Assignment 9: Runway Capacity and Runway Grades

Date Due: November 19, 2025
Instructor: Trani

Problem 1

The objective of the problem is to find the saturation capacity of the airport configuration shown in Figure 1. The airport has a fast-scan airport surveillance radar (ASR) and ADS-B surveillance to track aircraft up to 60 nautical miles from the airport site. The ADS-B system can update the position of aircraft every second. The airport is located at 143 feet above mean sea level conditions. Note that both runways are used in mixed operations (I.e., arrivals and departures).

Tables 1 and 2 show some technical parameters including aircraft fleet mix, runway occupancy times, and approach speeds. Runway 33L is used by commercial aircraft operations (CWT groups B,E, and F). Runway 33R is dedicated to general aviation traffic including corporate jets (CWT groups G,H, and I).

The airport has the following technical air traffic control parameters: a) in-trail delivery error (σ_0) of 20 seconds, b) departure-arrival separation for IMC conditions is 2.4 nautical miles (includes a small 0.4 nm ATC buffer), c) probability of violation is 5%. Air traffic controllers direct traffic to intercept the final approach fixes located 16 and 15 nautical miles from the runway threshold (see Figure 1). Arrivals follow in trail after crossing the final approach fix (also called the entry gate).

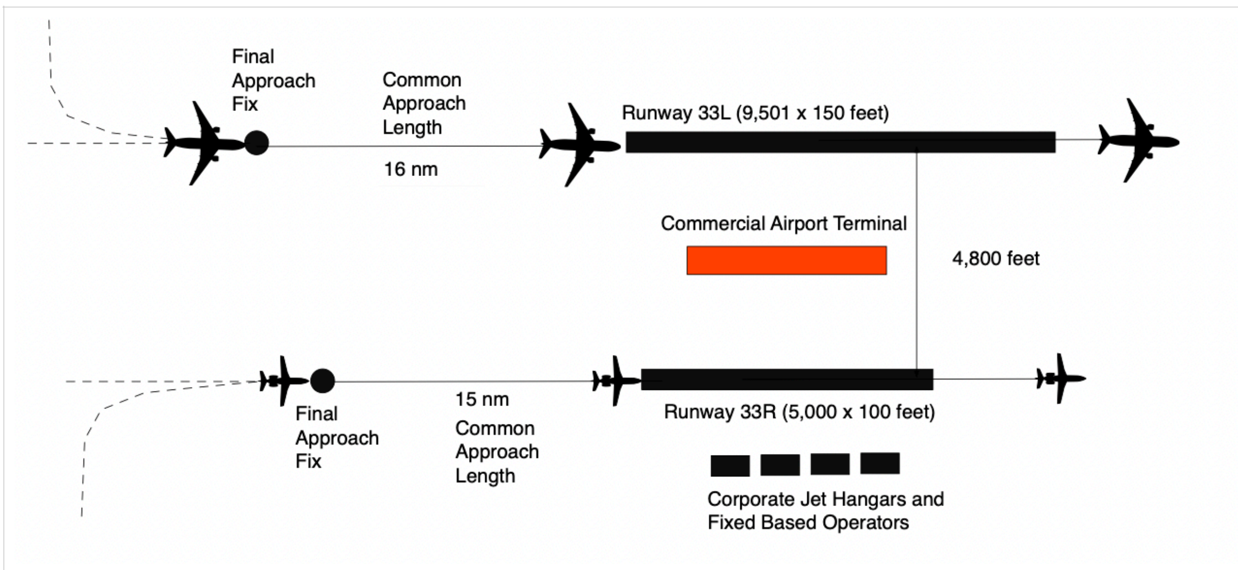

Figure 1. Runway Configuration for Problem 1.

Table 1. Runway Occupancy Times and Fleet Mix for Runway 33L at the Airport.

Consolidated Wake Turbulence Aircraft Group	Percent Mix (%)	Runway Occupancy Time (s)	Average Approach Speed (knots) from Final Approach Fix
F	83	56	136
E	6	58	137
B	11	65	149
Totals	100		

Table 2. Runway Occupancy Times and Fleet Mix for Runway 33R at the Airport.

