In [ ]:

```
import glob
import pandas as pd
pd.options.display.max_columns = None
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
from datetime import datetime

from sklearn.tree import DecisionTreeClassifier
from sklearn.naive_bayes import GaussianNB
from sklearn.ensemble import RandomForestClassifier
from sklearn.preprocessing import StandardScaler, OneHotEncoder, LabelEncoder
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.compose import make_column_transformer
from sklearn.neighbors import KNeighborsClassifier
from sklearn.linear_model import LogisticRegression
from sklearn import metrics
from sklearn.metrics import accuracy_score, f1_score, precision_score, recall_score, classification_report, confusion_matrix, precision_recall_curve

import xgboost as xgb
from xgboost import XGBClassifier
```

In [ ]:

```
# getting csv files from the folder MyProject
path = "/Users/jhuang/Library/CloudStorage/GoogleDrive-dimitripanch@gmail.com/My Drive/College/Graduate/NEU/Spring 2023/CS5002 Discrete Structures/Final Projects/Final Data/"

# read all the files with extension .csv
filenames = glob.glob(path + "DOT Data/*.csv")

# for loop to iterate all csv files
raw_df = []
for file in filenames:
   # reading csv files
   raw_df.append(pd.read_csv(file))

df = pd.concat(raw_df)
df.columns = df.columns.str.lower()
df = df.loc[df['origin']=='SEA']

# convert the 'date' column to datetime format
df['fl_date'] = pd.to_datetime(df['fl_date'], format='%m/%d/%Y %I:%M:%S %p')

# extract only the date part of the datetime object
df['fl_date'] = df['fl_date'].dt.date
df.head()
```

Out[ ]:

	month	day_of_month	day_of_week	fl_date	mkt_carrier_fl_num	op_unique_carrier	origin	origin_city_name	dest	dest_city_name	crs_dep_time	dep_time	dep_delay_new	dep_del15	cancelled	diverted	crs_elapsed_time	distance
58	11	1	2	2022-11-01	101	AS	SEA	Seattle, WA	ANC	Anchorage, AK	2315	2313.0	0.0	0.0	0.0	0.0	222.0	1448.0
73	11	1	2	2022-11-01	1012	AS	SEA	Seattle, WA	MSP	Minneapolis, MN	1825	1818.0	0.0	0.0	0.0	0.0	194.0	1399.0
81	11	1	2	2022-11-01	1014	AS	SEA	Seattle, WA	ORD	Chicago, IL	600	601.0	1.0	0.0	0.0	0.0	253.0	1721.0
132	11	1	2	2022-11-01	1023	DL	SEA	Seattle, WA	CVG	Cincinnati, OH	1005	1000.0	0.0	0.0	0.0	0.0	255.0	1965.0
155	11	1	2	2022-11-01	1028	DL	SEA	Seattle, WA	LAX	Los Angeles, CA	1348	1343.0	0.0	0.0	0.0	0.0	157.0	954.0

In [ ]:

```
# check a few variables to make sure data loading is correct
print(df.shape)

print(df['month'].unique(), len(df['month'].unique()))

print(df['day_of_month'].unique(), len(df['day_of_month'].unique()))

print(df['day_of_week'].unique(), len(df['day_of_week'].unique()))

print(df['op_unique_carrier'].unique(), len(df['op_unique_carrier'].unique()))

print(len(df['origin'].unique()), len(df['origin_city_name'].unique()))

print(len(df['dest'].unique()), len(df['dest_city_name'].unique()))
```

```
(174009, 18)
[11 12 10  9  4  3  2  6  5  7  8  1] 12
[ 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
 25 26 27 28 29 30 31] 31
[2 3 4 5 6 7 1] 7
['AS' 'DL' 'UA' 'WN' 'AA' 'NK' 'QX' 'HA' 'F9' 'B6' 'OO'] 11
1 1
93 91
```

In [ ]:

```
# https://aspm.faa.gov/aspmhelp/index/ASQP__Carrier_Codes_and_Names.html
carrier = pd.read_csv(path + 'Carrier_codes_and_names.csv')
carrier.columns = carrier.columns.str.lower()
carrier.head()
```

Out[ ]:

	iata code	icao code	air carrier name
0	ZW	AWI	Air Wisconsin
1	AS	ASA	Alaska Airlines
2	G4	AAY	Allegiant Air LLC
3	AA	AAL	American Airlines
4	C5	UCA	Champlain Air

In [ ]:

```python
df = pd.merge(df, carrier[['iata code','air carrier name']], how="left", left_on='op_unique_carrier', right_on='iata code')
df.head()
```

Out[ ]:

	month	day_of_month	day_of_week	fl_date	mkt_carrier_fl_num	op_unique_carrier	origin	origin_city_name	dest	dest_city_name	crs_dep_time	dep_time	dep_delay_new	dep_del15	cancelled	diverted	crs_elapsed_time	distance	iata code	air carrier name
0	11	1	2	2022-11-01	101	AS	SEA	Seattle, WA	ANC	Anchorage, AK	2315	2313.0	0.0	0.0	0.0	0.0	222.0	1448.0	AS	Alaska Airlines
1	11	1	2	2022-11-01	1012	AS	SEA	Seattle, WA	MSP	Minneapolis, MN	1825	1818.0	0.0	0.0	0.0	0.0	194.0	1399.0	AS	Alaska Airlines
2	11	1	2	2022-11-01	1014	AS	SEA	Seattle, WA	ORD	Chicago, IL	600	601.0	1.0	0.0	0.0	0.0	253.0	1721.0	AS	Alaska Airlines
3	11	1	2	2022-11-01	1023	DL	SEA	Seattle, WA	CVG	Cincinnati, OH	1005	1000.0	0.0	0.0	0.0	0.0	255.0	1965.0	DL	Delta Air Lines, Inc.
4	11	1	2	2022-11-01	1028	DL	SEA	Seattle, WA	LAX	Los Angeles, CA	1348	1343.0	0.0	0.0	0.0	0.0	157.0	954.0	DL	Delta Air Lines, Inc.

In [ ]:

```python
# https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00024233/detail
weather = pd.read_csv(path + 'seatac_weather.csv')

# convert the 'date' column to datetime format
weather['date'] = pd.to_datetime(weather['date'], format='%m/%d/%y')

# extract only the date part of the datetime object
weather['date'] = weather['date'].dt.date

weather.head()
```

Out[ ]:

	date	average_wind_speed	precipitation	snowfall	snow_depth	average_temperature	maximum_temperature	minimum_temperature	fog	heavy_fog
0	2022-01-01	8.05	0.00	0.0	3.1	25	34	22	0	0
1	2022-01-02	8.50	0.79	0.0	3.1	34	43	30	1	0
2	2022-01-03	11.41	0.49	0.0	0.0	38	41	33	1	0
3	2022-01-04	9.62	0.22	0.0	0.0	36	42	35	1	0
4	2022-01-05	4.92	0.33	0.0	0.0	38	39	34	1	0

In [ ]:

```python
weather.shape
```

Out[ ]:

```
(365, 10)
```

In [ ]:

```python
df = pd.merge(df, weather, how="left", left_on='fl_date', right_on='date')
df.head()
```

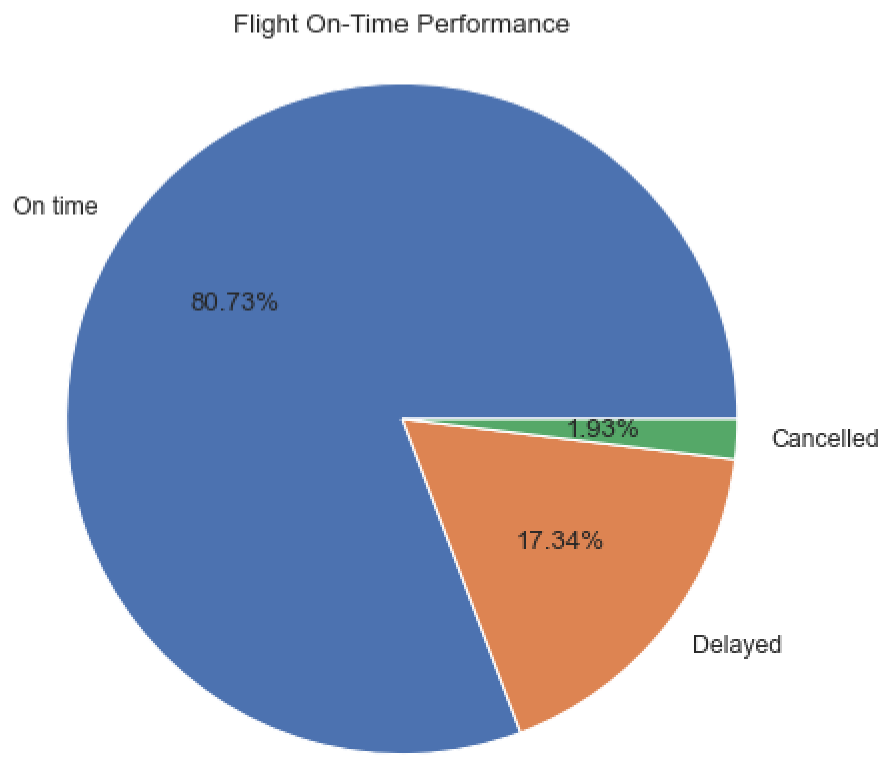
Out[ ]:

