flight delays

May 23, 2025

Background You work for a major airline operating flights across the USA. Flight delays are a significant challenge for both the airline and passengers, causing disruptions, financial losses, and dissatisfaction. As part of the airline's data analytics team, your goal is to analyze historical flight data to uncover delay patterns, identify operational inefficiencies, and predict delays before they occur. By identifying delay patterns, predicting delays, and uncovering the factors that contribute most to delays, you'll be able to drive operational efficiency and enhance the overall passenger experience. Your insights will help the airline make data-driven decisions to optimize scheduling, improve on-time performance, and enhance passenger satisfaction.

Can you crack the code behind flight delays and revolutionize air travel?

Challenge Create a report summarizing your insights. Your report should explore the following questions:

1. How do different airlines compare in terms of their departure and arrival times? Are there noticeable trends in their on-time performance over the year? A well-structured visualization could help uncover patterns.
2. Are there particular months/weeks/time of day where there is a general trend of greater delays in flights across all carriers? If so, what could be the reasons?
3. Some airports seem to operate like clockwork, while others are notorious for disruptions. How do different airports compare when it comes to departure and arrival punctuality? Could location, traffic volume, or other factors play a role? Are there patterns that emerge when looking at delays across various airports?
4. [Optional 1] Predict whether a flight will have a delay of 15 minutes or more at departure.
5. [Optional 2] What underlying factors influence flight delays the most? Are some routes more prone to disruptions than others? Do external variables like time of day, distance, or carrier policies play a significant role? By analyzing the relationships between different features, you might discover unexpected insights.

[1]:
```
import pandas as pd
flight_data = pd.read_csv('flights_data/flights.csv')
print(flight_data.head().to_string(index=False))
```

```
 id  year  month  day  dep_time  sched_dep_time  dep_delay  arr_time
sched_arr_time  arr_delay carrier  flight tailnum origin dest  air_time
distance  hour  minute           time_hour                     name
  0  2013      1    1     517.0             515        2.0     830.0
819       11.0      UA    1545  N14228    EWR  IAH     227.0      1400     5
15 2013-01-01 05:00:00  United Air Lines Inc.
  1  2013      1    1     533.0             529        4.0     850.0
```

```
830       20.0      UA    1714  N24211    LGA  IAH     227.0      1416     5
29 2013-01-01 05:00:00  United Air Lines Inc.
  2  2013      1    1     542.0            540       2.0     923.0
850       33.0      AA    1141  N619AA    JFK  MIA     160.0      1089     5
40 2013-01-01 05:00:00 American Airlines Inc.
  3  2013      1    1     544.0            545      -1.0    1004.0
1022      -18.0      B6     725  N804JB    JFK  BQN     183.0      1576     5
45 2013-01-01 05:00:00        JetBlue Airways
  4  2013      1    1     554.0            600      -6.0     812.0
837      -25.0      DL     461  N668DN    LGA  ATL     116.0       762     6
0 2013-01-01 06:00:00   Delta Air Lines Inc.
```

[3]:
```
flight_data.columns
```

[3]:
```
Index(['id', 'year', 'month', 'day', 'dep_time', 'sched_dep_time', 'dep_delay',
       'arr_time', 'sched_arr_time', 'arr_delay', 'carrier', 'flight',
       'tailnum', 'origin', 'dest', 'air_time', 'distance', 'hour', 'minute',
       'time_hour', 'name'],
      dtype='object')
```

[4]:
```
flight_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 336776 entries, 0 to 336775
Data columns (total 21 columns):
 #   Column          Non-Null Count   Dtype
---  ------          --------------   -----
 0   id              336776 non-null  int64
 1   year            336776 non-null  int64
 2   month           336776 non-null  int64
 3   day             336776 non-null  int64
 4   dep_time        328521 non-null  float64
 5   sched_dep_time  336776 non-null  int64
 6   dep_delay       328521 non-null  float64
 7   arr_time        328063 non-null  float64
 8   sched_arr_time  336776 non-null  int64
 9   arr_delay       327346 non-null  float64
 10  carrier         336776 non-null  object
 11  flight          336776 non-null  int64
 12  tailnum         334264 non-null  object
 13  origin          336776 non-null  object
 14  dest            336776 non-null  object
 15  air_time        327346 non-null  float64
 16  distance        336776 non-null  int64
 17  hour            336776 non-null  int64
 18  minute          336776 non-null  int64
 19  time_hour       336776 non-null  object
 20  name            336776 non-null  object
```

```
dtypes: float64(5), int64(10), object(6)
memory usage: 54.0+ MB
```

