Assignment 8: Runway Exit Placement and Geometric Design

Date Due: Solution

Problem 1

A large commercial airport is planning to construct a 9,800-foot runway (see Figure 1). The airport serves 5% AAC A class aircraft, 70% AAC C class aircraft, and 25% AAC D class aircraft. The largest aircraft expected to operate at the airport is the Airbus A350-1000 (see Figure 2).

Using the cumulative runway exit distribution charts (see Figure 4-17 in the FAA AC 150/5300-13B) provided in class on pages 73-78 of the Runway Exit Design handout to perform a first-order analysis of runway exit locations. During the peak periods, the airport expects 35 operations per hour on the new runway. The design team suggests two high-speed exits per runway direction (see Figure 1). **The airport is located 2,800 feet above mean sea level.**

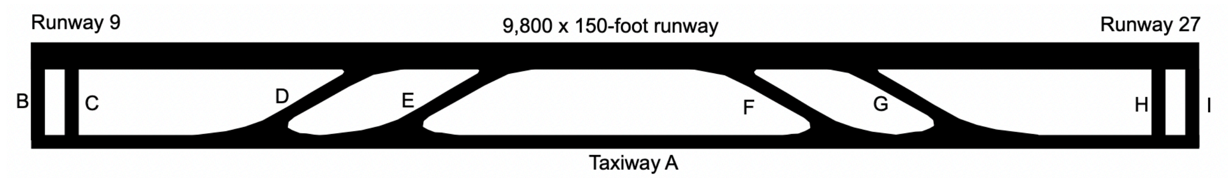


Figure 1. New Runway Configuration.

a) Locate two high-speed locations F and G from runway 9 threshold. Use the class guidance of 50% of percent operations able to make the first high-speed runway exit and 95% by the second high-speed exit. In your analysis, consider AAC groups C and D to locate the high speed runway exits. **The airfield elevation should be considered in the analysis**. Clearly state your assumptions and correction factors for airfield elevation used. Remember that the locations suggested by the cumulative curves are the locations the point of curvature (PC) of each runway exit.

