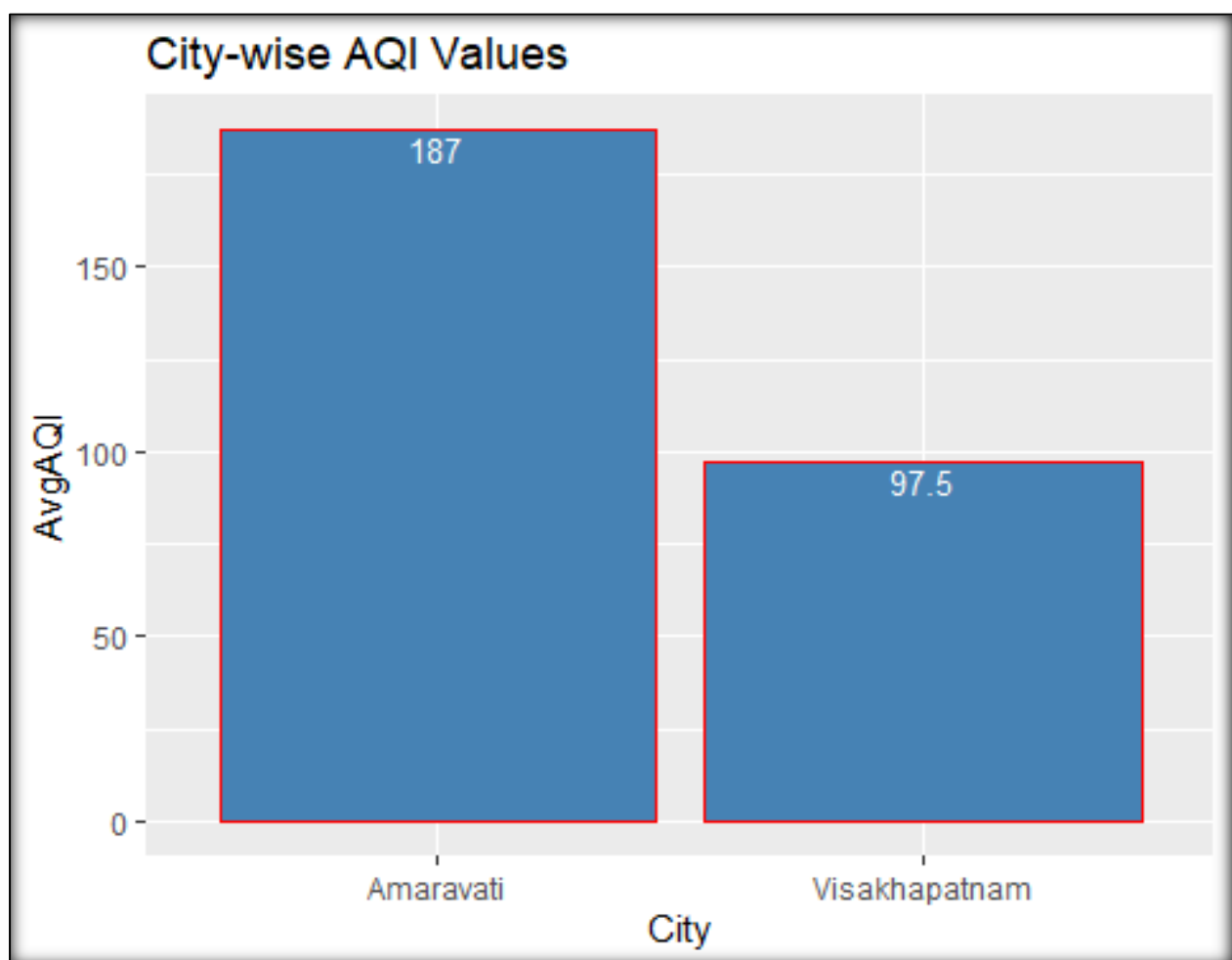


Inference: Here, we can see the correlation matrix using corrplot for the data.

With reference to the multiple regression in the above section, the independent variables namely "PM2.5", "PM10", "CO", "Toluene" are perfectly regressed wrt AQI and we can see in the regression matrix, these variables have the highest correlation with AQI.

➤ **Phase - 9: Average AQI for given cities in a state:**

```
City_avg = aggregate(x=AQI_data$AQI,by=list(AQI_data$City),FUN = mean)
City_avg_1 = City_avg[c(2,15),]
colnames(City_avg_1)[1] = "City"
colnames(City_avg_1)[2] = "AvgAQI"
ggplot(City_avg_1,aes(x = City, y = AvgAQI)) + ggtitle("City-wise AQI Values") + geom_bar(stat = "identity",color ="red", fill = "steelblue") + geom_text(aes(label = AvgAQI),vjust = 1.2,color = "white", position = position_dodge(0.9),size = 3.5 )
```



Inference: In the Andhra Pradesh, we have considered two cities 'Amravati' and 'Vishakhapatnam', looking at the bar plot, we can say that the mean Air Quality Index of 'Amravati' is higher than 'Vishakhapatnam', therefore Vishakhapatnam has safer air than Amravati.

➤ **Phase – 9: Chi Square Test:**

In this section, we took the AQI Status that was given as 'Good', 'Satisfactory', 'Moderate', 'Poor', 'Very Poor' and 'Severe' and converted them into numeric data i.e., 1, 2, 3, 4, 5 and 6 respectively.

```
getwd()

## [1] "E:/DA-IICT/Study/Sem 1/R Project/Indian_Air_Pollution_Data"

chi_sq = read.csv("Column_15_16.csv")
head(chi_sq)

##   Toluene AQI_Bucket
## 1    5.92          3
## 2    6.50          3
## 3    7.95          3
## 4    2.85          3
## 5    2.79          3
## 6    3.82          4

# Chi-Square test:
data1 = data.matrix(chi_sq)
chisq.test(data1)

## Warning in chisq.test(data1): Chi-squared approximation may be incorrect

##
## Pearson's Chi-squared test
##
## data:  data1
## X-squared = 146.95, df = 86, p-value = 4.708e-05
```

Inference: Here, we have performed Chi-Square test between two variables CO and AQI Status.

We can see that the p-value ($4.708e-05$) < Alpha (0.05), and also observed Chi-squared value (146.95) > Critical Chi-squared value (101.87) for 86 degrees of freedom.

So, we reject the H_0 and can conclude that there is a significant relationship between these variables CO and AQI status.

❖ Conclusion:

- We found that all the factors i.e., "NO₂", "PM_{2.5}", "PM₁₀", "CO", "CO₂", "Benzene", "O₃", "Xylene", "Toluene", etc. are the pollutants that generally affect the AQI of any place.
- From the above-mentioned factors, "PM_{2.5}", "PM₁₀", "CO" and "Toluene" are the major affecting factors for AQI and also have very high Correlation with it.
- "O₃" and "Xylene" are least correlated and don't have much effect on the AQI values.
- "Uttar-Pradesh" and "Gujarat" have the highest mean AQI which means that these states have high air pollution and lie in the "Severe" category.
- "Telangana" has a lower mean AQI and comes in the "Good" AQI category. And on the second number is "Karnataka" with "Satisfactory" AQI values.

❖ References:

- Dataset: Air Quality Data India.
Link: https://www.kaggle.com/rohanrao/air-quality-data-in-india?select=station_day.csv