Assignment 2 - CBD3334 - Data Mining and Analysis

Topic: Mobile Price prediction using phone Specifications - Regression

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Importing packages

- all the required packages are imported starting from the loading the dataset in the form csv till the validation of model performance and plotting the values using visualization tools

In [1]:
```
from pandas import read_csv
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from tabulate import tabulate
import numpy as np
from sklearn.preprocessing import LabelEncoder
import scipy.stats as stats
from sklearn.linear_model import LinearRegression, Ridge, Lasso
from sklearn.ensemble import RandomForestRegressor,GradientBoostingRegressor
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
from sklearn.pipeline import Pipeline
from sklearn.compose import ColumnTransformer
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.impute import SimpleImputer
from sklearn.model_selection import train_test_split
import hvplot.pandas
import plotly.express as px
from sklearn.model_selection import GridSearchCV, RandomizedSearchCV
from sklearn.feature_selection import SelectKBest, f_regression
```

In [54]:
```
#creation of pandas dataframe and defining the read_csv function to load the data
df = read_csv(r'ndtv_data_final.csv')
```

In [3]:
```
df.head()
```

Out[3]:

	Unnamed: 0	Name	Brand	Model	Battery capacity (mAh)	Screen size (inches)	Touchscreen	Resolution x	Resolution y	Processor	...	Rear camera	Front camera	Operating system	Wi-Fi	Bluetooth	GPS	Number of SIMs	3G	4G/ LTE	Price
0	0	OnePlus 7T Pro McLaren Edition	OnePlus	7T Pro McLaren Edition	4085	6.67	Yes	1440	3120	8	...	48.0	16.0	Android	Yes	Yes	Yes	2	Yes	Yes	58998
1	1	Realme X2 Pro	Realme	X2 Pro	4000	6.50	Yes	1080	2400	8	...	64.0	16.0	Android	Yes	Yes	Yes	2	Yes	Yes	27999
2	2	iPhone 11 Pro Max	Apple	iPhone 11 Pro Max	3969	6.50	Yes	1242	2688	6	...	12.0	12.0	iOS	Yes	Yes	Yes	2	Yes	Yes	106900
3	3	iPhone 11	Apple	iPhone 11	3110	6.10	Yes	828	1792	6	...	12.0	12.0	iOS	Yes	Yes	Yes	2	Yes	Yes	62900
4	4	LG G8X ThinQ	LG	G8X ThinQ	4000	6.40	Yes	1080	2340	8	...	12.0	32.0	Android	Yes	Yes	Yes	1	No	No	49990

5 rows × 22 columns

Dataset Understanding:

- Name - Name of the mobile phone
- Brand - The Brand name of the particular mobile phone
- Model - Model name specifces the version of the particular mobile phone (eg: iphone13 has mini,pro,promax as model names)
- Battery - Defines the battey capacity in milli Amphere (hour)
- Screen size - diagnoal measurement of the screen in inches
- Resolution x and y - are the pixel values of respective axes
- RAM - processing memory is specifiedi n MegaBytes
- Internal Storage - storage size of the phone in GigaBytes
- Rear and Front Camera - pixel capturing ability of the phone usin camera lens in MegaPixels
- OS - The operating system of the phone
- Number of sims - total number of sim accomodated in the phone
- processor number - total number of physical and virutal processor
- Feature presence
  - Bluetooh
  - WiFi
  - 3G and 4G
  - GPS
  - Touch screen
- Price - Target variable

In [4]:
```
df.shape
```

Out[4]: (1359, 22)

In [5]:
```
df.drop(columns=['Unnamed: 0'], inplace=True) # Index column
```

In [6]:
```
df.shape
```

Out[6]: (1359, 21)

Exploratory Data Analysis

In [7]:
```
class EDABasic:
    def __init__(self, df, numcols, catcols):
        self.df = df
        self.numcols = numcols
        self.catcols = catcols
        self.basicEDA()

    def basicEDA(self):
        '''
            function: basicEDA -> This function is used for the basic EDA of data frame such as shape, statstic summary
            arg: None
            return: None
        '''
        # checking the shape of the data frame
        shape = self.df.shape
        print("SHAPE OF DATAFRAME:")
        print('Columns = {}'.format(shape[0]))
        print('Rows = {}\n\n'.format(shape[1]))

        # cheking the missing values
        nullValues = self.df.isna().sum()
        noNull = 'No Null values' if nullValues.sum == 0 else nullValues
        print('Checking the missing values:\n')
        print('Missing values:\n{}\n\n'.format(noNull))

        # checking the duplicates
        duplicates = self.df.duplicated().sum()
        noduplicates = 'No Duplicat values' if duplicates == 0 else duplicates
        print('Checking the Duplicate values:')
        print('Duplicate values = {}\n\n'.format(noduplicates))

        # statstic summary of data frame
        print('The static summary: ')
        des = self.df.describe().T.reset_index()
        des.rename({'Index': 'Stats'}, inplace=True)
        dasData = des.to_dict(orient='list')
        table = tabulate(dasData, headers='keys', tablefmt='github', numalign='right') # tabulate converts data into table format
        print(table, '\n\n')

        # information of the data set
        print('The information: ')
        print(self.df.info(),'\n\n')

    def colPrice(self):
        '''
            function: colPrice -> shows the distribution of price in against other numaric columns in data frame using line graph
            arg: df (pandas.core.frame.DataFrame) -> data frame
            return: None
        '''
```

```python
        numlist = self.numcols.columns.tolist()
        plt.figure(figsize=(5, 5))

        for column in range(0, len(numlist)-1, 2):
            fig, axes = plt.subplots(1, 2, figsize=(10, 5))
            sns.lineplot(x=self.numcols[numlist[column]], y=self.df['Price'], data=self.numcols, ax=axes[0])
            axes[0].set_title(numlist[column])

            sns.lineplot(x=self.numcols[numlist[column + 1]], y=self.df['Price'], data=self.numcols, ax=axes[1])
            axes[1].set_title(numlist[column + 1])

            plt.show()

    def calculateOutlires(self):
        '''
            function: calculateOutlires -> calculates the outlires in each numarical columns using IQR method
            arg: df (pandas.core.frame.DataFrame) -> data frame
            return: None
        '''
        numlist = self.numcols.columns.tolist()
        dataList = [['Name', 'q1', 'q3', 'IQR', 'Count']]
        for column in range(len(numlist)-1):
            q1 = self.numcols[numlist[column]].quantile(0.25)
            q3 = self.numcols[numlist[column]].quantile(0.75)

            IQR = q3 - q1

            lB = q1 - 1.5 * IQR
            uB = q3 + 1.5 * IQR
            dataList.append([numlist[column],q1,q3,IQR,((self.numcols[numlist[column]] < lB) | (self.numcols[numlist[column]] > uB)).sum()])
        table = tabulate(dataList, tablefmt='pretty') # tabulate converts data into table format
        print(table)

    def outliresBox(self):
        '''
            function: outliresBox -> shows the distribution of outlires using box plots
            arg: df (pandas.core.frame.DataFrame) -> data frame
            return: None
        '''
        numlist = self.numcols.columns.tolist()
        for column in range(0, len(numlist)-1, 2):
            fig, axes = plt.subplots(1, 2, figsize=(10, 5))

            sns.boxplot(self.numcols[numlist[column]], ax=axes[0])
            axes[0].set_title(numlist[column])

            sns.boxplot(self.numcols[numlist[column + 1]], ax=axes[1])
            axes[1].set_title(numlist[column + 1])

    def bollValuePlot(self, df):
        '''
            function: bollValuePlot -> shows the distribution of boolean features from the data set using pie charts
            arg: df (pandas.core.frame.DataFrame) -> data frame
            return: None
        '''
        fig, axes = plt.subplots(2, 3, figsize=(10,7))
        axes = axes.flatten()
        palettes = ['pastel', 'deep', 'bright', 'muted', 'colorblind', 'viridis']
        font_size = 15
        title_font = 20

        for i, (columnNmae, ax) in enumerate(zip(df.columns, axes)):
```

```python
            size = df[columnNmae].value_counts()
            palette = sns.color_palette(palettes[i])
            ax.pie(size, labels=size.index, colors=palette, autopct='%1.1f%%', startangle=140, textprops={'fontsize': font_size})
            ax.set_title(columnNmae, fontsize=title_font)

        plt.tight_layout()
        plt.show()

    def FreCount(self, col, figsize_, dispercent):
        '''
            function: FreCount -> counts the percentage of catagorical columns and show the distribution using bar plots
            arg: col (pandas.core.series.Series) -> column of the data set
                 figsize_ (tuple) -> size of the graph
                 dispercent (boolean) -> 1: display the percentage of the distribution
                                         0: does not display the percentage of the distribution
            return: None
        '''
        df_brand = col.value_counts()
        percent = round((df_brand * 100) / self.df.shape[0], 2)

        plt.figure(figsize=figsize_)
        ax = sns.barplot(x=percent.index, y=percent.values, palette='dark')
        plt.xlabel(col.name)
        plt.ylabel('Frequency')
        plt.xticks(rotation=90)
        if dispercent:
            for i, value in enumerate(percent):
                plt.text(i, value, str(value), ha='center', va='bottom')
        plt.show()

    def corr(self):
        '''
            function: corr -> Represent the correlation of each numaric column using heat map
            arg: None
            return: None
        '''
        coff = self.df.corr(method='pearson', numeric_only=True)
        plt.figure(figsize=(12,10))
        sns.heatmap(data=coff, cmap="coolwarm", annot=True, fmt=".2f", linewidths=1, linecolor='black')
        plt.show()
```

In [8]:
```python
numcols = df.select_dtypes(include='number') # numeric column data set
catCols = df.select_dtypes(exclude='number') # catagorical column data set
catCols.drop(columns=['Name'], inplace=True)
```

```
C:\Users\bhair\AppData\Roaming\Python\Python37\site-packages\pandas\core\frame.py:4913: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  errors=errors,
```

In [9]:
```python
numcols.head()
```

Out[9]:

	Battery capacity (mAh)	Screen size (inches)	Resolution x	Resolution y	Processor	RAM (MB)	Internal storage (GB)	Rear camera	Front camera	Number of SIMs	Price
0	4085	6.67	1440	3120	8	12000	256.0	48.0	16.0	2	58998
1	4000	6.50	1080	2400	8	6000	64.0	64.0	16.0	2	27999
2	3969	6.50	1242	2688	6	4000	64.0	12.0	12.0	2	106900
3	3110	6.10	828	1792	6	4000	64.0	12.0	12.0	2	62900
4	4000	6.40	1080	2340	8	6000	128.0	12.0	32.0	1	49990

In [10]:

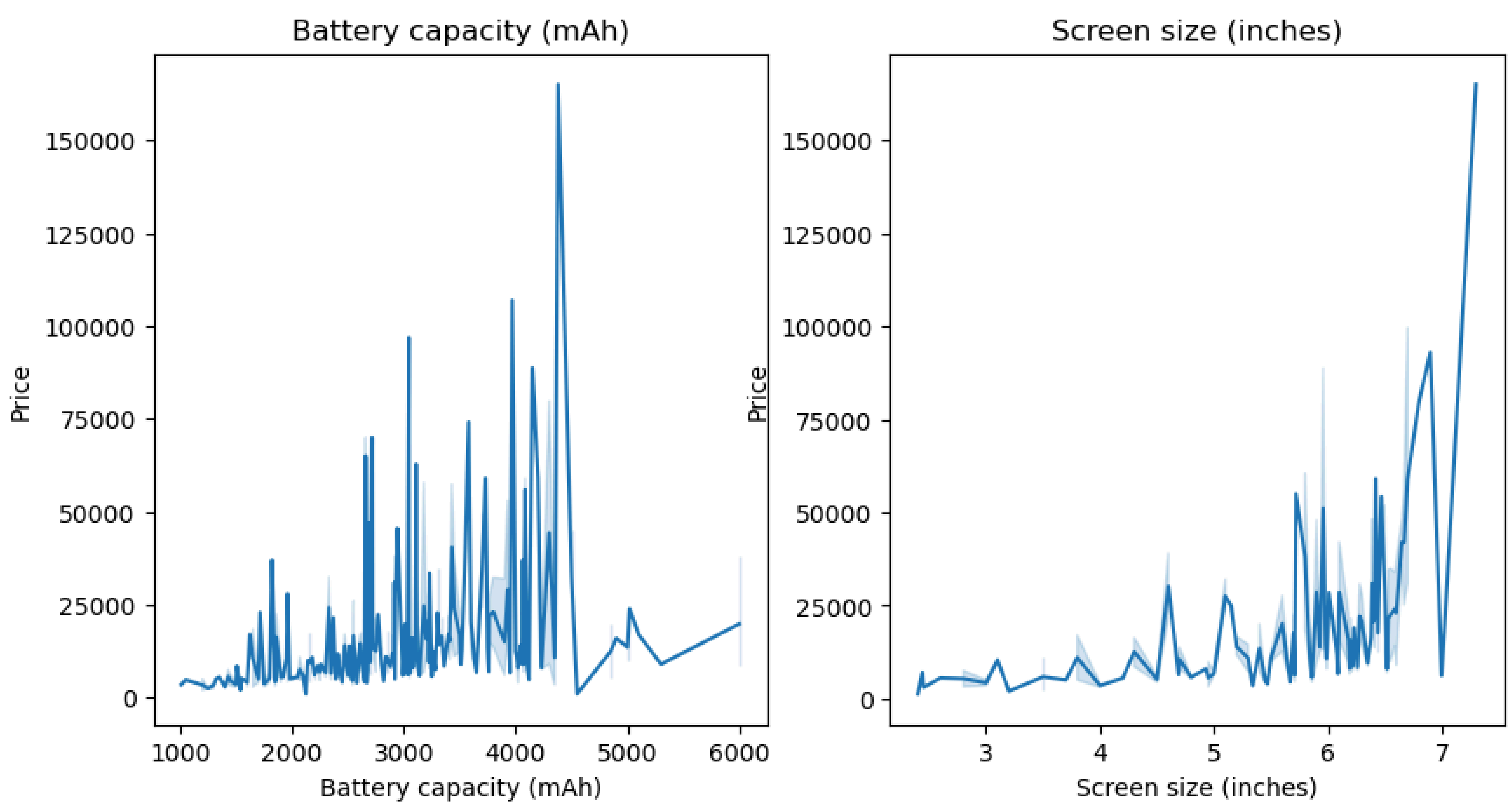
```
print('BASIC EDA\n')
eda = EDABasic(df, numcols, catCols) # creating a class instance
```

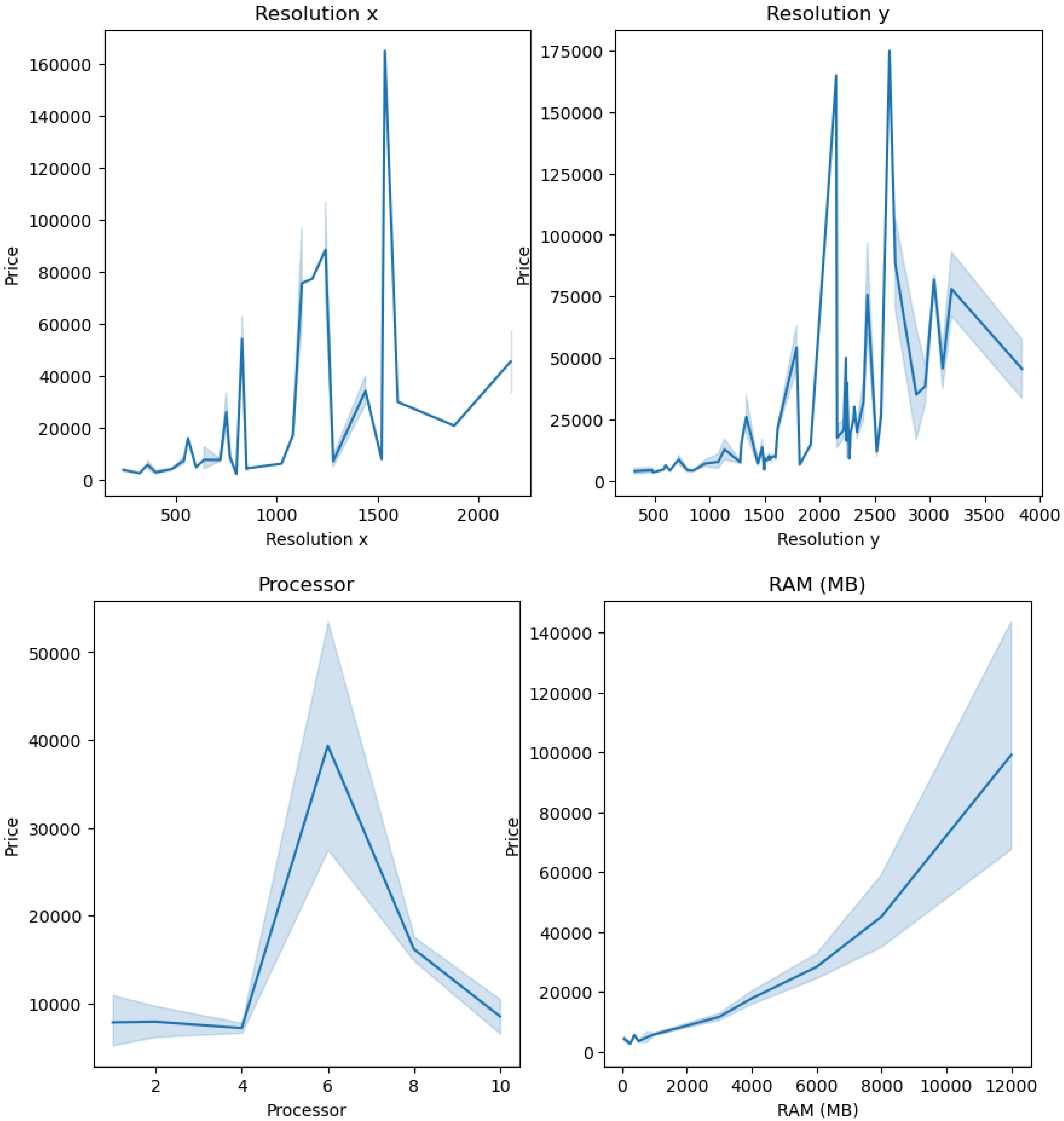
```
BASIC EDA

SHAPE OF DATAFRAME:
Columns = 1359
Rows = 21


Checking the missing values:

Missing values:
Name                      0
Brand                     0
Model                     0
Battery capacity (mAh)    0
Screen size (inches)      0
Touchscreen               0
Resolution x              0
Resolution y              0
Processor                 0
RAM (MB)                  0
Internal storage (GB)     0
Rear camera               0
Front camera              0
Operating system          0
Wi-Fi                     0
Bluetooth                 0
GPS                       0
Number of SIMs            0
3G                        0
4G/ LTE                   0
Price                     0
dtype: int64


Checking the Duplicate values:
Duplicate values = No Duplicat values


The static summary:
| index                  |   count |    mean |       std |   min |    25% |   50% |   75% |    max |
|------------------------|---------|---------|-----------|-------|--------|-------|-------|--------|
| Battery capacity (mAh) |    1359 | 2938.49 |   873.514 |  1010 |   2300 |  3000 |  3500 |   6000 |
| Screen size (inches)   |    1359 | 5.29131 |  0.671357 |   2.4 |      5 |   5.2 |   5.7 |    7.3 |
| Resolution x           |    1359 | 811.543 |   270.707 |   240 |    720 |   720 |  1080 |   2160 |
| Resolution y           |    1359 | 1490.78 |    557.78 |   320 |   1280 |  1280 |  1920 |   3840 |
| Processor              |    1359 | 5.55114 |   2.19656 |     1 |      4 |     4 |     8 |     10 |
| RAM (MB)               |    1359 | 2488.78 |   1664.44 |    64 |   1000 |  2000 |  3000 |  12000 |
| Internal storage (GB)  |    1359 | 30.6549 |   36.9502 | 0.064 |      8 |    16 |    32 |    512 |
| Rear camera            |    1359 | 12.0702 |   8.94834 |     0 |      8 |  12.2 |    13 |    108 |
| Front camera           |    1359 | 7.03797 |   6.29545 |     0 |      2 |     5 |     8 |     48 |
| Number of SIMs         |    1359 |  1.8337 |  0.374457 |     1 |      2 |     2 |     2 |      3 |
| Price                  |    1359 | 11465.8 |   13857.5 |   494 | 4763.5 |  6999 | 11999 | 174990 |


The information:
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1359 entries, 0 to 1358
Data columns (total 21 columns):
 #   Column                  Non-Null Count  Dtype
---  ------                  --------------  -----
 0   Name                    1359 non-null   object
 1   Brand                   1359 non-null   object
```