[5]:
```
flight_data.describe
```

[5]:
```
<bound method NDFrame.describe of             id  year  month  day  dep_time
sched_dep_time  dep_delay  \
0            0  2013      1    1     517.0            515        2.0
1            1  2013      1    1     533.0            529        4.0
2            2  2013      1    1     542.0            540        2.0
3            3  2013      1    1     544.0            545       -1.0
4            4  2013      1    1     554.0            600       -6.0
…          …   …     …  …        …           …        …
336771  336771  2013      9   30       NaN           1455        NaN
336772  336772  2013      9   30       NaN           2200        NaN
336773  336773  2013      9   30       NaN           1210        NaN
336774  336774  2013      9   30       NaN           1159        NaN
336775  336775  2013      9   30       NaN            840        NaN

        arr_time  sched_arr_time  arr_delay  … flight  tailnum origin dest  \
0          830.0             819       11.0  …   1545   N14228    EWR  IAH
1          850.0             830       20.0  …   1714   N24211    LGA  IAH
2          923.0             850       33.0  …   1141   N619AA    JFK  MIA
3         1004.0            1022      -18.0  …    725   N804JB    JFK  BQN
4          812.0             837      -25.0  …    461   N668DN    LGA  ATL
…            …               …        … …      …     …     …   …
336771       NaN            1634        NaN  …   3393      NaN    JFK  DCA
336772       NaN            2312        NaN  …   3525      NaN    LGA  SYR
336773       NaN            1330        NaN  …   3461   N535MQ    LGA  BNA
336774       NaN            1344        NaN  …   3572   N511MQ    LGA  CLE
336775       NaN            1020        NaN  …   3531   N839MQ    LGA  RDU

       air_time  distance  hour  minute            time_hour  \
0         227.0      1400     5      15  2013-01-01 05:00:00
1         227.0      1416     5      29  2013-01-01 05:00:00
2         160.0      1089     5      40  2013-01-01 05:00:00
3         183.0      1576     5      45  2013-01-01 05:00:00
4         116.0       762     6       0  2013-01-01 06:00:00
…           …     …   …     …                  …
336771      NaN       213    14      55  2013-09-30 14:00:00
336772      NaN       198    22       0  2013-09-30 22:00:00
336773      NaN       764    12      10  2013-09-30 12:00:00
336774      NaN       419    11      59  2013-09-30 11:00:00
336775      NaN       431     8      40  2013-09-30 08:00:00

                    name
0        United Air Lines Inc.
```

```
1           United Air Lines Inc.
2          American Airlines Inc.
3                 JetBlue Airways
4            Delta Air Lines Inc.
…                             …
336771          Endeavor Air Inc.
336772          Endeavor Air Inc.
336773                  Envoy Air
336774                  Envoy Air
336775                  Envoy Air

[336776 rows x 21 columns]>
```

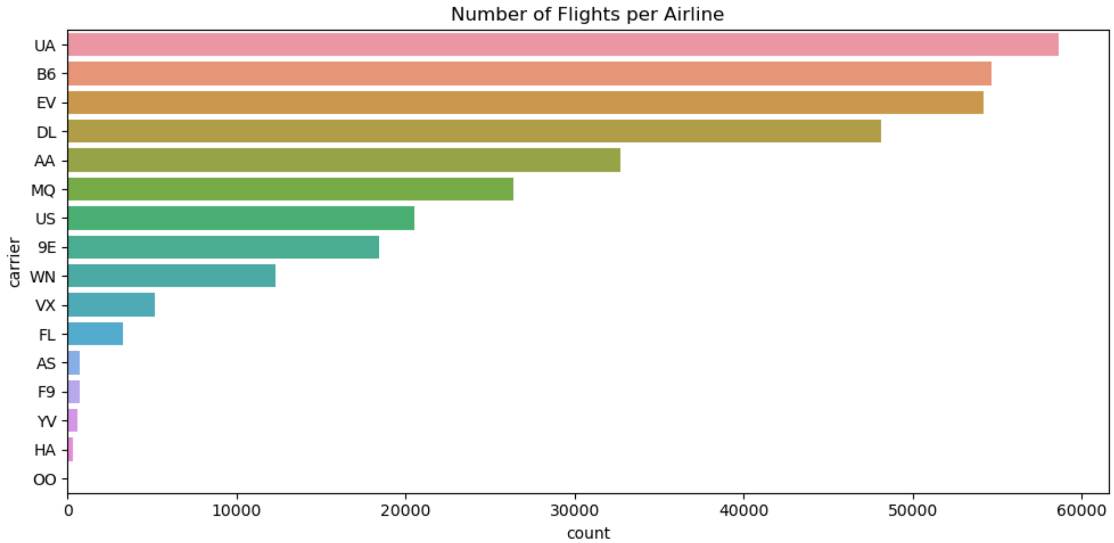
[6]:

```python
missing = flight_data.isnull().sum()
print(missing[missing > 0])
```

