S10_T01_Aprenentage_Supervisat_Clasificacio

June 1, 2022

Sprint 10. Aprenentatge Supervisat - Classificació

Libraries

[192]:
```
#Data Manipulation
import pandas as pd
import numpy as np

#Data Modeling
import category_encoders as ce
from scipy import stats
from statsmodels.stats.outliers_influence import variance_inflation_factor
from imblearn.over_sampling import SMOTE
from imblearn.under_sampling import RandomUnderSampler
from imblearn.pipeline import Pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split, GridSearchCV,␣
↪cross_validate,cross_val_predict
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import classification_report, roc_curve
from sklearn.metrics import mean_squared_error, confusion_matrix,roc_curve
from sklearn.metrics import roc_auc_score,plot_confusion_matrix,␣
↪accuracy_score,f1_score
from sklearn import svm
from sklearn.neighbors import KNeighborsClassifier
from sklearn.tree import DecisionTreeClassifier

#Data Visualization
import seaborn as sns
import matplotlib.pyplot as plt
```

Notebook Function

[2]:
```
#1: Percent of nan values
def percent_nan(df):
    return round((df.isnull().sum()/df.shape[0])*100,2)
```

[3]:
```
#2: impute nan with zeros
def imputation_nan_zero(df,list_col):
```

```
    for i in list_col:
        df[i] = df[i].fillna(0)
```

[4]:
```
#3: function to return the value of the taxi time by airport
def airport(lista,df,feature,index):
    airport = df[feature].iloc[index]
    for x,val in enumerate(lista.index):
        if val == airport:
            return lista.iloc[x]
```

[5]:
```
#4: imput  from the list values
def imputation_value (lista,df,col):
    for i in lista:
        df[col] = df[col].fillna(i,limit=1)
```

[6]:
```
#5: Transform type
def astype_convertion(df,cols,dtype):
    df[cols] = df[cols].astype(dtype)
```

[7]:
```
#6: correlation matrix

def matrix_plot (df,name):

    fig, ax = plt.subplots(figsize=(15, 15))

# Data
    corr_matrix= df.select_dtypes(include=[np.number]).corr(method='pearson')
    half_matrix = np.triu(corr_matrix)

# Heatmap Matrix
    sns.heatmap(corr_matrix, annot=True, mask = half_matrix,
                cmap=sns.color_palette('YlOrBr', as_cmap=True),
                annot_kws = {"size": 10})
    ax.set_xticklabels(ax.get_xticklabels(),rotation = 90,horizontalalignment =␣
 ↪'right',)
    ax.set_yticklabels(ax.get_yticklabels(),rotation = 0,horizontalalignment =␣
 ↪'right',)
    ax.tick_params(labelsize = 15)
    fig.suptitle(name, fontsize = 13, fontweight = "bold")
    plt.show()
```

[8]:
```
#7: Variance Inflation Factor(VIF)
def vif(Z):
    vif_data = pd.DataFrame()
    vif_data['feature'] = Z.columns
```

```
    vif_data['Variance Inflation Factor(VIF)'] = [variance_inflation_factor(Z.
↪values, i)
                                                  for i in range(len(Z.
↪columns))]
    return vif_data
```

[9]:
```
#8 convert time to ordinal value
def time_to_ordinal(df,col,newCol):
    df[newCol] = df[col].apply(lambda x: x.toordinal())
```

[10]:
```
#9 plot confusion matrix and roc

def␣
↪subplots_ROC_CM(main_title,rtitle,mtitle,mod,accuracy,auc,matrix,model,Xtest,ytest):
↪
    fig , axes = plt.subplots(1,2,figsize=(10,8))


    y_pred_prob1_rs = mod.predict_proba(Xtest)[:,1]
    fpr1_rs, tpr1_rs, thresholds1_rs = roc_curve(ytest, y_pred_prob1_rs)
    axes[0].plot([0, 1], [0, 1], 'k--')
    axes[0].plot(fpr1_rs, tpr1_rs, label='Logistic Regression')
    axes[0].legend(loc="best")
    axes[0].set_xlabel('False Positive Rate')
    axes[0].set_xlabel('True Positive Rate')
    axes[0].set_title(rtitle + "\n" +
             "AUC : {0:.2%}".format(accuracy.get(model)))


    group_counts = ["{0:0.0f}".format(v) for v in matrix.flatten()]
    group_percentages = ["{0:.2%}".format(value)
                         for value in matrix.flatten()/np.sum(matrix)]
    labels = [f"{ant1}\n{ant2}" for ant1, ant2 in␣
↪zip(group_counts,group_percentages)]
    labels = np.asarray(labels).reshape(2,2)
    ax = sns.heatmap(matrix, annot=labels, fmt='',
                 cmap='Blues', ax=axes[1])
    axes[1].set_title(mtitle+ "\n" +"Accuracy Score: {0:.2%}".format(auc.
↪get(model)))
    axes[1].set_xlabel('\nPredicted Values')
    axes[1].set_ylabel('Actual Values ')
    axes[1].xaxis.set_ticklabels(['False','True'])
    axes[1].yaxis.set_ticklabels(['False','True'])

    plt.suptitle(main_title)
    plt.show()
```

This dataset is composed by the following variables: Year 2008 **Month** 1-12 **DayofMonth** 1-31 **DayOfWeek** 1 (Monday) - 7 (Sunday) **DepTime** actual departure time (local, hhmm) **CRSDepTime** scheduled departure time (local, hhmm) **ArrTime** actual arrival time (local, hhmm) **CRSArrTime** scheduled arrival time (local, hhmm) **UniqueCarrier** unique carrier code **FlightNum** flight number **TailNum** plane tail number: aircraft registration, unique aircraft identifier **ActualElapsedTime** in minutes **CRSElapsedTime** in minutes **AirTime** in minutes **ArrDelay** arrival delay, in minutes: A flight is counted as "on time" if it operated less than 15 minutes later the scheduled time shown in the carriers' Computerized Reservations Systems (CRS). **DepDelay** departure delay, in minutes **Origin** origin IATA airport code **Dest** destination IATA airport code **Distance** in miles **TaxiIn** taxi in time, in minutes **TaxiOut** taxi out time in minutes **Cancelled** was the flight cancelled **CancellationCode** reason for cancellation (A = carrier, B = weather, C = NAS, D = security) **Diverted** 1 = yes, 0 = no **CarrierDelay in minutes:** Carrier delay is within the control of the air carrier. Examples of occurrences that may determine carrier delay are: aircraft cleaning, aircraft damage, awaiting the arrival of connecting passengers or crew, baggage, bird strike, cargo loading, catering, computer, outage-carrier equipment, crew legality (pilot or attendant rest), damage by hazardous goods, engineering inspection, fueling, handling disabled passengers, late crew, lavatory servicing, maintenance, oversales, potable water servicing, removal of unruly passenger, slow boarding or seating, stowing carry-on baggage, weight and balance delays. **WeatherDelay in minutes:** Weather delay is caused by extreme or hazardous weather conditions that are forecasted or manifest themselves on point of departure, enroute, or on point of arrival. **NASDelay in minutes:** Delay that is within the control of the National Airspace System (NAS) may include: non-extreme weather conditions, airport operations, heavy traffic volume, air traffic control, etc. **SecurityDelay in minutes:** Security delay is caused by evacuation of a terminal or concourse, re-boarding of aircraft because of security breach, inoperative screening equipment and/or long lines in excess of 29 minutes at screening areas. **LateAircraftDelay in minutes:** Arrival delay at an airport due to the late arrival of the same aircraft at a previous airport. The ripple effect of an earlier delay at downstream airports is referred to as delay propagation.

[11]:
```
data = pd.read_csv("DelayedFlights.csv",
                   parse_dates=[["Year", "Month","DayofMonth"]])
```

[12]:
```
data.head().T
```

[12]:

	0	1	\
Year_Month_DayofMonth	2008-01-03 00:00:00	2008-01-03 00:00:00	
Unnamed: 0	0	1	
DayOfWeek	4	4	
DepTime	2003.0	754.0	
CRSDepTime	1955	735	
ArrTime	2211.0	1002.0	
CRSArrTime	2225	1000	
UniqueCarrier	WN	WN	
FlightNum	335	3231	
TailNum	N712SW	N772SW	
ActualElapsedTime	128.0	128.0	
CRSElapsedTime	150.0	145.0	
AirTime	116.0	113.0	

```
ArrDelay                                -14.0                 2.0
DepDelay                                  8.0                19.0
Origin                                    IAD                 IAD
Dest                                      TPA                 TPA
Distance                                  810                 810
TaxiIn                                    4.0                 5.0
TaxiOut                                   8.0                10.0
Cancelled                                   0                   0
CancellationCode                            N                   N
Diverted                                    0                   0
CarrierDelay                              NaN                 NaN
WeatherDelay                              NaN                 NaN
NASDelay                                  NaN                 NaN
SecurityDelay                             NaN                 NaN
LateAircraftDelay                         NaN                 NaN

                                            2                   3  \
Year_Month_DayofMonth  2008-01-03 00:00:00  2008-01-03 00:00:00
Unnamed: 0                                  2                   4
DayOfWeek                                   4                   4
DepTime                                 628.0              1829.0
CRSDepTime                                620                1755
ArrTime                                 804.0              1959.0
CRSArrTime                                750                1925
UniqueCarrier                              WN                  WN
FlightNum                                 448                3920
TailNum                                 N428WN             N464WN
ActualElapsedTime                         96.0                90.0
CRSElapsedTime                            90.0                90.0
AirTime                                   76.0                77.0
ArrDelay                                  14.0                34.0
DepDelay                                   8.0                34.0
Origin                                     IND                 IND
Dest                                       BWI                 BWI
Distance                                   515                 515
TaxiIn                                     3.0                 3.0
TaxiOut                                   17.0                10.0
Cancelled                                    0                   0
CancellationCode                             N                   N
Diverted                                     0                   0
CarrierDelay                               NaN                 2.0
WeatherDelay                               NaN                 0.0
NASDelay                                   NaN                 0.0
SecurityDelay                              NaN                 0.0
LateAircraftDelay                          NaN                32.0

                                             4
```

```
Year_Month_DayofMonth  2008-01-03 00:00:00
Unnamed: 0                               5
DayOfWeek                                4
DepTime                             1940.0
CRSDepTime                            1915
ArrTime                             2121.0
CRSArrTime                            2110
UniqueCarrier                           WN
FlightNum                              378
TailNum                             N726SW
ActualElapsedTime                    101.0
CRSElapsedTime                       115.0
AirTime                               87.0
ArrDelay                              11.0
DepDelay                              25.0
Origin                                 IND
Dest                                   JAX
Distance                               688
TaxiIn                                 4.0
TaxiOut                               10.0
Cancelled                                0
CancellationCode                         N
Diverted                                 0
CarrierDelay                           NaN
WeatherDelay                           NaN
NASDelay                               NaN
SecurityDelay                          NaN
LateAircraftDelay                      NaN
```

DEA

[13]:
```
df = data.copy()
```

[14]:
```
df.rename(columns={"Year_Month_DayofMonth":"Date"},inplace=True)
```

[15]:
```
df.head().T
```

[15]:
```
                                    0                    1  \
Date                2008-01-03 00:00:00  2008-01-03 00:00:00
Unnamed: 0                            0                    1
DayOfWeek                             4                    4
DepTime                          2003.0                754.0
CRSDepTime                         1955                  735
ArrTime                          2211.0               1002.0
CRSArrTime                         2225                 1000
UniqueCarrier                        WN                   WN
FlightNum                           335                 3231
```

TailNum	N712SW	N772SW
ActualElapsedTime	128.0	128.0
CRSElapsedTime	150.0	145.0
AirTime	116.0	113.0
ArrDelay	-14.0	2.0
DepDelay	8.0	19.0
Origin	IAD	IAD
Dest	TPA	TPA
Distance	810	810
TaxiIn	4.0	5.0
TaxiOut	8.0	10.0
Cancelled	0	0
CancellationCode	N	N
Diverted	0	0
CarrierDelay	NaN	NaN
WeatherDelay	NaN	NaN
NASDelay	NaN	NaN
SecurityDelay	NaN	NaN
LateAircraftDelay	NaN	NaN

			\
	2	3	
Date	2008-01-03 00:00:00	2008-01-03 00:00:00	
Unnamed: 0	2	4	
DayOfWeek	4	4	
DepTime	628.0	1829.0	
CRSDepTime	620	1755	
ArrTime	804.0	1959.0	
CRSArrTime	750	1925	
UniqueCarrier	WN	WN	
FlightNum	448	3920	
TailNum	N428WN	N464WN	
ActualElapsedTime	96.0	90.0	
CRSElapsedTime	90.0	90.0	
AirTime	76.0	77.0	
ArrDelay	14.0	34.0	
DepDelay	8.0	34.0	
Origin	IND	IND	
Dest	BWI	BWI	
Distance	515	515	
TaxiIn	3.0	3.0	
TaxiOut	17.0	10.0	
Cancelled	0	0	
CancellationCode	N	N	
Diverted	0	0	
CarrierDelay	NaN	2.0	
WeatherDelay	NaN	0.0	
NASDelay	NaN	0.0	

```
SecurityDelay                      NaN                  0.0
LateAircraftDelay                  NaN                 32.0

                                     4
Date                 2008-01-03 00:00:00
Unnamed: 0                           5
DayOfWeek                            4
DepTime                         1940.0
CRSDepTime                        1915
ArrTime                         2121.0
CRSArrTime                        2110
UniqueCarrier                       WN
FlightNum                          378
TailNum                         N726SW
ActualElapsedTime                 101.0
CRSElapsedTime                    115.0
AirTime                            87.0
ArrDelay                           11.0
DepDelay                           25.0
Origin                              IND
Dest                                JAX
Distance                           688
TaxiIn                             4.0
TaxiOut                           10.0
Cancelled                            0
CancellationCode                     N
Diverted                             0
CarrierDelay                       NaN
WeatherDelay                       NaN
NASDelay                           NaN
SecurityDelay                      NaN
LateAircraftDelay                  NaN
```

[16]:
```
data.shape
```

[16]:
```
(1936758, 28)
```

[17]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1936758 entries, 0 to 1936757
Data columns (total 28 columns):
 #   Column                  Dtype
---  ------                  -----
 0   Year_Month_DayofMonth   datetime64[ns]
 1   Unnamed: 0              int64
 2   DayOfWeek               int64
```

```
 3   DepTime                float64
 4   CRSDepTime             int64
 5   ArrTime                float64
 6   CRSArrTime             int64
 7   UniqueCarrier          object
 8   FlightNum              int64
 9   TailNum                object
 10  ActualElapsedTime      float64
 11  CRSElapsedTime         float64
 12  AirTime                float64
 13  ArrDelay               float64
 14  DepDelay               float64
 15  Origin                 object
 16  Dest                   object
 17  Distance               int64
 18  TaxiIn                 float64
 19  TaxiOut                float64
 20  Cancelled              int64
 21  CancellationCode       object
 22  Diverted               int64
 23  CarrierDelay           float64
 24  WeatherDelay           float64
 25  NASDelay               float64
 26  SecurityDelay          float64
 27  LateAircraftDelay      float64
dtypes: datetime64[ns](1), float64(14), int64(8), object(5)
memory usage: 413.7+ MB
```

[18]:
```
df.isna().sum()
```

[18]:
```
Date                    0
Unnamed: 0              0
DayOfWeek               0
DepTime                 0
CRSDepTime              0
ArrTime              7110
CRSArrTime              0
UniqueCarrier           0
FlightNum               0
TailNum                 5
ActualElapsedTime    8387
CRSElapsedTime        198
AirTime              8387
ArrDelay             8387
DepDelay                0
Origin                  0
Dest                    0
```

```
Distance                 0
TaxiIn                7110
TaxiOut                455
Cancelled                0
CancellationCode         0
Diverted                 0
CarrierDelay        689270
WeatherDelay        689270
NASDelay            689270
SecurityDelay       689270
LateAircraftDelay   689270
dtype: int64
```

[19]:
```
df.describe().T
```

[19]:

	count	mean	std	min	25%	\
Unnamed: 0	1936758.0	3.341651e+06	2.066065e+06	0.0	1517452.5	
DayOfWeek	1936758.0	3.984827e+00	1.995966e+00	1.0	2.0	
DepTime	1936758.0	1.518534e+03	4.504853e+02	1.0	1203.0	
CRSDepTime	1936758.0	1.467473e+03	4.247668e+02	0.0	1135.0	
ArrTime	1929648.0	1.610141e+03	5.481781e+02	1.0	1316.0	
CRSArrTime	1936758.0	1.634225e+03	4.646347e+02	0.0	1325.0	
FlightNum	1936758.0	2.184263e+03	1.944702e+03	1.0	610.0	
ActualElapsedTime	1928371.0	1.333059e+02	7.206007e+01	14.0	80.0	
CRSElapsedTime	1936560.0	1.343027e+02	7.134144e+01	-25.0	82.0	
AirTime	1928371.0	1.082771e+02	6.864261e+01	0.0	58.0	
ArrDelay	1928371.0	4.219988e+01	5.678472e+01	-109.0	9.0	
DepDelay	1936758.0	4.318518e+01	5.340250e+01	6.0	12.0	
Distance	1936758.0	7.656862e+02	5.744797e+02	11.0	338.0	
TaxiIn	1929648.0	6.812975e+00	5.273595e+00	0.0	4.0	
TaxiOut	1936303.0	1.823220e+01	1.433853e+01	0.0	10.0	
Cancelled	1936758.0	3.268348e-04	1.807562e-02	0.0	0.0	
Diverted	1936758.0	4.003598e-03	6.314722e-02	0.0	0.0	
CarrierDelay	1247488.0	1.917940e+01	4.354621e+01	0.0	0.0	
WeatherDelay	1247488.0	3.703571e+00	2.149290e+01	0.0	0.0	
NASDelay	1247488.0	1.502164e+01	3.383305e+01	0.0	0.0	
SecurityDelay	1247488.0	9.013714e-02	2.022714e+00	0.0	0.0	
LateAircraftDelay	1247488.0	2.529647e+01	4.205486e+01	0.0	0.0	

	50%	75%	max
Unnamed: 0	3242558.0	4972466.75	7009727.0
DayOfWeek	4.0	6.00	7.0
DepTime	1545.0	1900.00	2400.0
CRSDepTime	1510.0	1815.00	2359.0
ArrTime	1715.0	2030.00	2400.0
CRSArrTime	1705.0	2014.00	2400.0
FlightNum	1543.0	3422.00	9742.0

```
ActualElapsedTime      116.0      165.00     1114.0
CRSElapsedTime         116.0      165.00      660.0
AirTime                 90.0      137.00     1091.0
ArrDelay                24.0       56.00     2461.0
DepDelay                24.0       53.00     2467.0
Distance               606.0      998.00     4962.0
TaxiIn                   6.0        8.00      240.0
TaxiOut                 14.0       21.00      422.0
Cancelled                0.0        0.00        1.0
Diverted                 0.0        0.00        1.0
CarrierDelay             2.0       21.00     2436.0
WeatherDelay             0.0        0.00     1352.0
NASDelay                 2.0       15.00     1357.0
SecurityDelay            0.0        0.00      392.0
LateAircraftDelay        8.0       33.00     1316.0
```

[20]:
```
df.describe(include="object").T
```

[20]:
```
                    count unique     top     freq
UniqueCarrier     1936758     20      WN   377602
TailNum           1936753   5366  N325SW      965
Origin            1936758    303     ATL   131613
Dest              1936758    304     ORD   108984
CancellationCode  1936758      4       N  1936125
```

[21]:
```
#use the function (1) to find the percent of nan values
percent_nan(df)
```

[21]:
```
Date                 0.00
Unnamed: 0           0.00
DayOfWeek            0.00
DepTime              0.00
CRSDepTime           0.00
ArrTime              0.37
CRSArrTime           0.00
UniqueCarrier        0.00
FlightNum            0.00
TailNum              0.00
ActualElapsedTime    0.43
CRSElapsedTime       0.01
AirTime              0.43
ArrDelay             0.43
DepDelay             0.00
Origin               0.00
Dest                 0.00
Distance             0.00
TaxiIn               0.37
```

```
TaxiOut              0.02
Cancelled            0.00
CancellationCode     0.00
Diverted             0.00
CarrierDelay        35.59
WeatherDelay        35.59
NASDelay            35.59
SecurityDelay       35.59
LateAircraftDelay   35.59
dtype: float64
```

Preproccesing Data

[22]:
```
df = df.loc[:, ~df.columns.str.contains('^Unnamed')]
```

[23]:
```
df.sample(10).T
```

[23]:
```
                                965126               773852   \
Date                2008-06-13 00:00:00  2008-05-08 00:00:00
DayOfWeek                             5                    4
DepTime                           946.0               2045.0
CRSDepTime                          845                 2015
ArrTime                          1108.0               2258.0
CRSArrTime                         1010                 2234
UniqueCarrier                        UA                   OH
FlightNum                           635                 5417
TailNum                          N347UA               N818CA
ActualElapsedTime                  82.0                133.0
CRSElapsedTime                     85.0                139.0
AirTime                            66.0                 94.0
ArrDelay                           58.0                 24.0
DepDelay                           61.0                 30.0
Origin                              ORD                  LGA
Dest                                OMA                  GSP
Distance                            416                  610
TaxiIn                              2.0                  6.0
TaxiOut                            14.0                 33.0
Cancelled                             0                    0
CancellationCode                      N                    N
Diverted                              0                    0
CarrierDelay                       42.0                  0.0
WeatherDelay                        0.0                 24.0
NASDelay                            0.0                  0.0
SecurityDelay                       0.0                  0.0
LateAircraftDelay                  16.0                  0.0

                                1135581              1576678  \
```

```
Date               2008-07-01 00:00:00  2008-10-16 00:00:00
DayOfWeek                            2                    4
DepTime                         2226.0               1738.0
CRSDepTime                        2050                 1435
ArrTime                          121.0               2045.0
CRSArrTime                        2346                 1746
UniqueCarrier                       OO                   DL
FlightNum                         6436                 1403
TailNum                          N405SW               N906DL
ActualElapsedTime                115.0                187.0
CRSElapsedTime                   116.0                191.0
AirTime                           91.0                159.0
ArrDelay                          95.0                179.0
DepDelay                          96.0                183.0
Origin                             LAX                  BDL
Dest                               ABQ                  FLL
Distance                           677                 1173
TaxiIn                             6.0                  5.0
TaxiOut                           18.0                 23.0
Cancelled                            0                    0
CancellationCode                     N                    N
Diverted                             0                    0
CarrierDelay                       0.0                 29.0
WeatherDelay                       0.0                  0.0
NASDelay                           0.0                  0.0
SecurityDelay                      0.0                  0.0
LateAircraftDelay                 95.0                150.0

