CIND820_Capstone_Project

June 26, 2023

0.1 CIND820 - Capstone Project

1 Investigate Airline passenger satisfaction using Machine Learning Techniques

2 Preparation:

[ ]:

```
! python -V
```

```
Python 3.10.12
```

Import csv file (the dataset and the data dictionary)

[1]:

```
# Importing required libraries

import pandas as pd

import numpy as np
import seaborn as sns
from matplotlib import pyplot as plt

from sklearn.model_selection import train_test_split

from sklearn import preprocessing
```

[2]:

```
# Import the dataset
# Use first column "ID" as Index by using index_col=0

url = 'https://raw.githubusercontent.com/HitomiMo/CIND820_Capstone-Project/main/
  ↪airline_passenger_satisfaction.csv'
df1 = pd.read_csv(url, index_col=0)
df1.head()
```

[2]:

```
    Gender  Age Customer Type Type of Travel     Class  Flight Distance  \
ID
1     Male   48    First-time       Business  Business              821
2   Female   35     Returning       Business  Business              821
3     Male   41     Returning       Business  Business              853
```

```
4     Male   50     Returning       Business  Business             1905
5   Female   49     Returning       Business  Business             3470

    Departure Delay  Arrival Delay  Departure and Arrival Time Convenience  \
ID
1                 2            5.0                                       3
2                26           39.0                                       2
3                 0            0.0                                       4
4                 0            0.0                                       2
5                 0            1.0                                       3

    Ease of Online Booking  …  On-board Service  Seat Comfort  \
ID                          …
1                        3  …                 3             5
2                        2  …                 5             4
3                        4  …                 3             5
4                        2  …                 5             5
5                        3  …                 3             4

    Leg Room Service  Cleanliness  Food and Drink  In-flight Service  \
ID
1                  2            5               5                  5
2                  5            5               3                  5
3                  3            5               5                  3
4                  5            4               4                  5
5                  4            5               4                  3

    In-flight Wifi Service  In-flight Entertainment  Baggage Handling  \
ID
1                        3                        5                 5
2                        2                        5                 5
3                        4                        3                 3
4                        2                        5                 5
5                        3                        3                 3

               Satisfaction
ID
1   Neutral or Dissatisfied
2                 Satisfied
3                 Satisfied
4                 Satisfied
5                 Satisfied

[5 rows x 23 columns]
```

[ ]:

```
# Import the dictionary
```

```python
url2 = 'https://raw.githubusercontent.com/HitomiMo/CIND820_Capstone-Project/
 ↪main/data_dictionary.csv'
data_dictionary = pd.read_csv(url2, index_col=0)
data_dictionary
```

[ ]:

```
Description
Field
ID                                                            Unique passenger
identifier
Gender                                              Gender of the passenger
(Female/Male)
Age                                                                  Age of the
passenger
Customer Type                             Type of airline customer (First-
time/Returning)
Type of Travel                                  Purpose of the flight
(Business/Personal)
Class                                   Travel class in the airplane for the
passenger…
Flight Distance                                                  Flight distance
in miles
Departure Delay                                         Flight departure delay
in minutes
Arrival Delay                                             Flight arrival delay
in minutes
Departure and Arrival Time Convenience  Satisfaction level with the convenience
of the…
Ease of Online Booking                  Satisfaction level with the online
booking exp…
Check-in Service                        Satisfaction level with the check-in
service f…
Online Boarding                         Satisfaction level with the online
boarding ex…
Gate Location                           Satisfaction level with the gate
location in t…
On-board Service                        Satisfaction level with the on-boarding
servic…
Seat Comfort                            Satisfaction level with the comfort of
the air…
Leg Room Service                        Satisfaction level with the leg room of
the ai…
Cleanliness                             Satisfaction level with the cleanliness
of the…
Food and Drink                          Satisfaction level with the food and
drinks on…
In-flight Service                       Satisfaction level with the in-flight
service …
```

```
In-flight Wifi Service                  Satisfaction level with the in-flight
Wifi ser…
In-flight Entertainment                 Satisfaction level with the in-flight
entertai…
Baggage Handling                        Satisfaction level with the baggage
handling f…
Satisfaction                            Overall satisfaction level with the
airline (S…
```

3 Exploratory Data Analysis (EDA)

Install pandas-profiling

```
[ ]: pip install pandas-profiling
```

```
[ ]: from pandas_profiling import ProfileReport
     prof = ProfileReport(df1)
     prof.to_file(output_file='output.html')
```

```
Summarize dataset:   0%|          | 0/5 [00:00<?, ?it/s]

Generate report structure:   0%|          | 0/1 [00:00<?, ?it/s]

Render HTML:   0%|          | 0/1 [00:00<?, ?it/s]

Export report to file:   0%|          | 0/1 [00:00<?, ?it/s]
```

```
[ ]: df1.head(10)
```

```
[ ]:     Gender  Age Customer Type Type of Travel     Class  Flight Distance  \
     ID
     1     Male   48    First-time       Business  Business              821
     2   Female   35     Returning       Business  Business              821
     3     Male   41     Returning       Business  Business              853
     4     Male   50     Returning       Business  Business             1905
     5   Female   49     Returning       Business  Business             3470
     6     Male   43     Returning       Business  Business             3788
     7     Male   43     Returning       Business  Business             1963
     8   Female   60     Returning       Business  Business              853
     9     Male   50     Returning       Business  Business             2607
     10  Female   38     Returning       Business  Business             2822

         Departure Delay  Arrival Delay  Departure and Arrival Time Convenience  \
     ID
     1                 2            5.0                                       3
     2                26           39.0                                       2
     3                 0            0.0                                       4
     4                 0            0.0                                       2
```

```
5                 0            1.0                                       3
6                 0            0.0                                       4
7                 0            0.0                                       3
8                 0            3.0                                       3
9                 0            0.0                                       1
10               13            0.0                                       2

    Ease of Online Booking  …  On-board Service  Seat Comfort  \
ID                          …                                   
1                        3  …                 3             5   
2                        2  …                 5             4   
3                        4  …                 3             5   
4                        2  …                 5             5   
5                        3  …                 3             4   
6                        4  …                 4             4   
7                        3  …                 5             5   
8                        4  …                 3             4   
9                        1  …                 4             3   
10                       5  …                 5             4   

    Leg Room Service  Cleanliness  Food and Drink  In-flight Service  \
ID                                                                     
1                  2            5               5                  5   
2                  5            5               3                  5   
3                  3            5               5                  3   
4                  5            4               4                  5   
5                  4            5               4                  3   
6                  4            3               3                  4   
7                  5            4               5                  5   
8                  4            4               4                  3   
9                  4            3               3                  4   
10                 5            4               2                  5   

    In-flight Wifi Service  In-flight Entertainment  Baggage Handling  \
ID                                                                      
1                        3                        5                 5   
2                        2                        5                 5   
3                        4                        3                 3   
4                        2                        5                 5   
5                        3                        3                 3   
6                        4                        4                 4   
7                        3                        5                 5   
8                        4                        3                 3   
9                        4                        4                 4   
10                       2                        5                 5   

               Satisfaction
```

```
ID
1   Neutral or Dissatisfied
2                 Satisfied
3                 Satisfied
4                 Satisfied
5                 Satisfied
6                 Satisfied
7                 Satisfied
8                 Satisfied
9   Neutral or Dissatisfied
10                Satisfied

[10 rows x 23 columns]
```

Check the dataset

[ ]:

```
df1.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 129880 entries, 1 to 129880
Data columns (total 23 columns):
 #   Column                                  Non-Null Count   Dtype
---  ------                                  --------------   -----
 0   Gender                                  129880 non-null  object
 1   Age                                     129880 non-null  int64
 2   Customer Type                           129880 non-null  object
 3   Type of Travel                          129880 non-null  object
 4   Class                                   129880 non-null  object
 5   Flight Distance                         129880 non-null  int64
 6   Departure Delay                         129880 non-null  int64
 7   Arrival Delay                           129487 non-null  float64
 8   Departure and Arrival Time Convenience  129880 non-null  int64
 9   Ease of Online Booking                  129880 non-null  int64
 10  Check-in Service                        129880 non-null  int64
 11  Online Boarding                         129880 non-null  int64
 12  Gate Location                           129880 non-null  int64
 13  On-board Service                        129880 non-null  int64
 14  Seat Comfort                            129880 non-null  int64
 15  Leg Room Service                        129880 non-null  int64
 16  Cleanliness                             129880 non-null  int64
 17  Food and Drink                          129880 non-null  int64
 18  In-flight Service                       129880 non-null  int64
 19  In-flight Wifi Service                  129880 non-null  int64
 20  In-flight Entertainment                 129880 non-null  int64
 21  Baggage Handling                        129880 non-null  int64
 22  Satisfaction                            129880 non-null  object
dtypes: float64(1), int64(17), object(5)
memory usage: 23.8+ MB
```

Observation: * Number of variable: 23 * Number of entries: 129880

Check missing data

[ ]:

```
missing_values = pd.isnull(df1)
missing_values.head()
```

[ ]:

```
    Gender    Age  Customer Type  Type of Travel  Class  Flight Distance  \
ID
1    False  False          False           False  False            False
2    False  False          False           False  False            False
3    False  False          False           False  False            False
4    False  False          False           False  False            False
5    False  False          False           False  False            False

    Departure Delay  Arrival Delay  Departure and Arrival Time Convenience  \
ID
1             False          False                                   False
2             False          False                                   False
3             False          False                                   False
4             False          False                                   False
5             False          False                                   False

    Ease of Online Booking  …  On-board Service  Seat Comfort  \
ID                          …
1                    False  …             False         False
2                    False  …             False         False
3                    False  …             False         False
4                    False  …             False         False
5                    False  …             False         False

    Leg Room Service  Cleanliness  Food and Drink  In-flight Service  \
ID
1              False        False           False              False
2              False        False           False              False
3              False        False           False              False
4              False        False           False              False
5              False        False           False              False

    In-flight Wifi Service  In-flight Entertainment  Baggage Handling  \
ID
1                    False                    False             False
2                    False                    False             False
3                    False                    False             False
4                    False                    False             False
5                    False                    False             False

    Satisfaction
```

```
ID
1          False
2          False
3          False
4          False
5          False

[5 rows x 23 columns]
```

```
[ ]: df1.isnull().sum()
```

```
[ ]: Gender                                       0
     Age                                          0
     Customer Type                                0
     Type of Travel                               0
     Class                                        0
     Flight Distance                              0
     Departure Delay                              0
     Arrival Delay                              393
     Departure and Arrival Time Convenience       0
     Ease of Online Booking                       0
     Check-in Service                             0
     Online Boarding                              0
     Gate Location                                0
     On-board Service                             0
     Seat Comfort                                 0
     Leg Room Service                             0
     Cleanliness                                  0
     Food and Drink                               0
     In-flight Service                            0
     In-flight Wifi Service                       0
     In-flight Entertainment                      0
     Baggage Handling                             0
     Satisfaction                                 0
     dtype: int64
```

Check description of the data

```
[ ]: df1.describe()
```

```
[ ]:                  Age  Flight Distance  Departure Delay  Arrival Delay  \
     count  129880.000000    129880.000000    129880.000000  129487.000000
     mean       39.427957      1190.316392        14.713713      15.091129
     std        15.119360       997.452477        38.071126      38.465650
     min         7.000000        31.000000         0.000000       0.000000
     25%        27.000000       414.000000         0.000000       0.000000
     50%        40.000000       844.000000         0.000000       0.000000
```

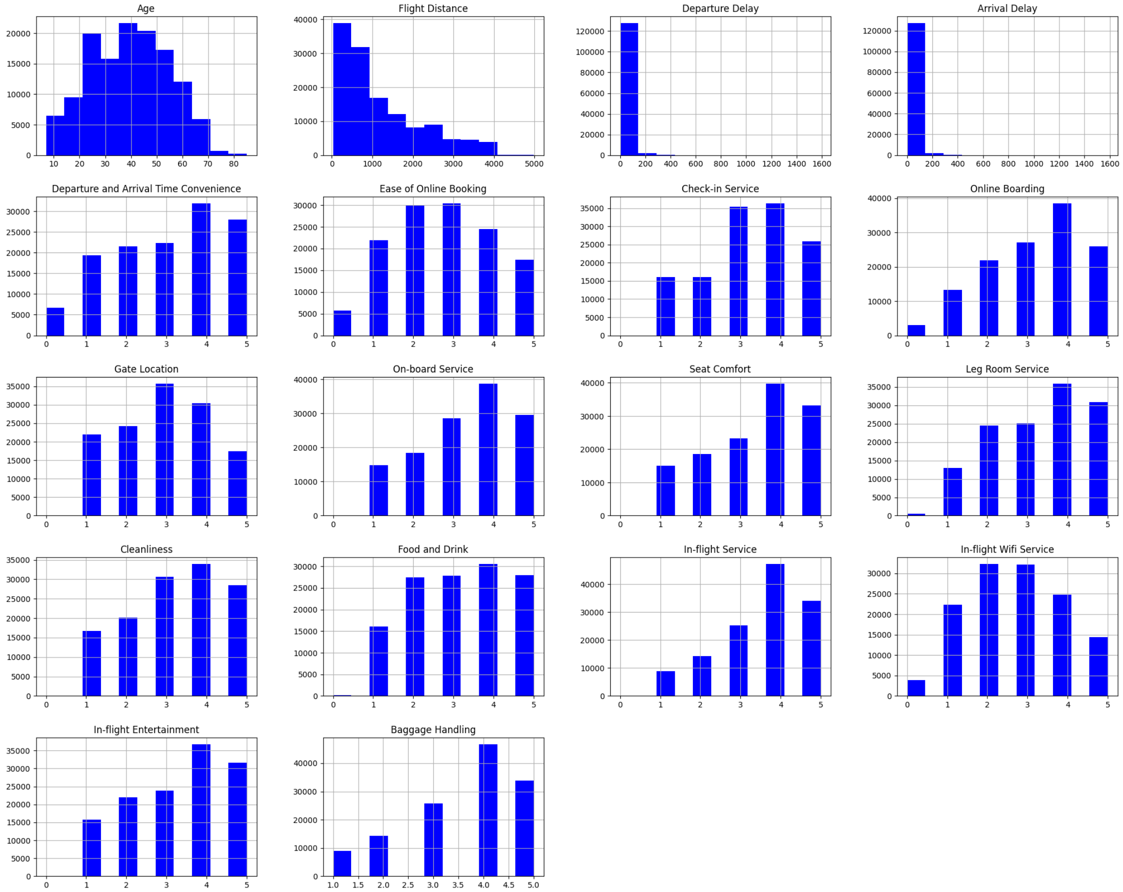
```
75%        51.000000      1744.000000        12.000000      13.000000
max        85.000000      4983.000000      1592.000000      1584.000000

       Departure and Arrival Time Convenience  Ease of Online Booking  \
count                           129880.000000           129880.000000
mean                                 3.057599                2.756876
std                                  1.526741                1.401740
min                                  0.000000                0.000000
25%                                  2.000000                2.000000
50%                                  3.000000                3.000000
75%                                  4.000000                4.000000
max                                  5.000000                5.000000

       Check-in Service  Online Boarding  Gate Location  On-board Service  \
count     129880.000000    129880.000000  129880.000000     129880.000000
mean           3.306267         3.252633       2.976925          3.383023
std            1.266185         1.350719       1.278520          1.287099
min            0.000000         0.000000       0.000000          0.000000
25%            3.000000         2.000000       2.000000          2.000000
50%            3.000000         3.000000       3.000000          4.000000
75%            4.000000         4.000000       4.000000          4.000000
max            5.000000         5.000000       5.000000          5.000000

        Seat Comfort  Leg Room Service    Cleanliness  Food and Drink  \
count  129880.000000     129880.000000  129880.000000   129880.000000
mean        3.441361          3.350878       3.286326        3.204774
std         1.319289          1.316252       1.313682        1.329933
min         0.000000          0.000000       0.000000        0.000000
25%         2.000000          2.000000       2.000000        2.000000
50%         4.000000          4.000000       3.000000        3.000000
75%         5.000000          4.000000       4.000000        4.000000
max         5.000000          5.000000       5.000000        5.000000

       In-flight Service  In-flight Wifi Service  In-flight Entertainment  \
count      129880.000000           129880.000000            129880.000000
mean            3.642193                2.728696                 3.358077
std             1.176669                1.329340                 1.334049
min             0.000000                0.000000                 0.000000
25%             3.000000                2.000000                 2.000000
50%             4.000000                3.000000                 4.000000
75%             5.000000                4.000000                 4.000000
max             5.000000                5.000000                 5.000000

       Baggage Handling
count     129880.000000
mean           3.632114
std            1.180025
```

```
min              1.000000
25%              3.000000
50%              4.000000
75%              5.000000
max              5.000000
```