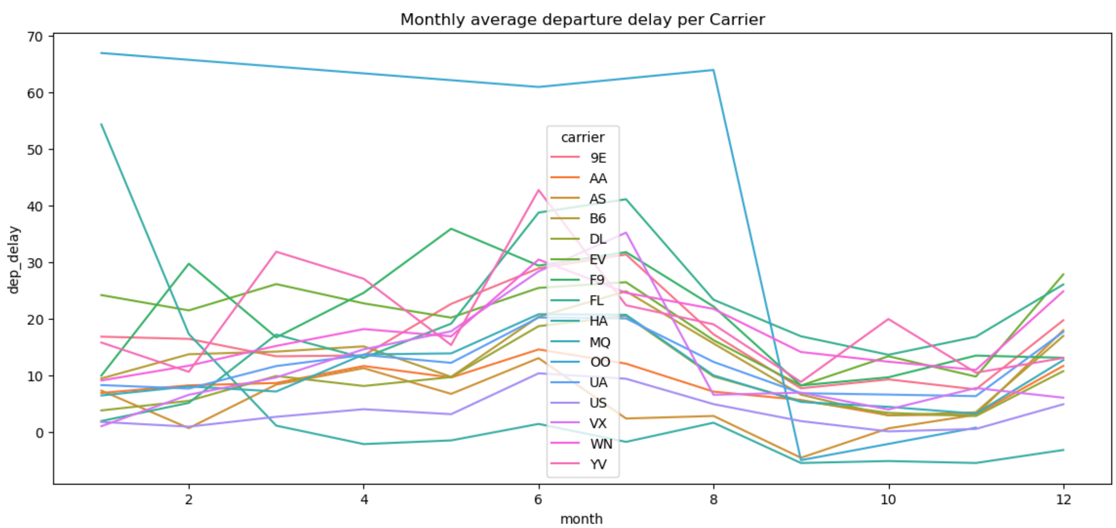
```
dep_time     8255
dep_delay    8255
arr_time     8713
arr_delay    9430
tailnum      2512
air_time     9430
dtype: int64
```

[7]:

```python
import matplotlib.pyplot as plt
import seaborn as sns

#count flights per airline
plt.figure(figsize=(10,5))
sns.countplot(y='carrier', data=flight_data, order=flight_data['carrier'].
 ↪value_counts().index)
plt.title("Number of Flights per Airline")
plt.tight_layout()
plt.show()
```

