Assignment 8: Runway Exit Placement and Capacity

Solution
Instructor: Trani

Problem 1

Using the cumulative runway exit distribution charts provided in class (or Figure 4-17 in the FAA AC 150/5300-13B), briefly answer the following questions:

a) Estimate the percent of AAC D aircraft that could take a high-speed runway exit located at 6100 feet at an airport located at sea level conditions.

65% of AAC D can make the high-speed runway exit. See the chart below with more detail the Figure 4-17 in the AC.

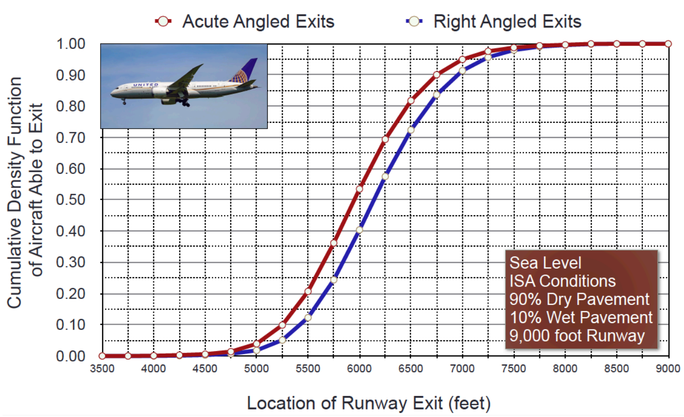


Figure 1. Cumulative Density Function of Runway Exit Use.

b) if the same high-speed runway exit is built at an airport located 3,500 feet above sea level, estimate the new location of the Point of Curvature (PC).

Recommended practice is offset runway exits by 150-167 feet for each 1,000 ft elevation. At 3,500 feet we could place the high-speed exit at 6,625-6,685 feet downrange instead.

c) Runway exit A5 is a right-angle exit located 4,450 feet from runway threshold 13 at Virginia Tech Montgomery Executive Airport. Estimate the percent of medium size corporate jets like the Cessna Citation XLS or the Bombardier Challenger 300 that could use runway exit A5.

The Bombardier Challenger 300 belongs to AAC group C. 10% of the AAC C could make it to the runway exit at 4,450 feet. This number is biased because the curves shown in the FAA AC assume an 8,000 foot runway for AAC aircraft. Using the REDIM model, we can do a better estimate of the percent utilization of that exit for the Challenger 300.

The Cessna Citation XLS belongs to AAC B. 90% of the aircraft in that class can take a right-angle exit located at 4,450 feet.

d) Why do we use 90% dry pavement conditions to design the locations of runway exits?

Weather conditions at airports favor dry pavement conditions most of the time. Analysis of pavement conditions at typical airports suggests 10% of the time the pavement may be wet.

Problem 2

Use the latest version of the Runway Exit Design Model (REDIM) developed by Virginia Tech for FAA to evaluate a proposed runway with the characteristics and aircraft fleet mix shown on Tables 1 and 2.

The current beta version (REDIM 4) can be downloaded at the link below:

https://atsl-software-downloads.s3.amazonaws.com/redim/V4.0.0.beta6/redim.exe

The updated MATLAB Runtime should install automatically. However, you can install it separately by downloading it here:

https://atsl-software-downloads.s3.amazonaws.com/redim/MATLAB_Runtimes/MATLAB_Runtime_R2021b_Update_3_win64.exe

Use the example described in the notes to do this exercise.

Table 1. Runway Characteristics for Problem 1.

Runway Exit	PC Location	Runway Exit Type
E1	1750	Right-angle
E2	4900	Right-angle
E3	6300	Right-angle
E4	9550	Right-angle
E5	9800	Right-angle

The proposed 10,000-foot runway will be constructed at an airport located 450 feet above mean sea level conditions. The design temperature if 70 deg.F. and use 90% dry pavement conditions. Run your analysis with Pilot Motivation Factors of 1.0 (default).