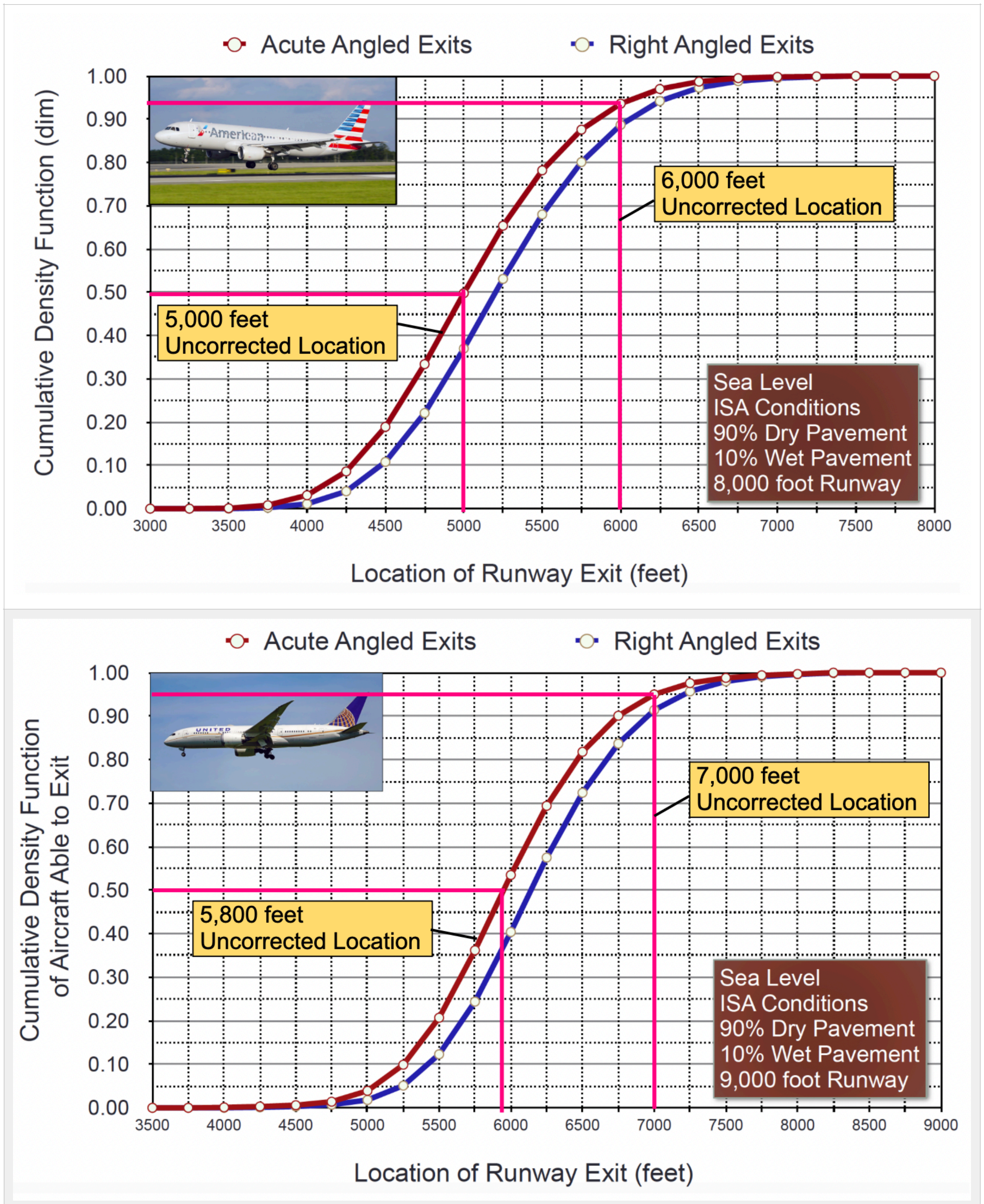


Figure 1.1. First-Order Method to Locate High-Speed Runway Exits. Top Figure is for AAC C Group Aircraft. Bottom Figure is for AAC D Group Aircraft.

Table 1.1 Sea Level and 2,800-foot Elevation Corrected High-Speed Runway Exit Locations. Used 150 feet Increase for Every 1,000 feet in Elevation.

AAC Group	Sea Level Location of First High-Speed Runway Exit (feet)	Sea Level Location of Second High-Speed Runway Exit (feet)	2,800-ft Elevation Location of First High-Speed Runway Exit (feet)	2,800-ft Elevation Location of Second High-Speed Runway Exit (feet)
C	5000	6000	5420	6420
D	5800	7000	6220	7420

Two possible methods to locate the runway exits based on information on Table 1.1:

1) Use the AAC group with highest operations at the airport (AAC C).

2) Use a weighted average approach considering the percentages of each AAC group.

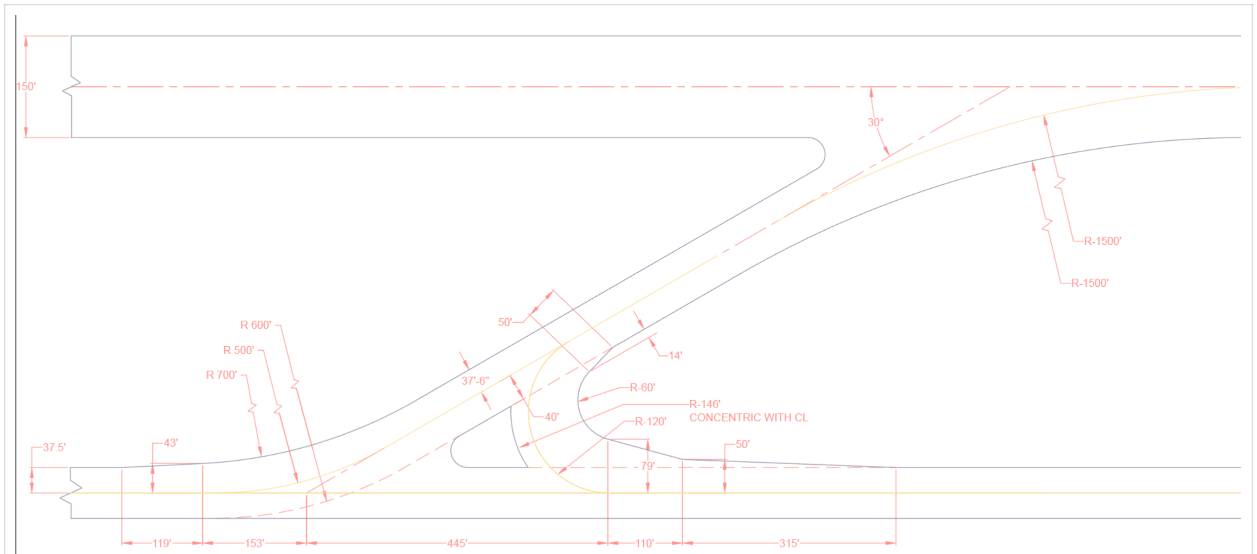
Table 1.2 Two Methods to Locate High-Speed Runway Exits. The Weighted Average Method Ignores the 5% of AAC C.