	month	day_of_month	day_of_week	fl_date	mkt_carrier_fl_num	op_unique_carrier	origin	origin_city_name	dest	dest_city_name	crs_dep_time	dep_time	dep_delay_new	dep_del15	cancelled	diverted	crs_elapsed_time	distance	iata code	air carrier name	date	average_wind_speed	precipitation	snowfall	snow_depth
0	11	1	2	2022-11-01	101	AS	SEA	Seattle, WA	ANC	Anchorage, AK	2315	2313.0	0.0	0.0	0.0	0.0	222.0	1448.0	AS	Alaska Airlines	2022-11-01	4.92	0.13	0.0	0.0
1	11	1	2	2022-11-01	1012	AS	SEA	Seattle, WA	MSP	Minneapolis, MN	1825	1818.0	0.0	0.0	0.0	0.0	194.0	1399.0	AS	Alaska Airlines	2022-11-01	4.92	0.13	0.0	0.0
2	11	1	2	2022-11-01	1014	AS	SEA	Seattle, WA	ORD	Chicago, IL	600	601.0	1.0	0.0	0.0	0.0	253.0	1721.0	AS	Alaska Airlines	2022-11-01	4.92	0.13	0.0	0.0
3	11	1	2	2022-11-01	1023	DL	SEA	Seattle, WA	CVG	Cincinnati, OH	1005	1000.0	0.0	0.0	0.0	0.0	255.0	1965.0	DL	Delta Air Lines, Inc.	2022-11-01	4.92	0.13	0.0	0.0
4	11	1	2	2022-11-01	1028	DL	SEA	Seattle, WA	LAX	Los Angeles, CA	1348	1343.0	0.0	0.0	0.0	0.0	157.0	954.0	DL	Delta Air Lines, Inc.	2022-11-01	4.92	0.13	0.0	0.0

In [ ]:

```python
# create on_time column
df.loc[df['cancelled']==1, 'on_time'] = 'Cancelled'
df.loc[df['dep_del15']==0, 'on_time'] = 'On time'
df.loc[df['dep_del15']==1, 'on_time'] = 'Delayed'

# Calculate value counts for on_time column
on_time_counts = df['on_time'].value_counts()

# Create lists of labels and sizes
labels = on_time_counts.index.tolist()
sizes = on_time_counts.tolist()

# Create pie chart
```

```
fig, ax = plt.subplots()
ax.pie(sizes, labels=labels, autopct='%1.2f%%')
ax.axis('equal')
plt.title('Flight On-Time Performance')
plt.show()
```



In [ ]:

```
# cancelled flights # from our data
len(df.loc[df['cancelled'] == 1.0])
```

Out[ ]:

```
3473
```

In [ ]:

```
# remove cancelled flights
df = df.loc[df['cancelled'] == 0.0]

# remove delay of more than 480 minutes
print(len(df.loc[df['dep_delay_new']>480]))

df = df.loc[df['dep_delay_new']<=480]
```

```
190
```

In [ ]:

```
# delayed flights %
print(len(df.loc[df['dep_del15'] == 1.0]) / len(df), df['dep_del15'].isnull().values.sum())
```

```
0.17561316379603864 0
```

In [ ]:

```
print(df['air carrier name'].isnull().values.sum())

# Total Number of Flights by Airline
flights_airlines = df.groupby(['air carrier name'], as_index=False)['dep_del15'].count()
flights_airlines.columns = ['airline', 'total_num_flights_airline']

# Number of Delayed Flights by Airline
flights_delayed_airlines = df.groupby(['air carrier name'], as_index=False)['dep_del15'].sum()
flights_delayed_airlines.columns = ['airline', 'total_num_delayed_flights_airline']

print(flights_airlines.head())
print(flights_delayed_airlines.head())
```

```
0
                    airline  total_num_flights_airline
0           Alaska Airlines                      68938
1         American Airlines                       5158
2    Delta Air Lines, Inc.                      28857
3  Frontier Airlines, Inc.                        493
4   Hawaiian Airlines Inc.                        727
                    airline  total_num_delayed_flights_airline
0           Alaska Airlines                            13466.0
1         American Airlines                             1026.0
2    Delta Air Lines, Inc.                              4869.0
3  Frontier Airlines, Inc.                               157.0
4   Hawaiian Airlines Inc.                                97.0
```

In [ ]:

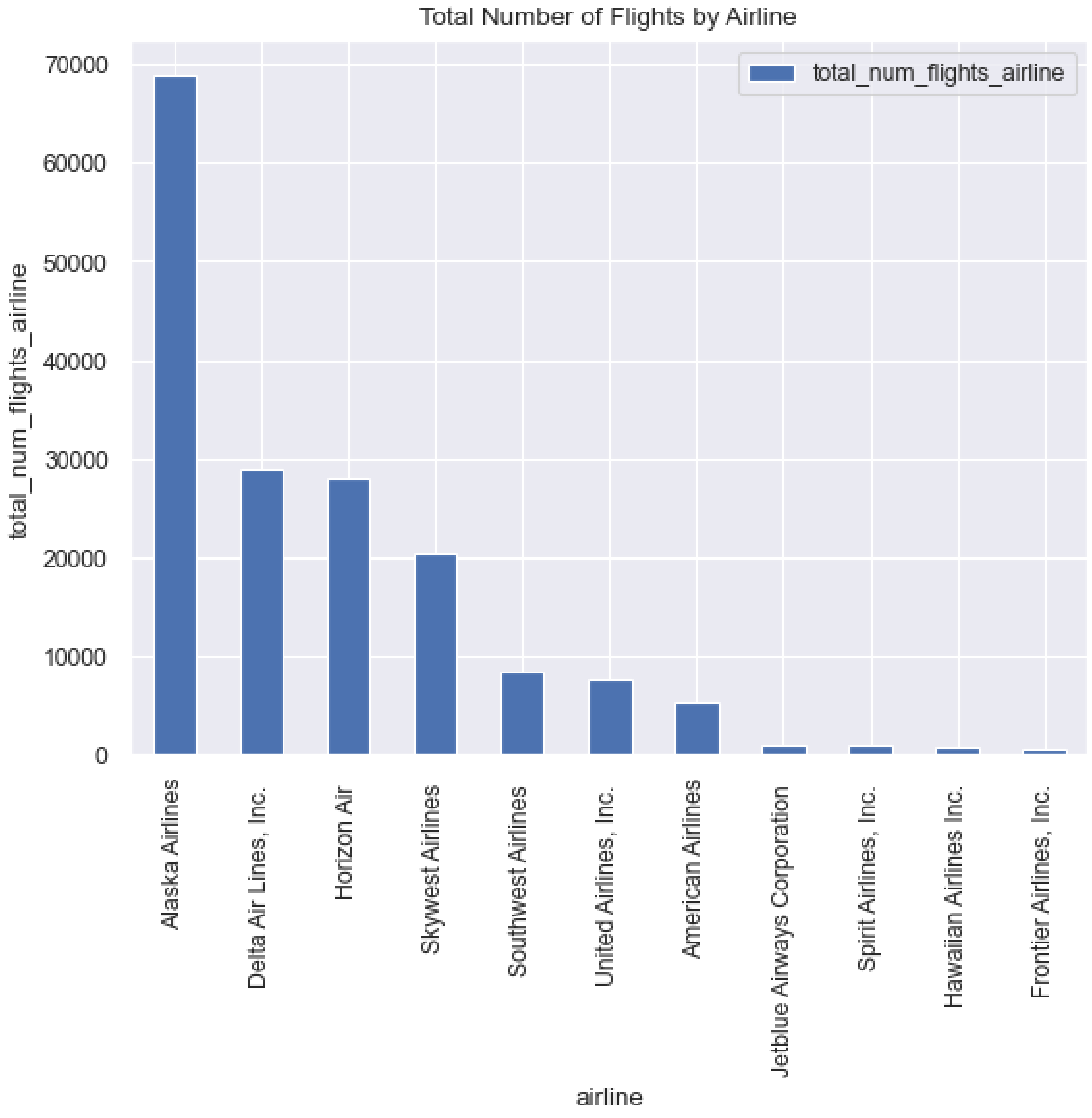
```
# Percentage of Delayed Flights by Airline
percent_flights_delayed_airlines = pd.merge(flights_airlines, flights_delayed_airlines, on='airline')
percent_flights_delayed_airlines['percent_delayed_airline'] = percent_flights_delayed_airlines['total_num_delayed_flights_airline'] / percent_flights_delayed_airlines['total_num_flights_airline']
percent_flights_delayed_airlines = percent_flights_delayed_airlines.sort_values(by="total_num_flights_airline", ascending=False)
percent_flights_delayed_airlines
```

Out[ ]:

	airline	total_num_flights_airline	total_num_delayed_flights_airline	percent_delayed_airline
0	Alaska Airlines	68938	13466.0	0.195335
2	Delta Air Lines, Inc.	28857	4869.0	0.168729
5	Horizon Air	28052	4287.0	0.152823
7	Skywest Airlines	20317	2265.0	0.111483
8	Southwest Airlines	8448	2042.0	0.241714
10	United Airlines, Inc.	7590	1036.0	0.136495
1	American Airlines	5158	1026.0	0.198914
6	Jetblue Airways Corporation	920	469.0	0.509783
9	Spirit Airlines, Inc.	846	201.0	0.237589
4	Hawaiian Airlines Inc.	727	97.0	0.133425
3	Frontier Airlines, Inc.	493	157.0	0.318458