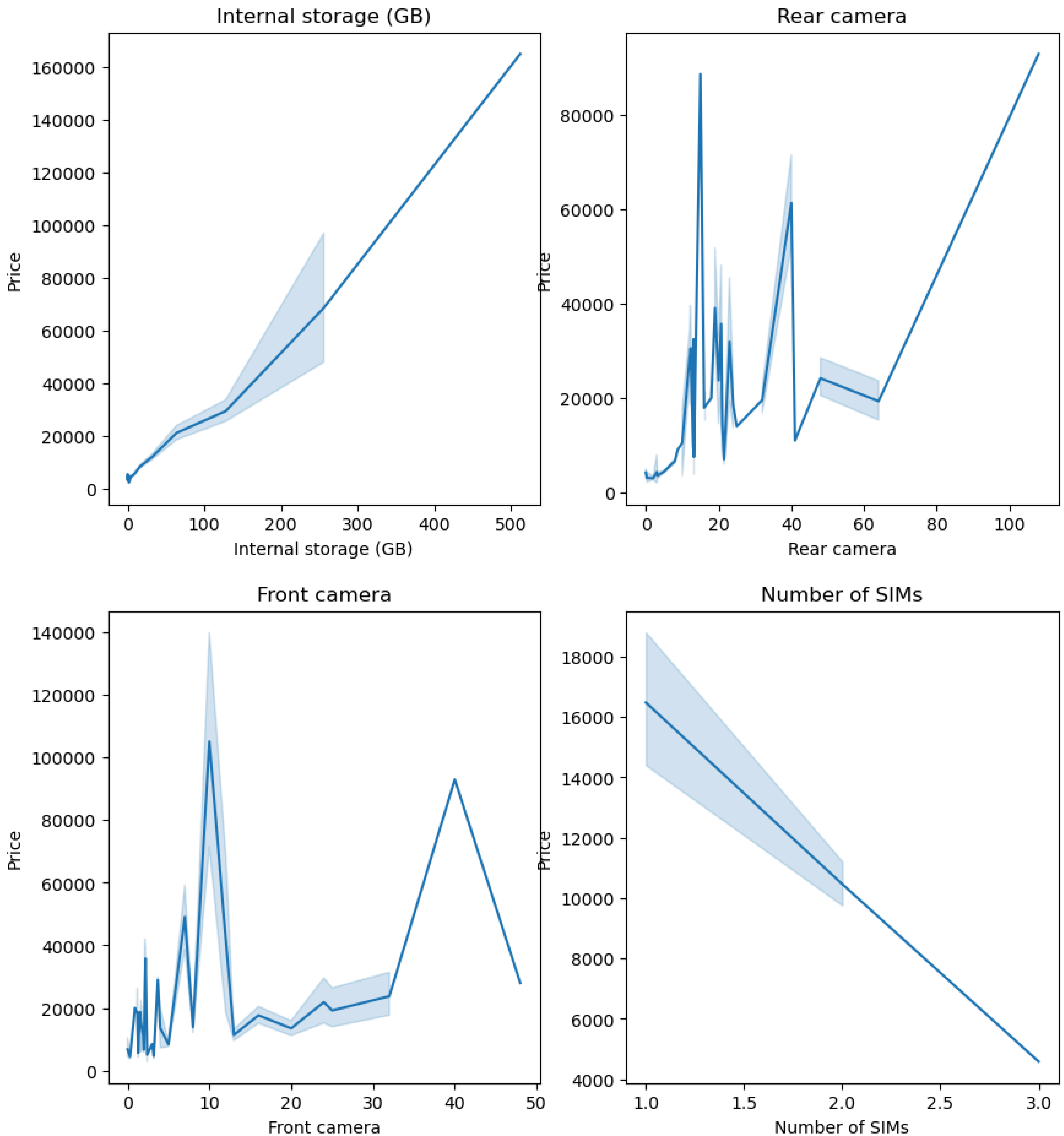
```
 2   Model                   1359 non-null   object
 3   Battery capacity (mAh)  1359 non-null   int64
 4   Screen size (inches)    1359 non-null   float64
 5   Touchscreen             1359 non-null   object
 6   Resolution x            1359 non-null   int64
 7   Resolution y            1359 non-null   int64
 8   Processor               1359 non-null   int64
 9   RAM (MB)                1359 non-null   int64
 10  Internal storage (GB)   1359 non-null   float64
 11  Rear camera             1359 non-null   float64
 12  Front camera            1359 non-null   float64
 13  Operating system        1359 non-null   object
 14  Wi-Fi                   1359 non-null   object
 15  Bluetooth               1359 non-null   object
 16  GPS                     1359 non-null   object
 17  Number of SIMs          1359 non-null   int64
 18  3G                      1359 non-null   object
 19  4G/ LTE                 1359 non-null   object
 20  Price                   1359 non-null   int64
dtypes: float64(4), int64(7), object(10)
memory usage: 223.1+ KB
None
```

In [11]:
```
eda.colPrice()
```

```
<Figure size 500x500 with 0 Axes>
```



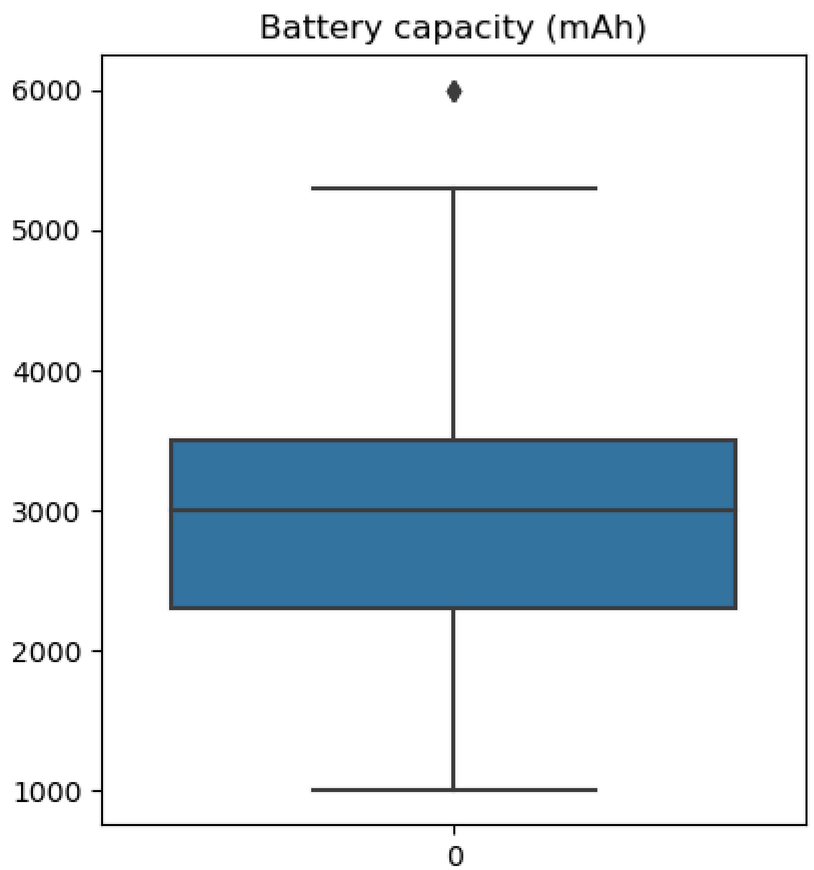

Resolution x
Price
0
20000
40000
60000
80000
100000
120000
140000
160000
500
1000
1500
2000
Resolution x
Resolution y
Price
0
25000
50000
75000
100000
125000
150000
175000
500
1000
1500
2000
2500
3000
3500
4000
Resolution y
Processor
Price
10000
20000
30000
40000
50000
2
4
6
8
10
Processor
RAM (MB)
Price
0
20000
40000
60000
80000
100000
120000
140000
0
2000
4000
6000
8000
10000
12000
RAM (MB)

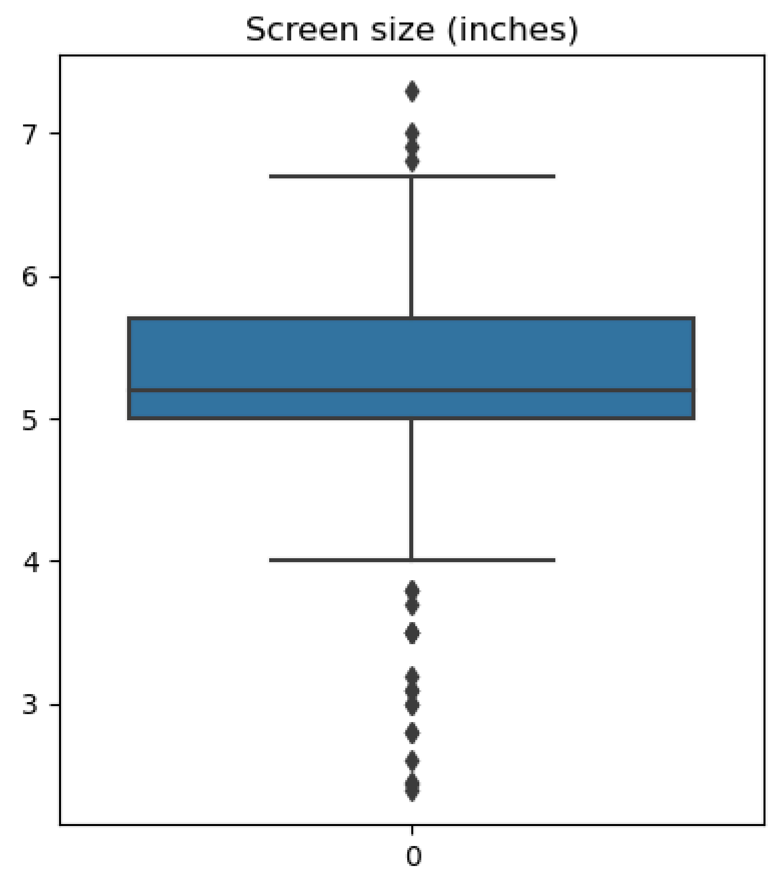


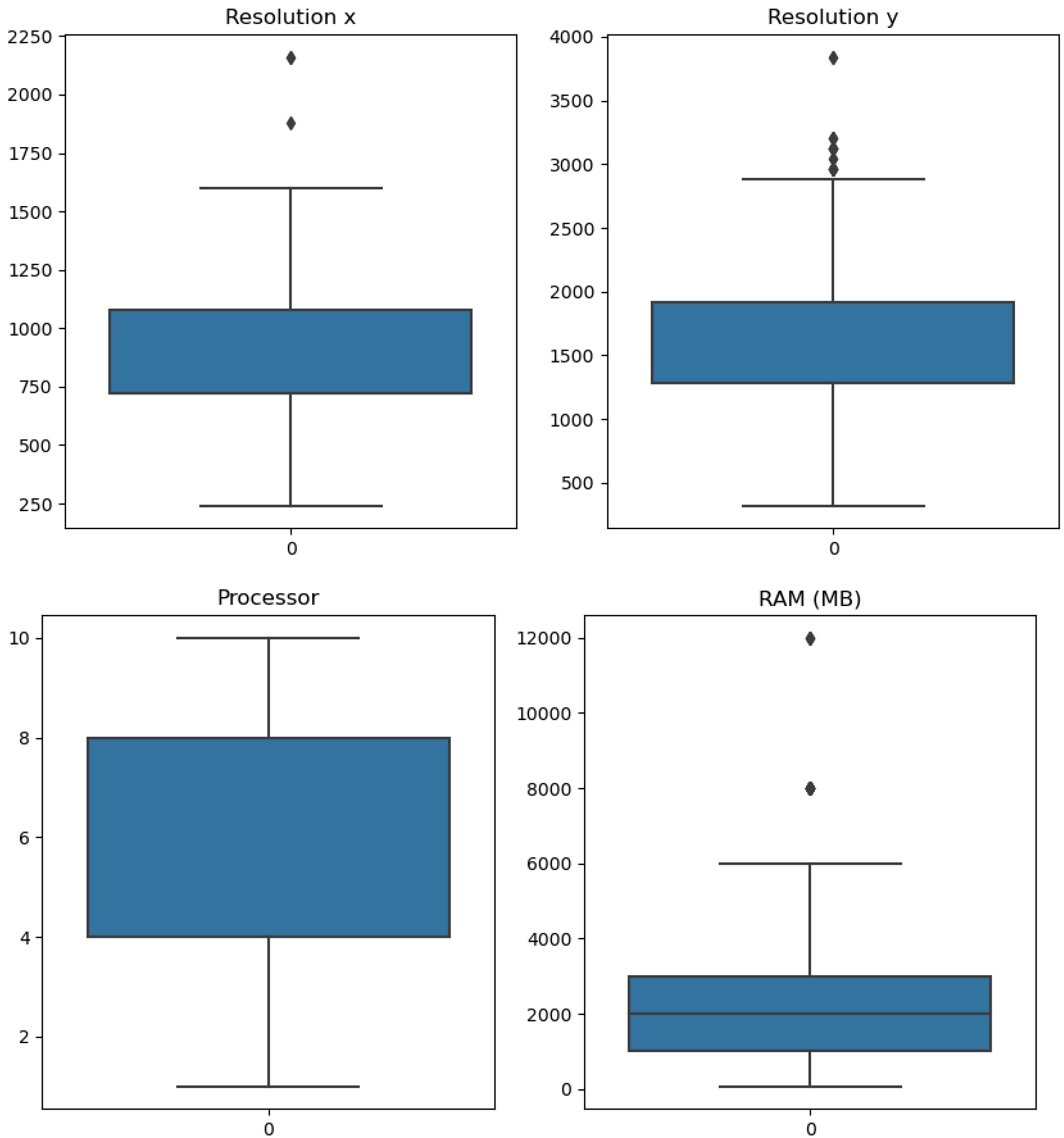
In [12]:
```
eda.calculateOutlires()
eda.outliresBox()
```

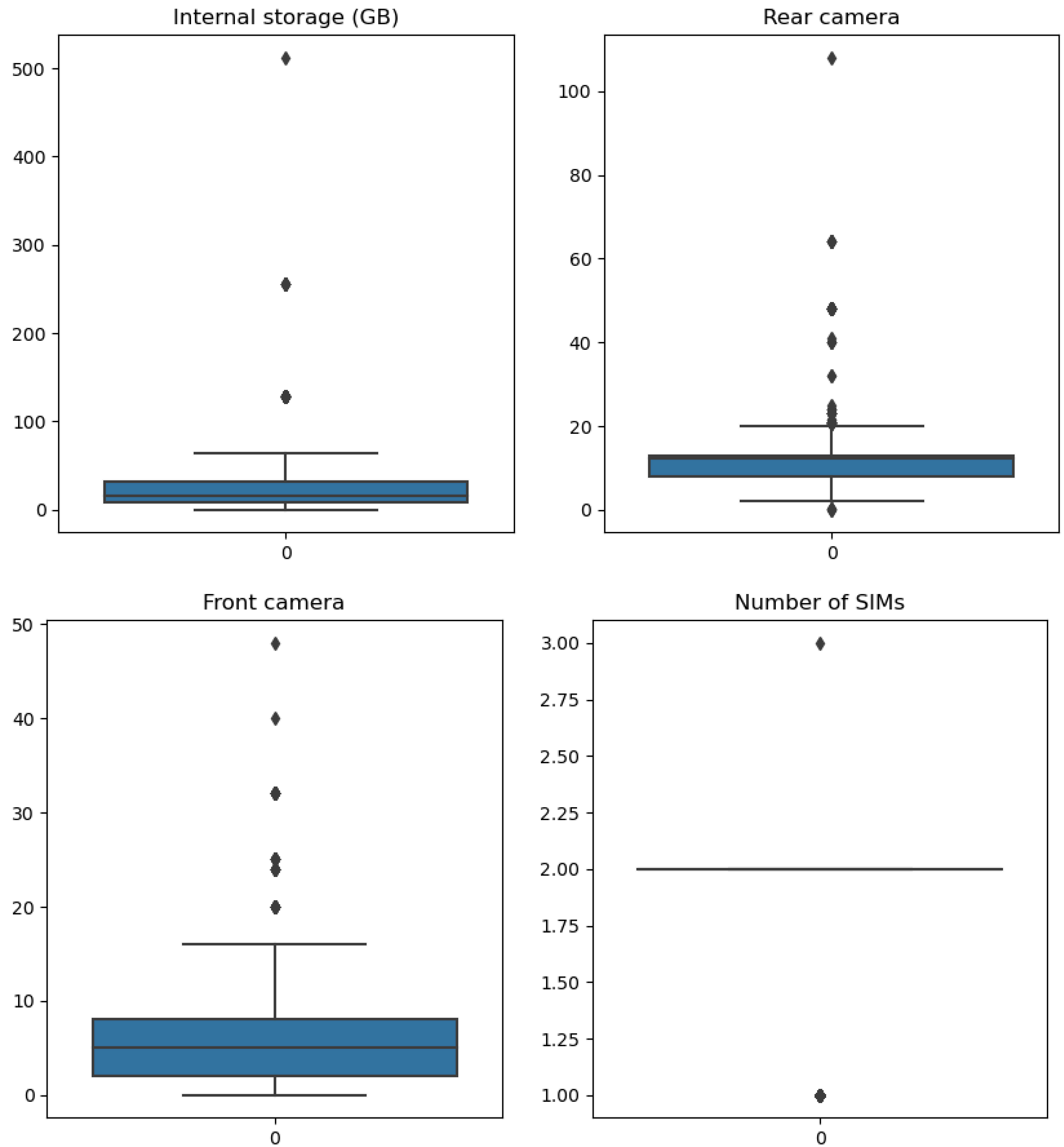
```
+----------------------+--------+--------+--------------------+-------+
|         Name         |   q1   |   q3   |        IQR         | Count |
| Battery capacity (mAh) | 2300.0 | 3500.0 |       1200.0       |   3   |
|  Screen size (inches) |  5.0   |  5.7   | 0.7000000000000002 |   22  |
|     Resolution x     | 720.0  | 1080.0 |       360.0        |   3   |
|     Resolution y     | 1280.0 | 1920.0 |       640.0        |   21  |
|      Processor       |  4.0   |  8.0   |        4.0         |   0   |
|       RAM (MB)       | 1000.0 | 3000.0 |       2000.0       |   33  |
| Internal storage (GB) |  8.0   |  32.0  |        24.0        |   79  |
|     Rear camera      |  8.0   |  13.0  |        5.0         |   91  |
|     Front camera     |  2.0   |  8.0   |        6.0         |   79  |
|    Number of SIMs    |  2.0   |  2.0   |        0.0         |  228  |
+----------------------+--------+--------+--------------------+-------+
```

In [13]:
```
eda.bollValuePlot(catCols.drop(columns=['Brand', 'Model', 'Operating system']))
```