                                1282253              1647324  \
Date               2008-08-17 00:00:00  2008-11-30 00:00:00
DayOfWeek                            7                    7
DepTime                         1658.0               1606.0
CRSDepTime                        1650                 1445
ArrTime                         1914.0               1819.0
CRSArrTime                        1910                 1710
UniqueCarrier                       WN                   XE
FlightNum                         1928                 2806
TailNum                          N750SA               N14116
ActualElapsedTime                136.0                193.0
CRSElapsedTime                   140.0                205.0
AirTime                          122.0                172.0
ArrDelay                           4.0                 69.0
DepDelay                           8.0                 81.0
Origin                             PIT                  EWR
Dest                               TPA                  MCI
Distance                           873                 1092
TaxiIn                             5.0                  5.0
```

```
TaxiOut                          9.0                 16.0
Cancelled                          0                    0
CancellationCode                   N                    N
Diverted                           0                    0
CarrierDelay                     NaN                  0.0
WeatherDelay                     NaN                  5.0
NASDelay                         NaN                  0.0
SecurityDelay                    NaN                  0.0
LateAircraftDelay                NaN                 64.0

                               1641344              1645169  \
Date                2008-11-23 00:00:00  2008-11-30 00:00:00
DayOfWeek                          7                    7
DepTime                       1821.0               1153.0
CRSDepTime                      1805                 1120
ArrTime                       2015.0               1250.0
CRSArrTime                      2020                 1220
UniqueCarrier                     WN                   WN
FlightNum                       1519                 3128
TailNum                        N628SW               N643SW
ActualElapsedTime              114.0                 57.0
CRSElapsedTime                 135.0                 60.0
AirTime                        101.0                 45.0
ArrDelay                        -5.0                 30.0
DepDelay                        16.0                 33.0
Origin                           SJC                  BOI
Dest                             SEA                  SLC
Distance                         697                  291
TaxiIn                           4.0                  5.0
TaxiOut                          9.0                  7.0
Cancelled                          0                    0
CancellationCode                   N                    N
Diverted                           0                    0
CarrierDelay                     NaN                  0.0
WeatherDelay                     NaN                  0.0
NASDelay                         NaN                  0.0
SecurityDelay                    NaN                  0.0
LateAircraftDelay                NaN                 30.0

                                800131               1774668
Date                2008-05-09 00:00:00  2008-12-26 00:00:00
DayOfWeek                          5                    5
DepTime                       730.0               1135.0
CRSDepTime                      715                 1055
ArrTime                       1052.0               1407.0
CRSArrTime                      1020                 1319
UniqueCarrier                     US                   XE
```

FlightNum	817	2352
TailNum	N444US	N13133
ActualElapsedTime	142.0	152.0
CRSElapsedTime	125.0	144.0
AirTime	102.0	133.0
ArrDelay	32.0	48.0
DepDelay	15.0	40.0
Origin	ORD	OMA
Dest	PHL	IAH
Distance	678	781
TaxiIn	17.0	9.0
TaxiOut	23.0	10.0
Cancelled	0	0
CancellationCode	N	N
Diverted	0	0
CarrierDelay	0.0	6.0
WeatherDelay	0.0	0.0
NASDelay	32.0	8.0
SecurityDelay	0.0	0.0
LateAircraftDelay	0.0	34.0

The original dataframe has more than 35% of NaN's values in the delay features, I will impute the delay features observation with Zero because these the NaN's represents NO delay in anyform.

There are observations in the delay features with zeros but these have at least one value delay more than zero, there're others observation that all its values are COMPLETAR MAS TARDE

[24]:
```
features_imputation_zero =␣
↪["WeatherDelay","CarrierDelay","NASDelay","SecurityDelay","LateAircraftDelay"]
```

[25]:
```
#use the function (2)to imputate nan with zeros
imputation_nan_zero(df,features_imputation_zero)
```

[26]:
```
#use the function (1) to find the percent of nan values
percent_nan(df)
```

[26]:
```
Date                0.00
DayOfWeek           0.00
DepTime             0.00
CRSDepTime          0.00
ArrTime             0.37
CRSArrTime          0.00
UniqueCarrier       0.00
FlightNum           0.00
TailNum             0.00
ActualElapsedTime   0.43
```

```
CRSElapsedTime       0.01
AirTime              0.43
ArrDelay             0.43
DepDelay             0.00
Origin               0.00
Dest                 0.00
Distance             0.00
TaxiIn               0.37
TaxiOut              0.02
Cancelled            0.00
CancellationCode     0.00
Diverted             0.00
CarrierDelay         0.00
WeatherDelay         0.00
NASDelay             0.00
SecurityDelay        0.00
LateAircraftDelay    0.00
dtype: float64
```

Imputation of TaxiOut

[27]:
```
# group by origin and get the mean of the features
grouped_by_origin = round(df.groupby("Origin").mean(),0)
grouped_by_origin
```

[27]:

Origin	DayOfWeek	DepTime	CRSDepTime	ArrTime	CRSArrTime	FlightNum	\
ABE	4.0	1412.0	1316.0	1561.0	1471.0	5096.0	
ABI	4.0	1191.0	1079.0	1286.0	1176.0	3477.0	
ABQ	4.0	1531.0	1479.0	1696.0	1668.0	1810.0	
ABY	4.0	1434.0	1355.0	1504.0	1446.0	4736.0	
ACK	4.0	1462.0	1362.0	1587.0	1499.0	3118.0	
…	…	…	…	…	…	…	
WYS	4.0	1735.0	1694.0	1856.0	1826.0	3634.0	
XNA	4.0	1339.0	1251.0	1528.0	1457.0	3988.0	
YAK	4.0	1601.0	1501.0	1652.0	1590.0	63.0	
YKM	5.0	1027.0	994.0	1290.0	1246.0	3906.0	
YUM	4.0	1343.0	1291.0	1425.0	1405.0	3955.0	

Origin	ActualElapsedTime	CRSElapsedTime	AirTime	ArrDelay	…	Distance	\
					…		
ABE	124.0	122.0	98.0	61.0	…	590.0	
ABI	57.0	58.0	38.0	66.0	…	158.0	
ABQ	108.0	110.0	91.0	34.0	…	643.0	
ABY	57.0	55.0	37.0	51.0	…	146.0	
ACK	83.0	83.0	52.0	66.0	…	210.0	
…	…	…	…	…	…	…	

```
WYS                  77.0           84.0     61.0      18.0  …     273.0
XNA                 116.0          114.0     90.0      57.0  …     607.0
YAK                  49.0           49.0     37.0      55.0  …     206.0
YKM                  96.0           93.0     80.0      26.0  …     586.0
YUM                  69.0           71.0     49.0      34.0  …     239.0

        TaxiIn  TaxiOut  Cancelled  Diverted  CarrierDelay  WeatherDelay  \
Origin
ABE       10.0     15.0        0.0       0.0          18.0           4.0
ABI        9.0     10.0        0.0       0.0          33.0          11.0
ABQ        6.0     11.0        0.0       0.0           7.0           1.0
ABY       11.0      9.0        0.0       0.0          19.0           8.0
ACK       11.0     20.0        0.0       0.0          16.0           6.0
…          …       …          …         …             …              …
WYS        5.0     11.0        0.0       0.0           0.0           0.0
XNA       10.0     16.0        0.0       0.0          15.0           3.0
YAK        4.0      8.0        0.0       0.0           5.0           0.0
YKM        6.0     10.0        0.0       0.0          10.0           3.0
YUM        7.0     13.0        0.0       0.0          22.0           1.0

        NASDelay  SecurityDelay  LateAircraftDelay
Origin
ABE         21.0            0.0               15.0
ABI          9.0            0.0               11.0
ABQ          4.0            0.0               19.0
ABY         14.0            0.0                8.0
ACK         23.0            0.0               20.0
…            …              …                  …
WYS          0.0            0.0               16.0
XNA         18.0            0.0               19.0
YAK          3.0            0.0               45.0
YKM          0.0            0.0                9.0
YUM          4.0            1.0                5.0

[303 rows x 21 columns]
```

The TaxiOut is the time spent by a aircraft between its initial movement from the gate and the actual take-off time. This is important because in congested airports its value may increase due to the wait for take-off.

[28]:
```
#get only the TaxiOut
taxiOut_by_origin = grouped_by_origin["TaxiOut"]
taxiOut_by_origin
```

[28]:
```
Origin
ABE    15.0
ABI    10.0
```

```
ABQ    11.0
ABY     9.0
ACK    20.0
       …
WYS    11.0
XNA    16.0
YAK     8.0
YKM    10.0
YUM    13.0
Name: TaxiOut, Length: 303, dtype: float64
```

[30]:
```
#get the indexes of the row with taxiOut as NaN values
index_taxiout_nan = df[df["TaxiOut"].isnull()].index
index_taxiout_nan
```

[30]:
```
Int64Index([1546593, 1547161, 1547178, 1548271, 1548430, 1550787, 1554099,
            1556173, 1559220, 1561026,
            …
            1930247, 1930288, 1930321, 1930326, 1930330, 1931769, 1933249,
            1934590, 1935491, 1935876],
           dtype='int64', length=455)
```

[31]:
```
#Use function (3) to get the taxiOut time and then append the
# values in a  list.
n_values_taxiOut = []
for i in index_taxiout_nan:
    x = airport(taxiOut_by_origin,df,"Origin",i)
    n_values_taxiOut.append(x)
```

[32]:
```
#Use function (4) to imput the TaxiOut takes time because it impute a value at␣
 ↪time
#This way the imputation is individual
imputation_value(n_values_taxiOut,df,"TaxiOut")
```

[33]:
```
#use the function (1) to find the percent of nan values
percent_nan(df)
```

[33]:
```
Date                0.00
DayOfWeek           0.00
DepTime             0.00
CRSDepTime          0.00
ArrTime             0.37
CRSArrTime          0.00
UniqueCarrier       0.00
FlightNum           0.00
TailNum             0.00
ActualElapsedTime   0.43
```

```
CRSElapsedTime       0.01
AirTime              0.43
ArrDelay             0.43
DepDelay             0.00
Origin               0.00
Dest                 0.00
Distance             0.00
TaxiIn               0.37
TaxiOut              0.00
Cancelled            0.00
CancellationCode     0.00
Diverted             0.00
CarrierDelay         0.00
WeatherDelay         0.00
NASDelay             0.00
SecurityDelay        0.00
LateAircraftDelay    0.00
dtype: float64
```

Imputation of TaxiIn

[34]:
```
# group by Dest and get the mean of the features
grouped_by_destination = round(df.groupby("Dest").mean(),0)
grouped_by_destination
```

[34]:

Dest	DayOfWeek	DepTime	CRSDepTime	ArrTime	CRSArrTime	FlightNum	\
ABE	4.0	1641.0	1571.0	1664.0	1763.0	4700.0	
ABI	4.0	1692.0	1627.0	1762.0	1718.0	3541.0	
ABQ	4.0	1543.0	1493.0	1609.0	1644.0	1730.0	
ABY	4.0	1569.0	1511.0	1601.0	1599.0	4729.0	
ACK	4.0	1506.0	1464.0	1501.0	1602.0	3261.0	
…	…	…	…	…	…	…	
WYS	4.0	1390.0	1333.0	1527.0	1498.0	3633.0	
XNA	4.0	1594.0	1528.0	1673.0	1685.0	4001.0	
YAK	4.0	1406.0	1319.0	1498.0	1414.0	63.0	
YKM	4.0	1766.0	1737.0	1841.0	1796.0	3937.0	
YUM	4.0	1459.0	1478.0	1492.0	1502.0	3992.0	

Dest	ActualElapsedTime	CRSElapsedTime	AirTime	ArrDelay	…	Distance	\
ABE	102.0	104.0	76.0	49.0	…	566.0	
ABI	54.0	54.0	34.0	37.0	…	158.0	
ABQ	115.0	118.0	96.0	32.0	…	682.0	
ABY	56.0	54.0	28.0	47.0	…	146.0	
ACK	89.0	87.0	45.0	59.0	…	211.0	
…	…	…	…	…	…	…	

```
WYS                81.0            89.0     59.0      24.0  …     273.0
XNA               110.0           110.0     85.0      47.0  …     565.0
YAK                55.0            54.0     38.0      53.0  …     205.0
YKM               107.0           102.0     85.0      27.0  …     586.0
YUM                69.0            70.0     45.0      36.0  …     218.0

      TaxiIn  TaxiOut  Cancelled  Diverted  CarrierDelay  WeatherDelay  \
Dest
ABE      5.0     22.0        0.0       0.0          19.0           3.0
ABI      3.0     16.0        0.0       0.0          14.0           5.0
ABQ      5.0     14.0        0.0       0.0          10.0           1.0
ABY      4.0     24.0        0.0       0.0          22.0           9.0
ACK      6.0     39.0        0.0       0.0          20.0           2.0
…        …       …           …         …            …              …
WYS      3.0     19.0        0.0       0.0          18.0           3.0
XNA      5.0     21.0        0.0       0.0          17.0           4.0
YAK      4.0     13.0        0.0       0.0          12.0           1.0
YKM      4.0     18.0        0.0       0.0          14.0           1.0
YUM      5.0     19.0        0.0       0.0          24.0           3.0

      NASDelay  SecurityDelay  LateAircraftDelay
Dest
ABE        7.0            0.0               18.0
ABI        4.0            0.0               11.0
ABQ        3.0            0.0               16.0
ABY       10.0            0.0                5.0
ACK       15.0            0.0               22.0
…          …              …                 …
WYS        1.0            0.0                1.0
XNA        6.0            0.0               19.0
YAK        3.0            0.0               34.0
YKM        4.0            0.0                5.0
YUM        2.0            0.0                4.0

[304 rows x 21 columns]
```

TaxiIn is the time of movement of the aircraft from the runway to the gate after it landed.

[35]:
```
#get only the TaxiOut
taxiIn_by_origin = grouped_by_destination["TaxiIn"]
taxiIn_by_origin
```

[35]:
```
Dest
ABE    5.0
ABI    3.0
ABQ    5.0
ABY    4.0
```

```
ACK    6.0
       …
WYS    3.0
XNA    5.0
YAK    4.0
YKM    4.0
YUM    5.0
Name: TaxiIn, Length: 304, dtype: float64
```

[36]:
```
#get the indexes of the row with taxiOut as NaN values
index_taxiIn_nan = df[df["TaxiIn"].isnull()].index
index_taxiIn_nan
```

[36]:
```
Int64Index([   1280,    1372,    1776,    1831,    2244,    2245,    2720,
                2831,    3075,    3179,
            …
            1930326, 1930330, 1931769, 1933249, 1933981, 1934590, 1935491,
            1935651, 1935876, 1936470],
           dtype='int64', length=7110)
```

[37]:
```
#Use function (3) to get the taxiOut time and then append the
# values in a  list.
n_values_taxiIn = []
for i in index_taxiIn_nan:
    x = airport(taxiIn_by_origin,df,"Dest",i)
    n_values_taxiIn.append(x)
```

[38]:
```
#Use function (4) to imput the TaxiIn takes time because it impute a value at␣
 ↪time
#This way the imputation is individual
imputation_value(n_values_taxiIn,df,"TaxiIn")
```

[39]:
```
#use the function (1) to find the percent of nan values
percent_nan(df)
```

[39]:
```
Date                0.00
DayOfWeek           0.00
DepTime             0.00
CRSDepTime          0.00
ArrTime             0.37
CRSArrTime          0.00
UniqueCarrier       0.00
FlightNum           0.00
TailNum             0.00
ActualElapsedTime   0.43
CRSElapsedTime      0.01
AirTime             0.43
```

```
ArrDelay             0.43
DepDelay             0.00
Origin               0.00
Dest                 0.00
Distance             0.00
TaxiIn               0.00
TaxiOut              0.00
Cancelled            0.00
CancellationCode     0.00
Diverted             0.00
CarrierDelay         0.00
WeatherDelay         0.00
NASDelay             0.00
SecurityDelay        0.00
LateAircraftDelay    0.00
dtype: float64
```

Imputation of ArrTime

[40]:
```
#get the indexes of the row with taxiOut as NaN values
index_ArrTime_nan = df[df["ArrTime"].isnull()].index
index_ArrTime_nan
```

[40]:
```
Int64Index([   1280,    1372,    1776,    1831,    2244,    2245,    2720,
               2831,    3075,    3179,
            …
            1930326, 1930330, 1931769, 1933249, 1933981, 1934590, 1935491,
            1935651, 1935876, 1936470],
           dtype='int64', length=7110)
```

[41]:
```
df.iloc[1936470]
```

[41]:
```
Date                 2008-12-12 00:00:00
DayOfWeek                              5
DepTime                            703.0
CRSDepTime                           630
ArrTime                              NaN
CRSArrTime                           734
UniqueCarrier                         DL
FlightNum                           1372
TailNum                           N908DE
ActualElapsedTime                    NaN
CRSElapsedTime                      64.0
AirTime                              NaN
ArrDelay                             NaN
DepDelay                            33.0
Origin                               LGA
```

```
Dest                                BOS
Distance                            185
TaxiIn                              NaN
TaxiOut                            33.0
Cancelled                             1
CancellationCode                      B
Diverted                              0
CarrierDelay                        0.0
WeatherDelay                        0.0
NASDelay                            0.0
SecurityDelay                       0.0
LateAircraftDelay                   0.0
Name: 1936470, dtype: object
```

I have reviewed some observations and concluded that the missing values are in ArrTime is because these flight are Diverted or Cancelled. The percent of the data is small so I will drop them because maybe it could be complicated to calculate them and the results can be wrong affecting the final result.

[42]:
```
#drop the NaN's
df.dropna(subset=["ArrTime"],inplace=True)
```

[43]:
```
 #use the function (1) to find the percent of nan values
percent_nan(df)
```

[43]:
```
Date                0.00
DayOfWeek           0.00
DepTime             0.00
CRSDepTime          0.00
ArrTime             0.00
CRSArrTime          0.00
UniqueCarrier       0.00
FlightNum           0.00
TailNum             0.00
ActualElapsedTime   0.07
CRSElapsedTime      0.00
AirTime             0.07
ArrDelay            0.07
DepDelay            0.00
Origin              0.00
Dest                0.00
Distance            0.00
TaxiIn              0.00
TaxiOut             0.00
Cancelled           0.00
CancellationCode    0.00
Diverted            0.00
```

```
CarrierDelay         0.00
WeatherDelay         0.00
NASDelay             0.00
SecurityDelay        0.00
LateAircraftDelay    0.00
dtype: float64
```

Converting to datetime

[44]:
```
date_cols = ["DepTime","ArrTime","CRSArrTime","CRSDepTime"]
```

[45]:
```
astype_convertion(df,date_cols,"int64")
```

[46]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 1929648 entries, 0 to 1936757
Data columns (total 27 columns):
 #   Column             Dtype
---  ------             -----
 0   Date               datetime64[ns]
 1   DayOfWeek          int64
 2   DepTime            int64
 3   CRSDepTime         int64
 4   ArrTime            int64
 5   CRSArrTime         int64
 6   UniqueCarrier      object
 7   FlightNum          int64
 8   TailNum            object
 9   ActualElapsedTime  float64
 10  CRSElapsedTime     float64
 11  AirTime            float64
 12  ArrDelay           float64
 13  DepDelay           float64
 14  Origin             object
 15  Dest               object
 16  Distance           int64
 17  TaxiIn             float64
 18  TaxiOut            float64
 19  Cancelled          int64
 20  CancellationCode   object
 21  Diverted           int64
 22  CarrierDelay       float64
 23  WeatherDelay       float64
 24  NASDelay           float64
 25  SecurityDelay      float64
 26  LateAircraftDelay  float64
dtypes: datetime64[ns](1), float64(12), int64(9), object(5)
```

```
memory usage: 412.2+ MB
```

[47]:
```
def convert_to_time(df,cols):
    for cols in date_cols:
        df[cols]= df[cols].astype(str).str.zfill(4)
        df[cols]= df[cols].str[:2] +':'+ df[cols].astype(str).str[2:]
        df.loc[df[cols]=="24:00",cols] = "00:00"
        df[cols] = pd.to_datetime(df[cols], format="%H:%M").dt.time
```

[48]:
```
convert_to_time(df,date_cols)
```

[49]:
```
df.head().T
```

[49]:

	0	1	\
Date	2008-01-03 00:00:00	2008-01-03 00:00:00	
DayOfWeek	4	4	
DepTime	20:03:00	07:54:00	
CRSDepTime	19:55:00	07:35:00	
ArrTime	22:11:00	10:02:00	
CRSArrTime	22:25:00	10:00:00	
UniqueCarrier	WN	WN	
FlightNum	335	3231	
TailNum	N712SW	N772SW	
ActualElapsedTime	128.0	128.0	
CRSElapsedTime	150.0	145.0	
AirTime	116.0	113.0	
ArrDelay	-14.0	2.0	
DepDelay	8.0	19.0	
Origin	IAD	IAD	
Dest	TPA	TPA	
Distance	810	810	
TaxiIn	4.0	5.0	
TaxiOut	8.0	10.0	
Cancelled	0	0	
CancellationCode	N	N	
Diverted	0	0	
CarrierDelay	0.0	0.0	
WeatherDelay	0.0	0.0	
NASDelay	0.0	0.0	
SecurityDelay	0.0	0.0	
LateAircraftDelay	0.0	0.0	

	2	3	\
Date	2008-01-03 00:00:00	2008-01-03 00:00:00	
DayOfWeek	4	4	
DepTime	06:28:00	18:29:00	
CRSDepTime	06:20:00	17:55:00	

```
ArrTime                    08:04:00            19:59:00
CRSArrTime                 07:50:00            19:25:00
UniqueCarrier                    WN                  WN
FlightNum                       448                3920
TailNum                      N428WN              N464WN
ActualElapsedTime              96.0                90.0
CRSElapsedTime                 90.0                90.0
AirTime                        76.0                77.0
ArrDelay                       14.0                34.0
DepDelay                        8.0                34.0
Origin                          IND                 IND
Dest                            BWI                 BWI
Distance                        515                 515
TaxiIn                          3.0                 3.0
TaxiOut                        17.0                10.0
Cancelled                         0                   0
CancellationCode                  N                   N
Diverted                          0                   0
CarrierDelay                    0.0                 2.0
WeatherDelay                    0.0                 0.0
NASDelay                        0.0                 0.0
SecurityDelay                   0.0                 0.0
LateAircraftDelay               0.0                32.0

                                  4
Date               2008-01-03 00:00:00
DayOfWeek                         4
DepTime                    19:40:00
CRSDepTime                 19:15:00
ArrTime                    21:21:00
CRSArrTime                 21:10:00
UniqueCarrier                    WN
FlightNum                       378
TailNum                      N726SW
ActualElapsedTime              101.0
CRSElapsedTime                 115.0
AirTime                         87.0
ArrDelay                        11.0
DepDelay                        25.0
Origin                          IND
Dest                            JAX
Distance                        688
TaxiIn                          4.0
TaxiOut                        10.0
Cancelled                         0
CancellationCode                  N
Diverted                          0
```

```
CarrierDelay                0.0
WeatherDelay                0.0
NASDelay                    0.0
SecurityDelay               0.0
LateAircraftDelay           0.0
```

Drop missing values

The remaining NaN values are less than 1% of total values and are from the same observations so I will drop them.

