Assignment 10 (Final Project): Delay Analysis and Airline Operations

Date Due: December 14, 2020 by 5 PM Instructor: Trani

Problem 1

An important airport in Europe has a runway configuration and saturation capacity diagram as shown in Figure 1. The airport operates in segregated mode for safety (one runway for arrivals and one for departures).

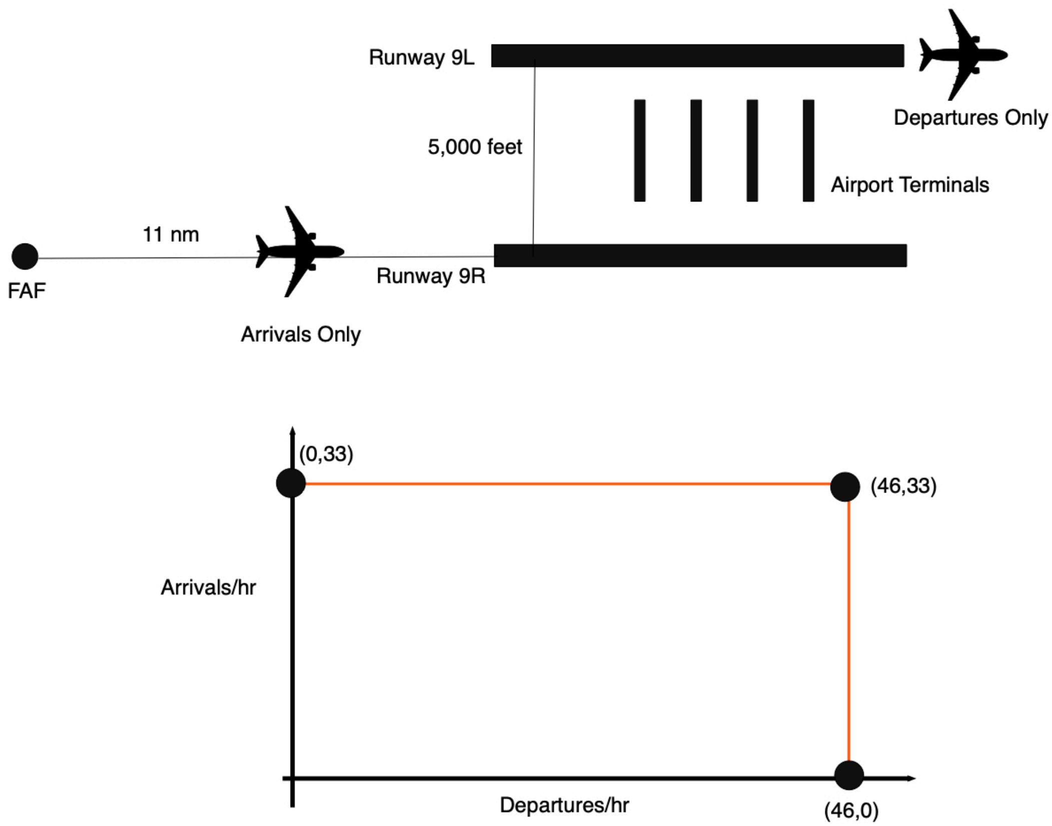

Figure 1. Runway Configuration and Arrival-Departure Diagram for Problem 1.

a) Table 1 shows the daily demand function for arrival and departures at the airport. Use the **deterministic queueing model** to estimate the **average delays per flight delayed** to both arrivals and departures at the airport.

b) Estimate the annual cost of delay to airlines if the hourly cost of for an arrival is $5,500/hr and the hourly cost of departures is $3,200/hr. Assume the airport is operated according to Table 1 for 365 days a year.

c) Estimate the annual cost of delay to passengers if the value of time for a passenger is $36/hr. The average passenger per flight at the airport is 175 passengers.

d) A third runway has been planned for 2022 to the South of runway 9R. The airport authority expect demand to growth at 3% per year for the next ten years. Would you recommend the third runway based on the analysis done and extrapolating the future delays?

e) If a third runway is built state what is the recommended separation between the old runway 9R and the new runway. Assume PRM and ADS-B (one second) position data technology is available to the project.

f) How would you recommend the third runway be operated at the airport? Be specific about your recommendation. For example, what periods of time should the third runway be operational.

Table 1. Flight Demand for Problem 1. Demand Values are Per Hour.

