Dimensonality reduction

Ran command install.packages("ggplot2") install.packages("lattice") install.packages("caret")

```
library(ggplot2)
library(lattice)
library(caret)
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 4.2.3
```

```
## Warning: package 'readr' was built under R version 4.2.3
```

```
## Warning: package 'forcats' was built under R version 4.2.3
```

```
## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──
## ✓ dplyr     1.1.0     ✓ readr     2.1.4
## ✓ forcats   1.0.0     ✓ stringr   1.5.0
## ✓ lubridate 1.9.2     ✓ tibble    3.1.8
## ✓ purrr     1.0.1     ✓ tidyr     1.3.0
## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## ✖ dplyr::filter() masks stats::filter()
## ✖ dplyr::lag()    masks stats::lag()
## ✖ purrr::lift()   masks caret::lift()
## ℹ Use the ]8;;http://conflicted.r-lib.org/conflicted package]8;; to force all conflicts to
become errors
```

- Data exploration
- Converted EMISSIONS into factor
- Since we are prediction emissions based on other variable I had converted emissions with a cutoff point 250 , greater than 200 to be 1, otherwise to be 0 also converted engine size ad factor for logistic regression

```
fuelData<- read.csv("Fuel_Consumption_2000-2022.csv")
str(fuelData)
```

```
## 'data.frame':    22556 obs. of  13 variables:
##  $ YEAR            : int  2000 2000 2000 2000 2000 2000 2000 2000 2000 2000 ...
##  $ MAKE            : chr  "ACURA" "ACURA" "ACURA" "ACURA" ...
##  $ MODEL           : chr  "1.6EL" "1.6EL" "3.2TL" "3.5RL" ...
##  $ VEHICLE.CLASS   : chr  "COMPACT" "COMPACT" "MID-SIZE" "MID-SIZE" ...
##  $ ENGINE.SIZE     : num  1.6 1.6 3.2 3.5 1.8 1.8 1.8 3 3.2 1.8 ...
##  $ CYLINDERS       : int  4 4 6 6 4 4 4 6 6 4 ...
##  $ TRANSMISSION    : chr  "A4" "M5" "AS5" "A4" ...
##  $ FUEL            : chr  "X" "X" "Z" "Z" ...
##  $ FUEL.CONSUMPTION: num  9.2 8.5 12.2 13.4 10 9.3 9.4 13.6 13.8 11.4 ...
##  $ HWY..L.100.km.  : num  6.7 6.5 7.4 9.2 7 6.8 7 9.2 9.1 7.2 ...
##  $ COMB..L.100.km. : num  8.1 7.6 10 11.5 8.6 8.2 8.3 11.6 11.7 9.5 ...
##  $ COMB..mpg.      : int  35 37 28 25 33 34 34 24 24 30 ...
##  $ EMISSIONS       : int  186 175 230 264 198 189 191 267 269 218 ...
```

```
summary((fuelData$YEAR))
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    2000    2006    2012    2012    2017    2022
```

```
fuelData$MAKE <- as.factor(fuelData$MAKE)
fuelData$EMISSIONS <- as.factor (ifelse (fuelData$EMISSIONS>250,1,0))
#fuelData$ENGINE.SIZE <- as.factor(fuelData$ENGINE.SIZE)
#fuelData$CYLINDERS<-as.factor(fuelData$CYLINDERS)
fuelData$EMISSIONS
```

```
##    [1] 0 0 0 1 0 0 0 1 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 0 0 0 0
##   [37] 0 0 0 0 0 0 1 0 1 0 1 1 1 1 1 1 1 0 0 1 1 0 0 0 0 1 0 0 0 1 0 1 1 1 1 1 1 1
##   [73] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0 0 0 0 0 0 1 0 1 1 1 1 1 1 1 0 0 1 1 1
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##  [145] 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
##  [181] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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##  [289] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0
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##  [613] 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 0 1 0 0 0 1 0 0 0 0 1 0 0 0 1
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##  [865] 1 1 1 1 1 1 0 0 1 0 1 1 1 1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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## [1045] 1 1 1 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 0 0 0 0 0 0 1 0 1 0 0 0 1
## [1081] 1 0 0 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1
## [1117] 1 0 0 1 1 1 1 0 0 0 0 0 1 1 0 0 0 1 1 0 0 1 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0
## [1153] 0 0 0 1 1 1 1 1 1 1 1 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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## [1297] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0
## [1333] 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0
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## [1621] 1 0 0 1 1 0 0 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [1657] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0
## [1693] 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 1 1 1 1 1 1 1 1 1
## [1729] 1 1 1 1 1 1 1 1 1 0 0 1 0 1 1 1 1 1 1 1 0 1 0 0 1 0 0 1 1 1 1 0 1 1 1 1 1
## [1765] 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 0 1 0 0 0 0 0 0 0 0 1 0 1 0
## [1801] 0 0 0 1 0 0 1 1 1 0 0 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0 0 0 0
```

```
##  [1837] 0 0 0 1 1 1 1 1 1 1 1 0 0 1 1 0 0 0 0 0 1 1 1 1 0 0 0 0 1 1 0 0 1 0 1 0
##  [1873] 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1
##  [1909] 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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##  [1981] 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 1 1 1 1 1 1 1 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0
##  [2017] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
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##  [2953] 1 0 0 0 0 0 0 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0
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##  [3061] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 0 0 1 1
##  [3097] 1 1 1 1 1 1 1 0 1 0 0 0 0 1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 1 1
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##  [3421] 0 0 0 0 0 0 1 0 0 0 0 1 1 0 0 0 1 0 0 0 0 0 1 0 0 0 0 1 0 1 0 0 0 0 0 0 0
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##  [3493] 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 1 1 0 0 1 0 1 0 0 0
##  [3529] 0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0 1 1 1 0 1 0 0 0 0 1 1 1 1 1 1 0 0 0 1 0 1
##  [3565] 0 1 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [3601] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0
##  [3637] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0
```

```
##  [3673] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 1 0 1 0 1 1 1 1 1 1 1 1 0 0 0 0 0
##  [3709] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 1 1 0
##  [3745] 0 0 0 1 1 1 1 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 0 0 1 1
##  [3781] 1 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 1 1 1 1
##  [3817] 1 1 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
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##  [4501] 0 1 0 0 0 0 0 1 1 0 0 0 0 0 1 0 1 0 0 0 0 0 1 0 1 0 1 1 0 0 0 0 0 0 0 0 0 0 0
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##  [4573] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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##  [4645] 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0
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##  [4933] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 1 0 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 0 1
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##  [5257] 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 0
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##  [5329] 0 0 0 0 1 1 1 0 0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 1 1 0 0 0 0 1 1 1 1 0
##  [5365] 0 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
##  [5401] 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 1 0 0 1 1 1 1 1 1 0 0 1 1 1 1 1 0
##  [5437] 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 1 0 0 0
##  [5473] 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 1 0 0 0 0 0 0 1 1 0 1 1
```