[50]:
```
df.dropna(inplace=True)
```

Change Data types

[51]:
```
float_cols = df.select_dtypes(["float64"]).columns
float_cols
```

[51]:
```
Index(['ActualElapsedTime', 'CRSElapsedTime', 'AirTime', 'ArrDelay',
       'DepDelay', 'TaxiIn', 'TaxiOut', 'CarrierDelay', 'WeatherDelay',
       'NASDelay', 'SecurityDelay', 'LateAircraftDelay'],
      dtype='object')
```

[52]:
```
astype_convertion(df,float_cols,"int64")
```

[53]:
```
object_cols = df.select_dtypes(["object"]).columns
object_cols
```

[53]:
```
Index(['DepTime', 'CRSDepTime', 'ArrTime', 'CRSArrTime', 'UniqueCarrier',
       'TailNum', 'Origin', 'Dest', 'CancellationCode'],
      dtype='object')
```

[54]:
```
astype_convertion(df,object_cols,"category")
```

[55]:
```
#run function (8) add a new feature named DateOrdinal
time_to_ordinal(df,"Date","OrdinalDate")
```

[56]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 1928368 entries, 0 to 1936757
Data columns (total 28 columns):
 #   Column             Dtype
---  ------             -----
 0   Date               datetime64[ns]
 1   DayOfWeek          int64
 2   DepTime            category
 3   CRSDepTime         category
```

```
 4   ArrTime            category
 5   CRSArrTime         category
 6   UniqueCarrier      category
 7   FlightNum          int64
 8   TailNum            category
 9   ActualElapsedTime  int64
 10  CRSElapsedTime     int64
 11  AirTime            int64
 12  ArrDelay           int64
 13  DepDelay           int64
 14  Origin             category
 15  Dest               category
 16  Distance           int64
 17  TaxiIn             int64
 18  TaxiOut            int64
 19  Cancelled          int64
 20  CancellationCode   category
 21  Diverted           int64
 22  CarrierDelay       int64
 23  WeatherDelay       int64
 24  NASDelay           int64
 25  SecurityDelay      int64
 26  LateAircraftDelay  int64
 27  OrdinalDate        int64
dtypes: category(9), datetime64[ns](1), int64(18)
memory usage: 324.0 MB
```

New feature: Flight Status

I will classify the fligh as delayed when have a delay more then 15min, ontime when is from 0-15 and early when have a negative ArrDelay.

[57]:
```
# Create our target variable in category
df["ArrDelay"] = [1 if x > 15 else 0 for x in df["ArrDelay"]]
df.head().T
```

[57]:

	0	1	\
Date	2008-01-03 00:00:00	2008-01-03 00:00:00	
DayOfWeek	4	4	
DepTime	20:03:00	07:54:00	
CRSDepTime	19:55:00	07:35:00	
ArrTime	22:11:00	10:02:00	
CRSArrTime	22:25:00	10:00:00	
UniqueCarrier	WN	WN	
FlightNum	335	3231	
TailNum	N712SW	N772SW	
ActualElapsedTime	128	128	
CRSElapsedTime	150	145	

```
AirTime                          116                  113
ArrDelay                           0                    0
DepDelay                           8                   19
Origin                           IAD                  IAD
Dest                             TPA                  TPA
Distance                         810                  810
TaxiIn                             4                    5
TaxiOut                            8                   10
Cancelled                          0                    0
CancellationCode                   N                    N
Diverted                           0                    0
CarrierDelay                       0                    0
WeatherDelay                       0                    0
NASDelay                           0                    0
SecurityDelay                      0                    0
LateAircraftDelay                  0                    0
OrdinalDate                   733044               733044

                                   2                    3  \
Date                2008-01-03 00:00:00  2008-01-03 00:00:00
DayOfWeek                          4                    4
DepTime                     06:28:00             18:29:00
CRSDepTime                  06:20:00             17:55:00
ArrTime                     08:04:00             19:59:00
CRSArrTime                  07:50:00             19:25:00
UniqueCarrier                     WN                   WN
FlightNum                        448                 3920
TailNum                        N428WN               N464WN
ActualElapsedTime                 96                   90
CRSElapsedTime                    90                   90
AirTime                           76                   77
ArrDelay                           0                    1
DepDelay                           8                   34
Origin                           IND                  IND
Dest                             BWI                  BWI
Distance                         515                  515
TaxiIn                             3                    3
TaxiOut                           17                   10
Cancelled                          0                    0
CancellationCode                   N                    N
Diverted                           0                    0
CarrierDelay                       0                    2
WeatherDelay                       0                    0
NASDelay                           0                    0
SecurityDelay                      0                    0
LateAircraftDelay                  0                   32
OrdinalDate                   733044               733044
```

```
                                4
Date               2008-01-03 00:00:00
DayOfWeek                          4
DepTime                     19:40:00
CRSDepTime                  19:15:00
ArrTime                     21:21:00
CRSArrTime                  21:10:00
UniqueCarrier                     WN
FlightNum                        378
TailNum                       N726SW
ActualElapsedTime                101
CRSElapsedTime                   115
AirTime                           87
ArrDelay                           0
DepDelay                          25
Origin                           IND
Dest                             JAX
Distance                         688
TaxiIn                             4
TaxiOut                           10
Cancelled                          0
CancellationCode                   N
Diverted                           0
CarrierDelay                       0
WeatherDelay                       0
NASDelay                           0
SecurityDelay                      0
LateAircraftDelay                  0
OrdinalDate                   733044
```

Encoding Categorical Variables

[58]:
```
objects_to_encoding = df.select_dtypes(["category"]).columns
objects_to_encoding
```

[58]:
```
Index(['DepTime', 'CRSDepTime', 'ArrTime', 'CRSArrTime', 'UniqueCarrier',
       'TailNum', 'Origin', 'Dest', 'CancellationCode'],
      dtype='object')
```

[60]:
```
#create the categorical values names for encoding

encoding_variables_names = []

for i in objects_to_encoding:
    name = "encoded_" + i
    encoding_variables_names.append(name)
```

```
encoding_variables_names
```

[60]:
```
['encoded_DepTime',
 'encoded_CRSDepTime',
 'encoded_ArrTime',
 'encoded_CRSArrTime',
 'encoded_UniqueCarrier',
 'encoded_TailNum',
 'encoded_Origin',
 'encoded_Dest',
 'encoded_CancellationCode']
```

[61]:
```
#loop the encoding code for the categorical values

for c,ev in zip(objects_to_encoding,encoding_variables_names):
    ev = ce.TargetEncoder(cols=c)
    df[c]= ev.fit_transform(df[c],df['ArrDelay'])
```

[62]:
```
df.head().T
```

[62]:

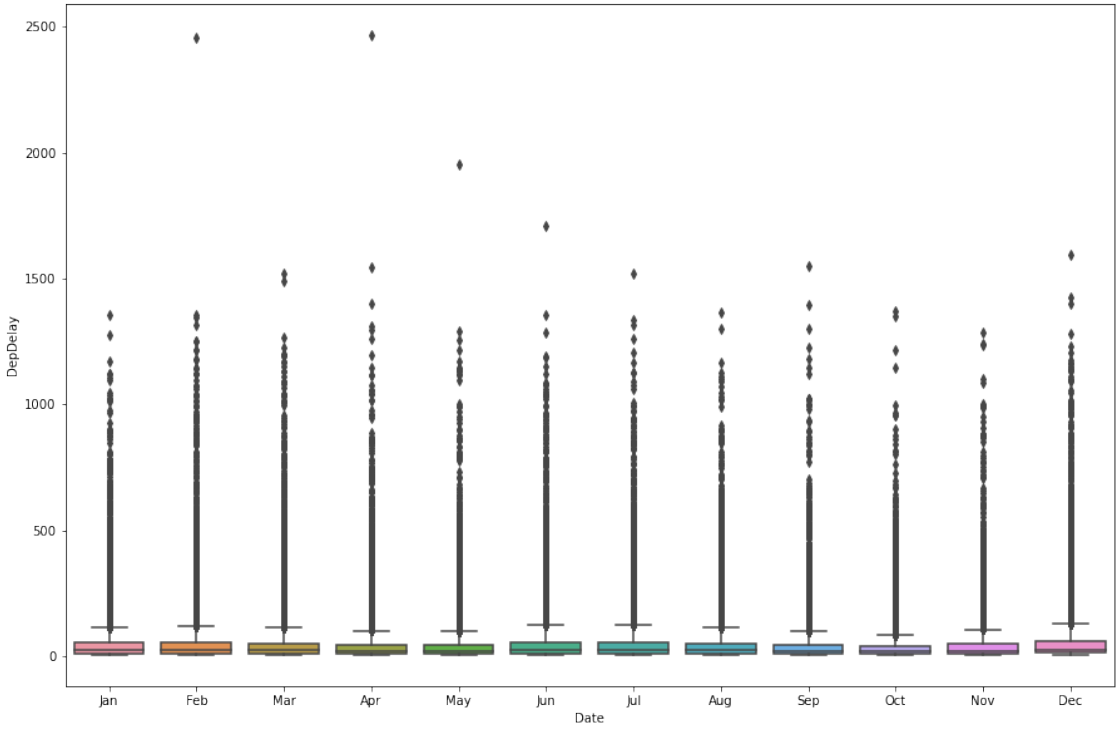
	0	1	\
Date	2008-01-03 00:00:00	2008-01-03 00:00:00	
DayOfWeek	4	4	
DepTime	0.671571	0.560784	
CRSDepTime	0.676369	0.582751	
ArrTime	0.70972	0.524862	
CRSArrTime	0.67242	0.587443	
UniqueCarrier	0.522125	0.522125	
FlightNum	335	3231	
TailNum	0.523438	0.486025	
ActualElapsedTime	128	128	
CRSElapsedTime	150	145	
AirTime	116	113	
ArrDelay	0	0	
DepDelay	8	19	
Origin	0.691697	0.691697	
Dest	0.57826	0.57826	
Distance	810	810	
TaxiIn	4	5	
TaxiOut	8	10	
Cancelled	0	0	
CancellationCode	0.630072	0.630072	
Diverted	0	0	
CarrierDelay	0	0	
WeatherDelay	0	0	
NASDelay	0	0	

```
SecurityDelay                      0                    0
LateAircraftDelay                  0                    0
OrdinalDate                   733044               733044

                                   2                    3  \
Date               2008-01-03 00:00:00  2008-01-03 00:00:00
DayOfWeek                          4                    4
DepTime                     0.415133             0.696876
CRSDepTime                    0.5472             0.657786
ArrTime                     0.432039             0.648252
CRSArrTime                  0.577914             0.631712
UniqueCarrier               0.522125             0.522125
FlightNum                        448                 3920
TailNum                     0.505843             0.571835
ActualElapsedTime                 96                   90
CRSElapsedTime                    90                   90
AirTime                           76                   77
ArrDelay                           0                    1
DepDelay                           8                   34
Origin                       0.65488              0.65488
Dest                           0.561                0.561
Distance                         515                  515
TaxiIn                             3                    3
TaxiOut                           17                   10
Cancelled                          0                    0
CancellationCode            0.630072             0.630072
Diverted                           0                    0
CarrierDelay                       0                    2
WeatherDelay                       0                    0
NASDelay                           0                    0
SecurityDelay                      0                    0
LateAircraftDelay                  0                   32
OrdinalDate                   733044               733044

                                   4
Date               2008-01-03 00:00:00
DayOfWeek                          4
DepTime                     0.733678
CRSDepTime                  0.680284
ArrTime                     0.714117
CRSArrTime                  0.671165
UniqueCarrier               0.522125
FlightNum                        378
TailNum                     0.523292
ActualElapsedTime                101
CRSElapsedTime                   115
AirTime                           87
```

ArrDelay	0
DepDelay	25
Origin	0.65488
Dest	0.625772
Distance	688
TaxiIn	4
TaxiOut	10
Cancelled	0
CancellationCode	0.630072
Diverted	0
CarrierDelay	0
WeatherDelay	0
NASDelay	0
SecurityDelay	0
LateAircraftDelay	0
OrdinalDate	733044

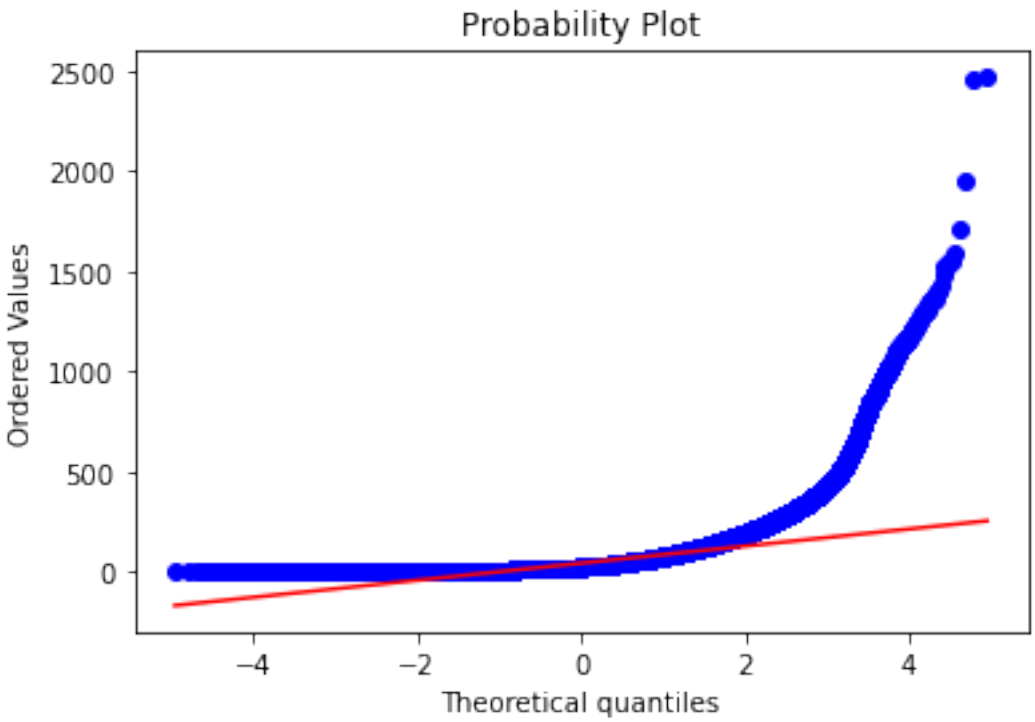
Data Distribution

[63]:
```
month =␣
↪["Jan","Feb","Mar","Apr","May","Jun","Jul","Aug","Sep","Oct","Nov","Dec"]
fig = plt.subplots(figsize=(15, 10))

moths = df["Date"].dt.month

fig = sns.boxplot(x = moths , y=df["DepDelay"])
fig.set_xticklabels(month)
plt.show()
```



The boxplot shows that there are many outtliers values,on the positive side are the delayed values and we can see that are many and in incremental. The negative side are the less values. The mean of the ArrDelay is moving but are similar in every month.

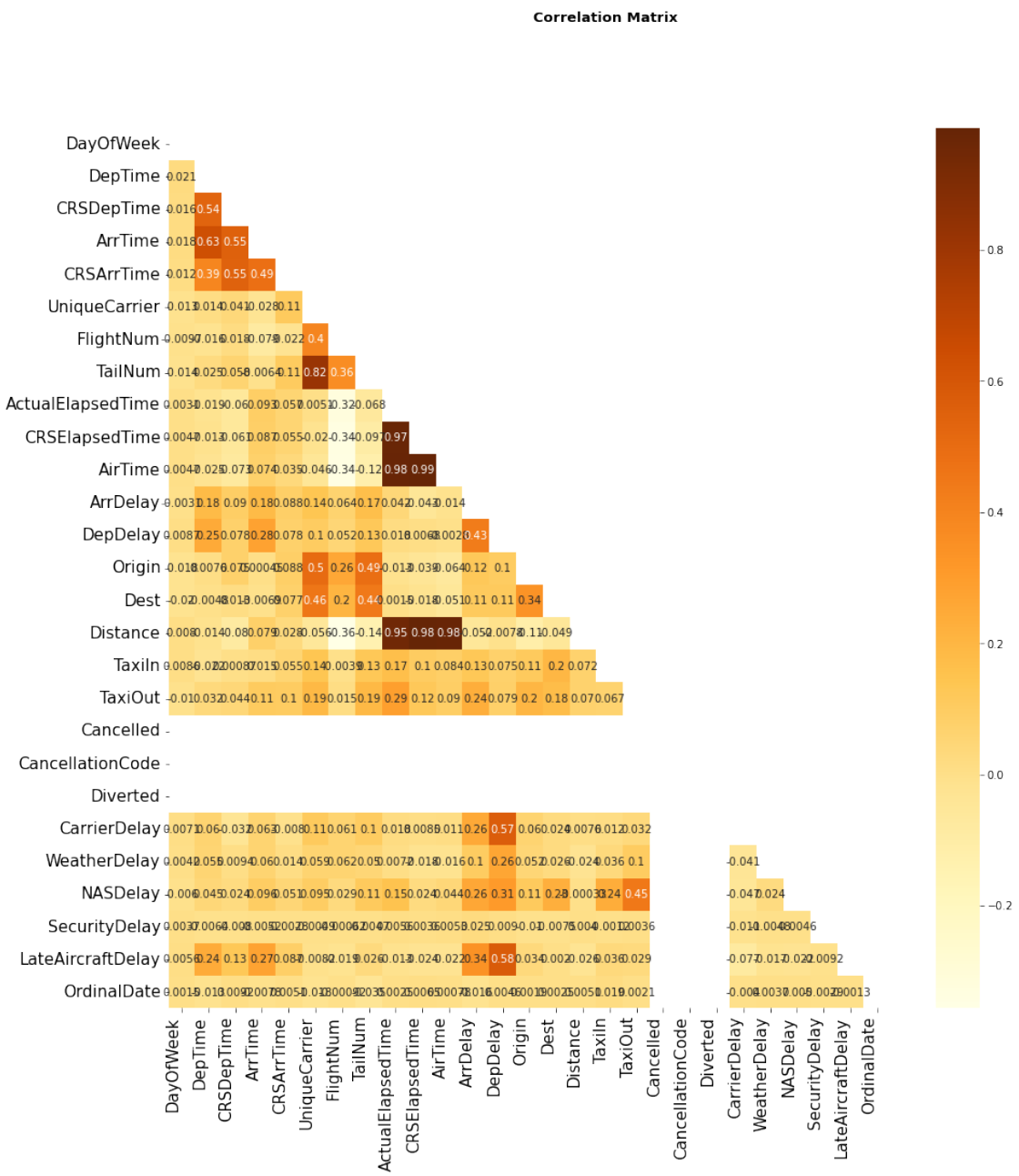
[64]:
```
stats.probplot(df["DepDelay"],plot=plt)
plt.show()
```



The QQplot suggest that the data distribution is not normal and is skewed as we can saw the dataset have many outliers.

Correlation and Multicollinearity

[65]:
```
#Use function (6) to plot the correlation matrix
matrix_plot(df,"Correlation Matrix")
```



The correlation matrix show that DepDelay have more weight to the ArrDelay.

[66]:
```
#Select the numeric values
z = df.select_dtypes(include = [np.number])
z.head().T
```

[66]:

	0	1	2	3	\
DayOfWeek	4.000000	4.000000	4.000000	4.000000	
DepTime	0.671571	0.560784	0.415133	0.696876	

CRSDepTime	0.676369	0.582751	0.547200	0.657786
ArrTime	0.709720	0.524862	0.432039	0.648252
CRSArrTime	0.672420	0.587443	0.577914	0.631712
UniqueCarrier	0.522125	0.522125	0.522125	0.522125
FlightNum	335.000000	3231.000000	448.000000	3920.000000
TailNum	0.523438	0.486025	0.505843	0.571835
ActualElapsedTime	128.000000	128.000000	96.000000	90.000000
CRSElapsedTime	150.000000	145.000000	90.000000	90.000000
AirTime	116.000000	113.000000	76.000000	77.000000
ArrDelay	0.000000	0.000000	0.000000	1.000000
DepDelay	8.000000	19.000000	8.000000	34.000000
Origin	0.691697	0.691697	0.654880	0.654880
Dest	0.578260	0.578260	0.561000	0.561000
Distance	810.000000	810.000000	515.000000	515.000000
TaxiIn	4.000000	5.000000	3.000000	3.000000
TaxiOut	8.000000	10.000000	17.000000	10.000000
Cancelled	0.000000	0.000000	0.000000	0.000000
CancellationCode	0.630072	0.630072	0.630072	0.630072
Diverted	0.000000	0.000000	0.000000	0.000000
CarrierDelay	0.000000	0.000000	0.000000	2.000000
WeatherDelay	0.000000	0.000000	0.000000	0.000000
NASDelay	0.000000	0.000000	0.000000	0.000000
SecurityDelay	0.000000	0.000000	0.000000	0.000000
LateAircraftDelay	0.000000	0.000000	0.000000	32.000000
OrdinalDate	733044.000000	733044.000000	733044.000000	733044.000000

	4
DayOfWeek	4.000000
DepTime	0.733678
CRSDepTime	0.680284
ArrTime	0.714117
CRSArrTime	0.671165
UniqueCarrier	0.522125
FlightNum	378.000000
TailNum	0.523292
ActualElapsedTime	101.000000
CRSElapsedTime	115.000000
AirTime	87.000000
ArrDelay	0.000000
DepDelay	25.000000
Origin	0.654880
Dest	0.625772
Distance	688.000000
TaxiIn	4.000000
TaxiOut	10.000000
Cancelled	0.000000
CancellationCode	0.630072

