Customer Churn Prediction

2024-03-08

Regarding the Analysis: The main objective of this kernel is to improve and refine my skills in data analysis.

This analysis specifically focuses on the behavior of telecom customers who are more inclined to discontinue their subscription. My aim is to identify the most significant patterns in customer behavior through exploratory data analysis (EDA) and subsequently utilize predictive analytics techniques to determine the customers who are at the highest risk of churning.

Regarding the data: (As provided in the overview/description)

The data includes information about customers who have terminated their subscription within the last month, which is indicated by the "Churn" column. It also encompasses the services that each customer has subscribed to, such as phone, multiple lines, internet, online security, online backup, device protection, tech support, and streaming TV and movies.

Additionally, the data contains customer account details, including the duration of their subscription, contract type, payment method, preference for paperless billing, monthly charges, and total charges.

```
library(tidyverse)
```

Furthermore, demographic information about customers is included, such as their gender, age range, and whether they have partners and dependents.

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.0     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(MASS)
```

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

```
library(car)
```

```
## Loading required package: carData
##
## Attaching package: 'car'
##
## The following object is masked from 'package:dplyr':
##
##     recode
##
## The following object is masked from 'package:purrr':
##
##     some
```

```
library(e1071)
library(caret)
```

```
## Loading required package: lattice
##
## Attaching package: 'caret'
##
## The following object is masked from 'package:purrr':
##
##     lift
```

```
library(cowplot)
```

```
##
## Attaching package: 'cowplot'
##
## The following object is masked from 'package:lubridate':
##
##     stamp
```

```
library(caTools)
library(pROC)
```

```
## Type 'citation("pROC")' for a citation.
##
## Attaching package: 'pROC'
##
## The following objects are masked from 'package:stats':
##
##     cov, smooth, var
```

```
library(ggcorrplot)
```

Including Plots

```
telco <- read.csv("WA_Fn-UseC_-Telco-Customer-Churn.csv")
```

```
glimpse(telco)
```

7043 observations with 21 variables.

```
## Rows: 7,043
## Columns: 21
```

```
## $ customerID       <chr> "7590-VHVEG", "5575-GNVDE", "3668-QPYBK", "7795-CFOCW~
## $ gender           <chr> "Female", "Male", "Male", "Male", "Female", "Female",~
## $ SeniorCitizen    <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Partner          <chr> "Yes", "No", "No", "No", "No", "No", "No", "No", "Yes~
## $ Dependents       <chr> "No", "No", "No", "No", "No", "No", "Yes", "No", "No"~
## $ tenure           <int> 1, 34, 2, 45, 2, 8, 22, 10, 28, 62, 13, 16, 58, 49, 2~
## $ PhoneService     <chr> "No", "Yes", "Yes", "No", "Yes", "Yes", "Yes", "No", ~
## $ MultipleLines    <chr> "No phone service", "No", "No", "No phone service", "~
## $ InternetService  <chr> "DSL", "DSL", "DSL", "DSL", "Fiber optic", "Fiber opt~
## $ OnlineSecurity   <chr> "No", "Yes", "Yes", "Yes", "No", "No", "No", "Yes", "~
## $ OnlineBackup     <chr> "Yes", "No", "Yes", "No", "No", "No", "Yes", "No", "N~
## $ DeviceProtection <chr> "No", "Yes", "No", "Yes", "No", "Yes", "No", "No", "Y~
## $ TechSupport      <chr> "No", "No", "No", "Yes", "No", "No", "No", "No", "Yes~
## $ StreamingTV      <chr> "No", "No", "No", "No", "No", "Yes", "Yes", "No", "Ye~
## $ StreamingMovies  <chr> "No", "No", "No", "No", "No", "Yes", "No", "No", "Yes~
## $ Contract         <chr> "Month-to-month", "One year", "Month-to-month", "One ~
## $ PaperlessBilling <chr> "Yes", "No", "Yes", "No", "Yes", "Yes", "Yes", "No", ~
## $ PaymentMethod    <chr> "Electronic check", "Mailed check", "Mailed check", "~
## $ MonthlyCharges   <dbl> 29.85, 56.95, 53.85, 42.30, 70.70, 99.65, 89.10, 29.7~
## $ TotalCharges     <dbl> 29.85, 1889.50, 108.15, 1840.75, 151.65, 820.50, 1949~
## $ Churn            <chr> "No", "No", "Yes", "No", "Yes", "Yes", "No", "No", "Y~
```

```
telco <- telco[complete.cases(telco),]

telco$SeniorCitizen <- as.factor(ifelse(telco$SeniorCitizen==1, 'YES', 'NO'))
```

EXPLORATORY DATA ANALYSIS:

```
theme1 <- theme_bw()+
theme(axis.text.x = element_text(angle = 0, hjust = 1, vjust = 0.5),legend.position="none")
theme2 <- theme_bw()+
theme(axis.text.x = element_text(angle = 90, hjust = 1, vjust = 0.5),legend.position="none")
```

```
glimpse(telco)
```

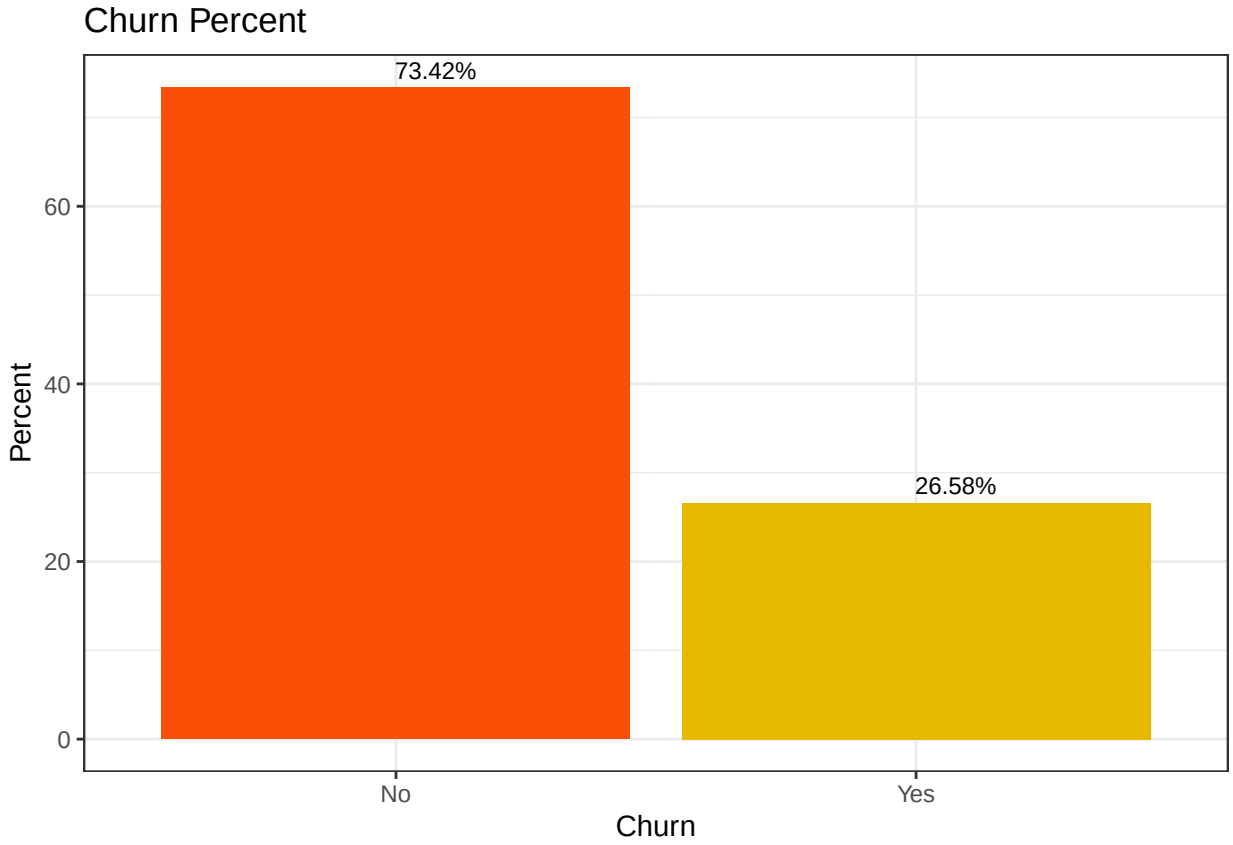
```
## Rows: 7,032
## Columns: 21
## $ customerID       <chr> "7590-VHVEG", "5575-GNVDE", "3668-QPYBK", "7795-CFOCW~
## $ gender           <chr> "Female", "Male", "Male", "Male", "Female", "Female",~
## $ SeniorCitizen    <fct> NO, NO, NO, NO, NO, NO, NO, NO, NO, NO, NO, NO, NO, N~
## $ Partner          <chr> "Yes", "No", "No", "No", "No", "No", "No", "No", "Yes~
## $ Dependents       <chr> "No", "No", "No", "No", "No", "No", "Yes", "No", "No"~
## $ tenure           <int> 1, 34, 2, 45, 2, 8, 22, 10, 28, 62, 13, 16, 58, 49, 2~
## $ PhoneService     <chr> "No", "Yes", "Yes", "No", "Yes", "Yes", "Yes", "No", ~
## $ MultipleLines    <chr> "No phone service", "No", "No", "No phone service", "~
## $ InternetService  <chr> "DSL", "DSL", "DSL", "DSL", "Fiber optic", "Fiber opt~
## $ OnlineSecurity   <chr> "No", "Yes", "Yes", "Yes", "No", "No", "No", "Yes", "~
## $ OnlineBackup     <chr> "Yes", "No", "Yes", "No", "No", "No", "Yes", "No", "N~
## $ DeviceProtection <chr> "No", "Yes", "No", "Yes", "No", "Yes", "No", "No", "Y~
## $ TechSupport      <chr> "No", "No", "No", "Yes", "No", "No", "No", "No", "Yes~
## $ StreamingTV      <chr> "No", "No", "No", "No", "No", "Yes", "Yes", "No", "Ye~
## $ StreamingMovies  <chr> "No", "No", "No", "No", "No", "Yes", "No", "No", "Yes~
## $ Contract         <chr> "Month-to-month", "One year", "Month-to-month", "One ~
## $ PaperlessBilling <chr> "Yes", "No", "Yes", "No", "Yes", "Yes", "Yes", "No", ~
## $ PaymentMethod    <chr> "Electronic check", "Mailed check", "Mailed check", "~
```