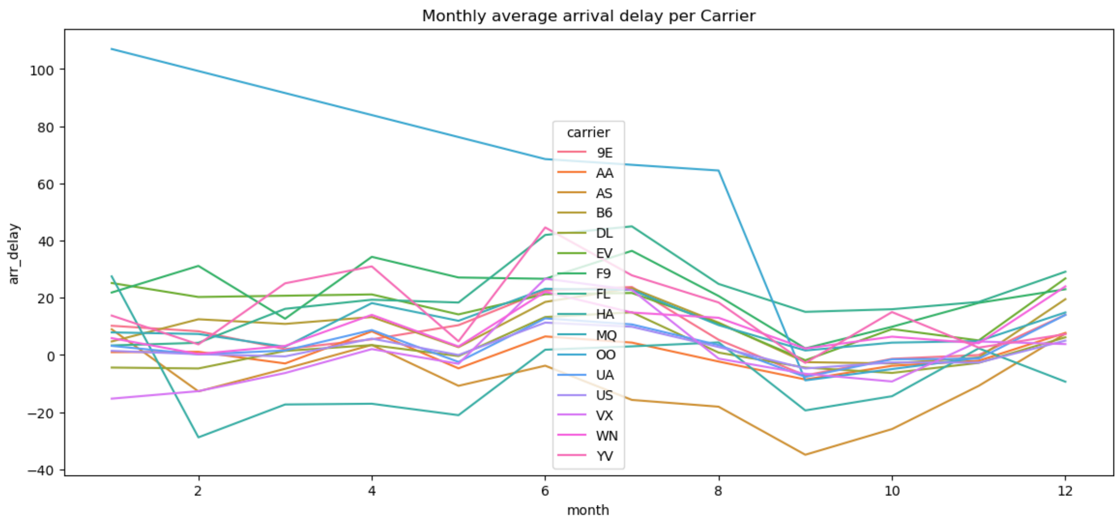


[8]:
```python
# Monthly trend per carrier
monthly_delay = flight_data.groupby(['month', 'carrier'])[['dep_delay',␣
    ↪'arr_delay']].mean().reset_index()

plt.figure(figsize=(14,6))
sns.lineplot(data=monthly_delay, x='month', y='dep_delay', hue='carrier')
plt.title("Monthly average departure delay per Carrier")
plt.show()
```



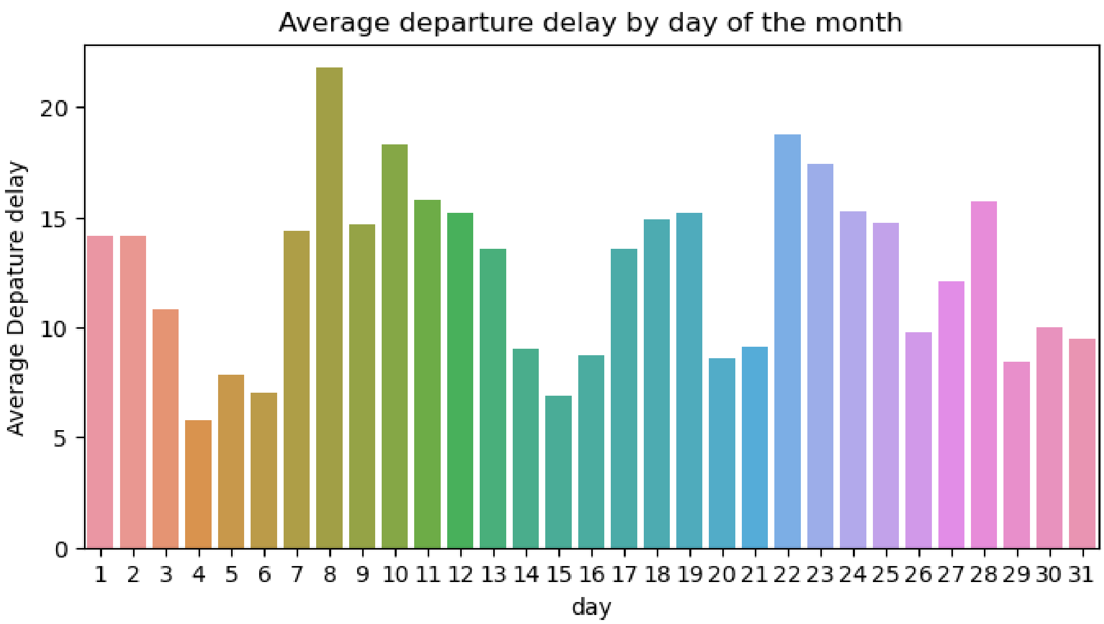
[11]:

```
# Monthly trend per carrier
monthly_delay = flight_data.groupby(['month', 'carrier'])[['dep_delay',␣
↪'arr_delay']].mean().reset_index()

plt.figure(figsize=(14,6))
sns.lineplot(data=monthly_delay, x='month', y='arr_delay', hue='carrier')
plt.title("Monthly average arrival delay per Carrier")
plt.show()
```

