Assignment 7: Runway Capacity

Solution Instructor: Trani

Problem 1

Review the runway configuration of San Diego International Airport. Assume IMC conditions in the solution to the problem. The airport operates on a West flow configuration with arrivals and departures using runway 27. The airport fleet mix is shown in Table 1. Assume the departing aircraft acceleration is 2.1 m/s^2 throughout the takeoff roll. The airport has a PRM radar at the facility. For this analysis we use the following technical parameters: a) in-trail delivery error of 18 seconds under IMC conditions, b) probability of violation is 5%. Arriving aircraft are “vectored” by ATC to the Final Approach Fix (FAF) located 12 miles from the runway threshold. Use the minimum arrival-arrival separations for on-approach operations described in the consolidated wake vortex separation document (or notes). The departure-departure separation matrix for SAN is shown on Table 2.

Table 1. Runway Operational Parameters and Fleet Mix for SAN Airport. RECAT Groups.

Aircraft RECAT Group	Percent Mix (%)	Runway Occupancy Time (s)	Typical Approach Speed (knots) from FAF
B	4	62	151
C	7	60	146
E	8	59	138
F	78	53	130
H	3	52	125
Totals	100		

Table 2. Departure-Departure Separations with Buffers Included. Columns 2-6 are the Following Aircraft. First Column Presents the Lead Aircraft. Values in are seconds (including departure buffers).

	Following Aircraft				
Lead Aircraft (Row Below)	**B**	**C**	**E**	**F**	**H**
B	135	135	140	140	140
C	95	120	135	135	140
E	70	70	70	70	75

	Following Aircraft				
Lead Aircraft (Row Below)	**B**	**C**	**E**	**F**	**H**
F	70	70	70	70	70
H	60	60	60	65	70

a) Estimate the IMC arrival runway capacity for SAN.

Use the supplied spreadsheet with modifications to accommodate a 5x5 matrix.

Runway Saturation Capacity Estimation					
Using the Analyical Model for Runway Capacity					
Programmer: A. Trani (August 2019)					
Amendments:	1				
Technical Parameters (inputs)				Parameter	Values
Dep-Arrival Separation (nm)				δ	2
Common Approach Length (nm)				γ	12
Standard deviation of Position Delivery Error (s)				σ	18
Probability of Violation				Pv	5
Cumulative Normal at Pv				qv	1.65
	H	F	E	C	B
ROT (s)	52	53	59	60	62
Percent Mix (%)	3	78	8	7	4
Vapproach (knots)	125	130	138	146	151
Minimum Separation Matrix (nm)			Arrivals-Arrivals		
		Trailing Aircraft (Header Columns)			
Lead (column 1)	H	F	E	C	B
H	3.00	3.00	3.00	3.00	3.00
F	3.00	3.00	3.00	3.00	3.00
E	3.00	3.00	3.00	3.00	3.00
C	5.00	3.50	3.50	3.00	3.00
B	6.00	5.00	5.00	4.00	3.00

Error Free Separation Matrix					
		Trailing Aircraft (Header Columns)			
Lead (column 1)	H	F	E	C	B
H	86	83	78	74	72
F	100	83	78	74	72
E	119	102	78	74	72
C	194	133	108	74	72
B	232	185	157	108	72

Pij Matrix					
		Trailing Aircraft (Header Columns)			
Lead (column 1)	H	F	E	C	B
H	0.001	0.023	0.002	0.002	0.001
F	0.023	0.608	0.062	0.055	0.031
E	0.002	0.062	0.006	0.006	0.003
C	0.002	0.055	0.006	0.005	0.003
B	0.001	0.031	0.003	0.003	0.002

Buffer Matrix (Bij)					
		Trailing Aircraft (Header Columns)			
Lead (column 1)	H	F	E	C	B
H	29.70	29.70	29.70	29.70	29.70
F	26.38	29.70	29.70	29.70	29.70
E	21.56	24.88	29.70	29.70	29.70
C	8.99	19.08	24.70	29.70	29.70
B	0.00	10.44	18.47	26.43	29.70

Augmented Matrix (Tij + Bij)					
		Trailing Aircraft (Header Columns)			
Lead (column 1)	H	F	E	C	B
H	116.10	112.78	107.96	103.67	101.22
F	126.07	112.78	107.96	103.67	101.22
E	140.52	127.23	107.96	103.67	101.22
C	202.70	152.42	133.15	103.67	101.22
B	232.31	195.12	175.86	134.86	101.22
Arrivals Only Capacity (per hour)			30.49		

Arrivals only capacity is 30.5 arrivals per hour.

b) Estimate the IMC departure runway capacity for SAN.

