ADSC1000

Statistical Data Analysis

Thompson Rivers University

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Mobile Price Classification

Submitted To:

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1.Introduction

1.1 Background

Starting one's own mobile company and giving a tough fight to big companies like Apple, Samsung etc. can be one of a great deal of an adventure. Bob an entrepreneur is keen on penetrating in the mobile phone creating and selling space. A major factor to this quest is Pricing of his new device. Mobile phones come in various models, each with different features and specifications. Our analysis helps in understanding the diverse factors influencing mobile phone prices.

1.2 Objective

Sales data collected from various mobile phone companies to specifically find out relation between features of a mobile phone and it's selling price. We as data science students have been tasked to use our knowledge to help relate mobile phone features and that of setting price of mobile phones.

1.3 Scope of Project

The project's scope encompasses in-depth feature analysis, statistical modeling in R, and leveraging a substantial dataset of 2,000 observations to classify mobile phones into distinct price ranges. The goal is to provide consumers with valuable insights for informed decision-making and contribute a systematic approach relevant to the competitive mobile device industry.

1.4 Significance and Motivation

The significance and motivation of this project is to exhibit our knowledge acquired in class on real-life situations and to proof our ability on what we have understood so far in the course under study.

2. Methodology

2.1 Data Source

Mobile price dataset is collected from Kaggle to find out relation between features of a mobile phone and its association with pricing.

Target Population: Our target population is all available mobile phones in the market.

Sample size: Mobile phones released from 2012 to 2016.

2.2 Variables and Measures

We will use the Mobile Price Classification data set which contains various variables both continues and categorical.

Feature	Description	Variable type
Battery Power	Total energy a battery can store in one time measured in mAh	Continuous
Blue	Has Bluetooth or not	Categorical
Clock speed	Speed at which microprocessor executes instructions	Continuous
Dual_sim	Has dual sim support or not	Categorical
Fc	Front Camera mega pixels	Continuous
four_g	Has 4G or not	Categorical
Int_memory	Internal Memory in Gigabytes	Continuous
m_dep	Mobile Depth in cm	Continuous
mobile_wt	Weight of mobile phone	Continuous
n_cores	Number of cores of processor	Continuous
Pc	Primary Camera mega pixels	Continuous
px_height	Pixel Resolution Height	Continuous
px_width	Pixel Resolution Width	Continuous
Ram	Random Access Memory in Megabytes	Continuous

sc_h	Screen Height of mobile in cm	Continuous
sc_w	Screen Width of mobile in cm	Continuous
talk_time	longest time that a single battery charge will last when you are	Continuous
three_g	Has 3G or not	Categorical
touch_screen	Has touch screen or not	Categorical
Wifi	Has wifi or not	Categorical

But for the purpose of our analysis, we will be focusing on these features – Battery Power ,Ram,Internal Memory,Pixel Width,Pixel Height,Four_g,Three_g

Price range was categorized into the below:

- 0 (low cost)
- 1 (medium cost)
- 2 (high cost)
- 3 (very high cost)

2.3 Data Analysis Techniques

Our data analysis techniques used were test ranging from a one-sample hypothesis test to determine the means of one major variable used in our study battery_power. A Two sample hypothesis test was also employed to verify the significant difference between battery_power and four_g networks and the difference in RAM and dual_sim. An Anova test was conducted to test the different means of our preferred variables and to check the normality of our data set a Shapiro test was conducted which proved that our data set was not normally distributed. Due to our non-normality of our data set a levene test was conducted to check how equal our homogeneity variance and our sample are. Due to violation of Anova assumptions, we performed Kruskal Wallis test. To verify the independence of the variables of our project a Chi-square test was conducted to prove whether our categorical variables were dependent or not to our Price range.

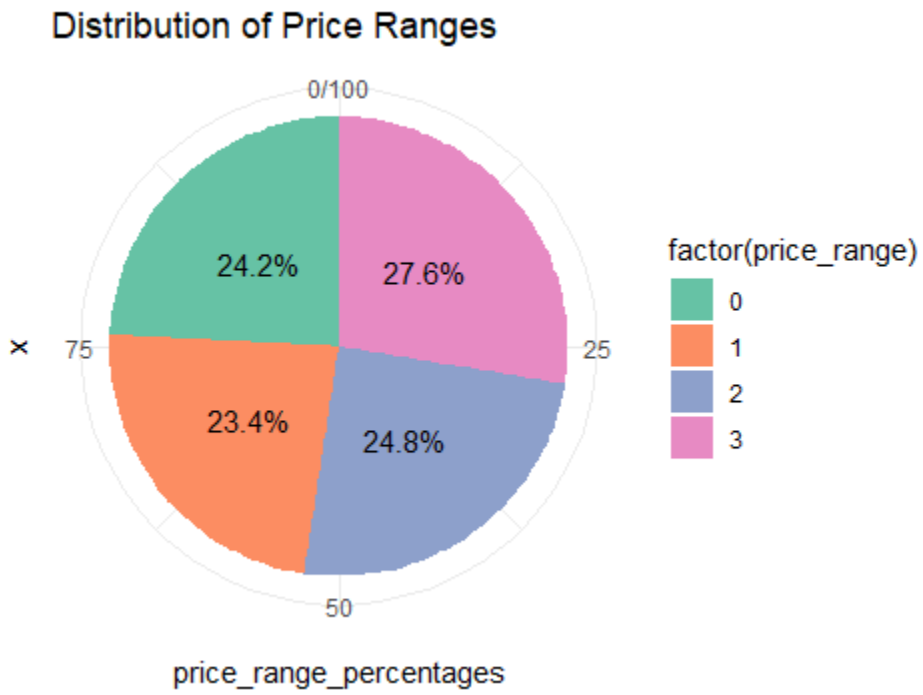
3.Exploratory Data Analysis (EDA)

3.1 Data Visualization

Visualizations, including Pie chart, Bar chart, histogram, boxplot were employed to discover trends and associations within the data.

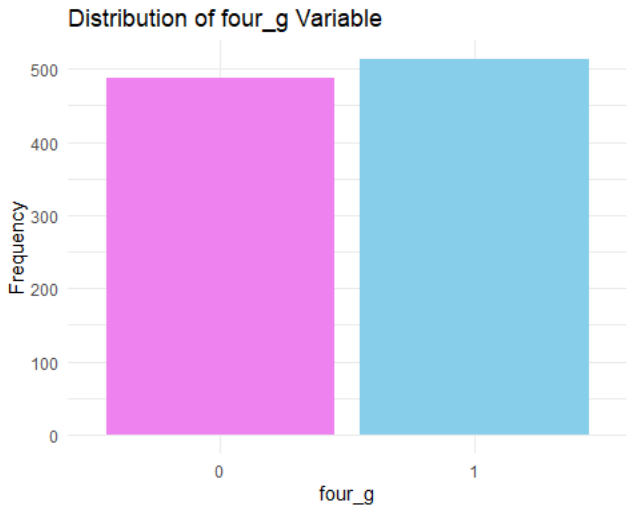
3.1.1 Categorical Variable Visuals

3.1.2 A pictorial view of the Price Range in percentage (Pie Chart)



From the visualization we see that category 3 has the most phones priced in that range. Category 0 and 2 are almost equal in terms of price range distribution in the mobile phone market. Category 1 has less pricing range terms of percentage.

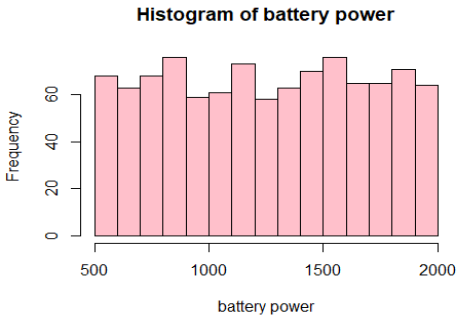
3.1.3 A pictorial view of four_g (Bar Chart)

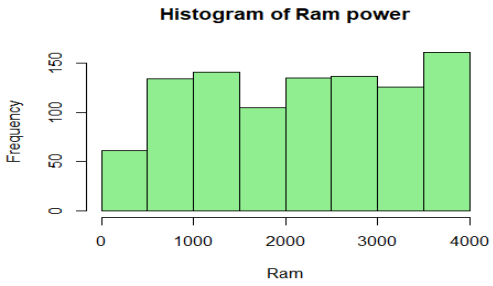


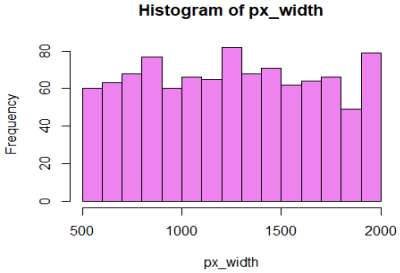
From the visualization we can state that mobiles with four_g are high in number compared to mobiles without four_g. The purple bar represents a non four_g mobile phone while the blue bar represents that of four_g.