```
Diverted                0.000000
CarrierDelay            0.000000
WeatherDelay            0.000000
NASDelay                0.000000
SecurityDelay           0.000000
LateAircraftDelay       0.000000
OrdinalDate        733044.000000
```

[67]:
```
#run the function (7) to get the Variance Inflation Factor(VIF)
vif(z)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/statsmodels/stats/outliers_influence.py:193: RuntimeWarning: divide by
zero encountered in double_scalars
  vif = 1. / (1. - r_squared_i)
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/statsmodels/regression/linear_model.py:1715: RuntimeWarning: invalid
value encountered in double_scalars
  return 1 - self.ssr/self.centered_tss
```

[67]:

	feature	Variance Inflation Factor(VIF)
0	DayOfWeek	1.001669e+00
1	DepTime	1.896807e+00
2	CRSDepTime	1.886334e+00
3	ArrTime	2.161968e+00
4	CRSArrTime	1.596426e+00
5	UniqueCarrier	3.507218e+00
6	FlightNum	1.390677e+00
7	TailNum	3.247991e+00
8	ActualElapsedTime	inf
9	CRSElapsedTime	2.566946e+02
10	AirTime	inf
11	ArrDelay	1.751998e+00
12	DepDelay	1.441872e+02
13	Origin	1.583363e+00
14	Dest	1.420314e+00
15	Distance	4.051608e+01
16	TaxiIn	inf
17	TaxiOut	inf
18	Cancelled	NaN
19	CancellationCode	1.319489e-23
20	Diverted	NaN
21	CarrierDelay	6.773278e+01
22	WeatherDelay	1.624246e+01
23	NASDelay	4.041222e+01
24	SecurityDelay	1.135841e+00
25	LateAircraftDelay	6.679682e+01

```
26          OrdinalDate                    1.004900e+00
```

The multicollinearity are the correlation of the independent variables I wil drop the variables with more than a VIF of 5 but with the exepcion of the important variables to predict the ArrDelay.

[68]:
```
#copy of the DF before drop features in case of use
df_copy = df.copy()
```

[69]:
```
#drop the features with high dependency
df.drop(columns=["CRSDepTime","ActualElapsedTime","CRSElapsedTime","AirTime",
                 ␣
 ↪"Distance","CarrierDelay","TaxiIn","Cancelled","CancellationCode",
                 "Diverted","CarrierDelay","WeatherDelay","NASDelay",
                 "SecurityDelay","LateAircraftDelay","Date"],inplace=True)
```

[70]:
```
#Select the numeric values
z = df.select_dtypes(include = [np.number])
z.head().T
```

[70]:

	0	1	2	3	\
DayOfWeek	4.000000	4.000000	4.000000	4.000000	
DepTime	0.671571	0.560784	0.415133	0.696876	
ArrTime	0.709720	0.524862	0.432039	0.648252	
CRSArrTime	0.672420	0.587443	0.577914	0.631712	
UniqueCarrier	0.522125	0.522125	0.522125	0.522125	
FlightNum	335.000000	3231.000000	448.000000	3920.000000	
TailNum	0.523438	0.486025	0.505843	0.571835	
ArrDelay	0.000000	0.000000	0.000000	1.000000	
DepDelay	8.000000	19.000000	8.000000	34.000000	
Origin	0.691697	0.691697	0.654880	0.654880	
Dest	0.578260	0.578260	0.561000	0.561000	
TaxiOut	8.000000	10.000000	17.000000	10.000000	
OrdinalDate	733044.000000	733044.000000	733044.000000	733044.000000	

	4
DayOfWeek	4.000000
DepTime	0.733678
ArrTime	0.714117
CRSArrTime	0.671165
UniqueCarrier	0.522125
FlightNum	378.000000
TailNum	0.523292
ArrDelay	0.000000
DepDelay	25.000000
Origin	0.654880
Dest	0.625772
TaxiOut	10.000000

```
OrdinalDate    733044.000000
```

[71]:
```
#run the function (7) to get the Variance Inflation Factor(VIF)
vif(z)
```

[71]:
```
           feature  Variance Inflation Factor(VIF)
0       DayOfWeek                        1.001171
1         DepTime                        1.738213
2         ArrTime                        2.000441
3      CRSArrTime                        1.380661
4   UniqueCarrier                        3.355531
5       FlightNum                        1.217455
6         TailNum                        3.179920
7        ArrDelay                        1.316773
8        DepDelay                        1.334533
9          Origin                        1.422497
10           Dest                        1.324398
11        TaxiOut                        1.134160
12    OrdinalDate                      404.480656
```

[72]:
```
#Select the numeric values
z = df.select_dtypes(include = [np.number])
z.head().T
```

[72]:
```
                          0             1             2             3  \
DayOfWeek          4.000000      4.000000      4.000000      4.000000
DepTime            0.671571      0.560784      0.415133      0.696876
ArrTime            0.709720      0.524862      0.432039      0.648252
CRSArrTime         0.672420      0.587443      0.577914      0.631712
UniqueCarrier      0.522125      0.522125      0.522125      0.522125
FlightNum        335.000000   3231.000000    448.000000   3920.000000
TailNum            0.523438      0.486025      0.505843      0.571835
ArrDelay           0.000000      0.000000      0.000000      1.000000
DepDelay           8.000000     19.000000      8.000000     34.000000
Origin             0.691697      0.691697      0.654880      0.654880
Dest               0.578260      0.578260      0.561000      0.561000
TaxiOut            8.000000     10.000000     17.000000     10.000000
OrdinalDate   733044.000000 733044.000000 733044.000000 733044.000000

                          4
DayOfWeek          4.000000
DepTime            0.733678
ArrTime            0.714117
CRSArrTime         0.671165
UniqueCarrier      0.522125
FlightNum        378.000000
TailNum            0.523292
```

```
ArrDelay            0.000000
DepDelay           25.000000
Origin              0.654880
Dest                0.625772
TaxiOut            10.000000
OrdinalDate    733044.000000
```

[73]:
```
#run the function (7) to get the Variance Inflation Factor(VIF)
vif(z)
```

[73]:
```
           feature  Variance Inflation Factor(VIF)
0       DayOfWeek                        1.001171
1         DepTime                        1.738213
2         ArrTime                        2.000441
3      CRSArrTime                        1.380661
4   UniqueCarrier                        3.355531
5       FlightNum                        1.217455
6         TailNum                        3.179920
7        ArrDelay                        1.316773
8        DepDelay                        1.334533
9          Origin                        1.422497
10           Dest                        1.324398
11        TaxiOut                        1.134160
12    OrdinalDate                      404.480656
```

[74]:
```
df.drop(columns=["OrdinalDate"],inplace=True)
```

[75]:
```
#Select the numeric values
z = df.select_dtypes(include = [np.number])
z.head().T
```

[75]:
```
                        0            1           2            3           4
DayOfWeek        4.000000     4.000000    4.000000     4.000000    4.000000
DepTime          0.671571     0.560784    0.415133     0.696876    0.733678
ArrTime          0.709720     0.524862    0.432039     0.648252    0.714117
CRSArrTime       0.672420     0.587443    0.577914     0.631712    0.671165
UniqueCarrier    0.522125     0.522125    0.522125     0.522125    0.522125
FlightNum      335.000000  3231.000000  448.000000  3920.000000  378.000000
TailNum          0.523438     0.486025    0.505843     0.571835    0.523292
ArrDelay         0.000000     0.000000    0.000000     1.000000    0.000000
DepDelay         8.000000    19.000000    8.000000    34.000000   25.000000
Origin           0.691697     0.691697    0.654880     0.654880    0.654880
Dest             0.578260     0.578260    0.561000     0.561000    0.625772
TaxiOut          8.000000    10.000000   17.000000    10.000000   10.000000
```

[76]:
```
#run the function (7) to get the Variance Inflation Factor(VIF)
vif(z)
```

[76]:

	feature	Variance Inflation Factor(VIF)
0	DayOfWeek	4.939323
1	DepTime	93.458431
2	ArrTime	104.562752
3	CRSArrTime	220.123273
4	UniqueCarrier	302.076047
5	FlightNum	2.708893
6	TailNum	194.956433
7	ArrDelay	3.557819
8	DepDelay	2.187897
9	Origin	143.995377
10	Dest	153.796934
11	TaxiOut	2.909335

[77]:
```
df.drop(columns=["DepTime","ArrTime","CRSArrTime","UniqueCarrier",
                 "TailNum","Dest","Origin","Dest"],inplace=True)
```

[78]:
```
#Select the numeric values
z = df.select_dtypes(include = [np.number])
z.head().T
```

[78]:

	0	1	2	3	4
DayOfWeek	4	4	4	4	4
FlightNum	335	3231	448	3920	378
ArrDelay	0	0	0	1	0
DepDelay	8	19	8	34	25
TaxiOut	8	10	17	10	10

[79]:
```
#run the function (7) to get the Variance Inflation Factor(VIF)
vif(z)
```

[79]:

	feature	Variance Inflation Factor(VIF)
0	DayOfWeek	2.710959
1	FlightNum	1.990138
2	ArrDelay	3.278851
3	DepDelay	2.027521
4	TaxiOut	2.452959

Level 1

Exercise 1

Create at least three different classification models to try to best predict DelayedFlights.csv flight delay (ArrDelay). Consider whether the flight is late or not (ArrDelay> 0).

Sampling

[80]:
```
#obtain the sample size
population = df.shape[0]
sample_size = round(population/(1+population*(.05**2)))
sample_size
```

[80]: 400

The size of the population is to large it will be 400 samples with this formula, I will take the 1% of all the size as a sample size. **The decision to take this percent is the poor performace of my computer when the K-Nearest Neighbors runs with a bigger sample.**

[81]:
```
#new sample size
sample_size = round(df.shape[0]*.01)
sample_size
```

[81]: 19284

[82]:
```
#sample of the DF
df_sample = df.sample(n = sample_size, random_state=7)
df_sample.head().T
```

[82]:

	259237	439183	1505172	1555433	23143
DayOfWeek	6	3	5	3	5
FlightNum	540	5461	791	6578	2092
ArrDelay	0	0	1	0	0
DepDelay	10	15	73	18	14
TaxiOut	17	16	16	14	9

[83]:
```
plt.figure(figsize=(10,5))
plt.style.use('ggplot')
sns.countplot(x="ArrDelay",data=df_sample)
plt.title("Flight Classes")
plt.tight_layout()
plt.show()
```

[84]:
```
X= df_sample.drop(["ArrDelay"], axis=1)
y = df_sample["ArrDelay"]
X.head()
```

[84]:

	DayOfWeek	FlightNum	DepDelay	TaxiOut
259237	6	540	10	17
439183	3	5461	15	16
1505172	5	791	73	16
1555433	3	6578	18	14
23143	5	2092	14	9

[85]:
```
over = SMOTE(sampling_strategy='not majority')
under = RandomUnderSampler(sampling_strategy='not majority')
steps = [('o', over), ('u', under)]
pipeline = Pipeline(steps=steps)
X_smru,y_smru = pipeline.fit_resample(X,y)
```

The decision to make a comparison is to know the differences between the two types of sampling

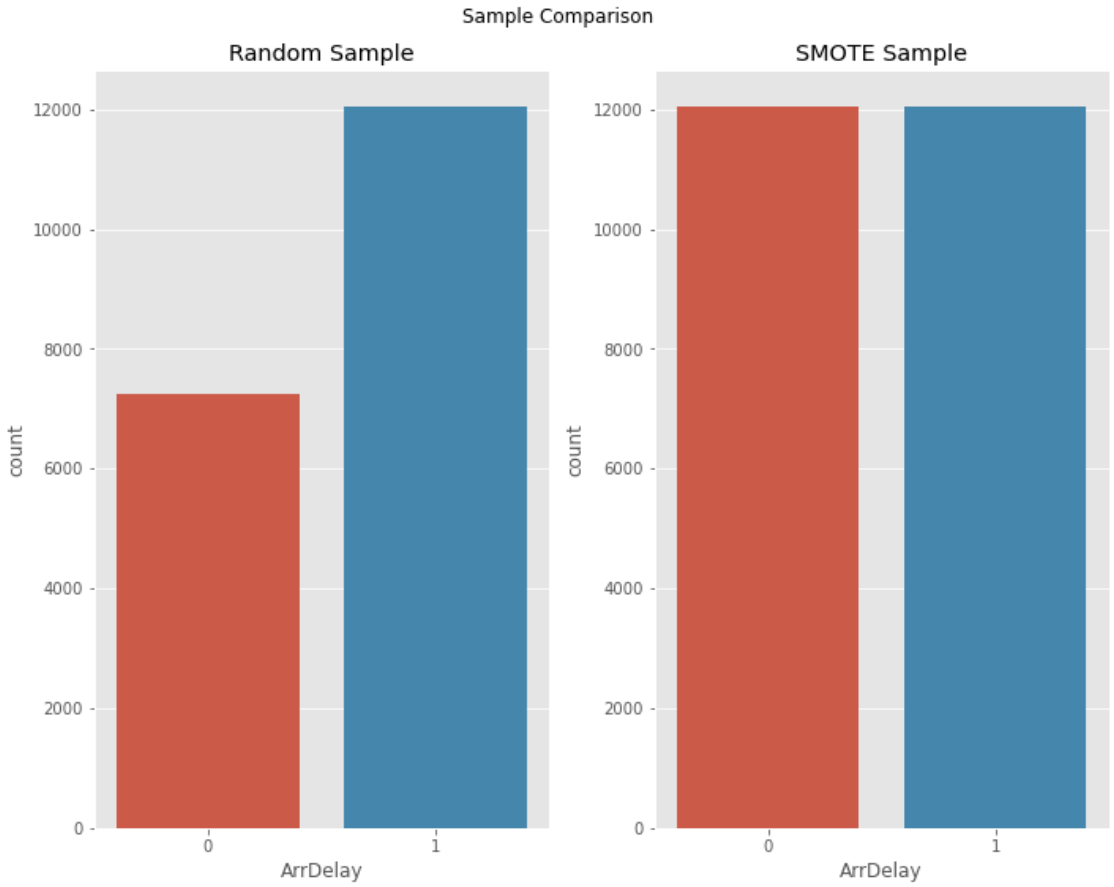
[86]:
```
plt.figure(figsize=(10,5))
plt.style.use('ggplot')
sns.countplot(y_smru)
plt.title("Flight Classes")
plt.tight_layout()
plt.show()
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/seaborn/_decorators.py:36: FutureWarning: Pass the following variable
```

```
as a keyword arg: x. From version 0.12, the only valid positional argument will
be `data`, and passing other arguments without an explicit keyword will result
in an error or misinterpretation.
  warnings.warn(
```

[87]:
```
#plot the Random Sampling vs SMOTE

fig , axes = plt.subplots(1,2,figsize=(10,8))

fig =sns.countplot(x="ArrDelay",data=df_sample,
                   label= "Train-Test" , ax=axes[0])
fig = sns.countplot(y_smru , ax=axes[1])

axes[0].set_title("Random Sample")
axes[1].set_title("SMOTE Sample")

plt.suptitle("Sample Comparison")
plt.tight_layout()
plt.show()
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/seaborn/_decorators.py:36: FutureWarning: Pass the following variable
as a keyword arg: x. From version 0.12, the only valid positional argument will
be `data`, and passing other arguments without an explicit keyword will result
in an error or misinterpretation.
  warnings.warn(
```



Split Data

[88]:
```
#Split set
X_train_rs, X_test_rs, y_train_rs, y_test_rs = train_test_split(X, y.values.
↪reshape(-1,1),
                                                    test_size= 0.20,␣
↪random_state=17,
                                                    shuffle = True)
```

[89]:
```
 #Split set
X_train_sm, X_test_sm, y_train_sm, y_test_sm = train_test_split(X_smru,y_smru.
↪values.reshape(-1,1),
                                                    test_size= 0.20,␣
↪random_state=17,
                                                    shuffle = True)
```

Model 1: Logistic Regression

Model 1: Logistic Regression Random Sample

[90]:
```
mod1_rs = LogisticRegression()
mod1_rs.fit(X_train_rs,y_train_rs)
y_pred1_rs = mod1_rs.predict(X_test_rs)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/utils/validation.py:63: 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 f(*args, **kwargs)
```

[91]:
```
#Confusion matrix
conf_matrix_mod1_rs = confusion_matrix(y_test_rs, y_pred1_rs)
#Accuracy
acu_mod1_rs = accuracy_score(y_test_rs, y_pred1_rs)
#AUC
auc_mod1_rs = roc_auc_score(y_test_rs, y_pred1_rs)
```

[92]:
```
report_mod1_rs = classification_report(y_test_rs, y_pred1_rs,output_dict=True)
df_report_mod1_rs = pd.DataFrame(report_mod1_rs).T
df_report_mod1_rs
```

[92]:

	precision	recall	f1-score	support
0	0.794922	0.853249	0.823054	1431.000000
1	0.909522	0.870157	0.889404	2426.000000
accuracy	0.863884	0.863884	0.863884	0.863884
macro avg	0.852222	0.861703	0.856229	3857.000000
weighted avg	0.867004	0.863884	0.864787	3857.000000

Model 1: Logistic Regression SMOTE

[93]:
```
mod1_sm = LogisticRegression()
mod1_sm.fit(X_train_sm,y_train_sm)
y_pred1_sm = mod1_sm.predict(X_test_sm)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/utils/validation.py:63: 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 f(*args, **kwargs)
```

[94]:
```
#Confusion matrix
conf_matrix_mod1_sm = confusion_matrix(y_test_sm, y_pred1_sm)
#Accuracy
acu_mod1_sm = accuracy_score(y_test_sm, y_pred1_sm)
#AUC
auc_mod1_sm = roc_auc_score(y_test_sm, y_pred1_sm)
```

[95]:
```
report_mod1_sm = classification_report(y_test_sm, y_pred1_sm,output_dict=True)
df_report_mod1_sm = pd.DataFrame(report_mod1_sm).T
df_report_mod1_sm
```

[95]:

	precision	recall	f1-score	support
0	0.862888	0.912146	0.886833	2470.000000
1	0.901721	0.847595	0.873820	2349.000000
accuracy	0.880681	0.880681	0.880681	0.880681
macro avg	0.882304	0.879870	0.880327	4819.000000
weighted avg	0.881817	0.880681	0.880490	4819.000000

Model 2: Support Vector Machine Classifier (SVMC)

Model 2: SVMC Random Sample

[96]:
```
mod2_rs = svm.SVC(probability=True)
mod2_rs.fit(X_train_rs,y_train_rs)
y_pred2_rs = mod2_rs.predict(X_test_rs)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/utils/validation.py:63: 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 f(*args, **kwargs)
```

[97]:
```
#Confusion matrix
conf_matrix_mod2_rs = confusion_matrix(y_test_rs, y_pred2_rs)
#Accuracy
acu_mod2_rs = accuracy_score(y_test_rs, y_pred2_rs)
#AUC
auc_mod2_rs = roc_auc_score(y_test_rs, y_pred2_rs)
```

[98]:
```
report_mod2_rs = classification_report(y_test_rs, y_pred2_rs,output_dict=True)
df_report_mod2_rs = pd.DataFrame(report_mod2_rs).T
df_report_mod2_rs
```

[98]:

	precision	recall	f1-score	support
0	0.962500	0.053809	0.101919	1431.000000
1	0.641514	0.998763	0.781235	2426.000000
accuracy	0.648172	0.648172	0.648172	0.648172
macro avg	0.802007	0.526286	0.441577	3857.000000
weighted avg	0.760604	0.648172	0.529199	3857.000000

Model 2: SVMC SMOTE

[99]:
```
mod2_sm = svm.SVC(probability=True)
mod2_sm.fit(X_train_sm,y_train_sm)
y_pred2_sm = mod2_sm.predict(X_test_sm)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/utils/validation.py:63: 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 f(*args, **kwargs)
```

[100]:
```
#Confusion matrix
conf_matrix_mod2_sm = confusion_matrix(y_test_sm, y_pred2_sm)
#Accuracy
acu_mod2_sm = accuracy_score(y_test_sm, y_pred2_sm)
#AUC
auc_mod2_sm = roc_auc_score(y_test_sm, y_pred2_sm)
```

[101]:
```
report_mod2_sm = classification_report(y_test_sm, y_pred2_sm,output_dict=True)
df_report_mod2_sm = pd.DataFrame(report_mod2_sm).T
df_report_mod2_sm
```

[101]:

	precision	recall	f1-score	support
0	0.691795	0.965992	0.806217	2470.000000
1	0.938686	0.547467	0.691584	2349.000000
accuracy	0.761984	0.761984	0.761984	0.761984
macro avg	0.815240	0.756729	0.748901	4819.000000
weighted avg	0.812141	0.761984	0.750340	4819.000000

Model 3: K-Nearest Neighbors Classifier (KNNC)

Model 3: KNNC Random Sample

[102]:
```
mod3_rs = KNeighborsClassifier()
mod3_rs.fit(X_train_rs,y_train_rs)
y_pred3_rs = mod3_rs.predict(X_test_rs)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/neighbors/_classification.py:179: 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)
```

[103]:
```
#Confusion matrix
conf_matrix_mod3_rs = confusion_matrix(y_test_rs, y_pred3_rs)
#Accuracy
acu_mod3_rs = accuracy_score(y_test_rs, y_pred3_rs)
#AUC
auc_mod3_rs = roc_auc_score(y_test_rs, y_pred3_rs)
```

[104]:
```
report_mod3_rs = classification_report(y_test_rs, y_pred3_rs,output_dict=True)
df_report_mod3_rs = pd.DataFrame(report_mod3_rs).T
df_report_mod3_rs
```

[104]:

	precision	recall	f1-score	support
0	0.768182	0.826695	0.796365	1431.000000
1	0.892965	0.852844	0.872444	2426.000000
accuracy	0.843142	0.843142	0.843142	0.843142
macro avg	0.830573	0.839769	0.834404	3857.000000
weighted avg	0.846669	0.843142	0.844217	3857.000000

Model 3: KNNC SMOTE

[105]:
```
mod3_sm = KNeighborsClassifier()
mod3_sm.fit(X_train_sm,y_train_sm)
y_pred3_sm = mod3_sm.predict(X_test_sm)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/neighbors/_classification.py:179: 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)
```

[106]:
```
#Confusion matrix
conf_matrix_mod3_sm = confusion_matrix(y_test_sm, y_pred3_sm)
#Accuracy
acu_mod3_sm = accuracy_score(y_test_sm, y_pred3_sm)
#AUC
auc_mod3_sm = roc_auc_score(y_test_sm, y_pred3_sm)
```

[107]:
```
report_mod3_sm = classification_report(y_test_sm, y_pred3_sm,output_dict=True)
df_report_mod3_sm = pd.DataFrame(report_mod3_sm).T
df_report_mod3_sm
```

[107]:

	precision	recall	f1-score	support
0	0.843311	0.923887	0.881762	2470.000000
1	0.911027	0.819498	0.862842	2349.000000
accuracy	0.873003	0.873003	0.873003	0.873003
macro avg	0.877169	0.871692	0.872302	4819.000000
weighted avg	0.876319	0.873003	0.872539	4819.000000

Model 4: Decision Tree Classifier (DTC)

Model 4: DT Random Sample

[108]:
```
mod4_rs = DecisionTreeClassifier()
mod4_rs.fit(X_train_rs,y_train_rs)
y_pred4_rs = mod4_rs.predict(X_test_rs)
```

[109]:
```
#Confusion matrix
conf_matrix_mod4_rs = confusion_matrix(y_test_rs, y_pred4_rs)
#Accuracy
acu_mod4_rs = accuracy_score(y_test_rs, y_pred4_rs)
```