In [ ]:

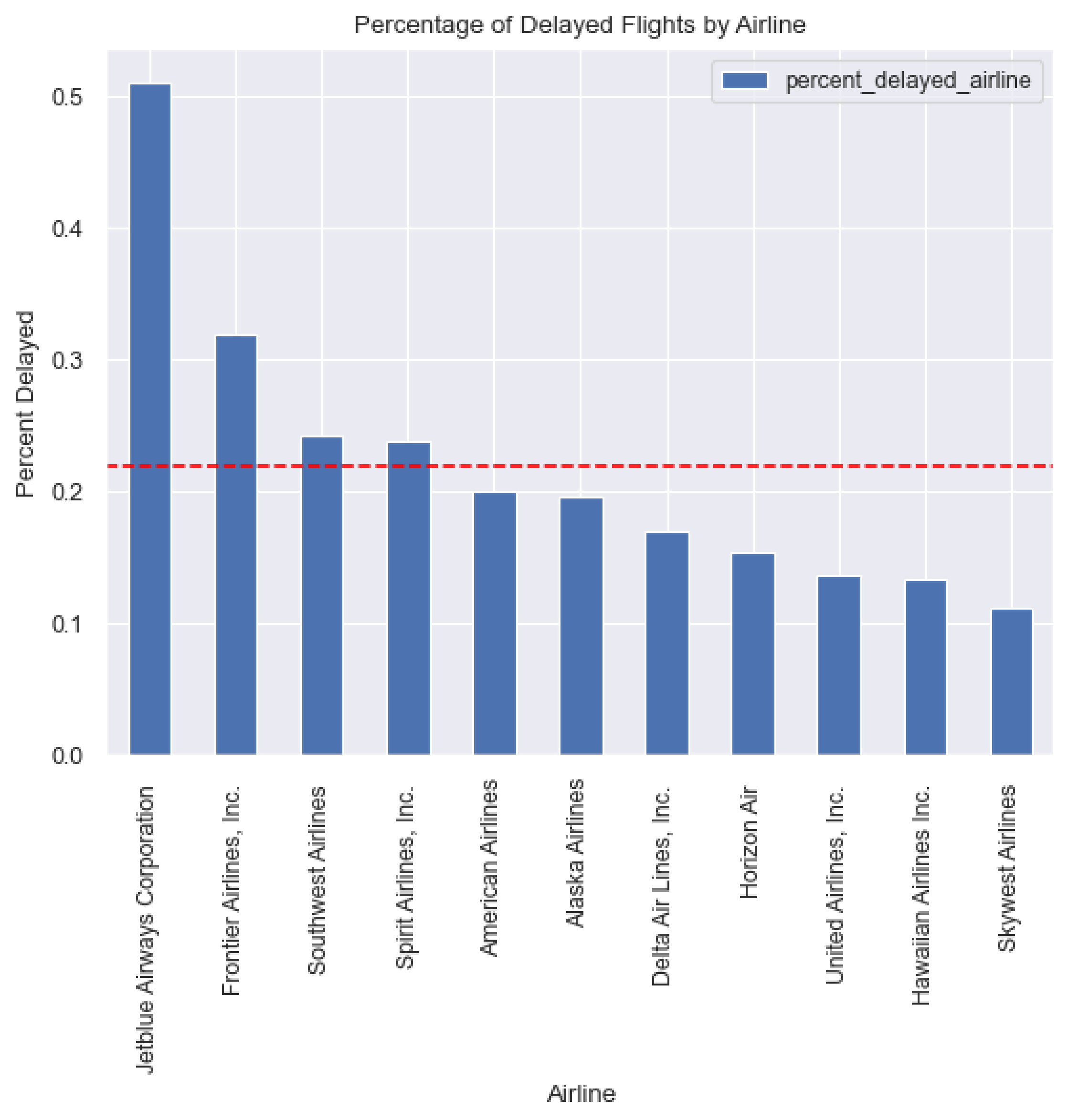
```python
# Create a bar plot of the DataFrame
ax = percent_flights_delayed_airlines.plot.bar(x='airline', y='total_num_flights_airline')

# Set the plot title and axis labels
ax.set_title('Total Number of Flights by Airline')
ax.set_xlabel('airline')
ax.set_ylabel('total_num_flights_airline')

# Display the plot
plt.show()
```



In [ ]:

```python
# Calculate the average value
avg_percent_delayed = percent_flights_delayed_airlines['percent_delayed_airline'].mean()

# Set the figure size
plt.figure(figsize=(10,5))

# Create a bar plot of the DataFrame
ax = percent_flights_delayed_airlines.sort_values(by="percent_delayed_airline", ascending=False).plot.bar(x='airline', y='percent_delayed_airline')

# Add a red line indicating the average value
ax.axhline(avg_percent_delayed, color='red', linestyle='--')

# Set the plot title and axis labels
ax.set_title('Percentage of Delayed Flights by Airline')
ax.set_xlabel('Airline')
ax.set_ylabel('Percent Delayed')

# Display the plot
plt.show()
```

```
<Figure size 1000x500 with 0 Axes>
```



Percentage of Delayed Flights by Airline

In [ ]:

```
# Average Delay Time by Airline
avg_delayed_time_airlines = df.groupby(['air carrier name'], as_index=False)['dep_delay_new'].mean()
avg_delayed_time_airlines.columns = ['airline', 'avg_delayed_minutes']
avg_delayed_time_airlines
```

Out[ ]:

	airline	avg_delayed_minutes
0	Alaska Airlines	10.495228
1	American Airlines	13.621365
2	Delta Air Lines, Inc.	11.605434
3	Frontier Airlines, Inc.	21.941176
4	Hawaiian Airlines Inc.	10.830812
5	Horizon Air	8.787823
6	Jetblue Airways Corporation	34.119565
7	Skywest Airlines	7.136585
8	Southwest Airlines	13.323864
9	Spirit Airlines, Inc.	15.341608
10	United Airlines, Inc.	10.009486

In [ ]:

```
# 20 Most Common Destination (Cities)
dest_top20 = df.groupby(['dest','dest_city_name'], as_index=False).size()
dest_top20.columns = ['dest','dest_city_name','num_of_flights_dest']
dest_top20.sort_values(by='num_of_flights_dest',ascending=False)[:20].reset_index(drop=True)
```

Out[ ]:

	dest	dest_city_name	num_of_flights_dest
0	PDX	Portland, OR	8045
1	ANC	Anchorage, AK	7140
2	SFO	San Francisco, CA	6633
3	GEG	Spokane, WA	6606
4	LAX	Los Angeles, CA	6530
5	LAS	Las Vegas, NV	6292
6	DEN	Denver, CO	5988
7	PHX	Phoenix, AZ	5980
8	BOI	Boise, ID	5154
9	SJC	San Jose, CA	4972
10	ORD	Chicago, IL	4706
11	SMF	Sacramento, CA	4517
12	SAN	San Diego, CA	4068
13	SNA	Santa Ana, CA	3623
14	DFW	Dallas/Fort Worth, TX	3546
15	SLC	Salt Lake City, UT	3529
16	JFK	New York, NY	3179
17	RDM	Bend/Redmond, OR	3170
18	ATL	Atlanta, GA	3119
19	EUG	Eugene, OR	3041

In [ ]:

```
# Worse and Best months to travel
month_delay = df.groupby(['month'], as_index=False)['dep_del15'].sum()
month_delay.columns = ['month', 'delayed_cnt_month']

month_flights = df.groupby(['month'], as_index=False)['dep_del15'].count()
month_flights.columns = ['month', 'flight_cnt_month']

month_flights_delay = pd.merge(month_flights, month_delay, on=['month'])
month_flights_delay['percent_delayed_month'] = month_delay['delayed_cnt_month'] / month_flights['flight_cnt_month']
month_flights_delay = month_flights_delay.sort_values(by='percent_delayed_month', ascending=False)

num = 1
for i in ['Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec']:
    month_flights_delay.loc[month_flights_delay['month']==num, 'month'] = i
    num += 1
month_flights_delay
```

Out[ ]:

