Assignment 9: Runway Capacity and Runway Grades

Solution
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Problem 1

The objective of the problem is to find the capacity of a busy single-runway airport (see Figure 1). The airport has a fast-scan airport surveillance radar (ASR) and ADS-B surveillance to track aircraft up to 65 nautical miles from the airport site. The ADS-B system can update the position of aircraft every second. Tables 1 through 3 show technical parameters and the typical ATC separations at the airport under Instrument Meteorological Conditions (IMC). Three aircraft groups (of the nine groups included in the Consolidated Wake Categories defined by FAA) operate at the airport. The airport has the following technical parameters: a) in-trail delivery error of 20 seconds, b) **departure-arrival separation for both VMC and IMC conditions is 2.3 nautical miles** (includes a small ATC buffer), c) probability of violation is 5%. Air traffic controllers direct traffic to intercept a final approach fix located 14 miles from the runway threshold. Arrivals follow in trail after crossing the final approach fix. The airport aircraft mix, runway occupancy times, and approach speeds are shown in Table 1.

You can modify the spreadsheet provided in class to solve the problem. Show me sample calculations for opening and closing cases so that I know you can do such calculations by hand.

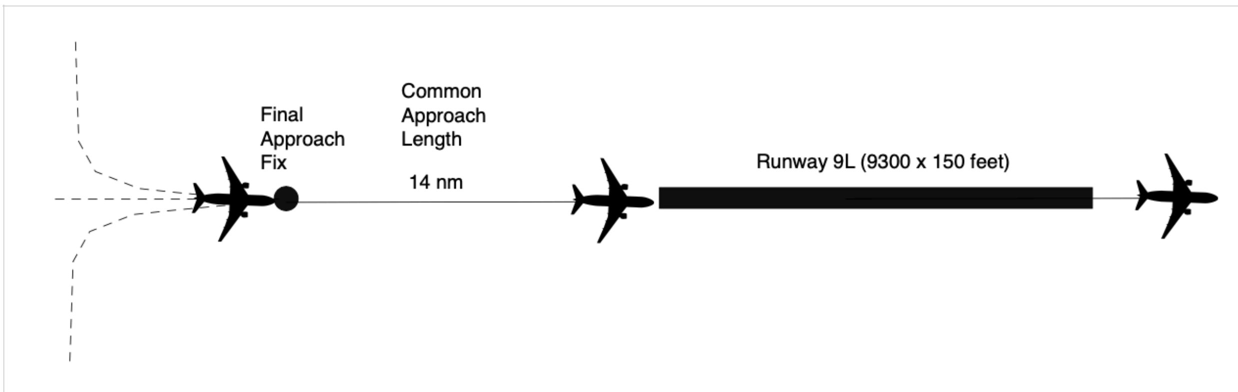

Figure 1. Runway Configuration for Problem 1.

Table 1. Runway Occupancy Times and Fleet Mix for a Busy Single Runway Airport.

Consolidated Wake Turbulence Aircraft Group	Percent Mix (%)	Runway Occupancy Time (s)	Average Approach Speed (knots) from Final Approach Fix
G	24	53	128
F	71	60	137
B	5	65	150
Totals	100		

Table 2. Minimum arrival-arrival separations under IMC conditions. Values are nautical miles. ***Values Shown Do Not Include Buffers.*** *The entire table is available on page 54 of the aircraft classifications handout.*

	Trailing Aircraft		
Lead (Column 1)	**G**	**F**	**B**
G	3	3	3
F	3	3	3
B	5	5	3

Table 3. Minimum departure-departure separations under IMC conditions. Values in are seconds. ***ATC Departure Buffers are Included.***

	Trailing Aircraft (Columns 2-5)		
Lead (Column 1)	**G**	**F**	**B**
G	65	65	65
F	70	70	70
B	125	125	125

a) Calculate the arrivals-only saturation capacity under IMC conditions.

Pij Matrix

	Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	B
G	0.058	0.170	0.012
F	0.170	0.504	0.036
B	0.012	0.036	0.003

Buffer Matrix (Bij)

	Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	B
G	33.00	33.00	33.00
F	27.46	33.00	33.00
B	12.38	21.61	33.00

Augmented Matrix (Tij + Bij)

	Trailing Aircraft (Header Columns)		
Lead (column 1)	G	F	B
G	117.38	111.83	105.00
F	137.70	111.83	105.00
B	210.75	184.88	105.00

Arrivals Only Capacity (per hour)	30.00

Figure 1.1. Intermediate Calculations.

30 arrival/hour

b) Calculate the departures-only saturation capacity under IMC conditions.