Check distribution of numerical variables in histgram

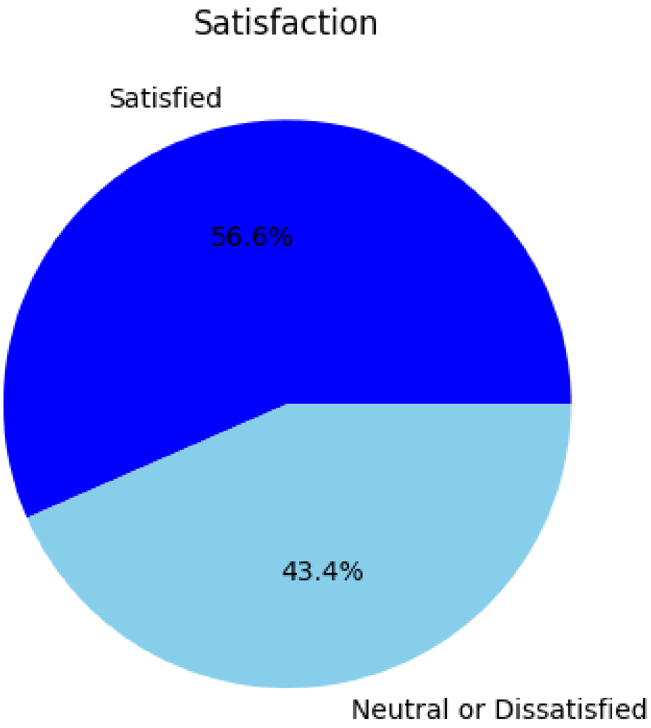
```
[ ]: # import numpy as np
     # import seaborn as sns
     # from matplotlib import pyplot as plt
```

```
[ ]: binwidth=2
     df1.iloc[:,1:].hist(bins=11, figsize=(25,20), color='blue')
     plt.show()
```

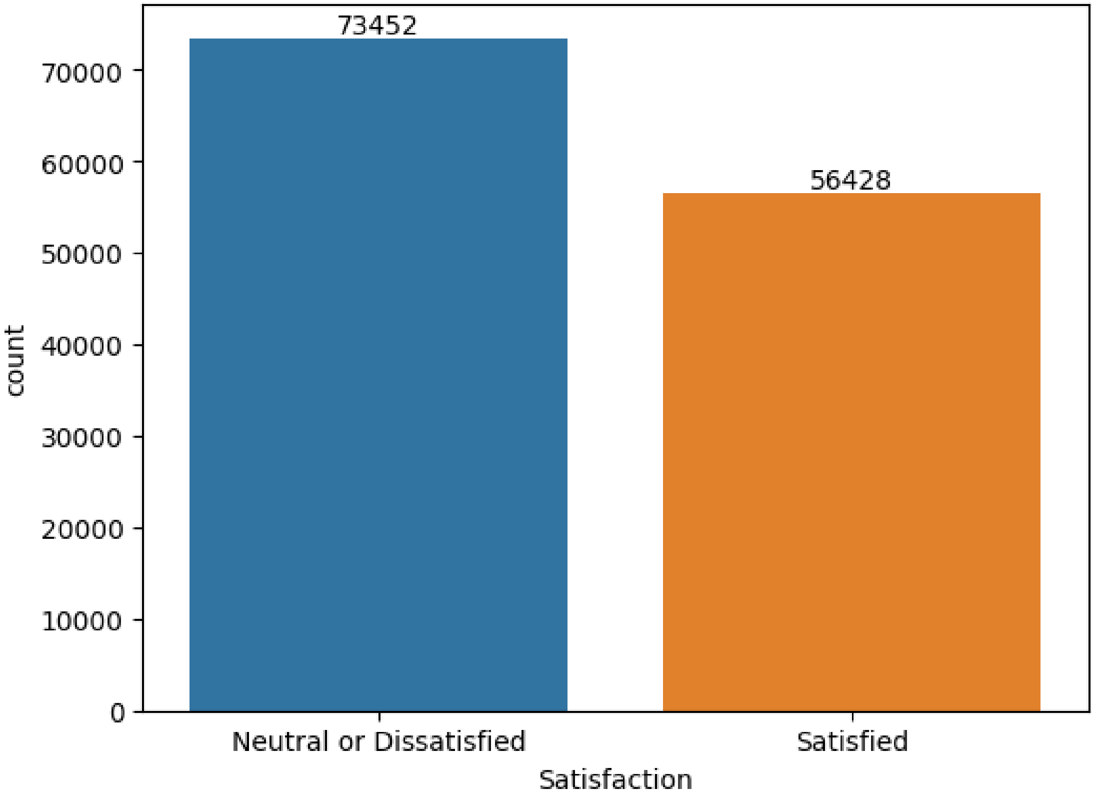


Check categorical veriables

[ ]:
```
y = df1["Satisfaction"].value_counts()
labels = ["Satisfied", "Neutral or Dissatisfied"]
mycolors = ["blue", "skyblue"]
y = df1["Satisfaction"].value_counts()
plt.pie(y, labels = labels, colors = mycolors, autopct = '%1.1f%%')
plt.title('Satisfaction')
plt.show()
```



[ ]:
```
# ChecK the # of customers - Satisfaction
mycolors2 = ["blue", "skyblue"]
s = sns.countplot(x='Satisfaction',data=df1)
abs_values = df1['Satisfaction'].value_counts().values

s.bar_label(container=s.containers[0], labels=abs_values);
```

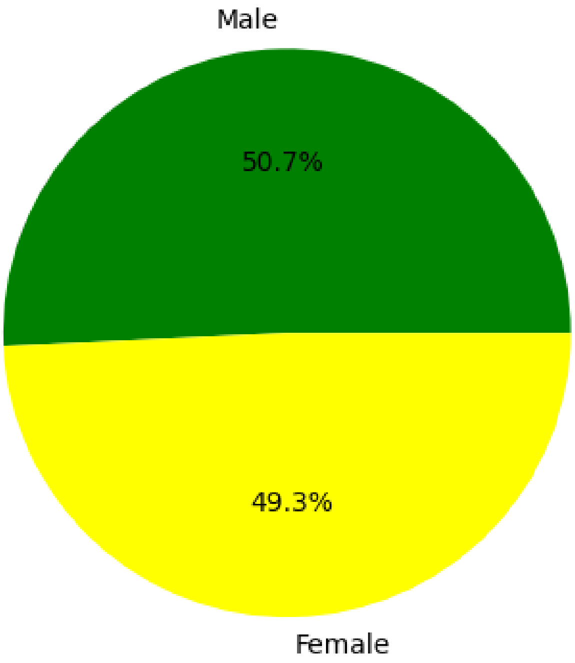


Observation:

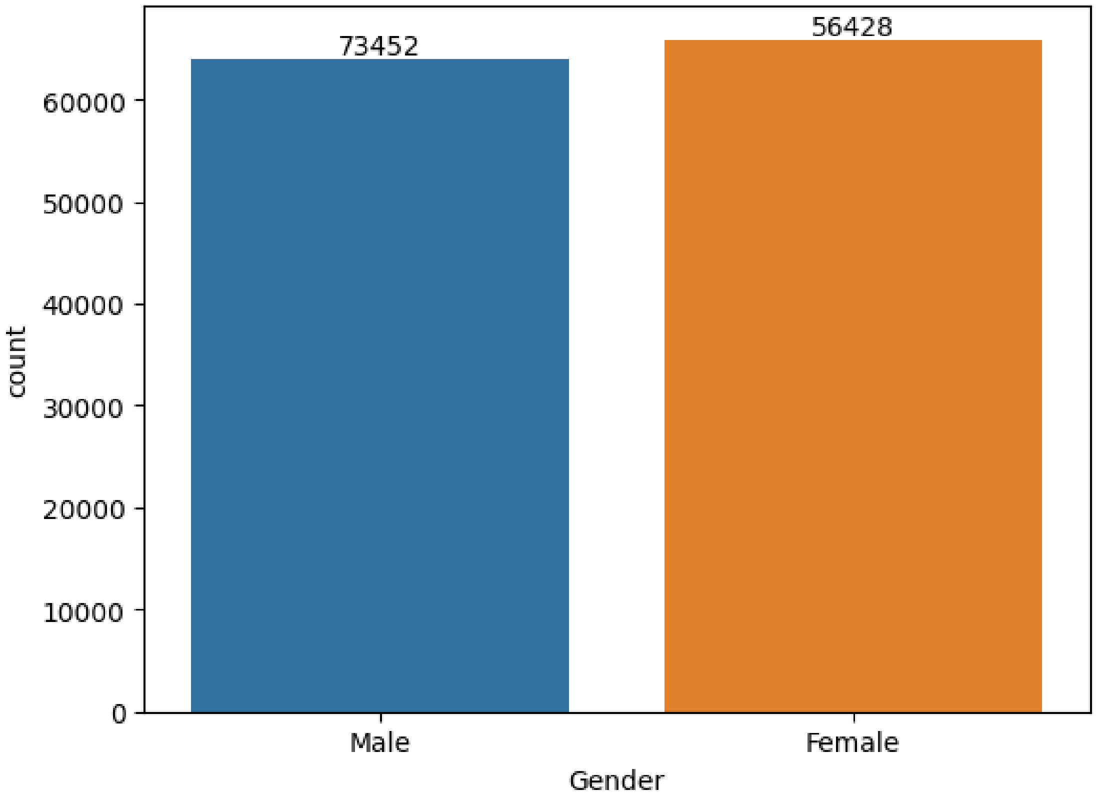
- Satisfaction is a terget class and it is imbalanced.

Pie chart for Gender

[ ]:
```
y = df1["Gender"].value_counts()
labels = ["Male", "Female"]
mycolors = ["Green", "Yellow"]
plt.pie(y, labels = labels,colors=mycolors ,autopct='%1.1f%%')
plt.show()
```



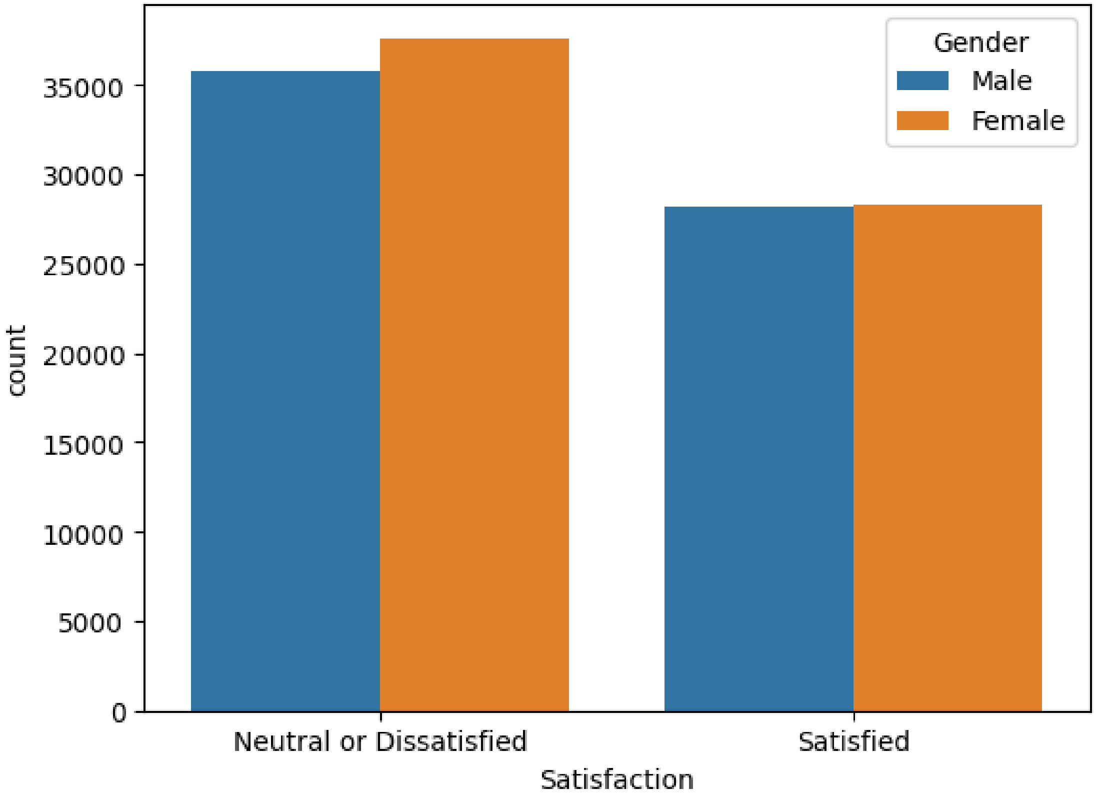
```
[ ]: # ChecK the # of customers - Gender
     s = sns.countplot(x='Gender',data=df1)
     abs_values = df1['Satisfaction'].value_counts().values

     s.bar_label(container=s.containers[0], labels=abs_values);
```



```
[ ]: # Grouping the data points based on Gender
     df1.groupby('Gender')['Satisfaction'].value_counts()
```

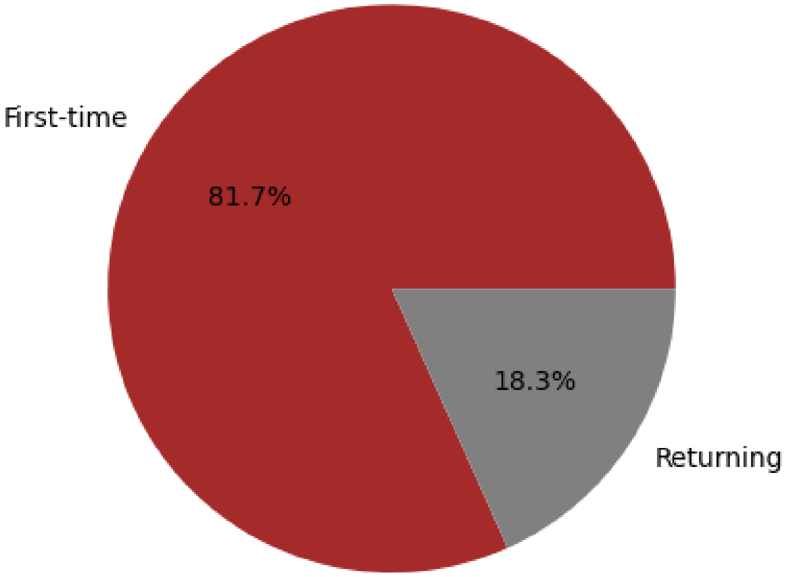
```
[ ]: Gender  Satisfaction
     Female  Neutral or Dissatisfied    37630
             Satisfied                  28269
     Male    Neutral or Dissatisfied    35822
             Satisfied                  28159
     Name: Satisfaction, dtype: int64
```

```
[ ]: sns.countplot(data = df1, x= df1['Satisfaction'], hue = df1["Gender"]);
```



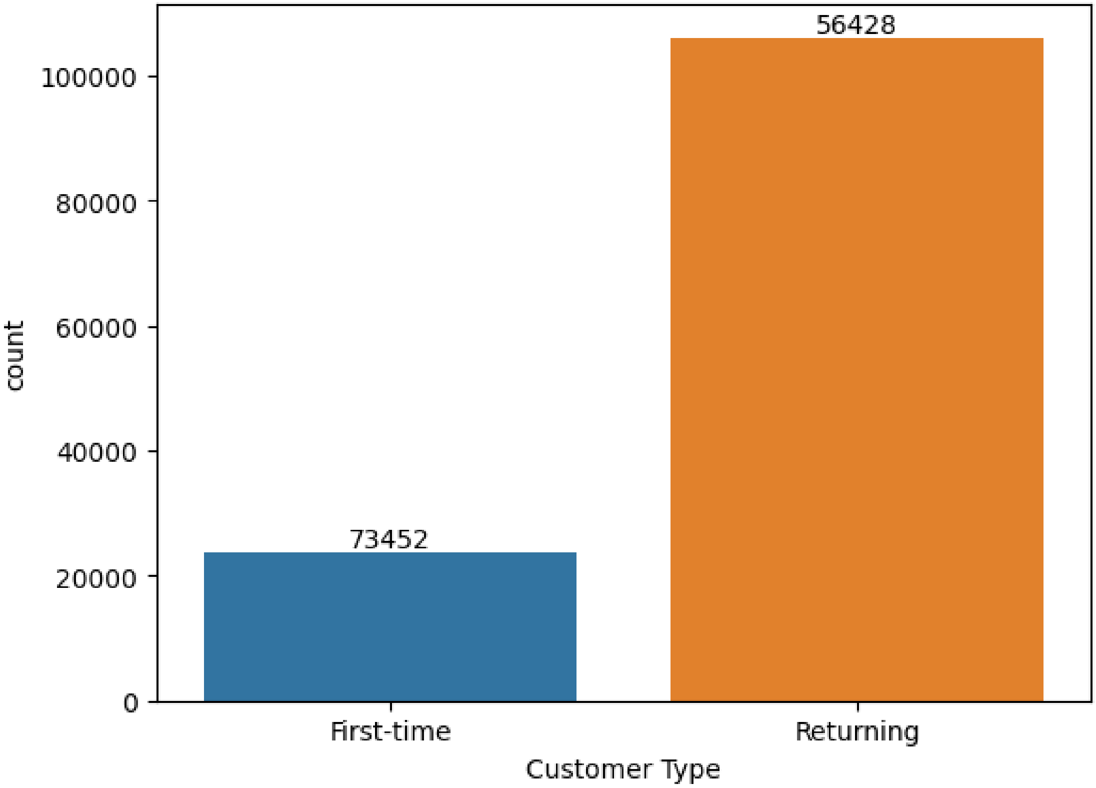
Pie chart for Customer Type

```
[ ]: y = df1["Customer Type"].value_counts()
     labels = ["First-time", "Returning"]
     mycolors = ["Brown", "Gray"]
     plt.pie(y, labels = labels,colors=mycolors ,autopct='%1.1f%%')
     plt.show()
```



