

## Assignment 10: Final Project

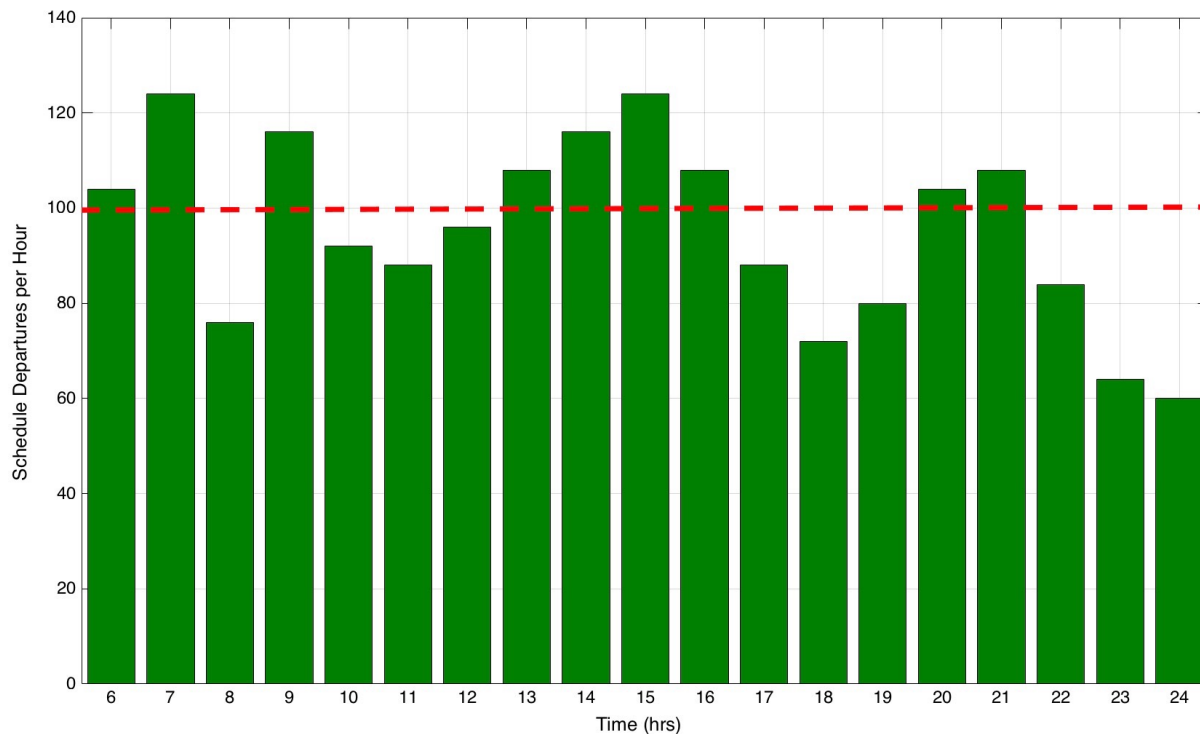
**Due: May 4, 2017 (via email and PDF)**

**Final Exam Time is May 5**

**Requirements for this assignment are: a) Slide presentation and b) 10+ page report with your findings.**

### Problem 1

Before embarking on a very expensive and ambitious runway reconfiguration project (see Figure 2), the Chicago O'Hare International Airport had a departure saturation capacity of 25 departures per 15-minute period (see red line in Figure 1). The airport is a major hub for United and American Airlines and back in 2001—2004 had a departure demand as shown in the blue line of Figure 1. The departure saturation capacity has been estimated using 2 independent runways for departures.



*Figure 1. Old IMC Departure Saturation Capacity (red line) and Scheduled Departure Profile for ORD Airport.*

The values of the departure demand ( $d$ ) at times ( $t$ ) are:

$t = [6$	7	8	9	10	11	12	13	14	15	16	17	18
19	20	21	22	23	24];							
$d = [104$	124	76	116	92	88	96	108	116	124	108	88	72
80	104	108	84	64	60];							

- Convert the graph shown to numerical values of departure demand over time.
- Estimate the aircraft departure queues that were likely to be experienced for the conditions shown in Figure 1.
- For the baseline year (2004), estimate the average delay per departure at ORD using the unsteady queueing model presented in class.
- Suppose that after the reconfiguration (to be completed in the year 2020), the departure capacity per hour increases to 130 departures per hour using 3 independent runways. In the year 2020, the new departure demand is expected to be 13% higher than that recorded in the year 2004 (assume each cell in the demand vector given above is just increased by 13%). Estimate the new delays at the airport. Assume the demand function remained the same. Was the additional runway needed for this airport?

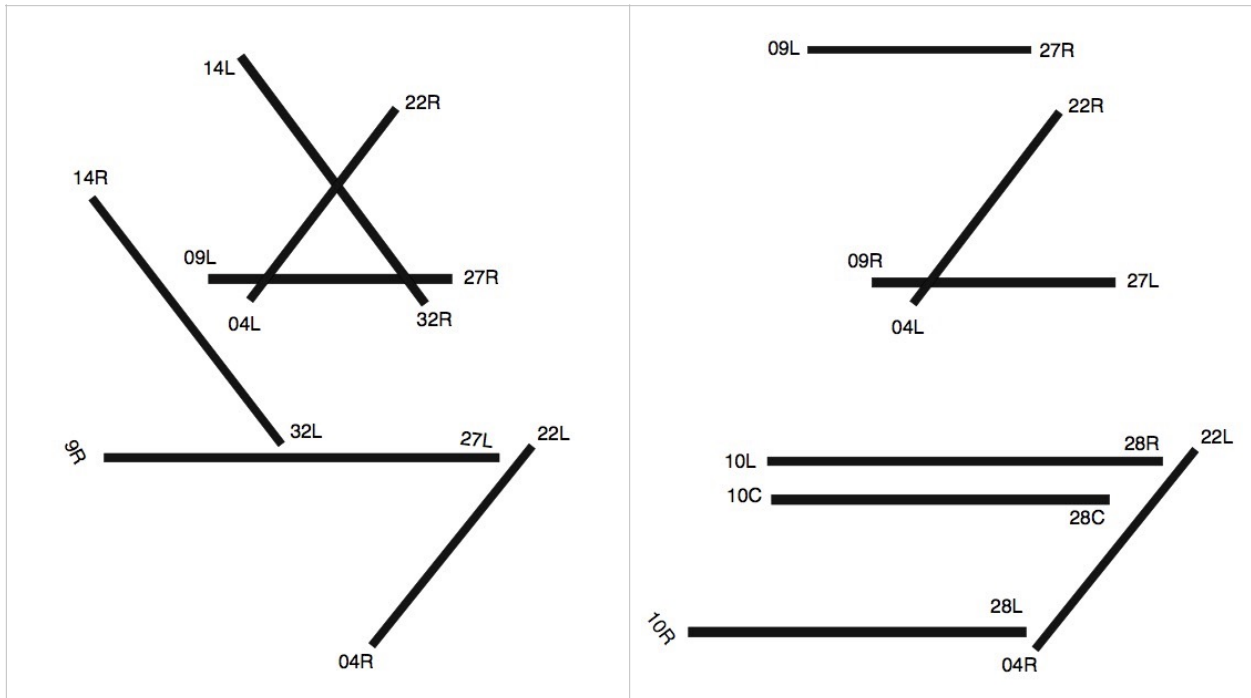


Figure 2. ORD Airport Layouts. Left-Hand side is the Original Runway Configuration (2004). Right-hand Side is the Reconfigured Airfield in the year 2018.

## Problem 2

Table 1 illustrates the typical aircraft fleet mix operating at ORD Airport in the typical day. This aircraft mix will be used to estimate the airport runway and gate capacity needs for the airport in the year 2020. In the typical day of the year 2016, the airport handled **2,580 operations daily**. Half of them arrivals and the other half departures. Recent airport data suggests 135 departures and 135 arrivals occur at night between 10 PM and 7:00 AM in the morning. The simplified fleet mix operating at the airport is shown in Table 1. The table also shows the average stage length (miles flown) by each departure.

Table 1. ORD Fleet Mix and INM Aircraft to be Used in the Study.

Aircraft	% Fleet Mix in 2014	INM Aircraft to Use	Wake Class	Average Stage Length Flown (statute miles)
Embraer 145	30	E145	Large	335
B737 (700-900)	11	737700	Large	1260
747-8/A380	4	747400	Super-heavy	5200
B767	5	767CF6	Heavy	3656
B757	2	PW2040	B757	1230
A320 (318-321)	10	A320-232	Large	1170
CRJ (200-900)	13	CL601	Large	359
CRJ 700	18	CRJ700	Large	460
B777 (200-300)	7	777300	Heavy	6534
Total	100			

Using the arrival-arrival and departure-departure separation matrices shown in Tables 2 and 3, determine the IMC saturation capacity of the airport for West Flow operations. West-flow operations assume runways 27R, 27L and 28C are used for arrivals. Runways 28R and 22L are used for departures (see Figure 2). Note that departure operations on runway 22L are NOT independent of arrival operations on runway 28C. This needs to be considered in your analysis. For guidance, assume controllers release a departure on runway 22L when an arrival to runway 28C is 2 nm from the runway 28C threshold. If the gap is not met, the departure on runway 22L has to wait.

Assume the ROT values at the airport for 5 wake classes are: 52 (small), 56 (large and B757), 63 (Heavy) and 83 (Superheavy) seconds. The approach speeds (in knots) derived from radar data are: 127 (small), 138 (large), 140 (B757), 152 (Heavy) and 152 (Superheavy). The airport has the following technical parameters: a) in-trail delivery error of 12 seconds, b) departure-arrival separation for IMC conditions is 2 nautical miles, c) probability of violation is 5%. Arriving aircraft are "vectored" by ATC to the final approach fix located 9 miles from the runway threshold.

**Table 2. Arrival-Arrival Separation Matrix. IFR Conditions.**

Minimum Separation Matrix (nm)		Arrivals-Arrivals				
Lead (column 1)	Trailing Aircraft (Header Columns)					
	Small	Large	B757	Heavy	Superheavy	
Small	2.5	2.5	2.5	2.5	2.5	
Large	4	3	2.5	2.5	2.5	
B757	5	4	3	3	2.5	
Heavy	6	5	4	4	4	
Superheavy	10	10	10	10	10	

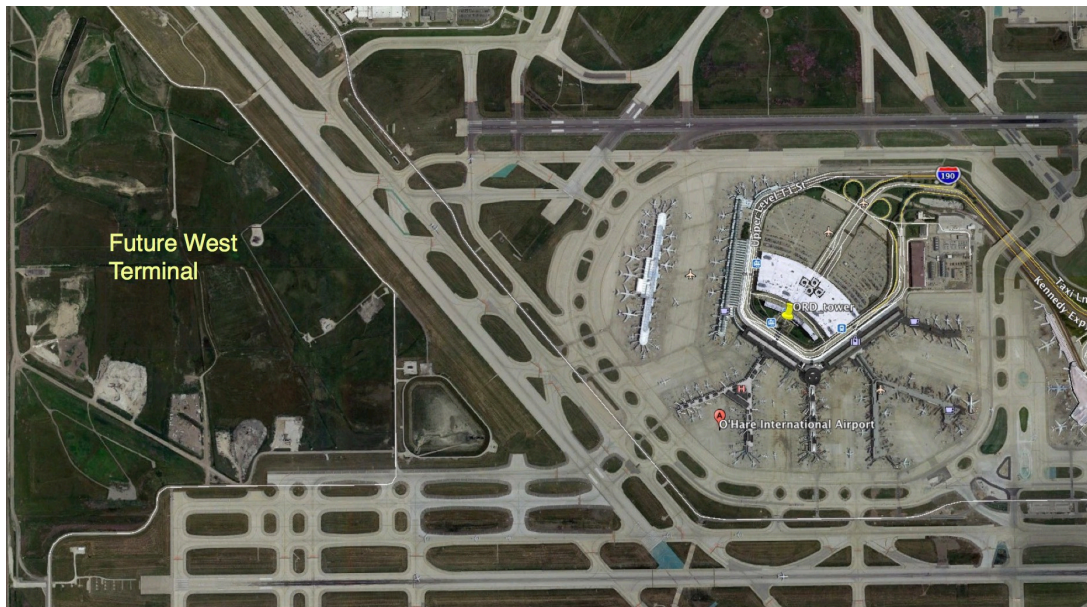
**Table 3. Departure-Departure Separation Matrix. IFR Conditions.**

Departure-Departure Separation Matrix (seconds)						
Lead (column 1)	Trailing Aircraft (Header Columns)					
	Small	Large	B757	Heavy	Superheavy	
Small	60	60	60	60	60	60
Large	90	60	60	60	60	60
B757	120	120	60	60	60	60
Heavy	120	120	120	120	120	90
Superheavy	150	120	120	120	120	120

- a) Plot the complete Pareto capacity diagram for VFR conditions at the airport. Label appropriately.

## Problem 3

ORD airport seems to have a shortage of gates (can read article <http://www.chicagotribune.com/news/columnists/ct-ohare-noise-study-met-0604-20150603-story.html>). The airport master plan expects a new West terminal to be constructed in airport land shown in Figure 3. The ultimate plan for this airport is to accommodate 3,070 flight daily (270 flights during the peak hour).



*Figure 3. Proposed Site of ORD West Terminal.*

- a) Design the basic layout of a West terminal capable of handling a minimum of 6 ADG VI, 10 ADG V aircraft and 20 ADG IV or III aircraft simultaneously. You are free to use any of the 4 basic landslide configurations described in class. The analysis should have enough detail to specify distances from existing runways and taxiways to comply with FAR 77 and TERP criteria. Also, provide enough dimensions to satisfy apron movement requirements for all the gates. In your design consider the following constraints:
- Runway 15-33 (old runway 14L-32L) will be converted into a taxiway by the year 2019.
  - The height of the new building should be consistent with boarding gates for an A380 aircraft. Assume a design height of the terminal building of 25 meters.
- b) Draw your design to scale using the CAD software of your choice.

- c) Estimate the gate capacity of your design. For example state how many passengers per year can be accommodated by your design.

## Problem 4

Departures from runway 28R fly over Bensenville and Itasca communities to the West of the ORD airport. Assume that aircraft fly runway heading after departure for 7 nm after liftoff from runway 28R. The liftoff point occurs around 8,500 feet from the start of the takeoff roll on runway 28R. The initial climb rate of a Boeing 737-800 is 2,300 feet/minute in a summer day. The aircraft flies at an average speed of 180 knots (180 nm/hr) after departure until reaching 4,000 feet in altitude.

- a) Use the INM model parameters (noise-power curves) to estimate the LDN level produced by 200 daily departures and 50 nightly departures of Boeing 737-800 at points along the departure path located 1.0, 2.0, 2.5 and 3.0 nm to the west of the end of runway 28R.
- b) Comment on the results obtained.

## Problem 2

Perform a noise study for the ORD airport considering the fleet mix shown presented in Table 1. The arrival and departure flow patterns are shown in Figure 1. Assume that the distribution of arrivals is that shown in Figure 1. The words PA stand for Percent Arrivals and PD for percent departures. Assign aircraft classes randomly the arrival and departure streams. Consider the number of arrivals and departures performed during the day and night time as described in the previous section.

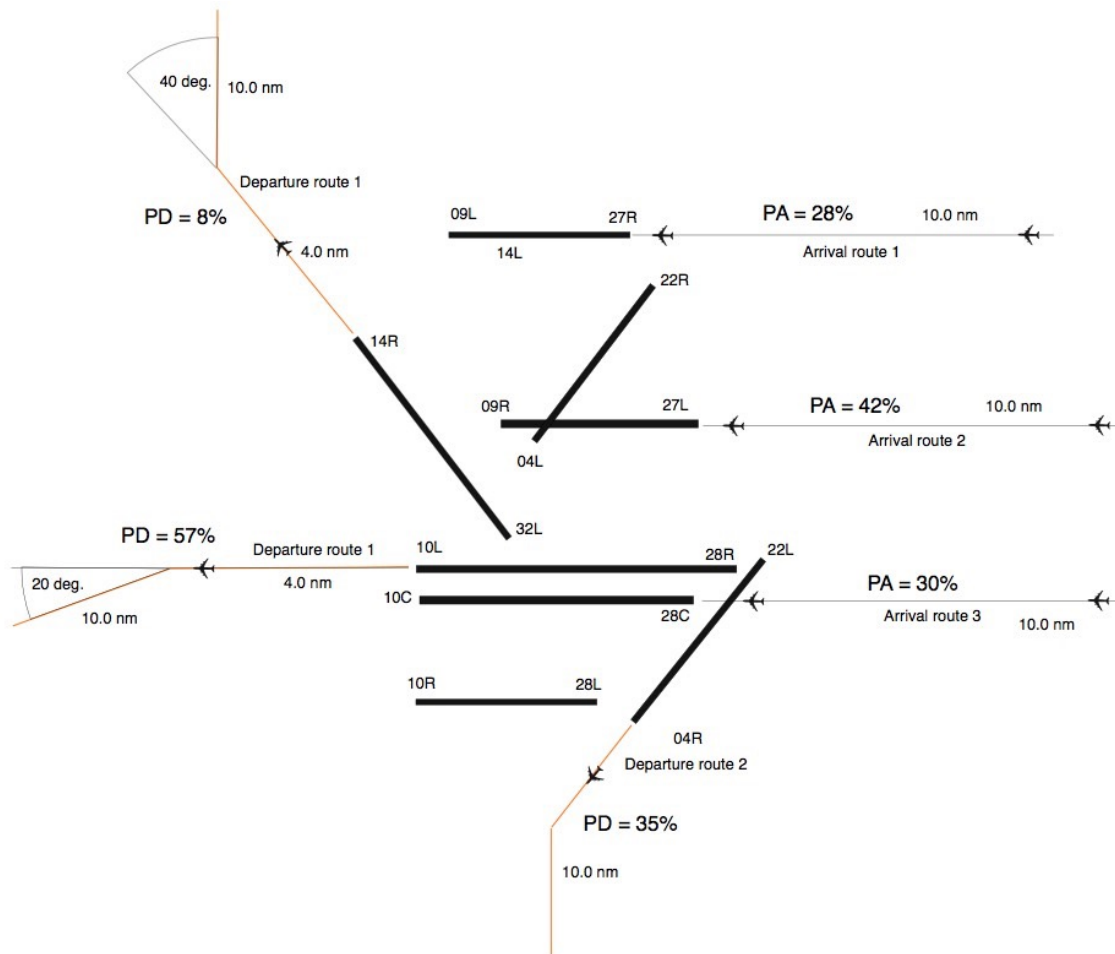


Figure 1. Simplified Arrival and Departure Patterns to ORD during West Flow Operations.

- Find the noise contours around the airport from 55-80 LDN. Plot using your CAD and INM skills. Export the noise contours to a DXF file and then read the file using Autocad or equivalent application.
- Estimate the area under the 55 and 65 LDN contours.
- Suggest improvements to reduce the noise at this airport.

Bonus: Export the contours to Google Earth and superimpose the contours exported as an Image Overlay (or layer) of the Google Earth satellite picture.