Assignment 8: Runway Capacity and Delay Analysis

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Problem 1

Consider the runway saturation capacity under IMC weather conditions for Ronald Reagan Airport (DCA) as shown in Figure 1. The diagram is available at: https://www.faa.gov/airports/planning_capacity/profiles/media/DCA-Airport-Capacity-Profile-2014.pdf. The assumption in the analysis shown in Figure 1 is that runway 1 is used for both arrivals and departures in IMC conditions.

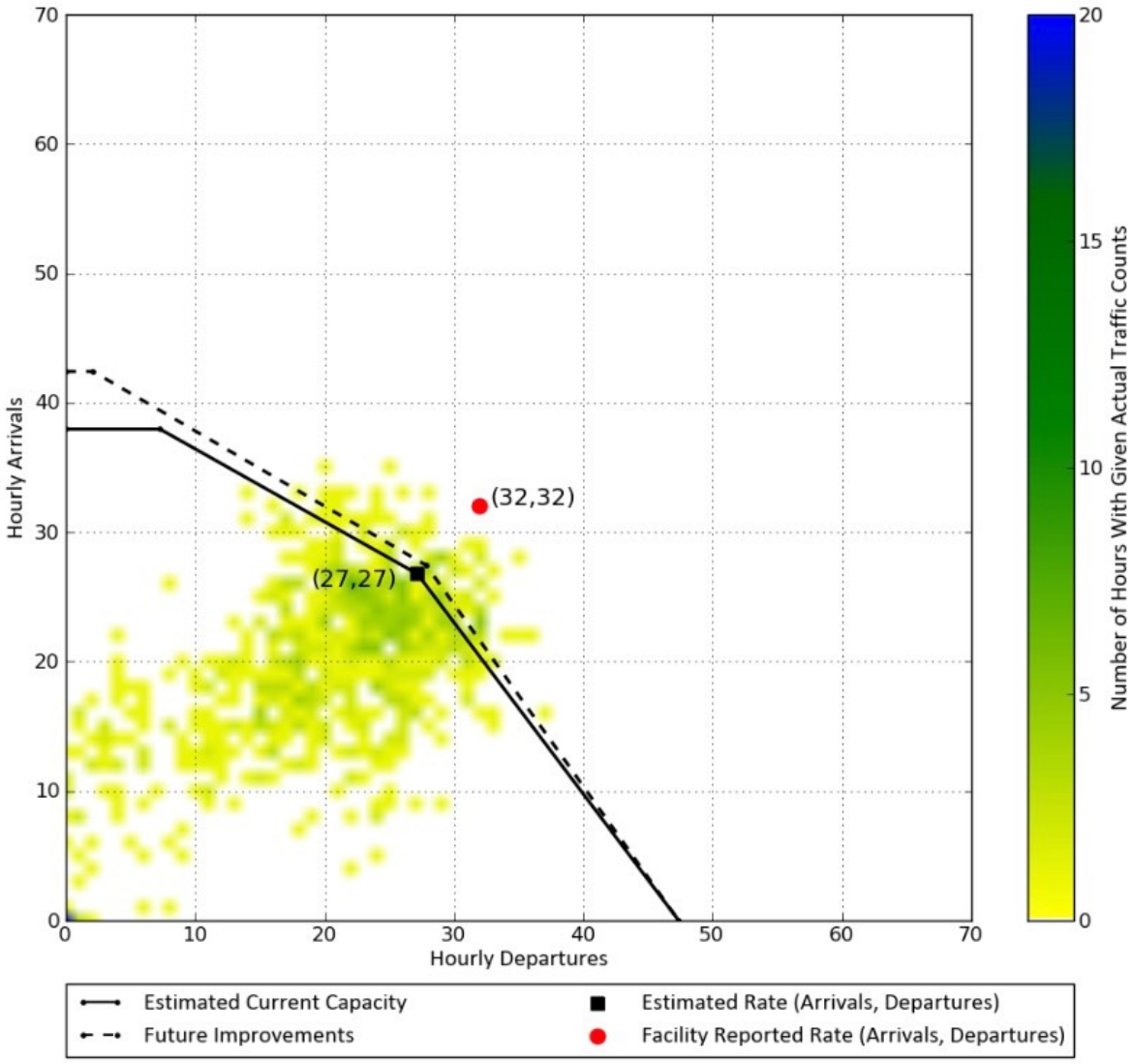

Figure 1. Pareto Diagram for DCA Airport (source: FAA, 2014).

a) Estimate the **average delays to both arrivals and departures** at the airport if the daily demand function is as shown in Table 1. Explain where in the Pareto diagram should the Air Traffic Control manager operate the airport in various hours of the day. Consider that for practical purposes, that

the maximum number of operating points along the Pareto boundary that can be operated daily is 4.