```
## $ MonthlyCharges   <dbl> 29.85, 56.95, 53.85, 42.30, 70.70, 99.65, 89.10, 29.7~
## $ TotalCharges     <dbl> 29.85, 1889.50, 108.15, 1840.75, 151.65, 820.50, 1949~
## $ Churn            <chr> "No", "No", "Yes", "No", "Yes", "Yes", "No", "No", "Y~
```

VISUALIZING THE CATEGORICAL DATA FIRST WITH RESPECT TO CHURN:

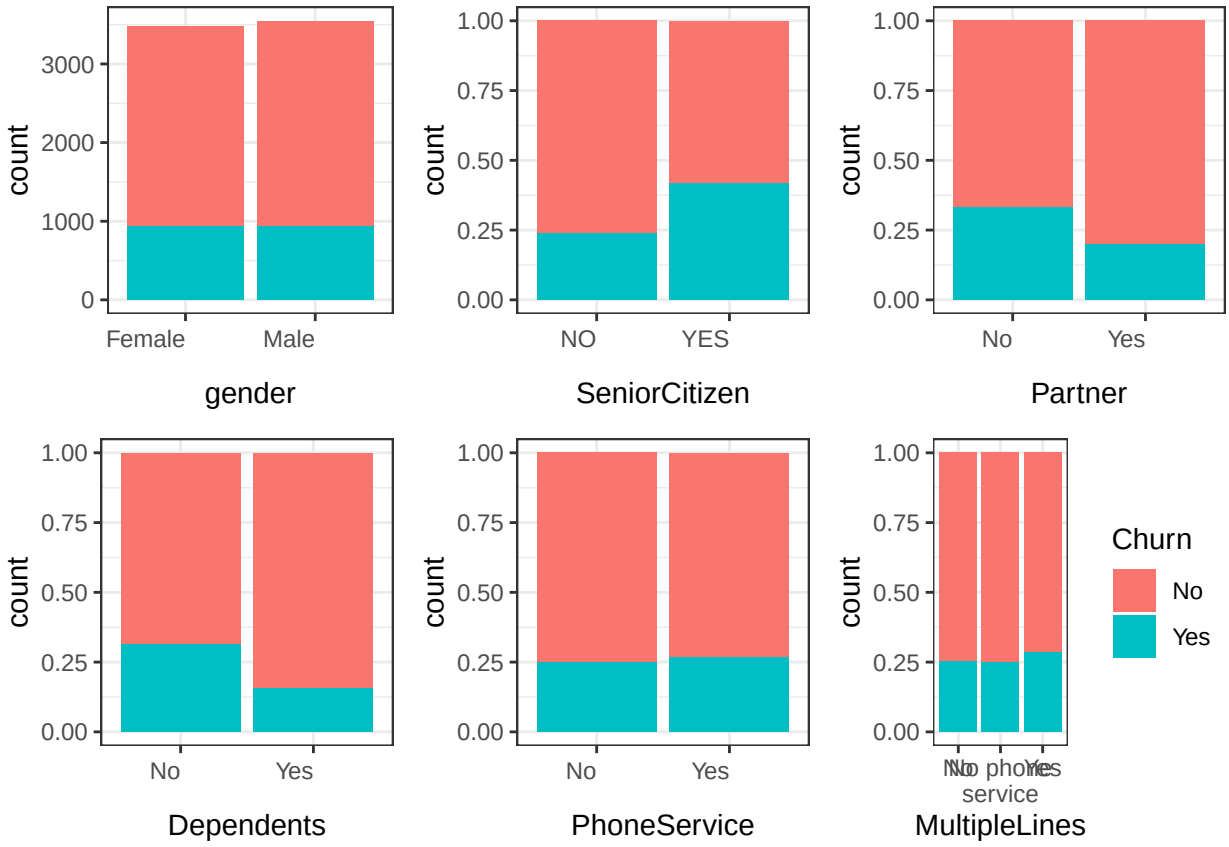
- CHURN columns tells us about the number of Customers who left within the last month.
- Around 26% of customers left the platform within the last month.

```
options(repr.plot.width = 6, repr.plot.height = 4)
telco %>%
group_by(Churn) %>%
summarise(Count = n())%>%
mutate(percent = prop.table(Count)*100)%>%
ggplot(aes(reorder(Churn, -percent), percent), fill = Churn)+
geom_col(fill = c("#FC4E07", "#E7B800"))+
geom_text(aes(label = sprintf("%.2f%%", percent)), hjust = 0.01,vjust = -0.5, size =3)+
theme_bw()+
xlab("Churn") +
ylab("Percent")+
ggtitle("Churn Percent")
```



- Gender - The churn percent is almost equal in case of Male and Females
- The percent of churn is higher in case of senior citizens
- Customers with Partners and Dependents have lower churn rate as compared to those who don't have * partners & Dependents.

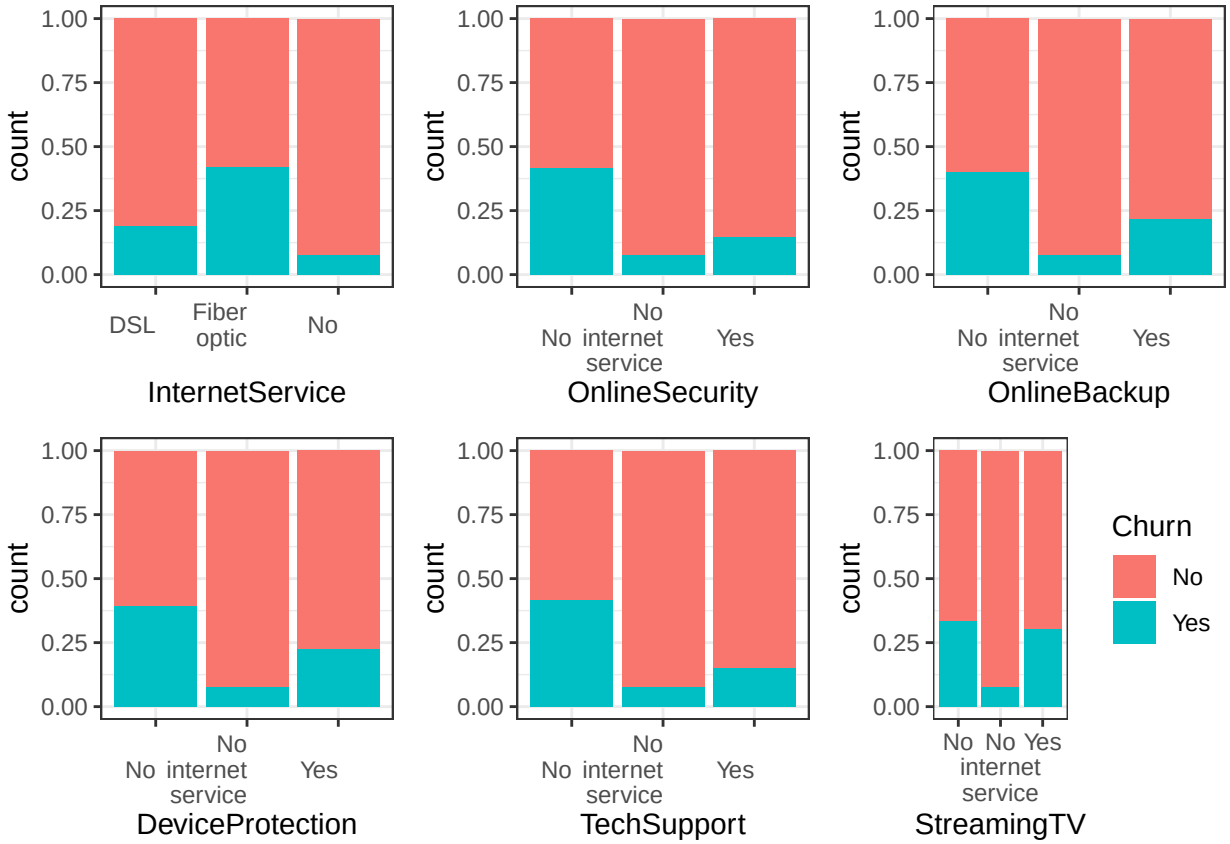
```
options(repr.plot.width = 12, repr.plot.height = 8)
plot_grid(ggplot(telco, aes(x=gender,fill=Churn))+ geom_bar()+ theme1,
          ggplot(telco, aes(x=SeniorCitizen,fill=Churn))+ geom_bar(position = 'fill')+theme1,
          ggplot(telco, aes(x=Partner,fill=Churn))+ geom_bar(position = 'fill')+theme1,
          ggplot(telco, aes(x=Dependents,fill=Churn))+ geom_bar(position = 'fill')+theme1,
          ggplot(telco, aes(x=PhoneService,fill=Churn))+ geom_bar(position = 'fill')+theme1,
          ggplot(telco, aes(x=MultipleLines,fill=Churn))+ geom_bar(position = 'fill')+theme_bw()+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          align = "h")
```



- Churn rate is much higher in case of Fiber Optic InternetServices.
- Customers who do not have services like No OnlineSecurity , OnlineBackup and TechSupport have left the platform in the past month.

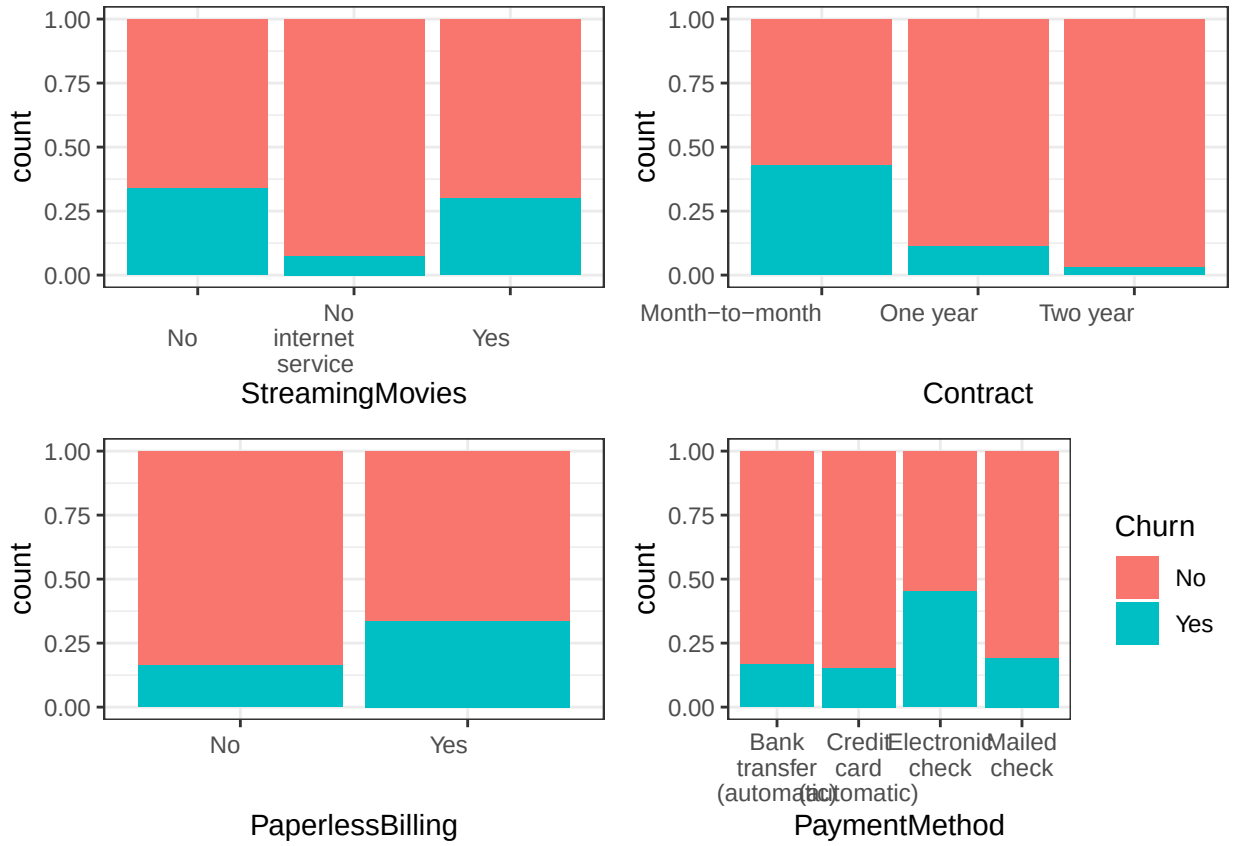
```
options(repr.plot.width = 12, repr.plot.height = 8)
plot_grid(ggplot(telco, aes(x=InternetService,fill=Churn))+ geom_bar(position = 'fill')+ theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=OnlineSecurity,fill=Churn))+ geom_bar(position = 'fill')+theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=OnlineBackup,fill=Churn))+ geom_bar(position = 'fill')+theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=DeviceProtection,fill=Churn))+ geom_bar(position = 'fill')+theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=TechSupport,fill=Churn))+ geom_bar(position = 'fill')+theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=StreamingTV,fill=Churn))+ geom_bar(position = 'fill')+theme_bw()+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
```