Method	Adjusted Location of First High-Speed Runway Exit (feet)	Adjusted Location of Second High-Speed Runway Exit (feet)
High Operations	5420	6420
Weighted Average	5628	6680

b) Recommend the runway centerline to taxiway centerline distance for the new runway.

Since most aircraft in AAC D are ADG V (TDG Groups 5 and 6), use 600 feet of recommended distance between the runway and taxiway centerlines. This makes the high-speed exits more effective.

c) Use the FAA high-speed templates (https://www.faa.gov/airports/engineering/airport_design) to draw (in CAD) the high-speed runway exit "Foxtrot" (F) in Figure 1. State the aircraft and taxiway design groups used in your analysis.



HIGH-SPEED EXIT FOR TDG-5 - 600' TO 150' RUNWAY

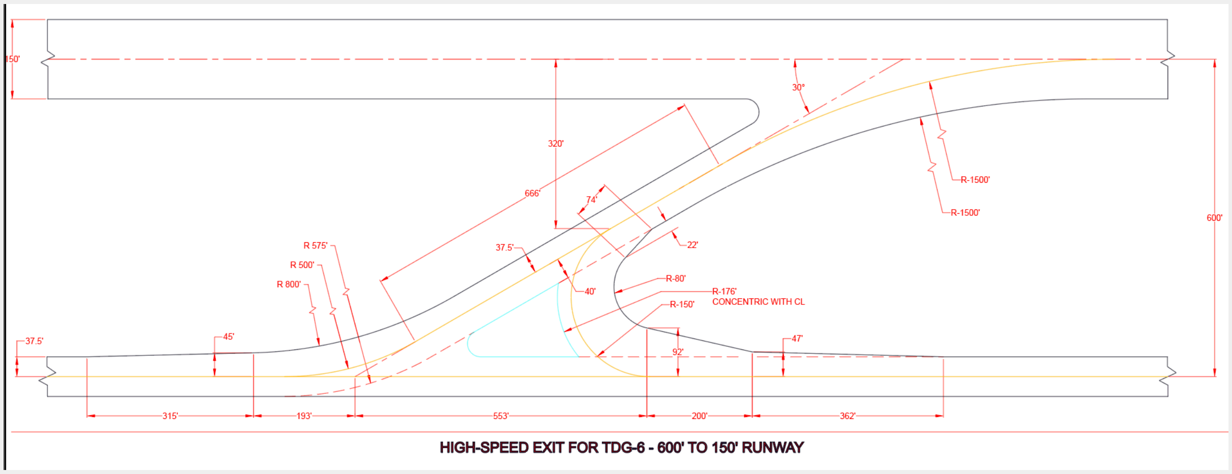


Figure 1.2. High-Speed Runway Exits for TDG 5 (top) and TDG 6 (Bottom).

Most aircraft in AAC D are ADG V (Belonging to TDG Groups 5 and 6), use 600 feet of recommended distance between the runway and taxiway centerlines. Figure 1.2 shows the two possible solutions for your design. There are several latest generation aircraft in TDG 6 (Boeing 787-10, Airbus A350-1000, etc.), hence a TDG 6 design is recommended.

d) Estimate the minimum centerline distance between runway exit centerlines H and I.

Use the taxiway-to-taxiway dimensional standards (see Table 4-1 in FAA AC 150/5300-13B). A partial table is reproduced below. For ADG V the recommended distance between centerlines is 249.5 feet. For ADG VI the recommended distance between centerlines is 298.5 feet.

Item	ADG					
	I	II	III	IV	V	VI
Taxiway and Taxilane Separation						
Taxiway centerline to parallel taxiway centerline [1]	70 ft (21.3 m)	101.5 ft (30.9 m)	144.5 ft (44.0 m)	207 ft (63.1 m)	249.5 ft (76.1 m)	298.5 ft (91.0 m)

Figure 1.4. FAA Design Criteria for Taxiway Design Standards (Partial Table 4-1).

e) Draw in CAD the dimensions of runway exit **H**. Your drawing should show the complete runway entrance from runway to parallel taxiway (no half solution is acceptable). Show the dimensions of your design in your drawing including the radius of the right-angle centerline and associated dimensions W0-W3, L1-L3, and three radii.