[ ]:

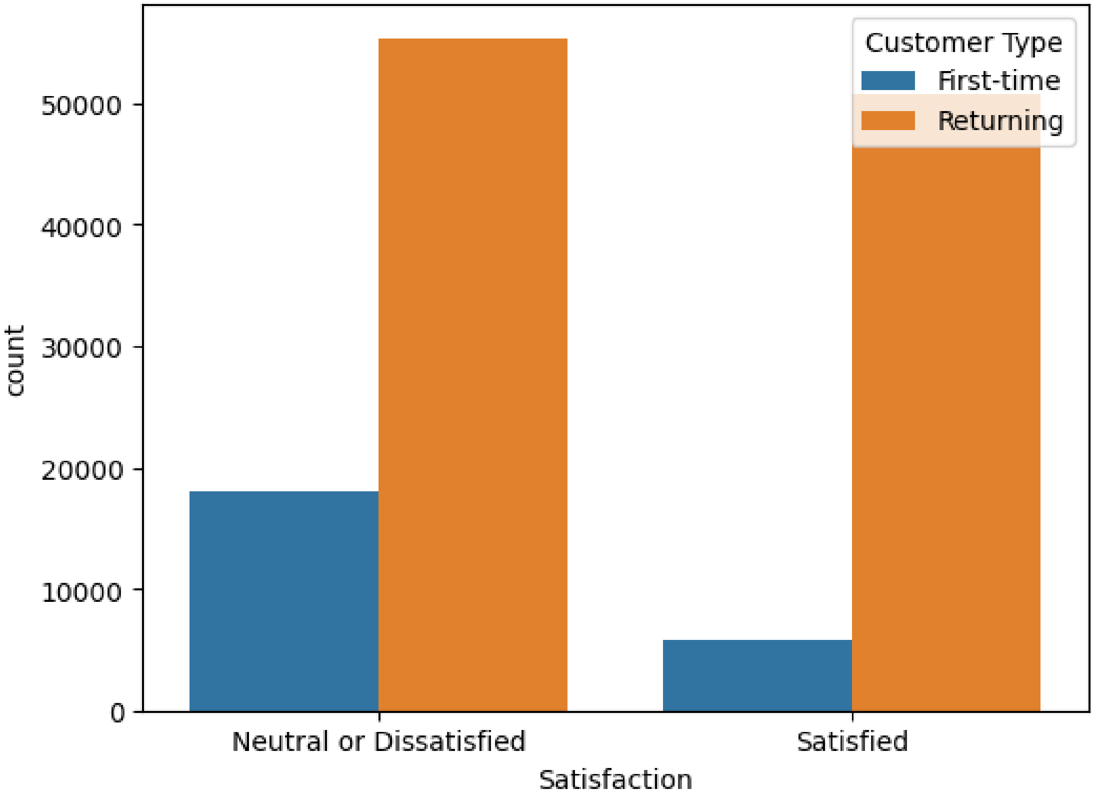
```
# ChecK the # of customers - Customer Type
s = sns.countplot(x='Customer Type',data=df1)
abs_values = df1['Satisfaction'].value_counts().values

s.bar_label(container=s.containers[0], labels=abs_values);
```



```
[ ]: # Grouping the data points based on Customer Type
     df1.groupby('Customer Type')['Satisfaction'].value_counts()
```

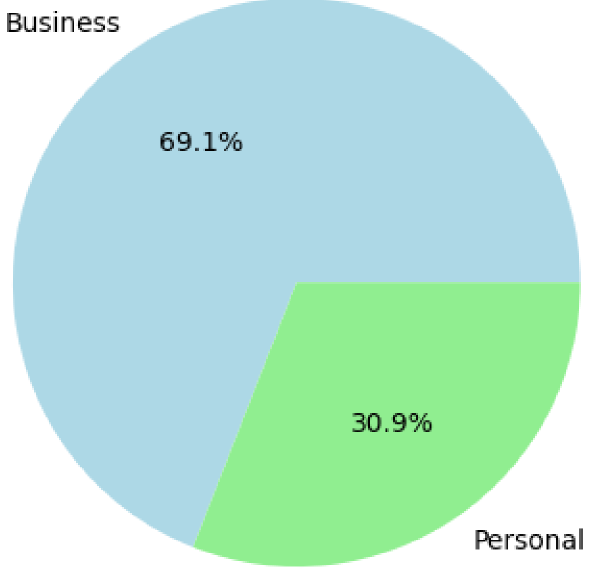
```
[ ]: Customer Type  Satisfaction
     First-time     Neutral or Dissatisfied    18080
                    Satisfied                   5700
     Returning      Neutral or Dissatisfied    55372
                    Satisfied                  50728
     Name: Satisfaction, dtype: int64
```

```
[ ]: sns.countplot(data = df1, x= df1['Satisfaction'], hue = df1["Customer Type"]);
```



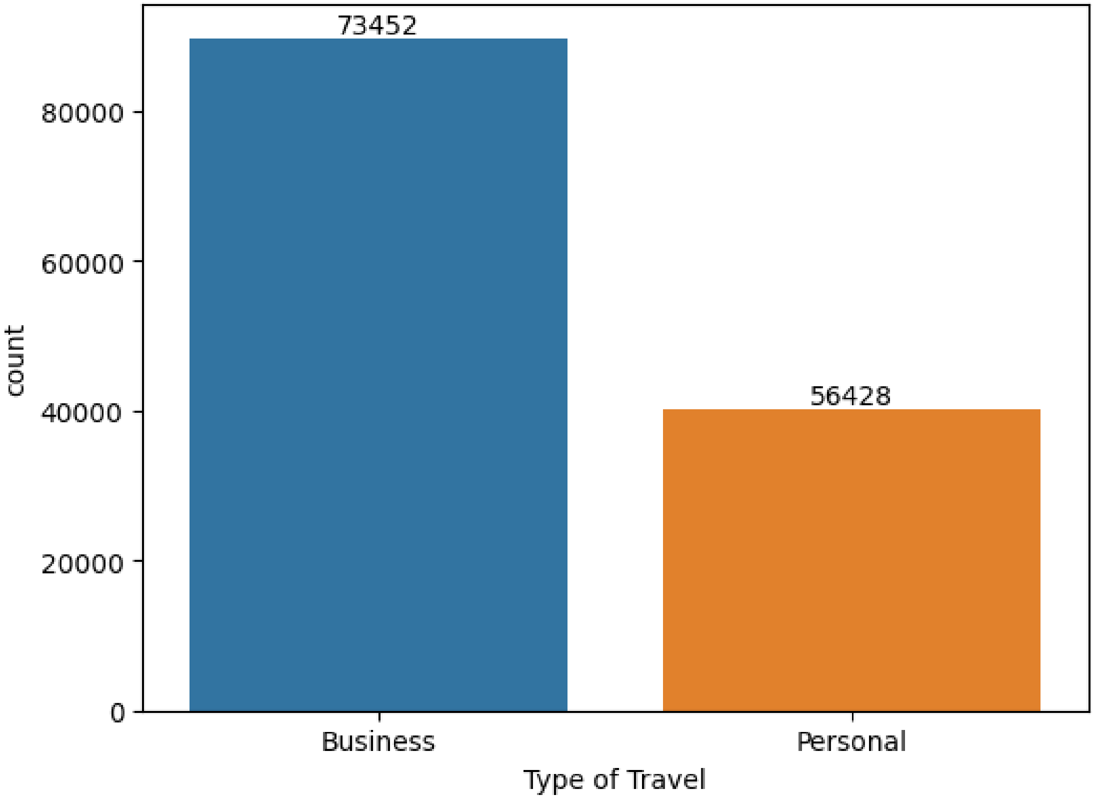
Pic chart for Type of Travel

```
[ ]: y = df1["Type of Travel"].value_counts()
     labels = ["Business", "Personal"]
     mycolors = ["Lightblue", "Lightgreen"]
     plt.pie(y, labels = labels,colors=mycolors ,autopct='%1.1f%%')
     plt.show()
```



[ ]:

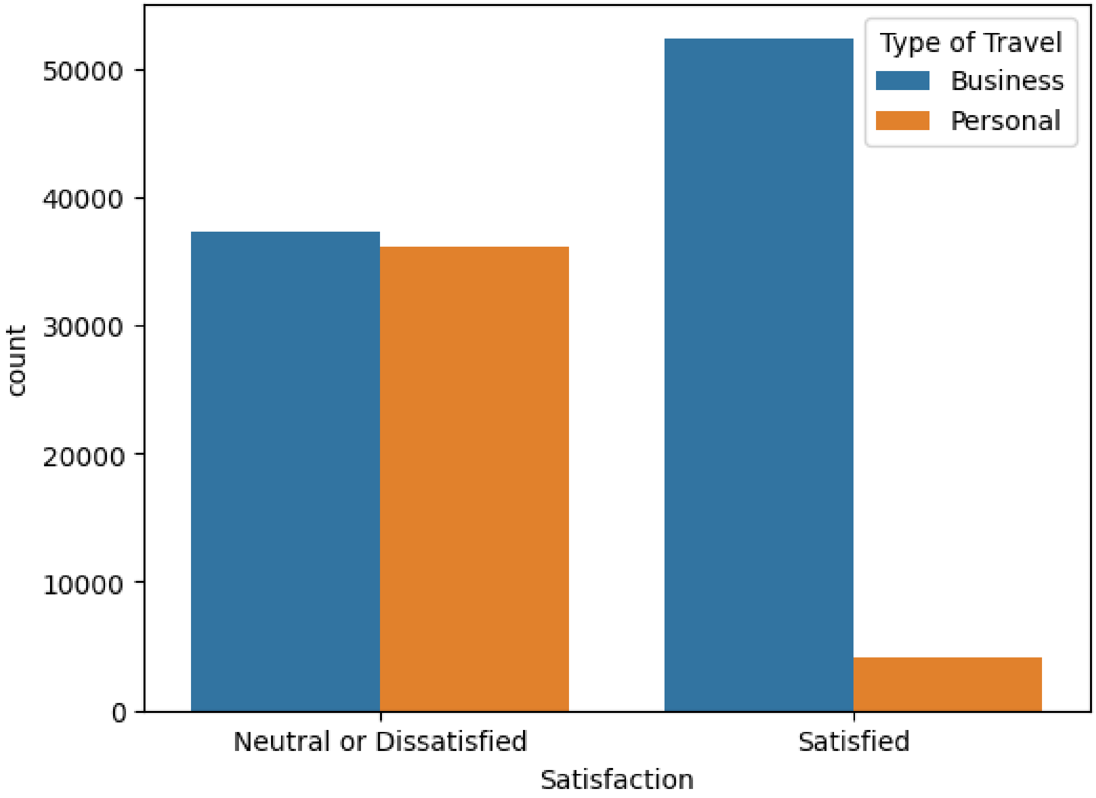
```
# ChecK the # of customers - Customer Type
s = sns.countplot(x='Type of Travel',data=df1)
abs_values = df1['Satisfaction'].value_counts().values

s.bar_label(container=s.containers[0], labels=abs_values);
```



```
[ ]: # Grouping the data points based on Type of Travel
     df1.groupby('Type of Travel')['Satisfaction'].value_counts()
```

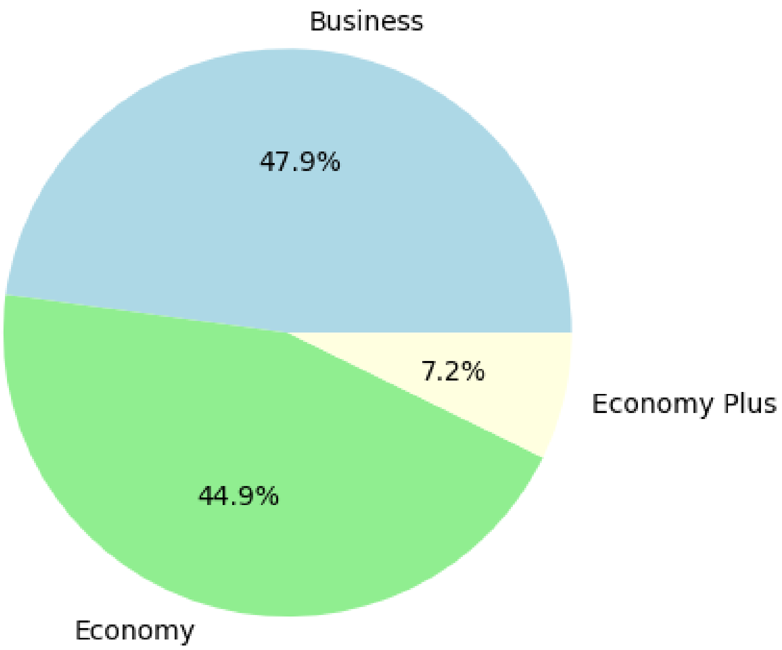
```
[ ]: Type of Travel  Satisfaction
     Business        Satisfied                  52356
                     Neutral or Dissatisfied    37337
     Personal        Neutral or Dissatisfied    36115
                     Satisfied                   4072
     Name: Satisfaction, dtype: int64
```

```
[ ]: sns.countplot(data = df1, x= df1['Satisfaction'], hue = df1["Type of Travel"]);
```

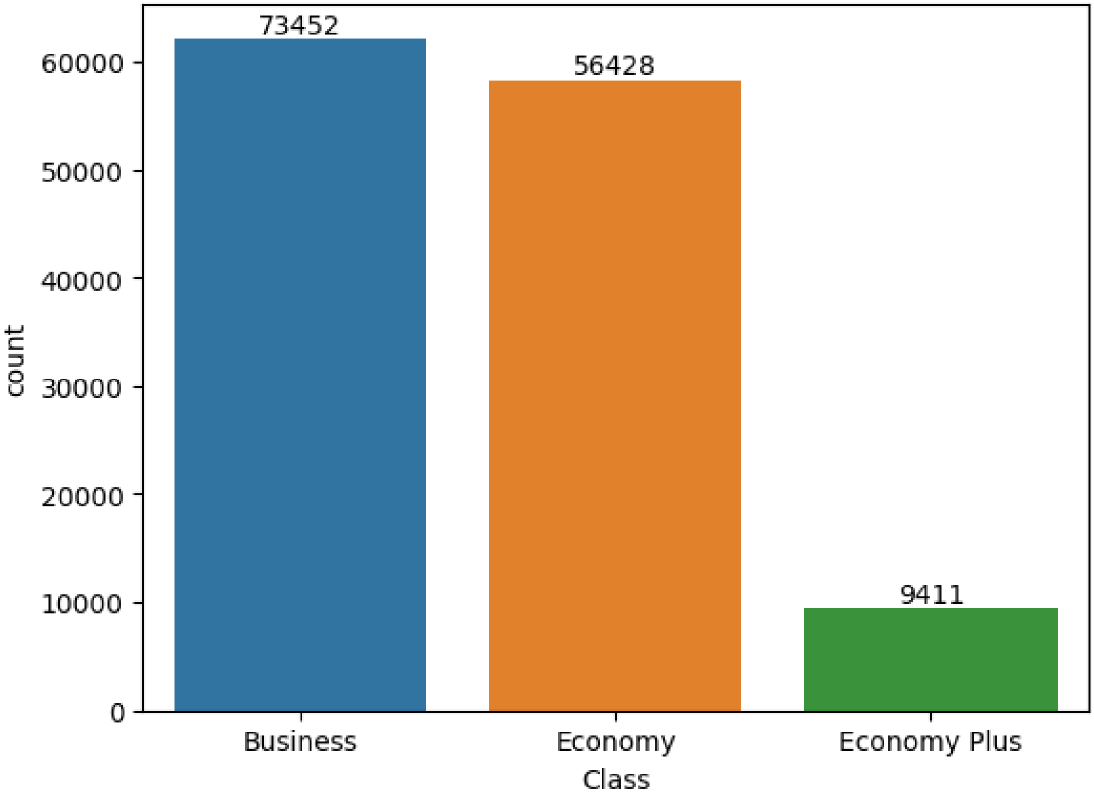


Pic chart for Class

```
[ ]: y = df1["Class"].value_counts()
     labels = ["Business", "Economy", "Economy Plus"]
     mycolors = ["Lightblue", "Lightgreen", "Lightyellow"]
     plt.pie(y, labels = labels,colors=mycolors ,autopct='%1.1f%%')
     plt.show()
```