```
          align = "h")
```



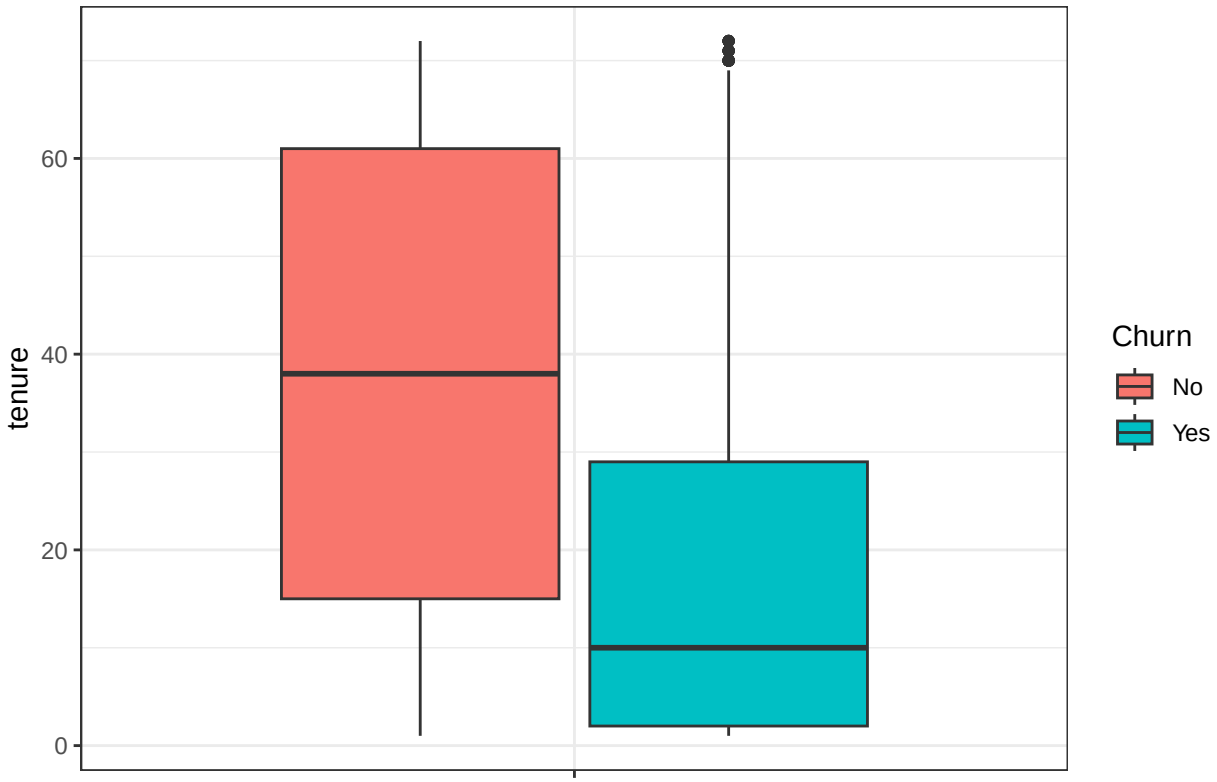
- A larger percent of Customers with monthly subscription have left when compared to Customers with one or two year contract.
- Churn percent is higher in case of cutsomers having paperless billing option.
- Customers who have ElectronicCheck PaymentMethod tend to leave the platform more when compared to other options.

```
plot_grid(ggplot(telco, aes(x=StreamingMovies,fill=Churn))+
          geom_bar(position = 'fill')+ theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=Contract,fill=Churn))+
          geom_bar(position = 'fill')+theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=PaperlessBilling,fill=Churn))+
          geom_bar(position = 'fill')+theme1+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          ggplot(telco, aes(x=PaymentMethod,fill=Churn))+
          geom_bar(position = 'fill')+theme_bw()+
          scale_x_discrete(labels = function(x) str_wrap(x, width = 10)),
          align = "h")
```

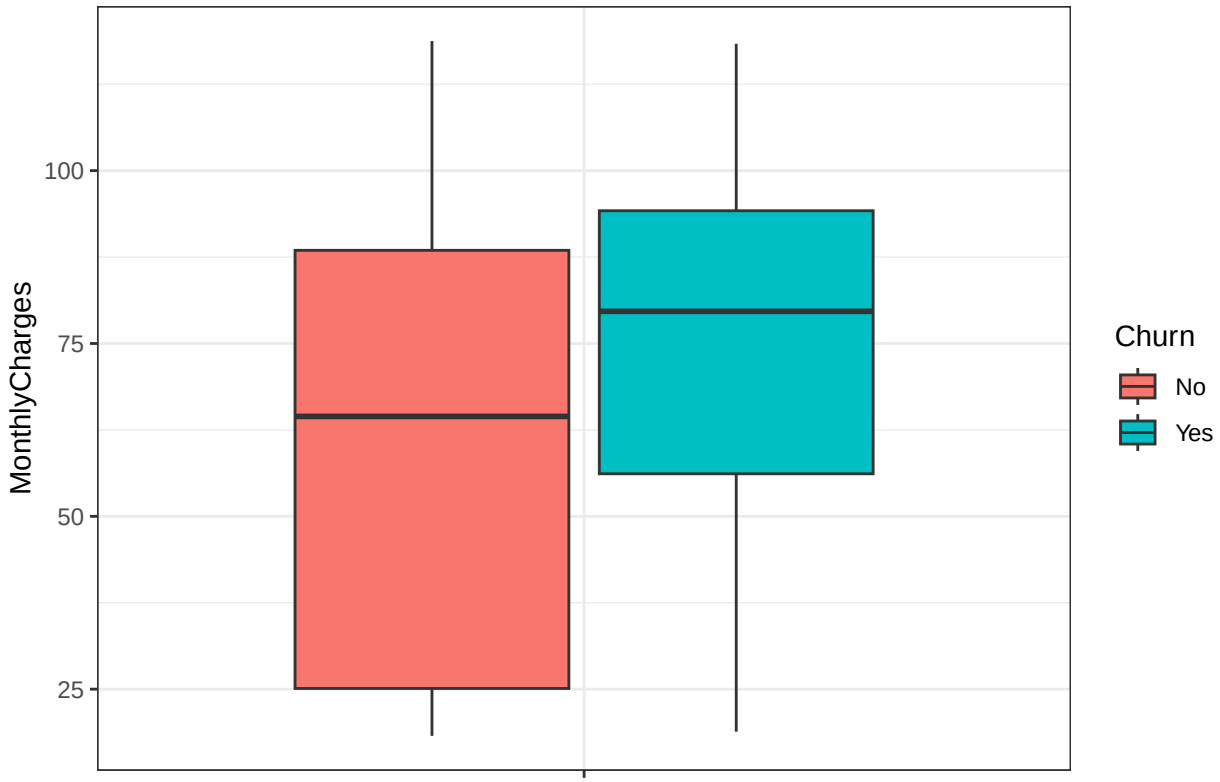


Analyzing the three continuous variables w.r.t CHURN:

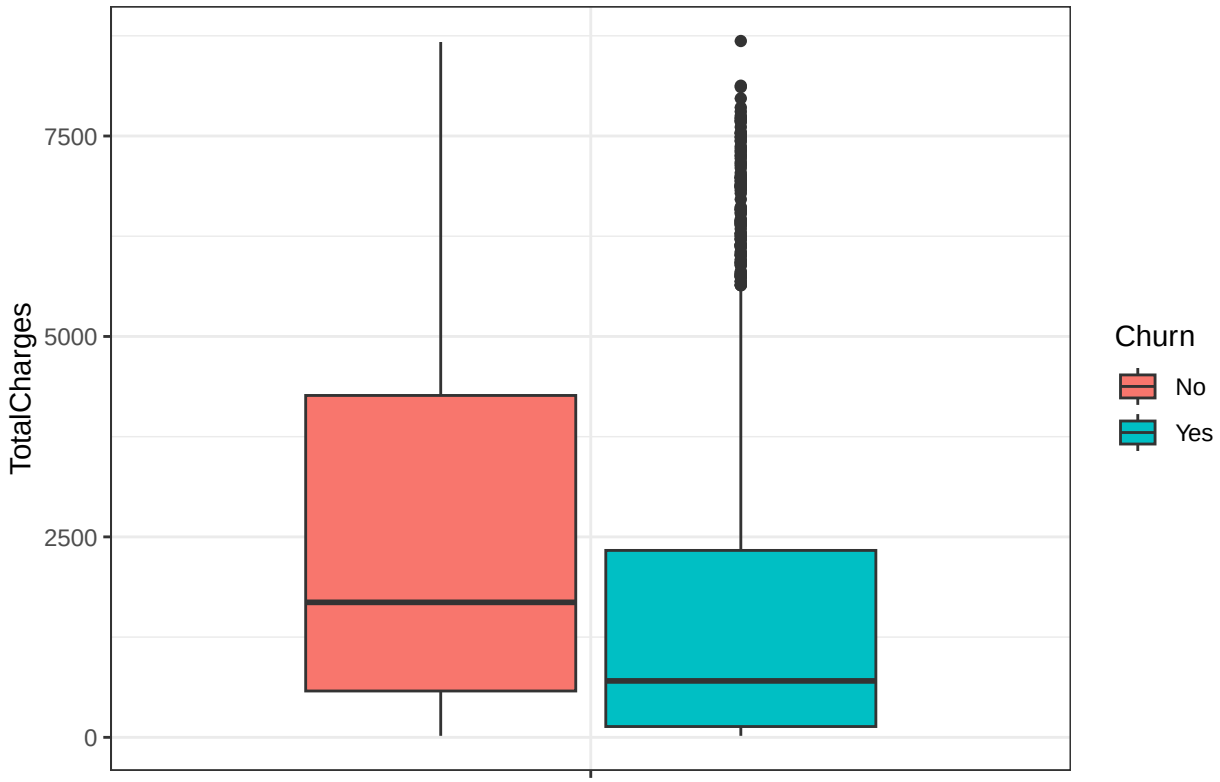
```
options(repr.plot.width =6, repr.plot.height = 2)
ggplot(telco, aes(y= tenure, x = "", fill = Churn)) +
geom_boxplot()+
theme_bw()+
xlab(" ")
```




```
ggplot(telco, aes(y= MonthlyCharges, x = "", fill = Churn)) +
geom_boxplot()+
theme_bw()+
xlab(" ")
```

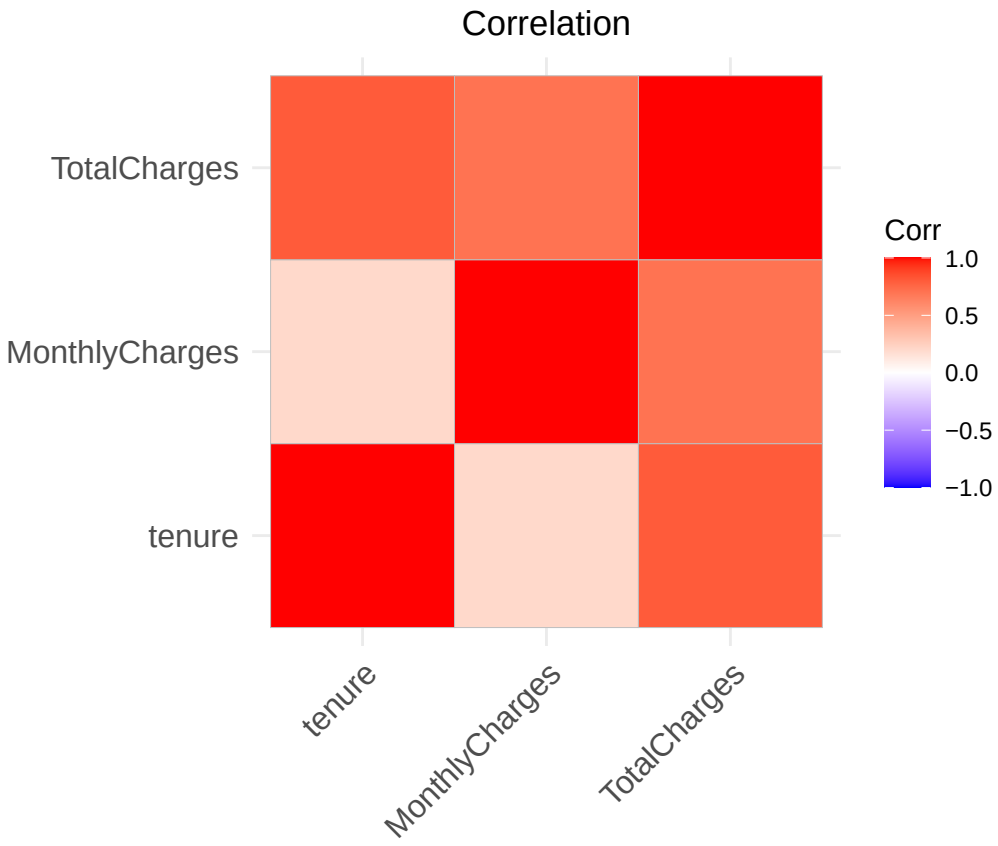



```
ggplot(telco, aes(y= TotalCharges, x = "", fill = Churn)) +
geom_boxplot()+
theme_bw()+
xlab(" ")
```




```
options(repr.plot.width =6, repr.plot.height = 4)
telco_cor <- round(cor(telco[,c("tenure", "MonthlyCharges", "TotalCharges")]), 1)

ggcorrplot(telco_cor,  title = "Correlation")+theme(plot.title = element_text(hjust = 0.5))
```



Data Preparation:

Cleaning the Categorical features

From the EDA above, we know that there are some categorical features that have 'No' and 'No Internet Service' or 'No Phone Service' as a category, we can make them as 'No' and clean these features.