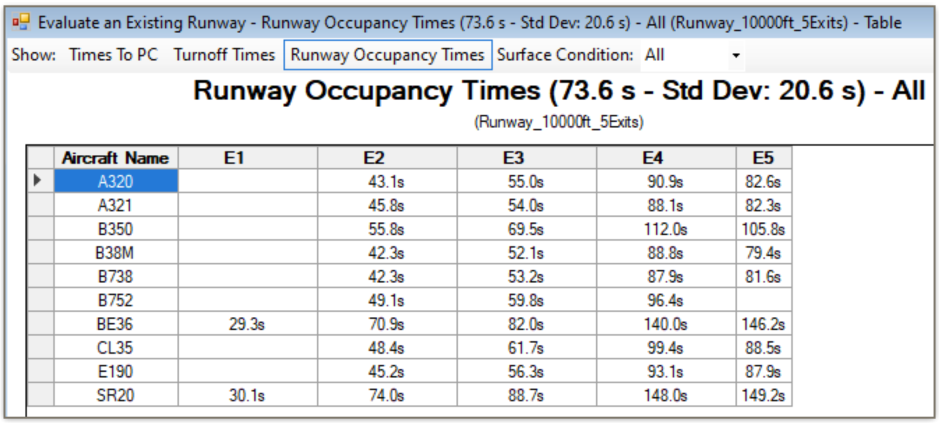
Table 2. Aircraft Fleet Mix.

Aircraft ID	Aircraft	Fleet Mix (%)
BE36	Beechcraft Bonanza 36	10
SR20	Cirrus SR20	10
B350	Beechcraft King Air 350	10
CL35	Bombardier Challenger 350	10
A320	Airbus A320	10
A321	Airbus A321	10
B38M	Boeing 737 Max8	10
B738	Boeing 737-800	10
B752	Boeing 757-200	10
E190	Embraer 190	10

Aircraft ID	Aircraft	Fleet Mix (%)
Totals		100

a) Estimate the weighted average runway occupancy time (ROT) and the standard deviation for the proposed configuration.

Weighted average ROT = 73.6 seconds. Standard deviation of ROT is 20.6 seconds. Both values are very high and imply that there are possible improvements to be made to the runway.



Evaluate an Existing Runway - Runway Occupancy Times (73.6 s - Std Dev: 20.6 s) - All (Runway_10000ft_5Exits) - Table

Show: Times To PC Turnoff Times Runway Occupancy Times Surface Condition: All

Runway Occupancy Times (73.6 s - Std Dev: 20.6 s) - All

(Runway_10000ft_5Exits)

Aircraft Name	E1	E2	E3	E4	E5
A320		43.1s	55.0s	90.9s	82.6s
A321		45.8s	54.0s	88.1s	82.3s
B350		55.8s	69.5s	112.0s	105.8s
B38M		42.3s	52.1s	88.8s	79.4s
B738		42.3s	53.2s	87.9s	81.6s
B752		49.1s	59.8s	96.4s	
BE36	29.3s	70.9s	82.0s	140.0s	146.2s
CL35		48.4s	61.7s	99.4s	88.5s
E190		45.2s	56.3s	93.1s	87.9s
SR20	30.1s	74.0s	88.7s	148.0s	149.2s

b) Show me the runway exit configuration diagram provided by REDIM 4.