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## [18793] 1 0 0 1 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
## [18829] 0 0 0 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1
## [18865] 1 1 1 1 1 1 1 1 0 0 0 0 0 0 1 1 1 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1
## [18901] 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 1 1
## [18937] 1 1 0 1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [18973] 1 1 1 1 1 1 1 1 1 0 0 0 0 0 1 0 0 0 0 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0
## [19009] 0 0 0 0 1 1 0 1 1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [19045] 1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
## [19081] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 1 1 1 0 0 0 0 0 0 0 0 0
## [19117] 0 0 0 0 0 0 0 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 1 1 1 1 0 1 1
## [19153] 0 0 0 1 0 0 1 1 1 1 0 0 1 1 1 1 1 1 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 1 0
## [19189] 1 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 1 1 0 1 1 0 0 0 0 0 0 0 0 0 0 1 0 0 1
## [19225] 0 0 0 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 0 1 0 0 0 1
## [19261] 1 1 0 1 1 1 0 1 0 1 0 0 0 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 0 1 0 0 1
## [19297] 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [19333] 0 0 0 0 0 0 1 1 1 1 1 1 1 1 0 0 0 0 0 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1
## [19369] 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 1 1 1 1 1 1 0
## [19405] 1 1 1 1 1 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [19441] 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 0
## [19477] 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1 0 0 0 0 0 0 1 0
## [19513] 1 0 0 0 0 1 1 1 1 1 1 1 0 0 1 1 0 0 1 1 1 1 1 0 0 0 1 0 0 1 1 1 0 0 0 1 0
## [19549] 0 1 1 0 1 1 0 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1
## [19585] 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0
## [19621] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1 0
## [19657] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [19693] 0 1 1 0 1 0 0 0 0 0 0 0 0 0 1 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1
## [19729] 1 0 0 1 1 1 1 1 1 0 1 0 0 0 1 0 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 0 0 0
## [19765] 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 1 1 1 1 1 1 1 0 0 1 0 0 0 1 1 0 0 0 1 1
## [19801] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 1 0 0 1 1 0 0 1 1 1 1
## [19837] 0 1 1 1 1 1 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 1 1 1 1 1
## [19873] 1 0 0 0 0 0 1 1 0 0 0 1 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1 0 0 0 1
## [19909] 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1
## [19945] 1 1 1 1 1 0 0 0 1 1 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1
## [19981] 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 0 1 0 0 1 1 1 0 1 1 1 1 1 1 1 1 1 1
## [20017] 1 1 1 1 1 1 1 0 0 1 0 0 0 0 0 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1
## [20053] 1 0 1 1 1 1 1 1 1 0 0 1 0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [20089] 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0
## [20125] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0
## [20161] 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 1 1 0 0 0 0 1 1 0 0 1 1 1
```