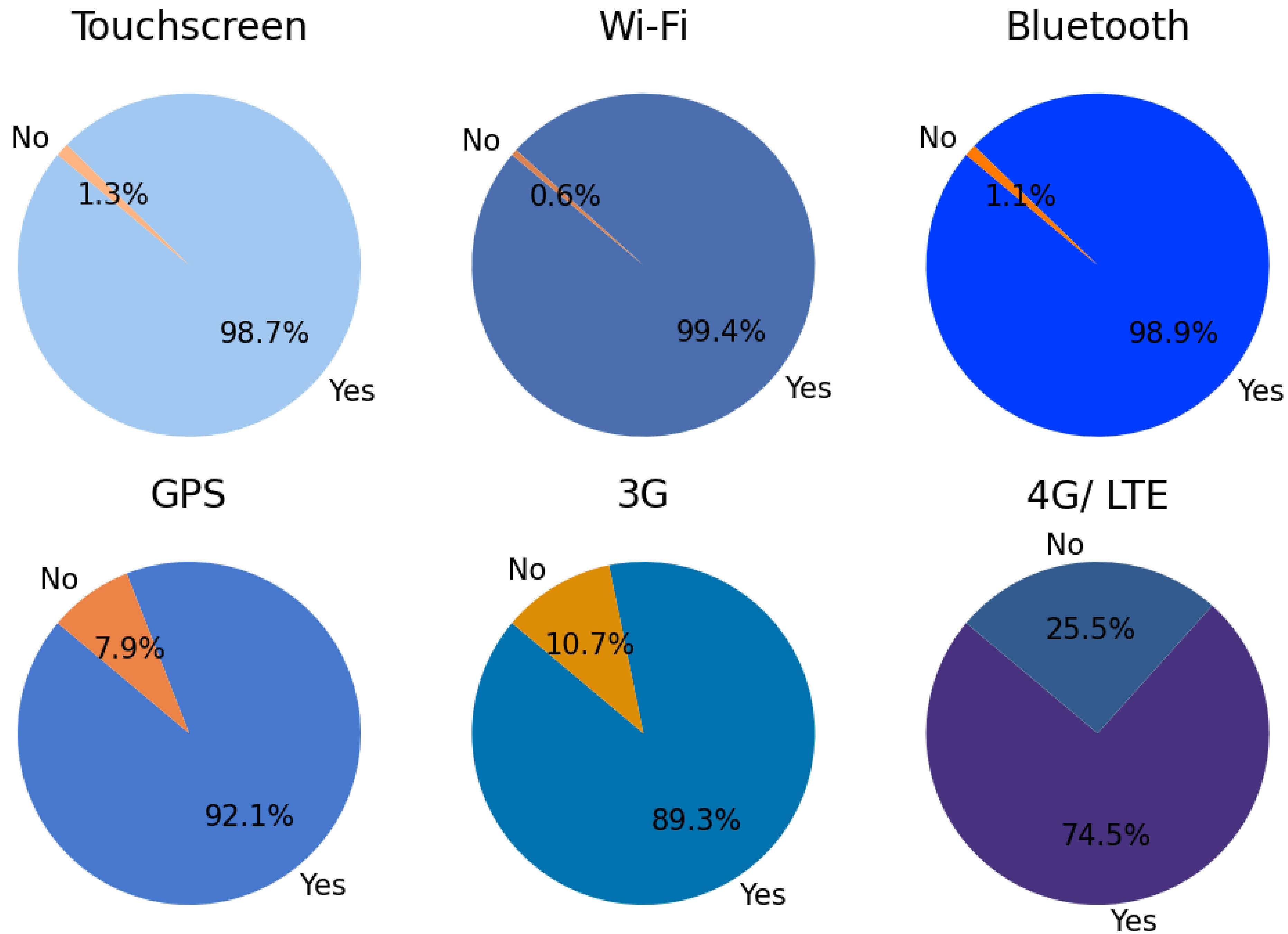




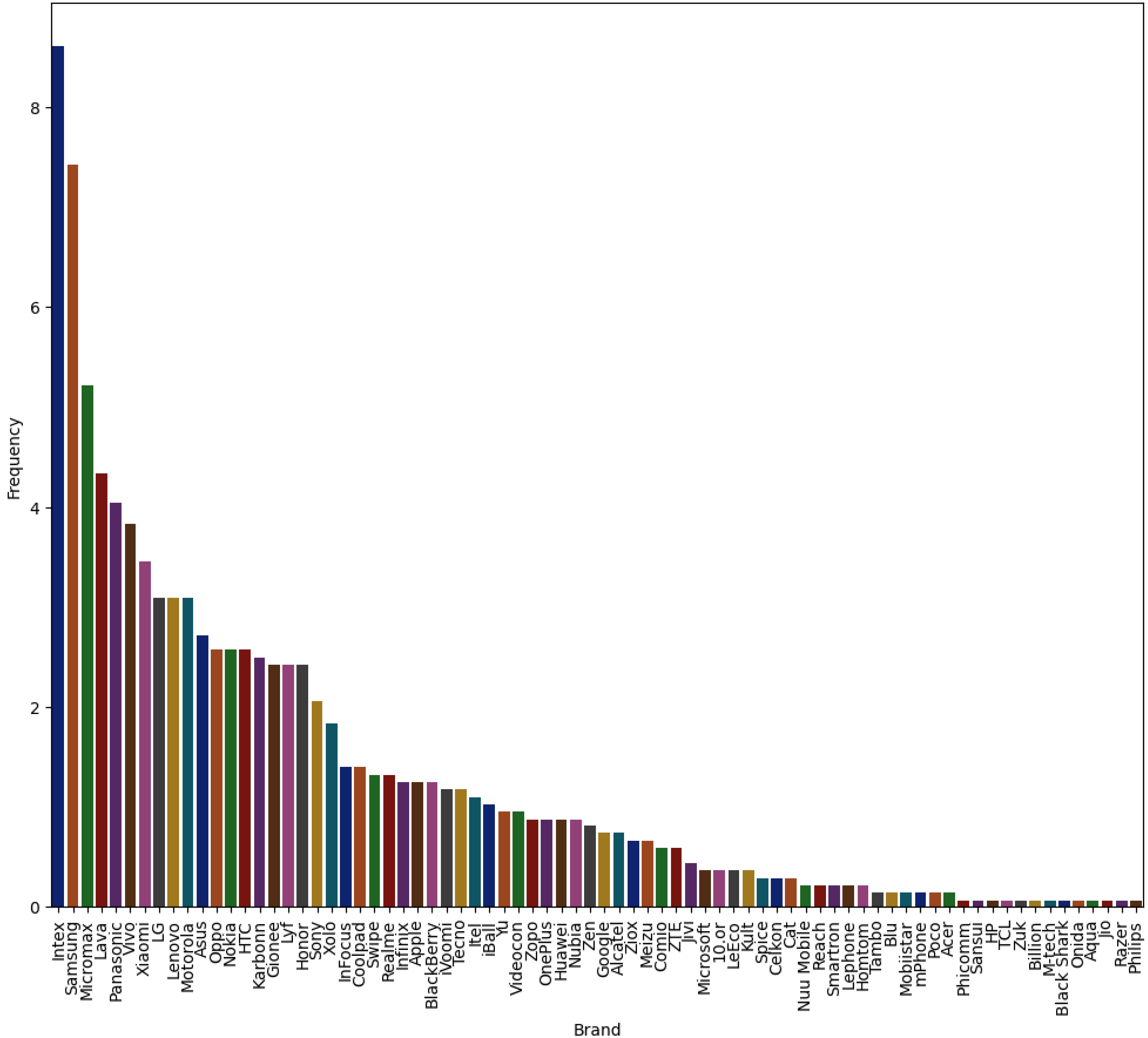

Resolution x
Resolution y
Processor
RAM (MB)
2250
2000
1750
1500
1250
1000
750
500
250
4000
3500
3000
2500
2000
1500
1000
500
10
8
6
4
2
12000
10000
8000
6000
4000
2000
0



Internal storage (GB)
Rear camera
Front camera
Number of SIMs



In [14]:
```
eda.FreCount(df['Brand'], (12, 10), 0)
```



In [15]:

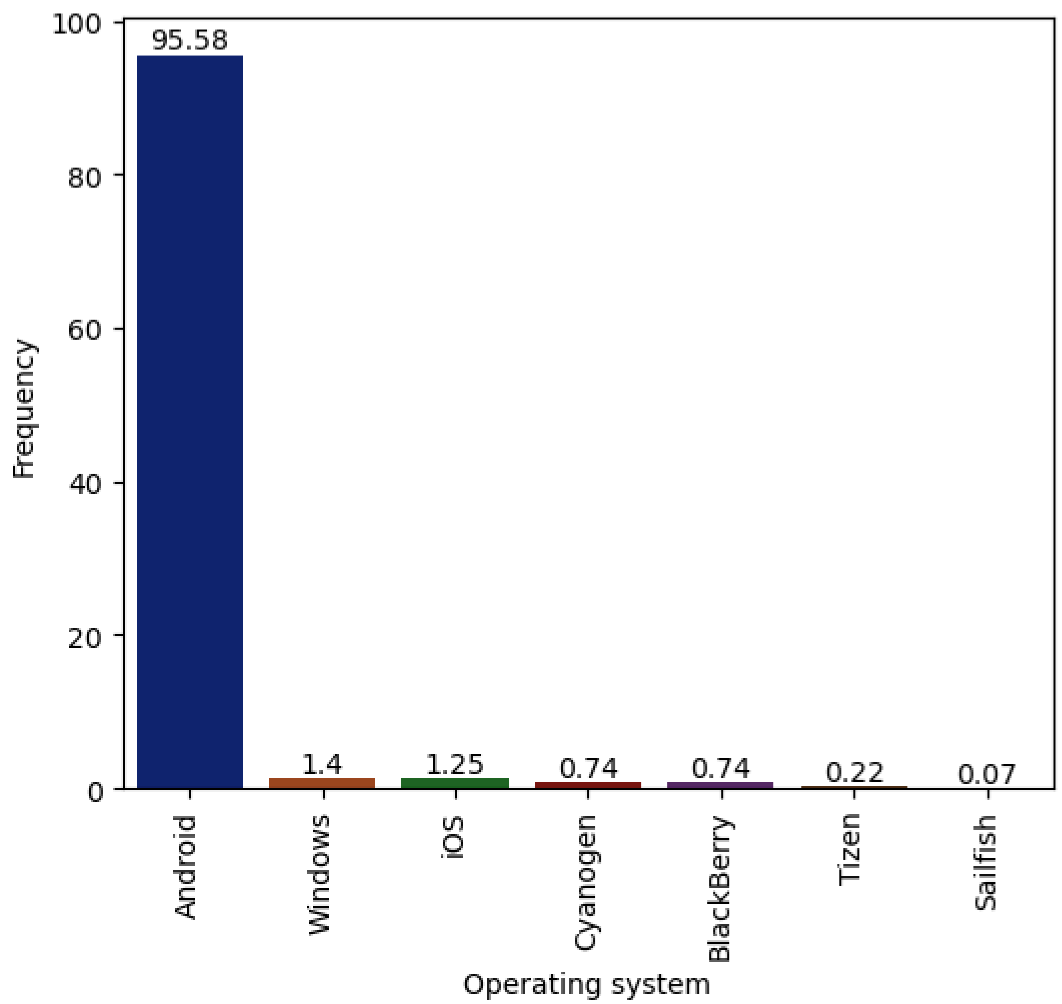
```
df.head(2)
```

Out[15]:

	Name	Brand	Model	Battery capacity (mAh)	Screen size (inches)	Touchscreen	Resolution x	Resolution y	Processor	RAM (MB)	...	Rear camera	Front camera	Operating system	Wi-Fi	Bluetooth	GPS	Number of SIMs	3G	4G/ LTE	Price
0	OnePlus 7T Pro McLaren Edition	OnePlus	7T Pro McLaren Edition	4085	6.67	Yes	1440	3120	8	12000	...	48.0	16.0	Android	Yes	Yes	Yes	2	Yes	Yes	58998
1	Realme X2 Pro	Realme	X2 Pro	4000	6.50	Yes	1080	2400	8	6000	...	64.0	16.0	Android	Yes	Yes	Yes	2	Yes	Yes	27999

2 rows × 21 columns

In [16]:
```
eda.FreCount(df['Operating system'], (6,5), 1)
```



In [17]:
```
# eda.corr()
```

In [ ]:

In [18]:
```
df.head()
```

Out[18]:

	Name	Brand	Model	Battery capacity (mAh)	Screen size (inches)	Touchscreen	Resolution x	Resolution y	Processor	RAM (MB)	...	Rear camera	Front camera	Operating system	Wi-Fi	Bluetooth	GPS	Number of SIMs	3G	4G/ LTE	Price
0	OnePlus 7T Pro McLaren Edition	OnePlus	7T Pro McLaren Edition	4085	6.67	Yes	1440	3120	8	12000	...	48.0	16.0	Android	Yes	Yes	Yes	2	Yes	Yes	58998
1	Realme X2 Pro	Realme	X2 Pro	4000	6.50	Yes	1080	2400	8	6000	...	64.0	16.0	Android	Yes	Yes	Yes	2	Yes	Yes	27999
2	iPhone 11 Pro Max	Apple	iPhone 11 Pro Max	3969	6.50	Yes	1242	2688	6	4000	...	12.0	12.0	iOS	Yes	Yes	Yes	2	Yes	Yes	106900
3	iPhone 11	Apple	iPhone 11	3110	6.10	Yes	828	1792	6	4000	...	12.0	12.0	iOS	Yes	Yes	Yes	2	Yes	Yes	62900
4	LG G8X ThinQ	LG	G8X ThinQ	4000	6.40	Yes	1080	2340	8	6000	...	12.0	32.0	Android	Yes	Yes	Yes	1	No	No	49990

5 rows × 21 columns

In [19]:
```
numeric_columns_=numcols.columns.tolist()
```

In [20]:
```
numeric_columns_
```

Out[20]:
```
['Battery capacity (mAh)',
 'Screen size (inches)',
 'Resolution x',
 'Resolution y',
 'Processor',
 'RAM (MB)',
 'Internal storage (GB)',
 'Rear camera',
 'Front camera',
 'Number of SIMs',
 'Price']
```

In [21]:
```
categorical_columns_=catCols.columns.tolist()
```

In [22]:
```
categorical_columns_
```

Out[22]:
```
['Brand',
 'Model',
 'Touchscreen',
 'Operating system',
 'Wi-Fi',
 'Bluetooth',
 'GPS',
 '3G',
 '4G/ LTE']
```

In [23]:
```
len(df.drop(columns='Name').columns.tolist())==len(numeric_columns_)+len(categorical_columns_)
```

Out[23]:
```
True
```

Pre-processing and feature analysis

In [24]:
```
class col_analyser:
    def __init__(self,data):
        """
        arg: dataframe to be processed for analysising the numeric and categorical columns
```

```
        function: class_constructor

        return: None
        """
        self.df=data

    def categorical_analyze(self):
        """
        arg: None

        function: detailed analysis (unique value and its count) of categorical columns present in the dataframe

        return: dataframe describing each categorical variable characteristic --> used to transform for pre-processing
        """
        self.categorical_columns=self.df.select_dtypes(include=['object']).columns.tolist()

        cat_tab=[]
        for i in self.categorical_columns:
            unique_element_counts=self.df[i].nunique()
            unique_elements=self.df[i].unique()
            cat_tab.append({'cat_column_name':i,'unique_value_counts':unique_element_counts,'unique_values':unique_elements})
        return pd.DataFrame(cat_tab)


    def numerical_analyze(self):
        """
        arg: None

        function: Visualizing the distribution and QQ plots to apply standradization on top of the numeric values before training

        return: None

        call: initiate the validation method
        """
        self.numerical_columns=self.df.select_dtypes(include='number').columns.tolist()
        for i in self.numerical_columns:
            unique_element_counts=self.df[i].nunique()
            sns.set_style('darkgrid')
            fig,axs=plt.subplots(1,2,figsize=(14,6))
            sns.histplot(df[i],ax=axs[1])
            stats.probplot(df[i],plot=axs[0],fit=True)
            axs[0].set_title('QQ_plot')
            axs[1].set_title('distribution')
            fig.suptitle("numerical column analysis - {}".format(i))
            plt.tight_layout()
            plt.show()
        self.validation_()


    def validation_(self):

        """
        arg: None

        function: overall numeric and categorical columns post analysis

        return: None
        """
        print("Categorical columns are :{}".format(self.categorical_columns))
        print("numerical columns are :{}".format(self.numerical_columns))
```

```python
    def correlation_with_target(self,df,target):

        """
        arg: dataframe on which correlation need to be applied
        arg: target column to calculate the correlation

        function: correlation analysis (numeric values with respect to target variable)

        return: correlation values in descending (importance) order
        """
        return(df.corr()[target].round(3).sort_values(ascending=False))

    def possible_high_correlation(self,df):


        """
        arg: dataframe

        function: identifying features of high correlation

        return:  columns which are having possiblity of correlations
        """
        correlation_=df.corr()
        unique_columns_with_high_correlations=set()
        for i in range(len(correlation_.columns)):
            for j in range(i):
                if abs(correlation_.iloc[i,j])>0.6:
                    suspect_column=correlation_.columns[i]
                    unique_columns_with_high_correlations.add(suspect_column)
        return(unique_columns_with_high_correlations)
```

In [25]:
```python
feature_analyze=col_analyser(df)
```

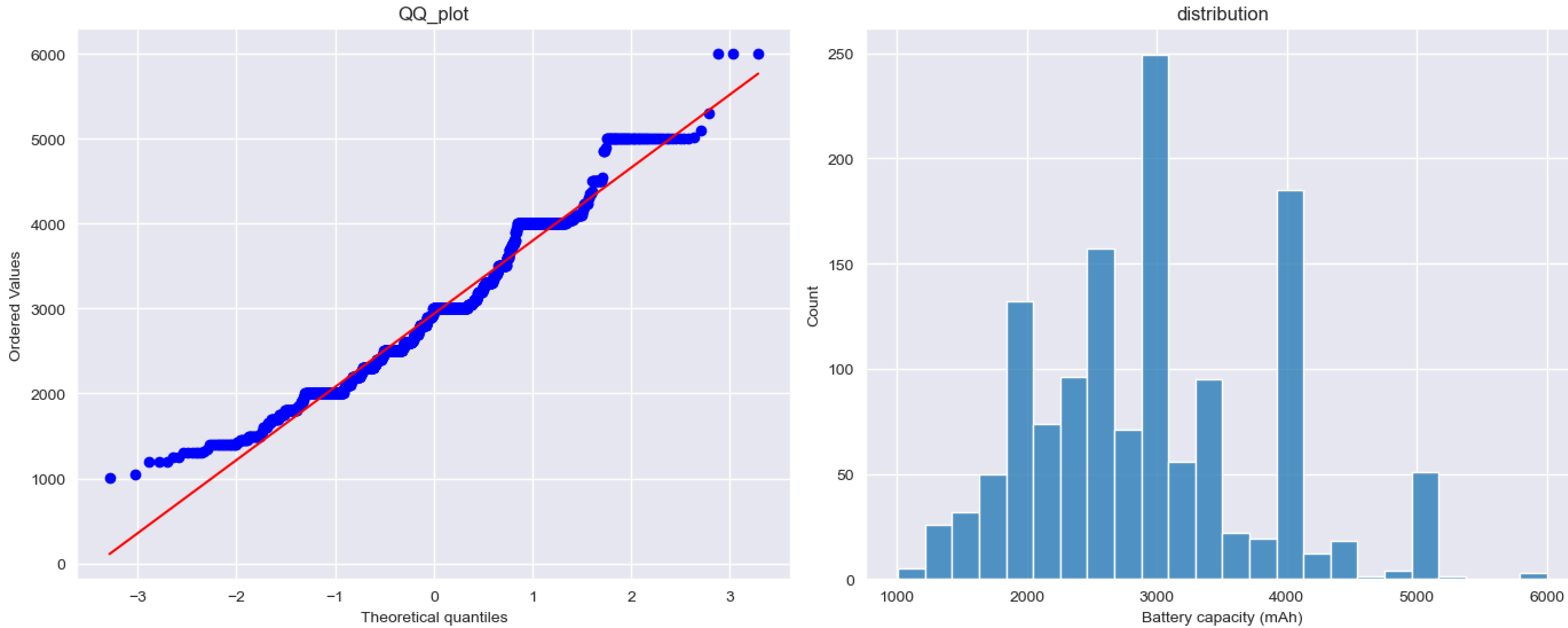
In [26]:
```python
feature_analyze.categorical_analyze()
```

