Final Assignment for CEE 4674 (15 Points of Grade per Syllabus)

Solution
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Problem 1

Prior to Covid-19, Atlanta International Airport had a peak demand flow of 10,800 passengers per hour (one-way) traveling from various concourses to the main terminal (see Figure 1). The Bombardier Innovia APM 100 system consists of Transit Units (TU) with four cars holding up to 70 passengers per car (at maximum capacity).

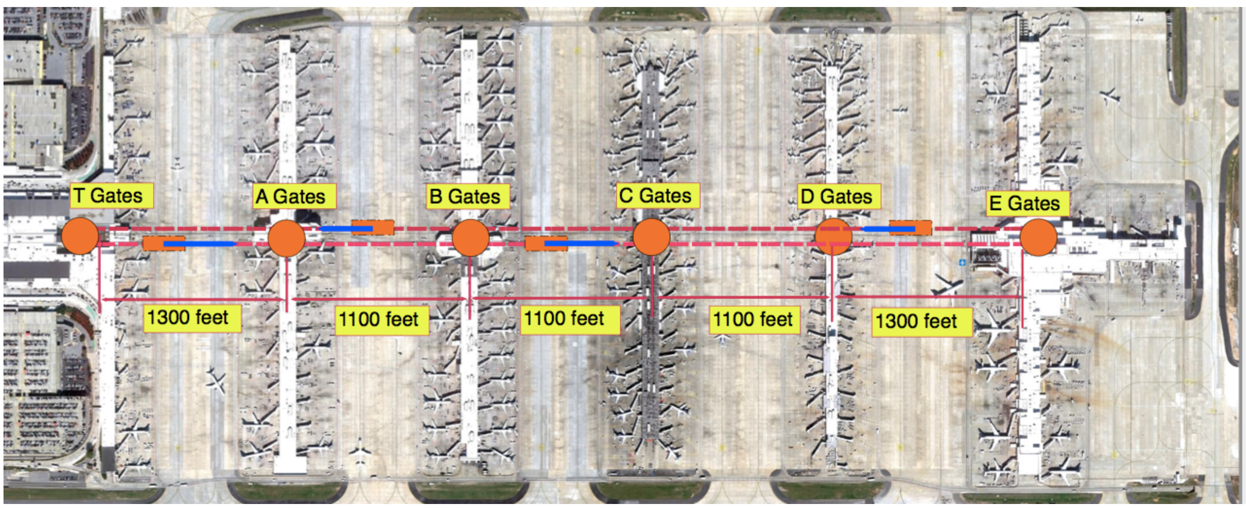
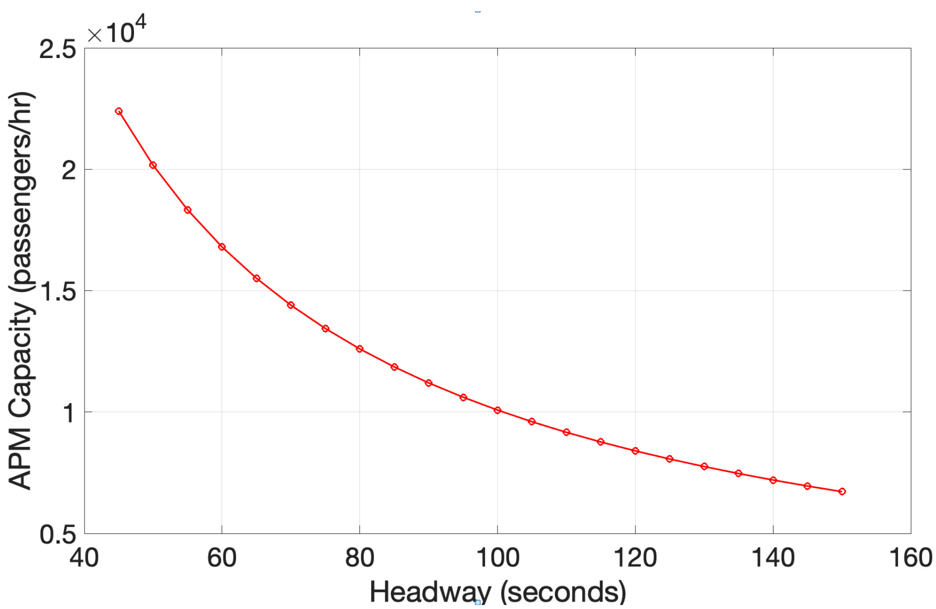


Figure 1. Atlanta APM System Layout.

a) Estimate and plot the capacity of APM system for headways ranging from 1 to 2 minutes. Estimate the recommended headway to handle the peak load.



To handle 10,800 passengers per hour (one direction) we need a ~94 second headway.

b) Use the FAA Terminal Area Forecast (TAF) to estimate the future passenger demand (enplanements) at ATL in the year 2045.

82.7 million passenger emplacements (passengers boarding an aircraft in Atlanta). This is an increase of 55.4% in passengers enplanements in 2045.

c) Assume the peak passenger flow using the APM system will increase proportionally with the changes in enplanements reflected in the FAA forecast. Find if the ATL APM system will be adequate in 2045. State any changes you may recommend to satisfy the passenger needs at the airport.