Use the FAA Fillet Design Tool to design a 90-degree (right-angle) runway exit for TDG 6. Figure 1.5 shows the dimensions obtained using the FAA Fillet Design Tool for TDG 6. I used a centerline radius of 150 feet instead of the minimum radius of 115 feet. The additional radius reduces the steering angle from 50 to 42 degrees.

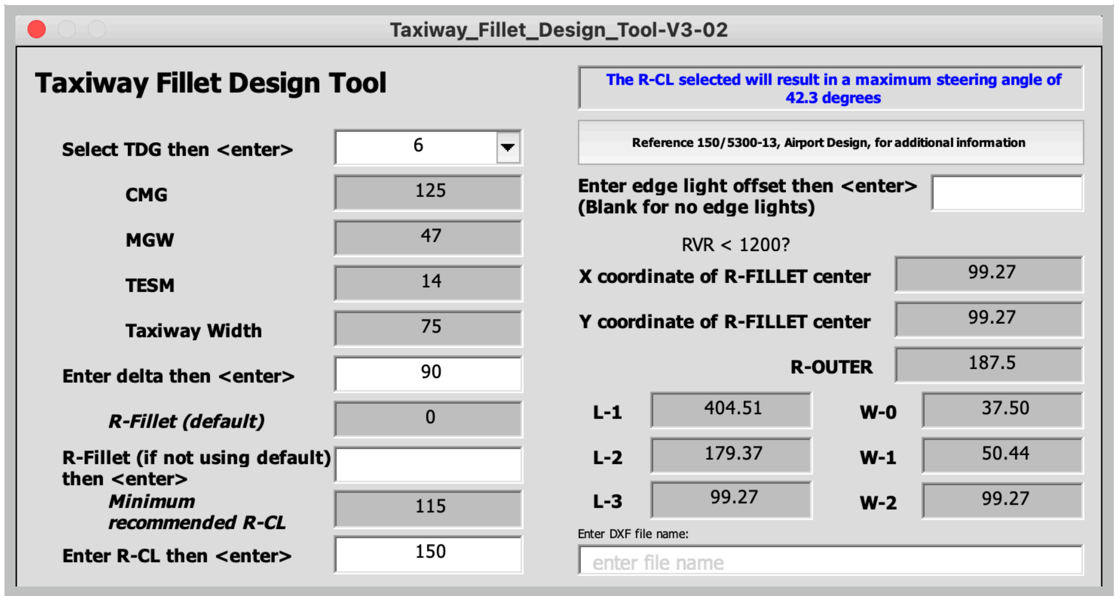


Figure 1.5. TDG 6 90-Degree Taxiway Fillet Dimensions with Centerline Radius 150 feet (42.3 Degrees Steering Angle). The Minimum Centerline Radius is 115 feet.