Out[26]:

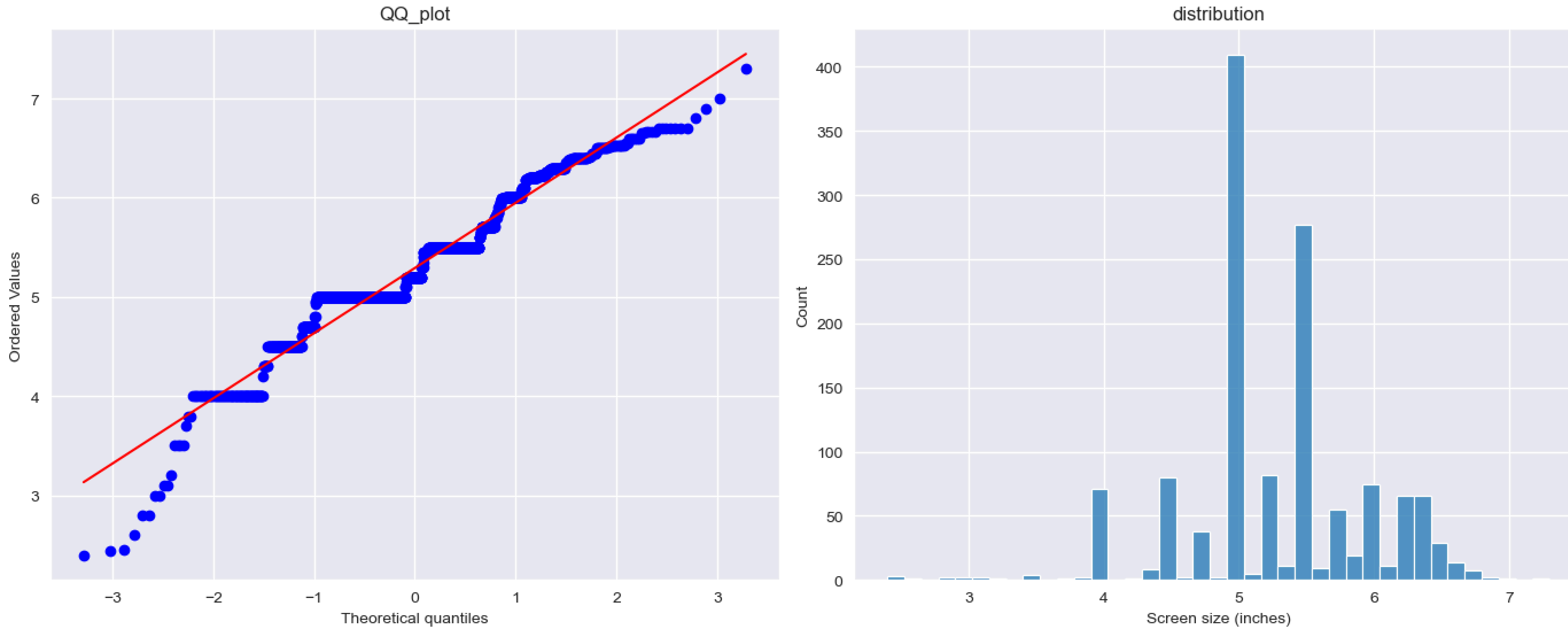
	cat_column_name	unique_value_counts	unique_values
0	Name	1359	[OnePlus 7T Pro McLaren Edition, Realme X2 Pro...
1	Brand	76	[OnePlus, Realme, Apple, LG, Samsung, Asus, Xi...
2	Model	1321	[7T Pro McLaren Edition, X2 Pro, iPhone 11 Pro...
3	Touchscreen	2	[Yes, No]
4	Operating system	7	[Android, iOS, Cyanogen, BlackBerry, Windows, ...
5	Wi-Fi	2	[Yes, No]
6	Bluetooth	2	[Yes, No]
7	GPS	2	[Yes, No]
8	3G	2	[Yes, No]
9	4G/ LTE	2	[Yes, No]

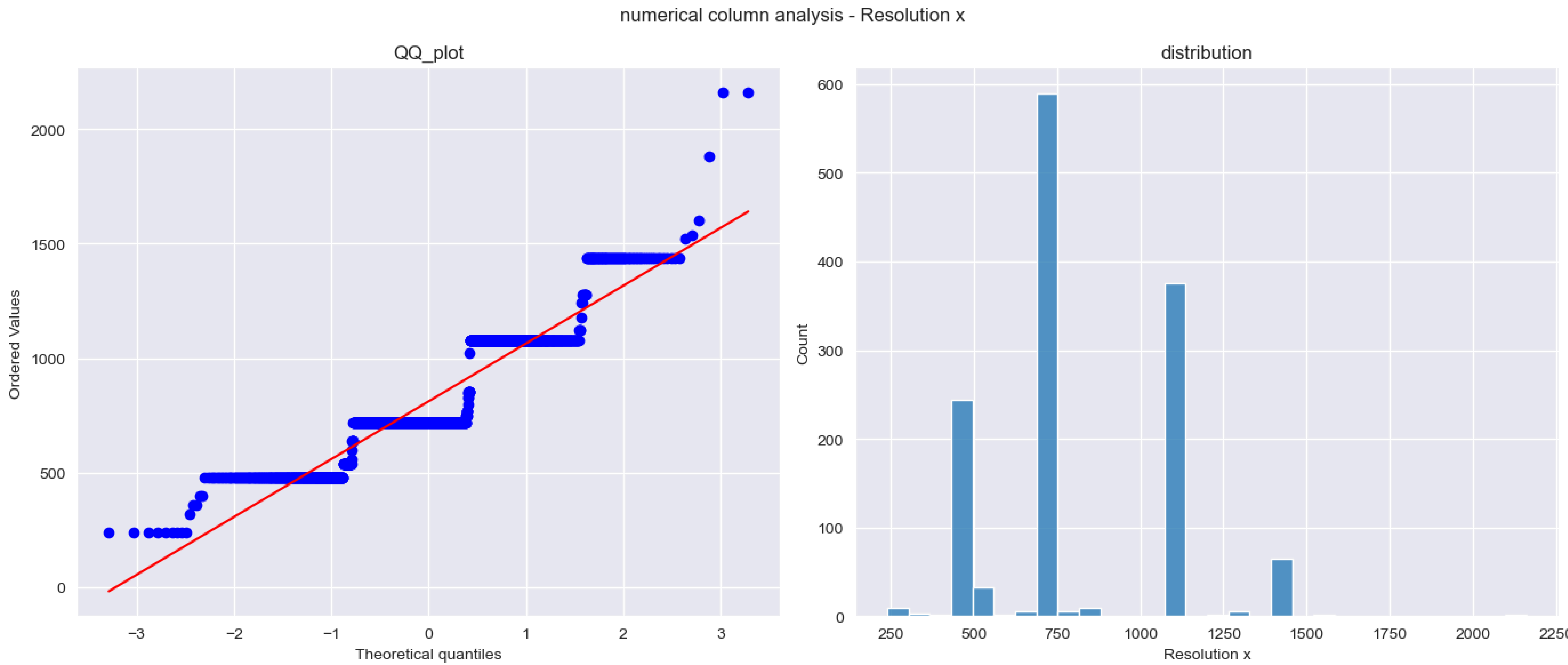
In [27]:
```python
feature_analyze.numerical_analyze()
```

numerical column analysis - Battery capacity (mAh)



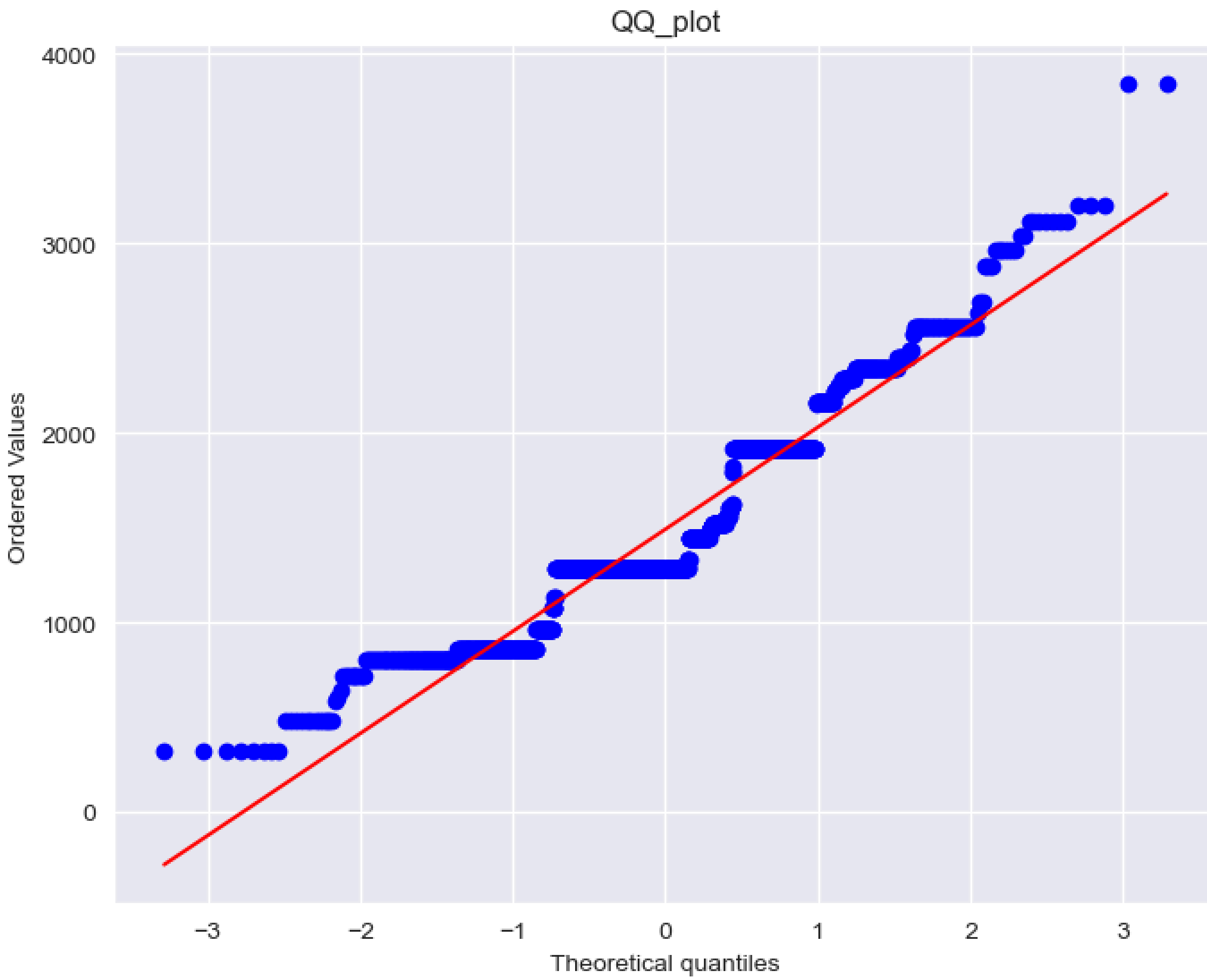
numerical column analysis - Screen size (inches)

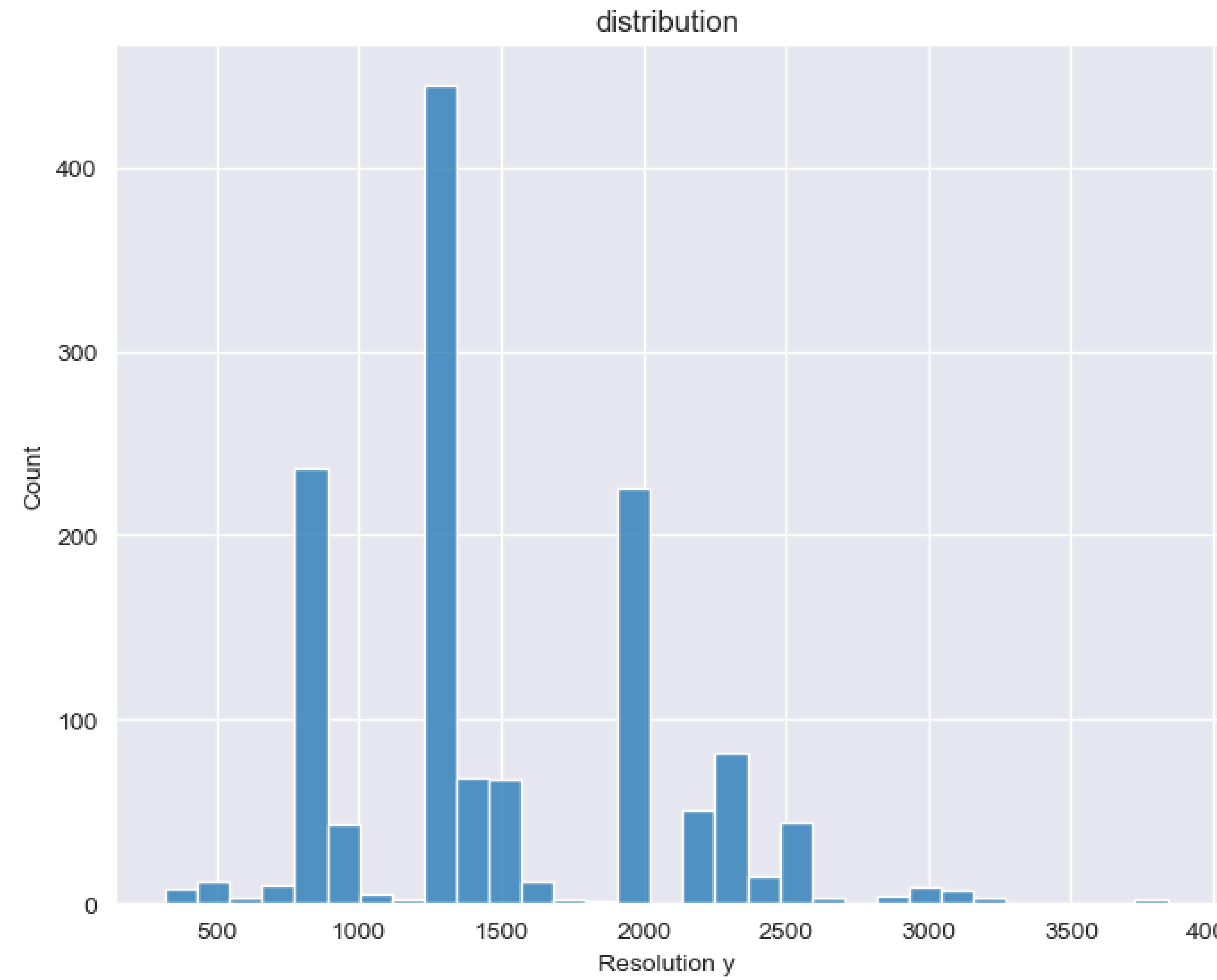


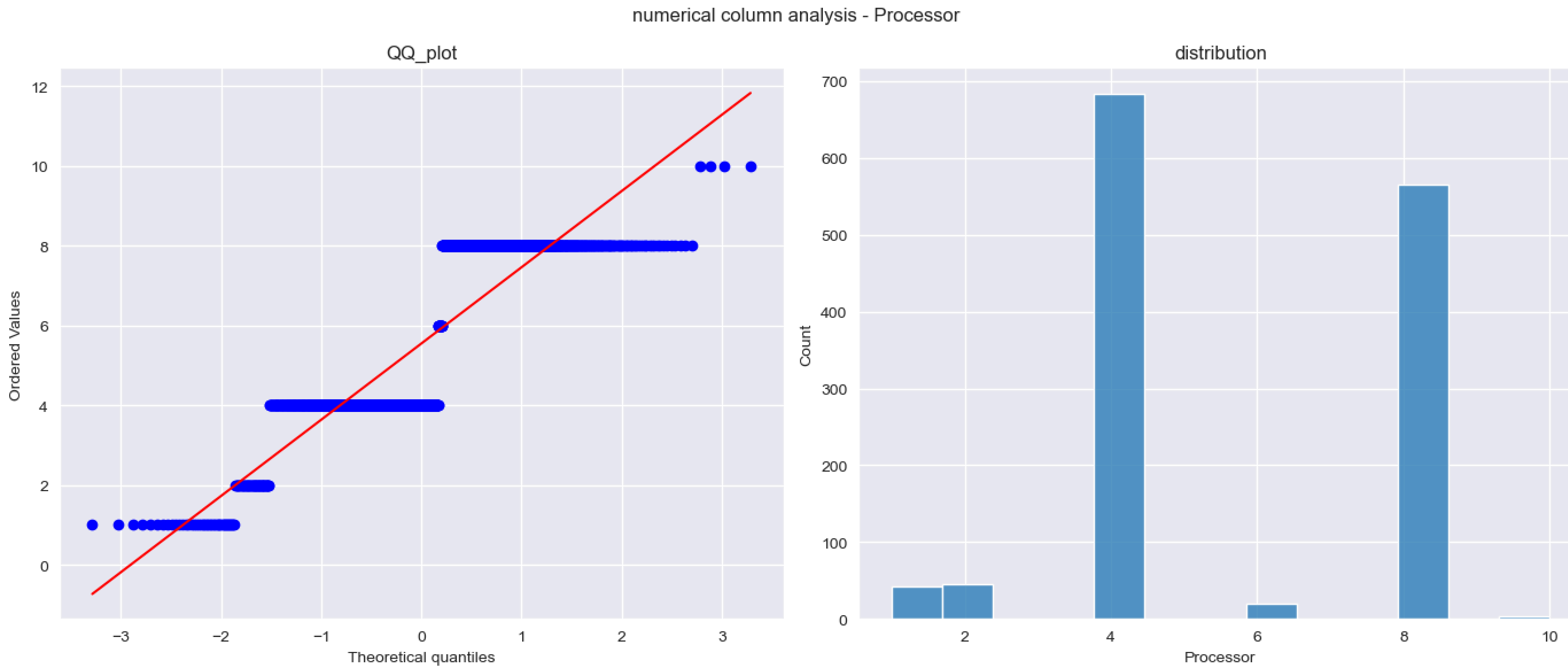


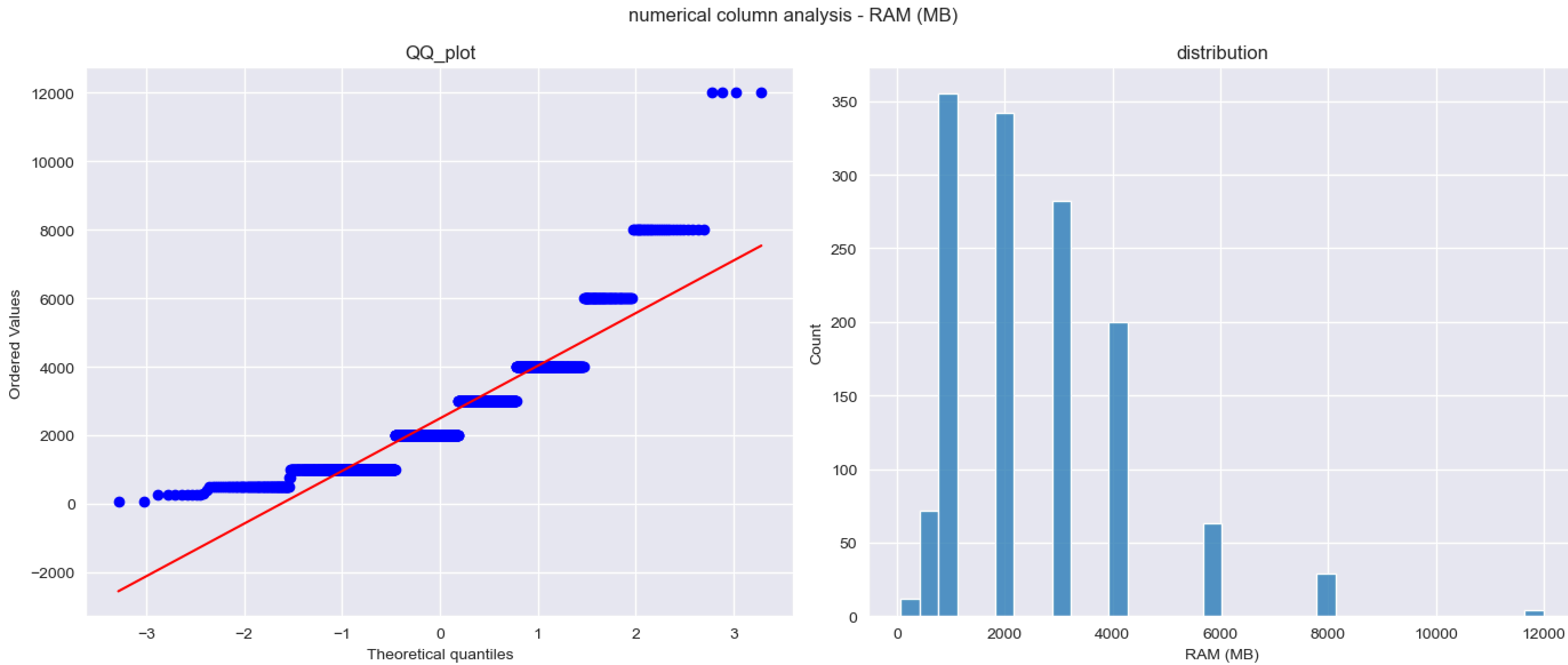
numerical column analysis - Resolution x
QQ_plot
Ordered Values
Theoretical quantiles
distribution
Count
Resolution x