Departure capacity is 46.6 departures per hour.

Departure-Departure Separation Matrix (seconds)

	Trailing Aircraft (Header Columns)						
Lead (column 1)	H	F	E	C	B		Expected Value
H	70	65	60	60	60		E(Td)
F	70	70	70	70	70		
E	75	70	70	70	70		76.991
C	140	135	135	120	95		
B	140	140	140	135	135		

Departures Only Capacity (per hour)	46.76

Estimation of Critical Departure Gaps

Departures	Gap (E∆Tij)		
		E(ROT)	54.30
		E(δ/Vj)	54.46
1	125.26	σg*qv	16.50
2	202.25		
3	279.24		
4	356.23		
5	433.23		

Departures per Gap

	Trailing Aircraft (Header Columns)				
Lead (column 1)	H	F	E	C	B
H	0	0	0	0	0
F	1	0	0	0	0
E	1	1	0	0	0
C	2	1	1	0	0
B	2	1	1	1	0

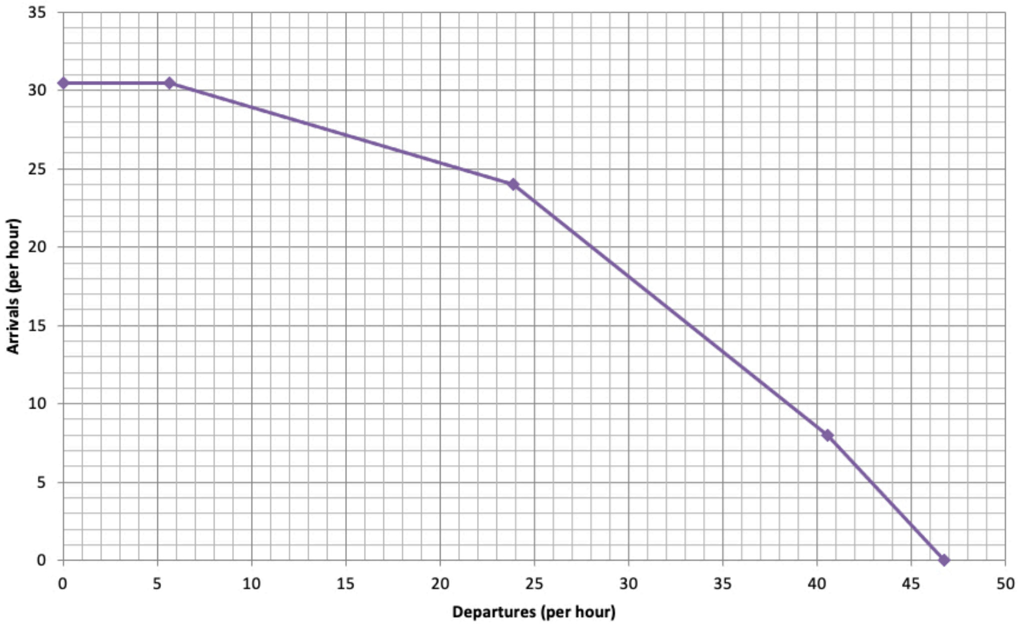
Departures per hour with 100% Arrival Priority