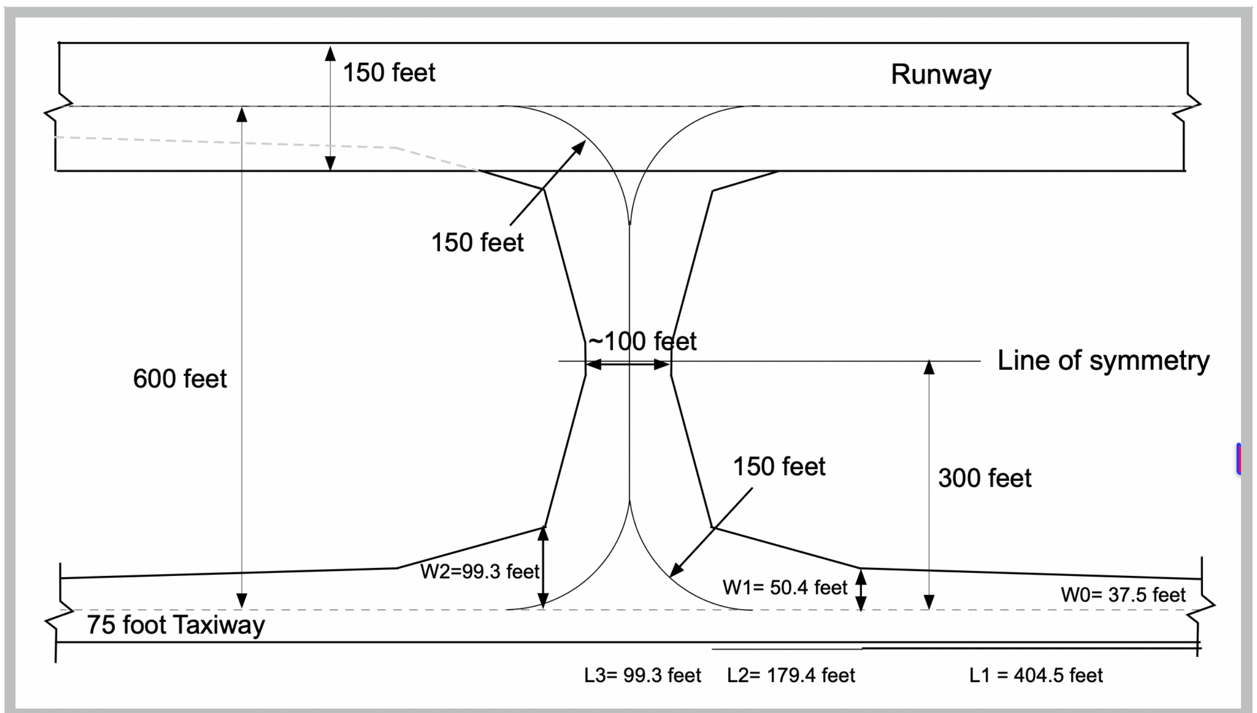


Figure 1.6. Runway Entrance Hotel Design Using TDG 6 Dimensions.

Figure 1.5. Runway Entrance Hotel (H) for the Problem.

Figure 2. Airbus A350-1000 at Atlanta Hartsfield International Airport (A. Trani).

Problem 2

Use the latest version (4.02) of the Runway Exit Design Model (REDIM) developed by Virginia Tech for FAA to evaluate the performance of your first-order analysis in Problem 1. Table 1 shows the fleet mix to be used in Problem 2. In the analysis, use the exit locations proposed in Problem 1.

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

https://atsl.cee.vt.edu/products/runway-exit-design-interactive-model--redim-1.html

The MATLAB Runtime should install automatically with the REDIM install. However, if the model fails to install the MATLAB runtime, 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.

Assume an operating temperature of 83 deg.F. and use 90% dry pavement conditions. Run your analysis with Pilot Motivation Factors of 1.0 (default).

Table 1. Aircraft Fleet Mix to Model Runway Occupancy Times for Problem 2. Use the Exit Locations Obtained in Problem 1.

Aircraft ID	Aircraft	Fleet Mix (%)
E55P	Embraer Phenom 300	5
A320	Airbus 320	35
B738	Boeing 737-800	20
B712	Boeing 717-200	10
E190	Embraer 190	10
B737	Boeing 737-700	15
A35K	Airbus 350-1000	5

Aircraft ID	Aircraft	Fleet Mix (%)
Totals		100

a) Estimate the weighted average runway occupancy time (ROT) and the standard deviation of ROT on the runway considering the fleet mix in Table 1.

Runway Exit	Location at Point of Curvature (feet)	Type of Exit
F	5628	High-speed (1500-ft radius)
G	6680	High-speed (1500-ft radius)
H	9350	Right-angle (150 ft. radius)
I	9600	Right-angle (150 ft. radius)

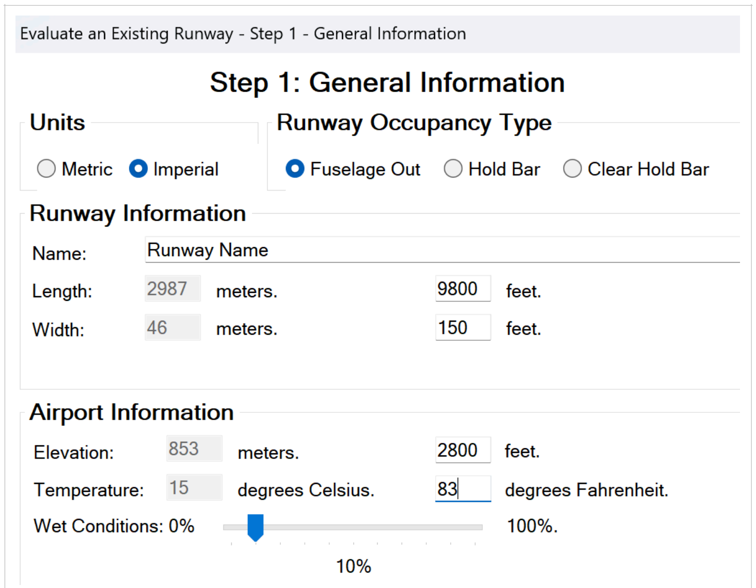


Figure 2.1 REDIM 4 Inputs for Problem 2. Step 1.