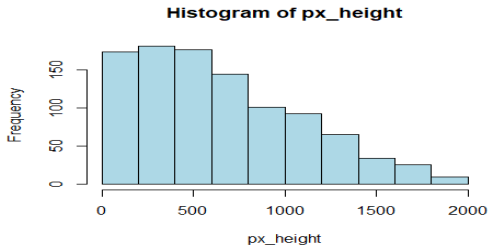
3.2 Continues Variable Visuals

3.2.1 A pictorial view of battery power, RAM, px_width and px_height (Histogram)





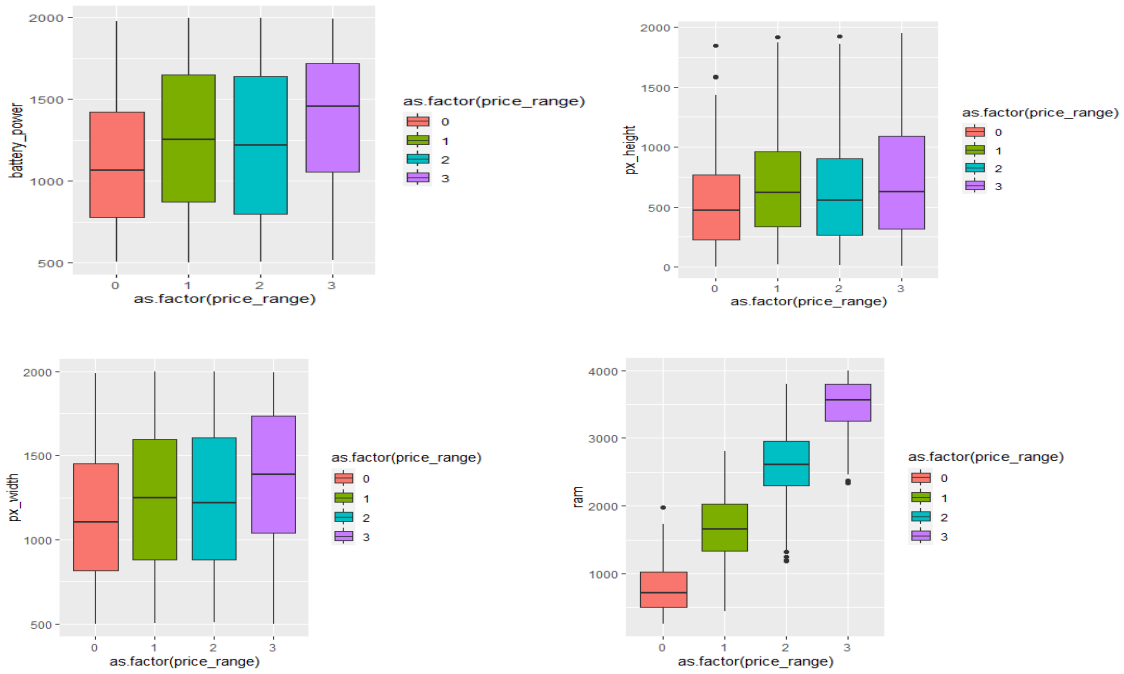




From the visualization we can see the various distributions of the variables being shown via a histogram.

PX_Height histogram is right skewed and all the other three histograms are mostly uniformly distributed

3.2.2 A pictorial view of battery power, RAM, px_width and px_height (box plot)



From the visualization we can see that the various medians are very close and also no major significant difference in the first three visuals. But for that of the fourth visual (RAM) the means are significantly different.

4. Hypothesis Tests

4.1 A one & two sample hypothesis test

Test	Null Hypothesis (H0):	Alternative Hypothesis (H1):	Result
One Sample t-test	The average battery power of mobile phones in the population is equal to or less than 1238 mAh	The average battery power of mobile phones in the population is greater than 1238 mAh.	0.1466

Welch Two Sample t-test	There is no difference in the average battery power between phones with and without 4G.	There is a significant difference in the average battery power between phones with and without 4G.	0.02489
Welch Two Sample t-test	There is no difference in the average RAM between phones with and without dual SIM	There is a significant difference in the average RAM between phones with and without dual SIM.	0.03928

From the results of one-sample t-test we can say that we don't have enough evidence to reject the null hypothesis which means the average battery power of mobile phones in the population is equal to or less than 1238 mAh

As p-values are less that 0.05 for both two samle t-test we can say that there is a significant difference in the average battery power between phones with and without 4G.and there is a significant difference in the average RAM between phones with and without dual SIM.

4.1.2 Chi-Square Test

A chi-square test results showing the independence or dependence of four_g and three_g against price range.

Null Hypothesis (H_0):	Alternative Hypothesis (H_a):	P-value
There is no significant association between the 'Three_G' variable and 'Price_Range' in the population.	There is a significant association between the 'Three_G' variable and 'Price_Range' in the population.	0.2994
There is no significant association between the 'Four_G' variable and 'Price_Range' in the population.	There is a significant association between the 'Four_G' variable and 'Price_Range' in the population.	0.1713

From the results of one-sample t-test we can say that we don't have enough evidence to reject the null hypothesis which states that there is no significant association between the 'Three_G' variable and 'Price_Range' in the population and there is no significant association between the 'Four_G' variable and 'Price_Range' in the population.

4.1.3 Anova hypothesis test

Higher F-Value suggests larger difference between group means and is more significant**.**Lower p-value indicates higher level of significance**.**

Feature	F-Value	P-Value
RAM	5568	<2e-16
Battery Power	48.42	6.23e-12
Pixel width	25.01	6.74e-07
Pixel height	16.2	6.12e-05
Internal memory	3.268	0.071
Primary Camera	2.24	0.135

Ram, Battery power, Pixel width, Pixel Height have average mean difference across the price range,where as Internal memory with p-value of 0.071 is marginally significant. Primary camera has no significance as p-value is greater than 0.05.

Here Ram has Higher F-Value and Lower P-Value which says there is strong association between independent variable (price range) and the dependent variable (RAM).

4.1.4. Shapiro-Wilk test and Levene's test

We conducted Shapiro-Wilk test to assess the normality of a distribution. As the p-value is less than 0.005, we concluded that the data is not normally distributed. We also performed Levene's test to assess the homogeneity of variances across different groups. The p-value from Levene's test was less than the 0.005, suggesting that there are significant differences in variances across groups.

4.1.5 Kruskal-Wallis Test

As our mobile data is not normally distributed and the variances are significantly different across groups, we consider using a non-parametric alternative to ANOVA, such as the Kruskal-Wallis test.

Feature	P-Value
RAM	2.2e-16
Battery Power	1.949e-11
Pixel width	1.808e-06
Pixel height	0.0002366
Internal memory	0.1356
Primary Camera	0.4012

There are significant differences in battery power, pixel height, RAM, and pixel width across different price ranges.

There are no significant differences in internal memory and PC across different price ranges. There are no significant differences in internal memory and PC across.

There are significant differences in battery power, pixel height, RAM, and pixel width across different price ranges. There are no significant differences in internal memory and PC across different price ranges.

5. Results and Findings

Higher RAM, larger battery power, and better camera specifications could contribute to higher price ranges. Whereas primary camera and internal memory may not be strong indicators of differences in mobile phone prices. The network type alone may not be a strong predictor of price range. The dual SIM phones may have different RAM specifications compared to single SIM phones.4G capability may be a factor influencing the battery power specifications of mobile phones.

6.Conclusion

This project provides a useful information for both consumers and the mobile industry by helping people make informed decisions about buying phones. It systematically analyzes key features to understand how factors like RAM and camera quality influence the price, making it easier for everyone involved to navigate the dynamic mobile market.

7.Appendix

7.1 References

https://www.kaggle.com/datasets/iabhishekofficial/mobile-price-classification

Team Work:

We collaborated together to interpret the tests that we can perform using Mobile Price dataset where we divided the work of analysis required to draw the statistics and documentation equally.