```
## [20197] 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 1 1 1 1 1 1 0 0 0 0
## [20233] 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 1 0 1 1 1 1 1
## [20269] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 1 1 0 0 0 1 1 1 0 1 1
## [20305] 1 0 1 0 1 0 0 0 1 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1
## [20341] 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1
## [20377] 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0
## [20413] 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 1 1 1 1 1 0 0 1 1 1 1 1 1 1 0 1 0 0 0 0 0 0 0
## [20449] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 1
## [20485] 1 0 0 0 0 0 0 1 1 0 0 0 0 0 1 1 0 0 0 0 0 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1
## [20521] 1 1 1 1 1 1 1 1 1 1 1 0 1 1 0 1 1 1 1 1 1 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1 1 0
## [20557] 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 0 0 0 0 0 0
## [20593] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1
## [20629] 1 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
## [20665] 0 0 1 1 0 0 1 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 1 1 1 1
## [20701] 1 1 1 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 1 1 1 1 1 1 1 1 0 0 0 0 0
## [20737] 0 0 1 1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 1 0 0 1 1
## [20773] 0 0 1 1 1 0 1 1 1 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1
## [20809] 1 1 1 1 0 0 0 0 1 0 1 0 0 0 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0
## [20845] 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1
## [20881] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 0 0 1 1 0 0 1 0 1 1 1 1 1 1
## [20917] 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1 0 0
## [20953] 0 0 0 1 1 0 0 1 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0
## [20989] 1 0 0 0 0 0 0 1 1 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1 1 0 1 0 1
## [21025] 1 0 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [21061] 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
## [21097] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
## [21133] 0 0 0 0 0 0 0 1 1 1 1 0 1 0 0 1 1 1 1 0 0 0 0 0 0 0 1 1 0 0 1 1 1 1 1 1 1
## [21169] 1 1 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0
## [21205] 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 0 1 1 1 1 0 1 0 1 0 0 0
## [21241] 1 1 1 1 1 1 0 0 0 0 0 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
## [21277] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 0 0
## [21313] 0 0 0 0 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0
## [21349] 0 0 0 1 0 0 0 0 0 1 0 1 1 1 1 1 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [21385] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0
## [21421] 1 1 1 1 0 0 0 0 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [21457] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0 1 1 1 1 1 1 1
## [21493] 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 0 0 0
## [21529] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
## [21565] 0 0 1 1 1 1 1 1 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [21601] 0 0 1 0 0 0 0 1 1 0 0 1 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [21637] 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1
## [21673] 0 0 0 0 0 0 1 1 1 1 1 0 0 1 1 1 0 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
## [21709] 1 0 0 0 0 0 1 1 0 0 1 1 0 0 1 1 1 0 1 1 1 1 1 0 0 1 1 1 1 1 0 0 0 0 0 0 0
## [21745] 0 0 0 0 0 0 0 1 1 0 1 0 1 1 1 1 1 1 1 1 1 0 0 0 0 1 0 1 0 1 0 1 0 0 1 1 1 1
## [21781] 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [21817] 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 1
## [21853] 1 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1
## [21889] 1 1 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 1 1 0 1 1 1 1 0 1 1 1 0 1 1 1 1 1 1 1 1 1
## [21925] 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0 0 0 0 0 0 0 1 1 0 0 1 0 1 1 1 1 1 1 1 1
## [21961] 0 0 0 0 0 0 0 0 0 0 1 0 1 1 0 1 0 1 0 1 0 1 0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1
## [21997] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0
```