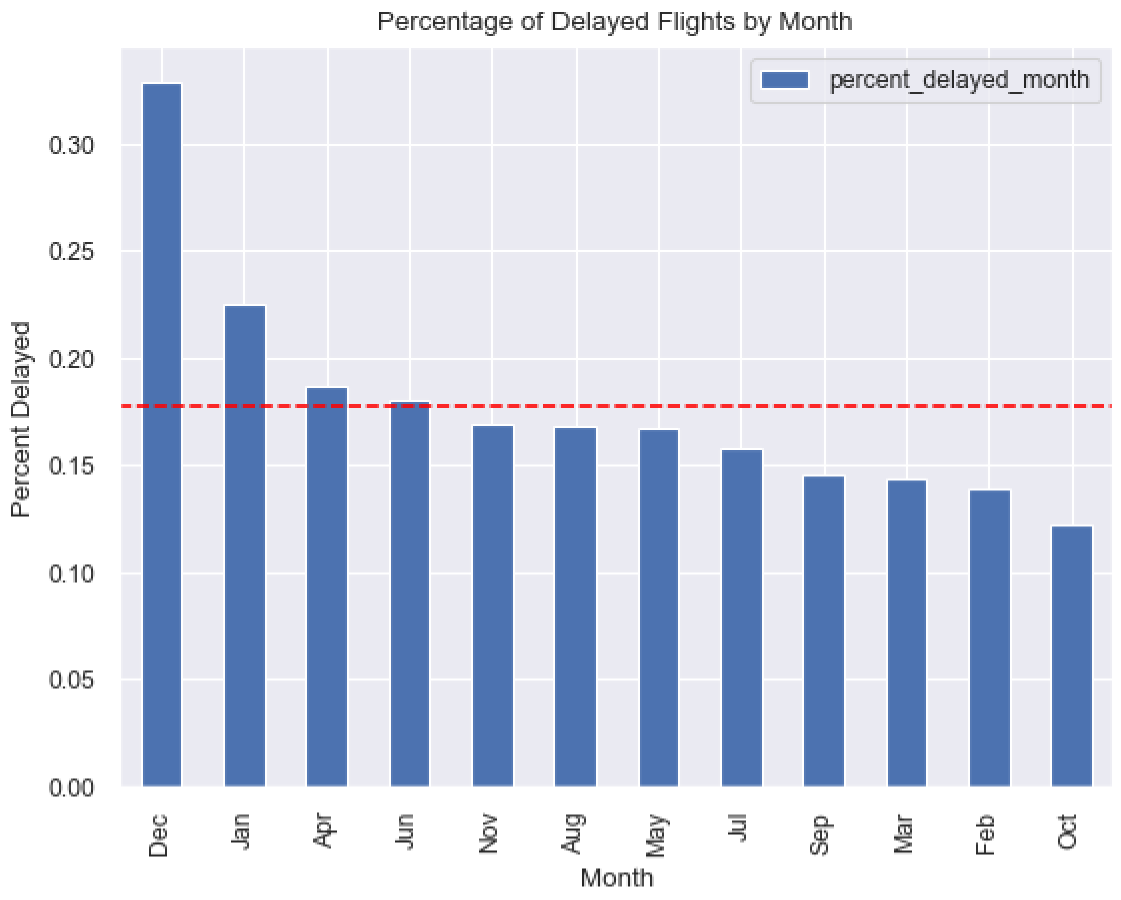
	month	flight_cnt_month	delayed_cnt_month	percent_delayed_month
11	Dec	12807	4213.0	0.328961
0	Jan	12205	2741.0	0.224580
3	Apr	13495	2514.0	0.186291
5	Jun	14940	2696.0	0.180455
10	Nov	13765	2320.0	0.168543
7	Aug	16243	2730.0	0.168072
4	May	14436	2415.0	0.167290
6	Jul	16217	2553.0	0.157427
8	Sep	15721	2287.0	0.145474
2	Mar	13661	1966.0	0.143913
1	Feb	11835	1650.0	0.139417
9	Oct	15021	1830.0	0.121829

In [ ]:

```
# Calculate the average value
avg_percent_delayed_month = month_flights_delay['percent_delayed_month'].mean()

# Set the figure size
plt.figure(figsize=(8,6))

# Create a bar plot of the DataFrame
ax = month_flights_delay.sort_values(by="percent_delayed_month", ascending=False).plot.bar(x='month', y='percent_delayed_month')

# Add a red line indicating the average value
ax.axhline(avg_percent_delayed_month, color='red', linestyle='--')

# Set the plot title and axis labels
ax.set_title('Percentage of Delayed Flights by Month')
ax.set_xlabel('Month')
ax.set_ylabel('Percent Delayed')
```

```
# Display the plot
plt.show()
```

```
<Figure size 800x600 with 0 Axes>
```



In [ ]:

```
# Best weekday to avoid delays
day_of_week_delay = df.groupby(['day_of_week'], as_index=False)['dep_del15'].sum()
day_of_week_delay.columns = ['day_of_week', 'delayed_cnt_day_of_week']

day_of_week_flights = df.groupby(['day_of_week'], as_index=False)['dep_del15'].count()
day_of_week_flights.columns = ['day_of_week', 'flight_cnt_day_of_week']

day_of_week_flights_delay = pd.merge(day_of_week_flights, day_of_week_delay, on=['day_of_week'])
day_of_week_flights_delay['percent_delayed_day_of_week'] = day_of_week_delay['delayed_cnt_day_of_week'] / day_of_week_flights['flight_cnt_day_of_week']
day_of_week_flights_delay = day_of_week_flights_delay.sort_values(by='percent_delayed_day_of_week', ascending=False)

num = 1
for i in ['Mon', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']:
    day_of_week_flights_delay.loc[day_of_week_flights_delay['day_of_week']==num, 'day_of_week'] = i
    num += 1
day_of_week_flights_delay
```

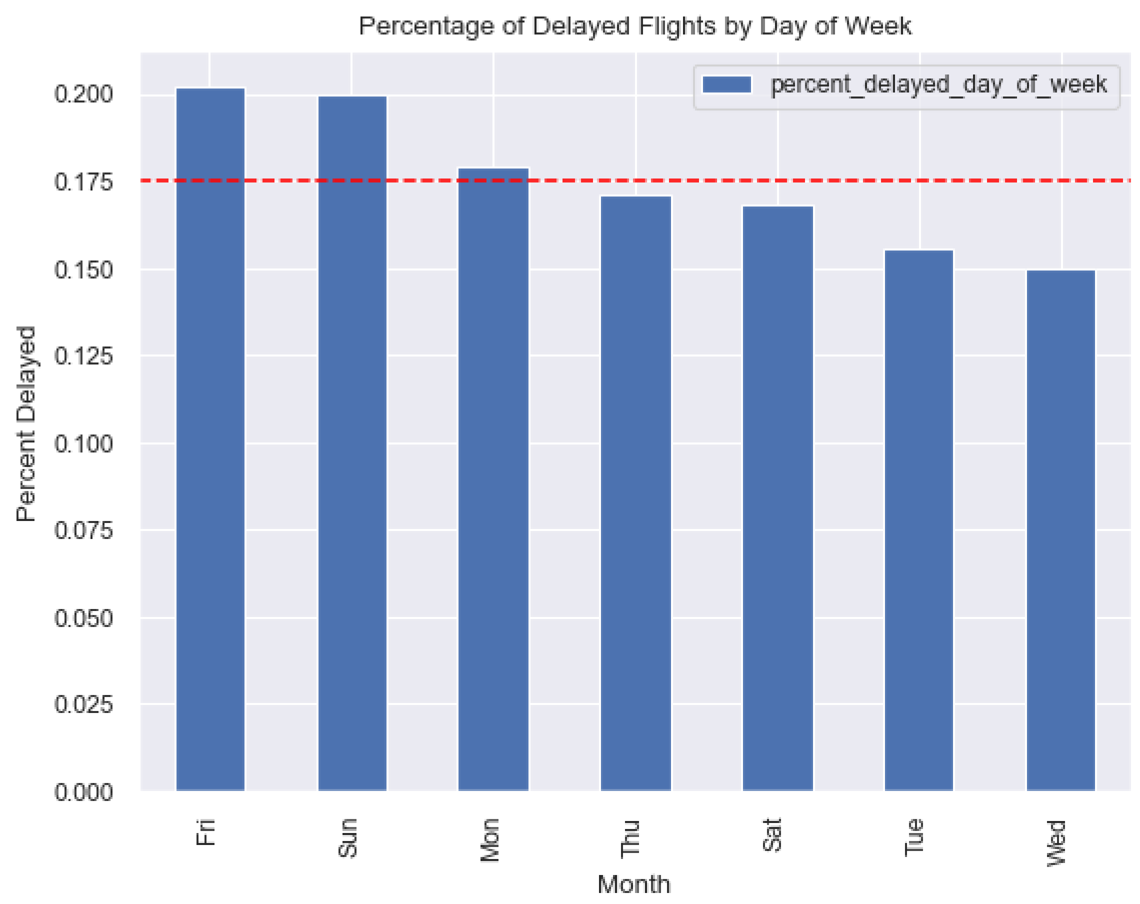
Out[ ]:

	day_of_week	flight_cnt_day_of_week	delayed_cnt_day_of_week	percent_delayed_day_of_week
4	Fri	25016	5055.0	0.202071
6	Sun	24682	4937.0	0.200024
0	Mon	25307	4534.0	0.179160
3	Thu	25240	4318.0	0.171078
5	Sat	22621	3808.0	0.168339
1	Tue	23640	3685.0	0.155880
2	Wed	23840	3578.0	0.150084

In [ ]:

```
# Calculate the average value
avg_percent_delayed_day = day_of_week_flights_delay['percent_delayed_day_of_week'].mean()

# Set the figure size
plt.figure(figsize=(8,6))

# Create a bar plot of the DataFrame
ax = day_of_week_flights_delay.sort_values(by="percent_delayed_day_of_week", ascending=False).plot.bar(x='day_of_week', y='percent_delayed_day_of_week')

# Add a red line indicating the average value
ax.axhline(avg_percent_delayed_day, color='red', linestyle='--')

# Set the plot title and axis labels
ax.set_title('Percentage of Delayed Flights by Day of Week')
ax.set_xlabel('Month')
ax.set_ylabel('Percent Delayed')

# Display the plot
plt.show()
```

```
<Figure size 800x600 with 0 Axes>
```



Modeling

Now that the data has been cleaned and gone through a thorough EDA process, its time to start with the modeling which will be a binary classification as described above.