7.2 Code

Appendix

Statistics Final project

2023-11-27

```
mobile_dataset<-read.csv("MobilePrice.csv",header = TRUE)
names(mobile_dataset)
```

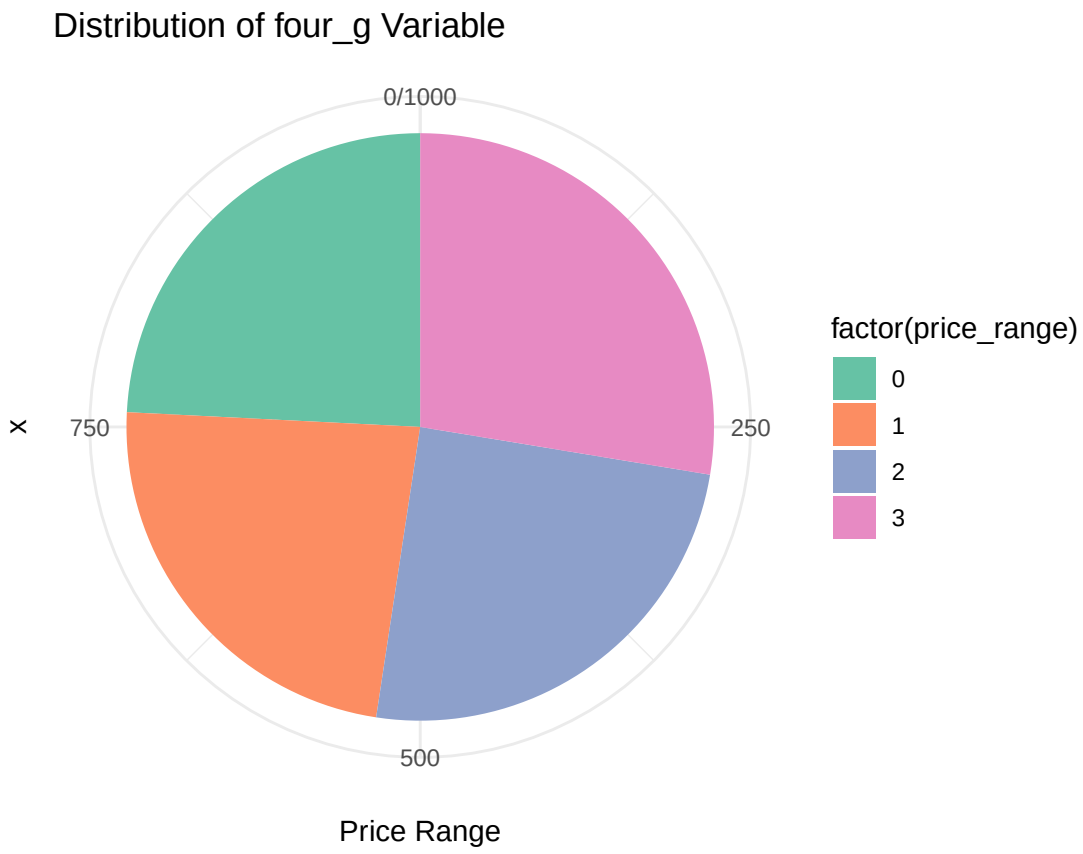
```
##  [1] "battery_power" "blue"          "clock_speed"   "dual_sim"
##  [5] "fc"            "four_g"        "int_memory"    "m_dep"
##  [9] "mobile_wt"     "n_cores"       "pc"            "px_height"
## [13] "px_width"      "ram"           "sc_h"          "sc_w"
## [17] "talk_time"     "three_g"       "touch_screen"  "wifi"
## [21] "price_range"
```

Pie Chart

```
library(ggplot2)
```

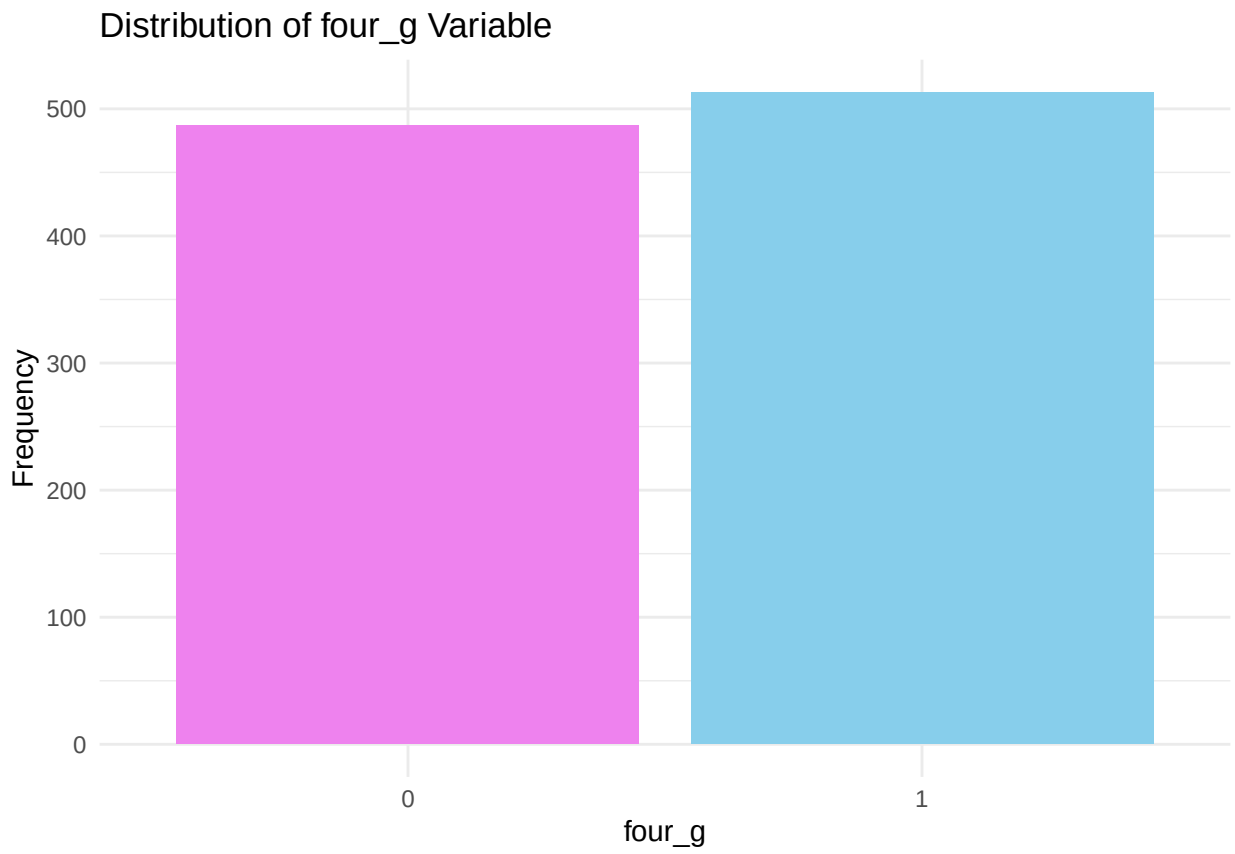
```
## Warning: package 'ggplot2' was built under R version 4.3.2
```

```
ggplot(mobile_dataset, aes(x = "", fill = factor(price_range))) +
  geom_bar(width = 1, stat = "count") +
  coord_polar("y") +
  labs(title = "Distribution of Price Ranges") +
  theme_void() +
  scale_fill_manual(values = c("#66c2a5", "#fc8d62", "#8da0cb", "#e78ac3"))+
  labs(title = "Distribution of four_g Variable") +
  ylab("Price Range") +
  theme_minimal()
```