```
## [22033] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1
## [22069] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 1 1 0 0 1 1 1 1 1 1 0 0 0 0 0
## [22105] 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
## [22141] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [22177] 1 1 1 1 1 1 1 1 1 1 0 0 0 0 1 0 1 1 1 1 1 0 1 0 1 0 0 0 0 1 1 1 1 1 0 0 0
## [22213] 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [22249] 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0
## [22285] 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 1 1 1 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [22321] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [22357] 0 0 0 0 0 1 1 1 1 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [22393] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [22429] 1 1 1 1 1 1 0 0 1 0 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0
## [22465] 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
## [22501] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 1 1 1 1 1 1 1 0 0 1 1 1 0 0 0 0 0
## [22537] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1
## Levels: 0 1
```

- Count NA
- We have 22556 observations with 13 variables
- Train 18000, test is the test 4556

```
colSums(is.na(fuelData))
```

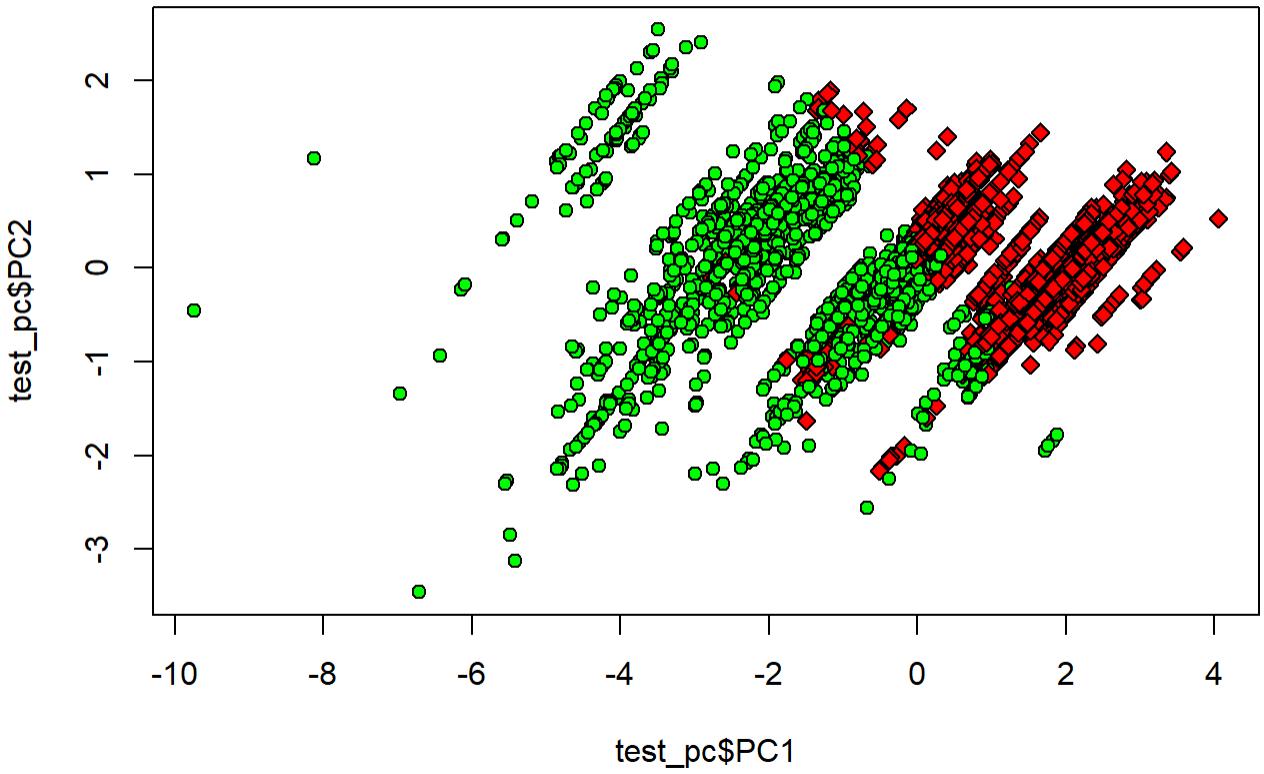
```
##             YEAR             MAKE            MODEL    VEHICLE.CLASS
##                0                0                0                0
##      ENGINE.SIZE        CYLINDERS     TRANSMISSION             FUEL
##                0                0                0                0
## FUEL.CONSUMPTION   HWY..L.100.km.  COMB..L.100.km.       COMB..mpg.
##                0                0                0                0
##        EMISSIONS
##                0
```