```
#AUC
auc_mod4_rs = roc_auc_score(y_test_rs, y_pred4_rs)
```

[110]:
```
report_mod4_rs = classification_report(y_test_rs, y_pred4_rs,output_dict=True)
df_report_mod4_rs = pd.DataFrame(report_mod4_rs).T
df_report_mod4_rs
```

[110]:

	precision	recall	f1-score	support
0	0.735254	0.749126	0.742125	1431.000000
1	0.850354	0.840890	0.845596	2426.000000
accuracy	0.806845	0.806845	0.806845	0.806845
macro avg	0.792804	0.795008	0.793861	3857.000000
weighted avg	0.807650	0.806845	0.807207	3857.000000

Model 4: DT SMOTE

[111]:
```
mod4_sm = DecisionTreeClassifier()
mod4_sm.fit(X_train_sm,y_train_sm)
y_pred4_sm = mod4_sm.predict(X_test_sm)
```

[112]:
```
#Confusion matrix
conf_matrix_mod4_sm = confusion_matrix(y_test_sm, y_pred4_sm)
#Accuracy
acu_mod4_sm = accuracy_score(y_test_sm, y_pred4_sm)
#AUC
auc_mod4_sm = roc_auc_score(y_test_sm, y_pred4_sm)
```

[113]:
```
report_mod4_sm = classification_report(y_test_sm, y_pred4_sm,output_dict=True)
df_report_mod4_sm = pd.DataFrame(report_mod4_sm).T
df_report_mod4_sm
```

[113]:

	precision	recall	f1-score	support
0	0.848894	0.839271	0.844055	2470.000000
1	0.832983	0.842912	0.837918	2349.000000
accuracy	0.841046	0.841046	0.841046	0.841046
macro avg	0.840939	0.841092	0.840987	4819.000000
weighted avg	0.841138	0.841046	0.841064	4819.000000

Exercise 2

Compare classification models using accuracy, a confidence matrix, and other more advanced metrics.

Accuracy

[114]:
```
acmod_rs = {"LR":round(acu_mod1_rs,4),
          "SVMC":round(acu_mod2_rs,4),"KNNC":round(acu_mod3_rs,4),
            "DTC":round(acu_mod4_rs,4)}
```

[115]:
```
acmod_sm = {"LR":round(acu_mod1_sm,4),
            "SVMC":round(acu_mod2_sm,4),"KNNC":round(acu_mod3_sm,4),
             "DTC":round(acu_mod4_sm,4)}
```

[116]:
```
aucmod_rs = {"LR":round(auc_mod1_rs,4),
            "SVMC":round(auc_mod2_rs,4),"KNNC":round(auc_mod3_rs,4),
              "DTC":round(auc_mod4_rs,4)}
```

[117]:
```
aucmod_sm = {"LR":round(auc_mod1_sm,4),
            "SVMC":round(auc_mod2_sm,4),"KNNC":round(auc_mod3_sm,4),
              "DTC":round(acu_mod4_sm,4)}
```

[118]:
```
metrics_df= pd.DataFrame([acmod_rs,acmod_sm],
                         index=["Accuracy RS","Accuracy SM"]).T
(metrics_df)*100
```

[118]:

	Accuracy RS	Accuracy SM
LR	86.39	88.07
SVMC	64.82	76.20
KNNC	84.31	87.30
DTC	80.68	84.10

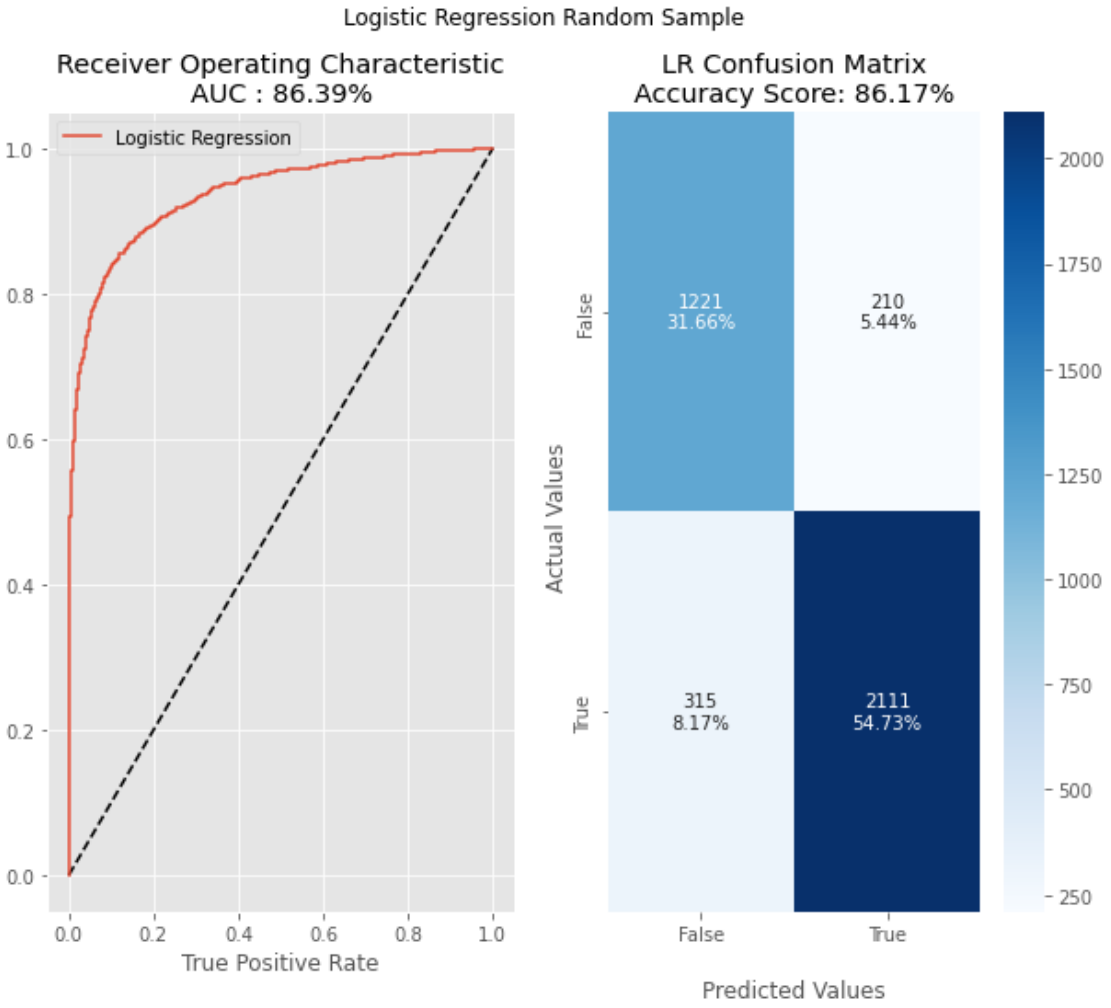
The Logistic Regression have the best accuracy scores and have similars results in a balanced and unbalanced sample. The models have a better performace with the balanced sample (SMOTE) so is important to check the class imbalance.

ROC and Confusion Matrix

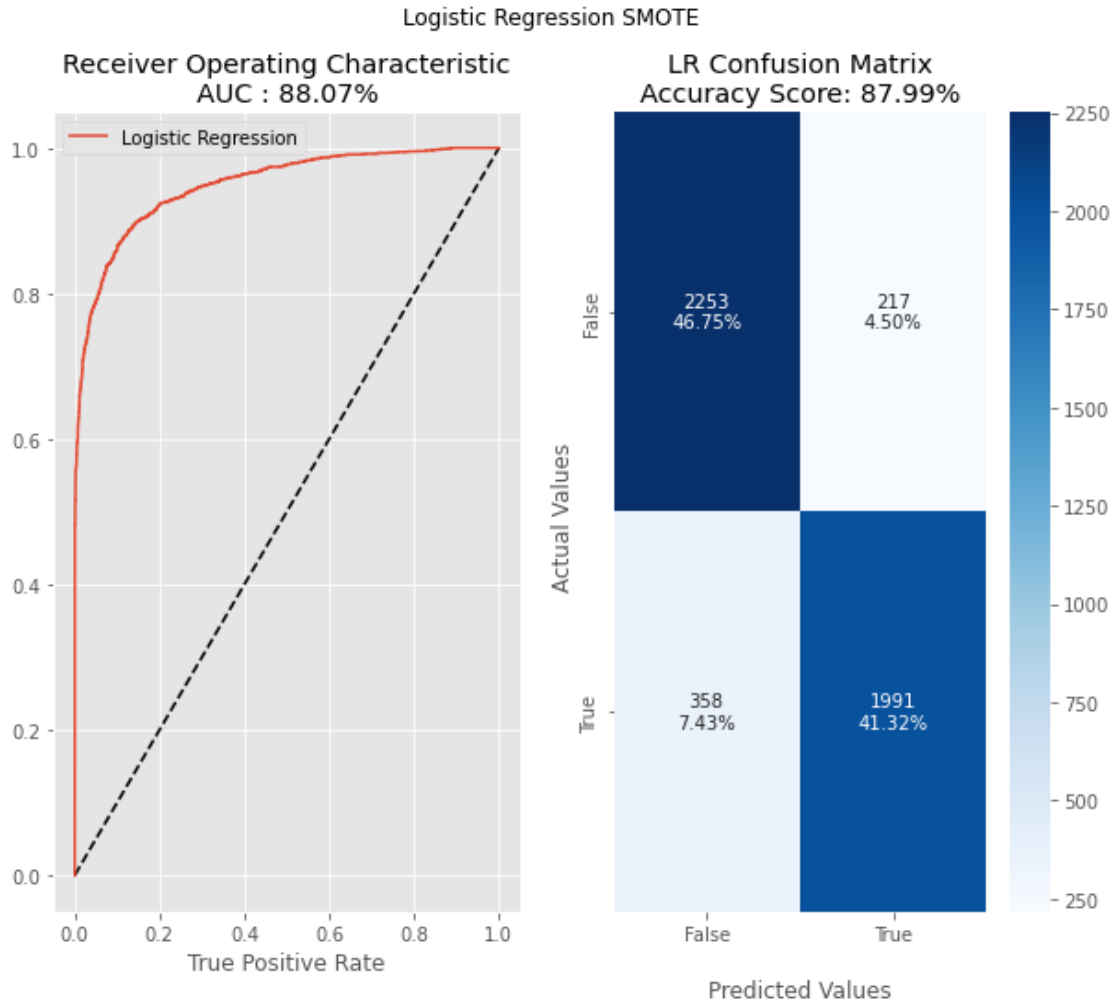
The sample are now balanced so the ROC is a good metric.

Logistic Regression

[119]:
```
#run the functiona (9)
subplots_ROC_CM("Logistic Regression Random Sample","Receiver Operating␣
↪Characteristic",
                "LR Confusion Matrix",
               ␣
↪mod1_rs,acmod_rs,aucmod_rs,conf_matrix_mod1_rs,"LR",X_test_rs,y_test_rs)
```

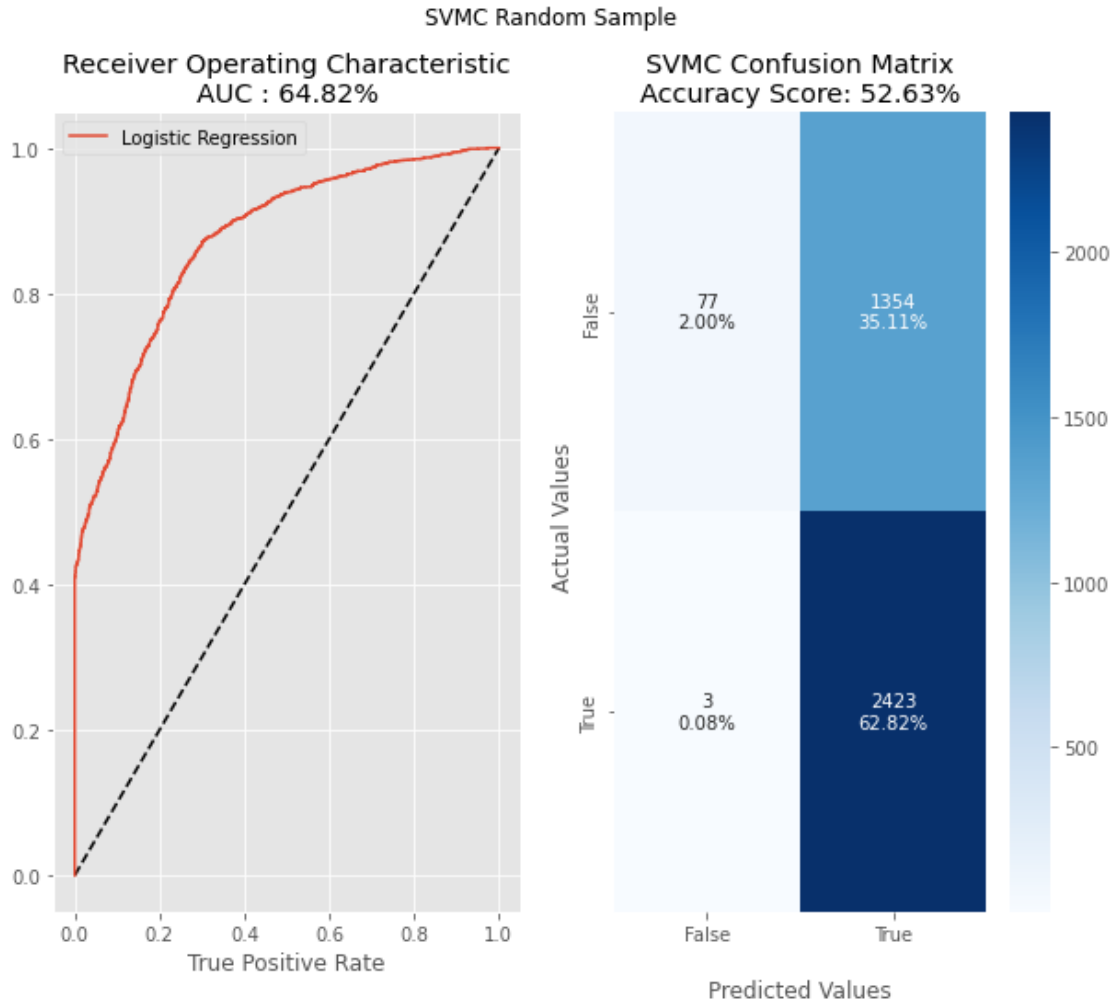


[120]:
```
#run the functiona (9)
subplots_ROC_CM("Logistic Regression SMOTE","Receiver Operating Characteristic",
                "LR Confusion Matrix",
                ␣
↪mod1_sm,acmod_sm,aucmod_sm,conf_matrix_mod1_sm,"LR",X_test_sm,y_test_sm)
```

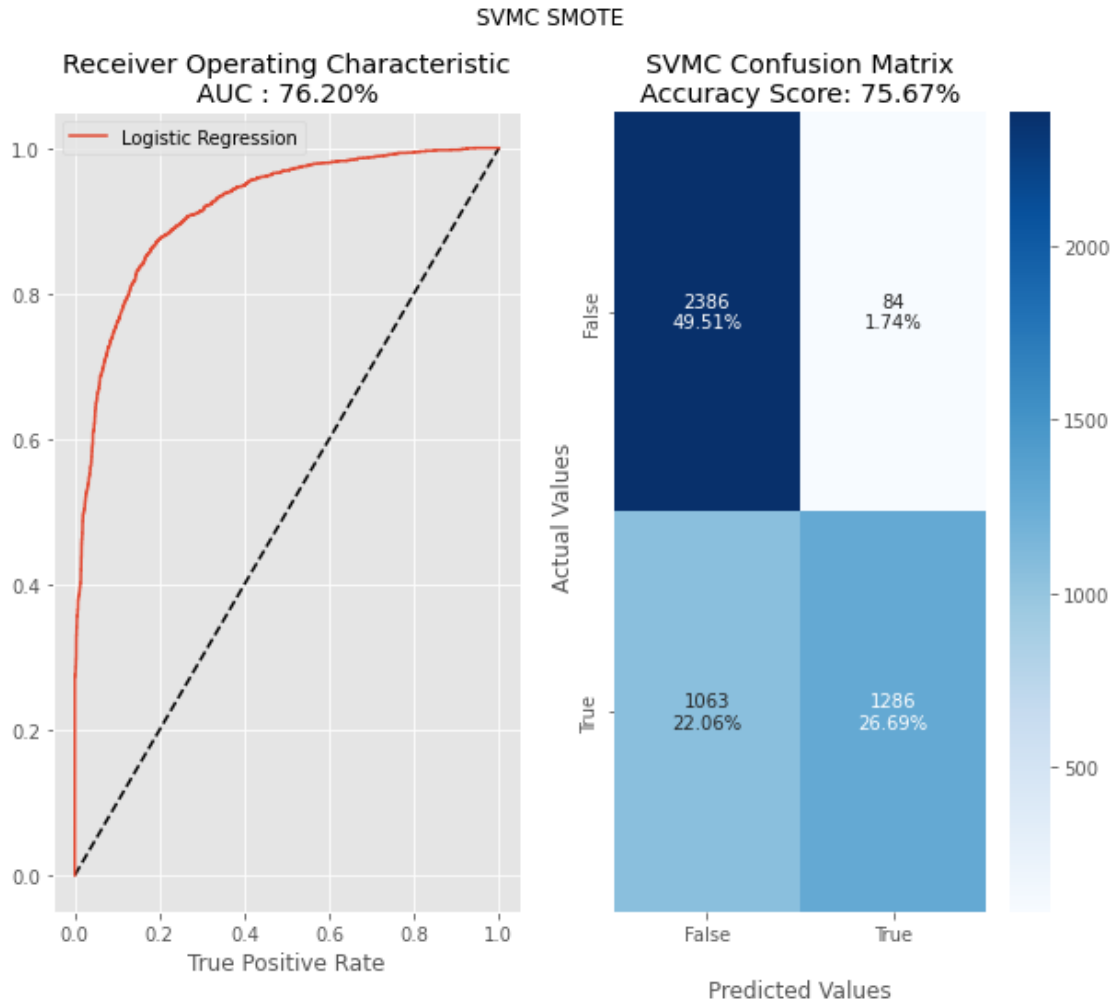


Support Vector Machine Classifier

[121]:
```
#run the functiona (9)
subplots_ROC_CM("SVMC Random Sample","Receiver Operating Characteristic",
                "SVMC Confusion Matrix",
                ␣
↪mod2_rs,acmod_rs,aucmod_rs,conf_matrix_mod2_rs,"SVMC",X_test_rs,y_test_rs)
```

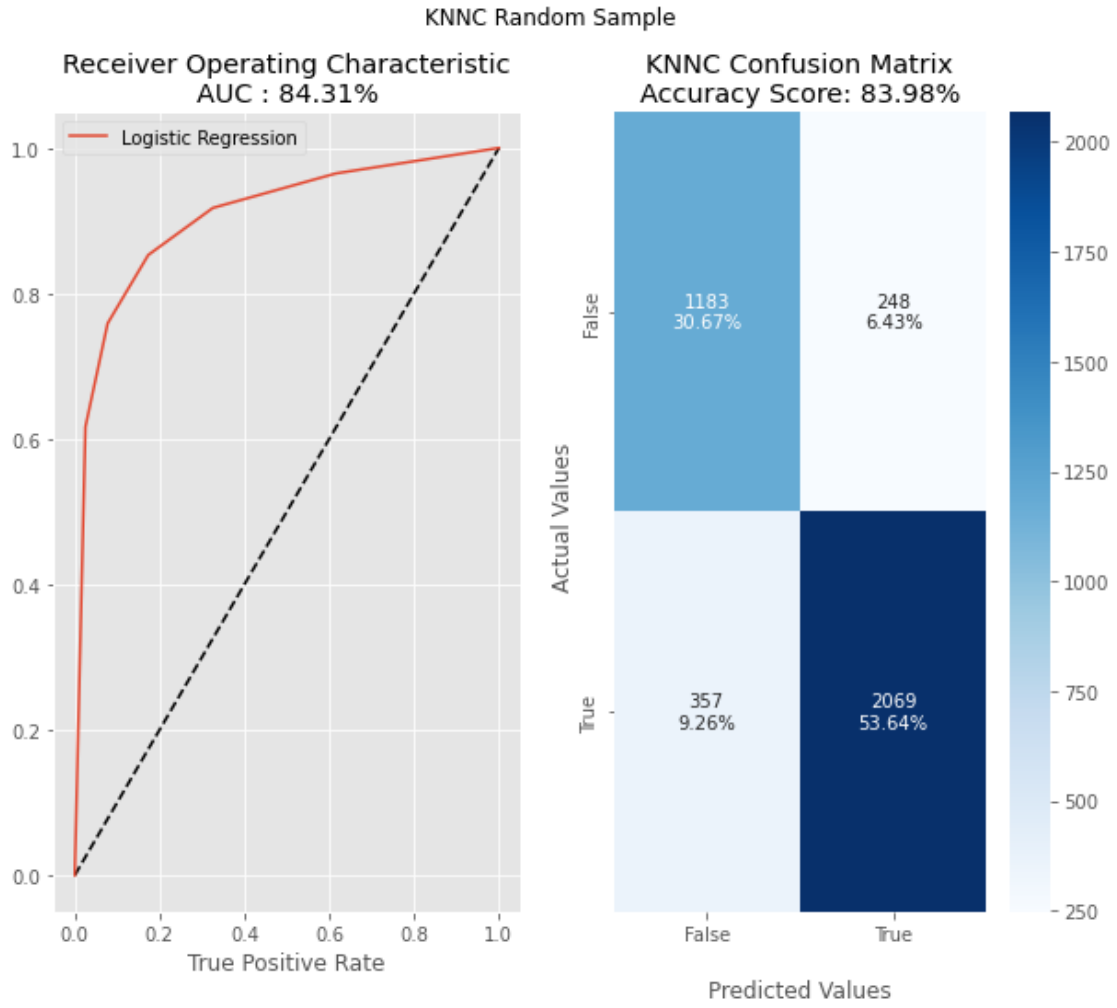


[122]:
```
#run the functiona (9)
subplots_ROC_CM("SVMC SMOTE","Receiver Operating Characteristic",
                "SVMC Confusion Matrix",
                ␣
↪mod2_sm,acmod_sm,aucmod_sm,conf_matrix_mod2_sm,"SVMC",X_test_sm,y_test_sm)
```

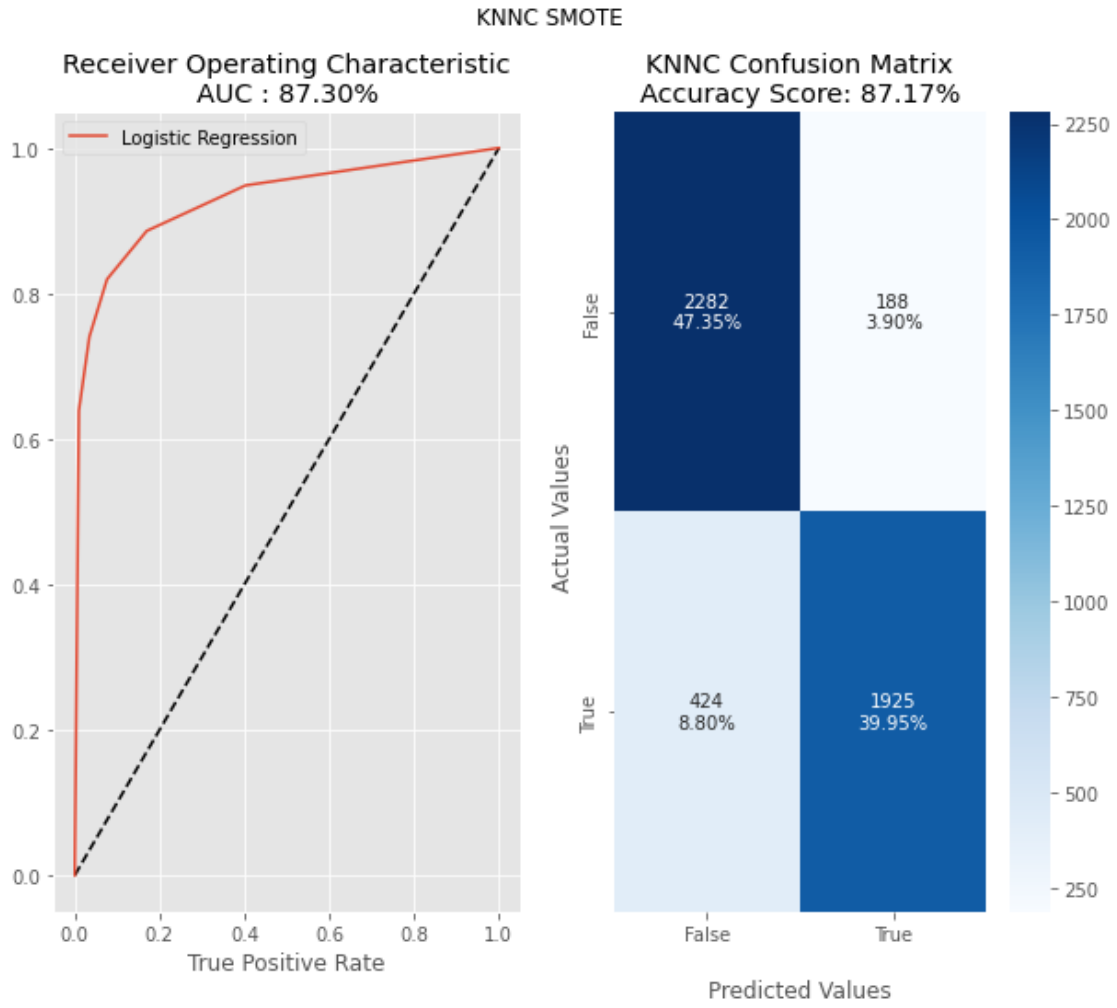


K-Nearest Neighbors Classifier

[123]:
```
#run the functiona (9)
subplots_ROC_CM("KNNC Random Sample","Receiver Operating Characteristic",
                "KNNC Confusion Matrix",
                ␣
 ↪mod3_rs,acmod_rs,aucmod_rs,conf_matrix_mod3_rs,"KNNC",X_test_rs,y_test_rs)
```

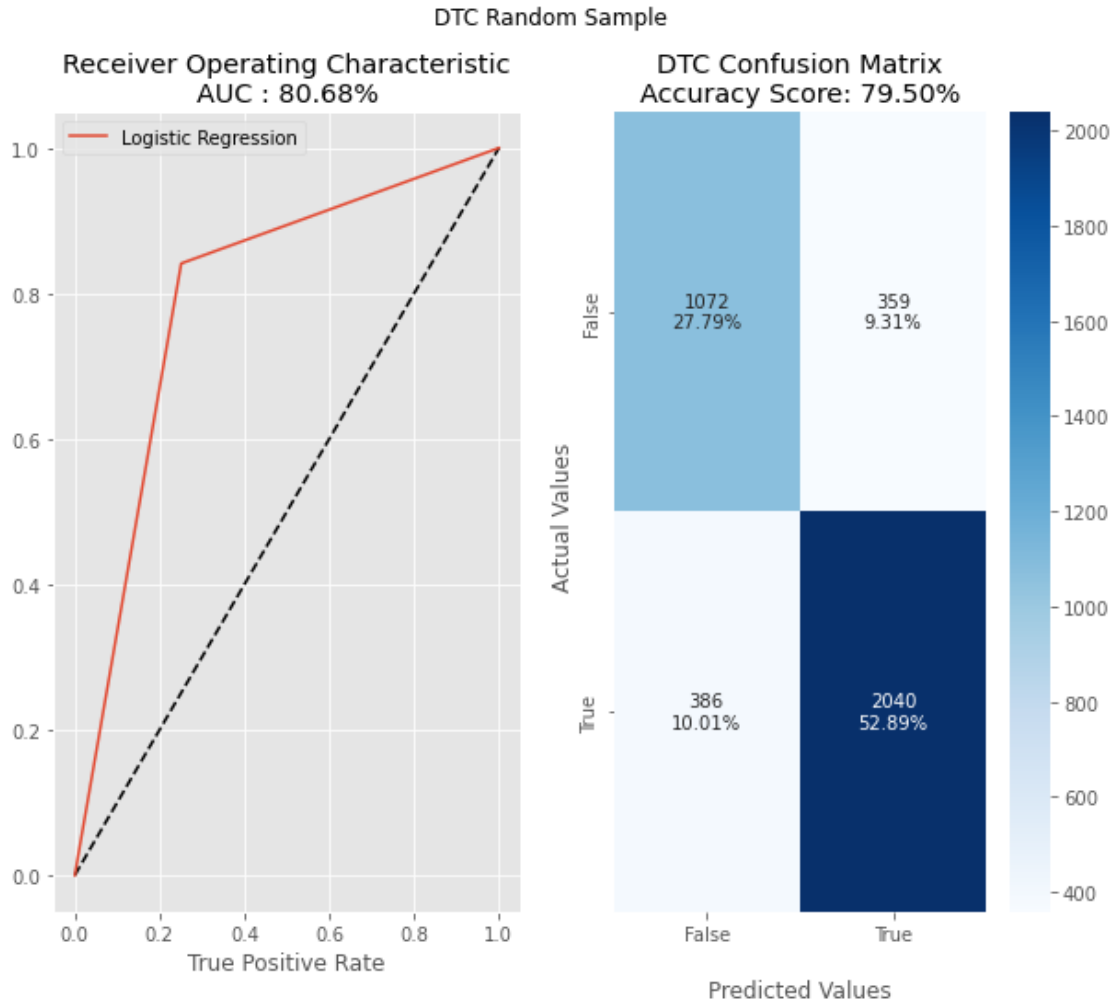


[124]:
```
#run the functiona (9)
subplots_ROC_CM("KNNC SMOTE","Receiver Operating Characteristic",
                "KNNC Confusion Matrix",
                ␣
↪mod3_sm,acmod_sm,aucmod_sm,conf_matrix_mod3_sm,"KNNC",X_test_sm,y_test_sm)
```

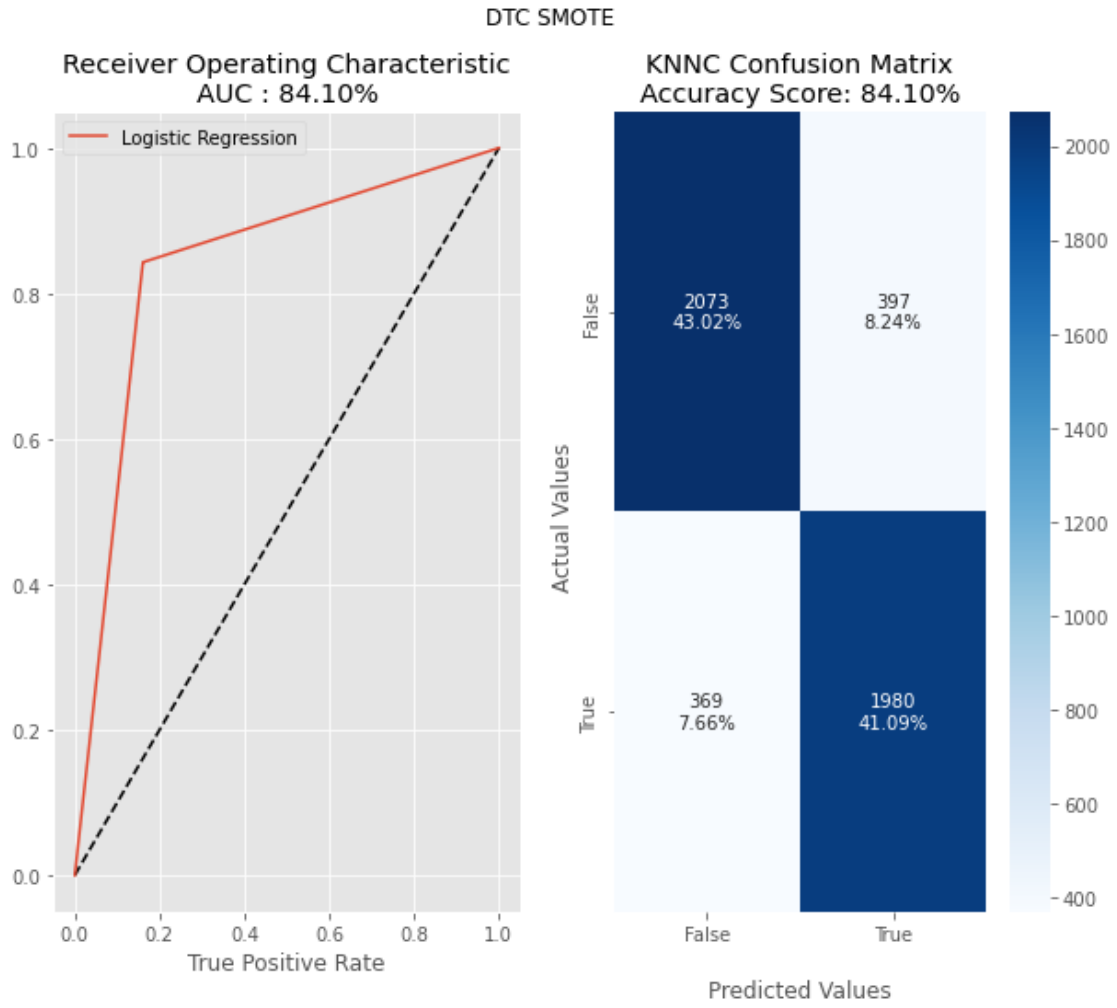


Decision Tree Classifier

[125]:
```
#run the functiona (9)
subplots_ROC_CM("DTC Random Sample","Receiver Operating Characteristic",
                "DTC Confusion Matrix",
                ␣
 ↪mod4_rs,acmod_rs,aucmod_rs,conf_matrix_mod4_rs,"DTC",X_test_rs,y_test_rs)
```



[126]:
```
#run the functiona (9)
subplots_ROC_CM("DTC SMOTE","Receiver Operating Characteristic",
                "KNNC Confusion Matrix",
                ␣
↪mod4_sm,acmod_sm,aucmod_sm,conf_matrix_mod4_sm,"DTC",X_test_sm,y_test_sm)
```



[127]:
```
TN1_rs = conf_matrix_mod1_rs[0,0]
FP1_rs = conf_matrix_mod1_rs[0,1]
FN1_rs = conf_matrix_mod1_rs[1,0]
TP1_rs = conf_matrix_mod1_rs[1,1]