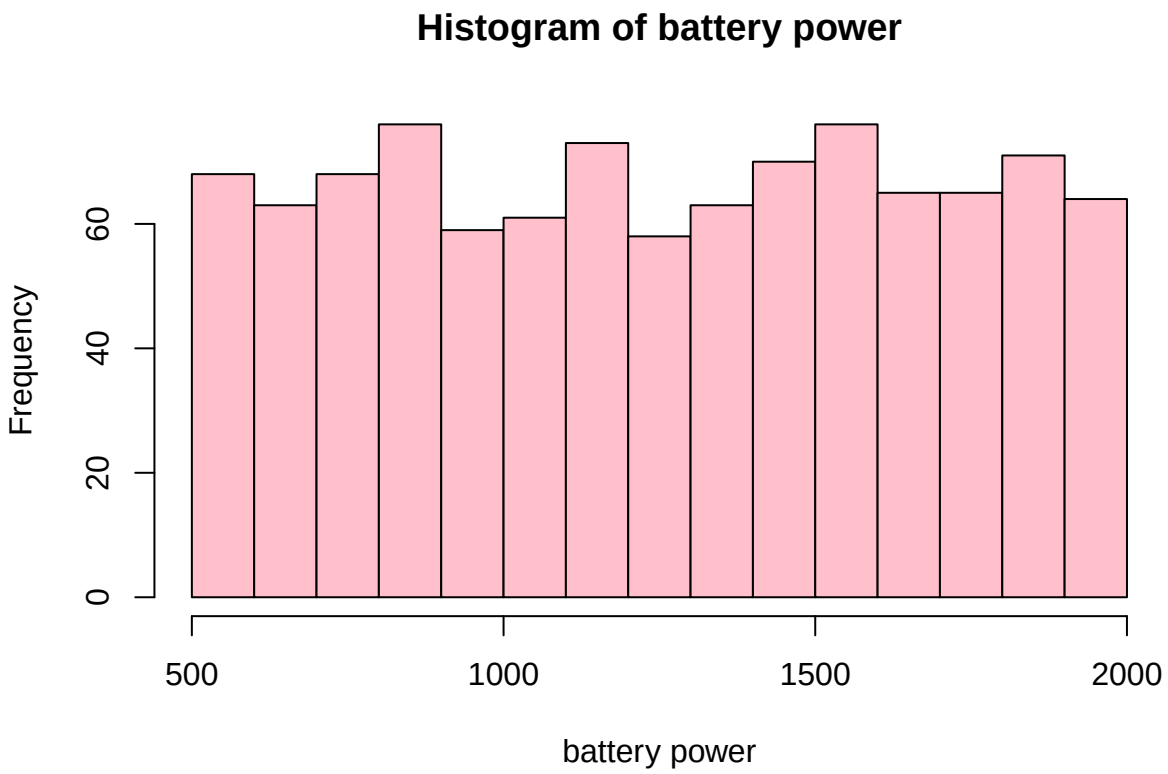
BAR CHART:

```
ggplot(mobile_dataset, aes(x = factor(four_g))) +
  geom_bar(fill = c("violet", "skyblue")) +  # Set colors for 1 and 0
  labs(title = "Distribution of four_g Variable") +
  xlab("four_g") +
  ylab("Frequency") +
  theme_minimal()
```

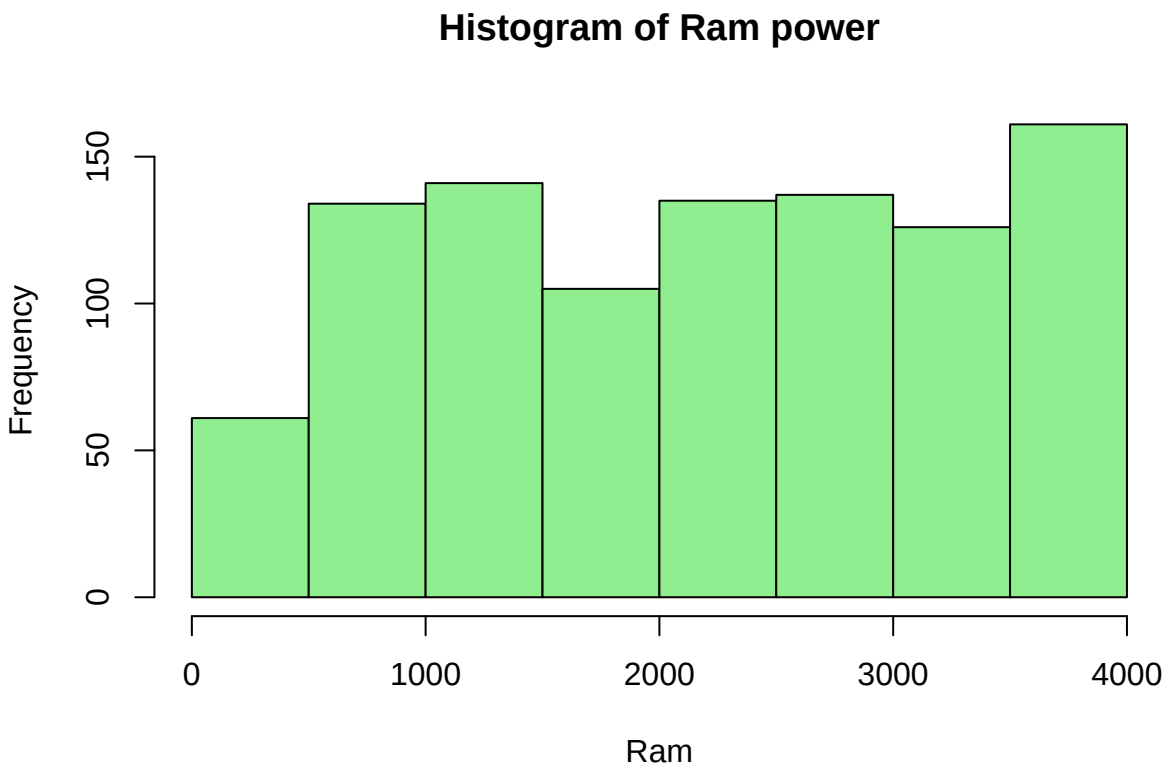


Histogram:

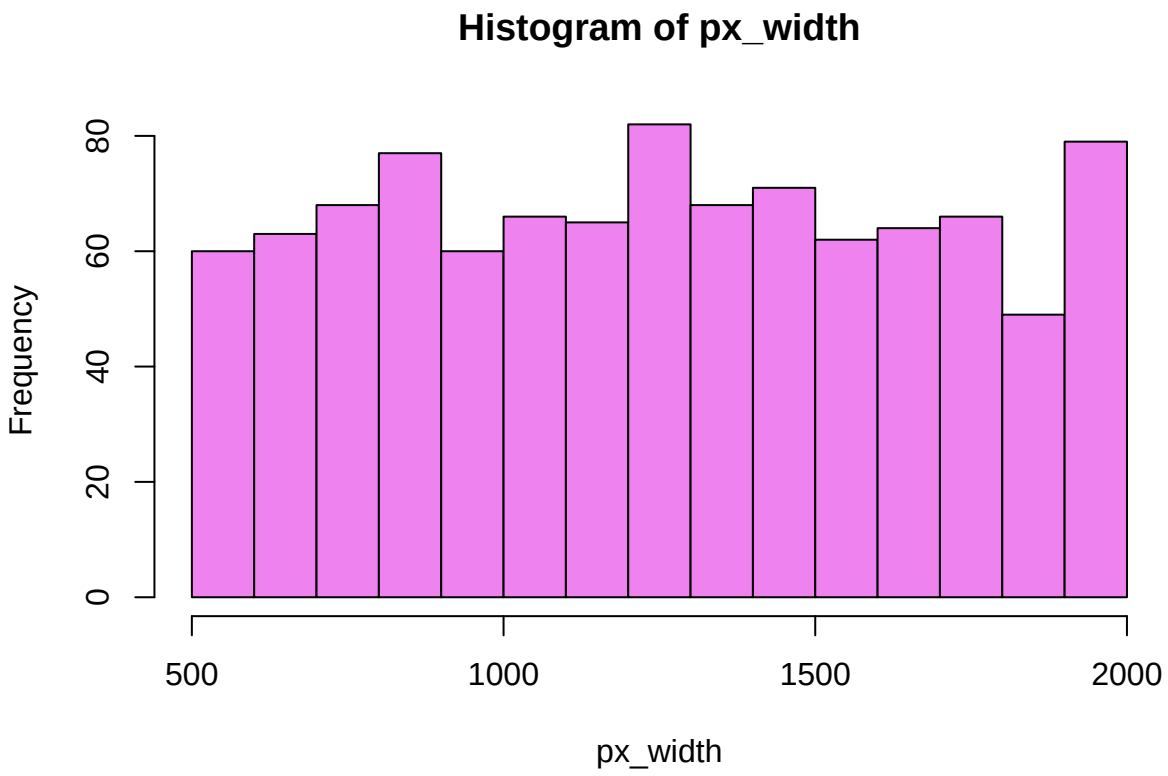
```
hist(mobile_dataset$battery_power,main = "Histogram of battery power",
     xlab = "battery power",col ="pink")
```