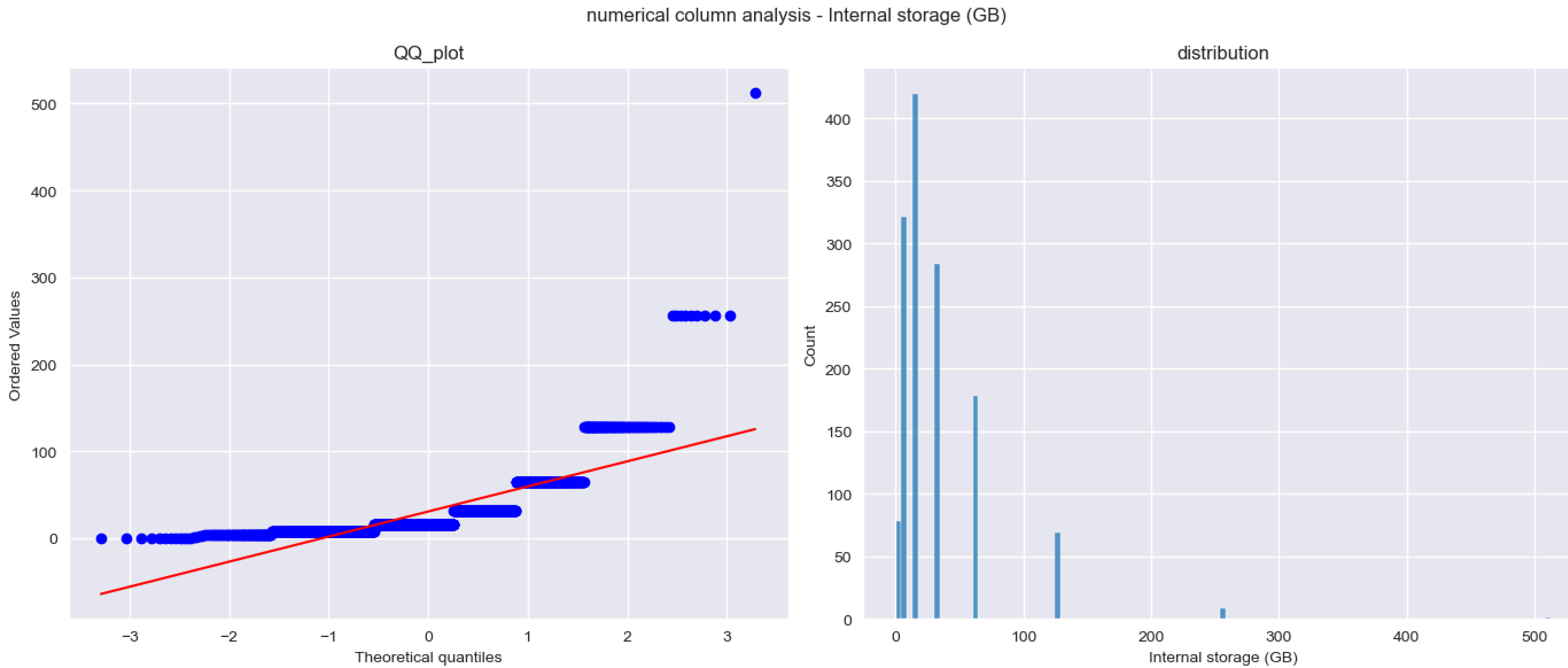
numerical column analysis - Resolution y





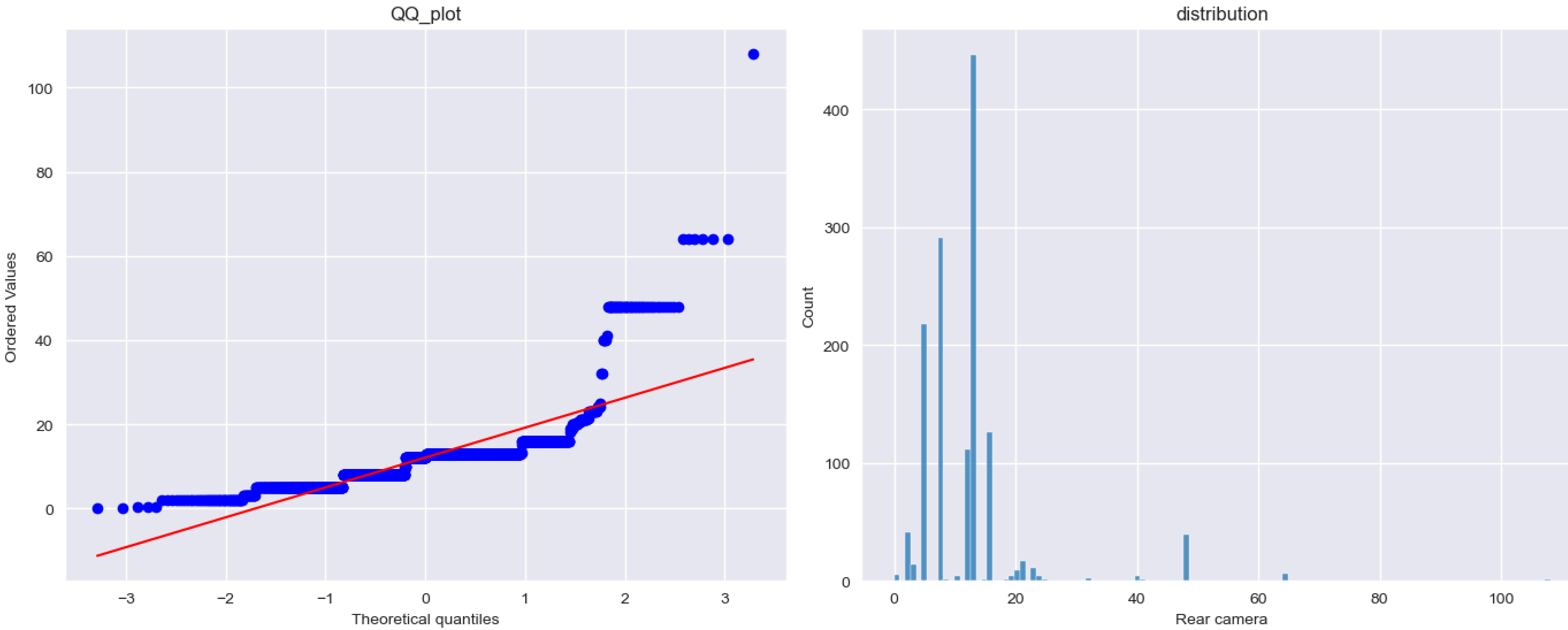

numerical column analysis - Processor
QQ_plot
Ordered Values
Theoretical quantiles
0
2
4
6
8
10
12
−3
−2
−1
0
1
2
3
distribution
Count
Processor
0
100
200
300
400
500
600
700
2
4
6
8
10


numerical column analysis - RAM (MB)
QQ_plot
Ordered Values
Theoretical quantiles
distribution
Count
RAM (MB)

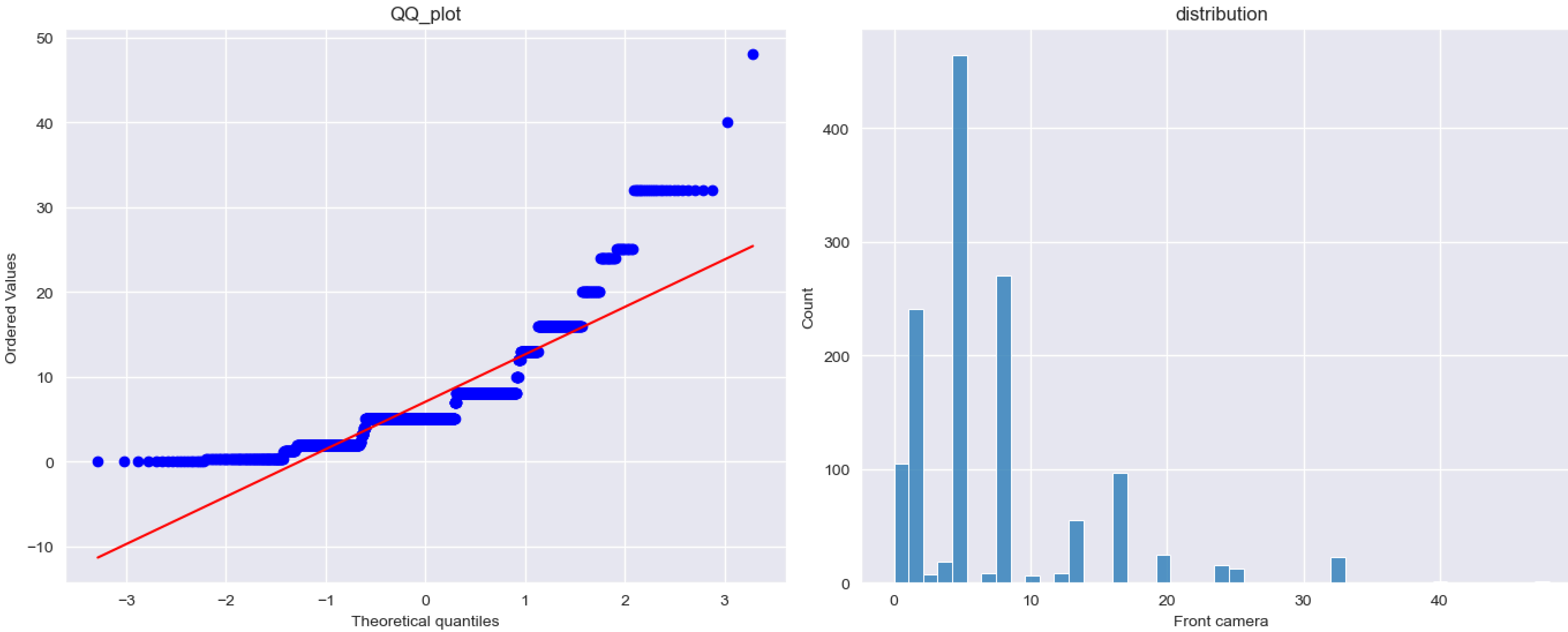


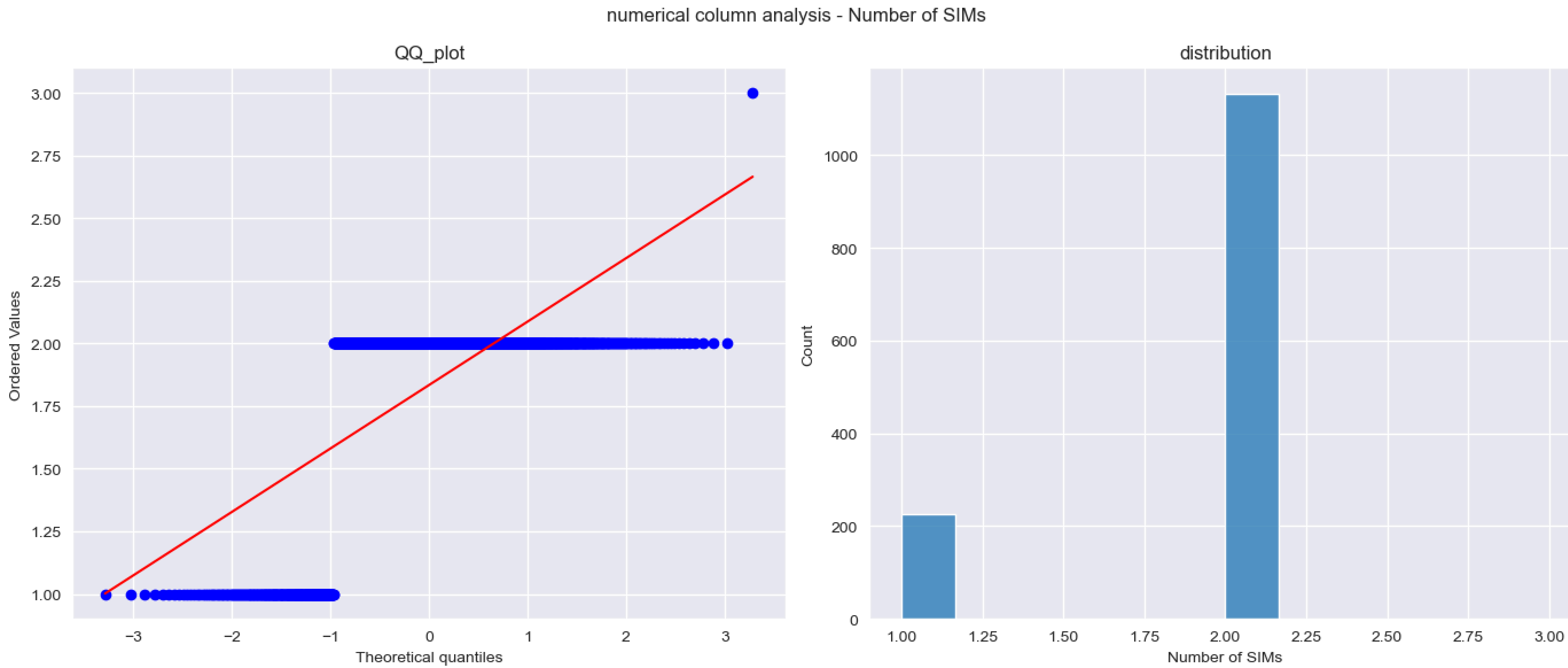
numerical column analysis - Internal storage (GB)
QQ_plot
Ordered Values
Theoretical quantiles
500
400
300
200
100
0
−3
−2
−1
0
1
2
3
distribution
Count
Internal storage (GB)
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500

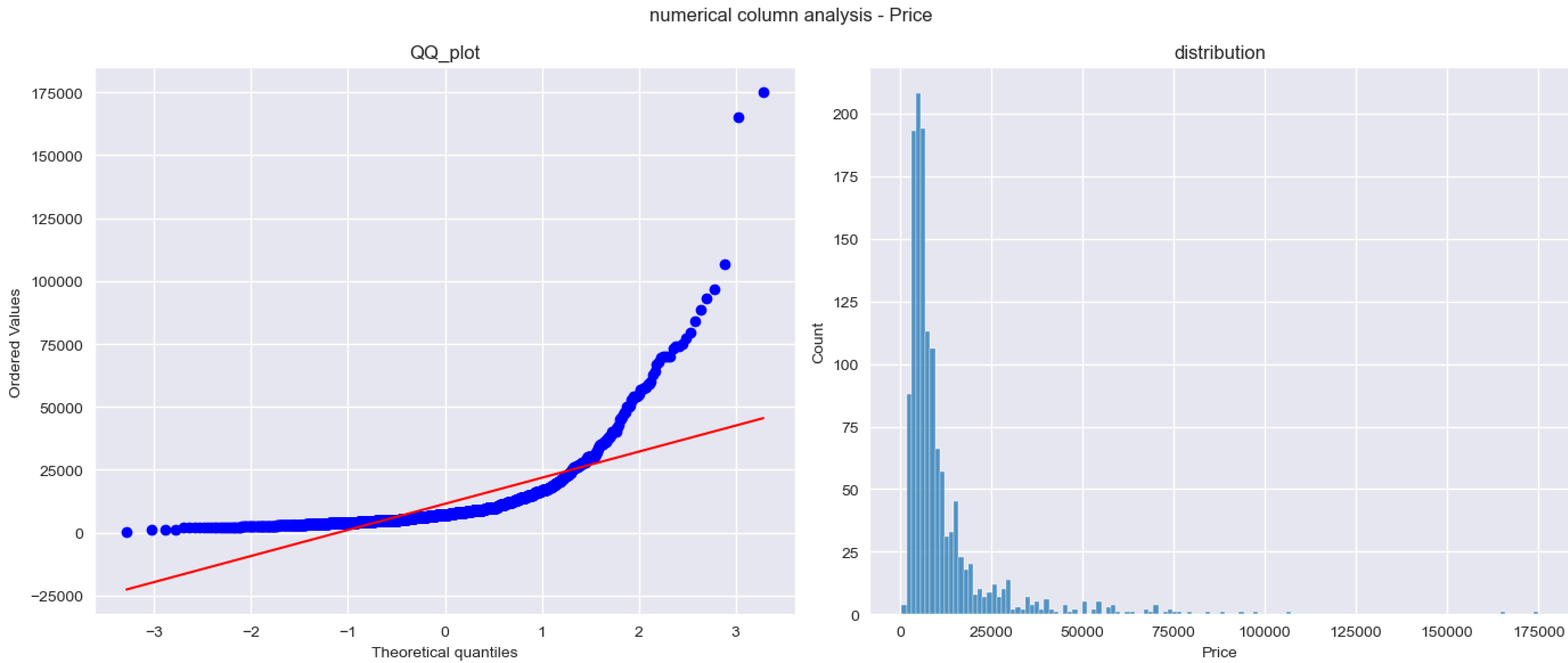
numerical column analysis - Rear camera



numerical column analysis - Front camera




numerical column analysis - Number of SIMs
QQ_plot
Ordered Values
Theoretical quantiles
distribution
Count
Number of SIMs




```
Categorical columns are :['Name', 'Brand', 'Model', 'Touchscreen', 'Operating system', 'Wi-Fi', 'Bluetooth', 'GPS', '3G', '4G/ LTE']
numerical columns are :['Battery capacity (mAh)', 'Screen size (inches)', 'Resolution x', 'Resolution y', 'Processor', 'RAM (MB)', 'Internal storage (GB)', 'Rear camera', 'Front camera', 'Number of SIMs', 'Pric
e']
```

In [28]:
```
feature_analyze.correlation_with_target(numcols,'Price')
```

Out[28]:
```
Price                     1.000
Internal storage (GB)     0.644
RAM (MB)                  0.613
Resolution y              0.576
Resolution x              0.541
Screen size (inches)      0.402
Rear camera               0.379
Front camera              0.311
Processor                 0.302
Battery capacity (mAh)    0.298
Number of SIMs           -0.162
Name: Price, dtype: float64
```