Examination of arrivals and departures given in Table 1 provides some clues about what runway configuration to use (i.e., where in the Pareto diagram should the airport be operated at). Table 2 shows the selected configurations for the analysis. The idea is to balance the delays for arrivals and departures.

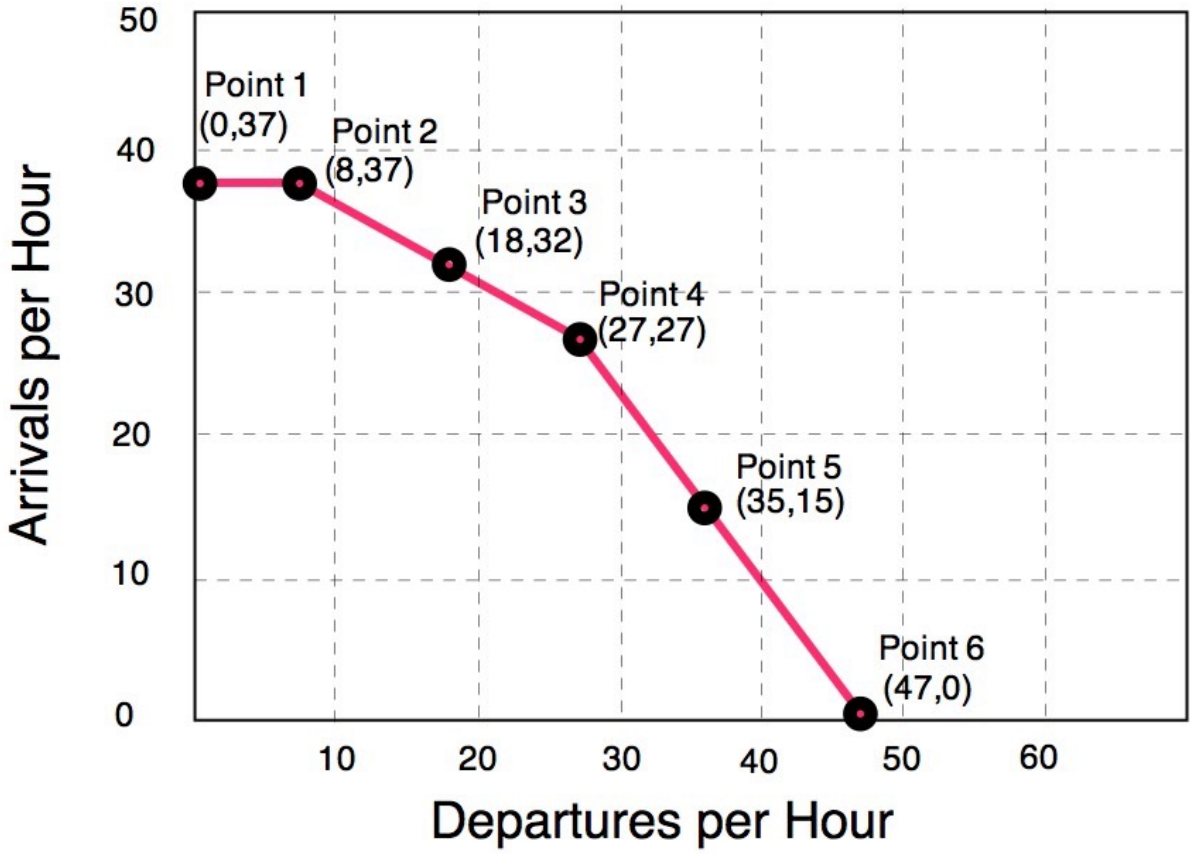

Figure 2. DCA Pareto Diagram.