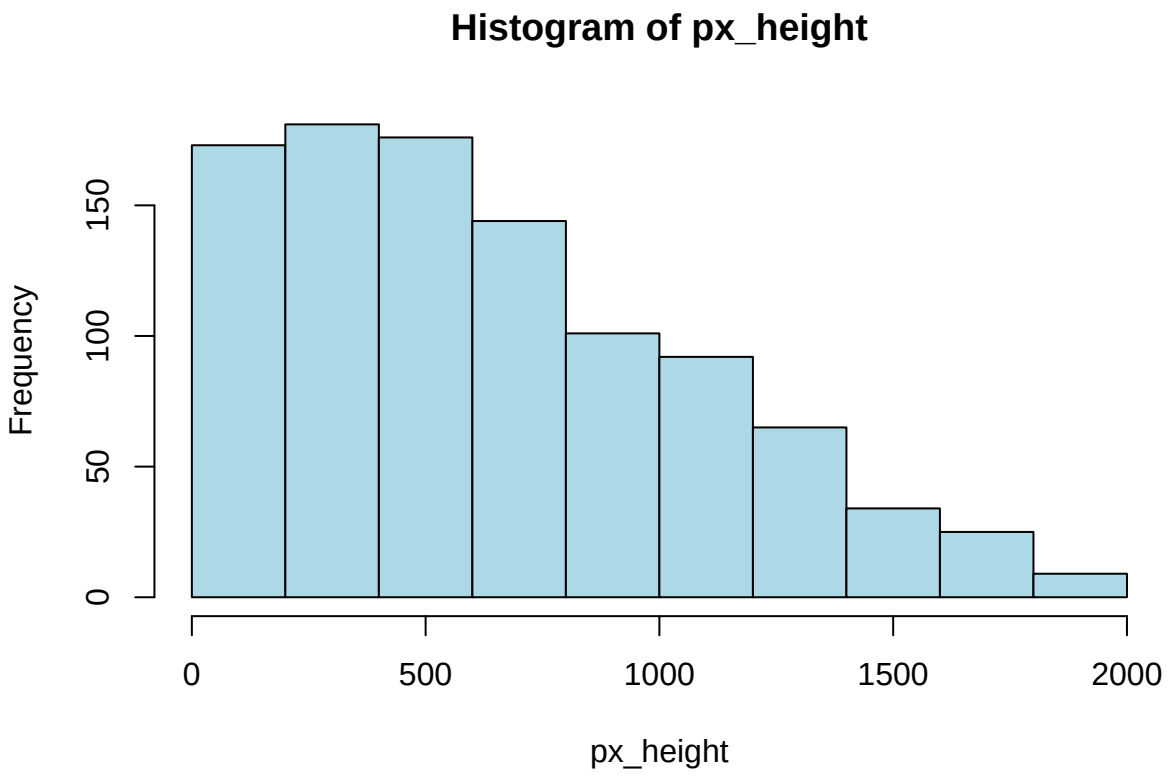

```
hist(mobile_dataset$ram,main = "Histogram of Ram power",xlab = "Ram",
     col="lightgreen")
```




```
hist(mobile_dataset$px_width,main = "Histogram of px_width",
     xlab = "px_width",col="violet")
```

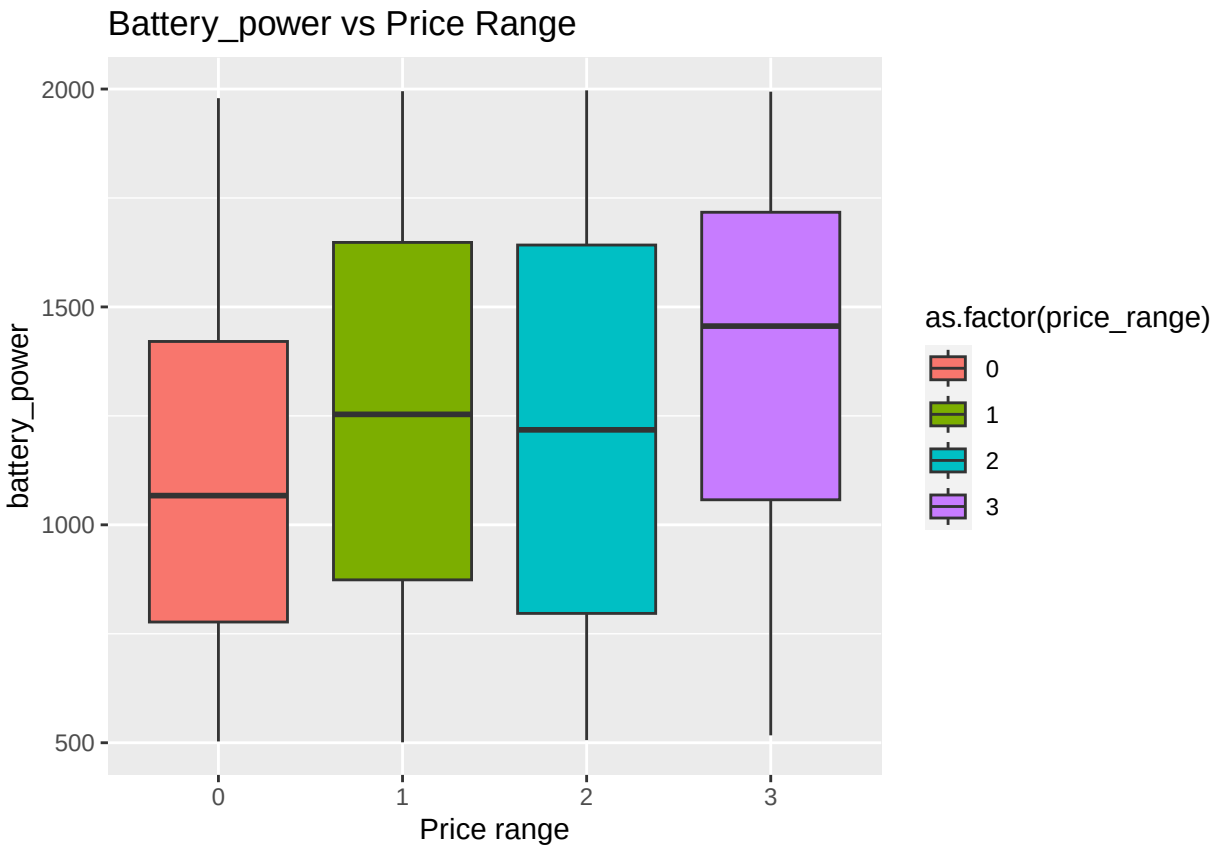



```
hist(mobile_dataset$px_height,main = "Histogram of px_height",
     xlab = "px_height",col="lightblue")
```