Peak passenger demand in 2045 could be 16,800 passenger/hr. The headway needed to accommodate the future demand is 60 seconds if the transit units remain at 4 vehicles.

Problem 2

a) Estimate the Day-Night Average Noise Level - DNL (or LDN) for three locations (A,B, and C) shown in Figure 2. The points of interest are located underneath the flight path of runway 27R. Runway 27R is only used for arrivals at the airport. For this problem assume the noise contribution of arrivals two runway 27L and 28C can be ignored to simplify the problem. Runway 27R is mostly used by regional aircraft such as the Embraer 145 and narrow-body aircraft represented by the Boeing 737-700. The Sound Exposure Level data is provided in class. The glide slope to runway 27R is three degrees according to the ILS approach procedure. In your calculations, assume aircraft touchdown ~1,000 ft from the runway threshold.

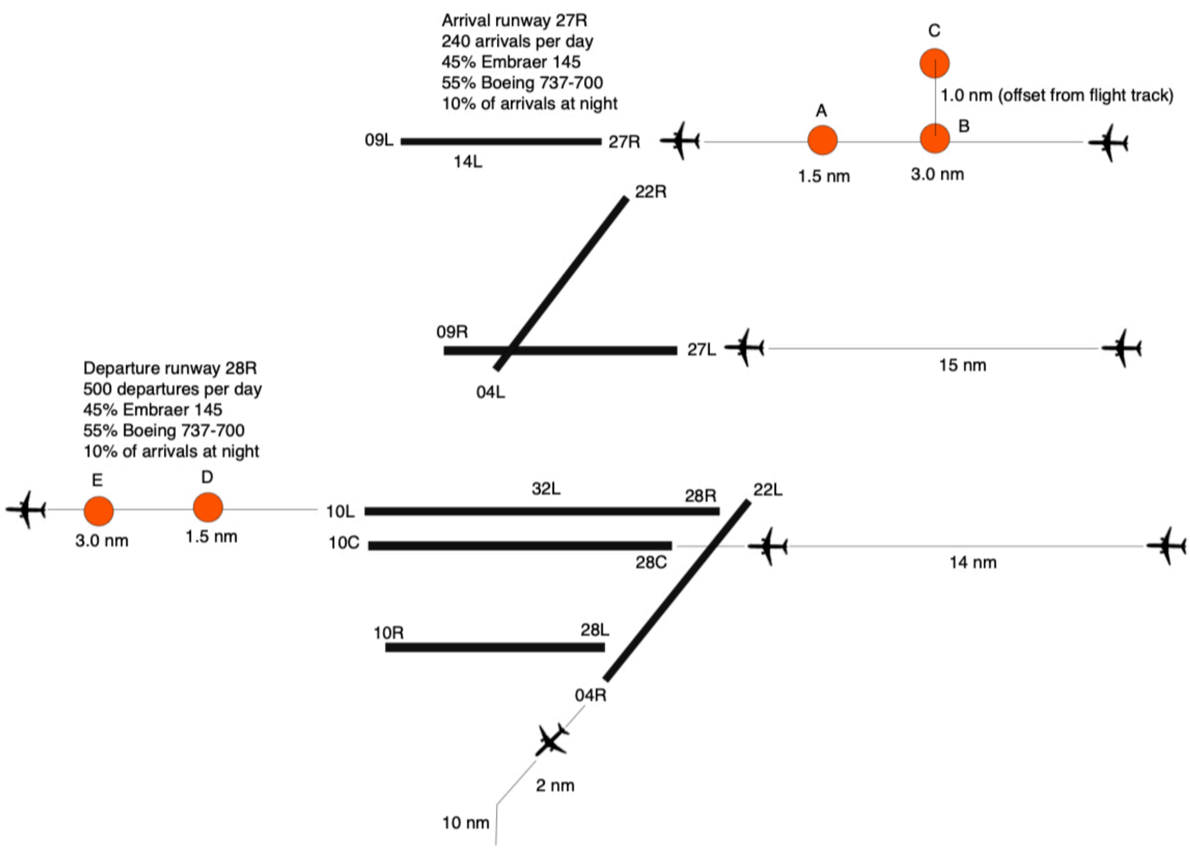


Figure 2. Chicago ORD Airport Configuration. Westflow Configuration.

Table with Landing Noise Data Analysis for Points A, B, and C

Point in Space	Distance to Observer (3-degree slope)	SEL Level (dBA)	Total DNL Level (dBA) at the Location of Interest	Percent of US Population Highly Annoyed
A for Embraer 145	530	86.8	64.9	~65%
A for Boeing 737-700	530	89.4		
B for Embraer 145	1,006	82.3	61.1	~51%
B for Boeing 737-700	1,006	84.8		
C for Embraer 145	6,163	66.5	44.2	< 10% (extrapolation)
C for Boeing 737-700	6,163	68.7		

Example DNL calculation for an observer located at Point C:

Daytime operations for E145 = 97.2

Daytime operations for B737 = 118.8

Nighttime operations for E145 = 10.8

Nighttime operations for B737 = 13.2

$$L_{DN} = 10log\left[\frac{1}{T}\sum_{i=1}^{N}10^{(SEL_i+W)_i/10}\right]$$

L_{DN} = Day-night Sound Level (dbA)

SEL_i = Sound exposure level associated with the ith flyover

T = Reference time (86,400 seconds in 24 hrs)

DNL=10*log10(1/86400*(97.2*10^(66.5/10)+118.8*10^(68.7/10)+10.8*(76.5/10)+13.2*10^(78.7/10)))

The black numbers in the equation above are adjusted SEL levels for nighttime operations (+10 dBA).