TN2_rs = conf_matrix_mod2_rs[0,0]
FP2_rs = conf_matrix_mod2_rs[0,1]
FN2_rs = conf_matrix_mod2_rs[1,0]
TP2_rs = conf_matrix_mod2_rs[1,1]

TN3_rs = conf_matrix_mod3_rs[0,0]
FP3_rs = conf_matrix_mod3_rs[0,1]
FN3_rs = conf_matrix_mod3_rs[1,0]
TP3_rs = conf_matrix_mod3_rs[1,1]

TN4_rs = conf_matrix_mod4_rs[0,0]
```

```
FP4_rs = conf_matrix_mod4_rs[0,1]
FN4_rs = conf_matrix_mod4_rs[1,0]
TP4_rs = conf_matrix_mod4_rs[1,1]
```

[128]:
```
TN1_sm = conf_matrix_mod1_sm[0,0]
FP1_sm = conf_matrix_mod1_sm[0,1]
FN1_sm = conf_matrix_mod1_sm[1,0]
TP1_sm = conf_matrix_mod1_sm[1,1]

TN2_sm = conf_matrix_mod2_sm[0,0]
FP2_sm = conf_matrix_mod2_sm[0,1]
FN2_sm = conf_matrix_mod2_sm[1,0]
TP2_sm = conf_matrix_mod2_sm[1,1]

TN3_sm = conf_matrix_mod3_sm[0,0]
FP3_sm = conf_matrix_mod3_sm[0,1]
FN3_sm = conf_matrix_mod3_sm[1,0]
TP3_sm = conf_matrix_mod3_sm[1,1]

TN4_sm = conf_matrix_mod4_sm[0,0]
FP4_sm = conf_matrix_mod4_sm[0,1]
FN4_sm = conf_matrix_mod4_sm[1,0]
TP4_sm = conf_matrix_mod4_sm[1,1]
```

[129]:
```
TN = [[TN1_sm,TN2_sm,TN3_sm,TN4_sm],[TN1_rs,TN2_rs,TN3_rs,TN4_rs]]
```

[130]:
```
FP = [FP1_rs, FP2_rs, FP3_rs, FP4_rs],[FP1_sm, FP2_sm,FP3_sm, FP4_sm]
```

[131]:
```
FN = [[FN1_rs,FN2_rs,FN3_rs,FN4_rs],[FN1_sm,FN2_sm,FN3_sm,FN4_sm]]
```

[132]:
```
TP = [TP1_rs,TP2_rs,TP3_rs,TP4_rs],[TP1_sm,TP2_sm,TP3_sm,TP4_sm]
```

[133]:
```
TN_df = pd.DataFrame(TN).T
FP_df = pd.DataFrame(FP).T
FN_df = pd.DataFrame(FN).T
TP_df = pd.DataFrame(TP).T

TN_df.rename(columns={0:"TN_RS",1:"TN_SM"},inplace=True)
FP_df.rename(columns={0:"FP_RS",1:"FP_SM"},inplace=True)
FN_df.rename(columns={0:"FN_RS",1:"FN_SM"},inplace=True)
TP_df.rename(columns={0:"TP_RS",1:"TP_SM"},inplace=True)
```

[134]:
```
models = ["LR","SVMC","KNNC","DTC"]
for i,j in zip(range(4),models):
    TN_df.rename(index={i:j},inplace=True)
    FP_df.rename(index={i:j},inplace=True)
    FN_df.rename(index={i:j},inplace=True)
```

```
    TP_df.rename(index={i:j},inplace=True)
```

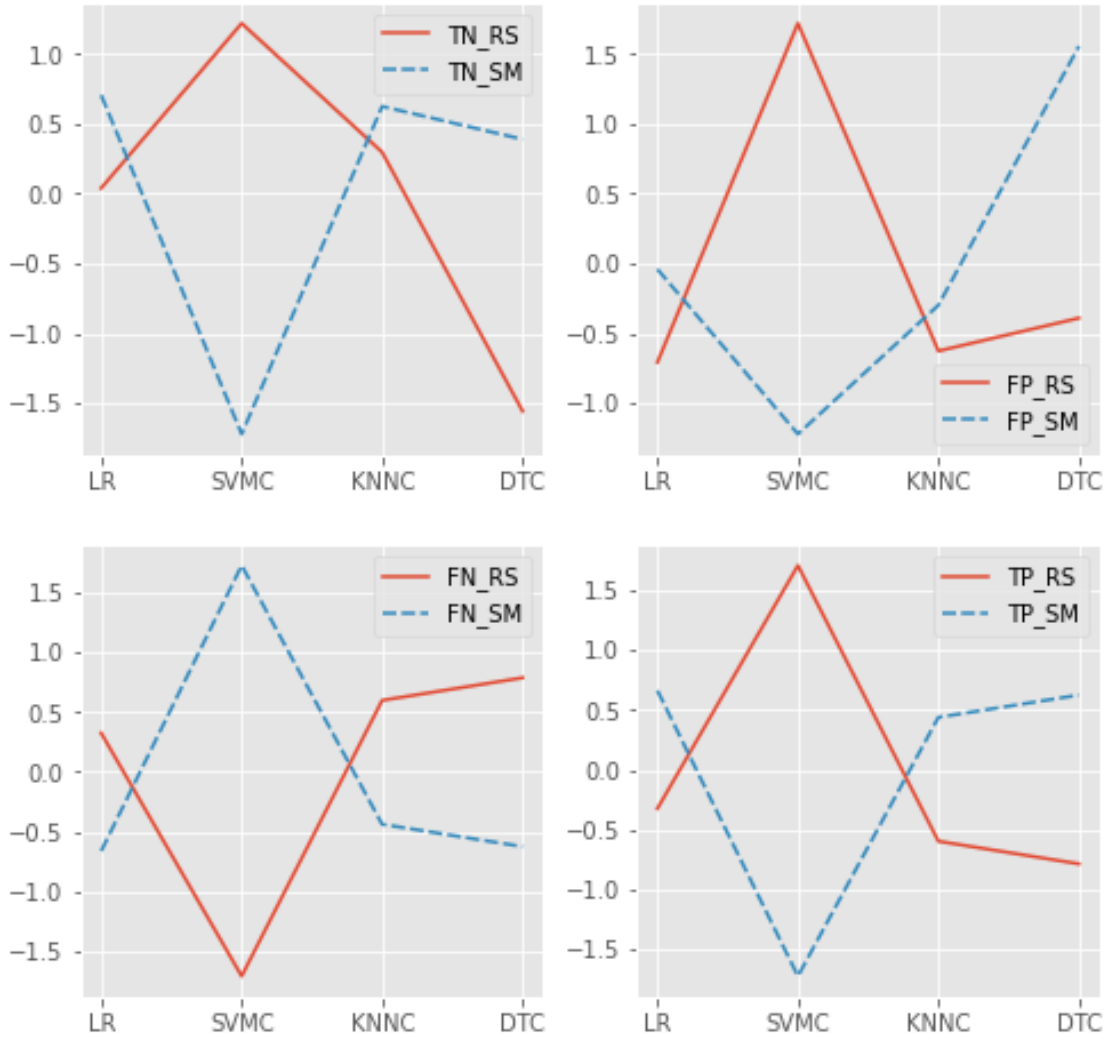
[135]:
```
matrix_models = pd.concat([TN_df,FP_df,FN_df,TP_df],axis=1)
matrix_models
```

[135]:

	TN_RS	TN_SM	FP_RS	FP_SM	FN_RS	FN_SM	TP_RS	TP_SM
LR	2253	1221	210	217	315	358	2111	1991
SVMC	2386	77	1354	84	3	1063	2423	1286
KNNC	2282	1183	248	188	357	424	2069	1925
DTC	2073	1072	359	397	386	369	2040	1980

[136]:
```
scaler = StandardScaler()
scaledMetrics_models = pd.DataFrame(scaler.fit_transform(matrix_models),
                                    index = models
                                    , columns=matrix_models.columns)
```

[137]:
```
fig,axes = plt.subplots(2,2,figsize=(8,8))
fig = sns.lineplot(data= scaledMetrics_models[["TN_RS","TN_SM"]],ax=axes[0,0])
fig = sns.lineplot(data= scaledMetrics_models[["FP_RS","FP_SM"]],ax=axes[0,1])
fig = sns.lineplot(data= scaledMetrics_models[["FN_RS","FN_SM"]],ax=axes[1,0])
fig = sns.lineplot(data= scaledMetrics_models[["TP_RS","TP_SM"]],ax=axes[1,1])
axes[0,0].legend(labels =["TN_RS","TN_SM"],loc="best")
axes[0,1].legend(labels =["FP_RS","FP_SM"],loc="best")
axes[1,0].legend(labels =["FN_RS","FN_SM"],loc="best")
axes[1,1].legend(labels =["TP_RS","TP_SM"],loc="best")
plt.show()
```



The above plot show the scores of the confusion matrix, the SVMC Random Sample TN and TP behaves better. We need to consider the FP this are the predicted positive and it's false (Type I Error) and the best model is SVMC SMOTE. The Logistic Regression have the better accuracy but it's the third better in FP the Confusion Matrix helped to see this.

[138]:
```
round(df_report_mod1_rs,4) ,round(df_report_mod1_sm,4)
```

[138]:
```
(              precision  recall  f1-score    support
 0                0.7949  0.8532    0.8231  1431.0000
 1                0.9095  0.8702    0.8894  2426.0000
 accuracy         0.8639  0.8639    0.8639     0.8639
 macro avg        0.8522  0.8617    0.8562  3857.0000
 weighted avg     0.8670  0.8639    0.8648  3857.0000,
                precision  recall  f1-score    support
 0                0.8629  0.9121    0.8868  2470.0000
```