In [ ]:

```
# create on_time column
df.loc[(df['crs_dep_time']>=600) & (df['crs_dep_time']<900), 'day_period'] = 'early morning'
df.loc[(df['crs_dep_time']>=900) & (df['crs_dep_time']<1200), 'day_period'] = 'late morning'
df.loc[(df['crs_dep_time']>=1200) & (df['crs_dep_time']<1500), 'day_period'] = 'early afternoon'
df.loc[(df['crs_dep_time']>=1500) & (df['crs_dep_time']<1800), 'day_period'] = 'late afternoon'
df.loc[(df['crs_dep_time']>=1800) & (df['crs_dep_time']<2100), 'day_period'] = 'early evening'
df.loc[df['crs_dep_time']>=2100, 'day_period'] = 'late evening'
df.loc[df['crs_dep_time']<500, 'day_period'] = 'after midnight'

num = 1
for i in ['Mon', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']:
    df.loc[df['day_of_week']==num, 'day_of_week'] = i
    num += 1

num = 1
for i in ['Jan', 'Feb', 'Mar', 'Apr', 'May', 'Jun', 'Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec']:
    df.loc[df['month']==num, 'month'] = i
    num += 1

df.head()
```

Out[ ]:

	month	day_of_month	day_of_week	fl_date	mkt_carrier_fl_num	op_unique_carrier	origin	origin_city_name	dest	dest_city_name	crs_dep_time	dep_time	dep_delay_new	dep_del15	cancelled	diverted	crs_elapsed_time	distance	iata code	air carrier name	date	average_wind_speed	precipitation	snowfall	snow_depth
0	Nov	1	Tue	2022-11-01	101	AS	SEA	Seattle, WA	ANC	Anchorage, AK	2315	2313.0	0.0	0.0	0.0	0.0	222.0	1448.0	AS	Alaska Airlines	2022-11-01	4.92	0.13	0.0	0.0
1	Nov	1	Tue	2022-11-01	1012	AS	SEA	Seattle, WA	MSP	Minneapolis, MN	1825	1818.0	0.0	0.0	0.0	0.0	194.0	1399.0	AS	Alaska Airlines	2022-11-01	4.92	0.13	0.0	0.0
2	Nov	1	Tue	2022-11-01	1014	AS	SEA	Seattle, WA	ORD	Chicago, IL	600	601.0	1.0	0.0	0.0	0.0	253.0	1721.0	AS	Alaska Airlines	2022-11-01	4.92	0.13	0.0	0.0
3	Nov	1	Tue	2022-11-01	1023	DL	SEA	Seattle, WA	CVG	Cincinnati, OH	1005	1000.0	0.0	0.0	0.0	0.0	255.0	1965.0	DL	Delta Air Lines, Inc.	2022-11-01	4.92	0.13	0.0	0.0
4	Nov	1	Tue	2022-11-01	1028	DL	SEA	Seattle, WA	LAX	Los Angeles, CA	1348	1343.0	0.0	0.0	0.0	0.0	157.0	954.0	DL	Delta Air Lines, Inc.	2022-11-01	4.92	0.13	0.0	0.0

In [ ]:

```
df['distance'].corr(df['dep_delay_new'])
```

Out[ ]:

```
0.04485429900314371
```

In [ ]:

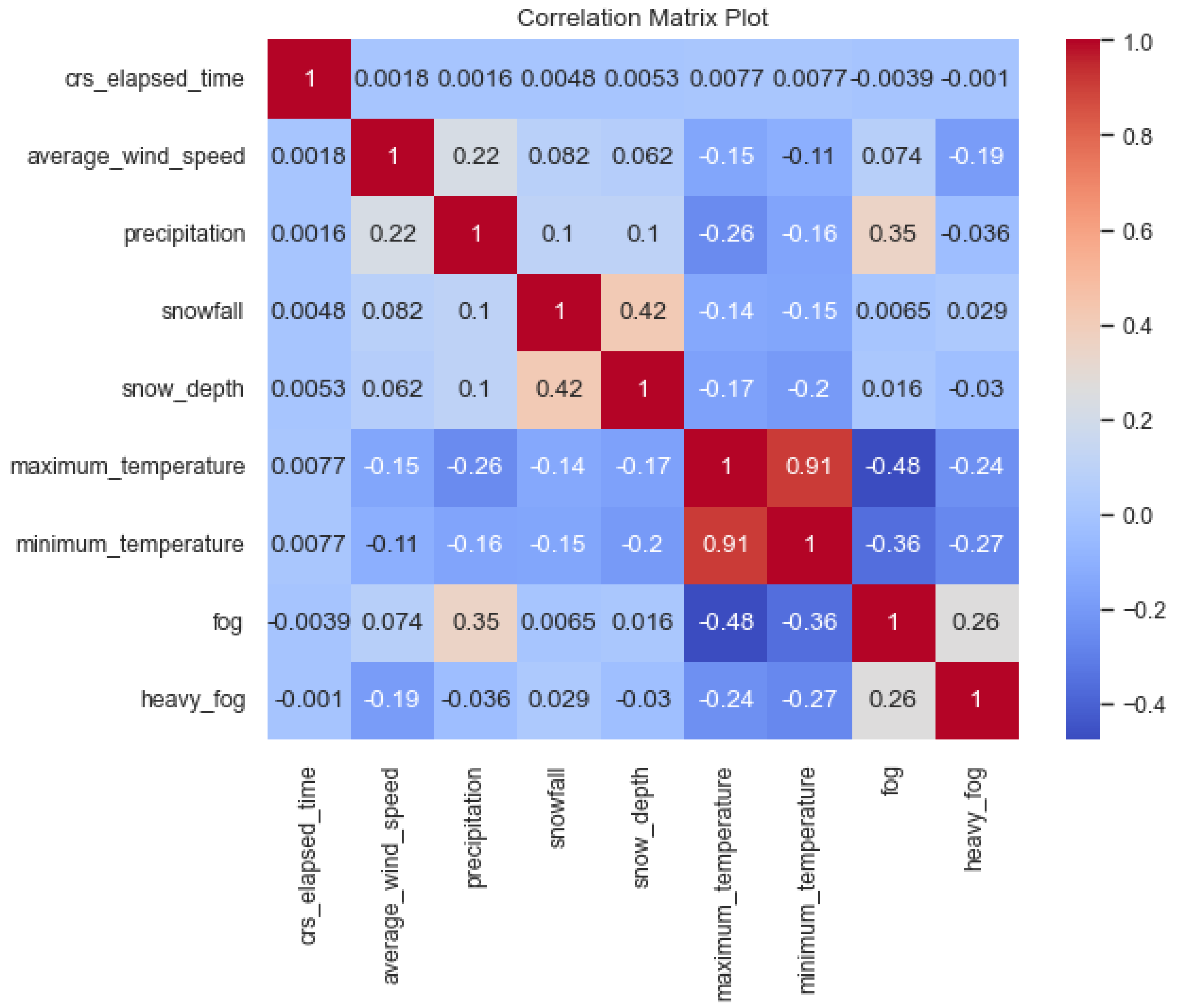
```
df_model = df[['month','day_of_week','op_unique_carrier','dest','dep_del15','crs_elapsed_time','day_period',
               'average_wind_speed','precipitation','snowfall','snow_depth','maximum_temperature','minimum_temperature','fog','heavy_fog']]
df_model.head()
```

Out[ ]:

	month	day_of_week	op_unique_carrier	dest	dep_del15	crs_elapsed_time	day_period	average_wind_speed	precipitation	snowfall	snow_depth	maximum_temperature	minimum_temperature	fog	heavy_fog
0	Nov	Tue	AS	ANC	0.0	222.0	late evening	4.92	0.13	0.0	0.0	51	41	1	0
1	Nov	Tue	AS	MSP	0.0	194.0	early evening	4.92	0.13	0.0	0.0	51	41	1	0
2	Nov	Tue	AS	ORD	0.0	253.0	early morning	4.92	0.13	0.0	0.0	51	41	1	0
3	Nov	Tue	DL	CVG	0.0	255.0	late morning	4.92	0.13	0.0	0.0	51	41	1	0
4	Nov	Tue	DL	LAX	0.0	157.0	early afternoon	4.92	0.13	0.0	0.0	51	41	1	0

In [ ]:

```
# Select columns to include in the correlation matrix plot
cols = ['crs_elapsed_time','average_wind_speed','precipitation','snowfall','snow_depth','maximum_temperature','minimum_temperature','fog','heavy_fog']
corr_matrix = df_model[cols].corr()

# Create a heatmap plot of the correlation matrix
sns.heatmap(corr_matrix, annot=True, cmap='coolwarm')
plt.title('Correlation Matrix Plot')
plt.show()
```



In [ ]:

```
df_model.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 170346 entries, 0 to 174008
Data columns (total 15 columns):
 #   Column               Non-Null Count   Dtype  
---  ------               --------------   -----  
 0   month                170346 non-null  object 
 1   day_of_week          170346 non-null  object 
 2   op_unique_carrier    170346 non-null  object 
 3   dest                 170346 non-null  object 
 4   dep_del15            170346 non-null  float64
 5   crs_elapsed_time     170346 non-null  float64
 6   day_period           167766 non-null  object 
 7   average_wind_speed   170346 non-null  float64
 8   precipitation        170346 non-null  float64
 9   snowfall             170346 non-null  float64
 10  snow_depth           170346 non-null  float64
 11  maximum_temperature  170346 non-null  int64  
 12  minimum_temperature  170346 non-null  int64  
 13  fog                  170346 non-null  int64  
 14  heavy_fog            170346 non-null  int64  
dtypes: float64(6), int64(4), object(5)
memory usage: 20.8+ MB
```