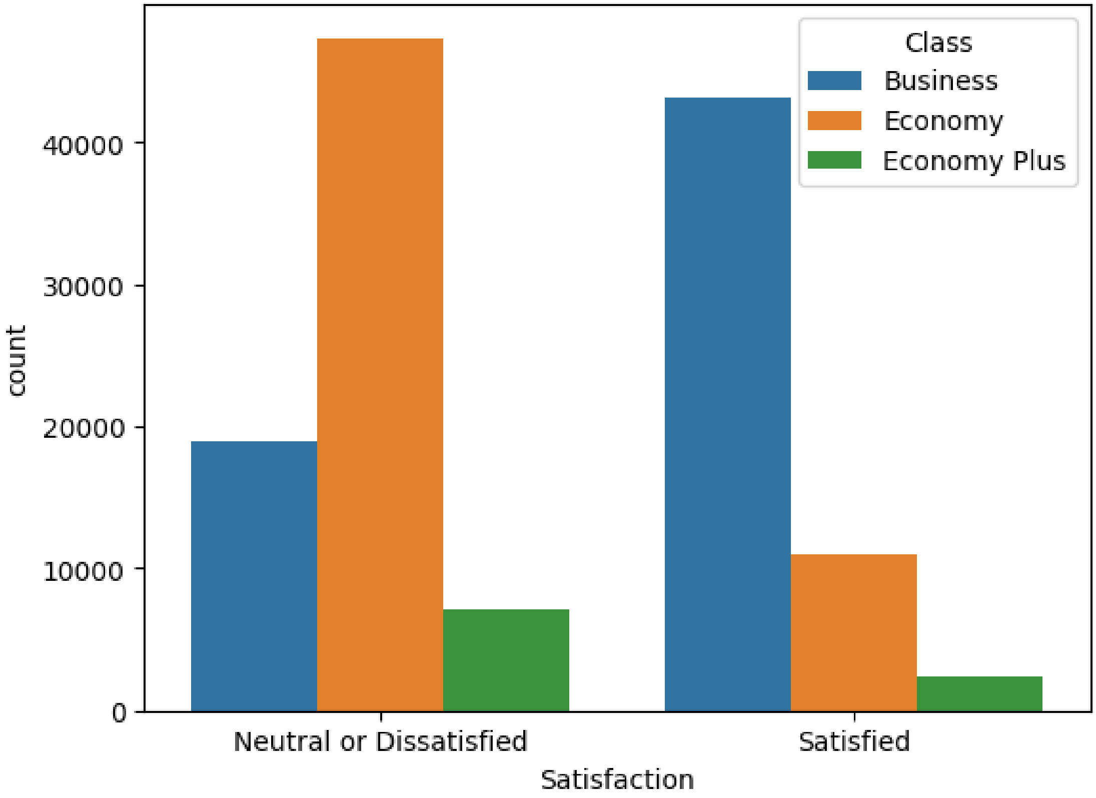
```
[ ]: # ChecK the # of customers - Customer Type
     s = sns.countplot(x='Class',data=df1)
     abs_values = df1['Satisfaction'].value_counts().values

     s.bar_label(container=s.containers[0], labels=abs_values);
```



```
[ ]: # Grouping the data points based on Class
     df1.groupby('Class')['Satisfaction'].value_counts()
```

```
[ ]: Class         Satisfaction
     Business      Satisfied                  43166
                   Neutral or Dissatisfied    18994
     Economy       Neutral or Dissatisfied    47366
                   Satisfied                  10943
     Economy Plus  Neutral or Dissatisfied     7092
                   Satisfied                   2319
     Name: Satisfaction, dtype: int64
```

```
[ ]: sns.countplot(data = df1, x= df1['Satisfaction'], hue = df1["Class"]);
```

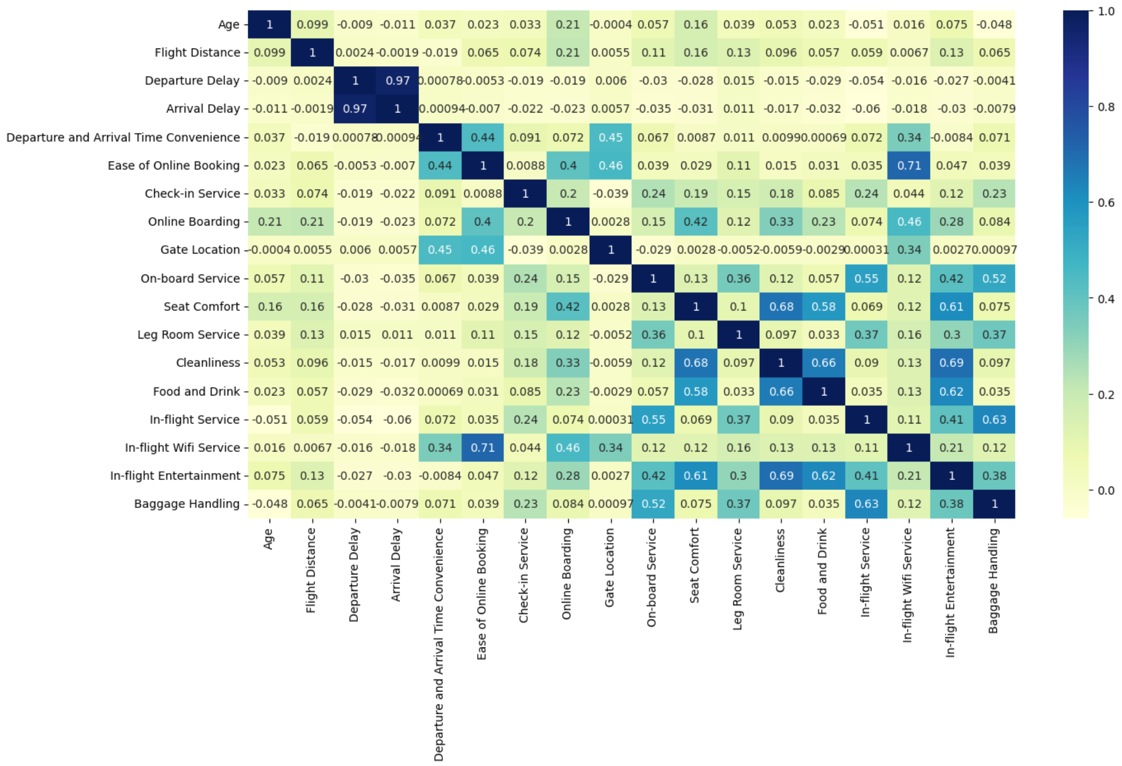


Check correlation matrix

```
[ ]: plt.figure(figsize = (15,8))
     sns.heatmap(df1.corr() , annot = True , cmap = "YlGnBu")
```

```
<ipython-input-29-46ea086570be>:2: FutureWarning: The default value of
numeric_only in DataFrame.corr is deprecated. In a future version, it will
default to False. Select only valid columns or specify the value of numeric_only
to silence this warning.
  sns.heatmap(df1.corr() , annot = True , cmap = "YlGnBu")
```

```
[ ]: <Axes: >
```



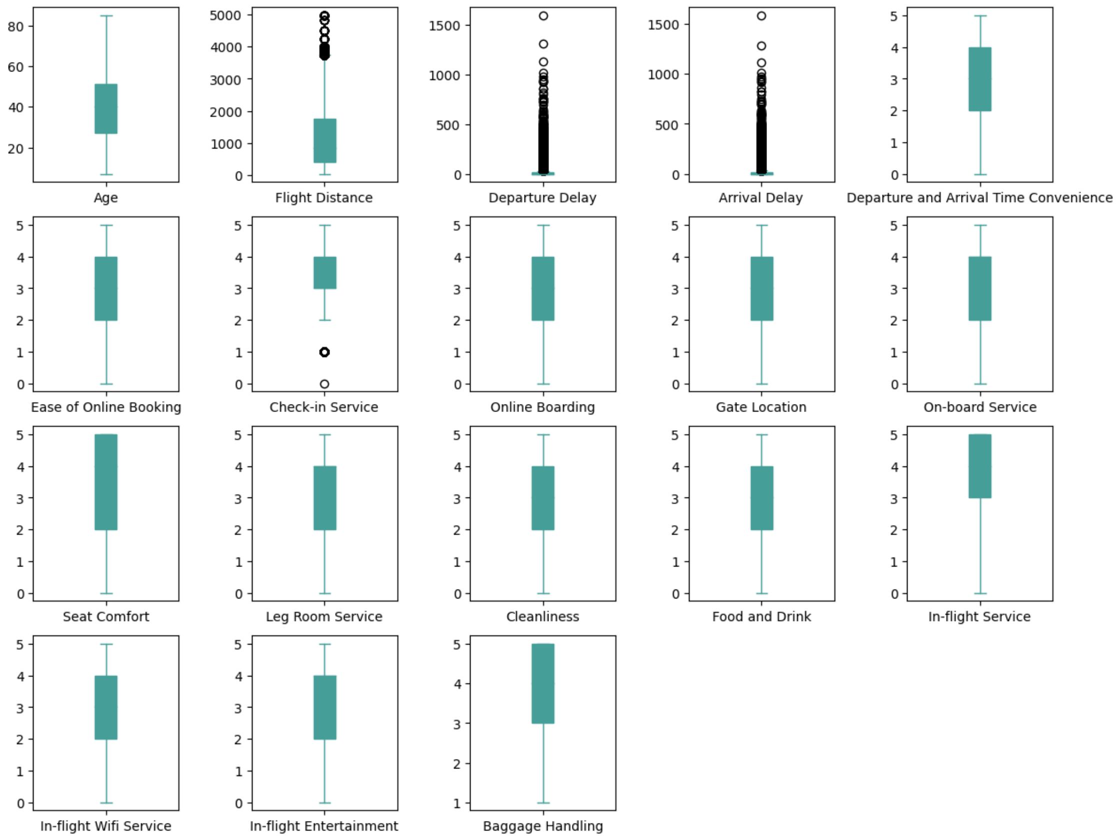
Observation:

- **Strong positive correlation** between Arrival Delay and Departure Delay which is 0.97.
- **Moderate positive correlation** between In-flight Wi-Fi Service and Ease of Online Booking which is 0.71.

Check outliers of numerical variables in histgram

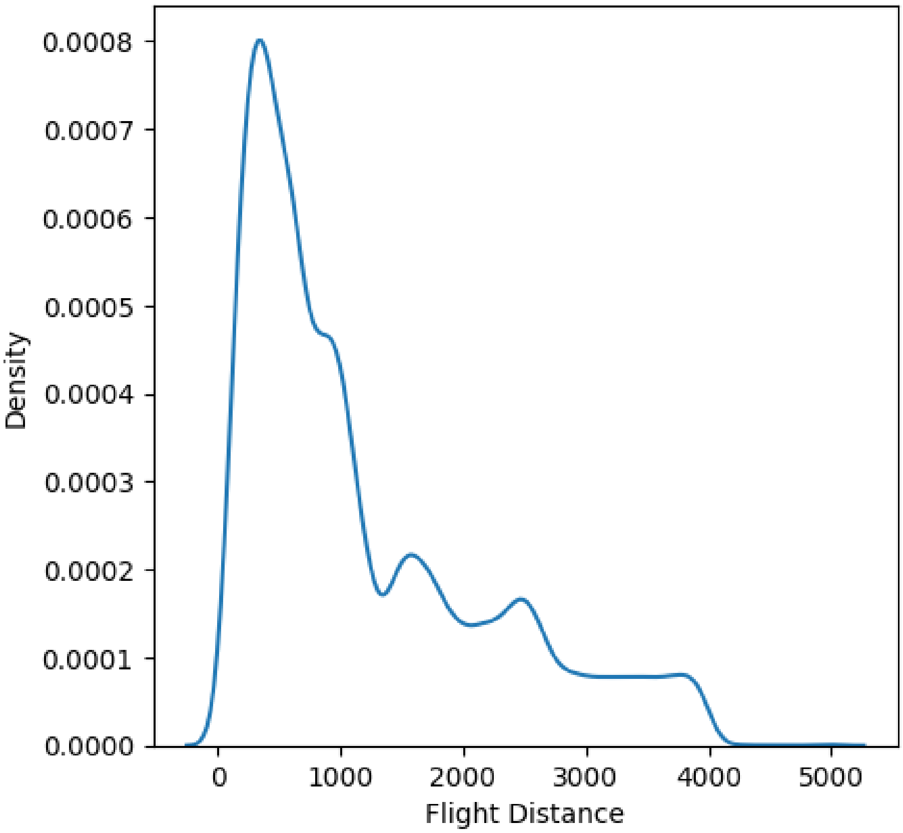
[ ]:
```
# df1.plot(kind='box', subplots=True, layout=(8,5), figsize=(17,20))
```

[ ]:
```
df1.plot(kind='box', subplots=True, layout=(5,5),␣
  ↪figsize=(14,14),patch_artist=True,color="#459E97")
plt.subplots_adjust(wspace = 0.5)
```



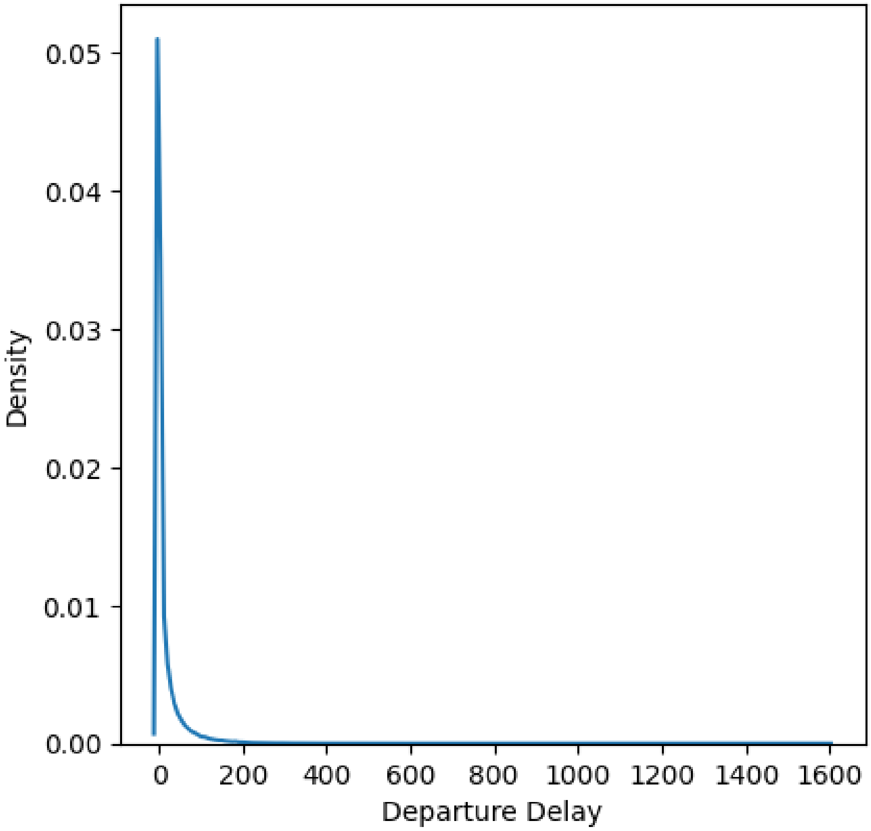
[ ]:

```
# check distribution of Flight Distance
plt.figure(figsize = (5,5))
sns.kdeplot(df1['Flight Distance']);
```