```
1               0.9017  0.8476    0.8738  2349.0000
accuracy        0.8807  0.8807    0.8807     0.8807
macro avg       0.8823  0.8799    0.8803  4819.0000
weighted avg    0.8818  0.8807    0.8805  4819.0000)
```

[139]:
```
round(df_report_mod2_rs,4) ,round(df_report_mod2_sm,4)
```

[139]:
```
(              precision  recall  f1-score    support
0                 0.9625  0.0538    0.1019  1431.0000
1                 0.6415  0.9988    0.7812  2426.0000
accuracy          0.6482  0.6482    0.6482     0.6482
macro avg         0.8020  0.5263    0.4416  3857.0000
weighted avg      0.7606  0.6482    0.5292  3857.0000,
               precision  recall  f1-score   support
0                 0.6918  0.9660    0.8062  2470.000
1                 0.9387  0.5475    0.6916  2349.000
accuracy          0.7620  0.7620    0.7620     0.762
macro avg         0.8152  0.7567    0.7489  4819.000
weighted avg      0.8121  0.7620    0.7503  4819.000)
```

[140]:
```
round(df_report_mod3_rs,4) ,round(df_report_mod3_sm,4)
```

[140]:
```
(              precision  recall  f1-score    support
0                 0.7682  0.8267    0.7964  1431.0000
1                 0.8930  0.8528    0.8724  2426.0000
accuracy          0.8431  0.8431    0.8431     0.8431
macro avg         0.8306  0.8398    0.8344  3857.0000
weighted avg      0.8467  0.8431    0.8442  3857.0000,
               precision  recall  f1-score   support
0                 0.8433  0.9239    0.8818  2470.000
1                 0.9110  0.8195    0.8628  2349.000
accuracy          0.8730  0.8730    0.8730     0.873
macro avg         0.8772  0.8717    0.8723  4819.000
weighted avg      0.8763  0.8730    0.8725  4819.000)
```

[141]:
```
round(df_report_mod4_rs,4) ,round(df_report_mod4_sm,4)
```

[141]:
```
(              precision  recall  f1-score    support
0                 0.7353  0.7491    0.7421  1431.0000
1                 0.8504  0.8409    0.8456  2426.0000
accuracy          0.8068  0.8068    0.8068     0.8068
macro avg         0.7928  0.7950    0.7939  3857.0000
weighted avg      0.8077  0.8068    0.8072  3857.0000,
               precision  recall  f1-score   support
0                 0.8489  0.8393    0.8441  2470.000
1                 0.8330  0.8429    0.8379  2349.000
accuracy          0.8410  0.8410    0.8410     0.841
```

```
macro avg        0.8409  0.8411    0.8410  4819.000
weighted avg     0.8411  0.8410    0.8411  4819.000)
```

The we can see in the classification report the mod2 SVMC has a better recall for the class 0 so this SVCM model can predict better the True Positive.

Exercise 3

Train them using the different parameters they support, I will use only the SMOTE sample__.

Model 1: Logistic Regression

[142]:
```
#Parameters
parameters = {'penalty':["l1","l2","elasticnet"],
              'solver':["newton-cg","lbfgs", "liblinear","sag","saga"],
              'class_weight':["balanced"]}

mod1_sm_p = LogisticRegression()
#instantiate the GridSearchCV object: log_grid
logR_grid_m1_sm = GridSearchCV(mod1_sm_p,parameters,scoring='roc_auc')

# Fit it to the data
logR_grid_m1_sm.fit(X_train_sm,y_train_sm)

# # Predict on the test data: y_pred
y_pred_logR_grid = logR_grid_m1_sm.predict(X_test_sm)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py:615: FitFailedWarning: Estimator
fit failed. The score on this train-test partition for these parameters will be
set to nan. Details:
Traceback (most recent call last):
  File "/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 598, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
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    solver = _check_solver(self.solver, self.penalty, self.dual)
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ValueError: Solver newton-cg supports only 'l2' or 'none' penalties, got l1
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```
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packages/sklearn/linear_model/_logistic.py", line 443, in _check_solver
```

```
    raise ValueError("Solver %s supports only 'l2' or 'none' penalties, "
ValueError: Solver sag supports only 'l2' or 'none' penalties, got l1 penalty.

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packages/scipy/optimize/linesearch.py:437: LineSearchWarning: Rounding errors
prevent the line search from converging
  warn(msg, LineSearchWarning)
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packages/scipy/optimize/linesearch.py:327: LineSearchWarning: The line search
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  warn('The line search algorithm did not converge', LineSearchWarning)
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packages/sklearn/utils/optimize.py:195: UserWarning: Line Search failed
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```

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/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/model_selection/_search.py:922: UserWarning: One or more of the
test scores are non-finite: [       nan        nan 0.94713862        nan
0.84084258 0.94713566
 0.94713555 0.94712915 0.84296903 0.84086094        nan        nan
        nan        nan        nan]
  warnings.warn(
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/utils/validation.py:63: 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 f(*args, **kwargs)
```

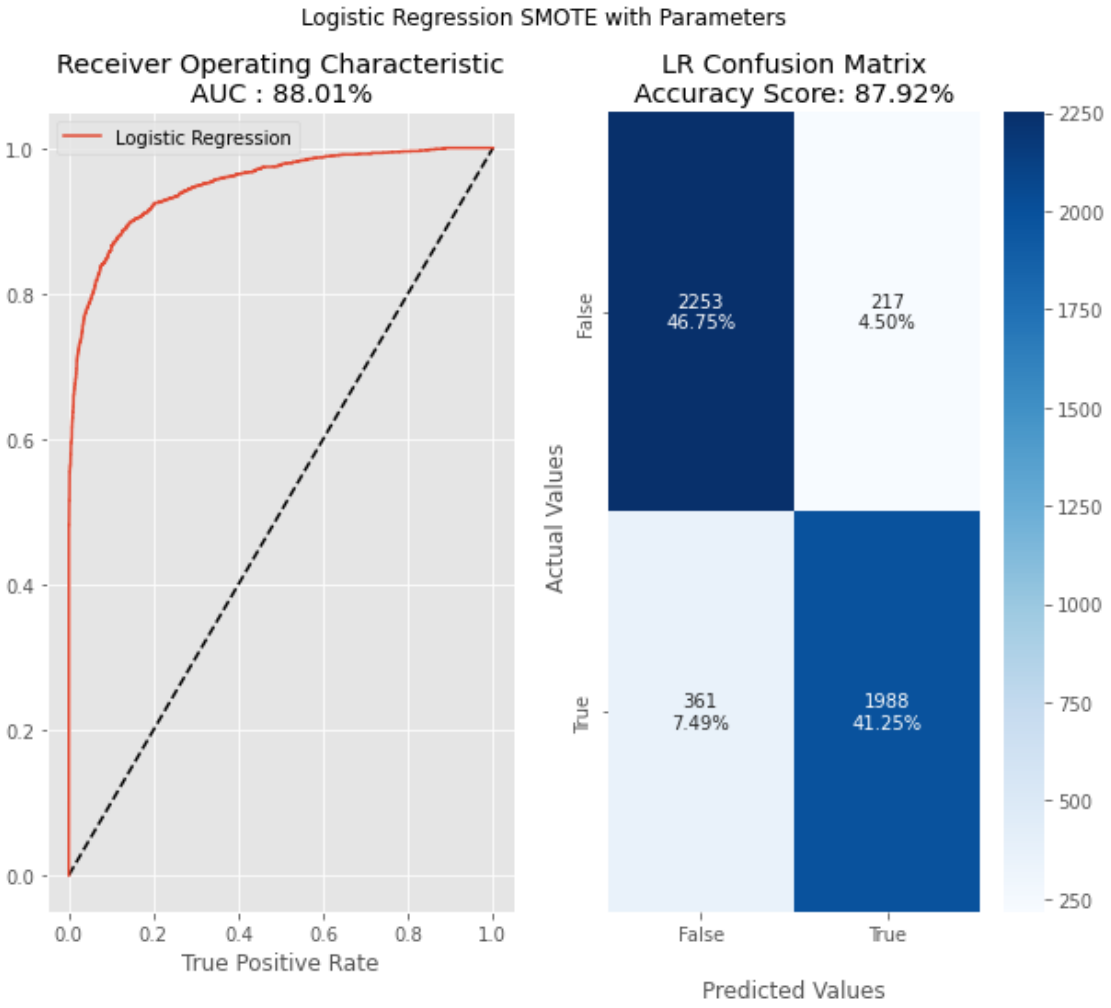
[143]:
```
#Confusion matrix
conf_matrix_mod1_log_grid_sm = confusion_matrix(y_test_sm, y_pred_logR_grid )
#Accuracy
acu_mod1_log_grid_sm = accuracy_score(y_test_sm, y_pred_logR_grid )
#AUC
auc_mod1_log_grid_sm = roc_auc_score(y_test_sm, y_pred_logR_grid )
```

[144]:
```
print("the best parameter for the Logistic Regression are:\n {}".
 ↪format(logR_grid_m1_sm.best_params_))
```

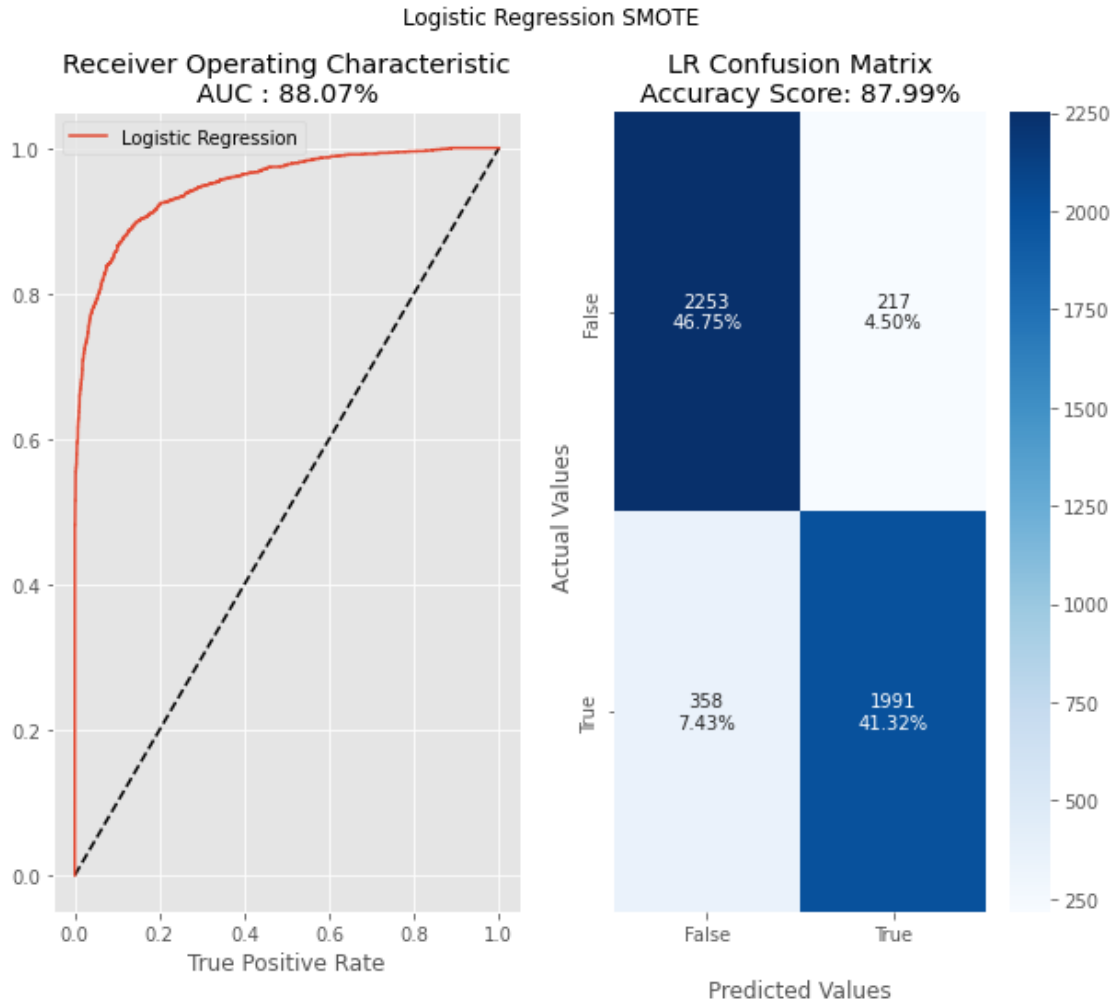
```
the best parameter for the Logistic Regression are:
 {'class_weight': 'balanced', 'penalty': 'l1', 'solver': 'liblinear'}
```

[145]:
```
acmod_grid_sm = {"LR":round(acu_mod1_log_grid_sm,4)}
aucmod_grid_sm = {"LR":round(auc_mod1_log_grid_sm,4)}
```

[146]:
```
#run the functiona (9)
subplots_ROC_CM("Logistic Regression SMOTE with Parameters",
                "Receiver Operating Characteristic",
                "LR Confusion Matrix",
                logR_grid_m1_sm,acmod_grid_sm,aucmod_grid_sm,
                conf_matrix_mod1_log_grid_sm,"LR",X_test_sm,y_test_sm)
```



[147]:
```
#run the functiona (9)
subplots_ROC_CM("Logistic Regression SMOTE","Receiver Operating Characteristic",
                "LR Confusion Matrix",
                ␣
↪mod1_sm,acmod_sm,aucmod_sm,conf_matrix_mod1_sm,"LR",X_test_sm,y_test_sm)
```



Model 2: SVMC

[148]:
```
#Parameters
parameters = {
               "gamma":["scale","auto" ],
              'class_weight':["balanced"]}


   # model
mod2_sm_p = svm.SVC(probability=True)
logR_grid_m2_sm = GridSearchCV(mod2_sm_p,parameters,scoring='roc_auc')
logR_grid_m2_sm.fit(X_train_sm,y_train_sm)
y_pred_logR_grid_m2 = logR_grid_m2_sm.predict(X_test_sm)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/utils/validation.py:63: DataConversionWarning: A column-vector
y was passed when a 1d array was expected. Please change the shape of y to
```

```
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```

[149]:
```
#Confusion matrix
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#Accuracy
acu_mod2_log_grid_sm = accuracy_score(y_test_sm, y_pred_logR_grid_m2 )
#AUC
auc_mod2_log_grid_sm = roc_auc_score(y_test_sm, y_pred_logR_grid_m2 )
```
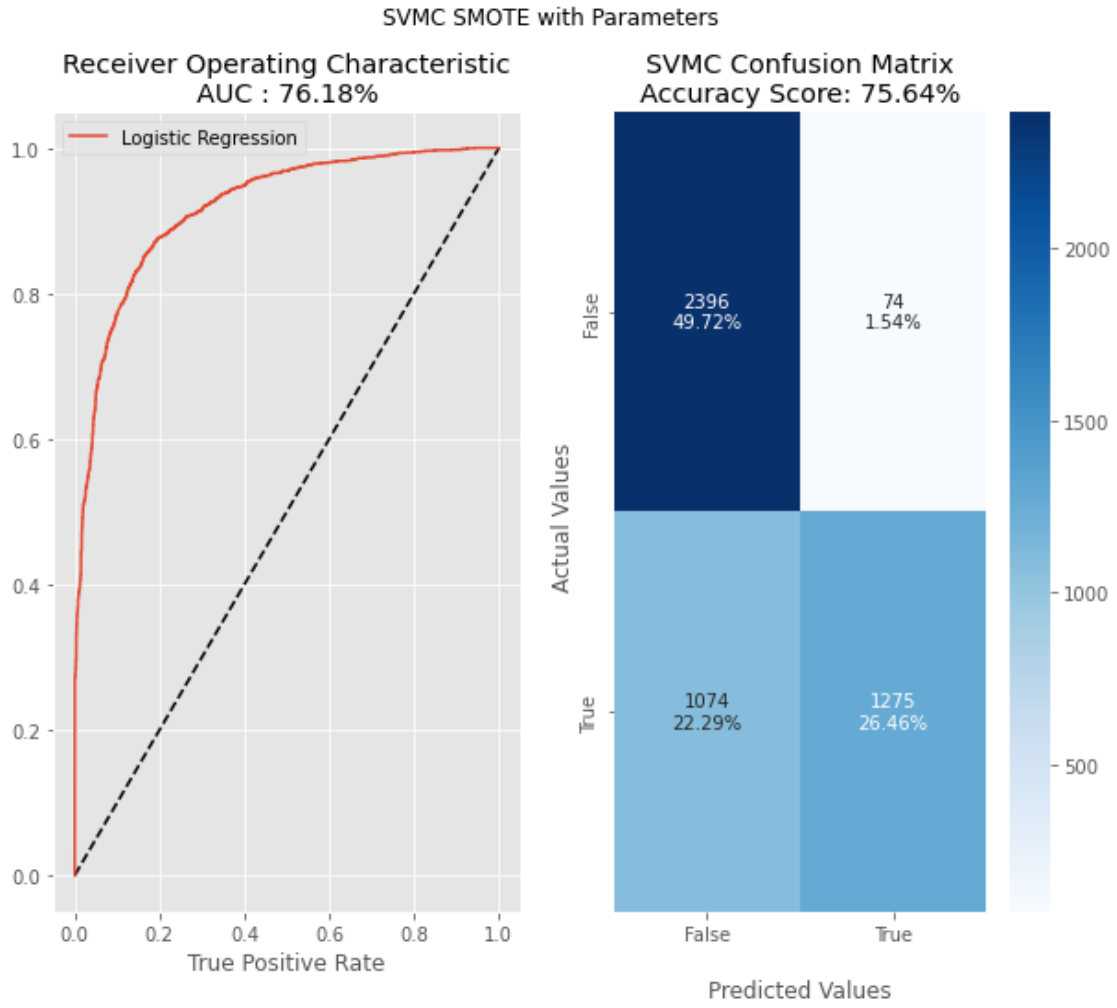

[177]:
```
print("the best parameter for the SVMC are:\n {}".format(logR_grid_m2_sm.
 ↪best_params_))
```

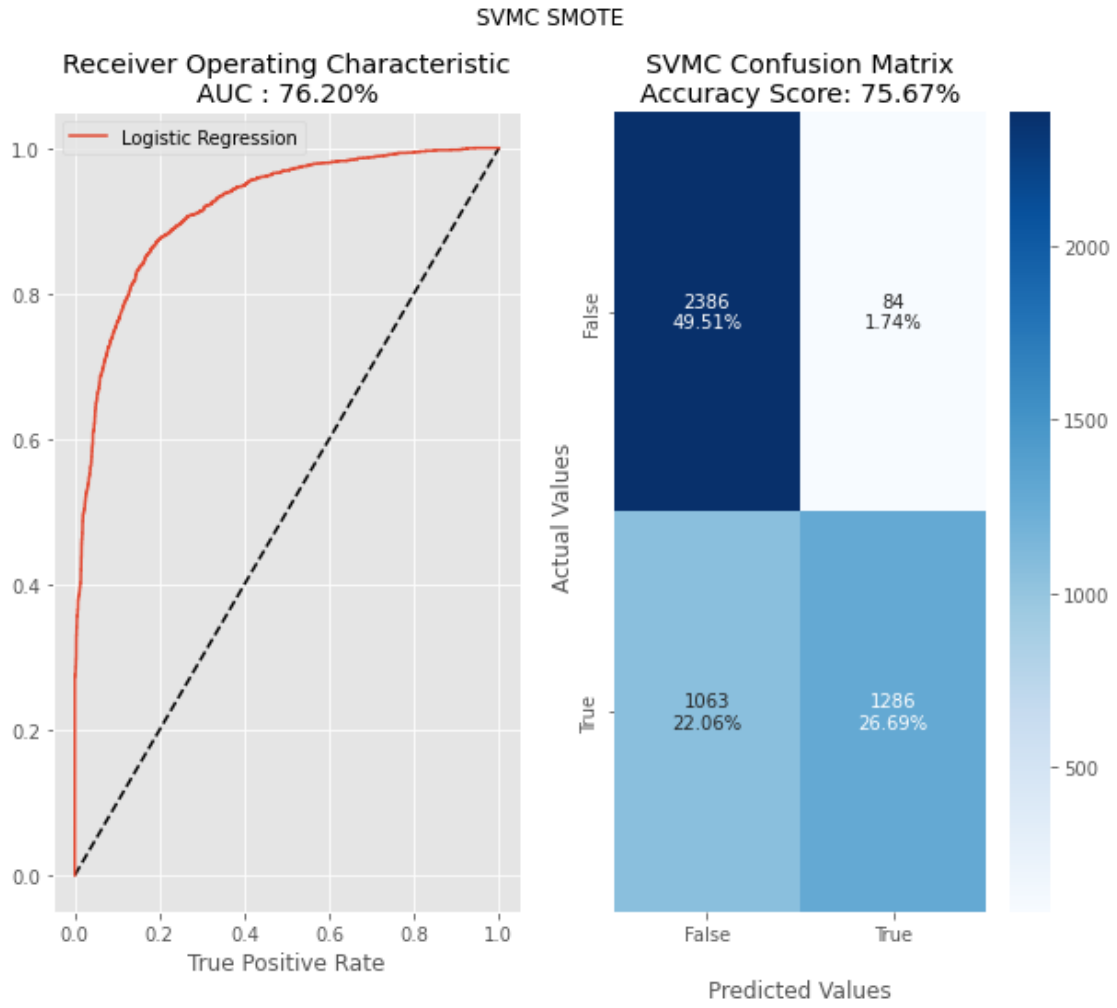
```
the best parameter for the SVMC are:
 {'class_weight': 'balanced', 'gamma': 'scale'}
```

[183]:
```
acmod_grid_m2_sm = {"SVMC":round(acu_mod2_log_grid_sm,4)}
aucmod_grid_m2_sm = {"SVMC":round(auc_mod2_log_grid_sm,4)}
```

[185]:
```
#run the functiona (9)
subplots_ROC_CM("SVMC SMOTE with Parameters",
                "Receiver Operating Characteristic",
                "SVMC Confusion Matrix",
                logR_grid_m2_sm,acmod_grid_m2_sm,aucmod_grid_m2_sm,
                conf_matrix_mod2_log_grid_sm,"SVMC",X_test_sm,y_test_sm)
```



[153]:
```
#run the functiona (9)
subplots_ROC_CM("SVMC SMOTE","Receiver Operating Characteristic",
                "SVMC Confusion Matrix",
                ␣
↪mod2_sm,acmod_sm,aucmod_sm,conf_matrix_mod2_sm,"SVMC",X_test_sm,y_test_sm)
```