Table 1. Flight Demand for Problem 1.

Time Period	Arrival/hr	Departures /hr	Configuration (Dep/Arr)
0-4	3	5	27/27
4-6	12	10	27/27
6-7	28	25	27/27
7-8	32	30	23/29
8-9	30	28	23/29

Time Period	Arrival/hr	Departures /hr	Configuration (Dep/Arr)
9-10	24	25	27/27
10-11	18	16	27/27
11-12	20	23	27/27
12-13	17	12	27/27
13-16	20	16	27/27
16-18	20	14	27/27
18-19	27	29	27/27
19-20	30	19	23/29
20-21	28	27	27/27
21-22	18	21	27/27
22-24	5	4	27/27

Table 2. Detailed Flight Demand for Problem 1.

Period Bin Center	Arrival/hr	Departures /hr	Configuration Departures	Configuration Arrivals
0.50	3	5	27	27
1.5	3	5	27	27
2.5	3	5	27	27
3.5	3	5	27	27
4.5	12	10	27	27
5.5	12	10	27	27
6.5	28	25	27	27
7.5	32	30	23	29
8.5	30	28	23	29
9.5	24	25	27	27
10.5	18	16	27	27
11.5	20	23	27	27
12.5	17	12	27	27
13.5	20	16	27	27
14.5	20	16	27	27

Period Bin Center	Arrival/hr	Departures /hr	Configuration Departures	Configuration Arrivals
15.5	20	16	27	27
16.5	20	14	27	27
17.5	20	14	27	27
18.5	27	29	27	27
19.5	30	19	23	29
20.5	28	27	27	27
21.5	18	21	27	27
22.5	5	4	27	27
23.5	5	4	27	27

Using the deterministic queueing model we find the following total delays for arrivals and departures.

For departures:

Simulation Period (hours) = 26.5
Total delay (aircraft-hour) = 25.2845
Max queue length (aircraft) = 10.4006

For arrivals

Simulation Period (hours) = 26.5
Total delay (aircraft-hour) = 10.8911
Max queue length (aircraft) = 4.1506

To find the average delay per operation you need to factor in the number of aircraft that were delayed using similar procedure as stated in the class notes. The selection of operating point in the Pareto boundary attempts to tradeoff delays for arrivals and departures. It is important to mention that arrival delays are more costly than departure delays.

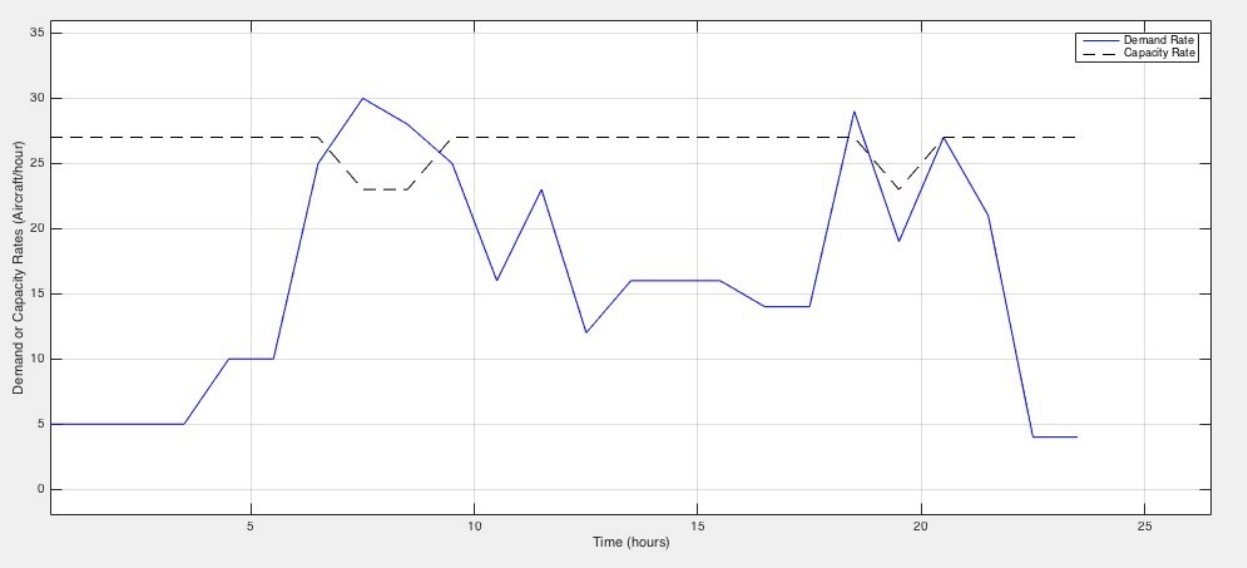

Figure 3. DCA Departure Operations per Hour vs. Departure Capacity.