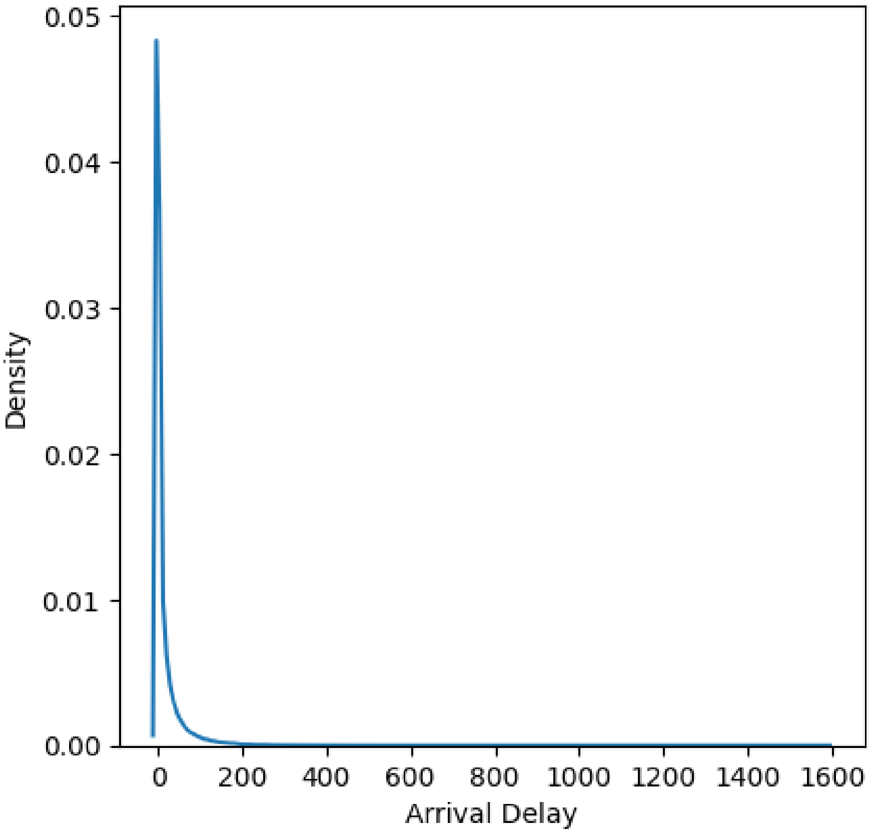


[ ]:

```
# check distribution of Departure Delay
plt.figure(figsize = (5,5))
sns.kdeplot(df1['Departure Delay']);
```



[ ]:
```
# check distribution of Arrival Delay
plt.figure(figsize = (5,5))
sns.kdeplot(df1['Arrival Delay']);
```



Observation:

- Outliers in Flight Distance, Departure Delay and Arrival Delay
- The distribution of all three variables are right skewed (Positively Skewed). This means that the mean is often greater than the median.
- Arrival Delay includes 393 missing values.

4 Data preparation for Supervised Machine Learning

Split the original dataset (df1) into Traing set and Test set

```
[88]: from sklearn.model_selection import train_test_split
```

```
[89]: X = df1.drop(['Satisfaction'], axis=1)
      y = df1['Satisfaction']
```

```
[90]: X_train, X_test, y_train, y_test = train_test_split(X, y, random_state= 0 ,␣
       ↪test_size=0.25, shuffle=True)
```

```
[91]: # view first few rows of train set
      X_train.head()
```

[91]:

```
       Gender  Age Customer Type Type of Travel     Class  Flight Distance  \
ID
2050     Male   47     Returning       Business   Economy              812
49177  Female   44     Returning       Business  Business             3285
38347    Male   26     Returning       Business   Economy             1173
36700    Male   48     Returning       Personal   Economy             1197
20522  Female   16     Returning       Personal  Business              533

       Departure Delay  Arrival Delay  Departure and Arrival Time Convenience  \
ID
2050                63           51.0                                       3
49177                0            0.0                                       0
38347                0            0.0                                       3
36700                9            0.0                                       5
20522                0            0.0                                       5

       Ease of Online Booking  …  Gate Location  On-board Service  \
ID                             …
2050                        3  …              3                 1
49177                       0  …              1                 3
38347                       3  …              3                 3
36700                       1  …              2                 5
20522                       1  …              4                 4

       Seat Comfort  Leg Room Service  Cleanliness  Food and Drink  \
ID
2050              3                 1            3               3
49177             3                 3            1               3
38347             4                 5            5               5
36700             4                 2            4               4
20522             5                 5            5               5

       In-flight Service  In-flight Wifi Service  In-flight Entertainment  \
ID
2050                   3                       3                        3
49177                  3                       0                        3
38347                  4                       5                        5
36700                  4                       1                        4
20522                  5                       1                        5

       Baggage Handling
ID
2050                  3
49177                 3
38347                 4
36700                 1
20522                 5
```

```
[5 rows x 22 columns]
```

```
[92]: X_train["Arrival Delay"].isnull().sum()
```

```
[92]: 290
```

```
[93]: X_train["Arrival Delay"].mean()
```

```
[93]: 15.105889621087314
```

```
[94]: # view first few rows of test set
      y_train.head()
```

```
[94]: ID
      2050     Neutral or Dissatisfied
      49177                  Satisfied
      38347                  Satisfied
      36700    Neutral or Dissatisfied
      20522    Neutral or Dissatisfied
      Name: Satisfaction, dtype: object
```

```
[95]: # check the size of each set
      print(X_train.shape, X_test.shape)
```

```
(97410, 22) (32470, 22)
```

```
[96]: # check missing value of train set
      X_train['Arrival Delay'].isnull().sum()
```

```
[96]: 290
```

```
[97]: # check missing value of test set
      X_test['Arrival Delay'].isnull().sum()
```

```
[97]: 103
```

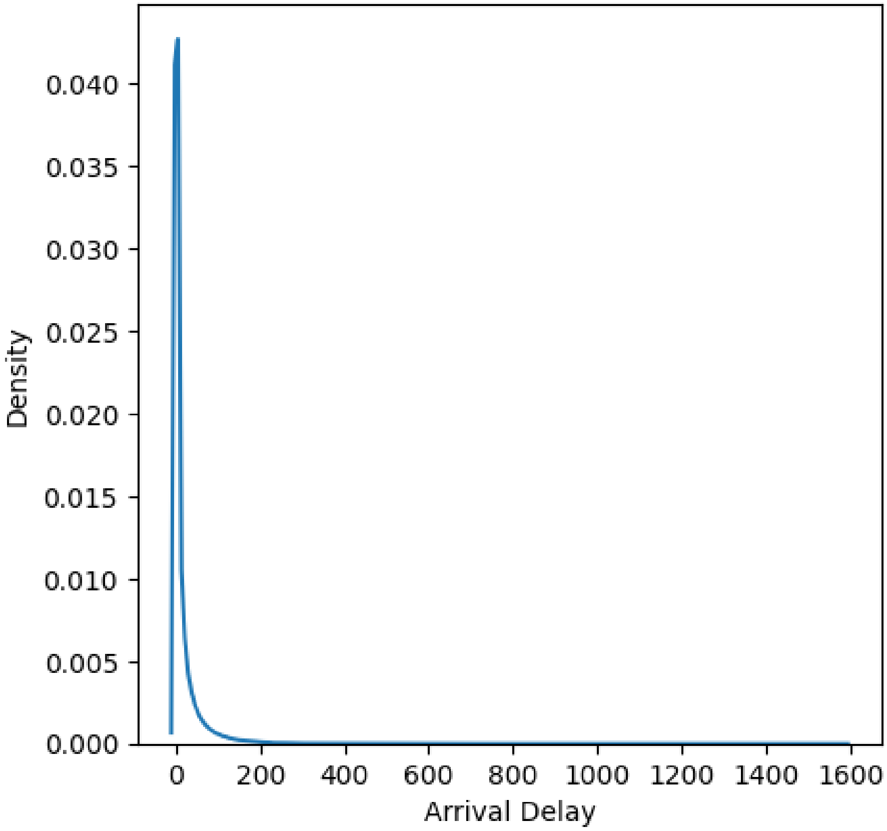
This test set contains some missing values. I am looking for a way to split the dataset into tarining and golden standard test set (no missing values in test set)

Handling missing value of train set

```
[98]: # check missing value of train set
      missing = X_train.isnull().sum()
      missing = missing[missing > 0]
      missing = missing.sort_values(ascending = False)
      missing
```

```
[98]: Arrival Delay    290
      dtype: int64
```

```
[99]: # check the distribution of Arrival Delay of train set
      plt.figure(figsize = (5,5))
      sns.kdeplot(X_train['Arrival Delay']);
```



Observation:

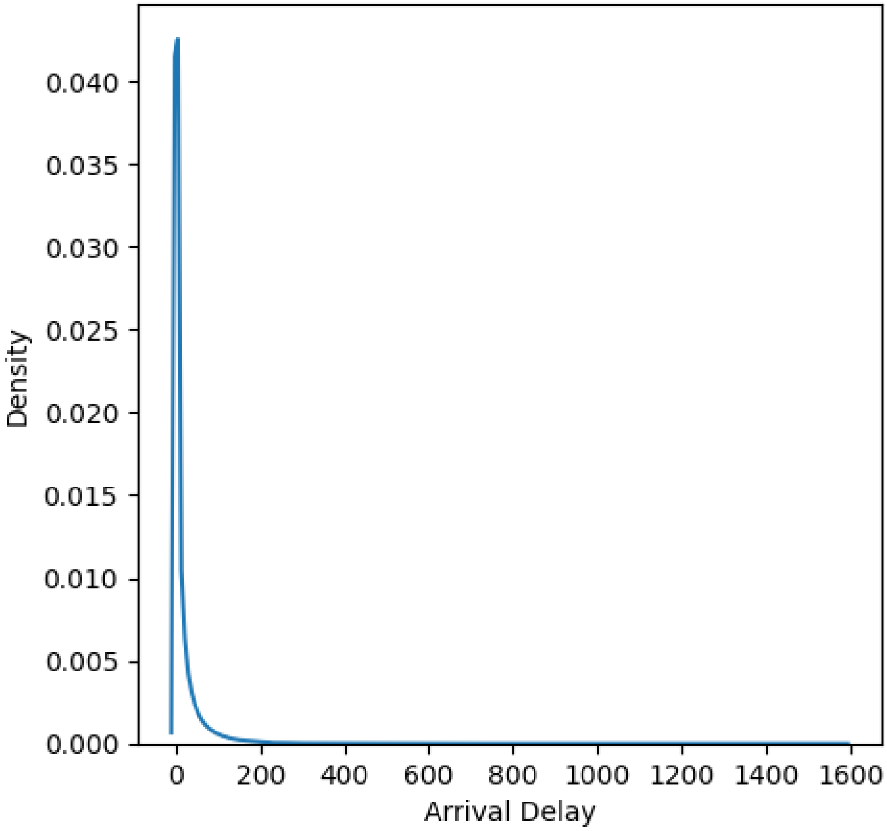
- Arrival Delay is right skewed distribtion. Therefore, we will impute the median to the missing values.

```
[100]: modified_X_train = X_train
       modified_X_train['Arrival Delay'].fillna(modified_X_train['Arrival Delay'].
        ↪median(), inplace=True)
```

```
[101]: modified_X_train['Arrival Delay'].isnull().sum()
```

```
[101]: 0
```

[102]:
```
# check the distribution of Arrival Delay of modified_train set (AFTER inpute␣
↪median value)
plt.figure(figsize = (5,5))
sns.kdeplot(modified_X_train['Arrival Delay']);
```



Observation: There is no significant change AFTER imputing the median value to fill the missing values.

Handling missing value of test set

To avoid data leakage, median value from Train train set is imputed to test set.

[103]:
```
modified_X_test = X_test
```

[104]:
```
modified_X_test['Arrival Delay'].fillna(modified_X_train['Arrival Delay'].
↪median(), inplace=True)
modified_X_test['Arrival Delay'].isnull().sum()
```

[104]:
```
0
```

[105]:
```
modified_X_test.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 32470 entries, 125670 to 34201
Data columns (total 22 columns):
 #   Column                                  Non-Null Count  Dtype  
---  ------                                  --------------  -----  
 0   Gender                                  32470 non-null  object 
 1   Age                                     32470 non-null  int64  
 2   Customer Type                           32470 non-null  object 
 3   Type of Travel                          32470 non-null  object 
 4   Class                                   32470 non-null  object 
 5   Flight Distance                         32470 non-null  int64  
 6   Departure Delay                         32470 non-null  int64  
 7   Arrival Delay                           32470 non-null  float64
 8   Departure and Arrival Time Convenience  32470 non-null  int64  
 9   Ease of Online Booking                  32470 non-null  int64  
 10  Check-in Service                        32470 non-null  int64  
 11  Online Boarding                         32470 non-null  int64  
 12  Gate Location                           32470 non-null  int64  
 13  On-board Service                        32470 non-null  int64  
 14  Seat Comfort                            32470 non-null  int64  
 15  Leg Room Service                        32470 non-null  int64  
 16  Cleanliness                             32470 non-null  int64  
 17  Food and Drink                          32470 non-null  int64  
 18  In-flight Service                       32470 non-null  int64  
 19  In-flight Wifi Service                  32470 non-null  int64  
 20  In-flight Entertainment                 32470 non-null  int64  
 21  Baggage Handling                        32470 non-null  int64  
dtypes: float64(1), int64(17), object(4)
memory usage: 5.7+ MB
```

Handling outliers of train set

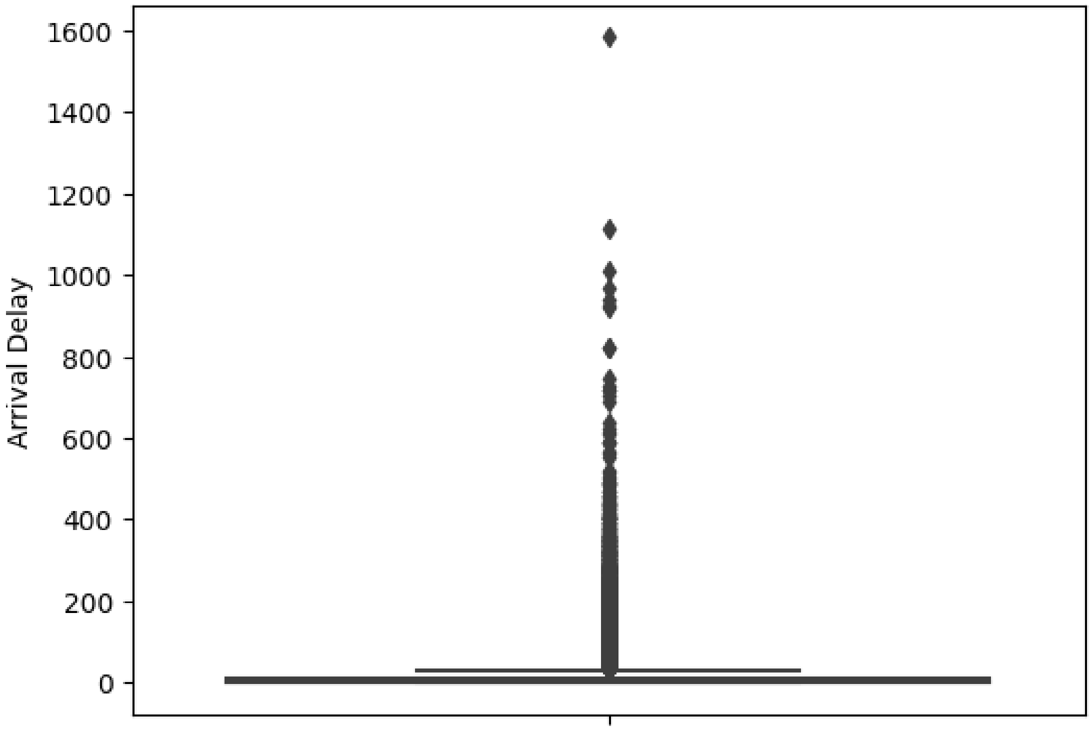
Use IQR (Inter Quartile Range) to finding the outliers and cap the outliers

- capping: to replace the outlier values with a maximum or minimum capped value

Arrival Delay

[106]:
```
# before capping outliers
sns.boxplot( y="Arrival Delay", data = modified_X_train)
```

[106]:
```
<Axes: ylabel='Arrival Delay'>
```



[107]:
```
# IQR
Q1 = np.percentile(modified_X_train['Arrival Delay'], 25, method='midpoint')
Q3 = np.percentile(modified_X_train['Arrival Delay'], 75, method='midpoint')
IQR = Q3 - Q1
print(IQR)
```

```
13.0
```