Time Period (Bin Center)	Arrival/hr	Departures /hr	Total Operations/hr
0.5	0	2	2
1.5	2	2	4
2.5	10	5	15
3.5	15	4	19
4.5	13	10	23
5.5	24	27	51
6.5	28	40	68
7.5	37	50	87
8.5	34	52	86
9.5	33	42	75
10.5	30	36	66
11.5	19	28	47
12.5	21	14	35
13.5	24	22	46
14.5	27	19	46
15.5	31	24	55
16.5	20	32	52
17.5	18	36	54
18.5	32	42	74
19.5	34	53	87
20.5	35	49	84
21.5	30	35	65

Time Period (Bin Center)	Arrival/hr	Departures /hr	Total Operations/hr
22.5	8	16	24
23.5	2	6	8
Totals	527	646	1173

Problem 2

Solve an updated version of the Airline Scheduling Problem (ASP-1) explained in class with the following characteristics. The airline in question is evaluating the purchase of CRJ-900, EMB-190, or Boeing 737-700 to operate services out of DCA airport. The aircraft characteristics are shown in Table 2. The new airline wants to operate in the markets shown in Table 3.

a) Maximize profit solving for the fleet size and frequency assignment **without a minimum frequency constraint**. Clearly state the number of aircraft of each type needed (use an **integer solution in Excel Solver**) and the number of flights between each origin-destination pair to satisfy the two basic constraints (demand and supply constraints). Use Excel Solver to do the analysis.

b) Calculate the fares to be charged in each O-D pair if the airline wants to recover its full cost for service plus a 10% profit. In your calculation assume the hourly operating cost of the aircraft shown in Table 2 is the operating cost not including the airline administrative costs. Assume an additional 30% cost due to administrative and other costs not related to operation of the aircraft.

c) Comment your assessment of the economics and flexibility of using regional jets such as the Bombardiers CRJ-900 and the Embraer 190 in the proposed routes.

d) Are there any benefits of operating regional jets with 84-86 seats? Explain.

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e) Embraer is offering a new version of the EMB-190 (called Embraer 190 E-Jet E2) which claims to lower hourly operating cost by 6% compared to the EMB-190. Would you recommend the new version of the aircraft instead of your solution obtained in part (a)?

All other parameters of the model are the same as ASP-1 discussed in class.

Table 2. Aircraft Operating Cost and Performance. Data source: Bureau of Transportation Statistics (2018).

Aircraft	Bombardier CRJ-900	Embraer EMB-190	Boeing 737-700
Short Name of the Aircraft	CRJ9	E190	B737
Seats	84	86	128
Block Speed (knots) Includes taxi-in and taxi-out times	325	335	342
Operating Cost ($/hr)	4,125	4,380	6,075
Typical maximum aircraft utilization (hrs/day) in service	12.3	12.5	12.5

Table 3. OD Markets for the Proposed New Airline.

Origin-Destination Airports	Daily Demand (passengers)
DCA-ATL	476
ATL-DCA	489
DCA-MIA	250
MIA-DCA	260
DCA-BOS	320
BOS-DCA	310
DCA-DFW	210
DFW-DCA	205
DCA-LGA	400
LGA-DCA	380

Problem 3 (Only for CEE 5614 Students)

Data is collected at an airport for two aircraft is shown in Table 4.

Table 4. Observed Normal Distributions for Two Aircraft in the Fleet Mix. Values in parenthesis are the mean and the standard deviation of each parameter. If one parameter is given assume the value is deterministic.

Parameter	Boeing 737-700	Bombardier Q400	Distribution
Touchdown distance (m)	*dt*=(410,105)	dt=(320,100)	Normal distribution
Approach speed (m/s) - at threshold	Vapp = (70.3,3.1)	Vapp = (58,3.3)	Normal distribution
Time to start applying brakes and thrust reverser after touchdown	tr = (2.3,0.5)	tr = (2.8, 0.6)	Normal distribution
Deceleration rate (m/s-s)	aMean = (-2.3,0.42)	aMean = (-2.2,0.34)	Normal distribution
Exit Speed (m/s) (high-speed exit)	Vexit = (21.4,2.5)	Vexit = (19.4,2.7)	Normal distribution

a) Using Matlab or Excel (your choice), and the kinematic equations of motion shown on the course notes (http://128.173.204.63/courses/cee5614/cee5614_pub/FAA_modeling_and_sim.pdf) and the distributions shown above, estimate the "natural distribution" of the landing distances to reach a high-speed exit point (i.e., point on the runway where the aircraft reaches the exit speed shown in Table 2). **This analysis requires a simple Monte Carlo simulation**. Assume each aircraft represents 50% of the population operating at the airport (i.e., only two aircraft operating at the airport).

b) Plot the distributions of the landing distances for both aircraft (either PDF or CDF) to reach the exit speed at the high-speed runway exit.

c) Where would you locate two high-speed runway exits if the airport has a single 2600 meter runway? State the distances from the threshold of your suggested high-speed runway exits. State your rationale for locating the two high-speed runway exits. Assume that a fourth runway exit (90 degree turnoff) will be located at the end of the runway.