Evaluate an Existing Runway - Step 2 - Define Aircraft Mix for New Runway

Step 2: Define Aircraft Mix for New Runway

Only provide the aircraft mix for the left or right side of the runway you are modeling.

Aircraft ID	Aircraft Name	Aircraft Design Group	Aircraft Approach Category	Aircraft Mix (%)	Motivation Factor
AT73	Aeropatiale ATR-72-300	III	B		1
AT74	Aeropatiale ATR-72-400	III	B		1
AT75	Aeropatiale ATR-72-500	III	B		1
AT76	Aeropatiale ATR-72-600	III	B		1
B37M	Boeing 737 MAX 7	III	C		1
B38M	Boeing 737 MAX 8	III	D		1
B39M	Boeing 737 MAX 9	III	D		1
B712	Boeing 717-200	III	C	10	1
B721	Boeing 727-100	III	C		1
B722	Boeing 727-200	III	C		1
B732	Boeing 737-200	III	C		1
B733	Boeing 737-300	III	C		1
B734	Boeing 737-400	III	C		1
B735	Boeing 737-500	III	C		1
B736	Boeing 737-600	III	C		1
B737	Boeing 737-700	III	C	15	1
B738	Boeing 737-800	III	D	20	1
B739	Boeing 737-900	III	D		1
B73Q	Boeing 737-200 Quick Conversion	III	C		1
BCS1	Airbus A220-100	III	C		1

Figure 2.2 REDIM 4 Inputs for Problem 2. Step 2.

Runway Exit Locations

(Runway Name)

Exit	Exit Status	Exit Geometry	Point Of Curvature Location (ft)
F	Open	30 degree High Speed	5,627
G	Open	30 degree High Speed	6,680
H	Open	90 degree	9,350
I	Open	90 degree	9,600

Figure 2.3 REDIM 4 Inputs for Problem 2. Step 3.

The Runway Exit Design Model (REDIM) predicts a weighted average ROT of 61.5 seconds (see Figure 2.4)

Runway Occupancy Times (61.5 s - Std Dev: 16.8 s) - All

(Runway Name)

Aircraft Name	F	G	H	I
A320	44.6s	52.3s	82.4s	78.7s
A35K	48.5s	55.8s	86.3s	80.4s
B712	42.3s	49.7s	81.7s	79.3s
B737	46.3s	53.1s	83.9s	79.9s
B738	43.4s	50.3s	79.9s	74.1s
E190	46.6s	53.5s	83.9s	79.0s
E55P	55.9s	61.5s	94.7s	95.8s

Figure 2.4 Predicted Runway Occupancy Times by Aircraft and by Exit.

Runway Exit Aircraft Assignment - All

(Runway Name)

Aircraft Name	F	G	H	I	Aircraft Mix
A320	21.8%	39.5%	37.8%	0.9%	35.0%
A35K	12.4%	32.0%	54.1%	1.4%	4.9%
B712	15.7%	43.0%	39.8%	1.5%	9.6%
B737	35.0%	40.9%	23.8%	0.3%	15.3%
B738	16.5%	42.3%	40.3%	0.9%	20.1%
E190	40.3%	34.9%	24.1%	0.6%	10.2%
E55P	66.2%	17.8%	14.7%	1.2%	5.0%
Exit Mix	25.8%	38.7%	34.6%	0.9%	

Figure 2.5 Predicted Runway Exit Use by Aircraft and by Exit.

b) Show me the runway exit configuration diagram provided by REDIM 4. The runway configuration diagram is a plot of the location of the runway exits done by REDIM.