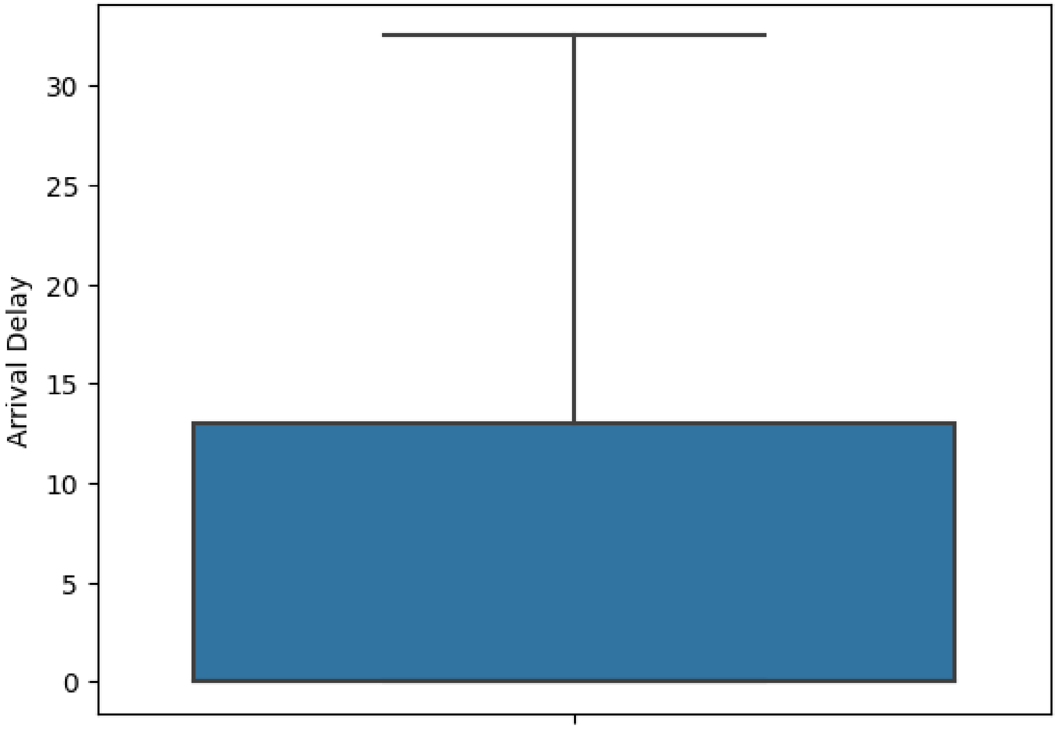
[108]:
```
upper_bound = Q3 + 1.5 * IQR
lower_bound = Q1 - 1.5 * IQR
print(upper_bound)
print(lower_bound)
```

```
32.5
-19.5
```

[109]:
```
modified_X_train["Arrival Delay"] = np.where(modified_X_train["Arrival Delay"]>␣
 ↪upper_bound, upper_bound,
                        np.where(modified_X_train["Arrival Delay"]<␣
 ↪lower_bound, lower_bound,
                          modified_X_train["Arrival Delay"]))
```

```
[110]: # after capping outliers
       sns.boxplot( y="Arrival Delay", data = modified_X_train)
```

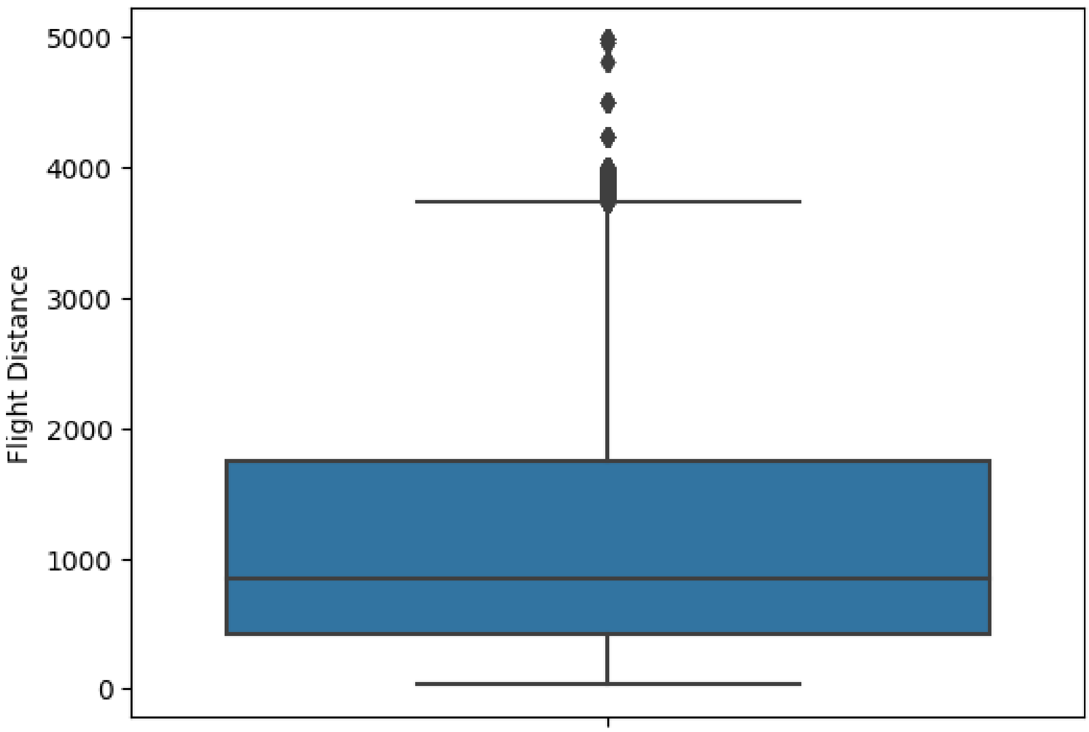
```
[110]: <Axes: ylabel='Arrival Delay'>
```



Flight Distance

```
[111]: # before capping outliers
       sns.boxplot( y="Flight Distance", data = modified_X_train)
       # sns.scatterplot(x= modified_train['Flight Distance'] , y =␣
        ↪modified_train['Satisfaction'])
```

```
[111]: <Axes: ylabel='Flight Distance'>
```



[112]:
```
# IQR
Q1 = np.percentile(df1['Flight Distance'], 25, method='midpoint')
Q3 = np.percentile(df1['Flight Distance'], 75, method='midpoint')
IQR = Q3 - Q1
print(IQR)
```

```
1330.0
```

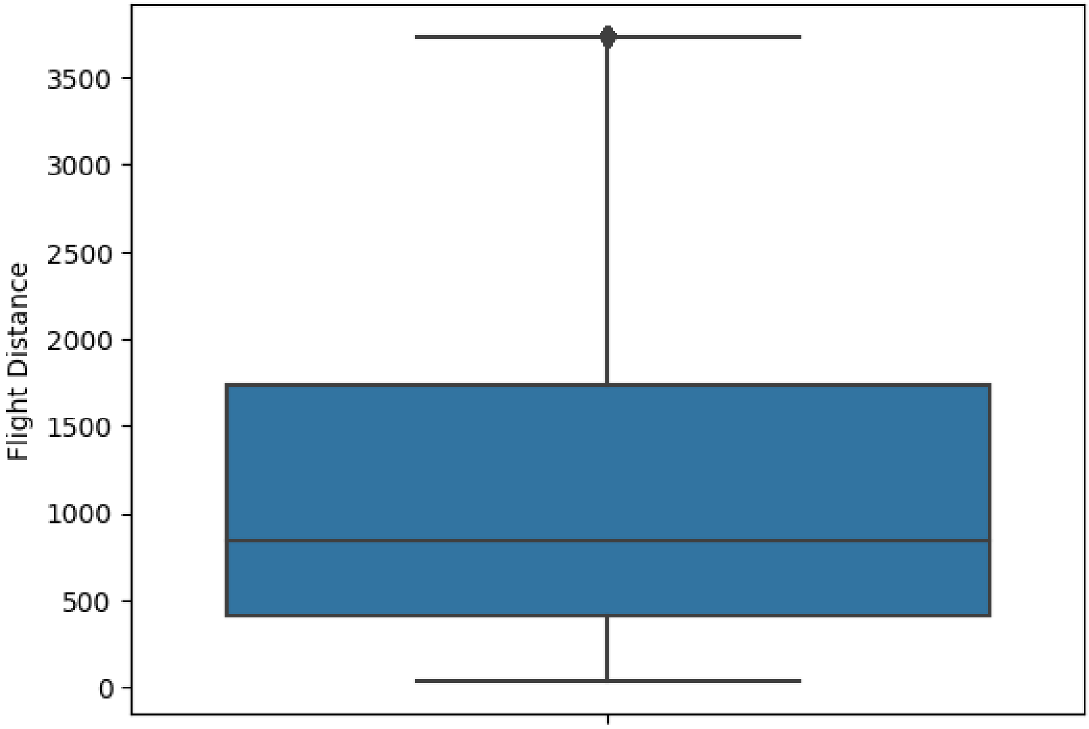
[113]:
```
upper_bound = Q3 + 1.5 * IQR
lower_bound = Q1 - 1.5 * IQR
print(upper_bound)
print(lower_bound)
```

```
3739.0
-1581.0
```

[114]:
```
modified_X_train["Flight Distance"] = np.where(modified_X_train["Flight␣
 ↪Distance"]> upper_bound, upper_bound,
                        np.where(modified_X_train["Flight Distance"]<␣
 ↪lower_bound, lower_bound,
                          modified_X_train["Flight Distance"]))
```

[115]:
```
# after capping outliers
sns.boxplot( y="Flight Distance", data = modified_X_train)
```

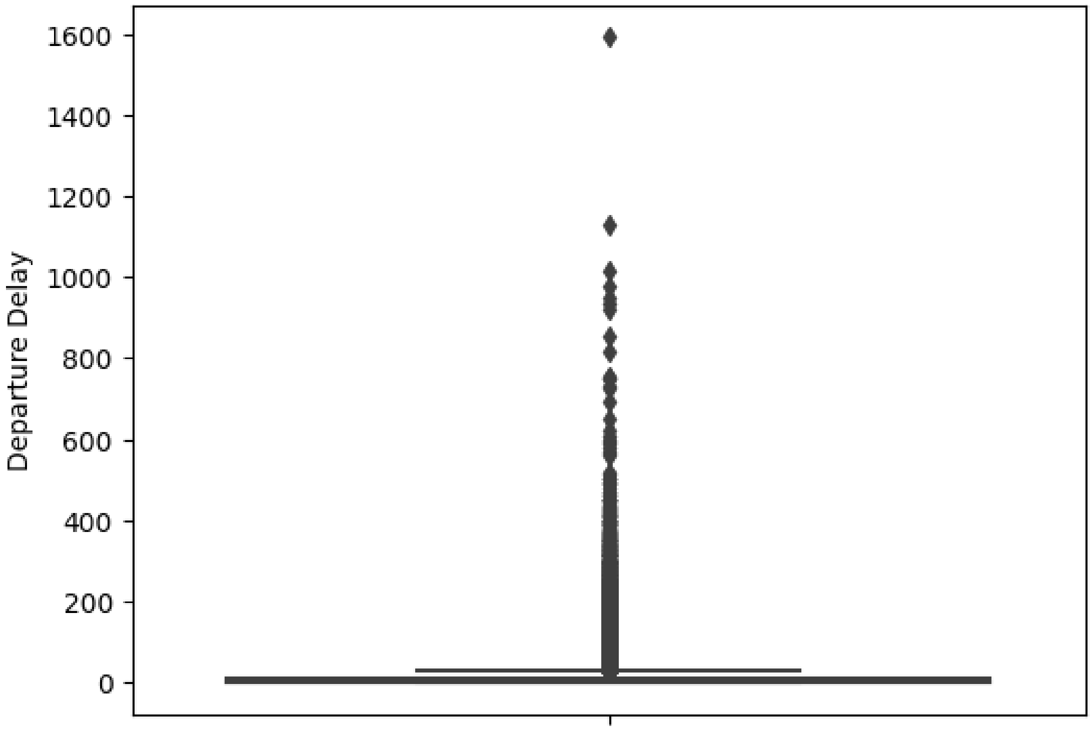
[115]:
```
<Axes: ylabel='Flight Distance'>
```



Departure Delay

[116]:
```
# before capping outliers
sns.boxplot( y="Departure Delay", data = modified_X_train)
# sns.scatterplot(x= modified_train['Departure Delay'] , y =␣
 ↪modified_train['Satisfaction'])
```

[116]:
```
<Axes: ylabel='Departure Delay'>
```



[117]:
```
# IQR
Q1 = np.percentile(df1['Departure Delay'], 25, method='midpoint')
Q3 = np.percentile(df1['Departure Delay'], 75, method='midpoint')
IQR = Q3 - Q1
print(IQR)
```

```
12.0
```

[118]:
```
upper_bound = Q3 + 1.5 * IQR
lower_bound = Q1 - 1.5 * IQR
print(upper_bound)
print(lower_bound)
```

```
30.0
-18.0
```

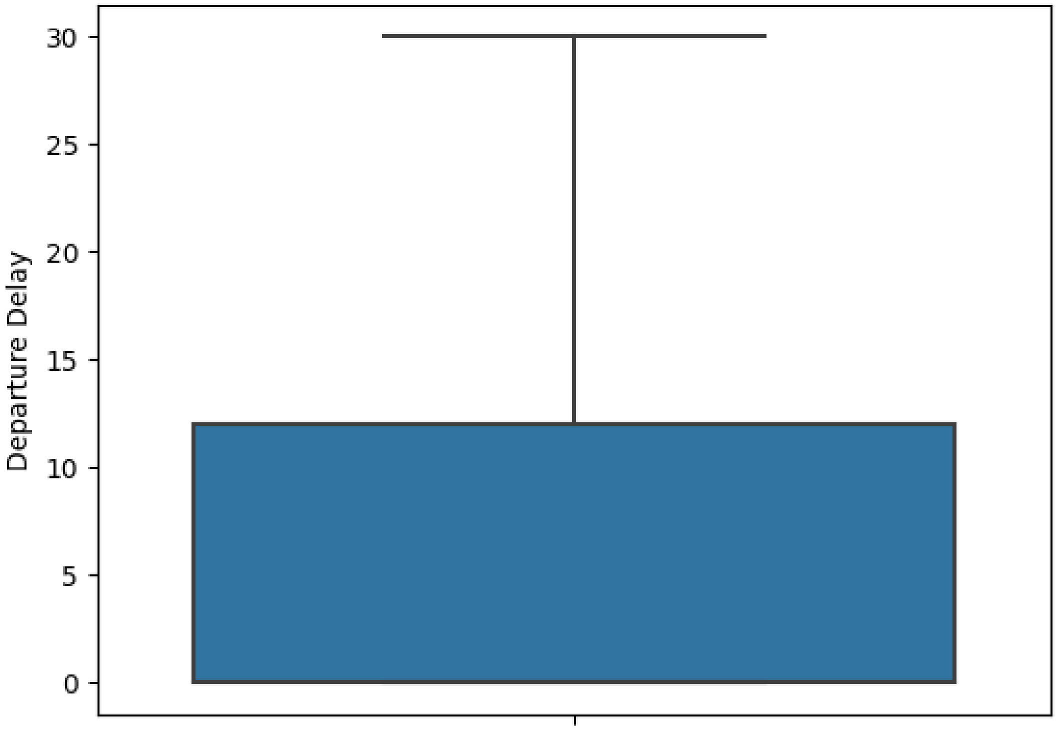
[119]:
```
modified_X_train["Departure Delay"] = np.where(modified_X_train["Departure␣
 ↪Delay"]> upper_bound, upper_bound,
                        np.where(modified_X_train["Departure Delay"]<␣
 ↪lower_bound, lower_bound,
                          modified_X_train["Departure Delay"]))
```

[120]:

```
# after capping outliers
sns.boxplot( y="Departure Delay", data = modified_X_train)
```

[120]:

```
<Axes: ylabel='Departure Delay'>
```



Encoding all categorical variables (columns with type : object) to numerical variables

[121]:

```
from sklearn.preprocessing import LabelEncoder
le = LabelEncoder()
```

[122]:

```
encoded_X_train = modified_X_train
```

[123]:

```
encoded_X_train["Gender"].value_counts()
```

[123]:

```
Female    49432
Male      47978
Name: Gender, dtype: int64
```

[124]:

```
encoded_X_train["Gender"]=le.fit_transform(encoded_X_train["Gender"])
encoded_X_train["Gender"].value_counts()
```