```
i <- sample(1:22566, 18000, replace = FALSE)
train <-fuelData[i,]
test<-fuelData[-i,]
set.seed(1234)
pca_out <-preProcess(train[, c(5,6,10,11)], method = c("center","scale","pca") )
pca_out
```

```
## Created from 17994 samples and 4 variables
##
## Pre-processing:
##   - centered (4)
##   - ignored (0)
##   - principal component signal extraction (4)
##   - scaled (4)
##
## PCA needed 2 components to capture 95 percent of the variance
```

- PCA suggested only 2 components as Variables
- Now plot the PCA
- build GLM using logistic regression and pca components

```
train_pc <- predict(pca_out, train[, c(5,6,10,11)])
test_pc <- predict(pca_out, test[,])
plot(test_pc$PC1, test_pc$PC2, pch=c(23,21,22)[unclass(test_pc$EMISSIONS)],bg=c("red","gree
n","blue")[unclass(test_pc$EMISSIONS)])
```




```
train_df <- data.frame(train_pc$PC1, train_pc$PC2, train$EMISSIONS)
test_df <- data.frame(test_pc$PC1, test_pc$PC2, test$EMISSIONS)
library(class)
set.seed(1234)

glm1 = glm(EMISSIONS~train_pc$PC1+train_pc$PC2, data = train, family = binomial)
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
probs <- predict(glm1, newdata = test , type = "response")
```

```
## Warning: 'newdata' had 4562 rows but variables found have 18000 rows
```

```
pred<-ifelse(probs> 0.5, 1,0)
acc1<- mean(pred == as.integer(test$EMISSIONS))
```

```
## Warning in pred == as.integer(test$EMISSIONS): longer object length is not a
## multiple of shorter object length
```

```
summary(glm1)
```

```
##
## Call:
## glm(formula = EMISSIONS ~ train_pc$PC1 + train_pc$PC2, family = binomial,
##     data = train)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -4.3966  -0.2252  -0.0207   0.1024   2.6367
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)   0.29000    0.03243   8.942   <2e-16 ***
## train_pc$PC1 -3.30594    0.05853 -56.479   <2e-16 ***
## train_pc$PC2 -2.00396    0.06309 -31.765   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 24805.0  on 17993  degrees of freedom
## Residual deviance:  7050.1  on 17991  degrees of freedom
##   (6 observations deleted due to missingness)
## AIC: 7056.1
##
## Number of Fisher Scoring iterations: 8
```

```
print(paste("glm1 has accuracy = ",acc1))
```

```
## [1] "glm1 has accuracy =  NA"
```

- Try logistic regression on the non-reduced data
- set ground truth

```
library(class)
set.seed(1234)
glm2 = glm(EMISSIONS~ HWY..L.100.km.+COMB..L.100.km.+ENGINE.SIZE+CYLINDERS, data = train, fam
ily = binomial)
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
probs <- predict(glm2, newdata = test , type = "response")
pred<-ifelse(probs> 0.5, 1,0)
acc2<- mean(pred == as.integer(test$EMISSIONS))
summary(glm2)
```

```
##
## Call:
## glm(formula = EMISSIONS ~ HWY..L.100.km. + COMB..L.100.km. +
##     ENGINE.SIZE + CYLINDERS, family = binomial, data = train)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -4.3903  -0.2246  -0.0204   0.1051   2.7184
##
## Coefficients:
##                  Estimate Std. Error z value Pr(>|z|)
## (Intercept)     -24.10398    0.43855 -54.963  < 2e-16 ***
## HWY..L.100.km.    1.18967    0.07228  16.460  < 2e-16 ***
## COMB..L.100.km.   0.91262    0.06765  13.490  < 2e-16 ***
## ENGINE.SIZE       0.32903    0.07035   4.677 2.91e-06 ***
## CYLINDERS         0.44349    0.05336   8.312  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 24805.0  on 17993  degrees of freedom
## Residual deviance:  7036.2  on 17989  degrees of freedom
##   (6 observations deleted due to missingness)
## AIC: 7046.2
##
## Number of Fisher Scoring iterations: 8
```