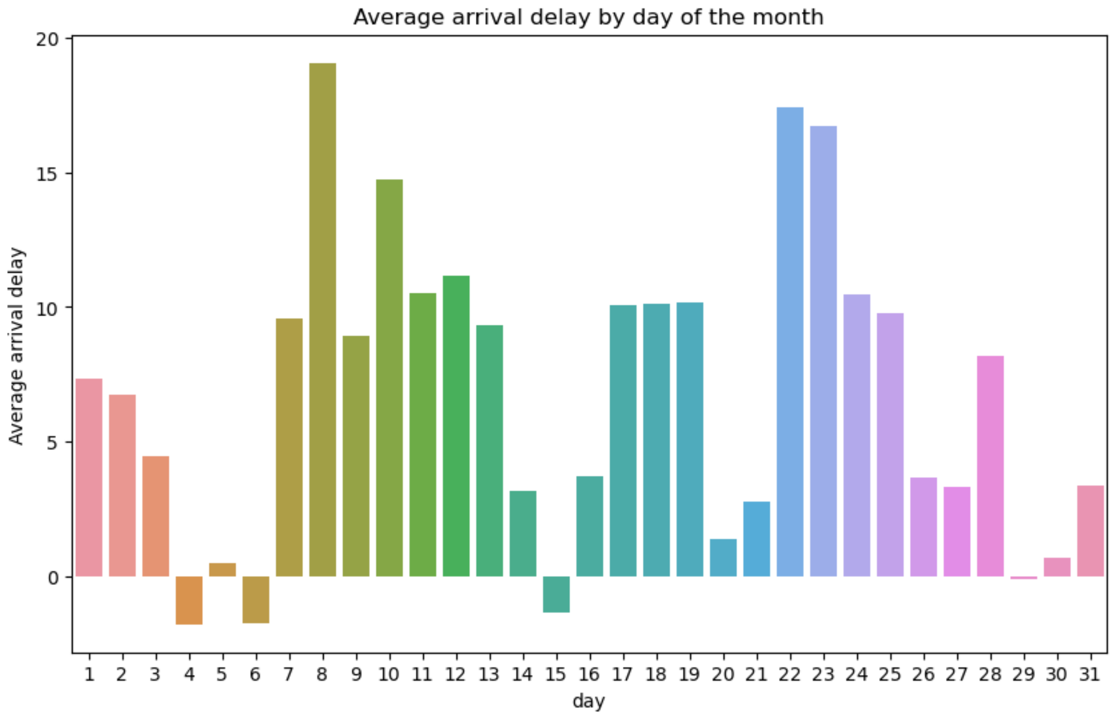


[ ]:

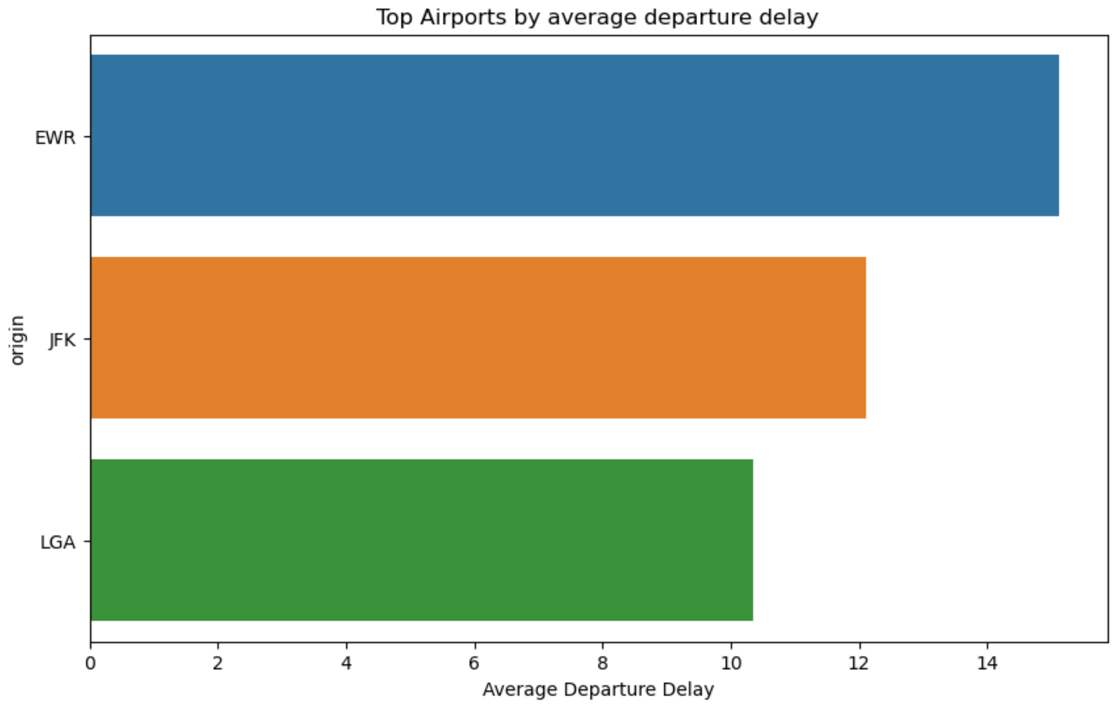
```
# Departure delay by day of the month
day_delay = flight_data.groupby('day')[['dep_delay', 'arr_delay']].mean().
↪reset_index()

plt.figure(figsize=(8,4))
sns.barplot(data=day_delay, x='day', y='dep_delay')
plt.title("Average departure delay by day of the month")
plt.ylabel("Average Depature delay")
plt.show()
```