50.31 departures/hour

c) Plot the arrival-departure saturation capacity diagram (Pareto diagram) under IMC conditions. Include at least one point in your diagram to estimate the departure capacity with 100% arrival priority under mixed runway operations. Show me a sample of calculations to estimate parameters Tij and Bij so I can judge your analysis.

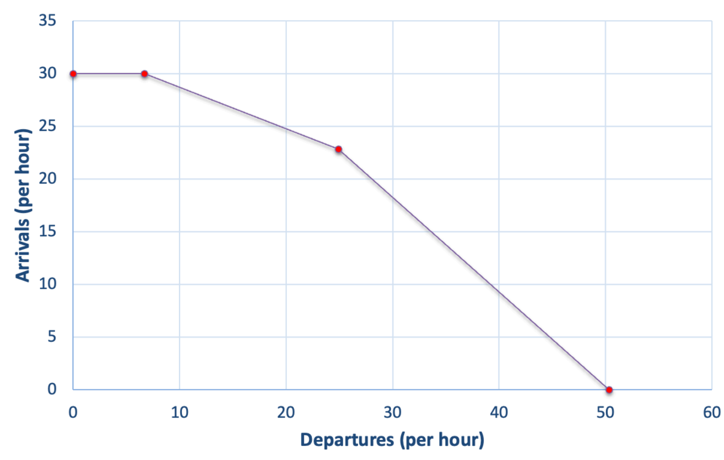

Figure 1.2. Runway Capacity for Problem 1. Baseline Case.

Problem 2

Study the effect of advanced airport technologies and infrastructure improvements applied to the airport described in Problem 1.

a) If the common approach path is reduced to 9 nm, calculate the arrivals-only saturation capacity under IMC conditions. A reduction of the common approach path may be achievable if more advanced ATC automation is implemented. Comment on the effect of reducing the common approach path.

New arrival capacity is 30.57 per hour

b) If the runway occupancy times (Table 1) are reduced to 50 seconds for all three aircraft groups by implementing two new high-speed runway exits, calculate the arrivals-only saturation capacity under IMC conditions. Explain how a reduction of ROT times improves the runway capacity.

This means reducing the minimum in-trail separations to 2.5 nautical miles (instead of 3 nm).

New arrival capacity (gamma = 14 nm) is 33.49 per hour

New arrival capacity (gamma = 9 nm) is 34.20 per hour

c) Calculate the departures-only saturation capacity under IMC conditions if the departure-departure separation (Table 3) is reduced by 10% (each cell value) due to improved ATC automation.

Departure-Departure Separation Matrix with Buffers (seconds)					
	Trailing Aircraft (Header Columns)				
Lead (column 1)	G	F	B		
G	60	60	60		
F	64	64	64		
B	114	114	114		
Departures Only Capacity (per hour) - includes departur			55.05		

Figure 1.3. Departure-Departure Separations with 10% Reduction (note: buffers not reduced since pilots are not machines).

New departure capacity (10% reduction in departure-departure separations) is 55.05 per hour

d) Plot the arrival-departure saturation capacity diagram (Pareto diagram) under IMC conditions using all three airport improvements (parts a-c) explained above. Include at least one point in your diagram to estimate the departure capacity with 100% arrival priority under mixed runway operations. Show me a sample of calculations to estimate parameters Tij and Bij so I can judge your analysis. Note that the airport uses both runways in mixed operations mode (i.e., arrivals and departures).

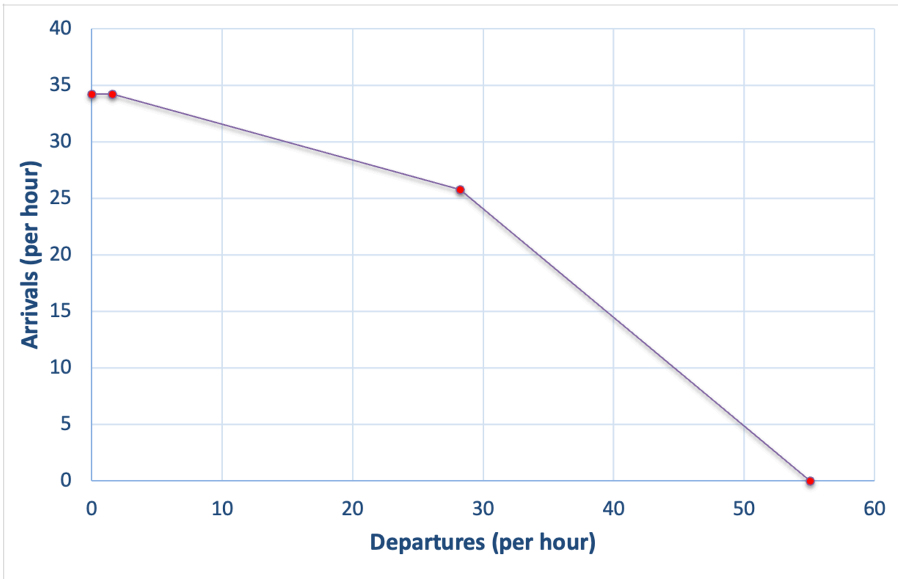

Figure 1.4. Runway Capacity for Problem 1. New Technologies - Improved Case.