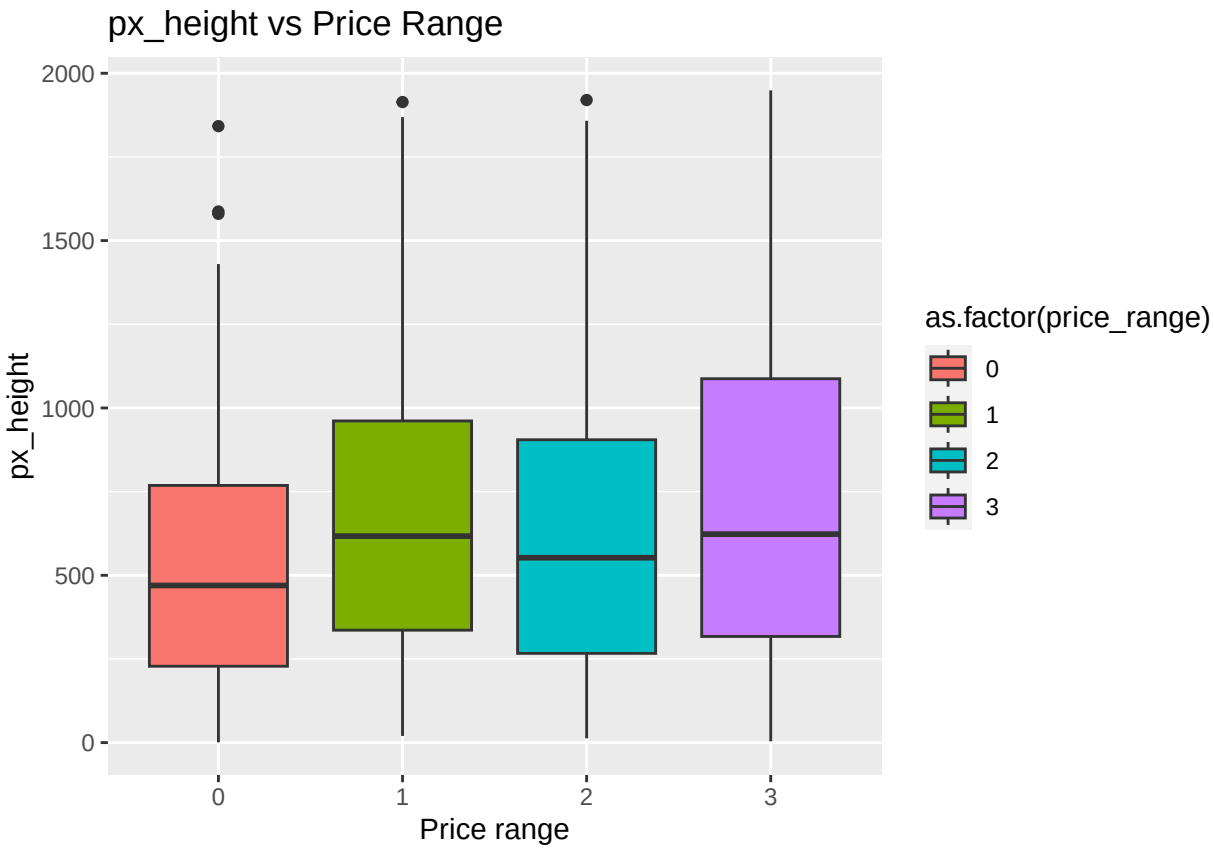


boxplot

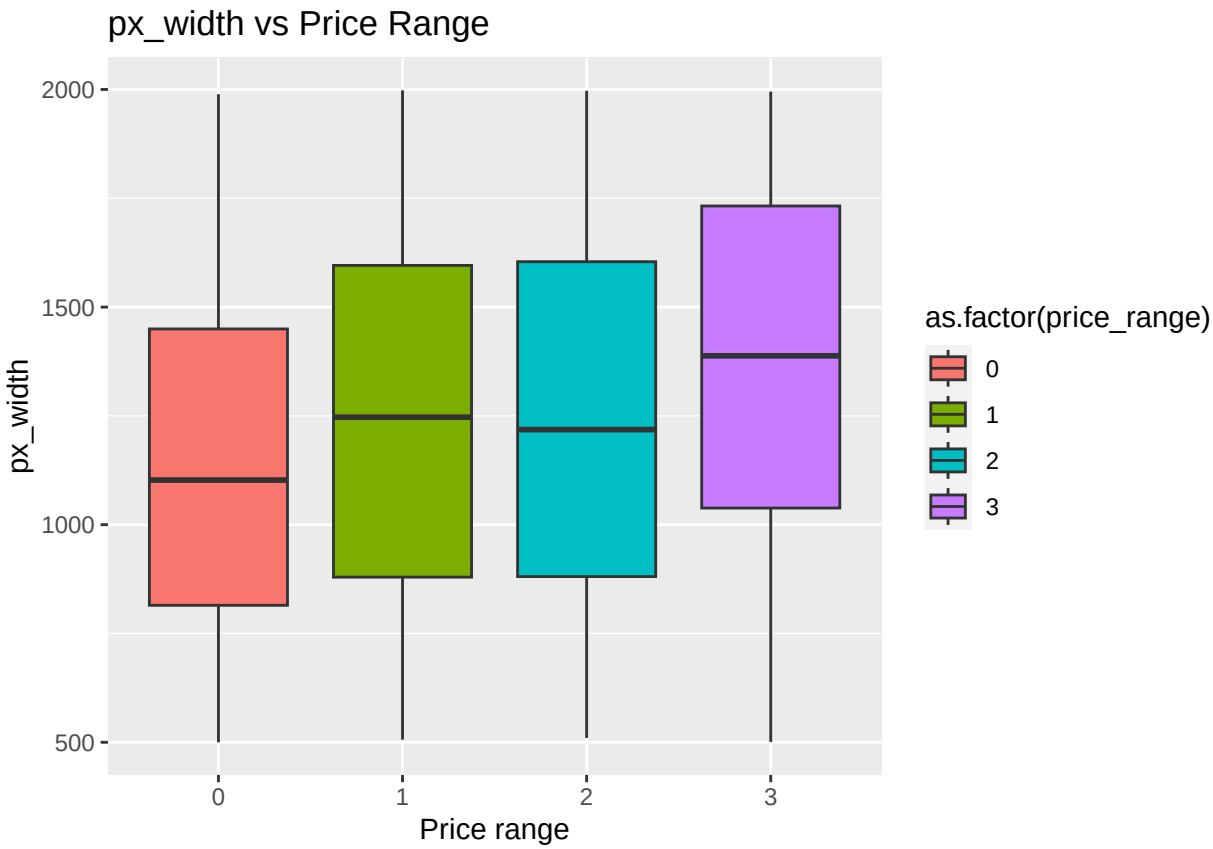
```
library(ggplot2)
par(mfrow = c(2, 2))
ggplot(mobile_dataset,aes(x=as.factor(price_range), y=battery_power,
                          fill=as.factor(price_range))) + geom_boxplot()+ labs(
    x = "Price range",
    y = "battery_power",
    title = "Battery_power vs Price Range"
  )
```



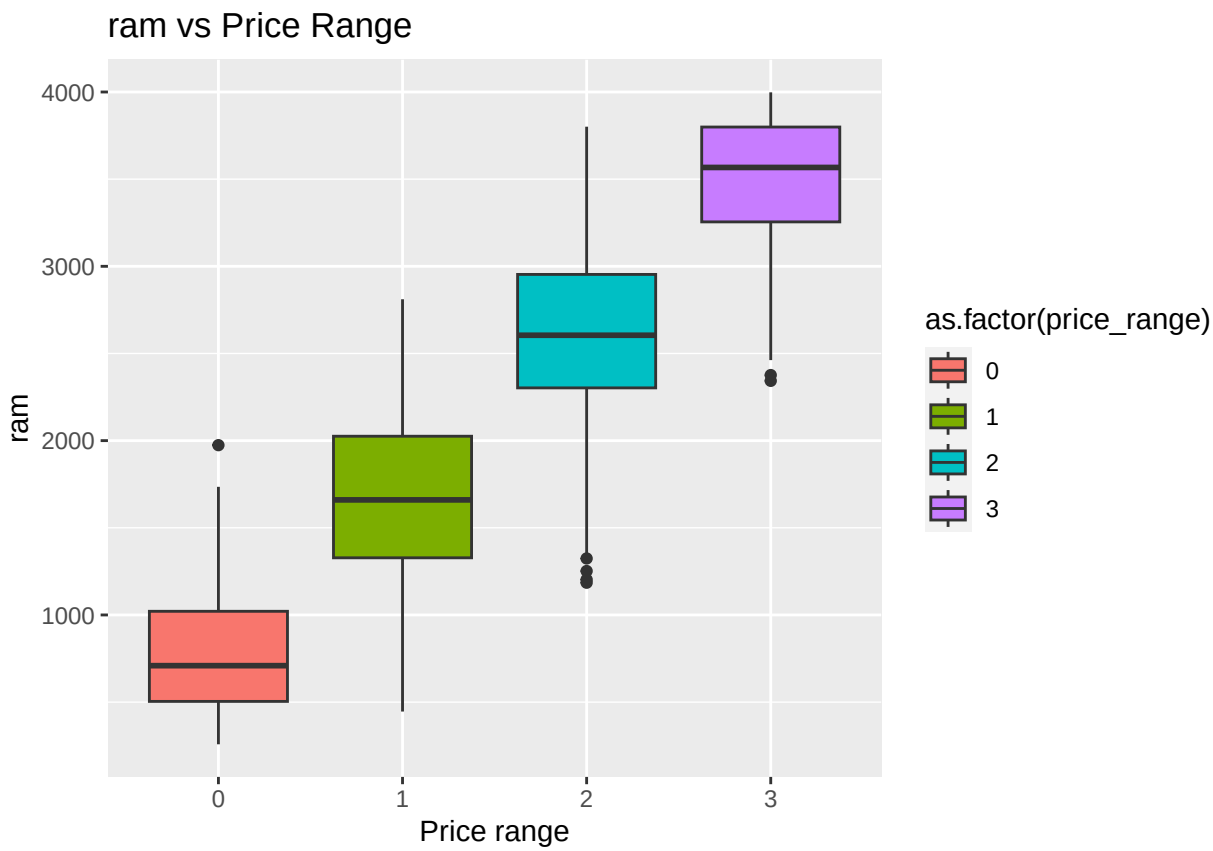

```
ggplot(mobile_dataset,aes(x=as.factor(price_range), y=px_height,
                          fill=as.factor(price_range))) + geom_boxplot()+ labs(
    x = "Price range",
    y = "px_height",
    title = "px_height vs Price Range"
  )
```