```
telco <- data.frame(lapply(telco, function(x) {
                  gsub("No internet service", "No", x)}))

telco <- data.frame(lapply(telco, function(x) {
                  gsub("No phone service", "No", x)}))
```

- Standardising Continuous features

```
num_columns <- c("tenure", "MonthlyCharges", "TotalCharges")
telco[num_columns] <- sapply(telco[num_columns], as.numeric)

telco_int <- telco[,c("tenure", "MonthlyCharges", "TotalCharges")]
telco_int <- data.frame(scale(telco_int))
```

Creating derived features

- I am trying to create a derived feature from tenure, where i have made different bins of tenure(which is in months) such as '0-1 year', '2-3 years', '3-4 years' etc.

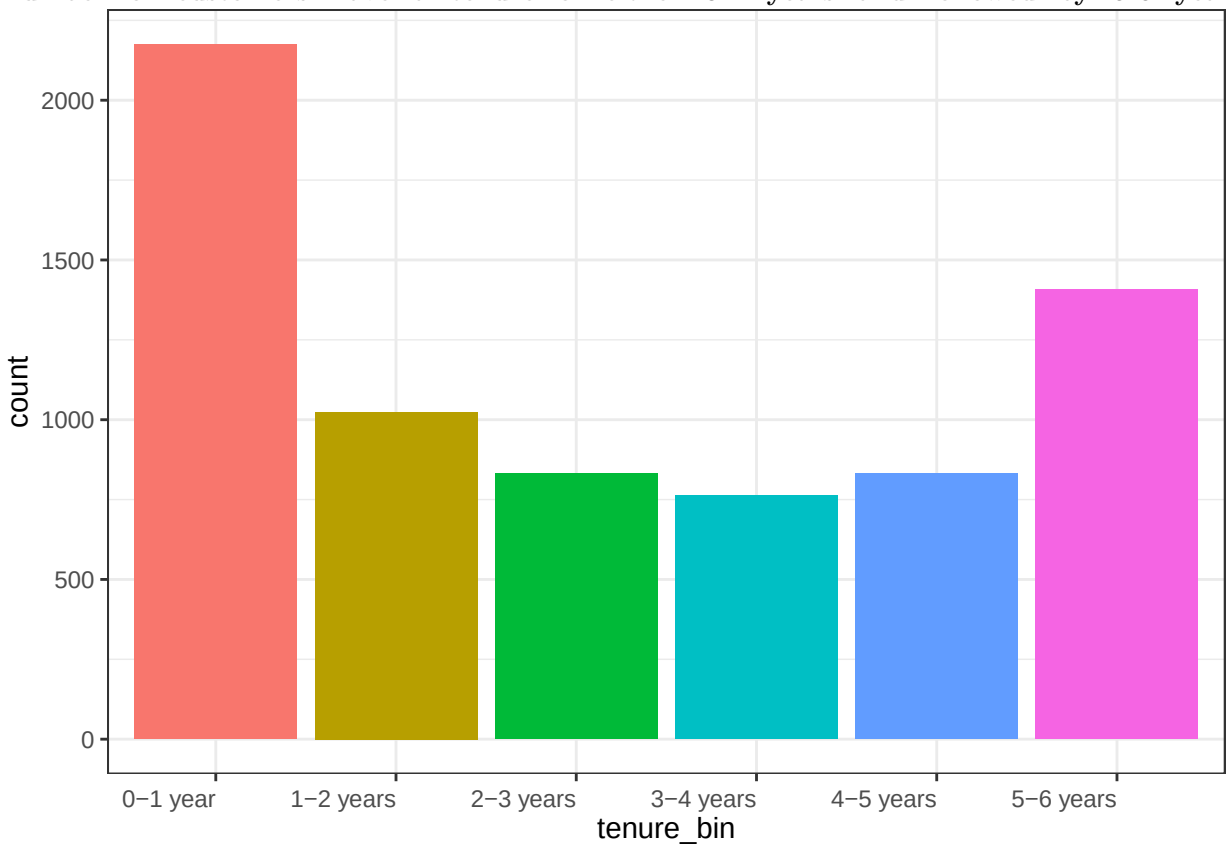
```
#max(telco$tenure)
#min(telco$tenure)
telco <- mutate(telco, tenure_bin = tenure)

telco$tenure_bin[telco$tenure_bin >=0 & telco$tenure_bin <= 12] <- '0-1 year'
telco$tenure_bin[telco$tenure_bin > 12 & telco$tenure_bin <= 24] <- '1-2 years'
telco$tenure_bin[telco$tenure_bin > 24 & telco$tenure_bin <= 36] <- '2-3 years'
telco$tenure_bin[telco$tenure_bin > 36 & telco$tenure_bin <= 48] <- '3-4 years'
telco$tenure_bin[telco$tenure_bin > 48 & telco$tenure_bin <= 60] <- '4-5 years'
telco$tenure_bin[telco$tenure_bin > 60 & telco$tenure_bin <= 72] <- '5-6 years'

telco$tenure_bin <- as.factor(telco$tenure_bin)
```

```
options(repr.plot.width =6, repr.plot.height = 3)
ggplot(telco, aes(tenure_bin, fill = tenure_bin)) + geom_bar()+ theme1
```

After checking the distribution of data in each tenure bin, we found that maximum number of customers have a tenure of either 0-1 years and followed by 5-6 years.




```
telco_cat <- telco[,-c(1,6,19,20)]

#Creating Dummy Variables
dummy<- data.frame(sapply(telco_cat,function(x) data.frame(model.matrix(~x-1,data =telco_cat))[,-1]))

head(dummy)
```

Creating Dummy Variables

```
##   gender SeniorCitizen Partner Dependents PhoneService MultipleLines
## 1      0             0       1          0            0             0
## 2      1             0       0          0            1             0
## 3      1             0       0          0            1             0
## 4      1             0       0          0            0             0
## 5      0             0       0          0            1             0
## 6      0             0       0          0            1             1
##   InternetService.xFiber.optic InternetService.xNo OnlineSecurity OnlineBackup
## 1                            0                  0              0            1
## 2                            0                  0              1            0
## 3                            0                  0              1            1
## 4                            0                  0              1            0
## 5                            1                  0              0            0
## 6                            1                  0              0            0
##   DeviceProtection TechSupport StreamingTV StreamingMovies Contract.xOne.year
## 1                0           0           0               0                  0
## 2                1           0           0               0                  1
## 3                0           0           0               0                  0
## 4                1           1           0               0                  1
## 5                0           0           0               0                  0
## 6                1           0           1               1                  0
##   Contract.xTwo.year PaperlessBilling PaymentMethod.xCredit.card..automatic.
## 1                  0                1                                     0
## 2                  0                0                                     0
## 3                  0                1                                     0
## 4                  0                0                                     0
## 5                  0                1                                     0
## 6                  0                1                                     0
##   PaymentMethod.xElectronic.check PaymentMethod.xMailed.check Churn
## 1                               1                           0     0
## 2                               0                           1     0
## 3                               0                           1     1
## 4                               0                           0     0
## 5                               1                           0     1
## 6                               1                           0     1
##   tenure_bin.x1.2.years tenure_bin.x2.3.years tenure_bin.x3.4.years
## 1                     0                     0                     0
## 2                     0                     1                     0
## 3                     0                     0                     0
## 4                     0                     0                     1
## 5                     0                     0                     0
## 6                     0                     0                     0
##   tenure_bin.x4.5.years tenure_bin.x5.6.years
## 1                     0                     0
## 2                     0                     0
## 3                     0                     0
## 4                     0                     0
## 5                     0                     0
## 6                     0                     0
```

```
#Combining the data
```

```
telco_final <- cbind(telco_int,dummy)
head(telco_final)
```

Creating the final dataset by combining the numeric and dummy data frames.

```
##        tenure MonthlyCharges TotalCharges gender SeniorCitizen Partner
## 1 -1.28015700     -1.1616113   -0.9941234      0             0       1
## 2  0.06429811     -0.2608594   -0.1737275      1             0       0
## 3 -1.23941594     -0.3638974   -0.9595809      1             0       0
## 4  0.51244982     -0.7477972   -0.1952338      1             0       0
## 5 -1.23941594      0.1961642   -0.9403906      0             0       0
## 6 -0.99496955      1.1584066   -0.6453233      0             0       0
##   Dependents PhoneService MultipleLines InternetService.xFiber.optic
## 1          0            0             0                           0
## 2          0            1             0                           0
## 3          0            1             0                           0
## 4          0            0             0                           0
## 5          0            1             0                           1
## 6          0            1             1                           1
##   InternetService.xNo OnlineSecurity OnlineBackup DeviceProtection TechSupport
## 1                   0              0            1                 0           0
## 2                   0              1            0                 1           0
## 3                   0              1            1                 0           0
## 4                   0              1            0                 1           1
## 5                   0              0            0                 0           0
## 6                   0              0            0                 1           0
##   StreamingTV StreamingMovies Contract.xOne.year Contract.xTwo.year
## 1           0               0                  0                  0
## 2           0               0                  1                  0
## 3           0               0                  0                  0
## 4           0               0                  1                  0
## 5           0               0                  0                  0
## 6           1               1                  0                  0
##   PaperlessBilling PaymentMethod.xCredit.card..automatic.
## 1                1                                     0
## 2                0                                     0
## 3                1                                     0
## 4                0                                     0
## 5                1                                     0
## 6                1                                     0
##   PaymentMethod.xElectronic.check PaymentMethod.xMailed.check Churn
## 1                               1                           0     0
## 2                               0                           1     0
## 3                               0                           1     1
## 4                               0                           0     0
## 5                               1                           0     1
## 6                               1                           0     1
##   tenure_bin.x1.2.years tenure_bin.x2.3.years tenure_bin.x3.4.years
## 1                     0                     0                     0
## 2                     0                     1                     0
## 3                     0                     0                     0
## 4                     0                     0                     1
## 5                     0                     0                     0
## 6                     0                     0                     0
```

```
##   tenure_bin.x4.5.years tenure_bin.x5.6.years
## 1                     0                     0
## 2                     0                     0
## 3                     0                     0
## 4                     0                     0
## 5                     0                     0
## 6                     0                     0
```

```r
#Splitting the data
set.seed(123)
indices = sample.split(telco_final$Churn, SplitRatio = 0.7)
train = telco_final[indices,]
validation = telco_final[!(indices),]
```

Splitting the data into train and validation data.

Model Building with Logistic Regression

```r
#Build the first model using all variables
model_1 = glm(Churn ~ ., data = train, family = "binomial")
summary(model_1)
```

```
##
## Call:
## glm(formula = Churn ~ ., family = "binomial", data = train)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.0959  -0.6765  -0.2674   0.6331   3.3919
##
## Coefficients:
##                                    Estimate Std. Error z value Pr(>|z|)
## (Intercept)                       -4.711690   1.580952  -2.980 0.002880
## tenure                            -2.419264   0.319733  -7.567 3.83e-14
## MonthlyCharges                    -1.523039   1.152472  -1.322 0.186321
## TotalCharges                       0.236922   0.200225   1.183 0.236699
## gender                            -0.004319   0.078799  -0.055 0.956292
## SeniorCitizen                      0.342668   0.102039   3.358 0.000784
## Partner                            0.049639   0.095330   0.521 0.602570
## Dependents                        -0.148501   0.110427  -1.345 0.178693
## PhoneService                       0.597310   0.785026   0.761 0.446729
## MultipleLines                      0.529622   0.214832   2.465 0.013691
## InternetService.xFiber.optic       2.048017   0.960709   2.132 0.033025
## InternetService.xNo               -2.254724   0.975826  -2.311 0.020856
## OnlineSecurity                    -0.177982   0.215524  -0.826 0.408913
## OnlineBackup                       0.126834   0.211103   0.601 0.547964
## DeviceProtection                   0.255562   0.213872   1.195 0.232114
## TechSupport                       -0.026070   0.215506  -0.121 0.903713
## StreamingTV                        0.756980   0.393508   1.924 0.054396
## StreamingMovies                    0.710913   0.394744   1.801 0.071711
## Contract.xOne.year                -0.693044   0.130362  -5.316 1.06e-07
## Contract.xTwo.year                -1.657976   0.233538  -7.099 1.25e-12
## PaperlessBilling                   0.384841   0.090753   4.241 2.23e-05
```