[ ]:
```
# Arrival delay by day of the month

plt.figure(figsize=(10,6))
sns.barplot(data=day_delay, x='day', y='arr_delay')
plt.title("Average arrival delay by day of the month")
plt.ylabel("Average arrival delay")
plt.show()
```

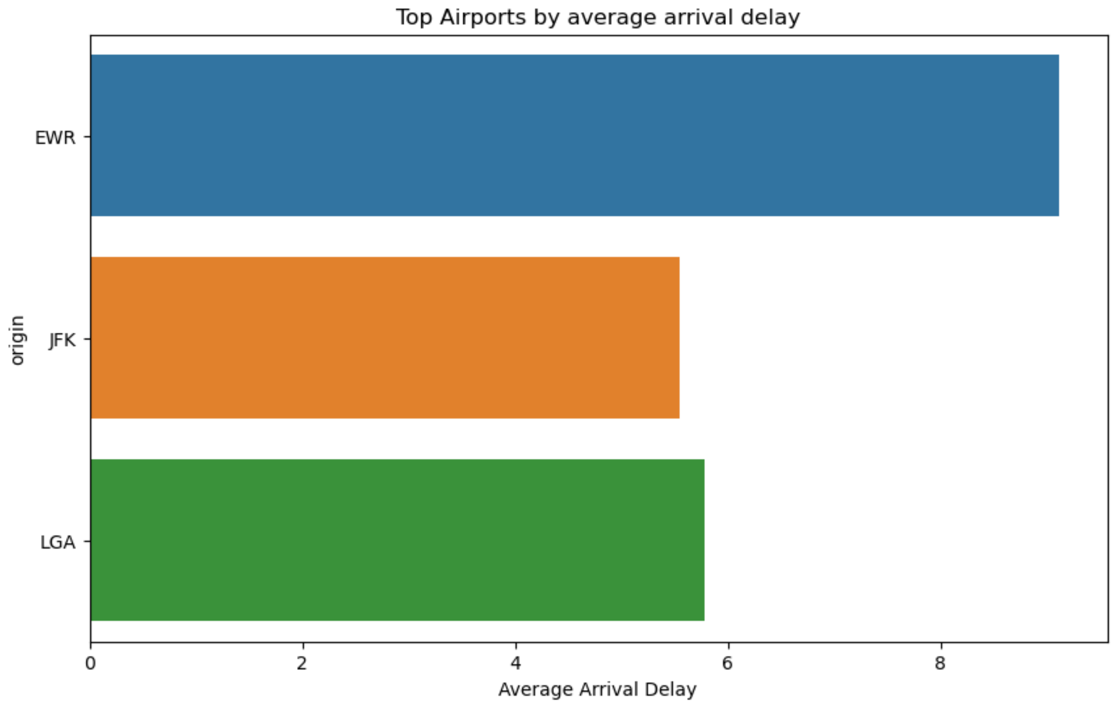


[29]:
```
# Airport performance
origin_delays = flight_data.groupby('origin')[['dep_delay','arr_delay']].mean().
↪sort_values(by='dep_delay', ascending=False)

plt.figure(figsize=(10,6))
sns.barplot(x=origin_delays['dep_delay'], y=origin_delays.index)
plt.title("Top Airports by average departure delay")
plt.xlabel("Average Departure Delay")
plt.show()
```



[36]:

```
plt.figure(figsize=(10,6))
sns.barplot(data=origin_delays,x='arr_delay',y=origin_delays.index)
plt.title("Top Airports by average arrival delay")
plt.xlabel("Average Arrival Delay")
plt.show()
```