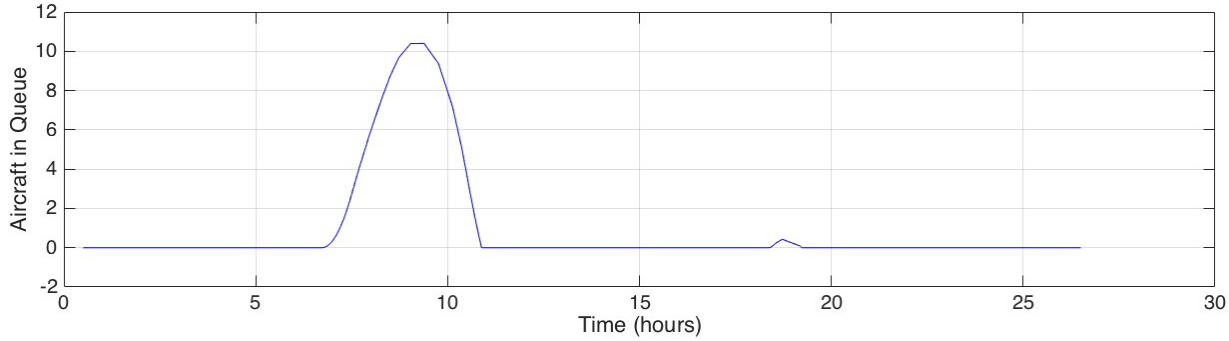

Figure 4. DCA Departure Queueing.