```
## PaymentMethod.xCredit.card..automatic. -0.050640   0.137167  -0.369 0.711991
## PaymentMethod.xElectronic.check         0.249223   0.113791   2.190 0.028512
## PaymentMethod.xMailed.check            -0.076660   0.138636  -0.553 0.580291
## tenure_bin.x1.2.years                   0.147347   0.191048   0.771 0.440556
## tenure_bin.x2.3.years                   0.964780   0.314795   3.065 0.002178
## tenure_bin.x3.4.years                   1.955341   0.447108   4.373 1.22e-05
## tenure_bin.x4.5.years                   2.801222   0.582303   4.811 1.50e-06
## tenure_bin.x5.6.years                   3.598926   0.728585   4.940 7.83e-07
##
## (Intercept)                            **
## tenure                                 ***
## MonthlyCharges
## TotalCharges
## gender
## SeniorCitizen                          ***
## Partner
## Dependents
## PhoneService
## MultipleLines                          *
## InternetService.xFiber.optic           *
## InternetService.xNo                    *
## OnlineSecurity
## OnlineBackup
## DeviceProtection
## TechSupport
## StreamingTV                            .
## StreamingMovies                        .
## Contract.xOne.year                     ***
## Contract.xTwo.year                     ***
## PaperlessBilling                       ***
## PaymentMethod.xCredit.card..automatic.
## PaymentMethod.xElectronic.check        *
## PaymentMethod.xMailed.check
## tenure_bin.x1.2.years
## tenure_bin.x2.3.years                  **
## tenure_bin.x3.4.years                  ***
## tenure_bin.x4.5.years                  ***
## tenure_bin.x5.6.years                  ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 5699.5  on 4921  degrees of freedom
## Residual deviance: 3983.3  on 4893  degrees of freedom
## AIC: 4041.3
##
## Number of Fisher Scoring iterations: 6
```

```
model_2<- stepAIC(model_1, direction="both")
```

The Variance Inflation Factor (VIF) is a tool utilized to assess the level of multicollinearity among predictor variables within a model. A predictor with a VIF of 2 or lower is typically

deemed acceptable, indicating minimal correlation with other predictors. Conversely, a higher VIF suggests a stronger correlation with other predictors. It is important to note that predictors with elevated VIF values may exhibit high p-values, indicating significance. Therefore, it is crucial to evaluate the significance of predictor variables before considering their removal from the model.

```
## Start:  AIC=4041.29
## Churn ~ tenure + MonthlyCharges + TotalCharges + gender + SeniorCitizen +
##     Partner + Dependents + PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     TechSupport + StreamingTV + StreamingMovies + Contract.xOne.year +
##     Contract.xTwo.year + PaperlessBilling + PaymentMethod.xCredit.card..automatic. +
##     PaymentMethod.xElectronic.check + PaymentMethod.xMailed.check +
##     tenure_bin.x1.2.years + tenure_bin.x2.3.years + tenure_bin.x3.4.years +
##     tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                        Df Deviance    AIC
## - gender                                1   3983.3 4039.3
## - TechSupport                           1   3983.3 4039.3
## - PaymentMethod.xCredit.card..automatic.  1   3983.4 4039.4
## - Partner                               1   3983.6 4039.6
## - PaymentMethod.xMailed.check           1   3983.6 4039.6
## - OnlineBackup                          1   3983.7 4039.7
## - PhoneService                          1   3983.9 4039.9
## - tenure_bin.x1.2.years                 1   3983.9 4039.9
## - OnlineSecurity                        1   3984.0 4040.0
## - DeviceProtection                      1   3984.7 4040.7
## - TotalCharges                          1   3984.7 4040.7
## - MonthlyCharges                        1   3985.0 4041.0
## - Dependents                            1   3985.1 4041.1
## <none>                                      3983.3 4041.3
## - StreamingMovies                       1   3986.5 4042.5
## - StreamingTV                           1   3987.0 4043.0
## - InternetService.xFiber.optic          1   3987.8 4043.8
## - PaymentMethod.xElectronic.check       1   3988.1 4044.1
## - InternetService.xNo                   1   3988.6 4044.6
## - MultipleLines                         1   3989.4 4045.4
## - tenure_bin.x2.3.years                 1   3992.7 4048.7
## - SeniorCitizen                         1   3994.5 4050.5
## - PaperlessBilling                      1   4001.4 4057.4
## - tenure_bin.x3.4.years                 1   4002.5 4058.5
## - tenure_bin.x4.5.years                 1   4006.6 4062.6
## - tenure_bin.x5.6.years                 1   4007.9 4063.9
## - Contract.xOne.year                    1   4012.9 4068.9
## - tenure                                1   4042.6 4098.6
## - Contract.xTwo.year                    1   4046.3 4102.3
##
## Step:  AIC=4039.29
## Churn ~ tenure + MonthlyCharges + TotalCharges + SeniorCitizen +
##     Partner + Dependents + PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     TechSupport + StreamingTV + StreamingMovies + Contract.xOne.year +
##     Contract.xTwo.year + PaperlessBilling + PaymentMethod.xCredit.card..automatic. +
##     PaymentMethod.xElectronic.check + PaymentMethod.xMailed.check +
```

```
##     tenure_bin.x1.2.years + tenure_bin.x2.3.years + tenure_bin.x3.4.years +
##     tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                        Df Deviance    AIC
## - TechSupport                           1   3983.3 4037.3
## - PaymentMethod.xCredit.card..automatic.  1   3983.4 4037.4
## - Partner                               1   3983.6 4037.6
## - PaymentMethod.xMailed.check           1   3983.6 4037.6
## - OnlineBackup                          1   3983.7 4037.7
## - PhoneService                          1   3983.9 4037.9
## - tenure_bin.x1.2.years                 1   3983.9 4037.9
## - OnlineSecurity                        1   3984.0 4038.0
## - TotalCharges                          1   3984.7 4038.7
## - DeviceProtection                      1   3984.7 4038.7
## - MonthlyCharges                        1   3985.0 4039.0
## - Dependents                            1   3985.1 4039.1
## <none>                                      3983.3 4039.3
## - StreamingMovies                       1   3986.6 4040.6
## - StreamingTV                           1   3987.0 4041.0
## + gender                                1   3983.3 4041.3
## - InternetService.xFiber.optic          1   3987.9 4041.9
## - PaymentMethod.xElectronic.check       1   3988.1 4042.1
## - InternetService.xNo                   1   3988.6 4042.6
## - MultipleLines                         1   3989.4 4043.4
## - tenure_bin.x2.3.years                 1   3992.7 4046.7
## - SeniorCitizen                         1   3994.6 4048.6
## - PaperlessBilling                      1   4001.4 4055.4
## - tenure_bin.x3.4.years                 1   4002.6 4056.6
## - tenure_bin.x4.5.years                 1   4006.6 4060.6
## - tenure_bin.x5.6.years                 1   4007.9 4061.9
## - Contract.xOne.year                    1   4012.9 4066.9
## - tenure                                1   4042.6 4096.6
## - Contract.xTwo.year                    1   4046.3 4100.3
##
## Step:  AIC=4037.31
## Churn ~ tenure + MonthlyCharges + TotalCharges + SeniorCitizen +
##     Partner + Dependents + PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xCredit.card..automatic. +
##     PaymentMethod.xElectronic.check + PaymentMethod.xMailed.check +
##     tenure_bin.x1.2.years + tenure_bin.x2.3.years + tenure_bin.x3.4.years +
##     tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                        Df Deviance    AIC
## - PaymentMethod.xCredit.card..automatic.  1   3983.4 4035.4
## - Partner                               1   3983.6 4035.6
## - PaymentMethod.xMailed.check           1   3983.6 4035.6
## - tenure_bin.x1.2.years                 1   3983.9 4035.9
## - OnlineBackup                          1   3984.6 4036.6
## - OnlineSecurity                        1   3984.6 4036.6
## - TotalCharges                          1   3984.7 4036.7
## - Dependents                            1   3985.1 4037.1
## <none>                                      3983.3 4037.3
```

```
## - PhoneService                              1   3986.2 4038.2
## + TechSupport                               1   3983.3 4039.3
## + gender                                    1   3983.3 4039.3
## - DeviceProtection                          1   3987.5 4039.5
## - PaymentMethod.xElectronic.check           1   3988.1 4040.1
## - MonthlyCharges                            1   3992.2 4044.2
## - tenure_bin.x2.3.years                     1   3992.8 4044.8
## - SeniorCitizen                             1   3994.6 4046.6
## - StreamingMovies                           1   3996.4 4048.4
## - StreamingTV                               1   3997.9 4049.9
## - MultipleLines                             1   4000.8 4052.8
## - PaperlessBilling                          1   4001.4 4053.4
## - tenure_bin.x3.4.years                     1   4002.6 4054.6
## - InternetService.xNo                       1   4004.4 4056.4
## - InternetService.xFiber.optic              1   4005.7 4057.7
## - tenure_bin.x4.5.years                     1   4006.7 4058.7
## - tenure_bin.x5.6.years                     1   4008.0 4060.0
## - Contract.xOne.year                        1   4013.1 4065.1
## - tenure                                    1   4042.7 4094.7
## - Contract.xTwo.year                        1   4046.8 4098.8
##
## Step:  AIC=4035.44
## Churn ~ tenure + MonthlyCharges + TotalCharges + SeniorCitizen +
##     Partner + Dependents + PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xElectronic.check + PaymentMethod.xMailed.check +
##     tenure_bin.x1.2.years + tenure_bin.x2.3.years + tenure_bin.x3.4.years +
##     tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                          Df Deviance    AIC
## - PaymentMethod.xMailed.check             1   3983.6 4033.6
## - Partner                                 1   3983.7 4033.7
## - tenure_bin.x1.2.years                   1   3984.0 4034.0
## - OnlineBackup                            1   3984.7 4034.7
## - OnlineSecurity                          1   3984.7 4034.7
## - TotalCharges                            1   3984.9 4034.9
## - Dependents                              1   3985.3 4035.3
## <none>                                        3983.4 4035.4
## - PhoneService                            1   3986.3 4036.3
## + PaymentMethod.xCredit.card..automatic.  1   3983.3 4037.3
## + TechSupport                             1   3983.4 4037.4
## + gender                                  1   3983.4 4037.4
## - DeviceProtection                        1   3987.6 4037.6
## - PaymentMethod.xElectronic.check         1   3991.9 4041.9
## - MonthlyCharges                          1   3992.3 4042.3
## - tenure_bin.x2.3.years                   1   3992.8 4042.8
## - SeniorCitizen                           1   3994.8 4044.8
## - StreamingMovies                         1   3996.5 4046.5
## - StreamingTV                             1   3998.1 4048.1
## - MultipleLines                           1   4000.9 4050.9
## - PaperlessBilling                        1   4001.6 4051.6
## - tenure_bin.x3.4.years                   1   4002.7 4052.7
## - InternetService.xNo                     1   4004.5 4054.5
```