[124]:

```
0    49432
1    47978
```

```
Name: Gender, dtype: int64
```

```
[125]: encoded_X_train["Customer Type"].value_counts()
```

```
[125]: Returning     79497
       First-time    17913
       Name: Customer Type, dtype: int64
```

```
[126]: encoded_X_train["Customer Type"]=le.fit_transform(encoded_X_train["Customer␣
        ↪Type"])
       encoded_X_train["Customer Type"].value_counts()
```

```
[126]: 1    79497
       0    17913
       Name: Customer Type, dtype: int64
```

```
[127]: encoded_X_train["Type of Travel"].value_counts()
```

```
[127]: Business    67234
       Personal    30176
       Name: Type of Travel, dtype: int64
```

```
[128]: encoded_X_train["Type of Travel"]=le.fit_transform(encoded_X_train["Type of␣
        ↪Travel"])
       encoded_X_train["Type of Travel"].value_counts()
```

```
[128]: 0    67234
       1    30176
       Name: Type of Travel, dtype: int64
```

```
[129]: encoded_X_train["Class"].value_counts()
```

```
[129]: Business        46509
       Economy         43832
       Economy Plus     7069
       Name: Class, dtype: int64
```

```
[130]: encoded_X_train["Class"]=le.fit_transform(encoded_X_train["Class"])
       encoded_X_train["Class"].value_counts()
```

```
[130]: 0    46509
       1    43832
       2     7069
       Name: Class, dtype: int64
```

```
[131]: encoded_X_train.head()
```

[131]:

```
       Gender  Age  Customer Type  Type of Travel  Class  Flight Distance  \
ID
2050        1   47              1               0      1            812.0
49177       0   44              1               0      0           3285.0
38347       1   26              1               0      1           1173.0
36700       1   48              1               1      1           1197.0
20522       0   16              1               1      0            533.0

       Departure Delay  Arrival Delay  Departure and Arrival Time Convenience  \
ID
2050              30.0           32.5                                       3
49177              0.0            0.0                                       0
38347              0.0            0.0                                       3
36700              9.0            0.0                                       5
20522              0.0            0.0                                       5

       Ease of Online Booking  …  Gate Location  On-board Service  \
ID                             …
2050                        3  …              3                 1
49177                       0  …              1                 3
38347                       3  …              3                 3
36700                       1  …              2                 5
20522                       1  …              4                 4

       Seat Comfort  Leg Room Service  Cleanliness  Food and Drink  \
ID
2050              3                 1            3               3
49177             3                 3            1               3
38347             4                 5            5               5
36700             4                 2            4               4
20522             5                 5            5               5

       In-flight Service  In-flight Wifi Service  In-flight Entertainment  \
ID
2050                   3                       3                        3
49177                  3                       0                        3
38347                  4                       5                        5
36700                  4                       1                        4
20522                  5                       1                        5

       Baggage Handling
ID
2050                  3
49177                 3
38347                 4
36700                 1
20522                 5
```

```
[5 rows x 22 columns]
```

[132]:
```
y_train.value_counts()
```

[132]:
```
Neutral or Dissatisfied    55153
Satisfied                  42257
Name: Satisfaction, dtype: int64
```

[133]:
```
encoded_y_train=le.fit_transform(y_train)
encoded_y_train
```

[133]:
```
array([0, 1, 1, …, 1, 0, 0])
```

[134]:
```
encoded_y_train = pd.DataFrame(encoded_y_train, index=encoded_y_train)
```

[135]:
```
encoded_y_train.columns = ['Satisfaction']
```

[136]:
```
encoded_y_train.head()
```

[136]:
```
   Satisfaction
0             0
1             1
1             1
0             0
0             0
```

Applying Feature Selection to reduce dimensions

[137]:
```
# Pre-processing and scaling dataset for feature selection
from sklearn import preprocessing

r_scaler = preprocessing.MinMaxScaler()
r_scaler.fit(encoded_X_train)

encoded_X_train_scaled = pd.DataFrame(r_scaler.transform(encoded_X_train),␣
  ↪columns = encoded_X_train.columns)
encoded_X_train_scaled.head()

encoded_y_train_scaled = encoded_y_train
```

[138]:
```
# Finding the best K for feature selection

import sklearn.feature_selection as fs
import sklearn.datasets as datasets
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
```

```python
import sklearn.metrics as metrics
import matplotlib.pyplot as plt

X = encoded_X_train_scaled
y = encoded_y_train_scaled

f1_list = []
for k in range(1, 22):
    bk = fs.SelectKBest(fs.f_classif, k = k)
    bk.fit(X, y)
    X_trans = bk.transform(X)
    train_x, test_x, train_y, test_y = train_test_split(X_trans,
                                                        y,
                                                        test_size=0.2,
                                                        random_state=42)
    lr = LogisticRegression()
    lr.fit(train_x, train_y)
    y_pred = lr.predict(test_x)
    #f1 = metrics.f1_score(test_y, y_pred, pos_label="Satisfied")
    f1 = metrics.f1_score(test_y, y_pred)
    f1_list.append(f1)

print(len(f1_list))

fig, axe = plt.subplots(dpi = 150)

print(type(axe))

axe.plot(range(0, len(f1_list)), f1_list)
axe.set_xlabel("best k features")
axe.set_ylabel("F1-score")
plt.grid(True)
plt.show()
# fig.savefig("img.png")
# plt.close(fig)
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
```

```
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
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```

```
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expected. Please change the shape of y to (n_samples, ), for example using
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```

```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
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expected. Please change the shape of y to (n_samples, ), for example using
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expected. Please change the shape of y to (n_samples, ), for example using
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```

```
ravel().
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expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```
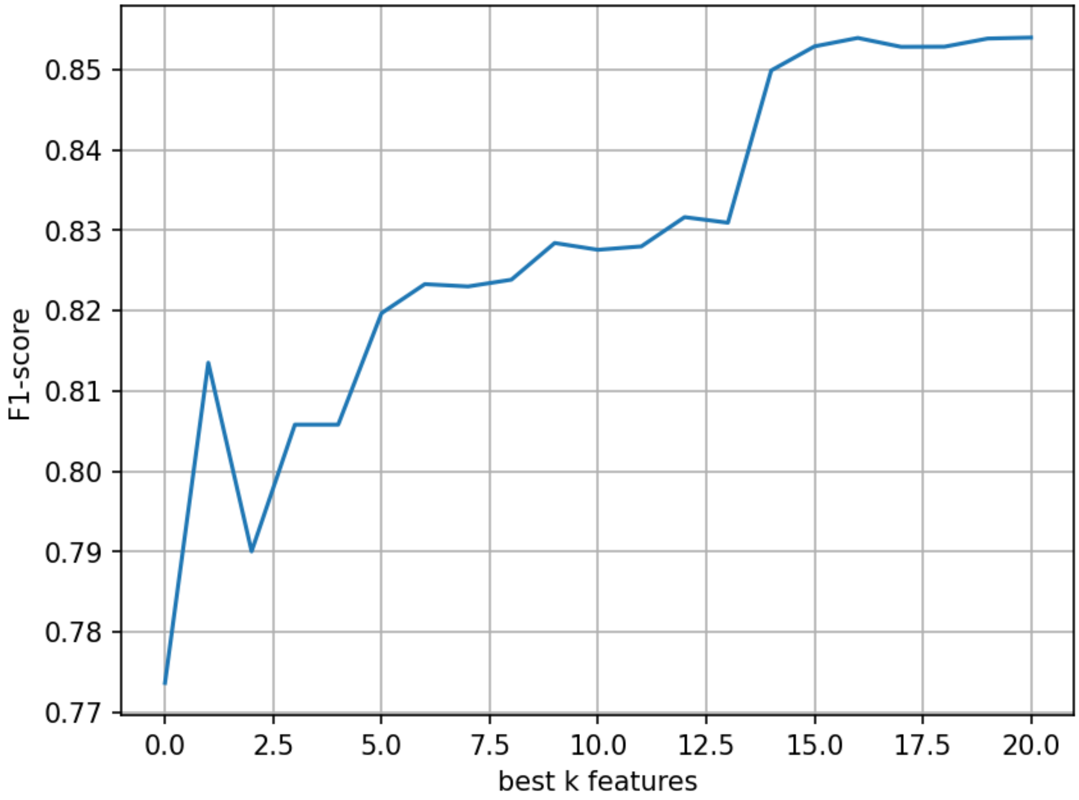

```
21
<class 'matplotlib.axes._axes.Axes'>
```



[139]:
```
# Feature selection, applying Select K Best to output the 14 most important␣
 ↪features
from sklearn.feature_selection import SelectKBest, f_classif

# X = encoded_X_train_scaled.loc[:,encoded_X_train_scaled.columns!
 ↪='Satisfaction']
X = encoded_X_train_scaled
y = encoded_y_train_scaled

selector = SelectKBest(f_classif, k = 14)
selector.fit(X, y)
```

```
selected_X_train_scaled = selector.transform(X)

features = (X.columns[selector.get_support(indices=True)])
features
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/utils/validation.py:1143:
DataConversionWarning: A column-vector y was passed when a 1d array was
expected. Please change the shape of y to (n_samples, ), for example using
ravel().
  y = column_or_1d(y, warn=True)
```

[139]:

```
Index(['Type of Travel', 'Class', 'Flight Distance', 'Check-in Service',
       'Online Boarding', 'On-board Service', 'Seat Comfort',
       'Leg Room Service', 'Cleanliness', 'Food and Drink',
       'In-flight Service', 'In-flight Wifi Service',
       'In-flight Entertainment', 'Baggage Handling'],
      dtype='object')
```

[140]:

```
features = pd.DataFrame(selected_X_train_scaled[selector.
 ↪get_support(indices=True)])
# features.head()
```

[141]:

```
features.columns = ['Type of Travel', 'Class', 'Flight Distance', 'Check-in␣
 ↪Service',
       'Online Boarding', 'On-board Service', 'Seat Comfort',
       'Leg Room Service', 'Cleanliness', 'Food and Drink',
       'In-flight Service', 'In-flight Wifi Service',
       'In-flight Entertainment', 'Baggage Handling']
```

[142]:

```
features.head()
```

[142]:

```
   Type of Travel  Class  Flight Distance  Check-in Service  Online Boarding  \
0             1.0    0.5         0.314455               0.4              0.2
1             1.0    0.0         0.135383               0.6              0.2
2             0.0    0.5         0.174757               0.8              0.6
3             1.0    0.5         0.154531               1.0              0.2
4             0.0    0.0         0.307983               0.8              0.8

   On-board Service  Seat Comfort  Leg Room Service  Cleanliness  \
0               1.0           0.8               0.4          0.8
1               0.8           1.0               1.0          1.0
2               0.8           0.4               0.2          0.4
3               1.0           1.0               1.0          1.0
4               1.0           1.0               0.8          1.0

   Food and Drink  In-flight Service  In-flight Wifi Service  \
0             0.8                0.8                     0.2
```

```
1            1.0                1.0                      0.2
2            0.4                0.6                      0.6
3            1.0                1.0                      0.2
4            1.0                0.8                      0.8

   In-flight Entertainment  Baggage Handling
0                      0.8              0.00
1                      1.0              1.00
2                      0.4              0.75
3                      1.0              0.75
4                      1.0              1.00
```

[143]:

```
selected_X_train_scaled.shape
```

[143]:

```
(97410, 14)
```

Applying undersampling, oversampling and SMOTE to address the imbalance in the target class, "Satisfaction".

Applying SMOTE

[144]:

```
from imblearn.over_sampling import SMOTE
from collections import Counter
# define dataset
X_SMOTE = selected_X_train_scaled
y_SMOTE = encoded_y_train_scaled
# summarize class distribution
counter = Counter(y_SMOTE)
print('Before SMOTE',(counter))
# transform the dataset
oversample = SMOTE()
X_SMOTE, y_SMOTE = oversample.fit_resample(X_SMOTE, y_SMOTE)
# summarize the new class distribution
counter = Counter(y_SMOTE)
print('After SMOTE',(counter))
```

```
Before SMOTE Counter({'Satisfaction': 1})
After SMOTE Counter({'Satisfaction': 1})
```

[145]:

```
SMOTE_train = pd.DataFrame(X_SMOTE)
SMOTE_train.columns = features.columns
```

[146]:

```
SMOTE_train.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 110306 entries, 0 to 110305
Data columns (total 14 columns):
 #   Column                  Non-Null Count   Dtype
```

```
---  ------                     ---------------  -----
 0   Type of Travel             110306 non-null  float64
 1   Class                      110306 non-null  float64
 2   Flight Distance            110306 non-null  float64
 3   Check-in Service           110306 non-null  float64
 4   Online Boarding            110306 non-null  float64
 5   On-board Service           110306 non-null  float64
 6   Seat Comfort               110306 non-null  float64
 7   Leg Room Service           110306 non-null  float64
 8   Cleanliness                110306 non-null  float64
 9   Food and Drink             110306 non-null  float64
 10  In-flight Service          110306 non-null  float64
 11  In-flight Wifi Service     110306 non-null  float64
 12  In-flight Entertainment    110306 non-null  float64
 13  Baggage Handling           110306 non-null  float64
dtypes: float64(14)
memory usage: 11.8 MB
```

[147]:
```
y_SMOTE.value_counts()
```

[147]:
```
Satisfaction
0               55153
1               55153
dtype: int64
```

Applying undersampling

[148]:
```
from imblearn.under_sampling import RandomUnderSampler
# define dataset
X_under = selected_X_train_scaled
y_under = encoded_y_train_scaled
# summarize class distribution
print('Before UnderSampling',(Counter(y_under)))
# define undersample strategy
undersample = RandomUnderSampler(sampling_strategy='majority')
# fit and apply the transform
X_under, y_under = undersample.fit_resample(X_under, y_under)
# summarize class distribution
print('After UnderSampling',(Counter(y_under)))
```

```
Before UnderSampling Counter({'Satisfaction': 1})
After UnderSampling Counter({'Satisfaction': 1})
```

[149]:
```
undersampling_train = pd.DataFrame(X_under)
undersampling_train.columns = features.columns
```

[150]:
```
undersampling_train.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 84514 entries, 0 to 84513
Data columns (total 14 columns):
 #   Column                    Non-Null Count  Dtype  
---  ------                    --------------  -----  
 0   Type of Travel            84514 non-null  float64
 1   Class                     84514 non-null  float64
 2   Flight Distance           84514 non-null  float64
 3   Check-in Service          84514 non-null  float64
 4   Online Boarding           84514 non-null  float64
 5   On-board Service          84514 non-null  float64
 6   Seat Comfort              84514 non-null  float64
 7   Leg Room Service          84514 non-null  float64
 8   Cleanliness               84514 non-null  float64
 9   Food and Drink            84514 non-null  float64
 10  In-flight Service         84514 non-null  float64
 11  In-flight Wifi Service    84514 non-null  float64
 12  In-flight Entertainment   84514 non-null  float64
 13  Baggage Handling          84514 non-null  float64
dtypes: float64(14)
memory usage: 9.0 MB
```

[151]:

```
y_under.value_counts()
```

[151]:

```
Satisfaction
0               42257
1               42257
dtype: int64
```

Applying oversampling

[152]:

```
from imblearn.over_sampling import RandomOverSampler
# define dataset
X_over = selected_X_train_scaled
# y_over = y_train
y_over = encoded_y_train_scaled
# summarize class distribution
print('Before OverSampling',(Counter(y_over)))
# define oversampling strategy
oversample = RandomOverSampler(sampling_strategy='minority')
# fit and apply the transform
X_over, y_over = oversample.fit_resample(X_over, y_over)
# summarize class distribution
print('After OverSampling',(Counter(y_over)))
```

```
Before OverSampling Counter({'Satisfaction': 1})
After OverSampling Counter({'Satisfaction': 1})
```

[153]:
```
oversampling_train = pd.DataFrame(X_over)
oversampling_train.columns = features.columns
```

[154]:
```
oversampling_train.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 110306 entries, 0 to 110305
Data columns (total 14 columns):
 #   Column                    Non-Null Count   Dtype
---  ------                    --------------   -----
 0   Type of Travel            110306 non-null  float64
 1   Class                     110306 non-null  float64
 2   Flight Distance           110306 non-null  float64
 3   Check-in Service          110306 non-null  float64
 4   Online Boarding           110306 non-null  float64
 5   On-board Service          110306 non-null  float64
 6   Seat Comfort              110306 non-null  float64
 7   Leg Room Service          110306 non-null  float64
 8   Cleanliness               110306 non-null  float64
 9   Food and Drink            110306 non-null  float64
 10  In-flight Service         110306 non-null  float64
 11  In-flight Wifi Service    110306 non-null  float64
 12  In-flight Entertainment   110306 non-null  float64
 13  Baggage Handling          110306 non-null  float64
dtypes: float64(14)
memory usage: 11.8 MB
```

[156]:
```
y_over.value_counts()
```

[156]:
```
Satisfaction
0               55153
1               55153
dtype: int64
```

Building Models

Apply Random Forest, k-Nearest Neighbours, and Gradient Boosting (Extreme Gradient Boosting (XGBoost))