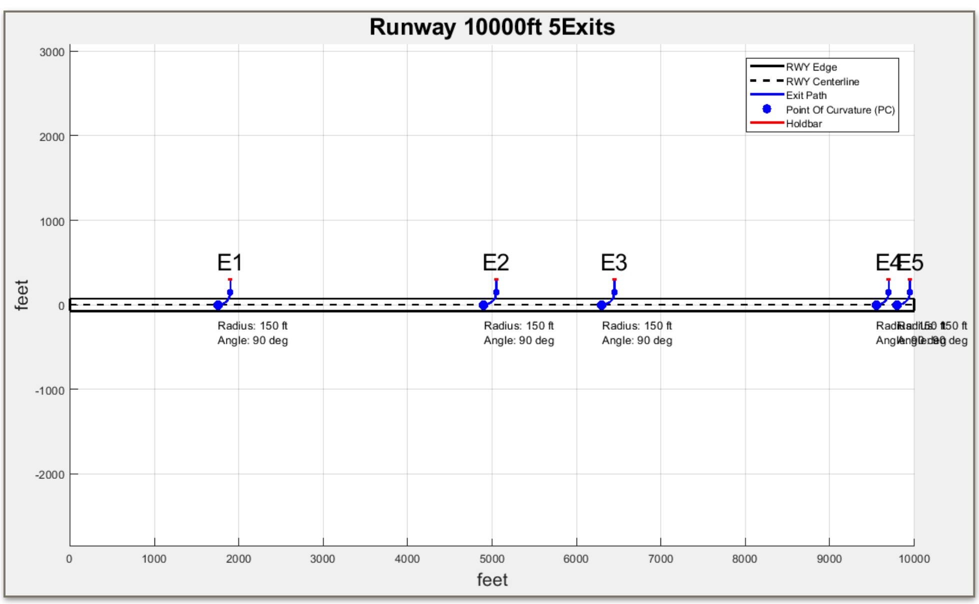


Figure 2. Runway Exits for Problem 2.

c) Estimate the percent of Embraer 190 landings likely to use runway exit E3. Show the full table of runway exit assignments provided by the model.

50.6% of Embraer 190 landings are expected to use runway exit E3.

d) Find the runway exit that is likely to be used the most at the new runway. Estimate the percent of landing using that exit.

Runway exit E4 is used 37% of the time. This is the exit that is likely to be used the most according to the REDIM model.

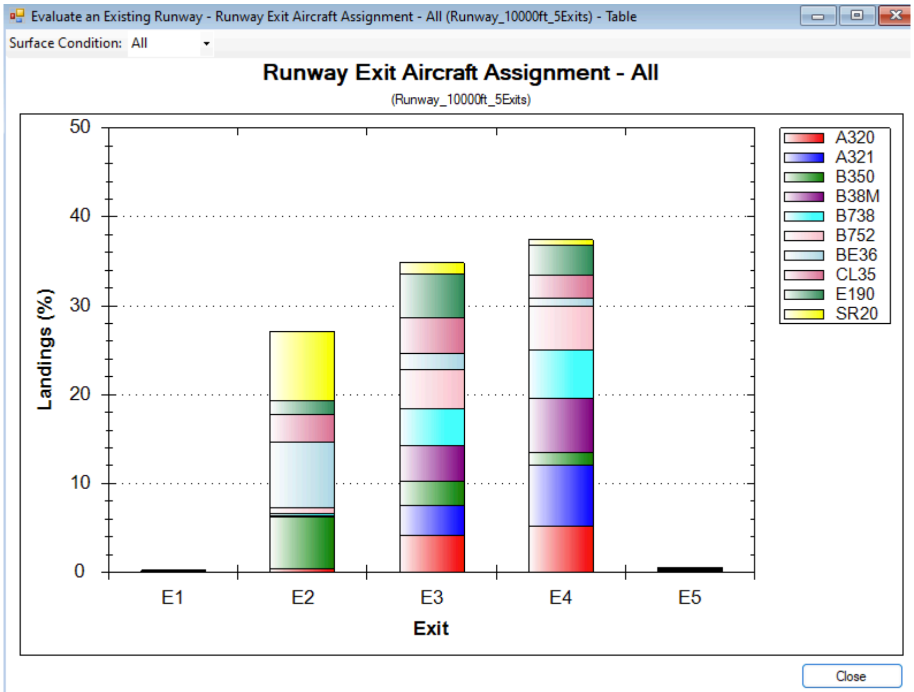


Figure 3 . Runway Exit Utilization Plot (Problem 2).

e) Explain why is that there are two exits E4 and E5 close to each other at the end of the runway.