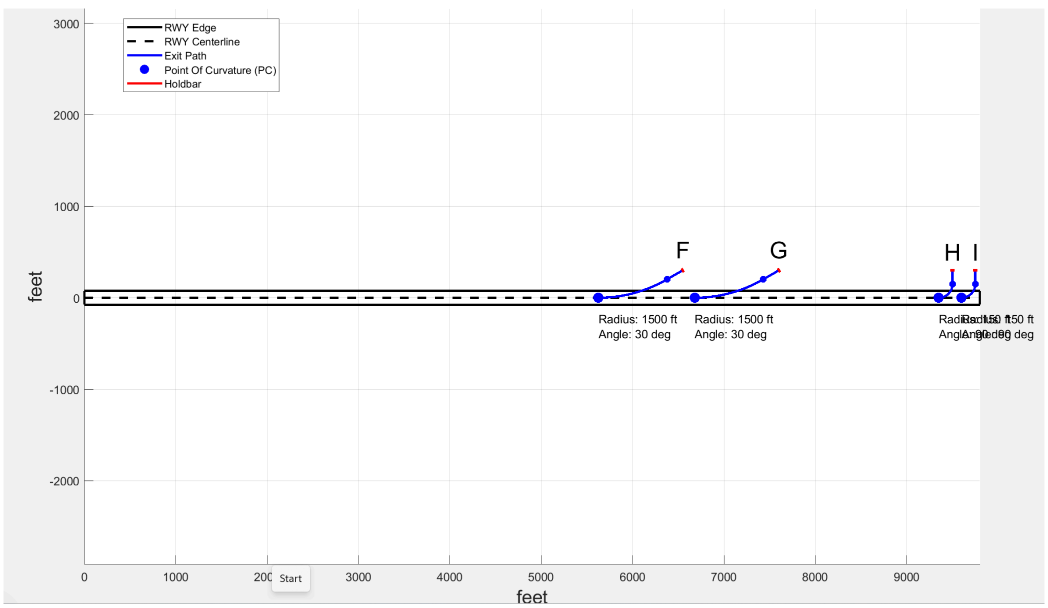


Figure 2.6 Runway Exit Diagram (only Eastflow Operations Shown).

c) Estimate the percent of Airbus A320 landings likely to use each of your two proposed high-speed runway exits (F and G in Figure 1) after the analysis done in Problem 1. Show the full table of runway exit assignments provided by the model.

21.8% of Airbus A320 may use the high-speed exit F. 39.5% of Airbus A320 may use the high-speed exit G.

d) Estimate the percent of Boeing 737-800 landings likely to use each of the two proposed high-speed runway exits (F and G in Figure 1) after the analysis done in Problem 1.

16.5% of Boeing 737-800 may use the high-speed exit F. 42.3% of Boeing may use the high-speed exit G.

e) Compare the runway exit utilization of the Embraer 190 and the Boeing 737-800 on both high-speed runway exits. Comment on the reasons for possible differences.

The Embraer 190 may use the high-speed exit F 40.3% compared to only 16.5% for the Boeing 737-800 for exit F. The Boeing 737-800 shows higher utilization of exit G (42.3%) compared to the E190 (34.9%).

f) Show me a plot of REDIM 4 with runway occupancy times for each exit and aircraft.

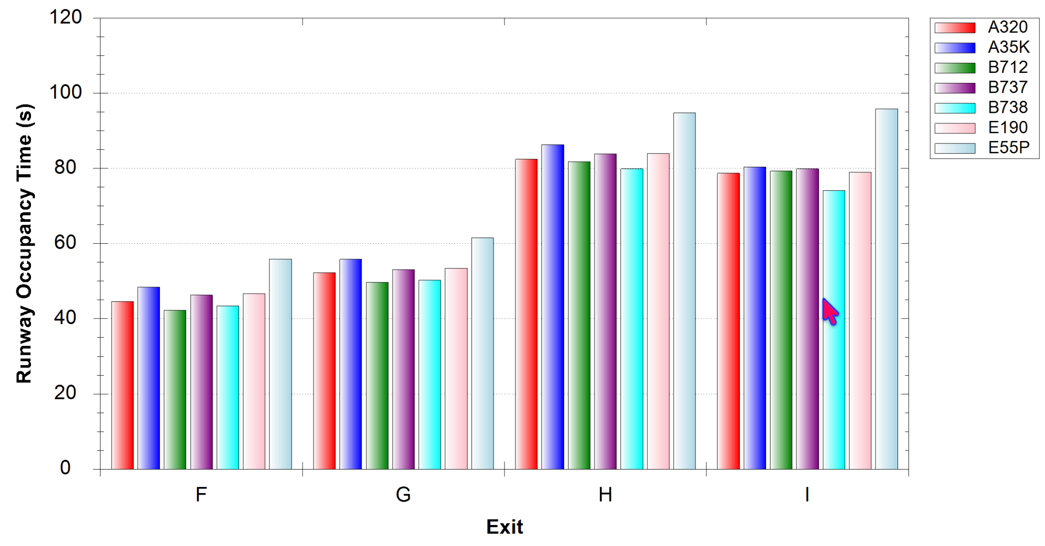


Figure 2.7 ROT Plot.