Consolidated Wake Turbulence Aircraft Group	Percent Mix (%)	Runway Occupancy Time (s)	Average Approach Speed (knots) from Final Approach Fix
I	24	50	118
H	46	51	125
G	30	52	129
Totals	100		

a) Can the two runways be operated independently in Instrument Meteorological Conditions? State the runway separation rule that applies.

Yes, The runways meet the separation criteria for independent arrival operations.

b) Calculate the headway (T_{ij}) and the buffer (B_{ij}) matrices for runways 33L and 33R. Show me the sum of both matrices ($T_{ij} + B_{ij}$) for each runway.

To estimate the headways, use the Consolidated Wake Turbulence (CWT) arrival-arrival separation categories provided in class. Consider if the runway is eligible for reduced separation minima.

Minimum Separation Matrix (nm)			Arrivals-Arrivals
		Trailing Aircraft (Header Columns)	
Lead (column 1)	F	E	B
F	3	3	3
E	3	3	3
B	5	5	3

		Trailing Aircraft (Header Columns)	
Lead (column 1)	F	E	B
F	0.689	0.091	0.050
E	0.091	0.012	0.007
B	0.050	0.007	0.004

		Trailing Aircraft (Header Columns)	
Lead (column 1)	F	E	B
F	33.00	33.00	33.00
E	32.42	33.00	33.00
B	21.45	22.42	33.00

		Trailing Aircraft (Header Columns)	
Lead (column 1)	F	E	B
F	112.41	111.83	105.48
E	114.92	111.83	105.48
B	190.76	187.67	105.48

Figure 1.1 CWT Separation Matrix, Probability Matrix, Buffer Matrix, and Headway Matrix (includes buffers). Runway 33L.

Minimum Separation Matrix (nm)			Arrivals-Arrivals
		Trailing Aircraft (Header Columns)	
Lead (column 1)	I	H	G
I	3	3	3
H	3	3	3
G	3	3	3

Pij Matrix			
		Trailing Aircraft (Header Columns)	
Lead (column 1)	I	H	G
I	0.058	0.110	0.072
H	0.110	0.212	0.138
G	0.072	0.138	0.090

Minimum Separation Matrix (nm)			Arrivals-Arrivals
		Trailing Aircraft (Header Columns)	
Lead (column 1)	I	H	G
I	3	3	3
H	3	3	3
G	3	3	3

Buffer Matrix (Bij)			
		Trailing Aircraft (Header Columns)	
Lead (column 1)	I	H	G
I	33.00	33.00	33.00
H	27.87	33.00	33.00
G	25.20	30.32	33.00

Augmented Matrix (Tij + Bij)			
		Trailing Aircraft (Header Columns)	
Lead (column 1)	I	H	G
I	124.53	119.40	116.72
H	145.03	119.40	116.72
G	155.74	130.12	116.72

Figure 1.2 CWT Separation Matrix, Probability Matrix, Buffer Matrix, and Headway Matrix (includes buffers). Runway 33R.

Rules of the analysis.

You are allowed to use the Excel program supplied in class. However, you need to show me two hand calculations for the following conditions:

Runway 33L: 1) Lead aircraft is B and following aircraft is F. 2) Lead aircraft is F and following aircraft is E.

Runway 33R: 1) Lead aircraft is G and following aircraft is I. 2) Lead aircraft is H and following aircraft is G.

c) **Find the arrivals-only capacity in IMC conditions** for each runway considering the headways and buffer times estimated in part (b).

30.88 arrivals per hour (31 arrivals per hour) for runway 33L.

28.61 arrivals per hour (29 arrivals per hour) for runway 33R.

d) Comment on the differences in the arrivals-only capacity for both runways.

Faster approach speeds produce higher capacity values if the common approach lengths are similar.

E) Find the total (maximum) number of arrivals the airport can process. Assume no departures.