Model 3: KNNC

[155]:
```
#Parameters
parameters = {"weights":[ "uniform","distance"],
              "algorithm":["auto" ,"ball_tree", "kd_tree","brute"] }

   # model
mod3_sm_p = KNeighborsClassifier()
knn_grid_m3_sm = GridSearchCV(mod3_sm_p,parameters,scoring='roc_auc')
knn_grid_m3_sm.fit(X_train_sm,y_train_sm)
y_pred_knn_grid_m3 = knn_grid_m3_sm.predict(X_test_sm)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/neighbors/_classification.py:179: 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)
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  return self._fit(X, y)
```

```
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```

```
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  return self._fit(X, y)
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  return self._fit(X, y)
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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)
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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)
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
```

```
packages/sklearn/neighbors/_classification.py:179: DataConversionWarning: A
column-vector y was passed when a 1d array was expected. Please change the shape
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  return self._fit(X, y)
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packages/sklearn/neighbors/_classification.py:179: 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)
```

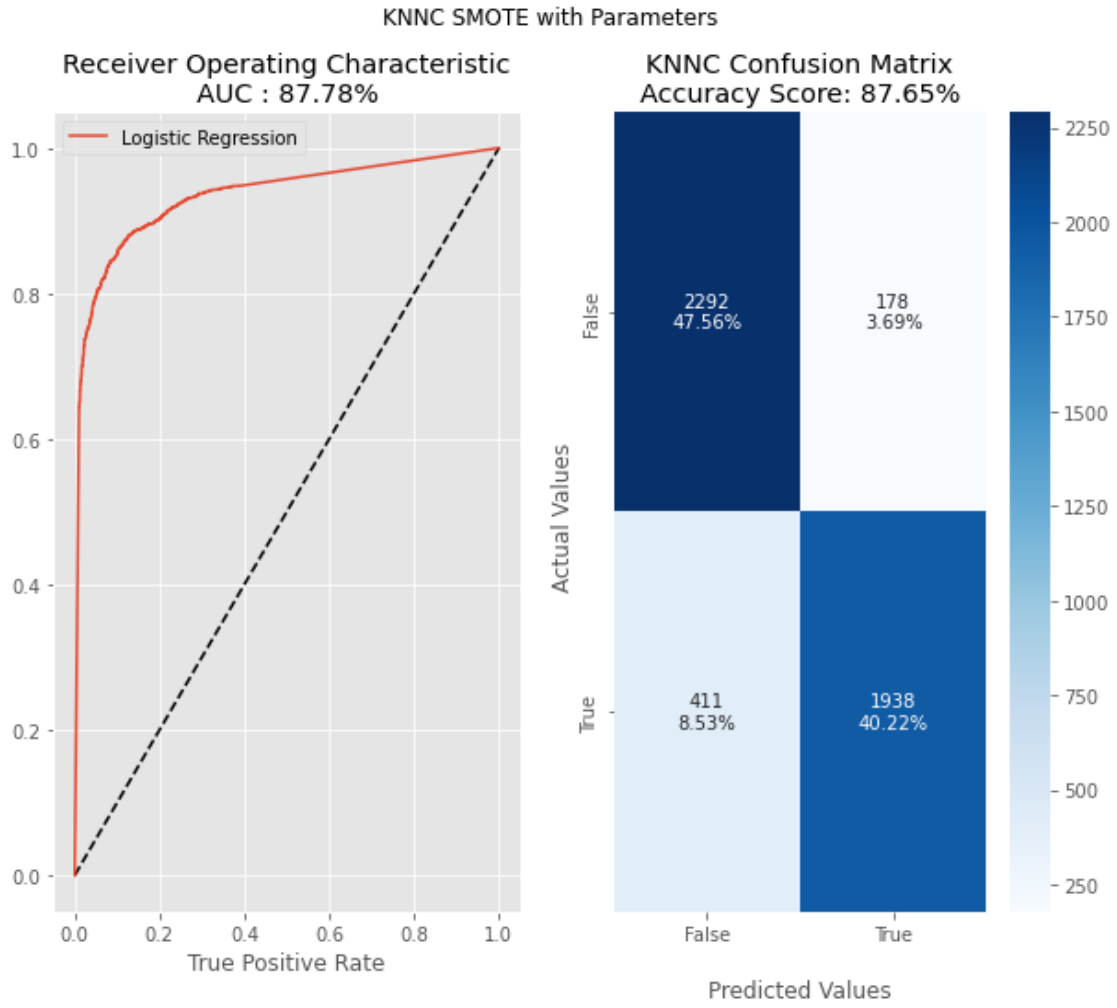
[156]:
```
#Confusion matrix
conf_matrix_mod3_knn_grid_sm = confusion_matrix(y_test_sm, y_pred_knn_grid_m3 )
#Accuracy
acu_mod3_knn_grid_sm = accuracy_score(y_test_sm, y_pred_knn_grid_m3 )
#AUC
auc_mod3_knn_grid_sm = roc_auc_score(y_test_sm, y_pred_knn_grid_m3 )
```

[178]:
```
print("the best parameter for the KNNC are:\n {}".format(knn_grid_m3_sm.
 ↪best_params_))
```

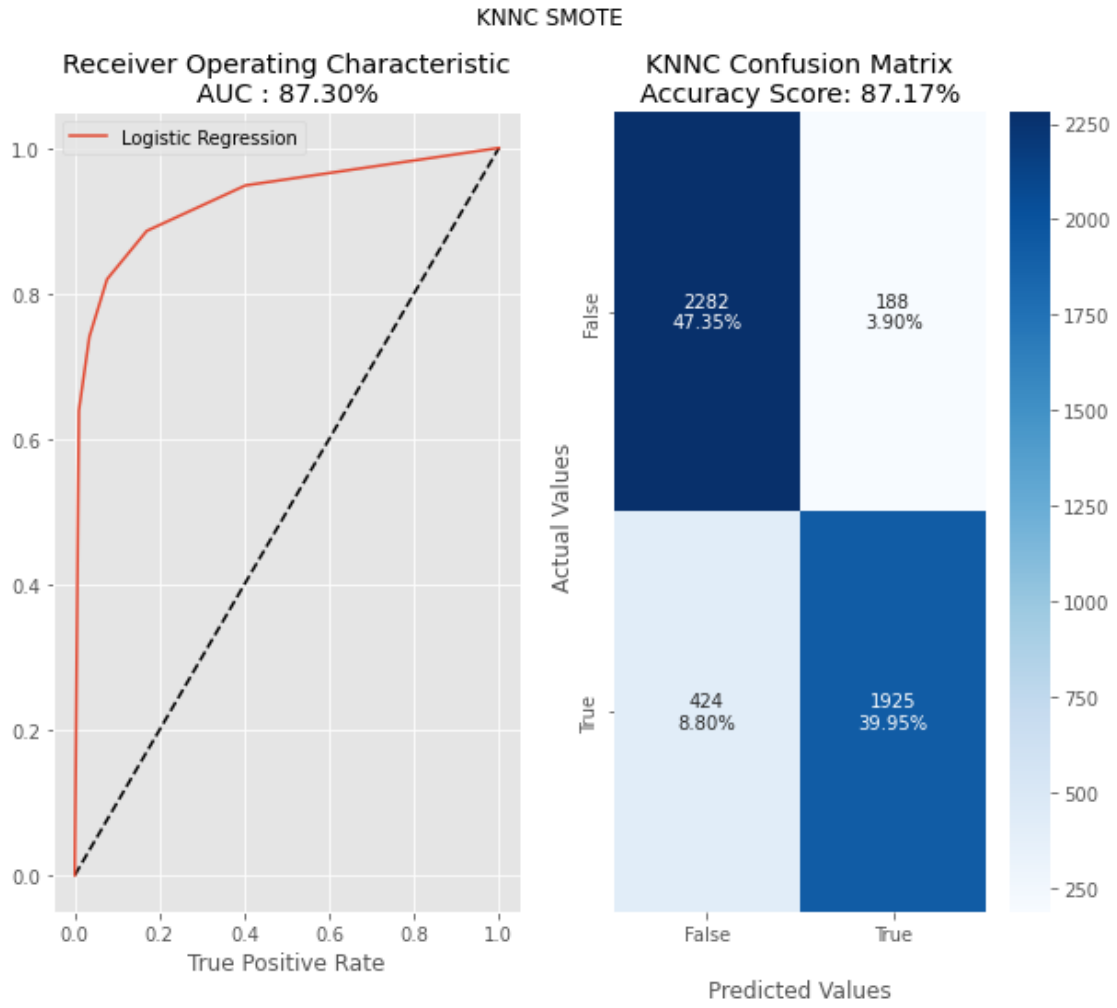
```
the best parameter for the KNNC are:
 {'algorithm': 'auto', 'weights': 'distance'}
```

[166]:
```
acmod_grid_m3_sm = {"KNNC":round(acu_mod3_knn_grid_sm,4)}
aucmod_grid_m3_sm = {"KNNC":round(auc_mod3_knn_grid_sm,4)}
```

[168]:
```
#run the functiona (9)
subplots_ROC_CM("KNNC SMOTE with Parameters","Receiver Operating␣
 ↪Characteristic",
                "KNNC Confusion Matrix",
                knn_grid_m3_sm,acmod_grid_m3_sm,aucmod_grid_m3_sm,
                conf_matrix_mod3_knn_grid_sm,"KNNC",X_test_sm,y_test_sm)
```



[169]:
```
#run the functiona (9)
subplots_ROC_CM("KNNC SMOTE","Receiver Operating Characteristic",
                "KNNC Confusion Matrix",
                ␣
↪mod3_sm,acmod_sm,aucmod_sm,conf_matrix_mod3_sm,"KNNC",X_test_sm,y_test_sm)
```



Model 4: DTC

[172]:
```
#Parameters
parameters = {"criterion":["gini", "entropy", "log_loss"],
              "min_samples_split":[5],
             "max_features":["auto", "sqrt", "log2"]}

mod4_sm_p = DecisionTreeClassifier()
dt_grid_m4_sm = GridSearchCV(mod4_sm_p,parameters,scoring='roc_auc')
dt_grid_m4_sm.fit(X_train_sm,y_train_sm)
y_pred_dt_grid_m4 = dt_grid_m4_sm.predict(X_test_sm)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py:615: FitFailedWarning: Estimator
fit failed. The score on this train-test partition for these parameters will be
set to nan. Details:
```

```
Traceback (most recent call last):
  File "/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/model_selection/_validation.py", line 598, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/tree/_classes.py", line 903, in fit
    super().fit(
  File "/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/tree/_classes.py", line 348, in fit
    criterion = CRITERIA_CLF[self.criterion](self.n_outputs_,
KeyError: 'log_loss'

  warnings.warn("Estimator fit failed. The score on this train-test"
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
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```
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```
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/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/model_selection/_search.py:922: UserWarning: One or more of the
test scores are non-finite: [0.86408193 0.86361374 0.86332653 0.86062812
0.86272477 0.85993032
        nan        nan        nan]
  warnings.warn(
```

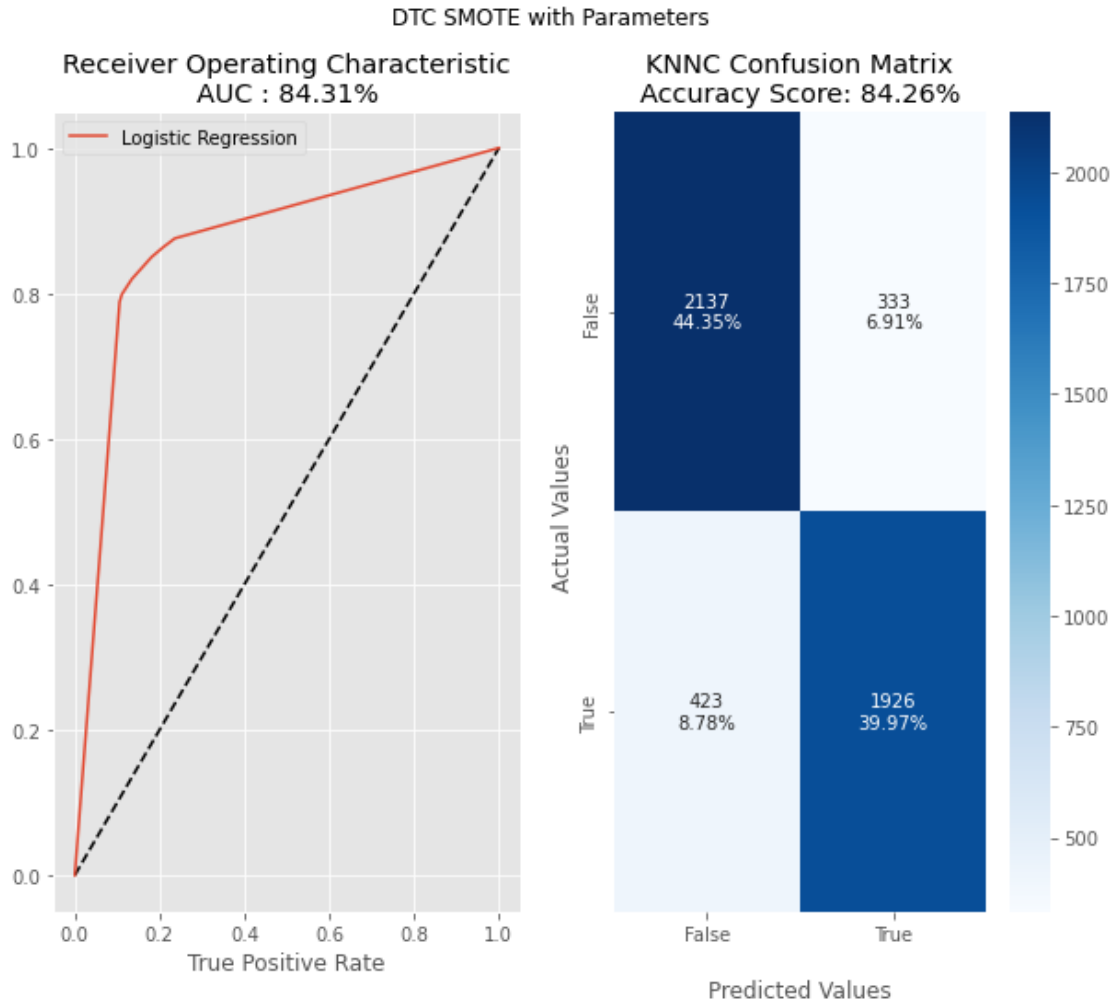
[173]:
```
#Confusion matrix
conf_matrix_mod4_dt_grid_sm = confusion_matrix(y_test_sm, y_pred_dt_grid_m4 )
#Accuracy
acu_mod4_dt_grid_sm = accuracy_score(y_test_sm, y_pred_dt_grid_m4 )
#AUC
auc_mod4_dt_grid_sm = roc_auc_score(y_test_sm, y_pred_dt_grid_m4 )
```

[175]:
```
print("the best parameter for the DT are:\n {}".format(dt_grid_m4_sm.
 ↪best_params_))
```

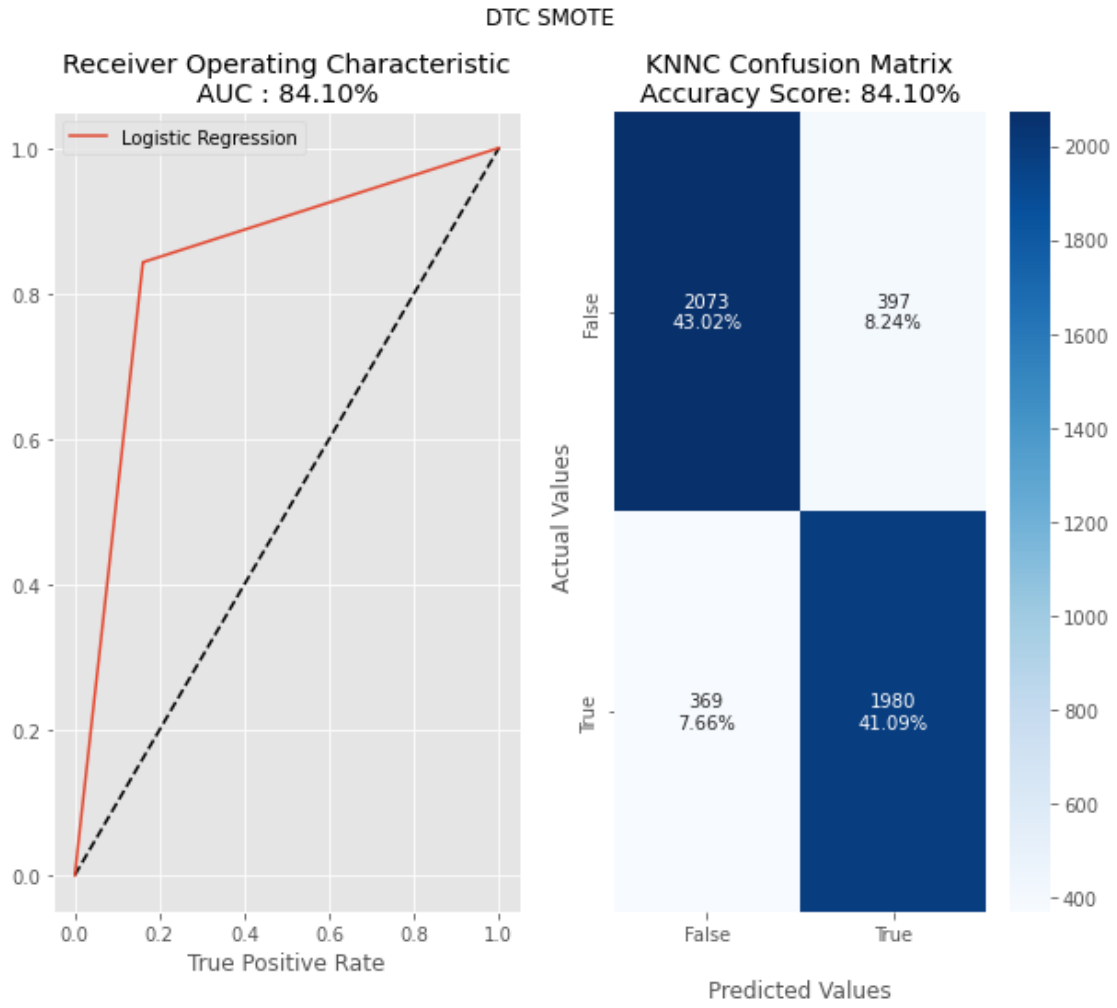
```
the best parameter for the KNNC are:
 {'criterion': 'gini', 'max_features': 'auto', 'min_samples_split': 5}
```

[180]:
```
acmod_grid_m4_sm = {"DTC":round(acu_mod4_dt_grid_sm,4)}
aucmod_grid_m4_sm = {"DTC":round(auc_mod4_dt_grid_sm,4)}
```

[181]:
```
#run the functiona (9)
subplots_ROC_CM("DTC SMOTE with Parameters","Receiver Operating Characteristic",
                "KNNC Confusion Matrix",
                dt_grid_m4_sm,acmod_grid_m4_sm,aucmod_grid_m4_sm,
                conf_matrix_mod4_dt_grid_sm,"DTC",X_test_sm,y_test_sm)
```



[182]:
```
#run the functiona (9)
subplots_ROC_CM("DTC SMOTE","Receiver Operating Characteristic",
                "KNNC Confusion Matrix",
                ␣
↪mod4_sm,acmod_sm,aucmod_sm,conf_matrix_mod4_sm,"DTC",X_test_sm,y_test_sm)
```



The model with parameters have better results but the SVMC model has a huge increase in computation time, in general with the SMOTE the increased performance is minimal but it can make a difference in some problems with sensitive performance.

Exercise 4

Compare your performance using the traint / test or cross-validation approach.

Model 1: Logistic Regression

[222]:
```
mod1_cv = LogisticRegression()
scores_mod1 = cross_validate(mod1_cv, X, y, cv=5,
                             scoring=('roc_auc'),
                            return_train_score=True)
```

```
/Users/franciscoregalado/opt/anaconda3/lib/python3.9/site-
packages/sklearn/linear_model/_logistic.py:763: ConvergenceWarning: lbfgs failed
to converge (status=1):
```

```
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-
regression
  n_iter_i = _check_optimize_result(
```

[237]:
```
print("The AUC by train-test with smote and parameters is {}% \n and by␣
↪cross-validation of the model is {}%".format(aucmod_grid_sm.get("LR")*100,
                                                                          ␣
↪              round(scores_mod1 ["test_score"].mean(),4)*100))
```

```
The AUC by train-test with smote and parameters is 87.92%
 and by cross-validation of the model is 94.23%
```

Model 2: SVMC

[223]:
```
mod2_cv = svm.SVC(probability=True)
scores_mod2 = cross_validate(mod2_cv, X, y, cv=5,
                         scoring=('roc_auc'),
                        return_train_score=True)
```

[236]:
```
print("The AUC by train-test with smote and parameters is {}% \n and by␣
↪cross-validation of the model is {}%".format(aucmod_grid_m2_sm.
↪get("SVMC")*100,
                                                                          ␣
↪              round(scores_mod2 ["test_score"].mean(),4)*100))
```

```
The AUC by train-test with smote and parameters is 75.64%
 and by cross-validation of the model is 87.7%
```

Model 3: KNNC

[226]:
```
mod3_cv = KNeighborsClassifier()
scores_mod3 = cross_validate(mod3_cv, X, y, cv=5,
                         scoring=('roc_auc'),
                        return_train_score=True)
```

[235]:
```
print("The AUC by train-test with smote and parameters is {}% \n and by␣
↪cross-validation of the model is {}%".format(aucmod_grid_m3_sm.
↪get("KNNC")*100,
                                                                          ␣
↪              round(scores_mod3 ["test_score"].mean(),4)*100))
```

```
The AUC by train-test with smote and parameters is 87.64999999999999%
 and by cross-validation of the model is 90.88000000000001%
```

Model 4: DTC

[232]:
```
mod4_cv = DecisionTreeClassifier()
scores_mod4 = cross_validate(mod4_cv, X, y, cv=5,
                         scoring=('roc_auc'),
                        return_train_score=True)
```

[234]:
```
print("The AUC by train-test with smote and parameters is {}% \n and by␣
↪cross-validation of the model is {}% ".format(aucmod_grid_m4_sm.
↪get("DTC")*100,
                                                                        ␣
↪              round(scores_mod4 ["test_score"].mean(),4)*100))
```

```
The AUC by train-test with smote and parameters is 84.26%
 and by cross-validation of the model is 79.96%
```

As expected the results by Cross-Validation (CV) are better than SMOTE and parameters, we can improve the results of CV using the smote sample and model parameters.

To continue...