Further optimization. The ROT times and runway exit use suggest that moving the first high-speed exit further downrange may reduce the ROT time.

Example: Move Runway Exit F to 6620 feet (location for AAC D group) and move the runway exit G to 7420 feet yields an ROT of 58.8 seconds (see Figure 2.8).

Runway Occupancy Times (58.8 s - Std Dev: 10.9 s) -

(Exits_6620_7420ft)

Aircraft Name	F	G	H	I
A320	53.3s	57.5s	79.9s	78.4s
A35K	56.6s	60.2s	82.9s	79.6s
B712	50.5s	54.6s	79.1s	78.1s
B737	54.7s	58.4s	81.4s	83.2s
B738	51.3s	54.7s	77.0s	74.1s
E190	55.6s	58.3s	80.5s	81.9s
E55P	66.5s	67.5s	92.7s	94.2s

Runway Exit Aircraft Assignment - All

(Exits_6620_7420ft)

Aircraft Name	F	G	H	I	Aircraft Mix
A320	59.2%	23.1%	16.7%	0.9%	35.0%
A35K	42.1%	29.5%	27.1%	1.3%	4.9%
B712	55.9%	26.7%	16.2%	1.2%	9.6%
B737	74.2%	16.4%	9.2%	0.2%	15.3%
B738	56.1%	25.9%	16.9%	1.1%	20.1%
E190	73.9%	16.3%	9.4%	0.4%	10.2%
E55P	84.3%	8.8%	6.4%	0.6%	5.0%
Exit Mix	62.5%	21.9%	14.8%	0.8%	

Figure 2.8 Predicted Runway Exit Use by Aircraft and by Exit with Runway Exit Locations Favoring AAC D Group.

Problem 3

Perform an evaluation of the runway exits at Charlotte International Airport runway 36L. **Use the Landing Event Database** developed by Virginia Tech for the FAA in the analysis. In your analysis consider all the operations in calendar year 2019.

a) Estimate the percent of Airbus 320neo (A20N) using high-speed runway exits W7 and W8.

Table 3.1 Airbus A320neo Use of Runway Exits W7 and W8 at CLT Runway 36L.

Runway Exit	Percent of Aircraft Using Exit (%)	Fuselage Out ROT Time (seconds)
W7	91.7	48.0
W8	8.3	61.9

b) For part(a), find the runway occupancy times (fuselage out) associated with Airbus A320neo operations for W7 and W8.

c) Estimate the percent of Boeing 737-900 (B739) using high-speed runway exits W7 and W8.

Table 3.2 Boeing 737-800 Use of Runway Exits W7 and W8 at CLT Runway 36L.

Runway Exit	Percent of Aircraft Using Exit (%)	Fuselage Out ROT Time (seconds)
W7	81.5	44.5
W8	18.5	52.0

d) Compare the landing performance of the A320neo and the B737-900 on runway 36L.

The Boeing 737-800 has higher approach speeds (AAC D) compared to the Airbus A320neo (AAC C). The exits W7 and W8 favor the Boeing 737-800 because it uses slightly longer landing distances. The ROT times for the Boeing 737-800 using W8 is almost 9 seconds lower than the Airbus A320neo.

e) Compare the landing performance of the A320neo/ B737-900 on runway 36L with wide body aircraft like the Boeing 777-200 and Boeing 767-300. Compare the ROT times and the runway exit utilization.

The Boeing 737-900 has higher approach speeds (AAC D) compared to the Airbus A320neo (AAC C). 60% of Boeing 737-900 landings use exit W7 compared to 91.7% for the Airbus A320neo.

The Boeing 777-200 (and 777-300) has higher approach speeds (AAC D) compared to the Airbus A320neo (AAC C). The Boeing 777 has longer distances. 100% of Boeing 777 landings use exit W8 compared to 91.7% for the Airbus A320neo.

f) Based on the average ROT values reported for runway 36L for A320neo and Boeing 737-900, does runway 36L qualify for minimum radar separations? Explain.

The weighted average ROT times for the Airbus A320neo and Boeing 737-900 are 49.1 and 49.2 seconds, respectively. The runway qualifies for reduced separation minima (I.e., 2.5 nm separations).