A total of ~60 arrivals (59.5 arrivals per hour) per hour can be processed adding the capacities of both runways

Problem 2

For Problem 1, execute the following analyses:

a) Calculate the **departures-only capacity** under IMC conditions for each runway. Use the departure-departure separation matrix provided in class (see the RunwayCapacityBasic_rfs.pdf class notes).

48.91 departures per hour (49 departures per hour) for runway 33L.

51.43 departures per hour (departures per hour) for runway 33R.

b) For each runway, calculate the number of departures possible with 100% arrival priority. Consider a 10-second human factors and mechanical delay (τ) to clear the aircraft for takeoff. **Show me hand calculations for the gap (in seconds) needed to release one and two departures for runway 33L.**

For runway 33L, the departures with 100% arrival priority is 1.69 per hour.

For runway 33R, the departures with 100% arrival priority is 5.04 per hour.

c) Considering both runways, plot the airport **arrival-departure capacity diagram** (Pareto diagram) under IMC conditions. This requires that you combine the individual capacities of both runways. Include at least one point in your diagram to estimate the departure capacity with 100% arrival priority under mixed runway operations.

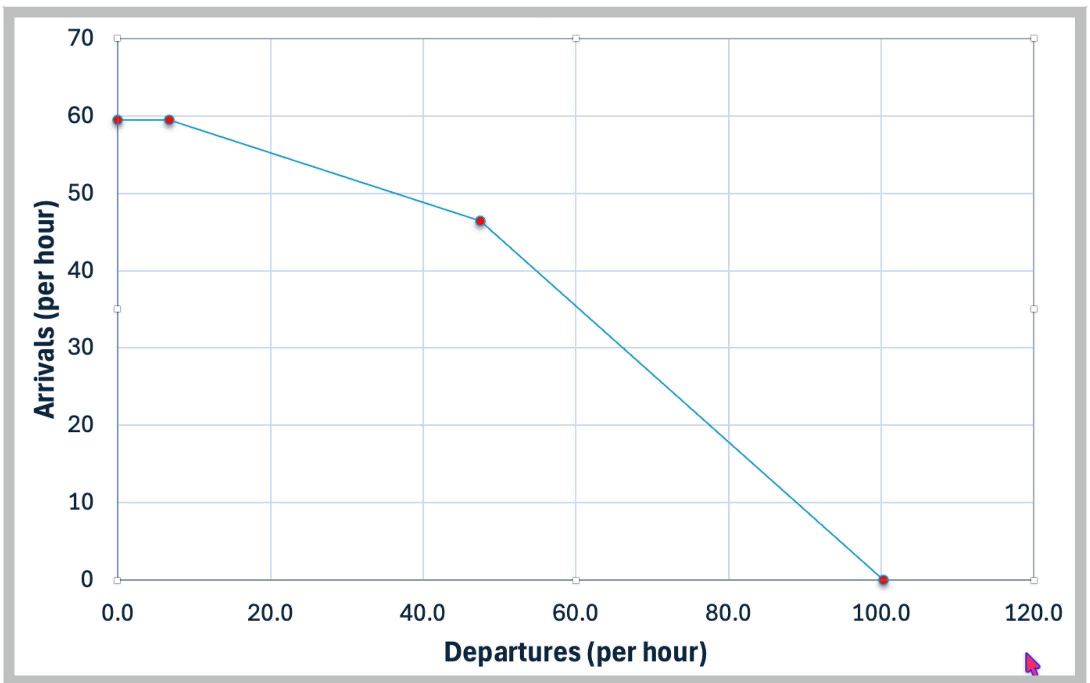

Figure 2.1 Arrival-Departure Diagram (Pareto Frontier) for Two Runways Operated in Mixed Mode.

Problem 3

Figure 2 shows the vertical profile of a runway at a commercial airport. The airport is designed to serve commercial operations using Boeing 757-200 aircraft (see Figure 3).

A) Evaluate if the runway vertical profile meet FAA standards? Comment on the FAA rules you considered in your analysis.