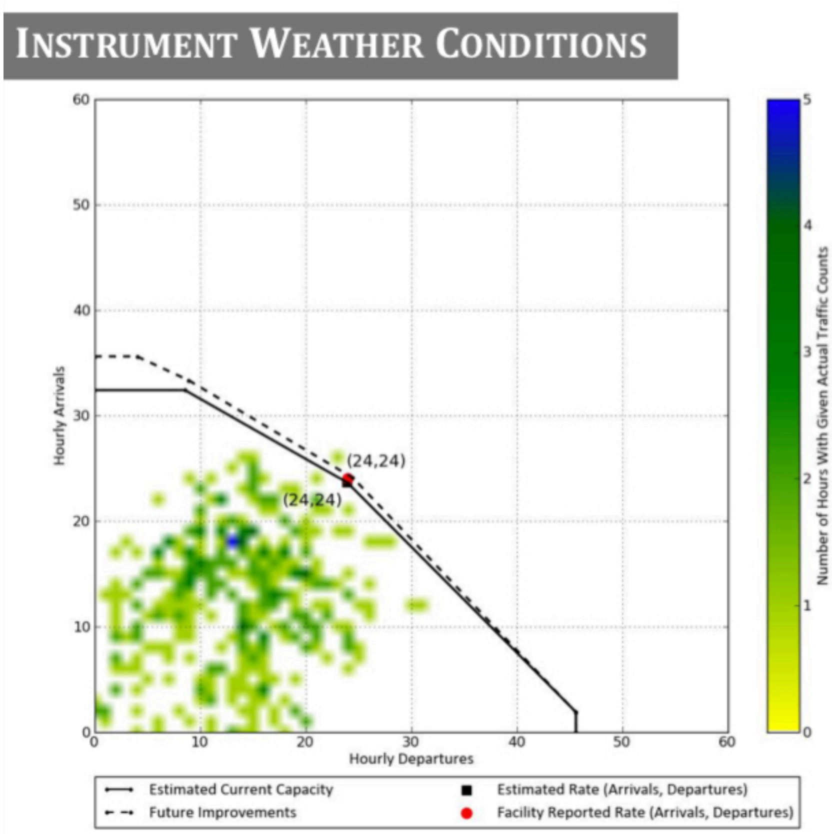
	Trailing Aircraft (Header Columns)					
Lead (column 1)	H	F	E	C	B	Sum
H	0.00	0.00	0.00	0.00	0.00	0.00
F	0.69	0.00	0.00	0.00	0.00	0.69
E	0.07	1.84	0.00	0.00	0.00	1.91
C	0.12	1.61	0.17	0.00	0.00	1.90
B	0.07	0.92	0.09	0.08	0.00	1.17
						5.67 Total Departures with 100% arrival priority

Summary for Arrival - Departure Diagram

c) Show the complete Pareto diagram (arrivals and departures) for SAN airport under IMC conditions.

d) Compare the answers with the FAA published airport capacity (available at https://www.faa.gov/airports/planning_capacity/profiles/).





Problem 2

Review the runway configuration of México City airport (see Figure 3 and consult Google Earth if necessary). Runway 5L is normally used for departures. Runway 5R is used for arrivals. Because the close proximity of the runways, ATC controllers block departures on runway 5L when an arrival is inside the “reserved zone” in Figure 3 to reduce the risk of a simultaneous go-around on runway 5R and a departure on 5L. Aircraft in line and wait position are clear to depart once the arrival is outside the reserved zone. Table 1 shows the fleet mix for México City. Figure 4 shows the standard ICAO separations applicable to México City (IMC conditions). Table 2 shows the typical departure-departure separations used in México City. Mexico has standard airport surveillance radar. The common approach length is 10 nm. Use a probability of violation of 1%. The ATC controllers are conservative and use an in-trail position error of 22 seconds.

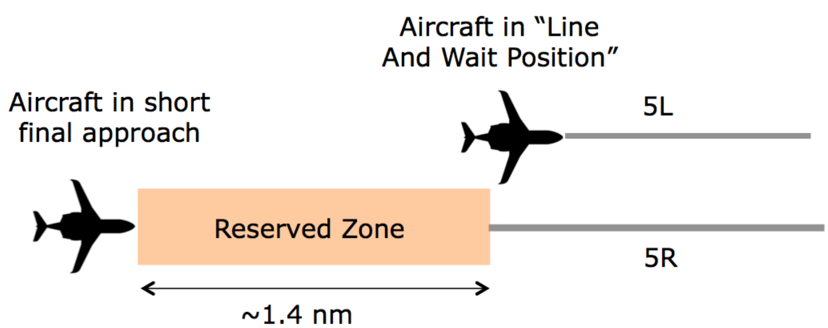


Figure 3. Close Parallel Configuration of Mexico City Airport.