Random Forest: SMOTE

[157]:
```
from sklearn.ensemble import RandomForestClassifier
```

[158]:
```
RF = RandomForestClassifier(max_features= 14,  max_depth=7)
```

[159]:
```
RF.fit(SMOTE_train , y_SMOTE)
RF.score(SMOTE_train , y_SMOTE)
```

```
<ipython-input-159-d365d61def11>:1: DataConversionWarning: A column-vector y was
```

```
passed when a 1d array was expected. Please change the shape of y to
(n_samples,), for example using ravel().
  RF.fit(SMOTE_train , y_SMOTE)
```

```
[159]: 0.9291969611807155
```

Random Forest: undersampling

```
[160]: RF.fit(undersampling_train, y_under)
        RF.score(undersampling_train, y_under)
```

```
<ipython-input-160-8503aaaec792>:1: DataConversionWarning: A column-vector y was
passed when a 1d array was expected. Please change the shape of y to
(n_samples,), for example using ravel().
  RF.fit(undersampling_train, y_under)
```

```
[160]: 0.9274203090612206
```

Random Forest: oversampling

```
[161]: RF.fit(oversampling_train, y_over)
        RF.score(oversampling_train, y_over)
```

```
<ipython-input-161-c7bc34fba153>:1: DataConversionWarning: A column-vector y was
passed when a 1d array was expected. Please change the shape of y to
(n_samples,), for example using ravel().
  RF.fit(oversampling_train, y_over)
```

```
[161]: 0.9266495022936195
```

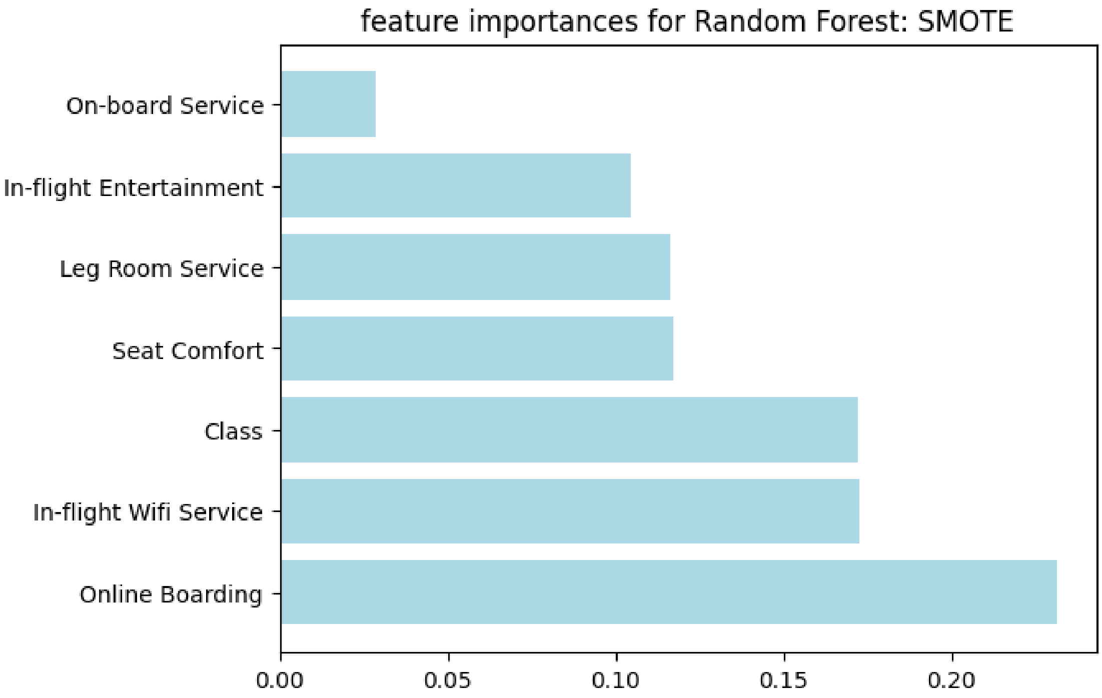
Observation: Random Forest: SMOTE is the highest score, 92.9 but there is no significant difference.

Checking the important features using Random Forest: SMOTE

```
[180]: RF_SMOTE_train = SMOTE_train
       RF_y_SMOTE = y_SMOTE

       def f_importances(coef, names, top=-1):
           imp = coef
           imp, names = zip(*sorted(list(zip(imp, names))))

           if top == -1:
               top = len(names)

           plt.barh(range(top), imp[::-1][0:top], align='center', color = 'LightBlue')
           plt.yticks(range(top), names[::-1][0:top])
           plt.title('feature importances for Random Forest: SMOTE')
           plt.show()
```

```
features_names = RF_SMOTE_train.columns

rf = RandomForestClassifier(n_estimators=4 , max_depth=3 , min_samples_split=25␣
 ↪, max_features=4, random_state=0)
rf.fit(RF_SMOTE_train , RF_y_SMOTE)
f_importances(abs(rf.feature_importances_), features_names, top=7)
```

```
<ipython-input-180-7e9ccdfb3c27>:19: DataConversionWarning: A column-vector y
was passed when a 1d array was expected. Please change the shape of y to
(n_samples,), for example using ravel().
  rf.fit(RF_SMOTE_train , RF_y_SMOTE)
```



KNN: SMOTE

[169]:
```
from sklearn.neighbors import KNeighborsClassifier
```

[170]:
```
KNN = KNeighborsClassifier(n_neighbors=5)
```

[171]:
```
KNN.fit(SMOTE_train , y_SMOTE)
KNN.score(SMOTE_train , y_SMOTE)
```

```
/usr/local/lib/python3.10/dist-
packages/sklearn/neighbors/_classification.py:215: DataConversionWarning: A
column-vector y was passed when a 1d array was expected. Please change the shape
```

```
of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
[171]: 0.9552698855909924
```

KNN: undersampling

```
[172]: KNN.fit(undersampling_train, y_under)
        KNN.score(undersampling_train, y_under)
```

```
/usr/local/lib/python3.10/dist-
packages/sklearn/neighbors/_classification.py:215: DataConversionWarning: A
column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
[172]: 0.9443287502662281
```

KNN: oversampling

```
[86]: KNN.fit(oversampling_train, y_over)
       KNN.score(oversampling_train, y_over)
```

```
/usr/local/lib/python3.10/dist-
packages/sklearn/neighbors/_classification.py:215: DataConversionWarning: A
column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```

```
[86]: 0.9511268652657153
```

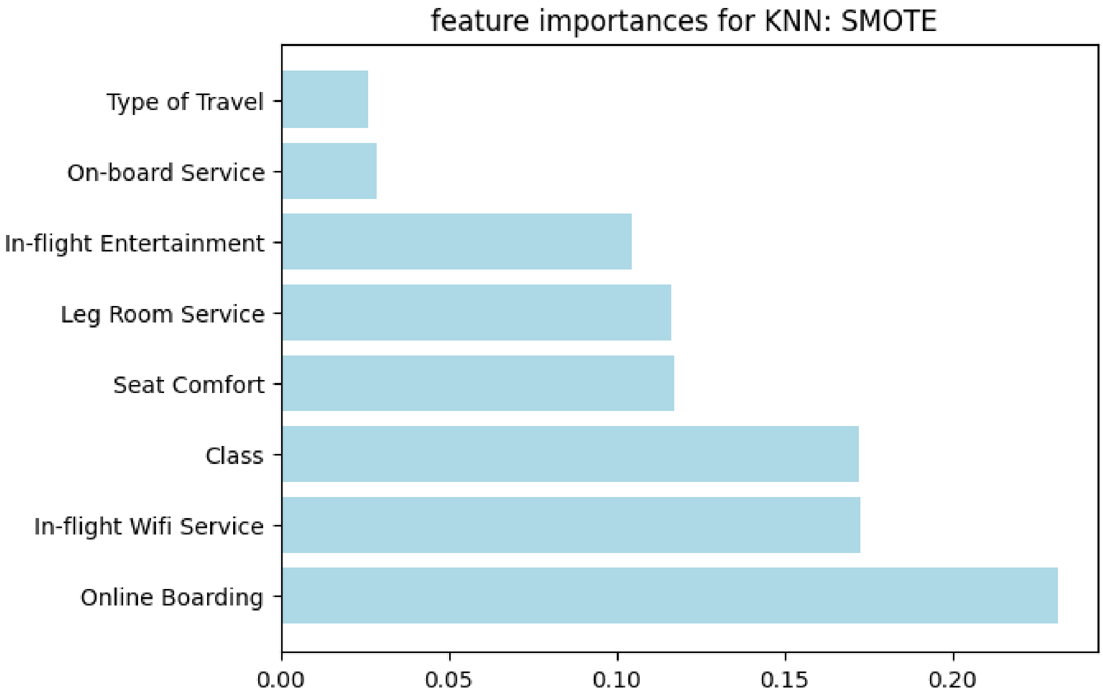
Observation: KNN: SMOTE is the highest score, 95.5 but there is no significant difference.

Checking the important features using KNN: SMOTE

```
[209]: KNN_SMOTE_train = SMOTE_train
       KNN_y_SMOTE = y_SMOTE

       def f_importances(coef, names, top=-1):
           imp = coef
           imp, names = zip(*sorted(list(zip(imp, names))))

           if top == -1:
               top = len(names)

           plt.barh(range(top), imp[::-1][0:top], align='center', color = 'LightBlue')
           plt.yticks(range(top), names[::-1][0:top])
           plt.title('feature importances for KNN: SMOTE ')
           plt.show()
```

```
features_names = KNN_SMOTE_train.columns

knn = KNeighborsClassifier(n_neighbors=5)
knn.fit(KNN_SMOTE_train , KNN_y_SMOTE)
f_importances(abs(rf.feature_importances_), features_names, top=8)
```

```
/usr/local/lib/python3.10/dist-
packages/sklearn/neighbors/_classification.py:215: DataConversionWarning: A
column-vector y was passed when a 1d array was expected. Please change the shape
of y to (n_samples,), for example using ravel().
  return self._fit(X, y)
```



XGBoost: SMOTE

[174]:

```
from xgboost import XGBClassifier
```

[175]:

```
XGB = XGBClassifier(max_depth = 18 , n_estimators= 6)
```

[176]:

```
XGB.fit(SMOTE_train , y_SMOTE)
XGB.score(SMOTE_train , y_SMOTE)
```

[176]:

```
0.9748608416586586
```

XGBoost: undersampling

[177]:
```
XGB.fit(undersampling_train, y_under)
XGB.score(undersampling_train, y_under)
```

[177]:
```
0.9741107982109473
```

XGBoost: oversampling

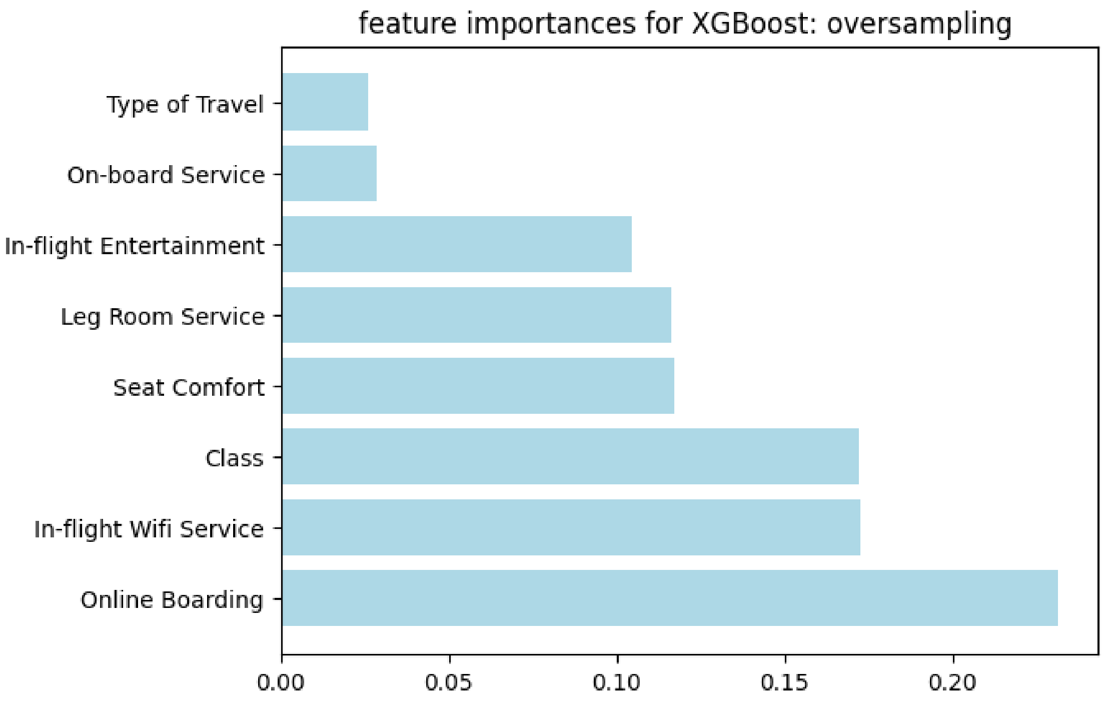
[178]:
```
XGB.fit(oversampling_train, y_over)
XGB.score(oversampling_train, y_over)
```

[178]:
```
0.9762388265370877
```

Observation: XGBoost: oversampling = Highest score, 97.6 but but there is no significant difference.

Checking the important features using XGBoost: oversampling

[210]:
```
XGB_oversampling_train = oversampling_train
XGB_y_over = y_over

def f_importances(coef, names, top=-1):
    imp = coef
    imp, names = zip(*sorted(list(zip(imp, names))))

    if top == -1:
        top = len(names)

    plt.barh(range(top), imp[::-1][0:top], align='center', color = 'LightBlue')
    plt.yticks(range(top), names[::-1][0:top])
    plt.title('feature importances for XGBoost: oversampling ')
    plt.show()

features_names = XGB_oversampling_train.columns

xgb = XGBClassifier(max_depth = 18 , n_estimators= 6)
xgb.fit(XGB_oversampling_train , XGB_y_over)
f_importances(abs(rf.feature_importances_), features_names, top=8)
```



[213]:

```python
import sklearn
import time
from resource import getrusage, RUSAGE_SELF
from sklearn.metrics import accuracy_score
from sklearn.metrics import precision_score
from sklearn.metrics import recall_score
from sklearn.metrics import roc_auc_score
from sklearn.metrics import confusion_matrix
from sklearn.metrics import roc_curve
```

[216]:

```python
# Model activation and result plot function
def get_model_metrics(model, SMOTE_train, modified_X_test, y_SMOTE, y_test):

    '''
    Model activation function, takes in model as a parameter and returns␣
 ↪metrics as specified.

    Inputs:
        model,  SMOTE_train, modified_X_test, y_SMOTE, y_test
    Output:
        Model output metrics, confusion matrix, ROC AUC curve
    '''

    # Mark of current time when model began running
    t0 = time.time()

    # Fit the model on the training data and run predictions on test data
    model.fit(SMOTE_train,  y_SMOTE)
    y_pred = model.predict(modified_X_test)
    y_pred_proba = model.predict_proba(modified_X_test)[:,1]
    # Obtain training accuracy as a comparative metric using Sklearn's metrics␣
↪package
    train_score = model.score(SMOTE_train,  y_SMOTE)
    # Obtain testing accuracy as a comparative metric using Sklearn's metrics␣
↪package
    accuracy = accuracy_score(y_test, y_pred)
    # Obtain precision from predictions using Sklearn's metrics package
    precision = precision_score(y_test, y_pred)
    # Obtain recall from predictions using Sklearn's metrics package
    recall = recall_score(y_test, y_pred)
    # Obtain ROC score from predictions using Sklearn's metrics package
    roc = roc_auc_score(y_test, y_pred_proba)
    # Obtain the time taken used to run the model, by subtracting the start␣
↪time from the current time
    time_taken = time.time() - t0
    # Obtain the resources consumed in running the model
    memory_used = int(getrusage(RUSAGE_SELF).ru_maxrss / 1024)

    # Outputting the metrics of the model performance
    print("Accuracy on Training = {}".format(train_score))
    print("Accuracy on Test = {} • Precision = {}".format(accuracy, precision))
    print("Recall = {} • ROC Area under Curve = {}".format(recall, roc))
    print("F1 = {} • ROC Area under Curve = {}".format(f1, roc))
    print("Time taken = {} seconds • Memory consumed = {} Bytes".
↪format(time_taken, memory_used))

    # Plotting the confusion matrix of the model's predictive capabilities
    plt.confusion_matrix(model, modified_X_test, y_test, cmap = plt.cm.Blues,␣
↪normalize = 'all')
    # Plotting the ROC AUC curve of the model
    plt.roc_curve(model, modified_X_test, y_test)
    plt.show()

    return model, train_score, accuracy, precision, recall, roc, time_taken,␣
↪memory_used
```