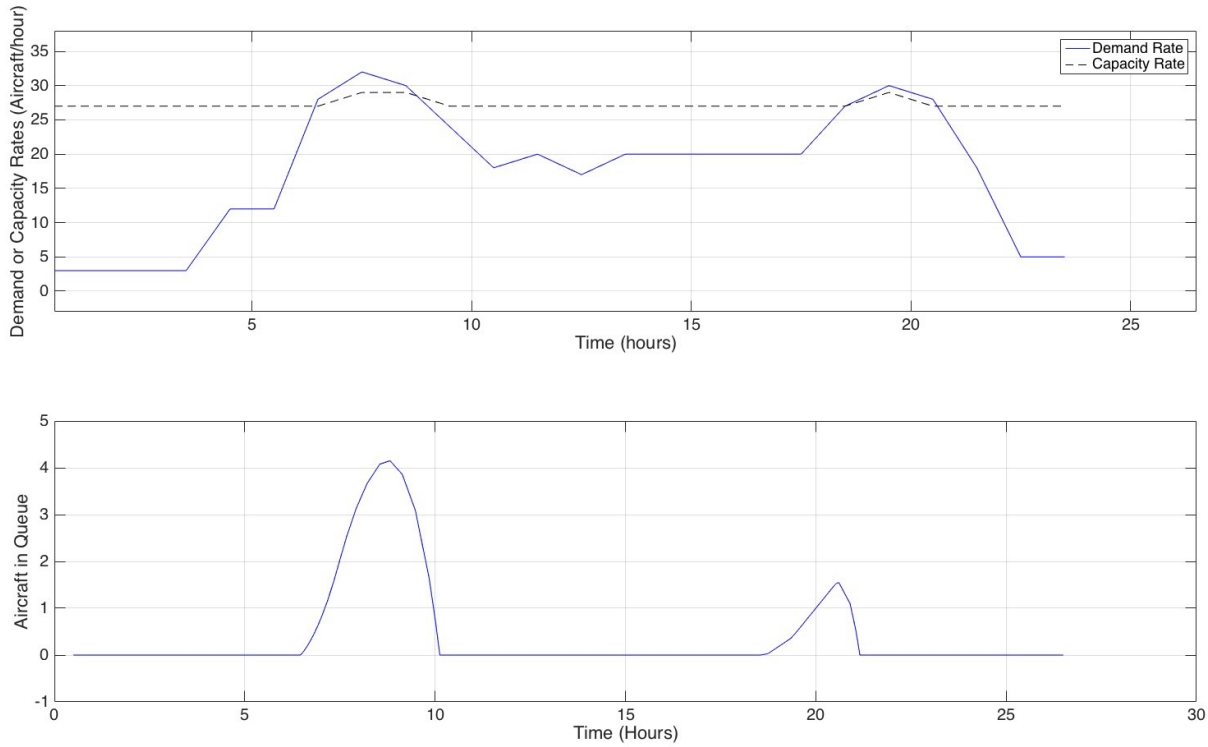

Figure 5. DCA Arrival Operations per Hour vs. Arrival Capacity.

b) Estimate the maximum number of aircraft waiting for departure at the departure queue of the runway during the busy period.

The maximum number of aircraft in the departure queue is estimated to be around 10.5. For arrivals, the maximum queue is around 4 in the busy morning period.

c) The dotted line in Figure 1 shows future improvements to this airport from various NextGen initiatives. Will there be relief to delays if these changes are implemented?

The Nextgen changes would provide additional capacity in the busy periods and hence they would help.

d) Observe that the ATC control tower reports a maximum arrival and departure rate of 32/32 per hours. Look at the configuration of DCA and provide some insight on what the reported rates are far better than the Pareto diagram shown in this figure .

DCA tower typically operates two arrival runways in busy periods. The second runway allows a coordination of more arrivals per hour and this provides additional capacity to the airport. For example during Sorthflow operations, DCA uses runways 19 and 15 as arrival runways. Runway 19 is used for departures. During Northflow operations DCA uses runway 1 and 33 as arrival runways. Runway 1 is used for departures.

DCA also has a unique procedure shown in Figure 7. This procedure allow an air traffic controller to open up larger arrival-arrival gaps by directing some arrival traffic from runway 1 to runway 33 as shown in the figure. The procedures only works in VMC conditions but is effective because it adds travel time between successive arrivals in Northflow operations. The additional time between arrivals allows ATC to release more departures per hour from runway 1.