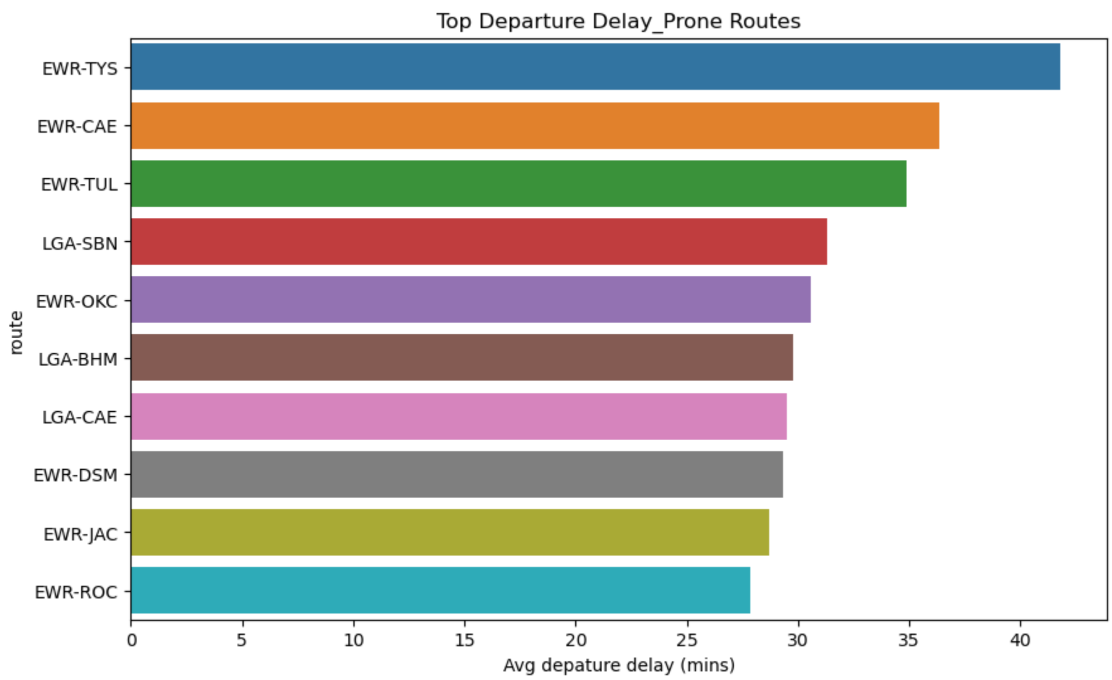


[51]:
```
# Predict a departure delay >=15 mins
from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestClassifier
from sklearn.preprocessing import LabelEncoder
from sklearn.metrics import classification_report

flight_data['delay_15'] = (flight_data['dep_delay'] >= 15).astype(int)

features = ['carrier', 'origin', 'dest', 'month','day']
X = flight_data[features].copy()
le = LabelEncoder()
for col in X.columns:
    X[col] = le.fit_transform(X[col])

y = flight_data['delay_15']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3,␣
↪random_state=42)
model = RandomForestClassifier(n_estimators=500, max_depth=10, random_state=42)
model.fit(X_train, y_train)

y_pred = model.predict(X_test)
print(classification_report(y_test, y_pred))
```

```
              precision    recall  f1-score   support
```

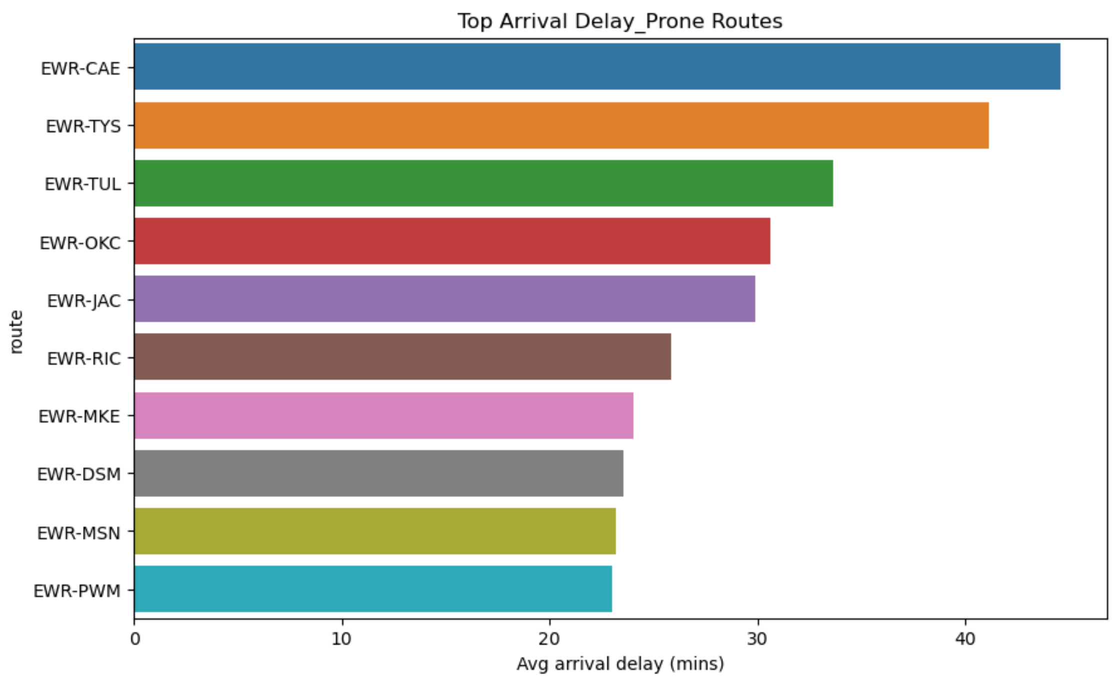
```
           0       0.79      1.00      0.88     79346
           1       0.68      0.01      0.02     21687

    accuracy                           0.79    101033
   macro avg       0.73      0.50      0.45    101033
weighted avg       0.76      0.79      0.69    101033
```