```
## - InternetService.xFiber.optic            1   4005.8 4055.8
## - tenure_bin.x4.5.years                   1   4006.8 4056.8
## - tenure_bin.x5.6.years                   1   4008.0 4058.0
## - Contract.xOne.year                      1   4013.3 4063.3
## - tenure                                  1   4042.8 4092.8
## - Contract.xTwo.year                      1   4047.0 4097.0
##
## Step:  AIC=4033.63
## Churn ~ tenure + MonthlyCharges + TotalCharges + SeniorCitizen +
##     Partner + Dependents + PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xElectronic.check + tenure_bin.x1.2.years +
##     tenure_bin.x2.3.years + tenure_bin.x3.4.years + tenure_bin.x4.5.years +
##     tenure_bin.x5.6.years
##
##                                         Df Deviance    AIC
## - Partner                                1   3983.9 4031.9
## - tenure_bin.x1.2.years                  1   3984.2 4032.2
## - OnlineSecurity                         1   3984.9 4032.9
## - OnlineBackup                           1   3984.9 4032.9
## - TotalCharges                           1   3985.0 4033.0
## - Dependents                             1   3985.5 4033.5
## <none>                                       3983.6 4033.6
## - PhoneService                           1   3986.5 4034.5
## + PaymentMethod.xMailed.check            1   3983.4 4035.4
## + TechSupport                            1   3983.6 4035.6
## + PaymentMethod.xCredit.card..automatic.  1   3983.6 4035.6
## + gender                                 1   3983.6 4035.6
## - DeviceProtection                       1   3987.8 4035.8
## - MonthlyCharges                         1   3992.5 4040.5
## - tenure_bin.x2.3.years                  1   3993.0 4041.0
## - SeniorCitizen                          1   3995.0 4043.0
## - PaymentMethod.xElectronic.check        1   3995.4 4043.4
## - StreamingMovies                        1   3996.8 4044.8
## - StreamingTV                            1   3998.3 4046.3
## - MultipleLines                          1   4001.3 4049.3
## - PaperlessBilling                       1   4001.9 4049.9
## - tenure_bin.x3.4.years                  1   4002.8 4050.8
## - InternetService.xNo                    1   4005.0 4053.0
## - InternetService.xFiber.optic           1   4006.2 4054.2
## - tenure_bin.x4.5.years                  1   4006.8 4054.8
## - tenure_bin.x5.6.years                  1   4008.1 4056.1
## - Contract.xOne.year                     1   4013.5 4061.5
## - tenure                                 1   4043.0 4091.0
## - Contract.xTwo.year                     1   4047.1 4095.1
##
## Step:  AIC=4031.93
## Churn ~ tenure + MonthlyCharges + TotalCharges + SeniorCitizen +
##     Dependents + PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xElectronic.check + tenure_bin.x1.2.years +
##     tenure_bin.x2.3.years + tenure_bin.x3.4.years + tenure_bin.x4.5.years +
```

```
##     tenure_bin.x5.6.years
##
##                                          Df Deviance    AIC
## - tenure_bin.x1.2.years                   1   3984.5 4030.5
## - OnlineSecurity                          1   3985.2 4031.2
## - OnlineBackup                            1   3985.2 4031.2
## - TotalCharges                            1   3985.3 4031.3
## - Dependents                              1   3985.5 4031.5
## <none>                                        3983.9 4031.9
## - PhoneService                            1   3986.8 4032.8
## + Partner                                 1   3983.6 4033.6
## + PaymentMethod.xMailed.check             1   3983.7 4033.7
## + PaymentMethod.xCredit.card..automatic.  1   3983.9 4033.9
## + TechSupport                             1   3983.9 4033.9
## + gender                                  1   3983.9 4033.9
## - DeviceProtection                        1   3988.2 4034.2
## - MonthlyCharges                          1   3992.9 4038.9
## - tenure_bin.x2.3.years                   1   3993.2 4039.2
## - PaymentMethod.xElectronic.check         1   3995.7 4041.7
## - SeniorCitizen                           1   3995.7 4041.7
## - StreamingMovies                         1   3997.2 4043.2
## - StreamingTV                             1   3998.7 4044.7
## - MultipleLines                           1   4001.7 4047.7
## - PaperlessBilling                        1   4002.3 4048.3
## - tenure_bin.x3.4.years                   1   4002.9 4048.9
## - InternetService.xNo                     1   4005.4 4051.4
## - InternetService.xFiber.optic            1   4006.7 4052.7
## - tenure_bin.x4.5.years                   1   4007.0 4053.0
## - tenure_bin.x5.6.years                   1   4008.2 4054.2
## - Contract.xOne.year                      1   4013.8 4059.8
## - tenure                                  1   4043.0 4089.0
## - Contract.xTwo.year                      1   4047.5 4093.5
##
## Step:  AIC=4030.5
## Churn ~ tenure + MonthlyCharges + TotalCharges + SeniorCitizen +
##     Dependents + PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xElectronic.check + tenure_bin.x2.3.years +
##     tenure_bin.x3.4.years + tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                          Df Deviance    AIC
## - TotalCharges                            1   3985.8 4029.8
## - OnlineBackup                            1   3985.8 4029.8
## - OnlineSecurity                          1   3985.8 4029.8
## - Dependents                              1   3986.0 4030.0
## <none>                                        3984.5 4030.5
## - PhoneService                            1   3987.4 4031.4
## + tenure_bin.x1.2.years                   1   3983.9 4031.9
## + Partner                                 1   3984.2 4032.2
## + PaymentMethod.xMailed.check             1   3984.3 4032.3
## + TechSupport                             1   3984.5 4032.5
## + PaymentMethod.xCredit.card..automatic.  1   3984.5 4032.5
## + gender                                  1   3984.5 4032.5
```

```
## - DeviceProtection                         1   3988.7 4032.7
## - MonthlyCharges                           1   3993.4 4037.4
## - PaymentMethod.xElectronic.check          1   3996.2 4040.2
## - SeniorCitizen                            1   3996.3 4040.3
## - StreamingMovies                          1   3997.7 4041.7
## - StreamingTV                              1   3999.2 4043.2
## - tenure_bin.x2.3.years                    1   4000.3 4044.3
## - MultipleLines                            1   4002.2 4046.2
## - PaperlessBilling                         1   4002.9 4046.9
## - InternetService.xNo                      1   4005.8 4049.8
## - InternetService.xFiber.optic             1   4007.2 4051.2
## - Contract.xOne.year                       1   4014.3 4058.3
## - tenure_bin.x3.4.years                    1   4022.8 4066.8
## - tenure_bin.x4.5.years                    1   4032.5 4076.5
## - tenure_bin.x5.6.years                    1   4033.0 4077.0
## - Contract.xTwo.year                       1   4049.2 4093.2
## - tenure                                   1   4099.3 4143.3
##
## Step:  AIC=4029.75
## Churn ~ tenure + MonthlyCharges + SeniorCitizen + Dependents +
##     PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + OnlineBackup + DeviceProtection +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xElectronic.check + tenure_bin.x2.3.years +
##     tenure_bin.x3.4.years + tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                        Df Deviance    AIC
## - OnlineBackup                          1   3987.0 4029.0
## - OnlineSecurity                        1   3987.1 4029.1
## - Dependents                            1   3987.3 4029.3
## <none>                                      3985.8 4029.8
## - PhoneService                          1   3988.5 4030.5
## + TotalCharges                          1   3984.5 4030.5
## + tenure_bin.x1.2.years                 1   3985.3 4031.3
## + Partner                               1   3985.5 4031.5
## + PaymentMethod.xMailed.check           1   3985.6 4031.6
## + PaymentMethod.xCredit.card..automatic. 1   3985.7 4031.7
## + TechSupport                           1   3985.7 4031.7
## + gender                                1   3985.7 4031.7
## - DeviceProtection                      1   3990.0 4032.0
## - MonthlyCharges                        1   3993.8 4035.8
## - PaymentMethod.xElectronic.check       1   3997.1 4039.1
## - SeniorCitizen                         1   3997.6 4039.6
## - StreamingMovies                       1   3998.7 4040.7
## - StreamingTV                           1   4000.2 4042.2
## - tenure_bin.x2.3.years                 1   4002.5 4044.5
## - MultipleLines                         1   4003.7 4045.7
## - PaperlessBilling                      1   4003.9 4045.9
## - InternetService.xNo                   1   4006.1 4048.1
## - InternetService.xFiber.optic          1   4007.9 4049.9
## - Contract.xOne.year                    1   4015.9 4057.9
## - tenure_bin.x3.4.years                 1   4028.0 4070.0
## - tenure_bin.x4.5.years                 1   4041.1 4083.1
## - tenure_bin.x5.6.years                 1   4046.5 4088.5
```

```
## - Contract.xTwo.year                       1   4052.5 4094.5
## - tenure                                   1   4131.0 4173.0
##
## Step:  AIC=4029.04
## Churn ~ tenure + MonthlyCharges + SeniorCitizen + Dependents +
##     PhoneService + MultipleLines + InternetService.xFiber.optic +
##     InternetService.xNo + OnlineSecurity + DeviceProtection +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xElectronic.check + tenure_bin.x2.3.years +
##     tenure_bin.x3.4.years + tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                         Df Deviance    AIC
## - PhoneService                           1   3988.5 4028.5
## - Dependents                             1   3988.6 4028.6
## <none>                                       3987.0 4029.0
## + OnlineBackup                           1   3985.8 4029.8
## + TotalCharges                           1   3985.8 4029.8
## - DeviceProtection                       1   3990.0 4030.0
## + TechSupport                            1   3986.1 4030.1
## + tenure_bin.x1.2.years                  1   3986.6 4030.6
## - OnlineSecurity                         1   3990.7 4030.7
## + Partner                                1   3986.7 4030.7
## + PaymentMethod.xMailed.check            1   3986.9 4030.9
## + PaymentMethod.xCredit.card..automatic. 1   3987.0 4031.0
## + gender                                 1   3987.0 4031.0
## - MonthlyCharges                         1   3995.3 4035.3
## - PaymentMethod.xElectronic.check        1   3998.8 4038.8
## - SeniorCitizen                          1   3999.4 4039.4
## - StreamingMovies                        1   4001.0 4041.0
## - StreamingTV                            1   4002.6 4042.6
## - tenure_bin.x2.3.years                  1   4003.7 4043.7
## - MultipleLines                          1   4004.6 4044.6
## - PaperlessBilling                       1   4005.4 4045.4
## - InternetService.xNo                    1   4011.2 4051.2
## - InternetService.xFiber.optic           1   4016.3 4056.3
## - Contract.xOne.year                     1   4018.2 4058.2
## - tenure_bin.x3.4.years                  1   4029.0 4069.0
## - tenure_bin.x4.5.years                  1   4042.5 4082.5
## - tenure_bin.x5.6.years                  1   4048.1 4088.1
## - Contract.xTwo.year                     1   4056.9 4096.9
## - tenure                                 1   4131.3 4171.3
##
## Step:  AIC=4028.46
## Churn ~ tenure + MonthlyCharges + SeniorCitizen + Dependents +
##     MultipleLines + InternetService.xFiber.optic + InternetService.xNo +
##     OnlineSecurity + DeviceProtection + StreamingTV + StreamingMovies +
##     Contract.xOne.year + Contract.xTwo.year + PaperlessBilling +
##     PaymentMethod.xElectronic.check + tenure_bin.x2.3.years +
##     tenure_bin.x3.4.years + tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                         Df Deviance    AIC
## - Dependents                             1   3990.0 4028.0
## - DeviceProtection                       1   3990.1 4028.1
## + TechSupport                            1   3986.3 4028.3
```