Problem 3

Figure 2 shows the vertical profile of a runway at a regional airport. The airport is designed to serve commercial operations using Airbus A220-300 aircraft (see Figure 3).

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

No.

The grade change at point B exceeds the maximum allowed grade change (1.5%)

The first quarter of each end of the runway meets the maximum grade (0.8%)

The distance between points B and C comply with the FAA criteria

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

To meet the maximum grade change at point B, the profiles G3 and G2 need to be flattened.

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

The length of the curve is 1000 * (0.73 + 0.85) = 1,580 feet

D) Use the vertical curve Matlab program demonstrated in class to design a vertical curve for point B. Assume the datum point (A) elevation is 1,350 feet above sea level conditions and the datum station is zero.

Length of curve (L) = 1,580 feet

L/2 = 790 feet

The vertical curve starts at station 2610 feet (point of curvature - PC)

Elevation of the PC point of the vertical curve is = 1350 - 2610*.0073 = 1330.95 feet

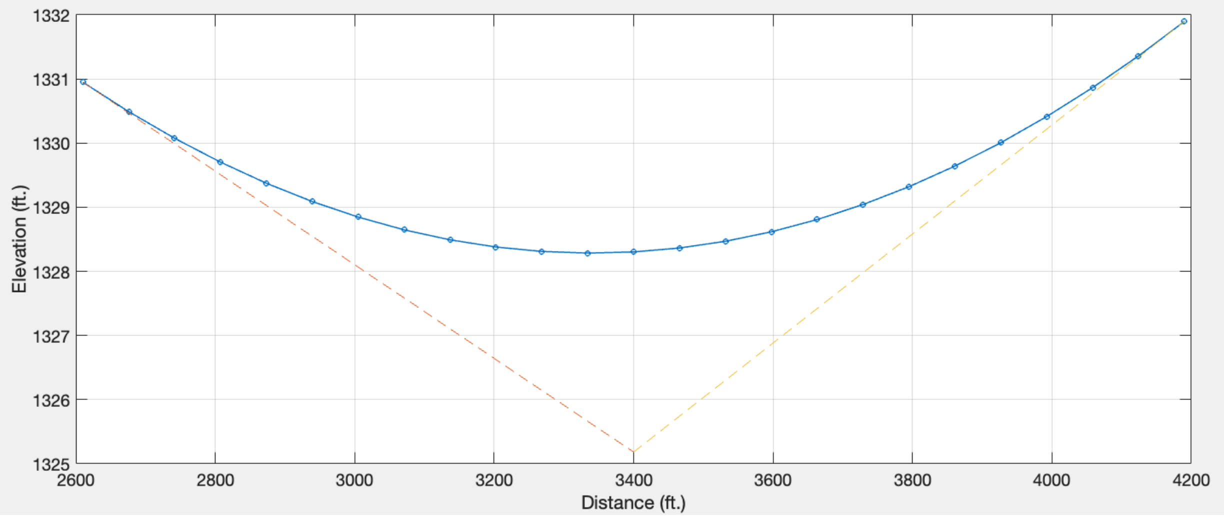

Figure 2.1 Vertical Transition Curve for Problem 3.

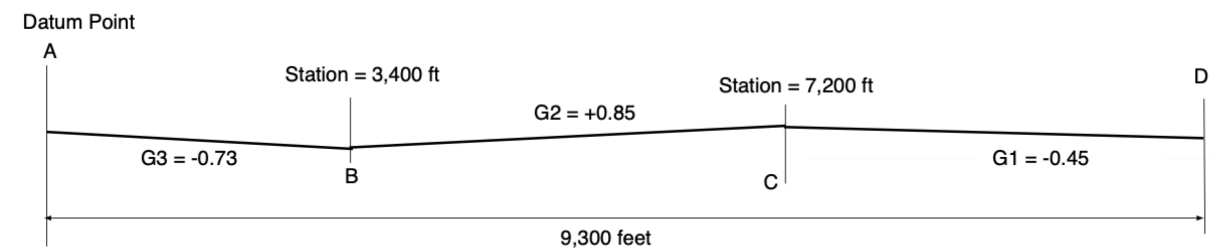

Figure 2. Vertical Profile of Runway Configuration for Problem 3.

Figure 3. Critical Aircraft for Problem 3 (Airbus A220-300 - A. Trani).