[47]:
```python
# Route-based insights

flight_data['route'] = flight_data['origin'] + "-" + flight_data['dest']
route_delay = flight_data.groupby('route')[['dep_delay', 'arr_delay']].mean().
 ↪sort_values(by='dep_delay', ascending=False).head(10)

plt.figure(figsize=(10,6))
sns.barplot(data=route_delay, x='dep_delay', y=route_delay.index)
plt.title("Top Departure Delay_Prone Routes")
plt.xlabel("Avg depature delay (mins)")
plt.show()
```

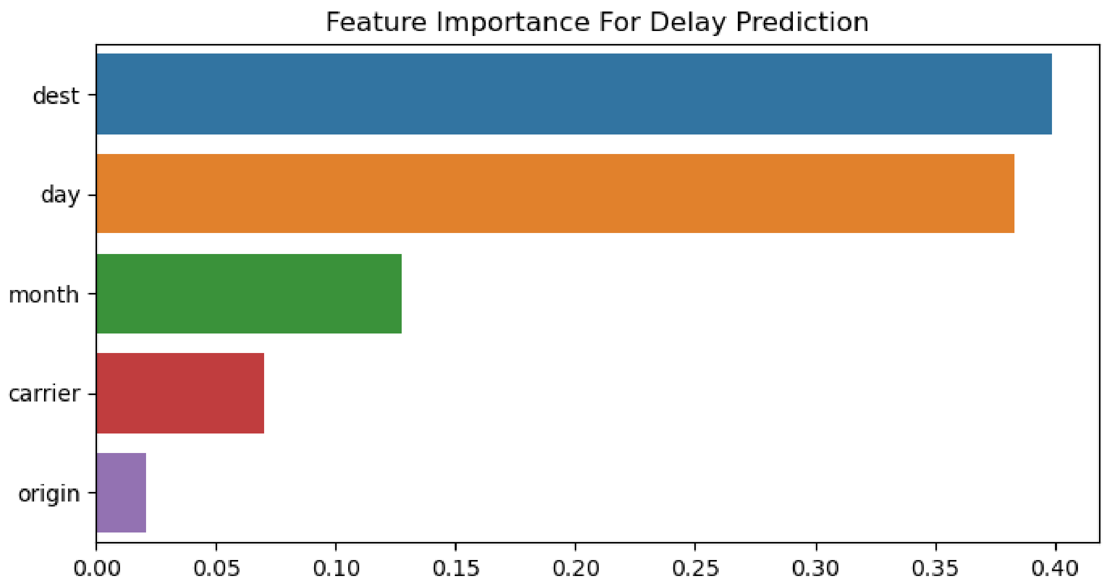


[48]:
```python
# Route-based insights

flight_data['route'] = flight_data['origin'] + "-" + flight_data['dest']
```

```
route_delay = flight_data.groupby('route')[['dep_delay', 'arr_delay']].mean().
    ↪sort_values(by='arr_delay', ascending=False).head(10)

plt.figure(figsize=(10,6))
sns.barplot(data=route_delay, x='arr_delay', y=route_delay.index)
plt.title("Top Arrival Delay_Prone Routes")
plt.xlabel("Avg arrival delay (mins)")
plt.show()
```



[38]:
```
# Feature importance on delay prediction
importances = pd.Series(model.feature_importances_, index=features).
    ↪sort_values(ascending=False)

plt.figure(figsize=(8,4))
sns.barplot(x=importances, y=importances.index)
plt.title("Feature Importance For Delay Prediction")
plt.show()
```


Feature Importance For Delay Prediction
dest
day
month
carrier
origin
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40