In [29]:
```
feature_analyze.possible_high_correlation(numcols)
```

```
Out[29]: {'Front camera',
 'Internal storage (GB)',
 'Price',
 'Processor',
 'RAM (MB)',
 'Rear camera',
 'Resolution y',
 'Screen size (inches)'}
```

model_pre processing

```
In [30]: class preProcessing:
    def __init__(self, df):
        self.df = df

    def outlireHandeling(self, col):
        '''
            function: outlireHandeling -> Performs the log transformation on the columnn
            arg: col (pandas.core.series.Series) -> column of the data set
            return: 'This column does not exsist in data set' (str) -> if the column does not exsist
        '''
        if col not in self.df.columns.tolist():
            return 'This column does not exsist in data set'
        self.df['logTranforedPrice'] = round(np.log10(df[col] + 1),2)

    def log_tranformation(self,df):

        """
        arg: dataframe(numeric_columns_only)

        function: applying lograthemic transformation on all the numeric columns

        return: None
        """
        for col in df:
            self.df[col]=self.df[col].map(lambda i: np.log(i) if i>0 else 0)

    def comparisionofResults(self, col1, col2):
        '''
            function: comparisionofResults -> shows the visual comaparision of two columns in two bar graph
            arg: col1 (pandas.core.series.Series) -> column of the data set
                 col2 (pandas.core.series.Series) -> column of the data set
            return: None
        '''
        fig, axes = plt.subplots(1, 2, figsize=(14, 4))
        plt.suptitle('Comparision of original price v/s log transformation', fontsize=20)
        sns.histplot(ax=axes[0], x=self.df['Price'], bins=70, kde=True, color=(0.95, 0.1, 0.85))
        axes[0].set_xlabel('Price', fontsize=15)
        axes[0].set_ylabel('Frequency', fontsize=15)
        sns.histplot(ax=axes[1], x=self.df['logTranforedPrice'], bins=50, kde=True, color=(0.2, 0.85, 0.95))
        axes[1].set_xlabel('Log Transformed Price', fontsize=15)
        axes[1].set_ylabel('Frequency', fontsize=15)
        plt.show()

    def labelEncoding(self, column):
        '''
            function: labelEncoding -> performs label encoding on the catagorical columns
            arg: column (pandas.core.indexes.base.Index) -> index of the columns
            return: None
        '''
```

```
        labelEncoder = LabelEncoder()
        for col in column:
            self.df[col] = labelEncoder.fit_transform(self.df[col])
```

In [31]:
```
preprocess = preProcessing(df)
```

In [32]:
```
preprocess.log_tranformation(numcols.drop(columns='Price'))
```

In [33]:
```
preprocess.outlireHandeling('Price')
```

In [34]:
```
preprocess.comparisionofResults('Price', 'logTranforedPrice')
```

In [35]:
```
preprocess.labelEncoding(catCols.drop(columns=['Brand']).columns)
```

In [36]:
```
df.head()
```

Out[36]:

	Name	Brand	Model	Battery capacity (mAh)	Screen size (inches)	Touchscreen	Resolution x	Resolution y	Processor	RAM (MB)	...	Front camera	Operating system	Wi-Fi	Bluetooth	GPS	Number of SIMs	3G	4G/ LTE	Price	logTranforedPrice
0	OnePlus 7T Pro McLaren Edition	OnePlus	49	8.315077	1.897620	1	7.272398	8.045588	2.079442	9.392662	...	2.772589	0	1	1	1	0.693147	1	1	58998	4.77
1	Realme X2 Pro	Realme	1142	8.294050	1.871802	1	6.984716	7.783224	2.079442	8.699515	...	2.772589	0	1	1	1	0.693147	1	1	27999	4.45
2	iPhone 11 Pro Max	Apple	1288	8.286269	1.871802	1	7.124478	7.896553	1.791759	8.294050	...	2.484907	6	1	1	1	0.693147	1	1	106900	5.03
3	iPhone 11	Apple	1286	8.042378	1.808289	1	6.719013	7.491088	1.791759	8.294050	...	2.484907	6	1	1	1	0.693147	1	1	62900	4.80
4	LG G8X ThinQ	LG	522	8.294050	1.856298	1	6.984716	7.757906	2.079442	8.699515	...	3.465736	0	1	1	1	0.000000	0	0	49990	4.70

5 rows × 22 columns

Modelling and testing Pipeline

In [56]:
```
class training_pipeline:
    def __init__(self,df,target,numeric,categorical,req_1,aplha):

        """
        arg: dataframe
        arg: target --> target variable
        arg: numeric --> numeric columns post_pre_processing and feature selection
        arg: req_1 --> required features for feature engineering
        arg: aplha --> alpha value for the regularizarion techniques

        function: class_constructor

        return: None
        """
        self.df=df
        self.target=target
        self.numeric=numeric
        self.categorical=categorical
        self.combining_features_cat=req_1
        self.alpha=aplha
        self.results = []

    def feature_selection(self):
        """
        arg: None

        function: checking the best features present in the dataset using selectKBest

        return: None
        """
        k = 5
        selector = SelectKBest(score_func=f_regression, k=k)
        X_selected = selector.fit_transform(self.X, self.y)
        selected_feature_indices = selector.get_support(indices=True)
        self.selected_features = list(self.X.columns[selected_feature_indices])
        print("="*50)
        print(self.selected_features)
        print("="*50)
    def process_module(self):

        """
        arg: None

        function: creating new feature (dimension reduction), process and traiing pipeline

        return: None
        """
        self.df['latest_tech_stack']=self.df[self.combining_features_cat].all(axis=1).astype(int)
        self.column_to_drop_trainig=['Name','Brand','Model','Touchscreen','Resolution y','Wi-Fi','Bluetooth','GPS','3G','4G/ LTE','Price','logTranforedPrice']
        self.X=self.df.drop(columns=self.column_to_drop_trainig)
        self.y=self.df[self.target]
        self.feature_selection()
        numeric_transformer = Pipeline(steps=[('scaler', StandardScaler())])
        preprocessor = ColumnTransformer(transformers=[('num', numeric_transformer, self.numeric)],remainder='passthrough')
        self.X_train, self.X_test, self.y_train, self.y_test = train_test_split(self.X, self.y, test_size=0.3, random_state=55)
#         print(type(self.X_train))
        models = {'Linear Regression': LinearRegression(),'Random Forest Regressor': RandomForestRegressor(),'Gradient Boosting Regressor': GradientBoostingRegressor(),
                  'Ridge Regression': Ridge(alpha=self.alpha)}
```

```
#        print((self.X_train[:4]))
#        print(type(self.X_train))
        pipeline=Pipeline(steps=[('preprocessor',preprocessor)])
        self.X_train=pipeline.fit_transform(self.X_train)
#        print(self.X_train[:4])
        self.X_test=pipeline.transform(self.X_test)
#        print(self.X_test[:1])
        for model_name,model in models.items():
            self.reg=model
            self.reg.fit(self.X_train,self.y_train)
            self.y_train_pred=self.reg.predict(self.X_train)
            self.y_test_pred=self.reg.predict(self.X_test)

            #evaluation
            train_r2=r2_score(self.y_train,self.y_train_pred).round(3)
            test_r2=r2_score(self.y_test,self.y_test_pred).round(3)
            #eval_mse
            train_mse=mean_squared_error(self.y_train,self.y_train_pred).round(3)
            test_mse=mean_squared_error(self.y_test,self.y_test_pred).round(3)
            #eval_mae
            train_mae=mean_absolute_error(self.y_train,self.y_train_pred).round(3)
            test_mae=mean_absolute_error(self.y_test,self.y_test_pred).round(3)
            self.sorted_=self.post_analysis(model_name)
            result={'model':model_name,'mae_train':train_mae,'mae_test':test_mae,'mse_train':train_mse,'mse_test':test_mse,'train_r2':train_r2,'test_r2':test_r2,'feature_seletion':self.selected_features,'feature
            self.results.append(result)
            self.vis_prediction(model_name)


    def vis_prediction(self,model_name):
        """
        arg: name of the model to be plotted

        function: using scatter plot to visulaise the regression model's prediction

        return: None
        """
        vis_df=pd.DataFrame({'Actual_value':self.y_test,'Prediction':self.y_test_pred})
        fig=px.scatter(vis_df,x='Actual_value',y='Prediction',trendline='ols',title="Performance_{}".format(model_name))
        fig.update_traces(marker=dict(color='blue', size=10))
        fig.update_layout(xaxis=dict(scaleanchor="y",scaleratio=1),yaxis=dict(scaleanchor="x",scaleratio=1))
        fig.show()


        diff_val=pd.DataFrame({'Difference|Error':(self.y_test-self.y_test_pred)})
        fig2=px.histogram(diff_val,x='Difference|Error',title="Erroe_distribution_in_{}".format(model_name),nbins=25,histnorm='probability density')
        fig2.show()



    def tuning_parameters(self):

        """
        arg: None

        function: hyper paramters tuning for the selected models and evaluation of the model resutls

        return: None
        """
        models={'hp_random_forest':{'base':RandomForestRegressor(),'params':{'n_estimators':[50,75,100],'min_samples_split': [2, 5, 10],'max_depth':[2,6,8]}},
               'hp_boosring':{'base':GradientBoostingRegressor(),'params':{'n_estimators':[50,100,120],'learning_rate': [0.01, 0.05, 0.1],'max_depth':[2,4]}},
               'hp_lasso':{'base':Lasso(),'params':{'alpha':[0.005,.03,.02,.1,.5,10,15,12,25]}}}
        for model_name,model in models.items():
```

```python
            search=RandomizedSearchCV(model['base'],model['params'],cv=5,n_iter=3,random_state=42,scoring='neg_mean_squared_error')
            search.fit(self.X_train,self.y_train)
            best=search.best_estimator_
            self.reg=best
            self.y_train_pred=self.reg.predict(self.X_train)
            self.y_test_pred=self.reg.predict(self.X_test)

            #evaluation
            train_r2=r2_score(self.y_train,self.y_train_pred).round(3)
            test_r2=r2_score(self.y_test,self.y_test_pred).round(3)
            #eval_mse
            train_mse=mean_squared_error(self.y_train,self.y_train_pred).round(3)
            test_mse=mean_squared_error(self.y_test,self.y_test_pred).round(3)
            #eval_mae
            train_mae=mean_absolute_error(self.y_train,self.y_train_pred).round(3)
            test_mae=mean_absolute_error(self.y_test,self.y_test_pred).round(3)
            self.sorted_=self.post_analysis(model_name)

            result={'model':model_name,'mae_train':train_mae,'mae_test':test_mae,'mse_train':train_mse,'mse_test':test_mse,'train_r2':train_r2,'test_r2':test_r2,'feature_seletion':self.selected_features,'feature
            self.results.append(result)
            self.vis_prediction(model_name)


    def post_analysis(self,model_name):

        """
        arg: model_name

        function: finding the best feature set used in that particualr model and get the feature importance

        return: list of top 5 important features identified in that particular model
        """
        if model_name in['hp_lasso','Linear Regression','Ridge Regression']:
            imp=self.reg.coef_
            print("="*50)
            print(self.reg.coef_)
            print("="*50)
        else:
            imp=self.reg.feature_importances_
            print("="*50)
            print(self.reg.feature_importances_)
            print("="*50)
        impo=pd.DataFrame({'feature_imp':imp}, index=self.X.columns)
        sorted_=impo.sort_values(by='feature_imp',ascending=False).head(5)
        print("="*50)
        print(sorted_)
        print("="*50)
        return(sorted_.index.tolist())



    def res_comp(self):

        """
        arg: None

        function: initializing and forming dataframe

        return: Evaluation metrics of the trained models
        """
```

```
        return pd.DataFrame(self.results)
```

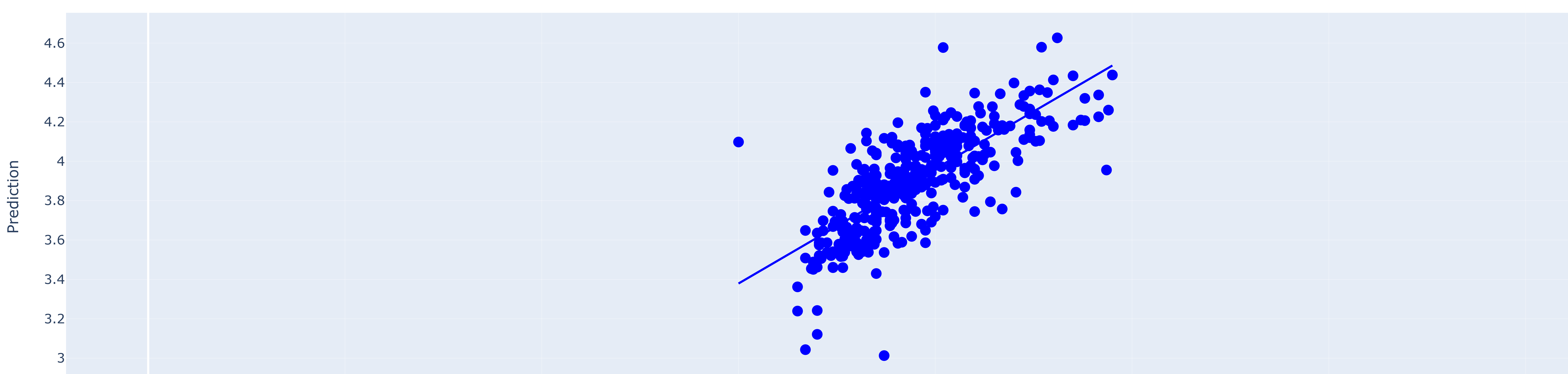
In [38]:
```
numeric=['Battery capacity (mAh)', 'Screen size (inches)', 'Resolution x','Processor', 'RAM (MB)', 'Internal storage (GB)','Rear camera', 'Front camera', 'Number of SIMs']
req_1=['Touchscreen', 'Wi-Fi', 'Bluetooth', 'GPS', '3G', '4G/ LTE']
categorical=['Operating system','latest_tech_stack']
```

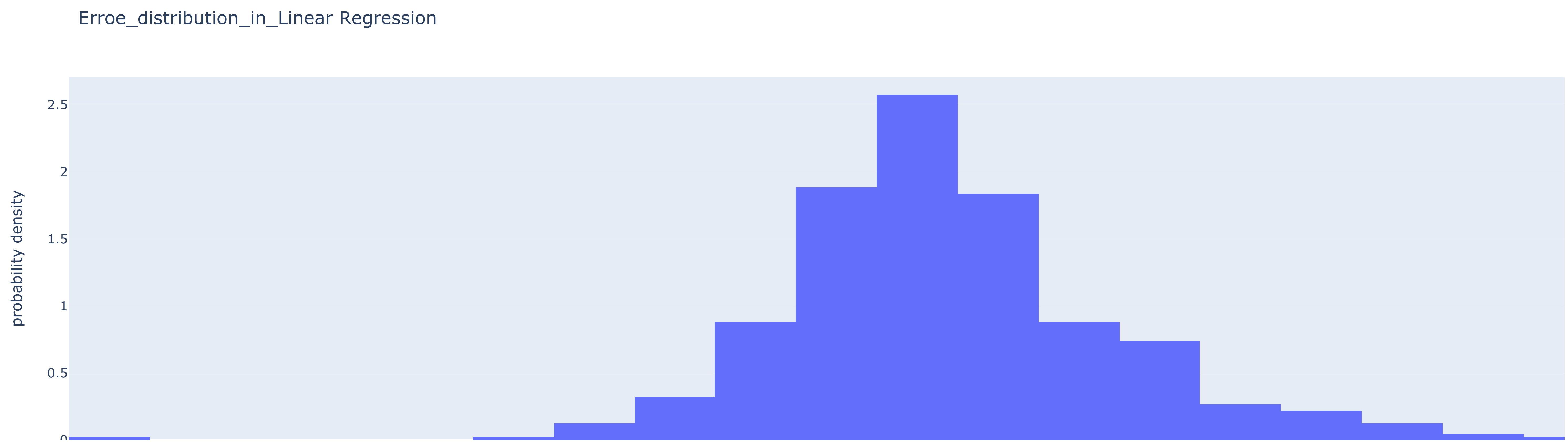
In [39]:
```
model_training=training_pipeline(df,'logTranforedPrice',numeric,categorical,req_1,0.5)
```

In [40]:
```
model_training.process_module()
```

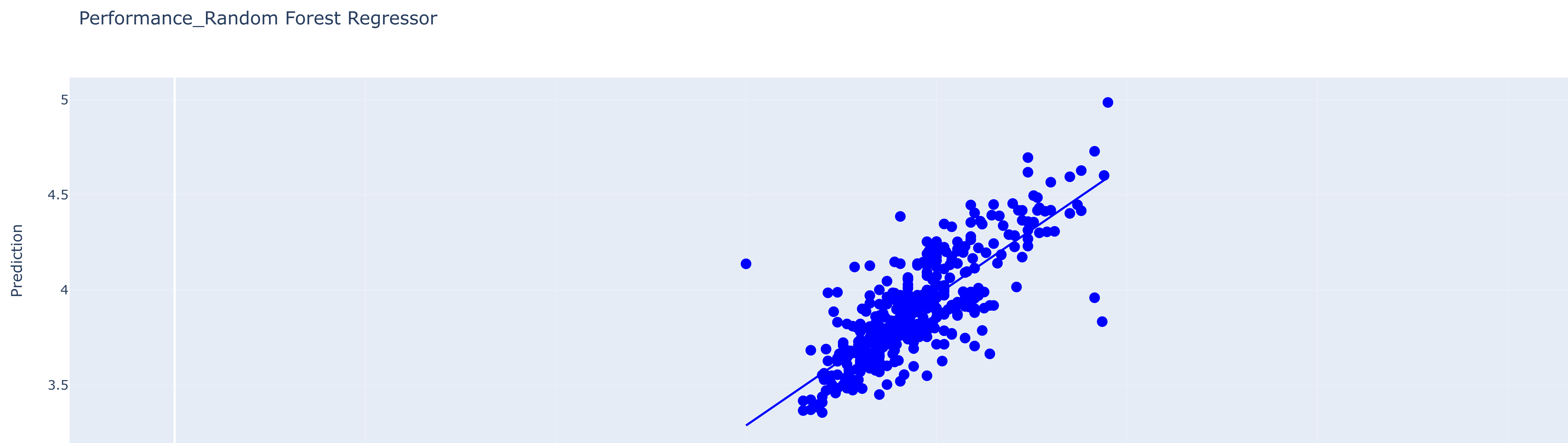
```
==================================================
['Screen size (inches)', 'Resolution x', 'RAM (MB)', 'Internal storage (GB)', 'Rear camera']
==================================================
==================================================
[-0.00752711  0.00379432  0.0980614  -0.01228158  0.06805006  0.08655844
  0.0646392  -0.04580307 -0.02422838  0.06997468 -0.00445728]
==================================================
==================================================
                       feature_imp
Resolution x              0.098061
Internal storage (GB)     0.086558
Number of SIMs            0.069975
RAM (MB)                  0.068050
Rear camera               0.064639
==================================================
```