Two runway entrance exits are required by the FAA under the new design guidelines.

Problem 3

Improve the runway design of Problem 1 by evaluating a new runway configuration with the following runway exit locations:

Table 3. Runway Characteristics for Problem 2.

Runway Exit	PC Location	Runway Exit Type
E1	1750	Right-angle
E2	4000	Right-angle
E3	5500	Acute-angle (30-deg angle)
E4	6800	Acute-angle (30-deg angle)
E5	8000	Right-angle
E6	9550	Right-angle
E7	9800	Right-angle

a) Estimate the weighted average runway occupancy time (ROT) and the standard deviation for the proposed configuration.

The new weighted ROT is 58.5 seconds. The standard deviation of ROT is 13.3 seconds. Both values are significant improvements compared to Problem 2.

Evaluate an Existing Runway - Runway Occupancy Times (58.5 s - Std Dev: 13.3 s) - All (Runway_10000ft_7Exits) - Table

Show: Times To PC | Turnoff Times | Runway Occupancy Times | Surface Condition: All

Runway Occupancy Times (58.5 s - Std Dev: 13.3 s) - All

(Runway_10000ft_7Exits)

Aircraft Name	E1	E2	E3	E4	E5	E6	E7
A320			45.5s	55.6s	68.5s	86.0s	76.8s
A321			43.7s	53.2s	66.6s	81.8s	79.4s
B350		46.8s	57.3s	67.7s	91.2s	110.4s	102.2s
B38M			44.2s	54.6s	65.7s	83.5s	82.8s
B738			43.6s	53.3s	66.3s	81.8s	82.3s
B752		43.2s	47.7s	58.3s	74.7s	91.6s	94.8s
BE36	29.6s	57.5s	68.8s	81.1s	94.6s	127.8s	140.0s
CL35		39.8s	50.7s	60.6s	77.0s	95.5s	90.7s
E190		37.0s	47.0s	56.9s	69.1s	86.3s	85.2s
SR20	30.3s	59.4s	73.4s	90.5s		148.6s	154.7s

b) Show me the runway exit configuration diagram provided by REDIM 4.

c) Find the runway exit with the highest utilization for the new configuration. Estimate the percent of landing using that exit.

The first high-speed runway exit (named E3 in my solution and located at 5,5000 feet from the runway threshold) has the highest utilization with 38% of the aircraft landing using that first high-speed exit. Figure 4 illustrates the runway exit use.