The following checks are required in your solution:

G3 is below 0.8% maximum permissible (first quarter of the runway)

G4 is below the 0.8% maximum permissible (first quarter of the runway)

No change in grade is acceptable in the first and last quarter of the runway. The runway meets the criteria at station 2800 feet (26% of the runway length).

No change in grade is acceptable in the first and last quarter of the runway. The runway change in slope at station D violates the criteria due to its location station 8300 feet (22% of the runway length).

Point of intersection B meets the 1.5% maximum change in grade (change in grade is 1.15%)

Point of intersection C meets the 1.5% maximum change in grade (change in grade is 0.75%)

Point of intersection C meets the 1.5% maximum change in grade (change in grade is 0.65%)

Maximum local grade is below the maximum 1.5% permissible (max. Slope at G3)

2. The maximum allowable grade change is ±1.50 percent; however, runway grade changes are not acceptable within the lesser of the following criteria:
   a. the first and last quarter of the physical runway length, or
   b. the first and last 2,500 feet (762 m) of the physical runway length.

Grade change at point C is 0.75%. Grade change at point of intersection D is 0.65%.

Therefore, the minimum distance between points of intersection C and D:

S = 1000 X (0.65 + 0.75) = 1,400 feet

The distance between points of curvature C and D meets the standard (distance is 2,200 feet).

B) Find the remedial actions needed to make the runway compliant with FAA longitudinal grade standards.

Work needs to be done on the runway to eliminate the change in grade at point of intersection D. Regrading slope G4 moving the intersection point D 300 feet to the left (see Figure 2) would suffice to make the slope compliant with the FAA rules. That change would move PI D to 2,500 feet from the end of the runway.

C) Find the length of the vertical transition curves at points B and C (before any remedial action). State the rule used.

Transition curves of length 1000 x (grade change) in feet are required for approach categories C, D, and E.

Length of transition curve at point of intersection B is 1,150 feet

Length of transition curve at point of intersection C is 750 feet

Length of transition curve at point of intersection D would have to be re-assessed once the grading plan is complete to move the point of intersection D to satisfy item (a).

D) Find the recommended slope of the RSA areas at ends 09 and 27.

The FAA specifies that RSA areas require a slope of from 0 to -3% for the first 200 feet at each end of the runway. The remaining 800 feet of the RSA length can be graded between 0 and -5% according to the FAA.

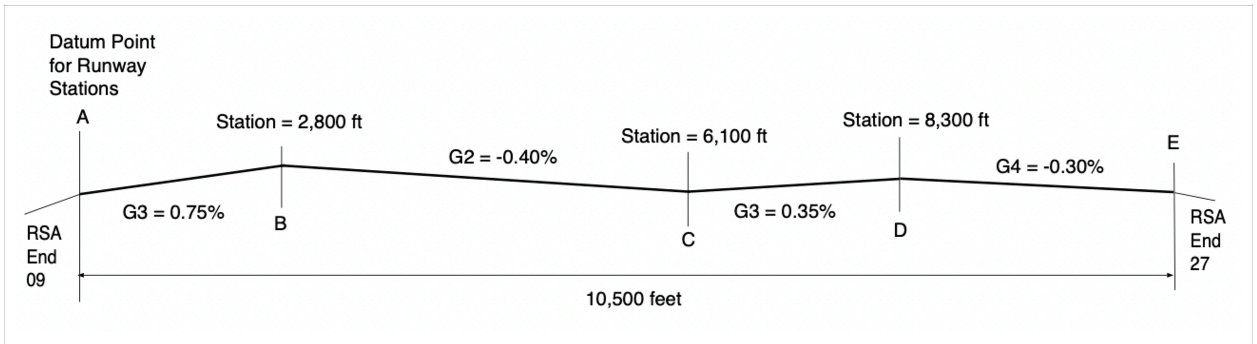

Figure 2. Vertical Profile of Runway Configuration for Problem 3.

Figure 3. Critical Aircraft for Problem 3 (Boeing 757-200 Landing at ATL — A. Trani).