In [ ]:

```
df_model
```

Out[ ]:

	month	day_of_week	op_unique_carrier	dest	dep_del15	crs_elapsed_time	day_period	average_wind_speed	precipitation	snowfall	snow_depth	maximum_temperature	minimum_temperature	fog	heavy_fog
0	Nov	Tue	AS	ANC	0.0	222.0	late evening	4.92	0.13	0.0	0.0	51	41	1	0
1	Nov	Tue	AS	MSP	0.0	194.0	early evening	4.92	0.13	0.0	0.0	51	41	1	0
2	Nov	Tue	AS	ORD	0.0	253.0	early morning	4.92	0.13	0.0	0.0	51	41	1	0
3	Nov	Tue	DL	CVG	0.0	255.0	late morning	4.92	0.13	0.0	0.0	51	41	1	0
4	Nov	Tue	DL	LAX	0.0	157.0	early afternoon	4.92	0.13	0.0	0.0	51	41	1	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
174004	Jan	Mon	WN	PHX	0.0	160.0	late afternoon	9.17	0.00	0.0	0.0	46	35	0	0
174005	Jan	Mon	DL	ATL	0.0	285.0	early morning	9.17	0.00	0.0	0.0	46	35	0	0
174006	Jan	Mon	DL	TPA	0.0	324.0	early morning	9.17	0.00	0.0	0.0	46	35	0	0
174007	Jan	Mon	DL	SLC	0.0	121.0	late morning	9.17	0.00	0.0	0.0	46	35	0	0
174008	Jan	Mon	AS	GEG	0.0	69.0	late morning	9.17	0.00	0.0	0.0	46	35	0	0

170346 rows × 15 columns

In [ ]:

```
print(len(np.unique(df['dest'])))
# Create an instance of LabelEncoder
encoder = LabelEncoder()

# Apply the encoder to the 'dest' column
df_model['dest_encoded'] = encoder.fit_transform(df_model['dest'])
```

```
93
```

```
/var/folders/2_/s_zjqk_1525359z27gq08hpr0000gn/T/ipykernel_18940/1227133656.py:6: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  df_model['dest_encoded'] = encoder.fit_transform(df_model['dest'])
```

In [ ]:

```
# Specify columns to encode
print(len(np.unique(df['op_unique_carrier'])))
columns_to_encode = ['month','day_of_week','op_unique_carrier','day_period']

# One-hot encode columns
one_hot_encoded = pd.get_dummies(df_model[columns_to_encode])

# Drop original columns to be encoded
df_model_dropped = df_model.drop(columns_to_encode+['dest'], axis=1)

# Concatenate the one-hot encoded columns with the original DataFrame
df_model = pd.concat([df_model_dropped, one_hot_encoded], axis=1)
```

```
11
```

In [ ]:

```
# Select the last 111 column names
last_column_names = df_model.columns[-37:]
# Replace True with 1 and False with 0 in columns
for col in last_column_names:
    df_model[col] = df_model[col].replace({True: 1, False: 0})

df_model.head()
```

Out[ ]:

	dep_del15	crs_elapsed_time	average_wind_speed	precipitation	snowfall	snow_depth	maximum_temperature	minimum_temperature	fog	heavy_fog	dest_encoded	month_Apr	month_Aug	month_Dec	month_Feb	month_Jan	month_Jul	month_Jun	month_Mar	month_May	month_Nov	month_Oct	month_Se
0	0.0	222.0	4.92	0.13	0.0	0.0	51	41	1	0	2	0	0	0	0	0	0	0	0	0	1	0	
1	0.0	194.0	4.92	0.13	0.0	0.0	51	41	1	0	57	0	0	0	0	0	0	0	0	0	1	0	
2	0.0	253.0	4.92	0.13	0.0	0.0	51	41	1	0	64	0	0	0	0	0	0	0	0	0	1	0	
3	0.0	255.0	4.92	0.13	0.0	0.0	51	41	1	0	17	0	0	0	0	0	0	0	0	0	1	0	
4	0.0	157.0	4.92	0.13	0.0	0.0	51	41	1	0	47	0	0	0	0	0	0	0	0	0	1	0	

In [ ]:

```
# Separate independent and dependent variables
X = df_model.drop('dep_del15', axis=1)
X.shape
```

Out[ ]:

```
(170346, 47)
```

In [ ]:

```
# Define target (dependtable variable)
y = df_model['dep_del15']
y.head()
```

Out[ ]:

```
0    0.0
1    0.0
2    0.0
3    0.0
4    0.0
Name: dep_del15, dtype: float64
```

split into train and test sets

In [ ]:
```
X_train, X_test, y_train, y_test = train_test_split(X,y,test_size=0.2,random_state=42)
print ('Train set:', X_train.shape,  y_train.shape)
print ('Test set:', X_test.shape,  y_test.shape)
```

```
Train set: (136276, 47) (136276,)
Test set: (34070, 47) (34070,)
```

In [ ]:
```
scaler = StandardScaler()
scaler.fit(X_train)
X_train = scaler.transform(X_train)
X_test = scaler.transform(X_test)
```

In [ ]:
```
def train(model, X_train, y_train, X_test, y_test, params, output=False, return_model=False):

    # Naive Bayes
    if model == 'gnb':
        model_fit = GaussianNB(**params)
    # Logistic Regression
    if model == 'logistic':
        model_fit = LogisticRegression(**params)

    model_fit.fit(X_train,y_train)
    y_pred = model_fit.predict(X_test)

    if output==True:
        confusionMatrix = confusion_matrix(y_test, y_pred)
        score = model_fit.score(X_test,y_test)
        print("Test Score:", score)

        print("F1 score :",f1_score(y_test, y_pred))
        print("Precision Score :" , precision_score(y_test, y_pred))
        print("Recall Score :" , recall_score(y_test, y_pred))
        print(classification_report(y_test, y_pred))

        sns.set(context="paper")
        plt.subplots(figsize=(6,6))
        sns.heatmap(confusionMatrix, annot=True, fmt=".0f", linewidths=1.5, square=True)
        plt.ylabel('Actual label')
        plt.xlabel('Predicted label')
        plt.title("Confusion Matrix", size = 15)
        plt.show()

    if return_model==True:
        return model_fit
```

In [ ]:
```
def plot_feature_importance(importance,names,model_type,top_n=None):

    #Create arrays from feature importance and feature names
    feature_importance = np.array(importance)
    feature_names = np.array(names)

    #Create a DataFrame using a Dictionary
    data={'feature_names':feature_names,'feature_importance':feature_importance}
    fi_df = pd.DataFrame(data)

    #Sort the DataFrame in order decreasing feature importance
    fi_df.sort_values(by=['feature_importance'], ascending=False,inplace=True)

    #Define size of bar plot
    plt.figure(figsize=(8,6))
    #Plot Searborn bar chart
    sns.barplot(x=fi_df['feature_importance'], y=fi_df['feature_names'][:top_n])
    #Add chart labels
    plt.title(model_type + ' Feature Importance')
    plt.xlabel('Feature Importance')
    plt.ylabel('Features')
```

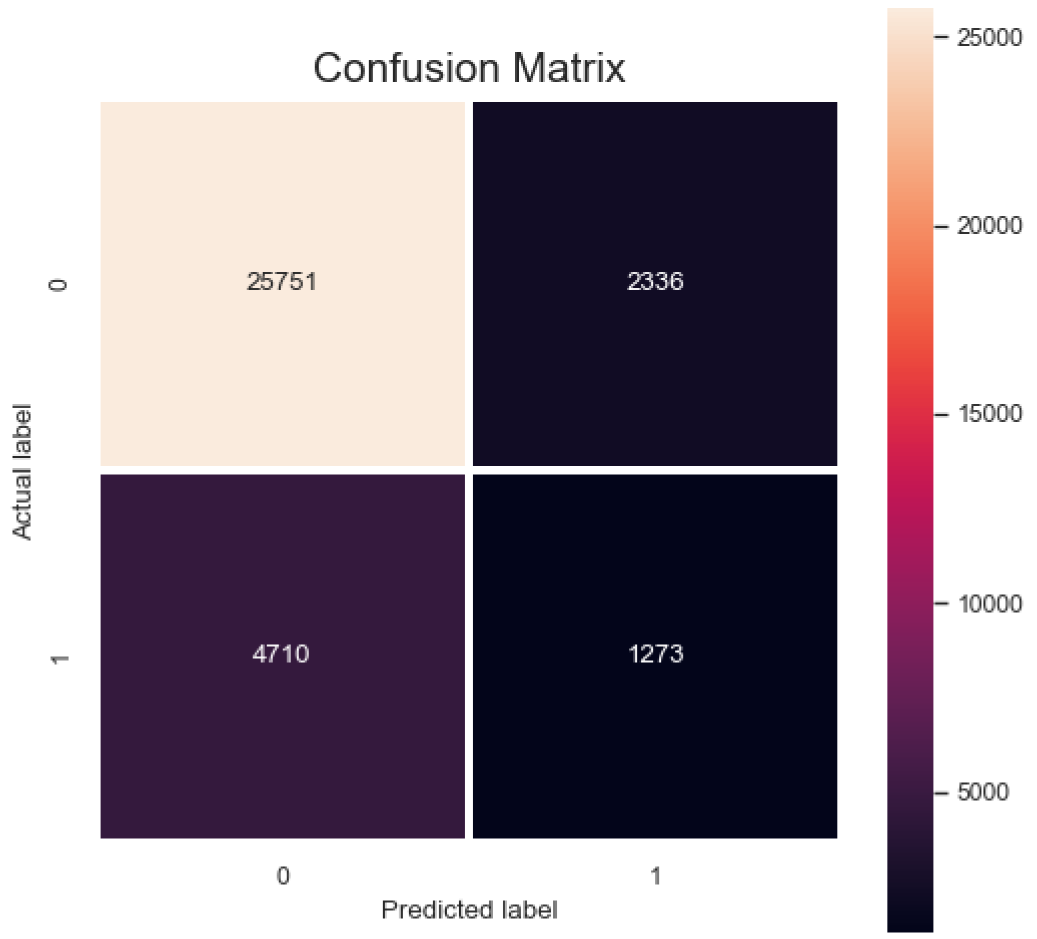
In [ ]:
```
def plotRocAuc(model, X_test, y_test, labels):

    y_pred = model.predict_proba(X_test)

    fpr, tpr, threshold= metrics.roc_curve(y_test, y_pred[:, 1])
    roc_auc = metrics.auc(fpr, tpr)

    plt.subplots(figsize=(6,6))
    plt.title("Receiver Operating Characteristic", fontsize=14)
    plt.plot(fpr, tpr, label = labels + " AUC = %0.2f"%roc_auc)
    plt.plot([0,1], [0,1], "--", label="Random guessing")
    plt.legend(loc = "lower right", prop={'size': 12})
    plt.ylabel("True Positive Rate")
    plt.xlabel("False Positive Rate")

    plt.show()
```