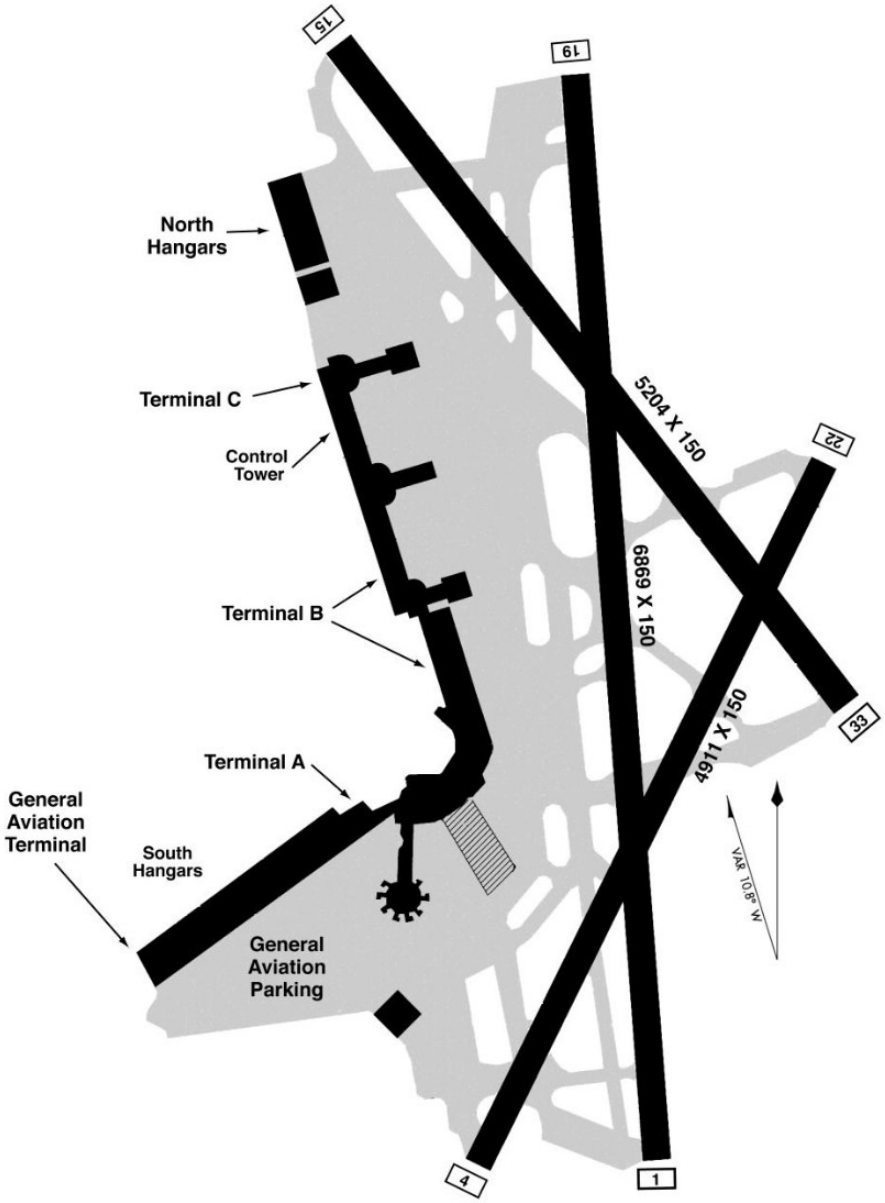

Figure 6. DCA Airport Configuration.

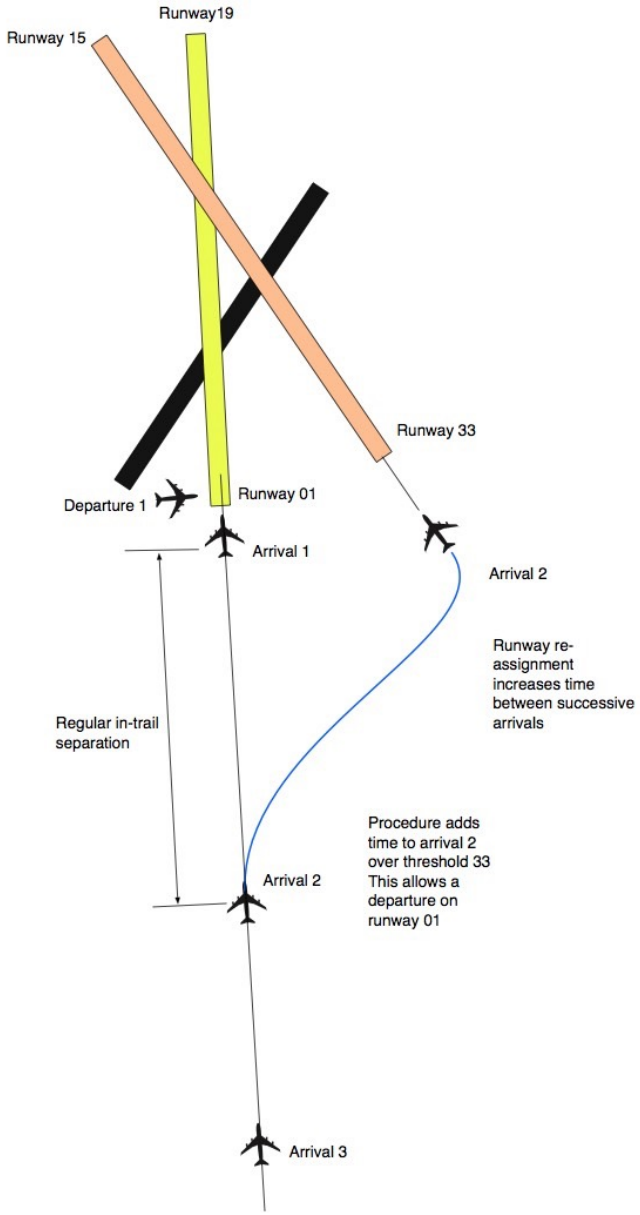

Figure 7. DCA Airport Procedure to Open-up Arrival Gaps.