Table 3. Runway Operational Parameters and Fleet Mix for México City Airport.

Aircraft	Percent Mix (%)	Runway Occupancy Time (s)	Typical Approach Speed (knots) from FAF
Small	4	50	126
Large	72	54	146
Heavy	22	61	161
Superheavy	2	76	158
Totals	100		

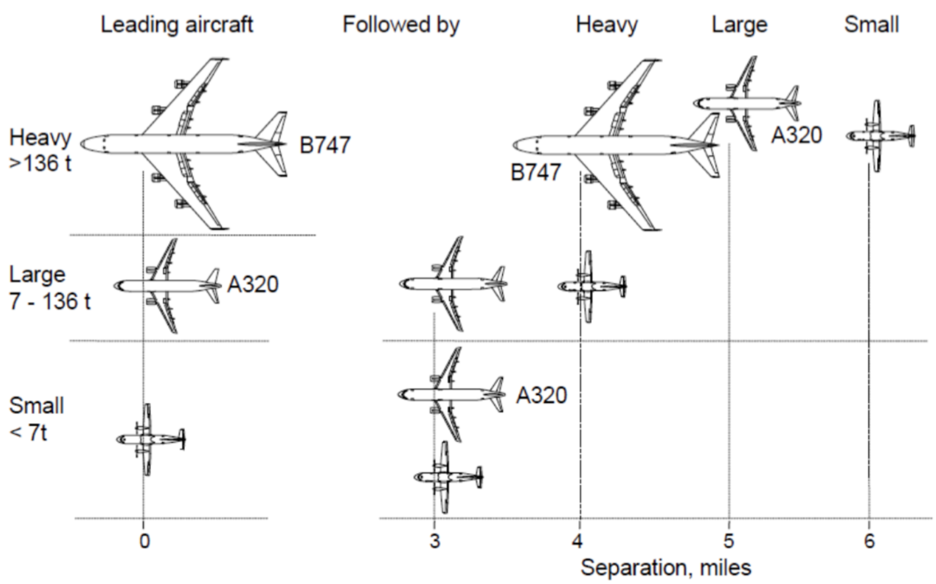


Figure 1. ICAO Recommended IMC Separations. Source: Lang et al., 2010. Arrival-Arrival Separations.

Table 3. Minimum Departure-Departure Separations. Columns are the Following Aircraft. Values in are seconds and Include Buffers.

Aircraft	Small	Large	Heavy	Superheavy
Small	75	75	95	95
Large	75	75	75	75
Heavy	125	125	125	125
Superheavy	190	130	130	130

a) Find the IMC capacity diagram for this airport. Clearly explain how did you accounted for the dependency between arrivals and departures.

Arrivals only capacity = 28.95 per hour

I assumed the arrival-arrival separation behind superheavy is 2 nm above that of heavy.

Departures only capacity = 41.2 per hour

To account for the reserved zone estimate the expected blocking time per hour when arrivals are inside the reserved zone.

For small aircraft (126 knots) - blocking time is 40 seconds

For Large aircraft (146 knots) - blocking time is 35 seconds

For heavy aircraft (161 knots) - blocking time is 31 seconds

Superheavy blocking time is 32 seconds

Expected value of blocking time = 34.3 seconds per landing

For 29 landings per hour a total of 993 seconds of one hour are blocked from departures on runway 5L. Hence, the estimated departure capacity when 100% arrivals are processed on runway 5R is (41.2 - 11.4 departures/hour) = 29.8 departures per hour. Note that according to the procedure, 11.37 departures per hour are blocked on runway 5L.

b) Plot the Pareto diagram for the two runways operated in IMC condition.