Performance_Linear Regression

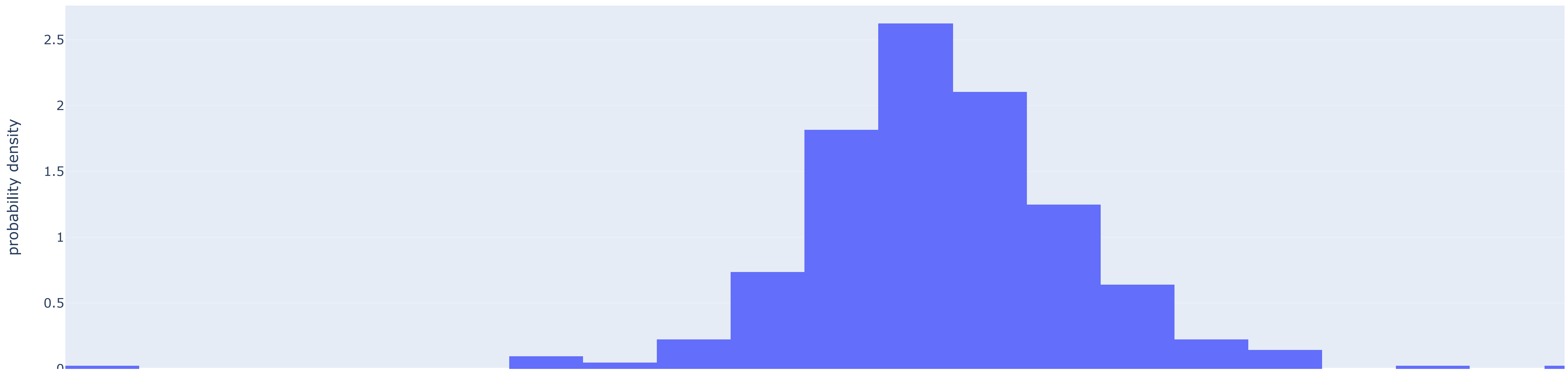




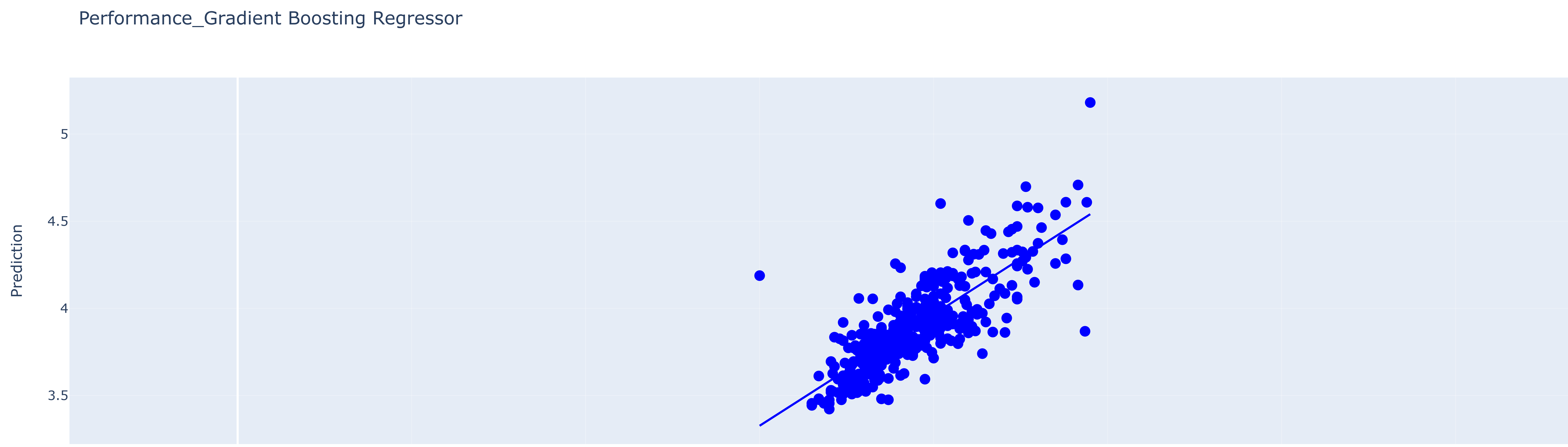

```
=================================================
[0.0855317  0.07075047 0.38879811 0.01713633 0.05739335 0.1384669
 0.1199177  0.0501595  0.02597798 0.02808621 0.01778174]
=================================================
=================================================
                        feature_imp
Resolution x               0.388798
Internal storage (GB)      0.138467
Rear camera                0.119918
Battery capacity (mAh)     0.085532
Screen size (inches)       0.070750
=================================================
```

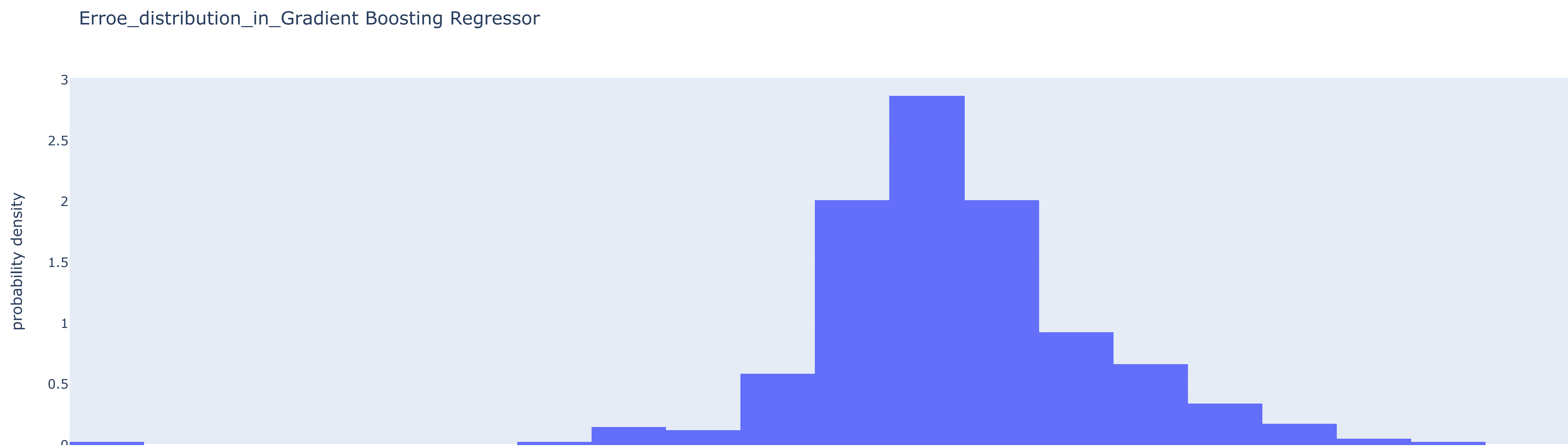

Performance_Random Forest Regressor
Prediction
5
4.5
4
3.5

Erroe_distribution_in_Random Forest Regressor

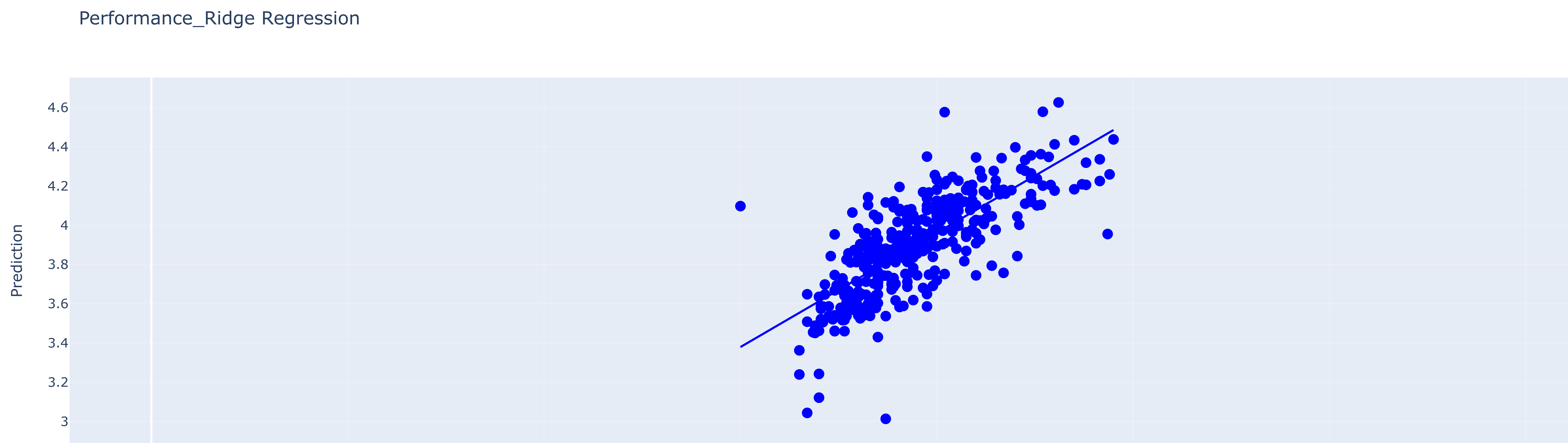



```
=================================================
[0.02549355 0.05748023 0.40347871 0.00762385 0.06038851 0.21555076
 0.12567797 0.02744723 0.02681855 0.0411807  0.00885993]
=================================================
=================================================
                       feature_imp
Resolution x              0.403479
Internal storage (GB)     0.215551
Rear camera               0.125678
RAM (MB)                  0.060389
Screen size (inches)      0.057480
=================================================
```


Performance_Gradient Boosting Regressor
Prediction
5
4.5
4
3.5




```
================================================
[-0.0074969   0.00384051  0.09798517 -0.01224427  0.06802842  0.0864571
  0.06457587 -0.04567981 -0.02425631  0.06995006 -0.00440495]
================================================
================================================
                      feature_imp
Resolution x             0.097985
Internal storage (GB)    0.086457
Number of SIMs           0.069950
RAM (MB)                 0.068028
Rear camera              0.064576
================================================
```


Performance_Ridge Regression
Prediction
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3

Erroe_distribution_in_Ridge Regression

In [41]:
```
# model_training.vis_prediction()
```

In [42]:
```
model_training.res_comp()
```

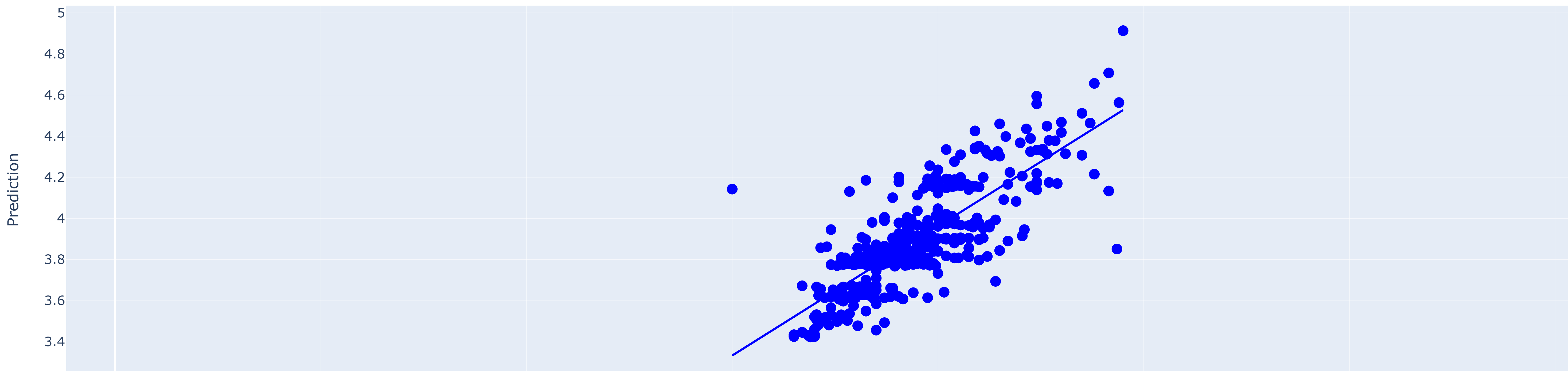
Out[42]:

	model	mae_train	mae_test	mse_train	mse_test	train_r2	test_r2	feature_seletion	feature_importance
0	Linear Regression	0.161	0.153	0.046	0.044	0.596	0.566	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...
1	Random Forest Regressor	0.060	0.137	0.007	0.036	0.940	0.638	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
2	Gradient Boosting Regressor	0.119	0.138	0.024	0.036	0.783	0.639	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
3	Ridge Regression	0.161	0.153	0.046	0.044	0.596	0.566	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...

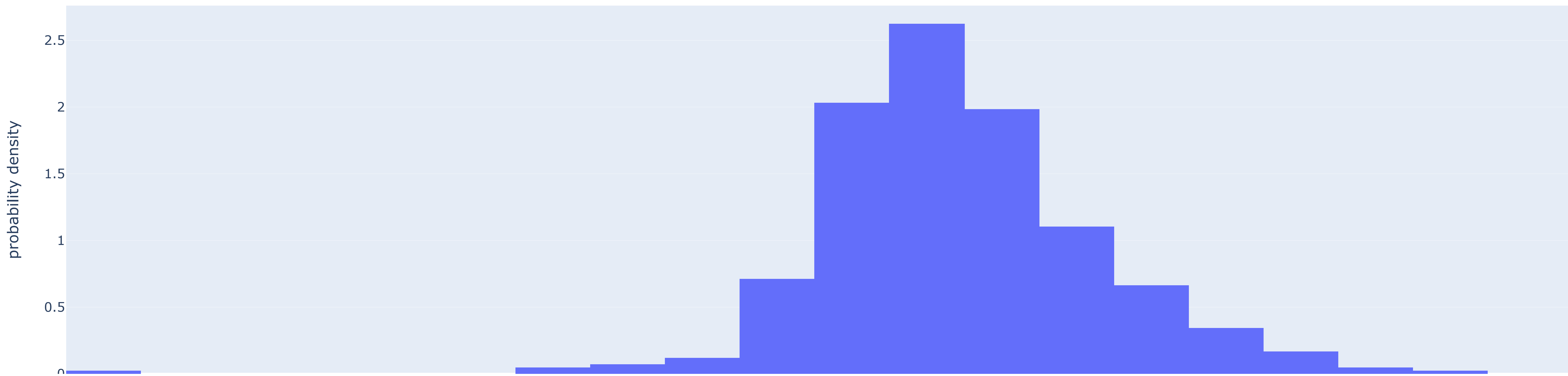
In [43]:
```
model_training.tuning_parameters()
```

```
==================================================
[0.02476721 0.05113026 0.44706005 0.01195384 0.04524952 0.19561535
 0.13224953 0.02883651 0.02755936 0.02674589 0.0088325 ]
==================================================
==================================================
                       feature_imp
Resolution x              0.447060
Internal storage (GB)     0.195615
Rear camera               0.132250
Screen size (inches)      0.051130
RAM (MB)                  0.045250
==================================================
```

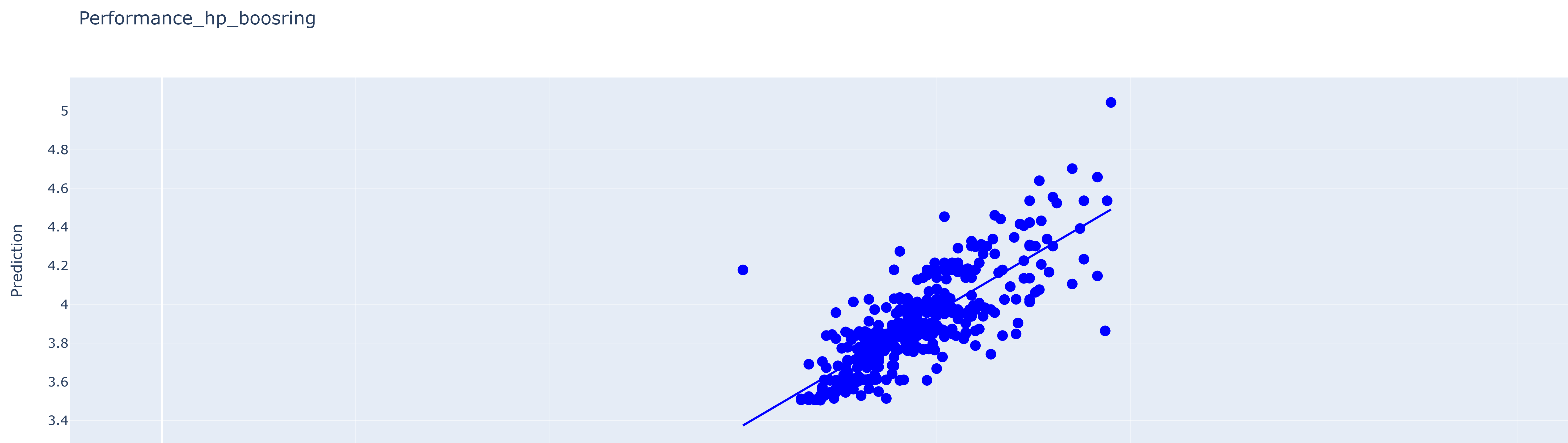
Performance_hp_random_forest



Erroe_distribution_in_hp_random_forest

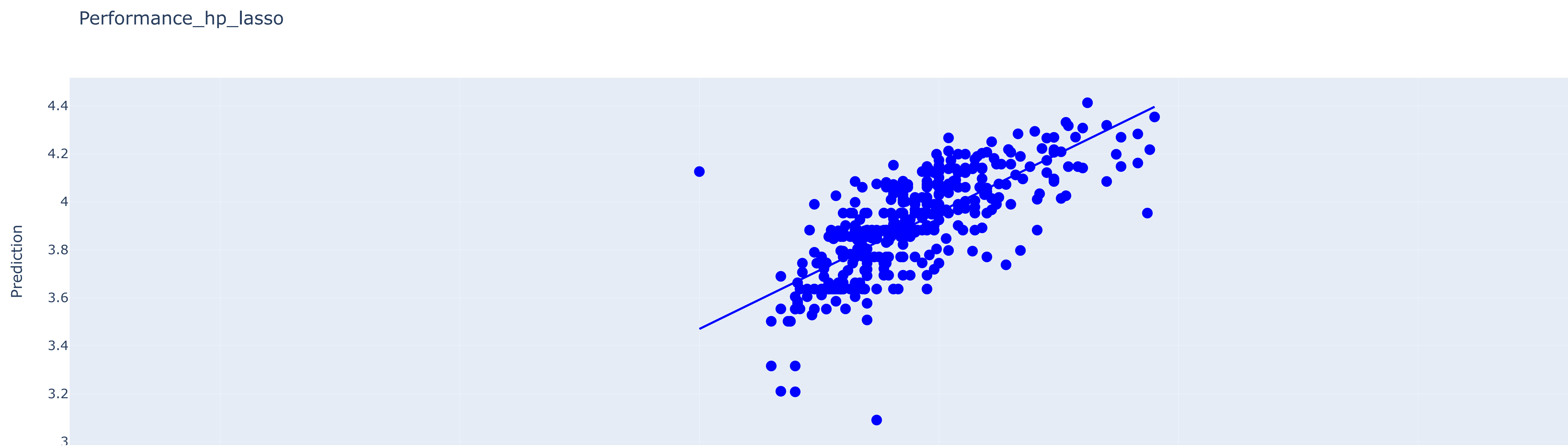



```
==================================================
[0.0051948  0.03716111 0.44001711 0.00046903 0.07689935 0.21266682
 0.14928501 0.00906831 0.01616858 0.05097666 0.00209323]
==================================================
==================================================
                       feature_imp
Resolution x              0.440017
Internal storage (GB)     0.212667
Rear camera               0.149285
RAM (MB)                  0.076899
Number of SIMs            0.050977
==================================================
```

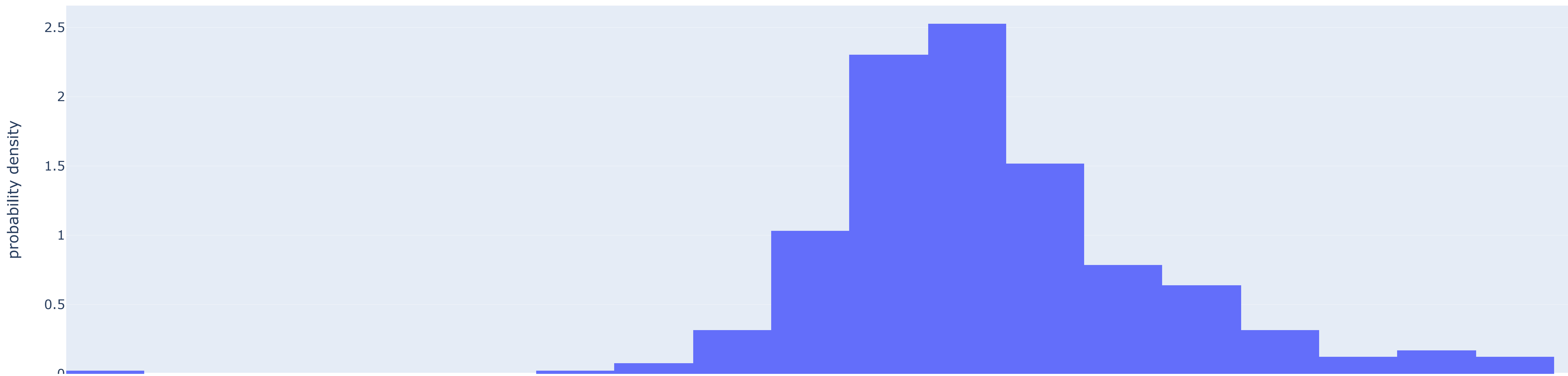

Performance_hp_boosring
Prediction
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4

Erroe_distribution_in_hp_boosring


```
================================================
[ 0.          0.          0.09003228  0.          0.03329687  0.07302402
  0.03473639  0.         -0.00899807  0.04554479  0.        ]
================================================
================================================
                       feature_imp
Resolution x              0.090032
Internal storage (GB)     0.073024
Number of SIMs            0.045545
Rear camera               0.034736
RAM (MB)                  0.033297
================================================
```


Performance_hp_lasso
Prediction
4.4
4.2
4
3.8
3.6
3.4
3.2
3

Erroe_distribution_in_hp_lasso



In [44]:
```
results=model_training.res_comp()
```

In [55]:
```
results
```

Out[55]:

model	mae_train	mae_test	mse_train	mse_test	train_r2	test_r2	feature_seletion	feature_importance
Linear Regression	0.161	0.153	0.046	0.044	0.596	0.566	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...
Random Forest Regressor	0.060	0.137	0.007	0.036	0.940	0.638	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
Gradient Boosting Regressor	0.119	0.138	0.024	0.036	0.783	0.639	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
Ridge Regression	0.161	0.153	0.046	0.044	0.596	0.566	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...
hp_random_forest	0.120	0.139	0.025	0.036	0.781	0.640	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
hp_boosring	0.138	0.143	0.033	0.038	0.704	0.618	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
hp_lasso	0.165	0.158	0.049	0.045	0.565	0.550	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...