```
## <none>                                        3988.5 4028.5
## + PhoneService                              1   3987.0 4029.0
## + TotalCharges                              1   3987.4 4029.4
## + tenure_bin.x1.2.years                     1   3988.0 4030.0
## + Partner                                   1   3988.1 4030.1
## + PaymentMethod.xMailed.check               1   3988.3 4030.3
## + PaymentMethod.xCredit.card..automatic.    1   3988.4 4030.4
## + OnlineBackup                              1   3988.5 4030.5
## + gender                                    1   3988.5 4030.5
## - OnlineSecurity                            1   3996.2 4034.2
## - PaymentMethod.xElectronic.check           1   4000.2 4038.2
## - SeniorCitizen                             1   4001.0 4039.0
## - MonthlyCharges                            1   4001.6 4039.6
## - MultipleLines                             1   4004.9 4042.9
## - StreamingMovies                           1   4005.0 4043.0
## - tenure_bin.x2.3.years                     1   4005.1 4043.1
## - PaperlessBilling                          1   4006.5 4044.5
## - StreamingTV                               1   4007.3 4045.3
## - Contract.xOne.year                        1   4020.3 4058.3
## - tenure_bin.x3.4.years                     1   4030.6 4068.6
## - InternetService.xFiber.optic              1   4033.8 4071.8
## - InternetService.xNo                       1   4041.7 4079.7
## - tenure_bin.x4.5.years                     1   4044.1 4082.1
## - tenure_bin.x5.6.years                     1   4049.7 4087.7
## - Contract.xTwo.year                        1   4060.4 4098.4
## - tenure                                    1   4137.1 4175.1
##
## Step:  AIC=4028.03
## Churn ~ tenure + MonthlyCharges + SeniorCitizen + MultipleLines +
##     InternetService.xFiber.optic + InternetService.xNo + OnlineSecurity +
##     DeviceProtection + StreamingTV + StreamingMovies + Contract.xOne.year +
##     Contract.xTwo.year + PaperlessBilling + PaymentMethod.xElectronic.check +
##     tenure_bin.x2.3.years + tenure_bin.x3.4.years + tenure_bin.x4.5.years +
##     tenure_bin.x5.6.years
##
##                                           Df Deviance    AIC
## - DeviceProtection                         1   3991.7 4027.7
## + TechSupport                              1   3987.8 4027.8
## <none>                                         3990.0 4028.0
## + Dependents                               1   3988.5 4028.5
## + PhoneService                             1   3988.6 4028.6
## + TotalCharges                             1   3988.9 4028.9
## + tenure_bin.x1.2.years                    1   3989.6 4029.6
## + PaymentMethod.xMailed.check              1   3989.9 4029.9
## + PaymentMethod.xCredit.card..automatic.   1   3990.0 4030.0
## + gender                                   1   3990.0 4030.0
## + OnlineBackup                             1   3990.0 4030.0
## + Partner                                  1   3990.0 4030.0
## - OnlineSecurity                           1   3997.8 4033.8
## - PaymentMethod.xElectronic.check          1   4002.1 4038.1
## - MonthlyCharges                           1   4003.4 4039.4
## - SeniorCitizen                            1   4004.4 4040.4
## - MultipleLines                            1   4006.8 4042.8
## - tenure_bin.x2.3.years                    1   4006.8 4042.8
```

```
## - StreamingMovies                          1   4006.9 4042.9
## - PaperlessBilling                         1   4008.4 4044.4
## - StreamingTV                              1   4008.9 4044.9
## - Contract.xOne.year                       1   4022.6 4058.6
## - tenure_bin.x3.4.years                    1   4032.5 4068.5
## - InternetService.xFiber.optic             1   4036.2 4072.2
## - InternetService.xNo                      1   4043.8 4079.8
## - tenure_bin.x4.5.years                    1   4046.4 4082.4
## - tenure_bin.x5.6.years                    1   4052.0 4088.0
## - Contract.xTwo.year                       1   4063.5 4099.5
## - tenure                                   1   4141.0 4177.0
##
## Step:  AIC=4027.71
## Churn ~ tenure + MonthlyCharges + SeniorCitizen + MultipleLines +
##     InternetService.xFiber.optic + InternetService.xNo + OnlineSecurity +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
##     PaperlessBilling + PaymentMethod.xElectronic.check + tenure_bin.x2.3.years +
##     tenure_bin.x3.4.years + tenure_bin.x4.5.years + tenure_bin.x5.6.years
##
##                                         Df Deviance    AIC
## + TechSupport                            1   3989.3 4027.3
## <none>                                       3991.7 4027.7
## + DeviceProtection                       1   3990.0 4028.0
## + Dependents                             1   3990.1 4028.1
## + TotalCharges                           1   3990.5 4028.5
## + tenure_bin.x1.2.years                  1   3991.3 4029.3
## + PaymentMethod.xMailed.check            1   3991.6 4029.6
## + PhoneService                           1   3991.6 4029.6
## + PaymentMethod.xCredit.card..automatic. 1   3991.7 4029.7
## + OnlineBackup                           1   3991.7 4029.7
## + gender                                 1   3991.7 4029.7
## + Partner                                1   3991.7 4029.7
## - OnlineSecurity                         1   4000.6 4034.6
## - MonthlyCharges                         1   4003.4 4037.4
## - PaymentMethod.xElectronic.check        1   4003.8 4037.8
## - SeniorCitizen                          1   4006.2 4040.2
## - MultipleLines                          1   4007.2 4041.2
## - StreamingMovies                        1   4007.7 4041.7
## - tenure_bin.x2.3.years                  1   4008.1 4042.1
## - StreamingTV                            1   4009.6 4043.6
## - PaperlessBilling                       1   4009.8 4043.8
## - Contract.xOne.year                     1   4023.5 4057.5
## - tenure_bin.x3.4.years                  1   4034.1 4068.1
## - InternetService.xFiber.optic           1   4036.8 4070.8
## - InternetService.xNo                    1   4043.9 4077.9
## - tenure_bin.x4.5.years                  1   4047.4 4081.4
## - tenure_bin.x5.6.years                  1   4053.1 4087.1
## - Contract.xTwo.year                     1   4064.2 4098.2
## - tenure                                 1   4141.1 4175.1
##
## Step:  AIC=4027.28
## Churn ~ tenure + MonthlyCharges + SeniorCitizen + MultipleLines +
##     InternetService.xFiber.optic + InternetService.xNo + OnlineSecurity +
##     StreamingTV + StreamingMovies + Contract.xOne.year + Contract.xTwo.year +
```

```
##     PaperlessBilling + PaymentMethod.xElectronic.check + tenure_bin.x2.3.years +
##     tenure_bin.x3.4.years + tenure_bin.x4.5.years + tenure_bin.x5.6.years +
##     TechSupport
##
##                                         Df Deviance    AIC
## <none>                                       3989.3 4027.3
## - TechSupport                            1   3991.7 4027.7
## + Dependents                             1   3987.7 4027.7
## + DeviceProtection                       1   3987.8 4027.8
## + TotalCharges                           1   3987.9 4027.9
## + tenure_bin.x1.2.years                  1   3988.9 4028.9
## + PhoneService                           1   3989.1 4029.1
## + PaymentMethod.xMailed.check            1   3989.2 4029.2
## + OnlineBackup                           1   3989.2 4029.2
## + PaymentMethod.xCredit.card..automatic. 1   3989.3 4029.3
## + gender                                 1   3989.3 4029.3
## + Partner                                1   3989.3 4029.3
## - MonthlyCharges                         1   3996.2 4032.2
## - OnlineSecurity                         1   3998.8 4034.8
## - PaymentMethod.xElectronic.check        1   4000.9 4036.9
## - MultipleLines                          1   4002.2 4038.2
## - StreamingMovies                        1   4002.8 4038.8
## - SeniorCitizen                          1   4002.9 4038.9
## - StreamingTV                            1   4004.6 4040.6
## - tenure_bin.x2.3.years                  1   4005.8 4041.8
## - PaperlessBilling                       1   4007.6 4043.6
## - Contract.xOne.year                     1   4019.1 4055.1
## - InternetService.xFiber.optic           1   4021.1 4057.1
## - tenure_bin.x3.4.years                  1   4031.5 4067.5
## - InternetService.xNo                    1   4038.0 4074.0
## - tenure_bin.x4.5.years                  1   4044.7 4080.7
## - tenure_bin.x5.6.years                  1   4050.1 4086.1
## - Contract.xTwo.year                     1   4055.8 4091.8
## - tenure                                 1   4137.1 4173.1
```

```
summary(model_2)
```

```
##
## Call:
## glm(formula = Churn ~ tenure + MonthlyCharges + SeniorCitizen +
##     MultipleLines + InternetService.xFiber.optic + InternetService.xNo +
##     OnlineSecurity + StreamingTV + StreamingMovies + Contract.xOne.year +
##     Contract.xTwo.year + PaperlessBilling + PaymentMethod.xElectronic.check +
##     tenure_bin.x2.3.years + tenure_bin.x3.4.years + tenure_bin.x4.5.years +
##     tenure_bin.x5.6.years + TechSupport, family = "binomial",
##     data = train)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.1461  -0.6661  -0.2733   0.6249   3.3018
##
## Coefficients:
##                               Estimate Std. Error z value Pr(>|z|)
## (Intercept)                   -3.37123    0.27189 -12.399  < 2e-16 ***
## tenure                        -2.07853    0.17751 -11.709  < 2e-16 ***
```

```
## MonthlyCharges                   -0.52335    0.19800  -2.643 0.008213 **
## SeniorCitizen                     0.37111    0.10031   3.700 0.000216 ***
## MultipleLines                     0.38516    0.10755   3.581 0.000342 ***
## InternetService.xFiber.optic      1.28144    0.22881   5.601 2.14e-08 ***
## InternetService.xNo              -1.45816    0.20985  -6.949 3.69e-12 ***
## OnlineSecurity                   -0.33178    0.10796  -3.073 0.002118 **
## StreamingTV                       0.46276    0.11865   3.900 9.61e-05 ***
## StreamingMovies                   0.42482    0.11585   3.667 0.000246 ***
## Contract.xOne.year               -0.69055    0.12950  -5.333 9.68e-08 ***
## Contract.xTwo.year               -1.68164    0.23166  -7.259 3.89e-13 ***
## PaperlessBilling                  0.38535    0.09046   4.260 2.05e-05 ***
## PaymentMethod.xElectronic.check   0.28932    0.08445   3.426 0.000613 ***
## tenure_bin.x2.3.years             0.78164    0.19291   4.052 5.08e-05 ***
## tenure_bin.x3.4.years             1.72393    0.26800   6.432 1.26e-10 ***
## tenure_bin.x4.5.years             2.52442    0.34433   7.331 2.28e-13 ***
## tenure_bin.x5.6.years             3.30141    0.43049   7.669 1.73e-14 ***
## TechSupport                      -0.17022    0.10928  -1.558 0.119308
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 5699.5  on 4921  degrees of freedom
## Residual deviance: 3989.3  on 4903  degrees of freedom
## AIC: 4027.3
##
## Number of Fisher Scoring iterations: 6
```

```
vif(model_2)
```

```
##                          tenure                  MonthlyCharges
##                       15.076710                      20.162188
##                   SeniorCitizen                   MultipleLines
##                        1.100707                       1.838876
##    InternetService.xFiber.optic             InternetService.xNo
##                        8.225529                       2.489968
##                  OnlineSecurity                     StreamingTV
##                        1.246308                       2.206225
##                 StreamingMovies              Contract.xOne.year
##                        2.122071                       1.386381
##              Contract.xTwo.year                PaperlessBilling
##                        1.371229                       1.125064
## PaymentMethod.xElectronic.check           tenure_bin.x2.3.years
##                        1.149683                       2.656673
##           tenure_bin.x3.4.years           tenure_bin.x4.5.years
##                        4.106103                       6.527227
##           tenure_bin.x5.6.years                     TechSupport
##                        8.568998                       1.332821
```

```
#Removing DeviceProtection due to high p-value
model_3 <-glm(formula = Churn ~ tenure + MonthlyCharges + SeniorCitizen +
    Partner + InternetService.xFiber.optic + InternetService.xNo +
    OnlineSecurity + OnlineBackup + TechSupport +
    StreamingTV + Contract.xOne.year + Contract.xTwo.year + PaperlessBilling +
    PaymentMethod.xElectronic.check + tenure_bin.x1.2.years +
```

```
    tenure_bin.x5.6.years, family = "binomial", data = train)
summary(model_3)
```