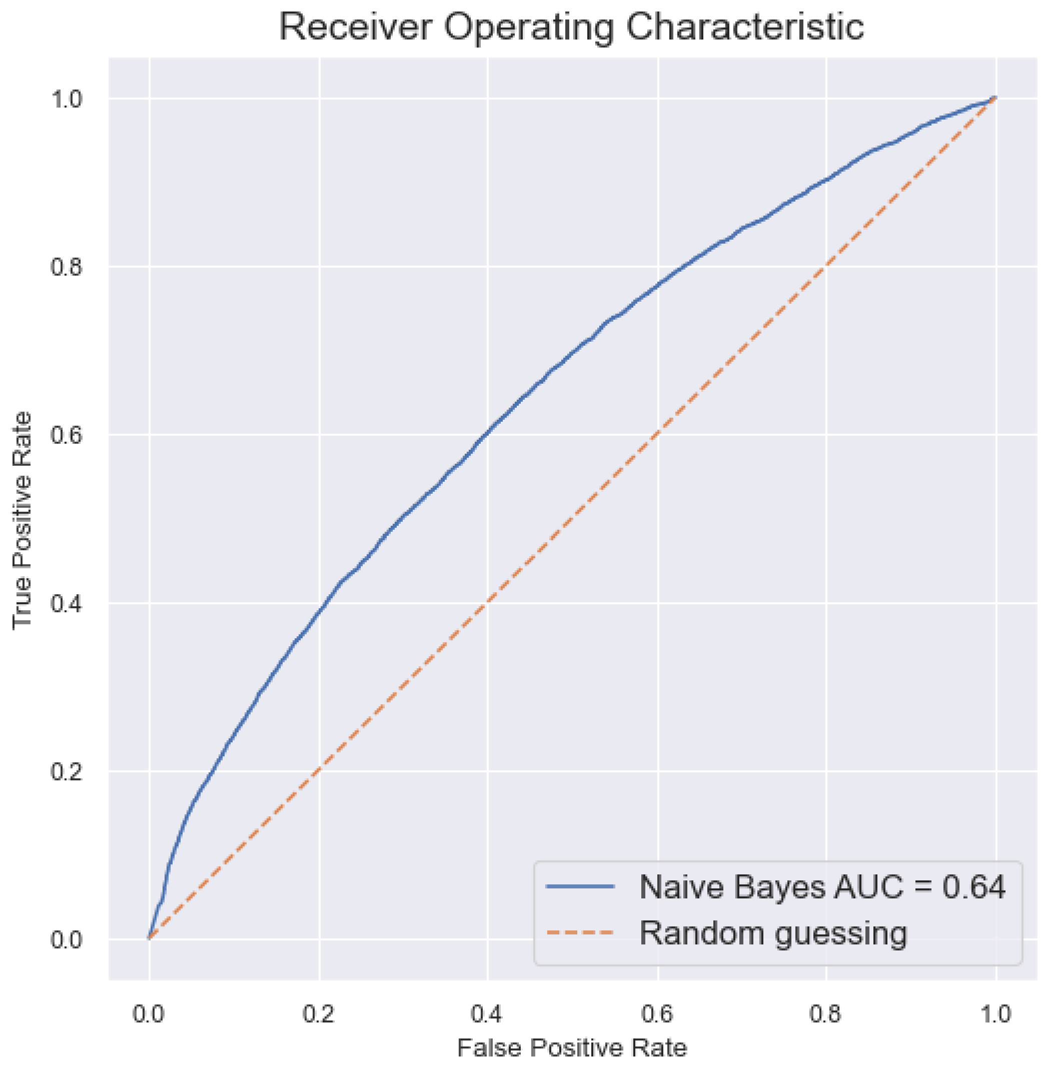
Naive Bayes

In [ ]:
```
param_grid = {}
train("gnb", X_train, y_train, X_test, y_test, params=param_grid, output=True, return_model=False)
```

```
model_fit = train("gnb", X_train, y_train, X_test, y_test, params=param_grid, output=False, return_model=True)
plotRocAuc(model=model_fit, X_test=X_test, y_test=y_test, labels='Naive Bayes')
```

```
Test Score: 0.7931904901673026
F1 score : 0.2654295246038365
Precision Score : 0.35272928789138264
Recall Score : 0.2127695136219288
              precision    recall  f1-score   support

         0.0       0.85      0.92      0.88     28087
         1.0       0.35      0.21      0.27      5983

    accuracy                           0.79     34070
   macro avg       0.60      0.56      0.57     34070
weighted avg       0.76      0.79      0.77     34070
```