```
print(paste("glm2 has accuracy = ",acc2))
```

```
## [1] "glm2 has accuracy =  0.0210434020166594"
```

```
table(pred, as.integer(test$EMISSIONS))
```

```
##
## pred    1    2
##    0 2424  145
##    1   96 1897
```

Accuracy from model is around 2% Confusion matrix shows the distribution of prediction where correct and

incorrect being around 0.50 margin.

LDA

```
library(MASS)
```

```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
lda1<-lda(EMISSIONS~ HWY..L.100.km.+COMB..L.100.km.+ENGINE.SIZE+CYLINDERS,data =train)
lda1$means
```

```
##   HWY..L.100.km. COMB..L.100.km. ENGINE.SIZE CYLINDERS
## 0       7.385158        9.047314    2.486813  4.721348
## 1      10.758776       13.409739    4.386665  7.194905
```

Above data shows a clear positive relativity between EMISSION and the rest of the predictors 0 classified vehicles with emission less than 250, and 1 is more than 250

```
lda_pred<- predict(lda1, newdata = test,type = "class")
lda_pred$class
```

```
##    [1] 0 0 0 0 0 1 1 1 1 0 0 1 1 0 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1
##   [38] 1 1 1 0 1 0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 0 1 1 1 1 1
##   [75] 0 0 0 0 0 0 0 1 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0
##  [112] 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0
##  [149] 0 0 1 0 0 0 0 0 0 1 1 1 0 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
##  [186] 0 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 0 1 1 0 0
##  [223] 0 1 0 0 1 0 0 1 1 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [260] 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 1
##  [297] 1 1 1 1 1 1 0 0 1 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0 1 1 1 1 1
##  [334] 1 1 1 1 0 0 0 0 0 1 1 1 1 1 0 1 0 0 1 0 1 1 1 0 1 1 1 1 0 0 0 0 1 1 1 1 0
##  [371] 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
##  [408] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1
##  [445] 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 1 1 0 1
##  [482] 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 1 0 0 0 0 0 0 1 1 1 0 0 0 1 0 0 0 0 1 0 0 0 0
##  [519] 0 1 1 0 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1
##  [556] 1 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 1 0 1 0 0 0 0 0 0 0 0 0 1 1 0 0 1 1
##  [593] 1 1 1 1 1 1 1 1 1 0 0 1 1 1 1 1 1 1 0 0 1 1 0 0 1 1 1 0 0 1 1 1 1 1 1 1 0 0
##  [630] 1 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 1 0 0 0 0 1 1 0 1 0 0 0 1 1 1 0 1 1 0
##  [667] 0 0 0 0 0 0 0 1 1 0 1 1 1 0 0 0 0 1 0 0 0 0 1 1 0 0 0 1 0 1 0 0 0 0 0 0 0
##  [704] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
##  [741] 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 1 1 1 0 0 1 0 1 1 1 1 1 1 1 1 1 0 0 0 1 1 1 1
##  [778] 1 1 1 1 1 1 0 0 0 1 0 0 1 1 0 0 1 1 1 0 1 1 0 0 0 1 1 1 1 1 1 0 0 1 0 1 1 0
##  [815] 1 1 0 0 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 1 0 0 1 1 1 0 0 1 0
##  [852] 0 1 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 1 1 1 0 0 0 0 1 0 0 1 0 0 0 0 0 0
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## [4552] 0 0 0 1 1 0 0 0 0 0 0
## Levels: 0 1
```

Summary: Predicted result shows an accuracy around 89% on the unreduced data. The LCA has not has as high as an accuracy rate comparing to PDA. where it was 95% accuracy using two predictors. Logistic regression wasn't able to predict anything practicaly using the reduced data

```
mean(lda_pred$class == test$EMISSIONS)
```

```
## [1] 0.9013591
```