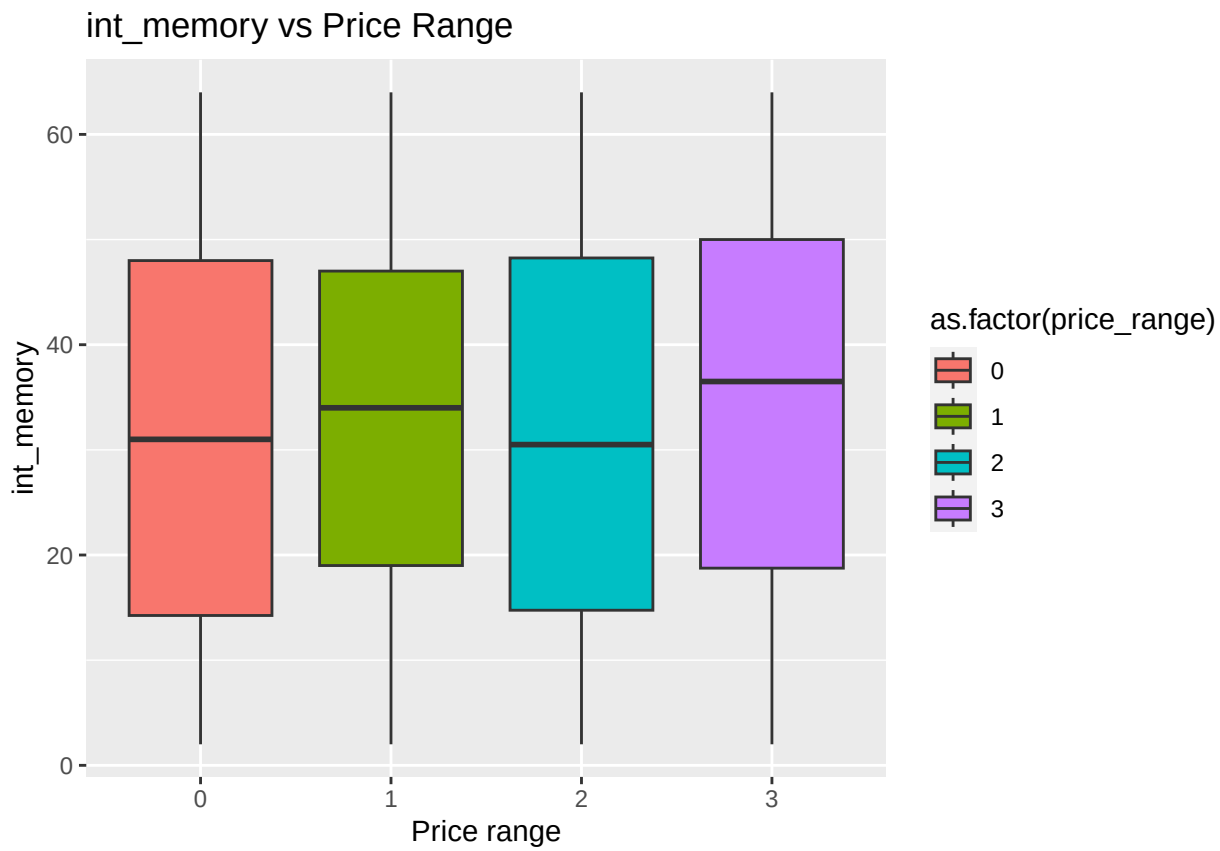

```
ggplot(mobile_dataset,aes(x=as.factor(price_range), y=px_width,
                          fill=as.factor(price_range))) + geom_boxplot()+labs(
    x = "Price range",
    y = "px_width",
    title = "px_width vs Price Range"
  )
```



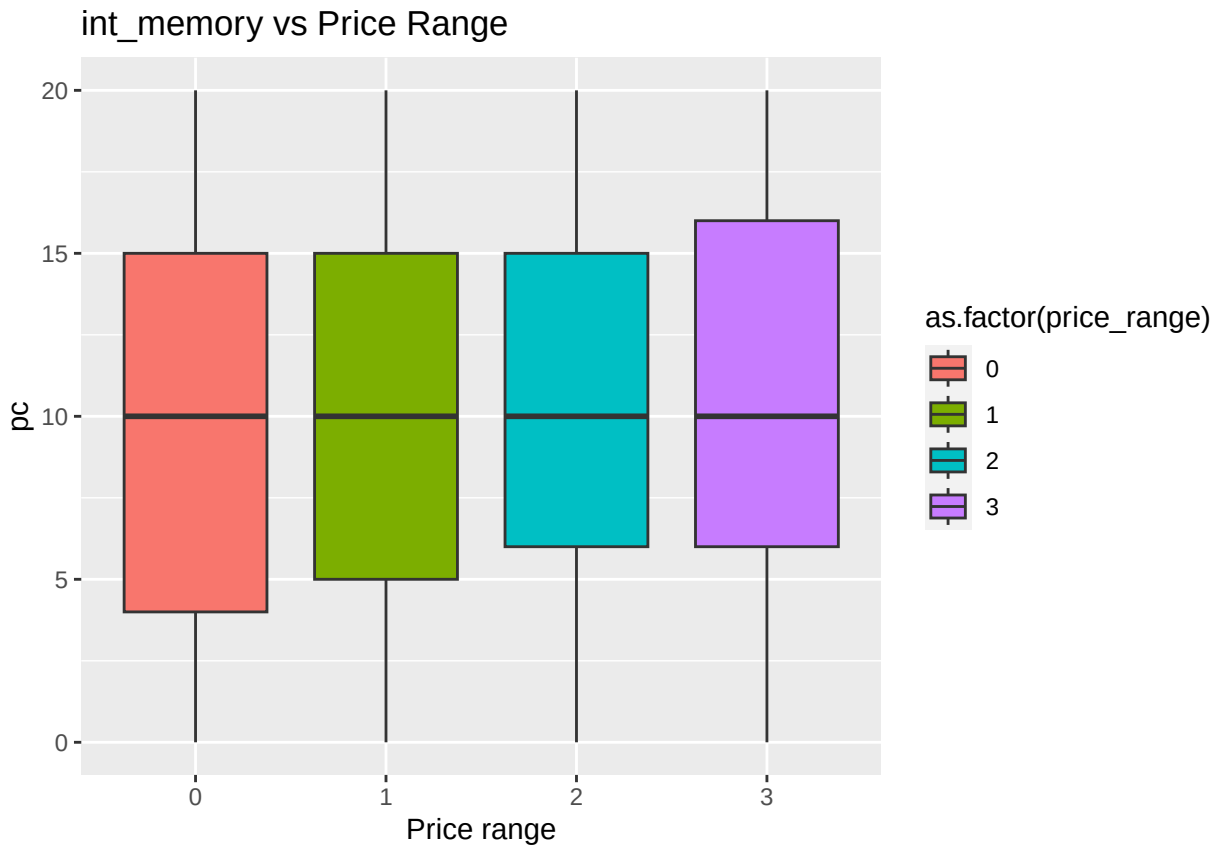

```
ggplot(mobile_dataset,aes(x=as.factor(price_range), y=ram,
                          fill=as.factor(price_range))) + geom_boxplot()+labs(
    x = "Price range",
    y = "ram",
    title = "ram vs Price Range"
  )
```




```
ggplot(mobile_dataset,aes(x=as.factor(price_range), y=int_memory,
                          fill=as.factor(price_range))) + geom_boxplot()+labs(
    x = "Price range",
    y = "int_memory",
    title = "int_memory vs Price Range"
  )
```




```
ggplot(mobile_dataset,aes(x=as.factor(price_range), y=pc,
                          fill=as.factor(price_range))) + geom_boxplot()+labs(
    x = "Price range",
    y = "pc",
    title = "int_memory vs Price Range"
  )
```




```
#We can see a huge difference in battery power between the price_range 0 and
#the price_range 3 but not so much between the 1 and 2.
```