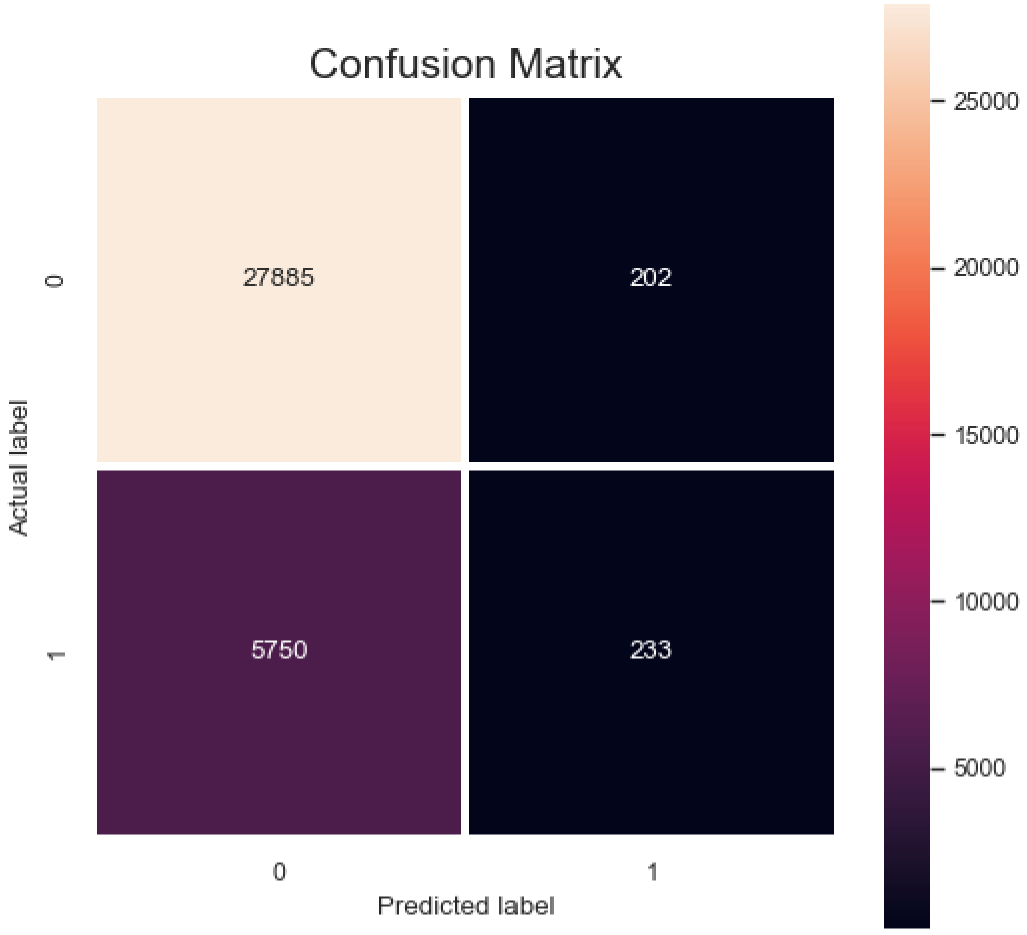


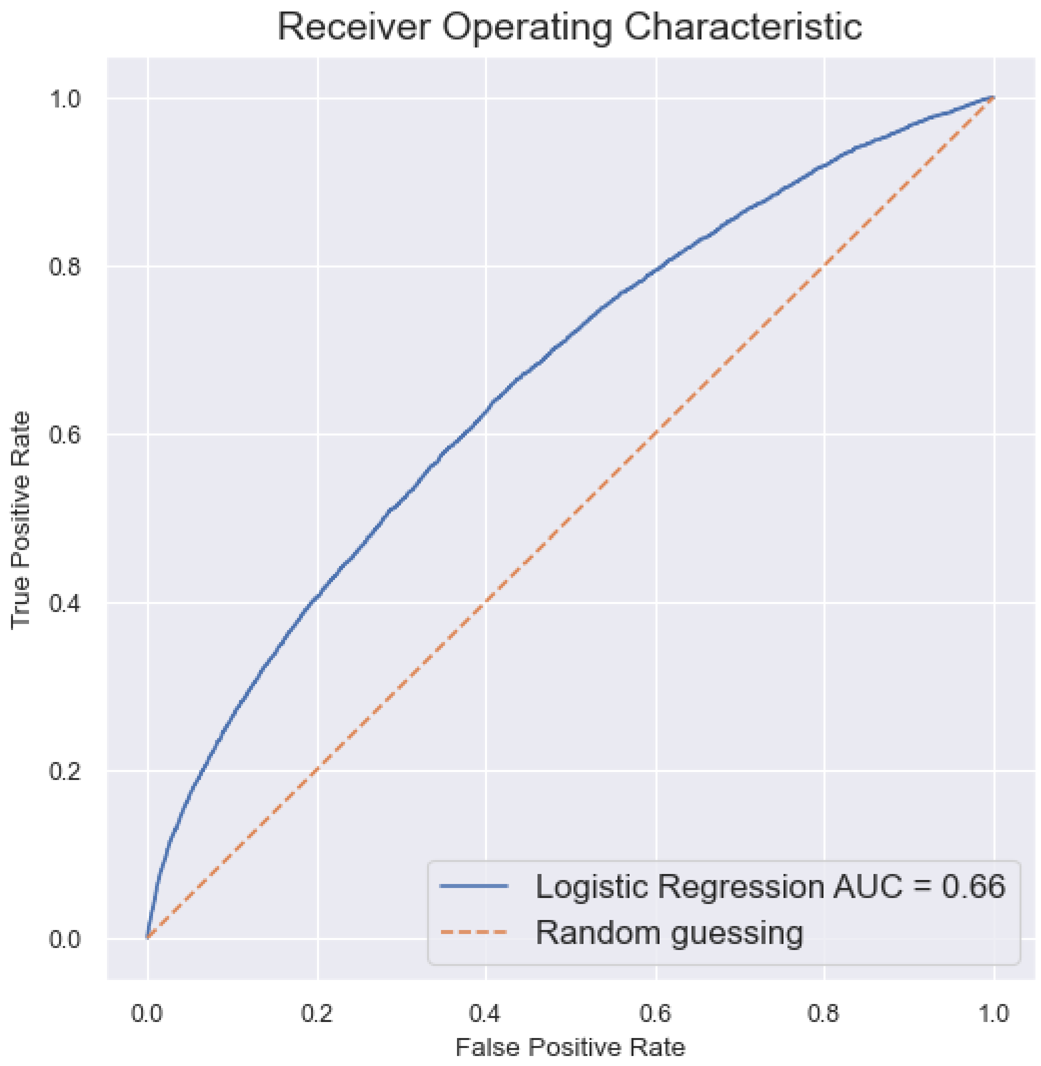
Logistic regression

In [ ]:

```
param_grid = {}
train("logistic", X_train, y_train, X_test, y_test, params=param_grid, output=True, return_model=False)
model_fit = train("logistic", X_train, y_train, X_test, y_test, params=param_grid, output=False, return_model=True)
plotRocAuc(model=model_fit, X_test=X_test, y_test=y_test, labels='Logistic Regression')
```

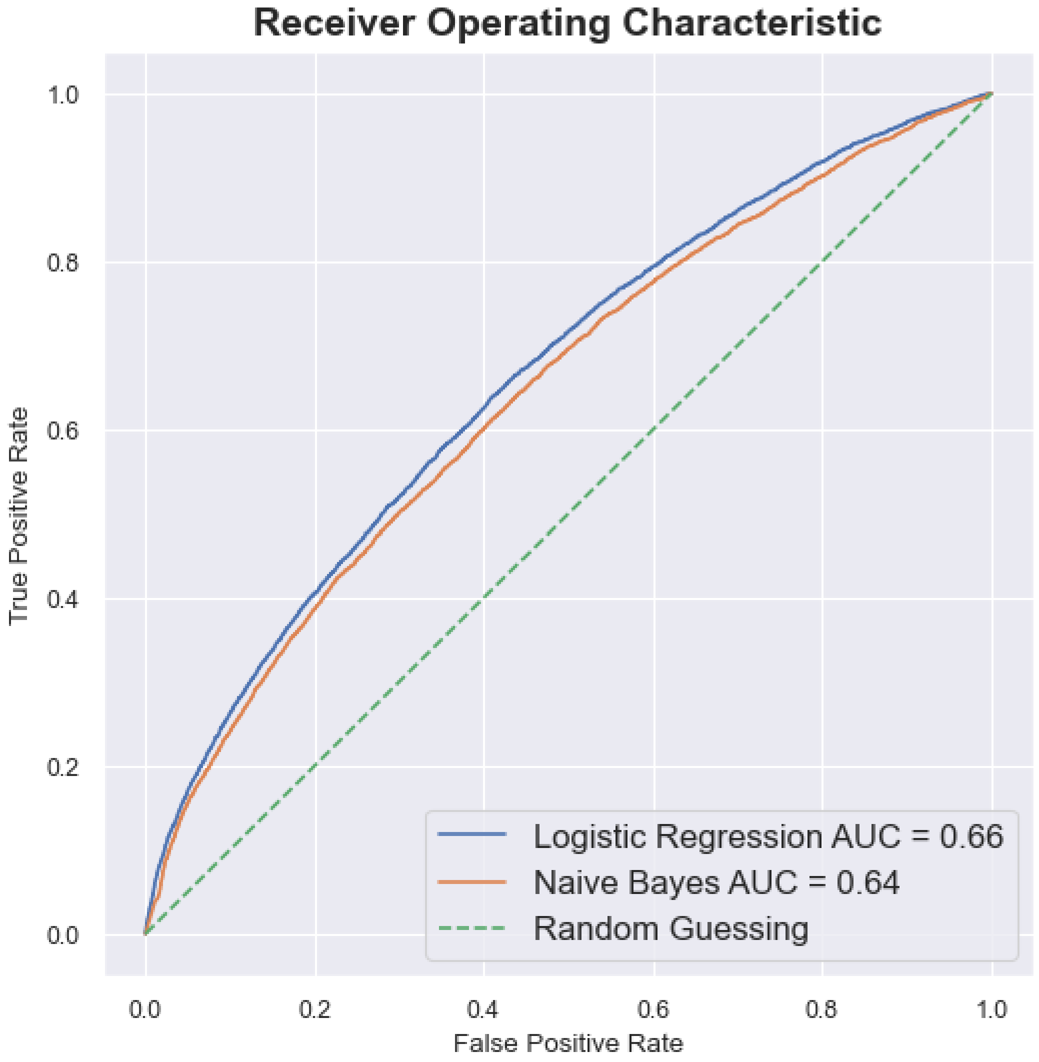
```
Test Score: 0.8253008511887291
F1 score : 0.07260828918666251
Precision Score : 0.535632183908046
Recall Score : 0.038943673742269765
              precision    recall  f1-score   support

         0.0       0.83      0.99      0.90     28087
         1.0       0.54      0.04      0.07      5983

    accuracy                           0.83     34070
   macro avg       0.68      0.52      0.49     34070
weighted avg       0.78      0.83      0.76     34070
```





```
In [ ]: models = ['logistic','gnb']
        params = [{},
                  {}]
        labels = ['Logistic Regression','Naive Bayes']
        plt.clf()
        plt.subplots(figsize=(6,6))

        for i in range(len(models)):
            print(i)
            trainedModel = train(models[i], X_train, y_train, X_test, y_test, params[i],  output=False, return_model=True)

            y_pred = trainedModel.predict_proba(X_test)
            fpr, tpr, threshold= metrics.roc_curve(y_test, y_pred[:, 1])
            roc_auc = metrics.auc(fpr, tpr)
            plt.plot(fpr, tpr, label = labels[i] + " AUC = %0.2f"%roc_auc)
        plt.plot([0,1], [0,1], "--", label="Random Guessing")

        plt.title("Receiver Operating Characteristic", fontsize=14, fontweight = "bold")
        plt.legend(loc = "lower right", prop={'size': 12})
        plt.ylabel("True Positive Rate")
        plt.xlabel("False Positive Rate")

        plt.show()
```

```
0
1
<Figure size 640x480 with 0 Axes>
```



```
In [ ]:
```