DNL = 44.2 dBA at point C

b) Explain the type of compatible land uses that you could expect at locations A, B and C based on the DNL noise levels calculated.

c) Estimate the percent of the US population that will be annoyed at locations A, B, and C. Use the US average response survey published by the FAA.

d) Estimate the Day-Night Average Noise Level - DNL (or LDN) for departure runway 28R at locations (D and E) shown in Figure 2. Assume the aircraft fly departure profiles at 170 knots and with typical climb rates of 2,400 feet/minute. Boeing 737-700 and E145 typically use 7,500 feet of runway while departing runway 28R.

Runway 28R is 13,000 feet long. The takeoff (or liftoff) point is 7,500 feet down the runway. Therefore at point D, the aircraft has traveled 14,614 feet (2.4 nautical miles). At 170 knots, it takes 50.9 seconds to reach point D after liftoff. Using the average climb rate of 2400 ft/minute, the aircraft reaches 2,037 feet over the observer (altitude above ground level). At point E, the altitude above ground level is estimated to be 3,308 feet above ground level.

Table with Departure Noise Data Analysis for Points D and E

Point in Space	Distance to Observer (3-degree slope)	SEL Level (dBA)	Total DNL Level (dBA) at Each Location	Percent of US Population Highly Annoyed
D for Embraer 145	2,037	82.7	69.3	~76%
D for Boeing 737-700	2,037	91.3		
E for Embraer 145	3,308	78.8	65.5	~67%
E for Boeing 737-700	3,308	87.4		

Example DNL calculation for an observer located at Point D:

Daytime operations for E145 = 202.5

Daytime operations for B737 = 247.5

Nighttime operations for E145 = 22.5

Nighttime operations for B737 = 27.5

$$L_{DN} = 10 log\left[\frac{1}{T}\sum_{i=1}^{N} 10^{(SEL_i + W)_i/10}\right]$$

L_{DN} = Day-night Sound Level (dbA)

SEL_i = Sound exposure level associated with the ith flyover

T = Reference time (86,400 seconds in 24 hrs)

DNL=10*log10(1/86400*(202.5*10^(82.7/10)+247.5*10^(91.3/10)+22.5*(92.7/10)+27.7*10^(101.3/10)))

DNL = 69.3 dBA at point D

e) Compare the arrival DNL with departure DNL levels.

Aircraft require higher engine thrust levels on departure and thus generate higher noise levels (SEL values). Therefore, the DNL levels tend to be higher for departure operations. Note that aircraft climb at higher rates compared to arrivals (typical departure flight path angle is 8 degrees instead of 3 degrees for arrival). That mitigates the noise a little bit. Still, departure noise contours are longer than those of the arrival operations.

Aircraft Sound Exposure Level Data (Source: FAA Integrated Noise Model and AEDT 3d Model)

Table 1. Sound Exposure Level Data for Embraer 145 Aircraft. Departure Operation with 6,000 lbs. of Thrust per Engine (Takeoff Thrust). Rolls-Royce AE3007 Engine.

Distance (feet)	SEL Level (dBA)
200	96.7
400	93.0
630	90.3
1000	87.5
2000	82.8
4000	77.2
6300	72.8
10000	67.7
16000	61.6
25000	54.9

Table 2. Sound Exposure Level Data for Embraer 145 Aircraft. Arrival with 3,000 lbs. of Thrust per Engine (Approach Thrust). Rolls-Royce AE3007 Engine.

Distance (feet)	SEL Level (dBA)
200	92.7
400	88.6
630	85.6
1000	82.3
2000	77.0
4000	70.9
6300	66.3
10000	61.0
16000	54.8
25000	47.9

Table 3. Sound Exposure Level Data for Boeing 737-700 Aircraft with CFM565 Engine. Departure Operation with 22,500 lbs. of Thrust per Engine (Takeoff Thrust).

Distance (feet)	SEL Level (dBA)
200	106.5
400	102.4
630	99.6
1000	96.4
2000	91.4
4000	85.7
6300	81.5
10000	76.5
16000	70.8
25000	64.3

Table 4. Sound Exposure Level Data for Boeing 737-700 Aircraft with CFM565 Engine. Arrival Operation Thrust Level (6,000 lbs of thrust).

Distance (feet)	SEL Level (dBA)
200	97.4
400	91.6
630	88.2
1000	84.8
2000	79.3
4000	73.1
6300	68.5
10000	63.3
16000	57.1
25000	50.6