```
##
## Call:
## glm(formula = Churn ~ tenure + MonthlyCharges + SeniorCitizen +
##     Partner + InternetService.xFiber.optic + InternetService.xNo +
##     OnlineSecurity + OnlineBackup + TechSupport + StreamingTV +
##     Contract.xOne.year + Contract.xTwo.year + PaperlessBilling +
##     PaymentMethod.xElectronic.check + tenure_bin.x1.2.years +
##     tenure_bin.x5.6.years, family = "binomial", data = train)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.9863  -0.6589  -0.2775   0.6424   3.2758
##
## Coefficients:
##                                 Estimate Std. Error z value Pr(>|z|)
## (Intercept)                     -1.48117    0.17354  -8.535  < 2e-16 ***
## tenure                          -0.88438    0.07316 -12.088  < 2e-16 ***
## MonthlyCharges                   0.08404    0.15461   0.544 0.586731
## SeniorCitizen                    0.37893    0.09935   3.814 0.000137 ***
## Partner                         -0.02734    0.08496  -0.322 0.747590
## InternetService.xFiber.optic     0.73441    0.20004   3.671 0.000241 ***
## InternetService.xNo             -1.07362    0.19318  -5.558 2.73e-08 ***
## OnlineSecurity                  -0.46885    0.10462  -4.481 7.42e-06 ***
## OnlineBackup                    -0.12936    0.09465  -1.367 0.171691
## TechSupport                     -0.29675    0.10623  -2.793 0.005216 **
## StreamingTV                      0.32029    0.11573   2.768 0.005647 **
## Contract.xOne.year              -0.69301    0.12783  -5.421 5.92e-08 ***
## Contract.xTwo.year              -1.72148    0.23296  -7.390 1.47e-13 ***
## PaperlessBilling                 0.40142    0.08954   4.483 7.36e-06 ***
## PaymentMethod.xElectronic.check  0.32498    0.08352   3.891 9.99e-05 ***
## tenure_bin.x1.2.years           -0.52142    0.10707  -4.870 1.12e-06 ***
## tenure_bin.x5.6.years            0.54321    0.19325   2.811 0.004940 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 5699.5  on 4921  degrees of freedom
## Residual deviance: 4042.5  on 4905  degrees of freedom
## AIC: 4076.5
##
## Number of Fisher Scoring iterations: 6
```

```
vif(model_3)
```

```
##                          tenure                  MonthlyCharges
##                        2.540970                       12.310900
##                   SeniorCitizen                         Partner
##                        1.092995                        1.133093
##    InternetService.xFiber.optic             InternetService.xNo
##                        6.398204                        2.142763
```

```
##                   OnlineSecurity                     OnlineBackup
##                         1.180975                         1.288093
##                      TechSupport                      StreamingTV
##                         1.271133                         2.122655
##               Contract.xOne.year              Contract.xTwo.year
##                         1.360444                         1.392469
##                PaperlessBilling PaymentMethod.xElectronic.check
##                         1.120396                         1.141949
##            tenure_bin.x1.2.years           tenure_bin.x5.6.years
##                         1.028052                         1.757701
```

```
#Removing StreamingTV  as it has high p-value

model_4 <- glm(formula = Churn ~ tenure + MonthlyCharges + SeniorCitizen +
    Partner + InternetService.xFiber.optic + InternetService.xNo +
    OnlineSecurity + OnlineBackup + TechSupport +
    Contract.xOne.year + Contract.xTwo.year + PaperlessBilling +
    PaymentMethod.xElectronic.check + tenure_bin.x1.2.years +
    tenure_bin.x5.6.years, family = "binomial", data = train)

summary(model_4)
```

```
##
## Call:
## glm(formula = Churn ~ tenure + MonthlyCharges + SeniorCitizen +
##     Partner + InternetService.xFiber.optic + InternetService.xNo +
##     OnlineSecurity + OnlineBackup + TechSupport + Contract.xOne.year +
##     Contract.xTwo.year + PaperlessBilling + PaymentMethod.xElectronic.check +
##     tenure_bin.x1.2.years + tenure_bin.x5.6.years, family = "binomial",
##     data = train)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.9552  -0.6643  -0.2791   0.6644   3.2717
##
## Coefficients:
##                                  Estimate Std. Error z value Pr(>|z|)
## (Intercept)                      -1.24627    0.15025  -8.295  < 2e-16 ***
## tenure                           -0.87338    0.07296 -11.970  < 2e-16 ***
## MonthlyCharges                    0.35114    0.12173   2.885 0.003918 **
## SeniorCitizen                     0.37827    0.09923   3.812 0.000138 ***
## Partner                          -0.02668    0.08487  -0.314 0.753275
## InternetService.xFiber.optic      0.45825    0.17270   2.653 0.007967 **
## InternetService.xNo              -0.91779    0.18585  -4.938 7.88e-07 ***
## OnlineSecurity                   -0.52247    0.10282  -5.081 3.75e-07 ***
## OnlineBackup                     -0.16988    0.09346  -1.818 0.069109 .
## TechSupport                      -0.33438    0.10525  -3.177 0.001488 **
## Contract.xOne.year               -0.67704    0.12751  -5.310 1.10e-07 ***
## Contract.xTwo.year               -1.70720    0.23269  -7.337 2.19e-13 ***
## PaperlessBilling                  0.41657    0.08924   4.668 3.04e-06 ***
## PaymentMethod.xElectronic.check   0.34692    0.08304   4.178 2.95e-05 ***
## tenure_bin.x1.2.years            -0.52044    0.10684  -4.871 1.11e-06 ***
## tenure_bin.x5.6.years             0.52669    0.19290   2.730 0.006326 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 5699.5  on 4921  degrees of freedom
## Residual deviance: 4050.2  on 4906  degrees of freedom
## AIC: 4082.2
##
## Number of Fisher Scoring iterations: 6
```

```
vif(model_4)
```

```
##                           tenure                  MonthlyCharges
##                         2.528728                         7.598828
##                     SeniorCitizen                          Partner
##                         1.092734                         1.133297
##    InternetService.xFiber.optic             InternetService.xNo
##                         4.776780                         1.985836
##                   OnlineSecurity                     OnlineBackup
##                         1.143833                         1.258626
##                      TechSupport              Contract.xOne.year
##                         1.252283                         1.358085
##              Contract.xTwo.year                PaperlessBilling
##                         1.390401                         1.114992
## PaymentMethod.xElectronic.check           tenure_bin.x1.2.years
##                         1.131205                         1.027896
##           tenure_bin.x5.6.years
##                         1.752778
```

```
final_model <- model_3
```

Model_3 all has significant variables, so let's just use it for prediction first

Model Evaluation using the validation data:

```
pred <- predict(final_model, type = "response", newdata = validation[,-24])
summary(pred)
```

```
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
## 0.004518 0.041437 0.186763 0.268617 0.470467 0.868907
```

```
validation$prob <- pred

# Using probability cutoff of 50%.

pred_churn <- factor(ifelse(pred >= 0.50, "Yes", "No"))
actual_churn <- factor(ifelse(validation$Churn==1,"Yes","No"))
table(actual_churn,pred_churn)
```

```
##             pred_churn
## actual_churn   No  Yes
##          No  1382  167
##          Yes  275  286
```

```
cutoff_churn <- factor(ifelse(pred >=0.50, "Yes", "No"))
conf_final <- confusionMatrix(cutoff_churn, actual_churn, positive = "Yes")
accuracy <- conf_final$overall[1]
sensitivity <- conf_final$byClass[1]
specificity <- conf_final$byClass[2]
accuracy
```

Let's find the Accuracy, Sensitivity, Specificity using 50% cutoff

```
##  Accuracy
## 0.7905213
```

```
sensitivity
```

```
## Sensitivity
##   0.5098039
```

```
specificity
```

```
## Specificity
##   0.8921885
```

```
perform_fn <- function(cutoff)
{
  predicted_churn <- factor(ifelse(pred >= cutoff, "Yes", "No"))
  conf <- confusionMatrix(predicted_churn, actual_churn, positive = "Yes")
  accuray <- conf$overall[1]
  sensitivity <- conf$byClass[1]
  specificity <- conf$byClass[2]
  out <- t(as.matrix(c(sensitivity, specificity, accuray)))
  colnames(out) <- c("sensitivity", "specificity", "accuracy")
  return(out)
}
```

```
options(repr.plot.width =8, repr.plot.height =6)
summary(pred)
```

As we can see above, when we are using a cutoff of 0.50, we are getting a good accuracy and specificity, but the sensitivity is very less. Hence, we need to find the optimal probalility cutoff which will give maximum accuracy, sensitivity and specificity

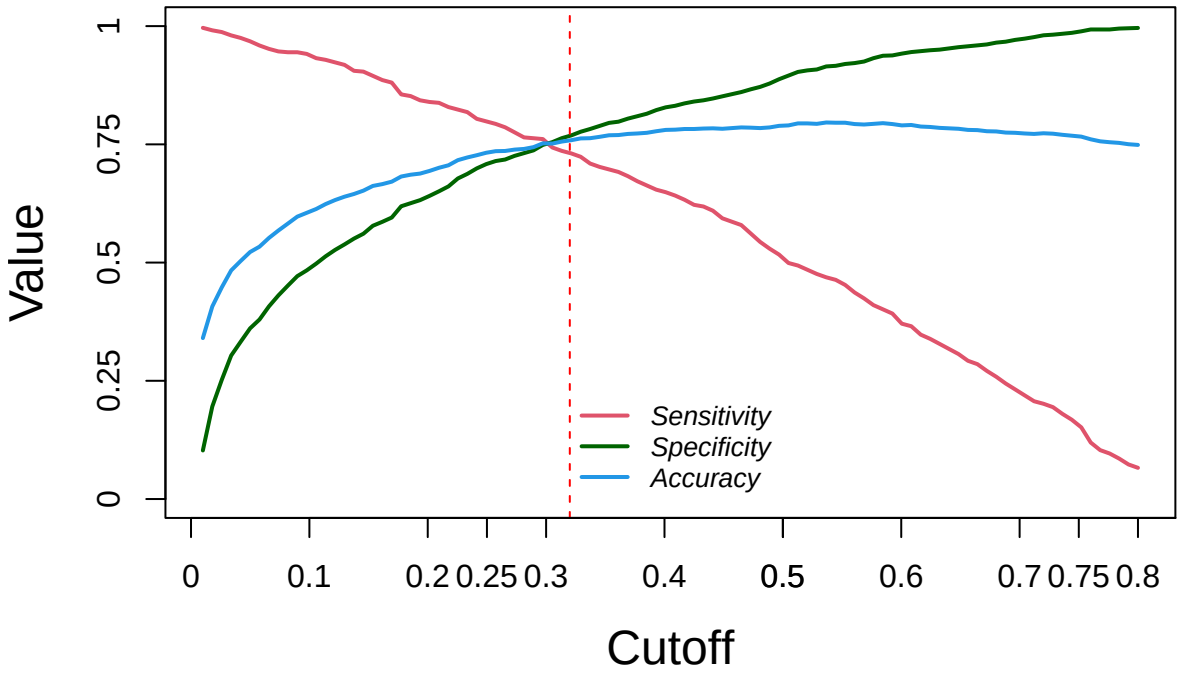
```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## 0.004518 0.041437 0.186763 0.268617 0.470467 0.868907
```

```
s = seq(0.01,0.80,length=100)
OUT = matrix(0,100,3)

for(i in 1:100)
{
  OUT[i,] = perform_fn(s[i])
}

plot(s, OUT[,1],xlab="Cutoff",ylab="Value",cex.lab=1.5,cex.axis=1.5,ylim=c(0,1),
     type="l",lwd=2,axes=FALSE,col=2)
```

```
axis(1,seq(0,1,length=5),seq(0,1,length=5),cex.lab=1.5)
axis(2,seq(0,1,length=5),seq(0,1,length=5),cex.lab=1.5)
lines(s,OUT[,2],col="darkgreen",lwd=2)
lines(s,OUT[,3],col=4,lwd=2)
box()
legend("bottom",col=c(2,"darkgreen",4,"darkred"),text.font =3,inset = 0.02,
       box.lty=0,cex = 0.8,
       lwd=c(2,2,2,2),c("Sensitivity","Specificity","Accuracy"))
abline(v = 0.32, col="red", lwd=1, lty=2)
axis(1, at = seq(0.1, 1, by = 0.1))
```




```
#cutoff <- s[which(abs(OUT[,1]-OUT[,2])<0.01)]
```

```
cutoff_churn <- factor(ifelse(pred >=0.32, "Yes", "No"))
conf_final <- confusionMatrix(cutoff_churn, actual_churn, positive = "Yes")
accuracy <- conf_final$overall[1]
sensitivity <- conf_final$byClass[1]
specificity <- conf_final$byClass[2]
accuracy
```

Let's choose a cutoff value of 0.32 for final model, where the three curves for accuracy, specificty and sensitivity meet

```
##  Accuracy
## 0.7582938
```

```
sensitivity
```

```
## Sensitivity
##   0.7308378
```

```
specificity
```

```
## Specificity
##   0.7682376
```

Logistic Regression with a cutoff probability value of 0.32 gives us better values of accuracy, sensitivity and specificity in the validation data.