Hypothesis testing one-sample hypothesis test: #Average battery power

```
battery_power_mean <- 1238 # average battery_power
t.test(mobile_dataset$battery_power,mu=1238,alternative = "less",
       conf.level = 0.95)
```

```
##
##  One Sample t-test
##
## data:  mobile_dataset$battery_power
## t = 1.0519, df = 999, p-value = 0.8534
## alternative hypothesis: true mean is less than 1238
## 95 percent confidence interval:
##      -Inf 1275.193
## sample estimates:
## mean of x
##  1252.499
```

```
#Do not reject as p value is greater than 0.05
#It means that we dont have enough evidence that the average battery power
#is less than 1238
```

Two sample hypothesis test: Null Hypothesis (H0): There is no difference in the average battery power between phones with and without 4G. Alternative Hypothesis (H1): There is a significant difference in the average battery power between phones with and without 4G.

```
battery_power_4g <- mobile_dataset$battery_power[mobile_dataset$four_g == 1]
battery_power_no_4g <- mobile_dataset$battery_power[mobile_dataset$four_g == 0]
t_test_result <- t.test(battery_power_4g, battery_power_no_4g)
t_test_result
```

```
##
##  Welch Two Sample t-test
##
## data:  battery_power_4g and battery_power_no_4g
## t = 2.2464, df = 996.61, p-value = 0.02489
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##    7.815816 115.787844
## sample estimates:
## mean of x mean of y
##  1282.596  1220.795
```

```
#Reject the hypothesis as there is a significant difference in average battery
# power between phones with and without 4G.
```

Null Hypothesis (H0): There is no difference in the average RAM between phones with and without dual SIM. Alternative Hypothesis (H1): There is a significant difference in the average RAM between phones with and without dual SIM.

```
ram_dual_sim <- mobile_dataset$ram[mobile_dataset$dual_sim == 1]
ram_no_dual_sim <- mobile_dataset$ram[mobile_dataset$dual_sim == 0]
t_test_result <- t.test(ram_dual_sim, ram_no_dual_sim)
print(t_test_result)
```

```
##
##  Welch Two Sample t-test
##
## data:  ram_dual_sim and ram_no_dual_sim
## t = 2.064, df = 995.8, p-value = 0.03928
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##    7.147532 283.120073
## sample estimates:
## mean of x mean of y
##  2254.109  2108.975
```

```
#reject the hypothesis as there is a significant difference in average ram
# between phones with and without dual sim.
```

ANOVA:

```r
anova_result <- aov(battery_power ~ price_range, data = mobile_dataset)
summary(anova_result)
```

```
##              Df    Sum Sq Mean Sq F value   Pr(>F)
## price_range   1   8782174 8782174   48.42 6.23e-12 ***
## Residuals   998 181023354  181386
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova_result1 <- aov(px_height ~ price_range, data = mobile_dataset)
summary(anova_result1)
```

```
##              Df    Sum Sq Mean Sq F value   Pr(>F)
## price_range   1   3127063 3127063    16.2 6.12e-05 ***
## Residuals   998 192593648  192980
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova_result2 <- aov(ram ~ price_range, data = mobile_dataset)
summary(anova_result2)
```

```
##              Df    Sum Sq   Mean Sq F value Pr(>F)
## price_range   1 1.050e+09 1.050e+09    5568 <2e-16 ***
## Residuals   998 1.882e+08 1.886e+05
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova_result3 <- aov(px_width ~ price_range, data = mobile_dataset)
summary(anova_result3)
```

```
##              Df    Sum Sq Mean Sq F value   Pr(>F)
## price_range   1   4454605 4454605   25.01 6.74e-07 ***
## Residuals   998 177760259  178116
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova_result4 <- aov(int_memory ~ price_range, data = mobile_dataset)
summary(anova_result4)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## price_range   1   1065  1064.6   3.268  0.071 .
## Residuals   998 325156   325.8
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova_result5 <- aov(pc ~ price_range, data = mobile_dataset)
summary(anova_result5)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## price_range   1     82   82.00    2.24  0.135
## Residuals   998  36534   36.61
```

CHI-SQUARE:

```
chi_squared_result_3g <- chisq.test(table(mobile_dataset$three_g,
                                          mobile_dataset$price_range))
chi_squared_result_3g
```

```
##
##  Pearson's Chi-squared test
##
## data:  table(mobile_dataset$three_g, mobile_dataset$price_range)
## X-squared = 3.67, df = 3, p-value = 0.2994
```

```
chi_squared_result_sim <- chisq.test(table(mobile_dataset$four_g,
                                           mobile_dataset$price_range))
chi_squared_result_sim
```

```
##
##  Pearson's Chi-squared test
##
## data:  table(mobile_dataset$four_g, mobile_dataset$price_range)
## X-squared = 5.007, df = 3, p-value = 0.1713
```

```
#If the p-value is less than the significance level (0.05), we reject the null
#hypothesis, suggesting evidence of an association.
```

shapiro test

```
shapiro_test_result <- shapiro.test(mobile_dataset$ram)
shapiro_test_result
```

```
##
##  Shapiro-Wilk normality test
##
## data:  mobile_dataset$ram
## W = 0.946, p-value < 2.2e-16
```

```
#The data is not normally distributed.
```

Levene's test for homogeneity of variances

```
if (!requireNamespace("car", quietly = TRUE)) {
  install.packages("car")
}
library(car)
```

```
## Warning: package 'car' was built under R version 4.3.2
```

```
## Loading required package: carData
```

```
## Warning: package 'carData' was built under R version 4.3.2
```

```
levene_test_result <- leveneTest(mobile_dataset$battery_power,
                                 group = mobile_dataset$price_range)
```

```
## Warning in leveneTest.default(mobile_dataset$battery_power, group =
## mobile_dataset$price_range): mobile_dataset$price_range coerced to factor.
```

```
levene_test_result
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value    Pr(>F)
## group   3  6.2575 0.0003296 ***
##       996
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#Variances are significantly different across groups.
```

Kruskal-Wallis test(alternative to Anova test)

```
#install.packages("coin")
library(coin)
```

```
## Warning: package 'coin' was built under R version 4.3.2
```

```
## Loading required package: survival
```

```
kw_result1 <- kruskal.test(battery_power ~ price_range, data = mobile_dataset)
kw_result2 <- kruskal.test(px_height ~ price_range, data = mobile_dataset)
kw_result3 <- kruskal.test(ram ~ price_range, data = mobile_dataset)
kw_result4 <- kruskal.test(px_width ~ price_range, data = mobile_dataset)
kw_result5 <- kruskal.test(int_memory ~ price_range, data = mobile_dataset)
kw_result6 <- kruskal.test(pc ~ price_range, data = mobile_dataset)

print(kw_result1)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  battery_power by price_range
## Kruskal-Wallis chi-squared = 52.875, df = 3, p-value = 1.949e-11
```

```
print(kw_result2)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  px_height by price_range
## Kruskal-Wallis chi-squared = 19.303, df = 3, p-value = 0.0002366
```

```r
print(kw_result3)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  ram by price_range
## Kruskal-Wallis chi-squared = 843.2, df = 3, p-value < 2.2e-16
```

```r
print(kw_result4)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  px_width by price_range
## Kruskal-Wallis chi-squared = 29.443, df = 3, p-value = 1.808e-06
```

```r
print(kw_result5)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  int_memory by price_range
## Kruskal-Wallis chi-squared = 5.552, df = 3, p-value = 0.1356
```

```r
print(kw_result6)
```

```
##
##  Kruskal-Wallis rank sum test
##
## data:  pc by price_range
## Kruskal-Wallis chi-squared = 2.9383, df = 3, p-value = 0.4012
```