Validation and inference

In [45]:
```
results.iloc[:,:-2]
```

Out[45]:

	model	mae_train	mae_test	mse_train	mse_test	train_r2	test_r2
0	Linear Regression	0.161	0.153	0.046	0.044	0.596	0.566
1	Random Forest Regressor	0.060	0.137	0.007	0.036	0.940	0.638
2	Gradient Boosting Regressor	0.119	0.138	0.024	0.036	0.783	0.639
3	Ridge Regression	0.161	0.153	0.046	0.044	0.596	0.566
4	hp_random_forest	0.120	0.139	0.025	0.036	0.781	0.640
5	hp_boosring	0.138	0.143	0.033	0.038	0.704	0.618
6	hp_lasso	0.165	0.158	0.049	0.045	0.565	0.550

In [57]:

```
class inference:
    def __init__(self,data):
        """
        arg: data --> dataframe to be visulalised and compared

        function: class constructor

        return: None
        """
        self.df=data

    def feature_understanding(self):
        """
        arg: None

        function: concatinating the feature importance and feature selection columns to check for the match values

        aim :  to verify the feature selection by validating the important features of various model

        return: dataframe consists of model name, feature importance and feature selection before training (reference)
        """
        self.exp1=self.df.iloc[:,0]
        self.exp2=self.df.iloc[:,[-2,-1]]
        return(pd.concat([self.exp1,self.exp2],axis=1))

    def general_plot(self,x):

        """
        arg: scoring metric to be plotted

        function: plotting bar graph to check the scoring and evaluation metrics for various models

        return: None
        """
        df=self.df

        if df.index.name!='model':
            df.set_index('model',inplace=True)
        df[x].plot(kind='barh',figsize=(14,7))
        plt.show()

    def sort_plot(self,x,y):

        """
        arg: x--> train set metrics
        arg: y --> test set metrics
```

```
        function: unstacked bar chart to compare the model performance and indentify the overfitting and underfitting cases


        return: None
        """
        comp=self.df[[x,y]].plot(kind='bar',stacked=False,figsize=(12,6))
        plt.title('Comprasion of {} vs {}'.format(x,y))
        plt.xlabel('Model')
        plt.xticks(rotation=45, ha='right')

        plt.show()

    def plotyy(self,x,y):

        """
        arg: x--> train set metrics
        arg: y --> test set metrics


        function: interactive bar graph to closely analyse the results

        return: None
        """
        unstacked = self.df.reset_index().melt(id_vars='model', value_vars=[x, y], var_name='type', value_name='values')
        fig = px.bar(unstacked, x='model', y='values', color='type', barmode='group', )
        fig.show()
```

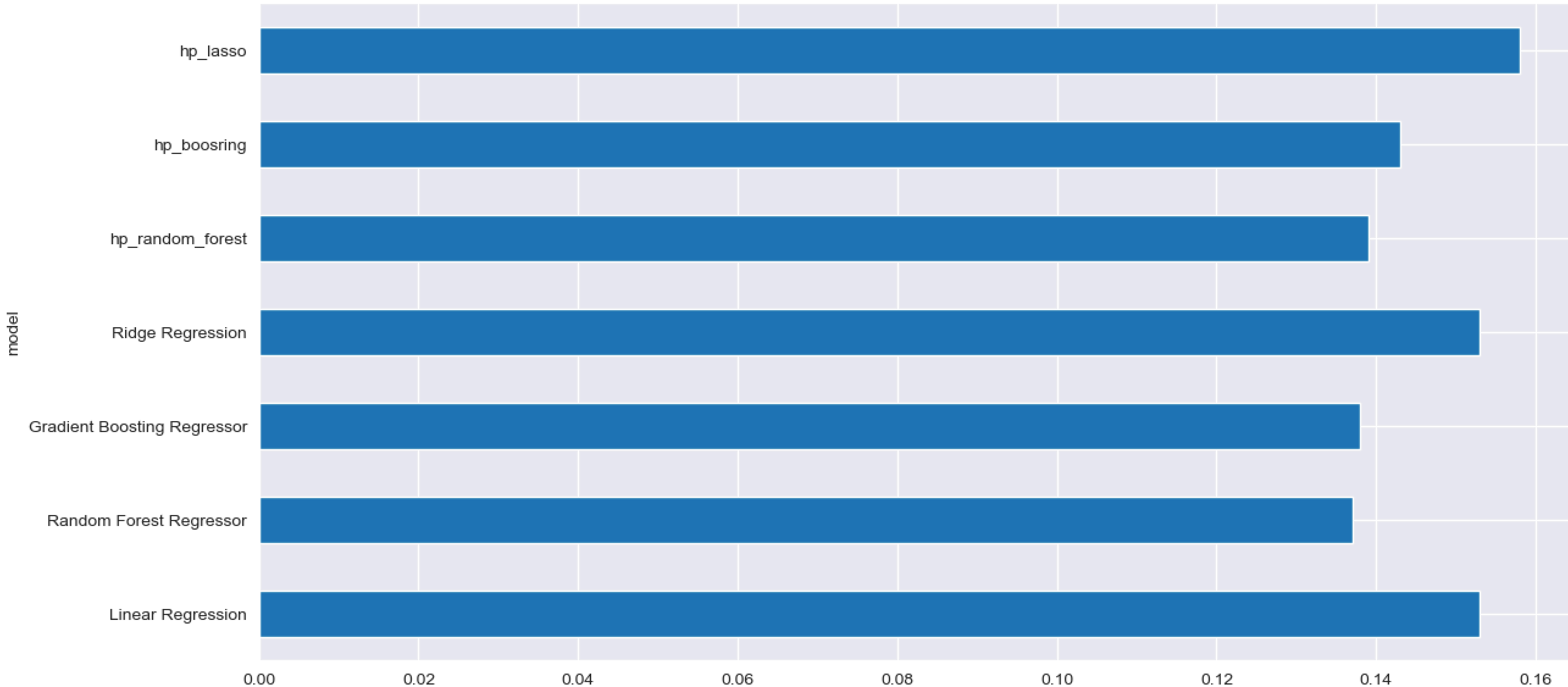
In [47]:
```
inf_=inference(results)
```

In [48]:
```
inf_.feature_understanding()
```

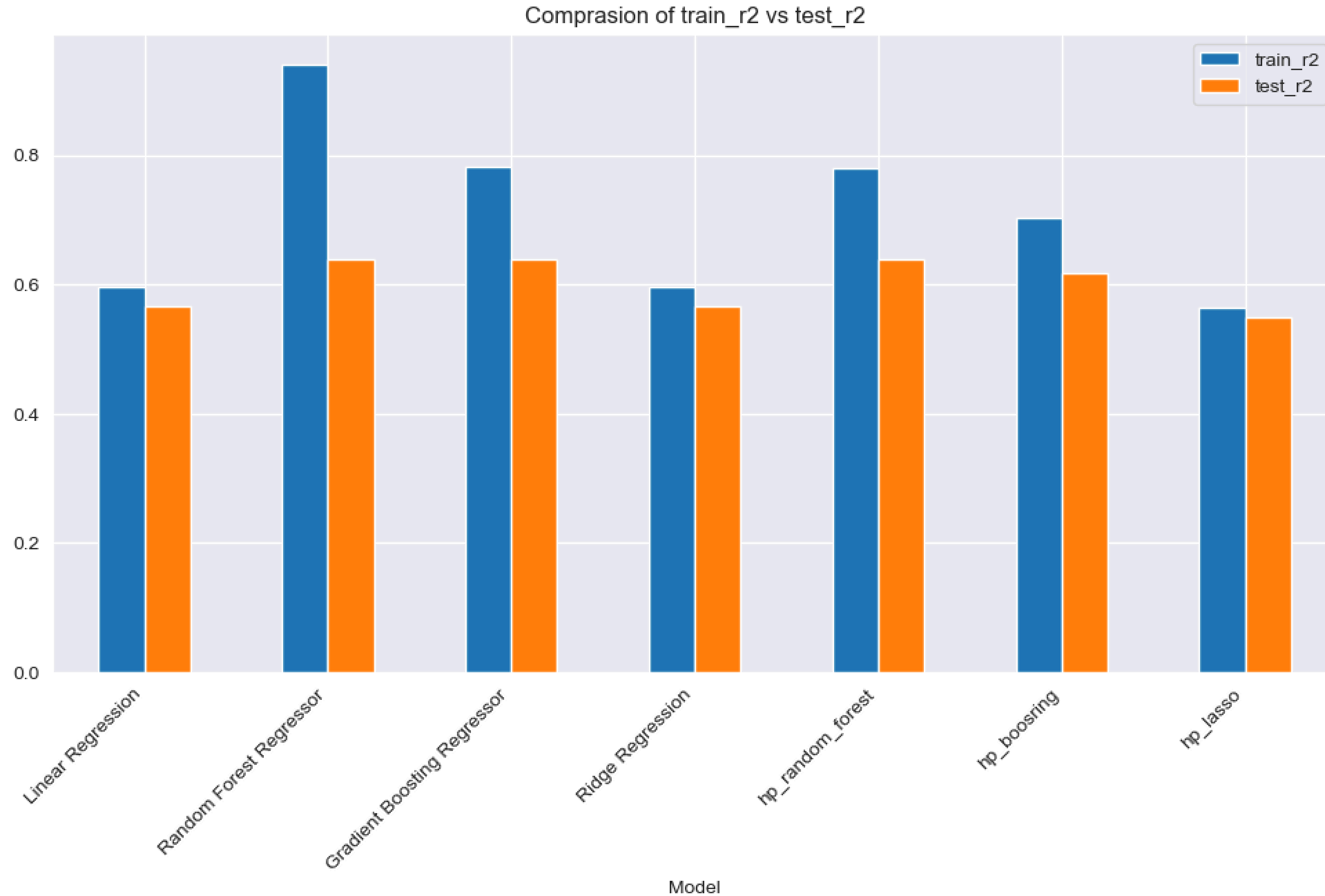
Out[48]:

	model	feature_seletion	feature_importance
0	Linear Regression	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...
1	Random Forest Regressor	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
2	Gradient Boosting Regressor	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
3	Ridge Regression	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...
4	hp_random_forest	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
5	hp_boosring	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Rear cam...
6	hp_lasso	[Screen size (inches), Resolution x, RAM (MB),...	[Resolution x, Internal storage (GB), Number o...

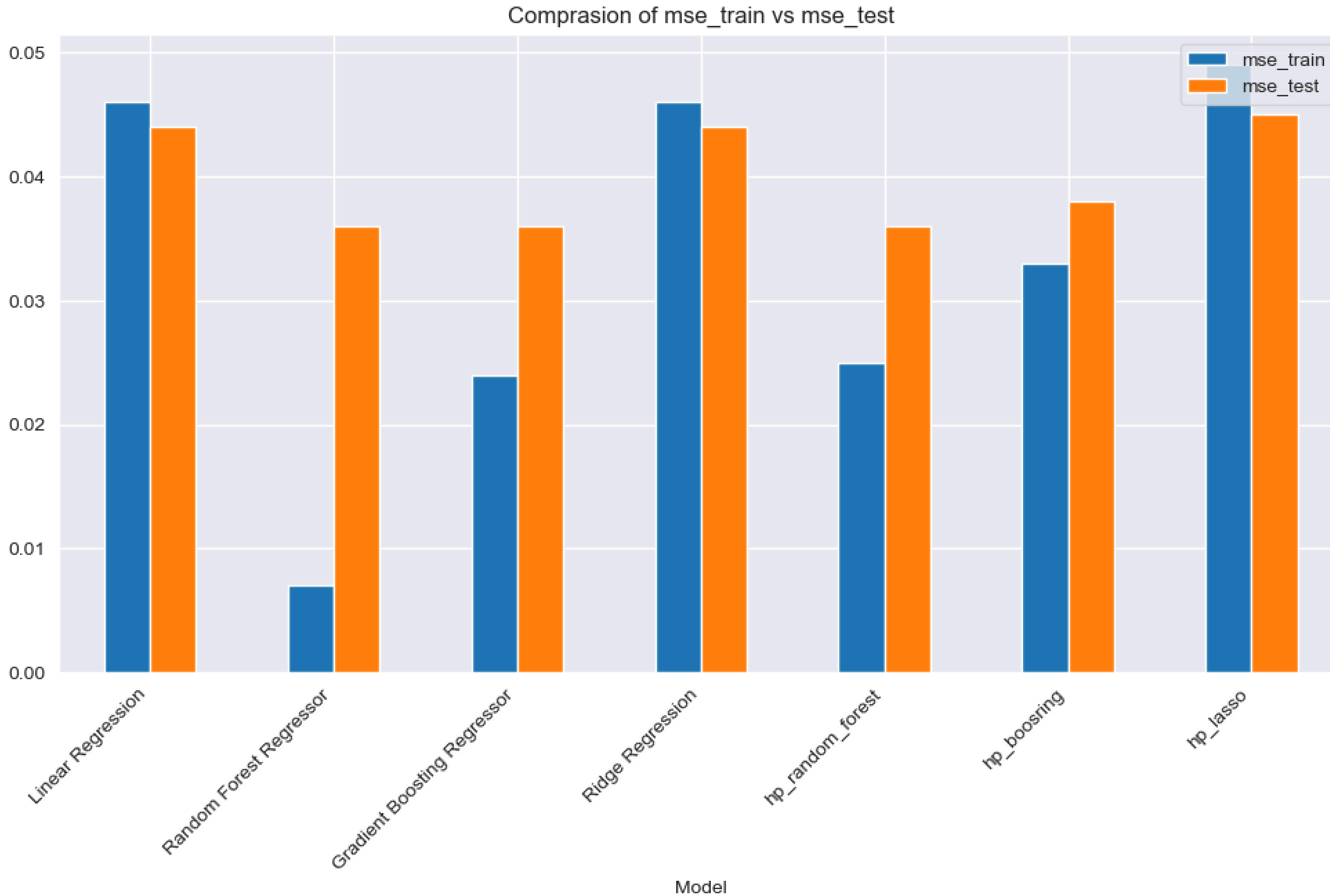
In [49]:
```
inf_.general_plot('mae_test')
```



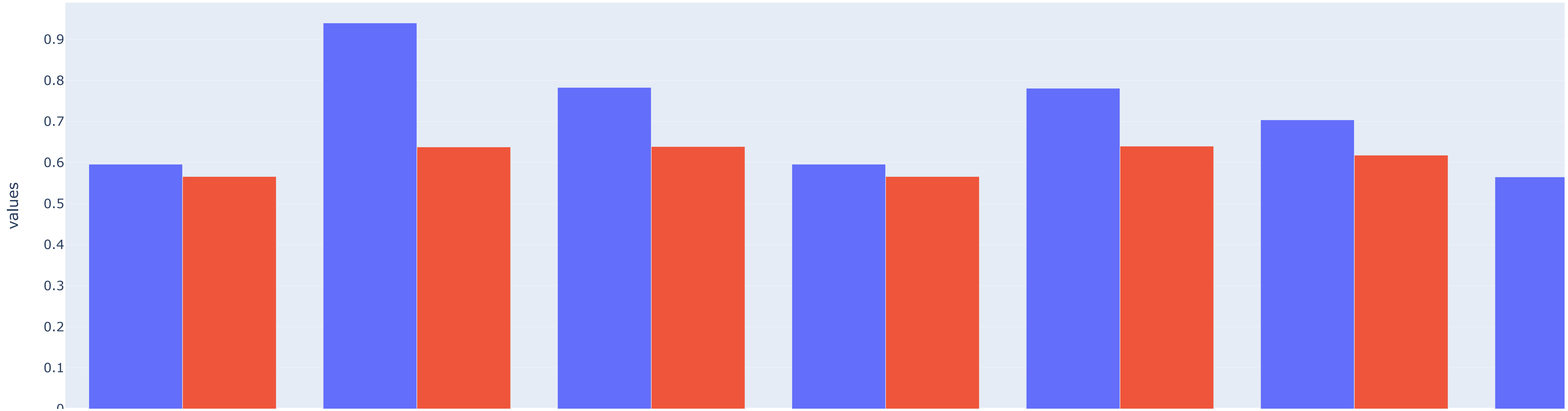
In [50]:
```
inf_.sort_plot('train_r2','test_r2')
```



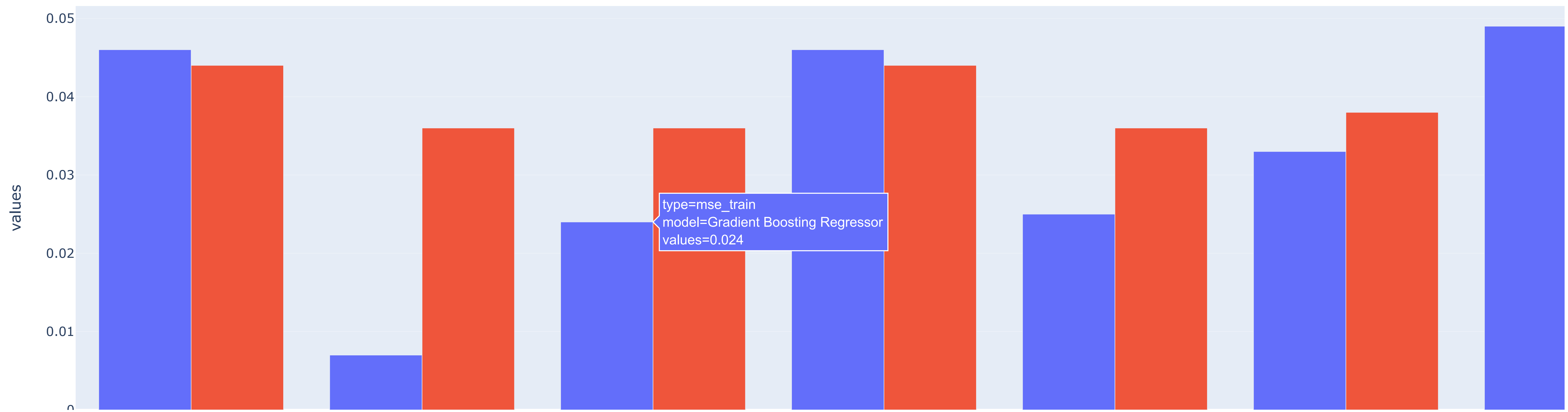
In [51]:
```
inf_.sort_plot('mse_train','mse_test')
```



In [52]:
```
inf_.plotyy('train_r2','test_r2')
```



In [53]:
```
inf_.plotyy('mse_train','mse_test')
```



In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]: