Assignment 7: Runway Capacity Analysis

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Problem 1

Use Google Earth or any other mapping tool to solve this problem.

a) Find the IMC arrival saturation capacity of the runway configuration for LGA airport when runway 13 is used for departures and runway 22 for arrivals. Assume that an arrival to runway 22 has to be 2 nm away from the threshold of runway 22 for a departure on runway 13 to be released. Consider human factors time lags in the solution to the problem. For example, allow 10 seconds for aircraft engine spool up time and pilot reaction time for departing aircraft on runway 13. Arrivals on runway 22 touchdown near the runway markings highlighted in Figure 1. Once on the runway, wake vorticity is not an issue for departures on runway 13 since they will not be airborne at the runway intersection. The operational parameters of the airport are shown in Table 1. The arrival path to runway 22 has a common approach length of 7 nm. The in-trail delivery error for the arrivals is ~15 seconds. In your analysis, assume aircraft accelerate at constant rate of 2.3 m/s^2 during the takeoff roll. Similarly, assume aircraft decelerate at 2.5 m/s^2 after touchdown. Assume a probability of violation of 5% is tolerable in this scenario.

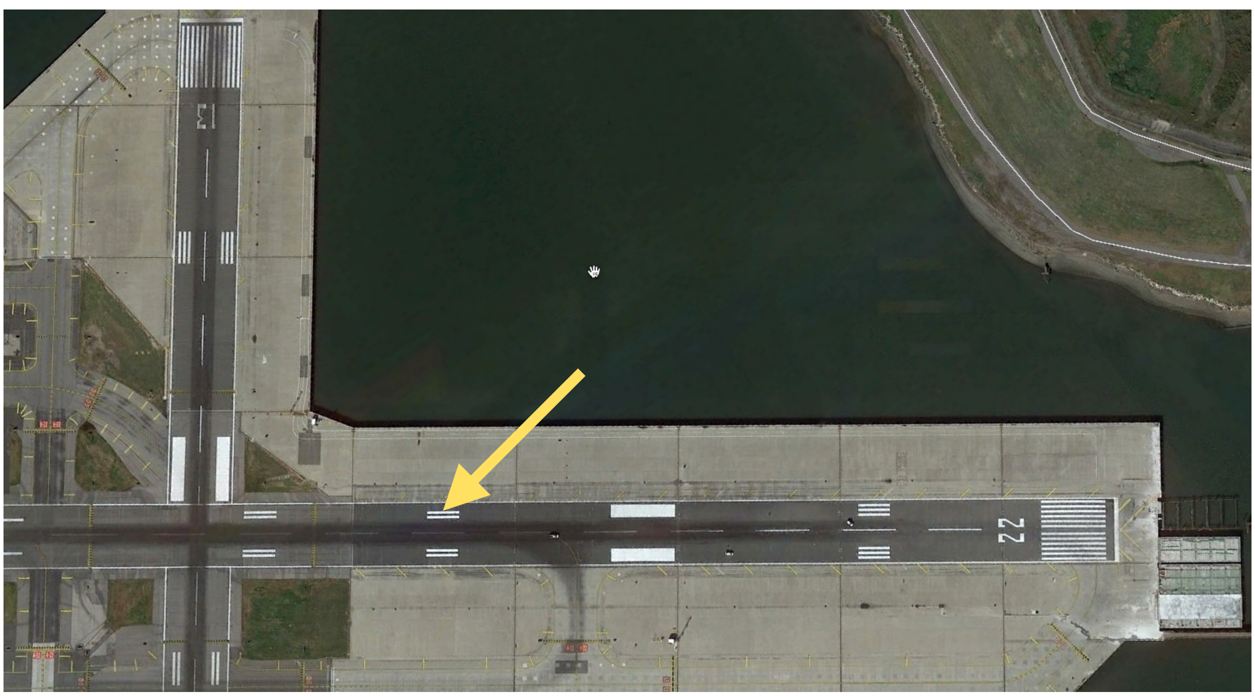

Figure 1. Configuration of LGA Airport Runways for the Problem. Arrow Points to the Area Where Landing Aircraft Main Landing Gear Touches Down.

b) Estimate the departure saturation capacity and the complete Pareto diagram for IMC conditions. Clearly state all your assumptions.

Step # 1 Estimate the arrivals only capacity on runway 22 assuming no departures on either runway 22 or runway 13.

Augmented Matrix (Tij + Bij) (seconds)			
		Trailing	
	Small	Large	Heavy
Small	98.52	89.04	88.13
Large	154.16	89.04	88.13
Heavy	206.14	154.05	126.16
Arrivals Only Capacity (per hour)			37.79

The saturation arrival capacity for runway 22 is 37.8 per hour.

Step # 2 Estimate the departure capacity on runway 13 if no arrivals are scheduled on runway 22.

Departure-Departure Separation Matrix (seconds)			
		Trailing	
	Small	Large	Heavy
Small	60	60	60
Large	90	60	60
Heavy	120	120	120
Departures Only Capacity (per hour)			55.94

The departure saturation capacity is 55.9 per hour.

Step # 3 Find the combined arrival and departure capacity using both runways in segregated mode (runway 22 for arrivals and runway 13 for departures). Establish the set of interaction behaviors using the data provided and your knowledge of ATC rules.

a) The touchdown point is 1,570 feet downrange of the runway 22.
b) The intersection point of the two runways is located 2,125 feet downrange from runway threshold 22 (555 feet downrange of touchdown location).
c) The intersection point of the two runways is located 1,220 feet downrange from runway threshold 13 (departure point).
d) The landing aircraft expected time to cross the intersection is estimated using three times to cross corresponding to each one of the three groups of aircraft using the runway. The computation has been done using the typical speed profile shown in Figure 2.

For small aircraft landing on runway 22,

Time to touchdown = 7.8 seconds

Time to cross runway 13 = 10.4 seconds

For large aircraft landing on runway 22,

Time to touchdown = 6.8 seconds

Time to cross runway 13 = 9.1 seconds

For heavy aircraft landing on runway 22,

Time to touchdown = 6.7 seconds

Time to cross runway 13 = 8.9 seconds

The expected value (value weighted across all 3 groups) of the crossing time of the runway is then 9.2 seconds.

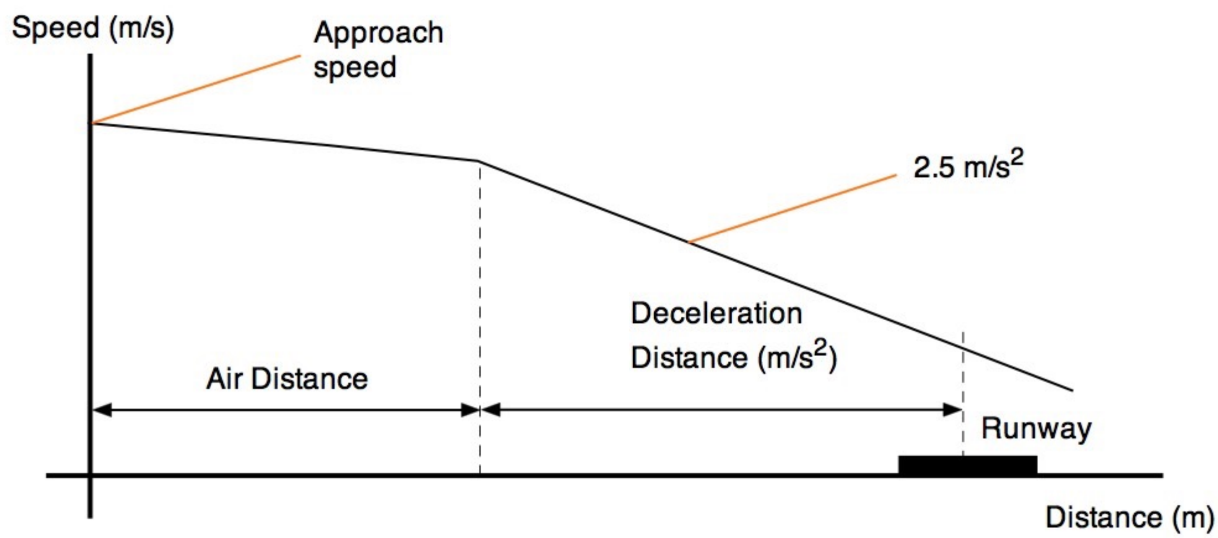

Figure 2. Speed Profile of a Landing Aircraft.

e) A departing aircraft takes 18 seconds after takeoff to cross the intersection.

Per ATC operational information, the departing aircraft will not be cleared unless the approaching aircraft is 2 nm from the arrival runway (runway 22) when the departing aircraft is cleared. The following calculations show the distance left between the following aircraft in the arrival sequence and the runway threshold using the nominal arrival-arrival separations plus the buffers. The second part of the table shows the number of departures possible on runway 13 if the time between successive departures on runway 13 is 65 seconds. The sum of departures on runway 13 with arrival priority on runway 22 is estimated to be 38 (shown in the table below).

Distance left between following aircraft and runway threshold (nm)			
n=1		Trailing	
	Small	Large	Heavy
Small	3.34	3.46	3.48
Large	5.22	3.46	3.48
Heavy	6.99	5.99	4.98

Number of Departures on runway 13 per arrival gap on 22			
n		Trailing	
	Small	Large	Heavy
Small	1.00	1.00	1.00
Large	2.00	1.00	1.00
Heavy	2.00	1.00	1.00

Number of departures on runway 13			
n		Trailing	
	Small	Large	Heavy
Small	0.09	1.66	0.09
Large	3.31	29.80	1.66
Heavy	0.18	1.66	0.09
Sum of departures on runway 13			38.54

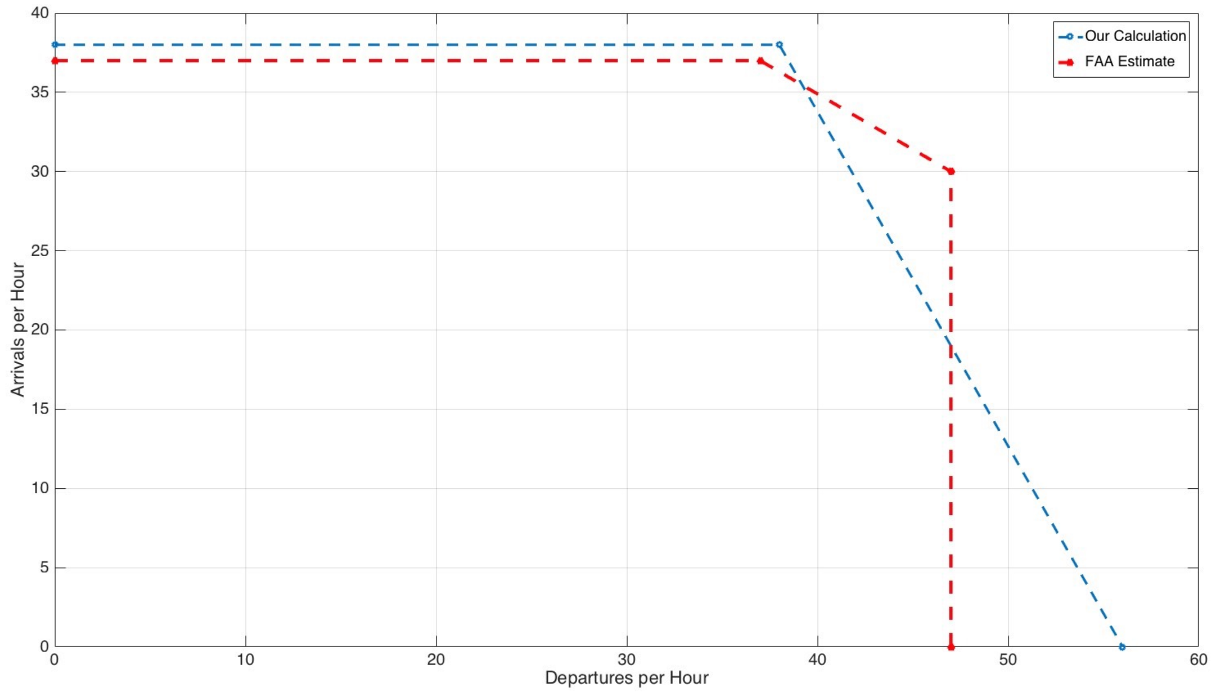

Figure 3. Estimated Pareto Diagram of IMC Runway Capacity at LGA.

c) Compare the answers obtained in your analysis with those published by FAA at their airports planning site (https://www.faa.gov/airports/planning_capacity/profiles/media/LGA-Airport-Capacity-Profile-2014.pdf). Comment on your answers and the FAA solution.

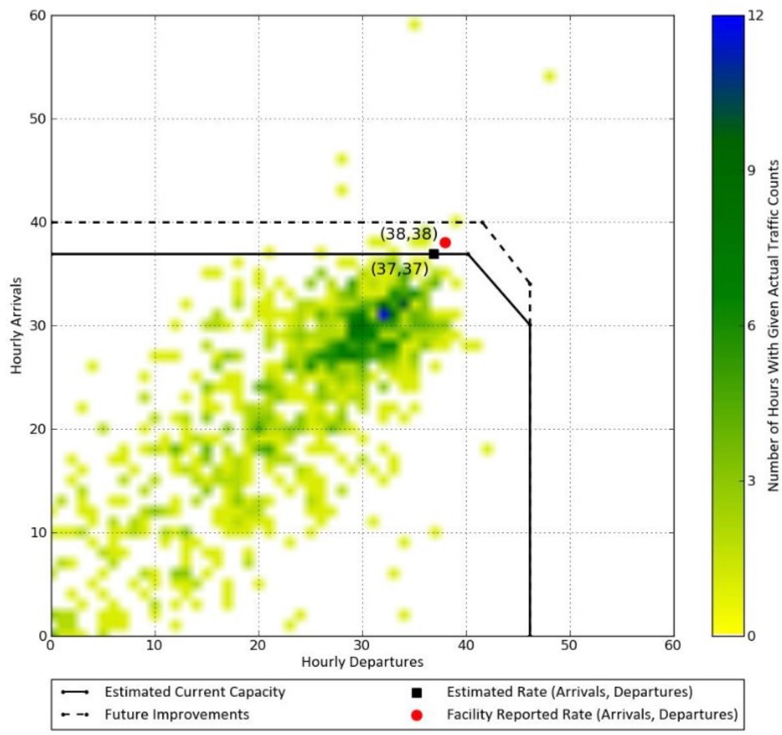

Figure 4. FAA Estimated Pareto Diagram for LGA.

A comparison of both solutions is shown in Figure 3. Note that our analysis seems very optimistic for the saturation departure capacity (56 vs 47 for the FAA estimate. Note that one aspect in our calculation is that departures-departure separations are considered to be 60 seconds in IMC. In real life, ATC controllers may use distance-based separations in such conditions thus increasing the headways between successive departures a little bit more (perhaps to 75 seconds average or 2.5 nm between departures). This provides the radar controller with a better separation between successive departures. If you change that value in the analysis just for the large-large group sequence, the answer for departure capacity is around 47 or the same as that of the FAA.

d) NextGen technologies could help this airport in the future. For example, if Performance Based Navigation (PBN) allows aircraft to follow more precise paths, the in-trail delivery error could be reduced to 5 seconds instead. Similarly, because PBN assume the common approach length is reduced to 5 nm. Show with actual calculations the possible improvements with NextGen technologies. Comment.

Using the new values of (σ_0) and common approach length (γ), we observe an increase in arrival capacity to 46 per hour. A noticeable improvement.

Table 1. Runway Operational Parameters and Fleet Mix for Problem 1.

Aircraft	Percent Mix (%)	Runway Occupancy Time (s)	Approach Speed (knots)
Small	5	45	122
Large	90	52	140
B757	5	55	142

Table 2. Minimum arrival-arrival separations under IMC conditions. Values in are nautical miles. Values Shown Do Not Include Buffers.

Minimum Separation Matrix (nm)		Arrivals-Arrivals			
		Trailing Aircraft (Header Columns)			
Lead (column 1)	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. Minimum departure-departure separations under IMC conditions on the same runway. Values in are seconds.

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

Problem 2

a) Work the IMC capacity problem for LGA airport if the wind changes the runway configuration to arrivals on runway 31 and departures on runway 4. For this configuration, the ATC local controller will release a departure on runway 4 if the arrival on 31 is 3 nm from the arrival threshold to runway 31.

The increase of required separation to 3 nm reduces considerably the number of departures on runway 31. This reduces the number of departures that can be conducted under arrival priority (saturation) conditions.

b) How different is the new Pareto compared to that obtained in Problem 1b? Comment and state all your assumptions.

Problem 3

Read about the Simultaneous Offset Instrument Approaches (SOIA) conducted at SFO and answer the following short questions. Before answering this problem it is instructive to see a video on the subject at :

https://www.youtube.com/watch?v=X5gGSWg_KcE. Also refer to the published FAA runway capacity diagram at the following link: https://www.faa.gov/airports/planning_capacity/profiles/media/SFO-Airport-Capacity-Profile-2014.pdf.

a) Starting with VMC conditions, estimate how often can the airport conduct SOIA approaches for the arrival saturation capacity shown in the FAA digram to hold true.
b) Watch a video of simultaneous departures from SFO. https://www.youtube.com/watch?v=cId1lDPJK0Y. Do you feel the departure capacity stated in the FAA diagram is achievable using three runways (1R, 1L and 20L)?
c) Explain why is the tradeoff region (tradeoff between arrivals and departures) for SFO under VMC so pronounced?

SFO can conduct close to 76 arrivals per hour in ideal conditions on runways 28L and 28R. This requires in many cases SOIA operations. Departures are normally conducted on runway 1R and 1L. However, runway 28L is also used for heavy aircraft departures. If a high departure rate is required during a period dog time, the arrivals on 28L and 28R would have to spaced at longer in-trail distances to increase the gaps between successive arrival. This creates a large tradeoff region in the capacity diagram.

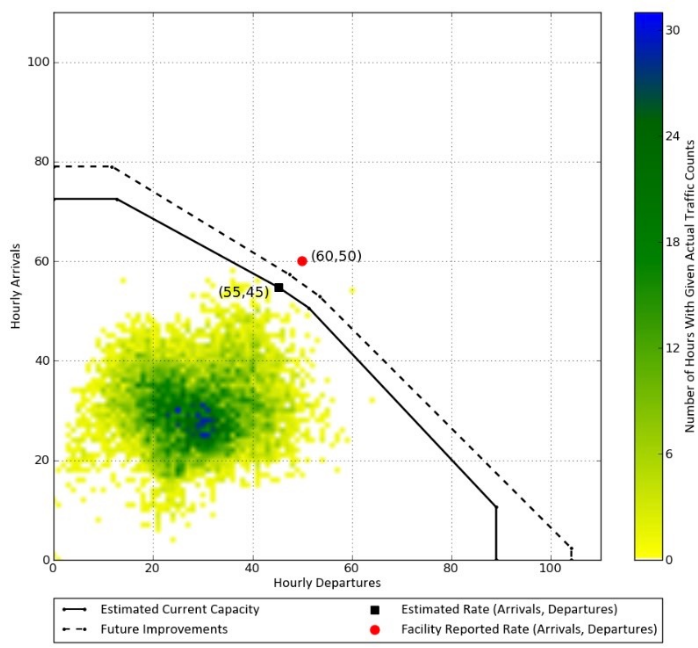

Figure 5. FAA SFO Pareto Diagram.

d) Explain in your own words but using technical arguments, what is the reason for the IMC at SFO to be so low.

Single runway operation for arrivals provides around 30 arrivals per hour.