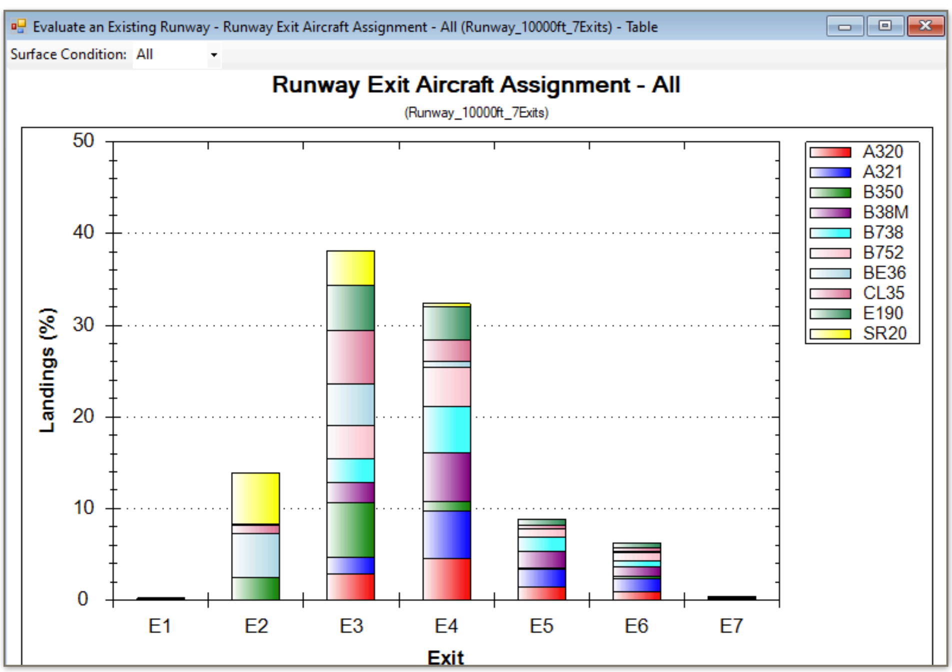


Figure 4. Runway Exit Utilization Plot for Problem 3.

d) Compare the solution obtained in Problem 1 and Problem 2. Comment.

A reduction in weighted average ROT of 15 seconds is a very big improvement. This may affect the capacity of the runway.

Problem 4

The objective of the problem is to find the capacity of busy single runway airport in the US West Coast. The airport has an airport surveillance radar (ASR) and ADS-B surveillance to track aircraft up to 75 nautical miles form the airport site. The ADS-B system can update the position of aircraft every one second. Tables 4 through 6 show technical parameters and the typical ATC separations at the airport under Instrument Meteorological Conditions (IMC). Four 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 15 seconds, b) **departure-arrival separation for both VMC and IMC conditions is 2.4 nautical miles** (includes a small ATC buffer), c) probability of violation is 5%. Air traffic controllers direct traffic to intercept a final approach fix (fix point in space) located 13 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 4.

Table 4. Runway Occupancy Times and Fleet Mix for a Busy Single Runway Airport in the US West Coast (Source: FAA/Virginia Tech Landing Database, Year 2019 Data).

Aircraft RECAT Group	Percent Mix (%)	Runway Occupancy Time (s)	Typical Approach Speed (knots) from FAF
G	10	47	128
F	81	52	138
E	5	61	143
B	4	64	151
Totals	100		

Table 5. Minimum arrival-arrival separations under IMC conditions. Values in are nautical miles. ***Values Shown Do Not Include Buffers.*** *Full Table Available on Page 54 of Aircraft Classifications Handout.*

	Trailing Aircraft (Columns 2-5)			
Lead (Column 1)	**G**	**F**	**E**	**B**
G	3	3	3	3
F	3	3	3	3
E	3	3	3	3
B	5	5	5	3

Table 6. Minimum departure-departure separations under IMC conditions. Values in are seconds. ***ATC Buffers are Included.***

	Trailing Aircraft (Columns 2-5)			
Lead (Column 1)	**G**	**F**	**E**	**B**
G	70	70	70	70
F	70	70	70	70
E	95	90	70	70
B	130	120	120	120

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

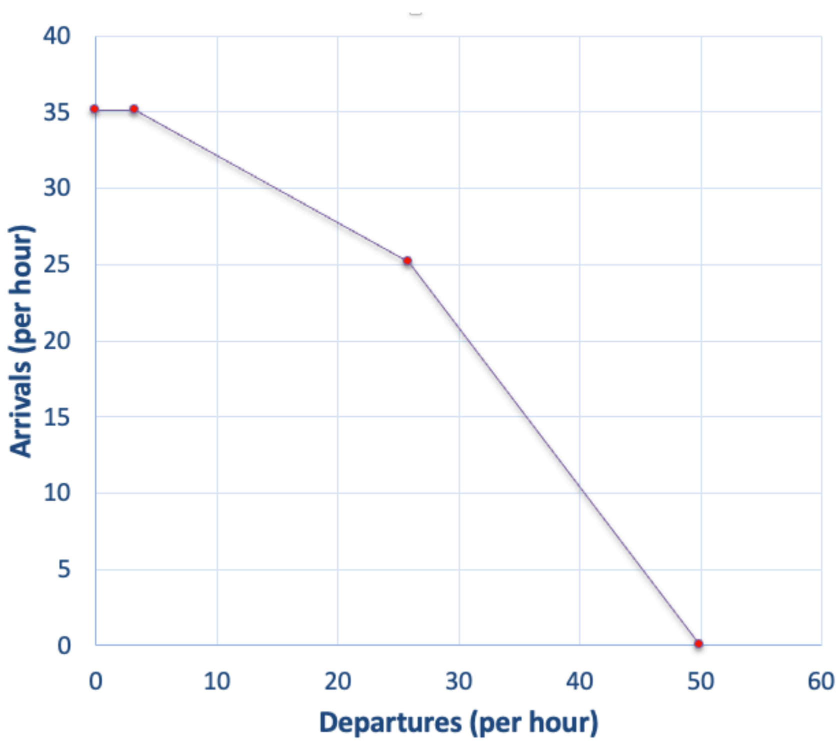
a) Calculate the arrivals-only saturation capacity under IMC conditions.

35.2 arrivals per hour (see Figure below).

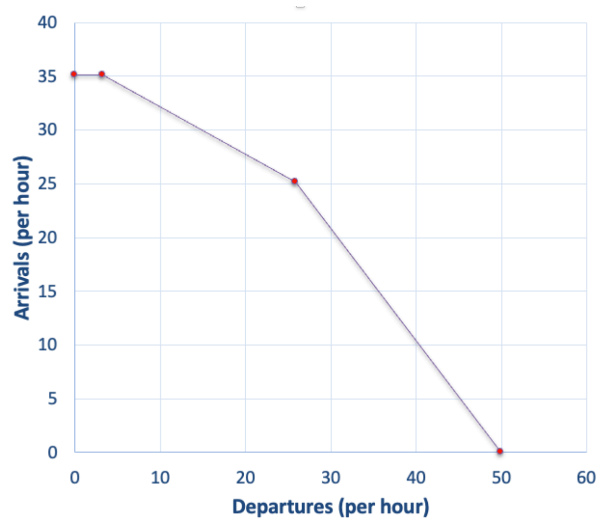
b) Calculate the departures-only saturation capacity under IMC conditions.

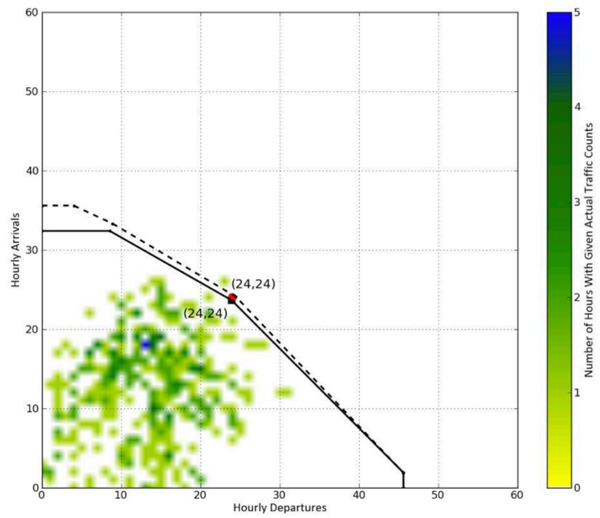
49.9 departures per hour (see Figure below).

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



d) Compare the solution obtained in part (c) with the FAA runway capacity diagram (https://www.faa.gov/airports/planning_capacity/profiles/media/SAN-Airport-Capacity-Profile-2014.pdf). Comment on the possible sources of error.





Arrivals only capacity = 35.2/hr Departures-only capacity = 49.9/hr 50/50 Point = 25 arrivals/hr and 25 departures/hr	Arrivals only capacity = 33/hr Departures-only capacity = 47/hr 50/50 Point = 24 arrivals/hr and 24 departures/hr

Overall, the time-space analysis model seems to replicate the conditions of the San Diego Airport.