Assignment 8: Deterministic Queueing Analysis

Date Due:November 10, 2014 Instructor: Trani

Problem 1

A single runway airport has Pareto Capacity diagram shown in Figure 1.

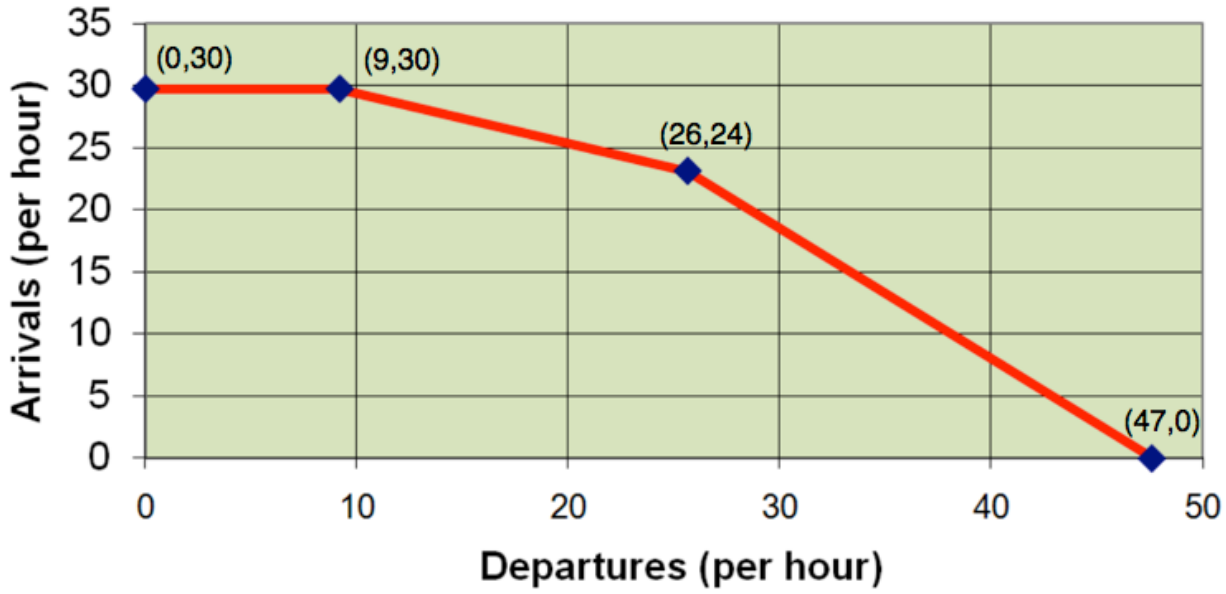

Figure 1. Single Runway Airport Pareto Diagram (IFR Conditions). Numbers in parenthesis indicate the arrivals/departure data points.

During a typical day, the airport has a demand function shown in Table 1. The table shows arrivals and departures scheduled by airlines operating at the airport. Note that a cargo operator flies a large number of flights to this airport in the period between 11:00 PM and 4:00 AM.

Table 1. Demand Function at the Airport for Problem #1.

Time (hrs) (Bin Center for Hourly Period)	Arrivals per Hour	Departures per Hour	Total Operations per Hour
0.5	3	1	4
1.5	5	5	10
2.5	3	3	6
3.5	6	2	8
4.5	4	6	10
5.5	8	4	12
6.5	10	12	22
7.5	23	28	51
8.5	29	32	61
9.5	28	27	55
10.5	20	24	44
11.5	23	18	41
12.5	21	25	46
13.5	22	34	56
14.5	28	29	57
15.5	30	27	57
16.5	21	25	46
17.5	18	25	43
18.5	19	20	39
19.5	14	14	28
20.5	9	11	20
21.5	6	7	13
22.5	10	6	16
23.5	5	3	8

a) Use a deterministic queueing model to find the expected arrival and departure delays per flight at the airport under IFR conditions if the airport tower decides to operate at the 50/50 arrivals/departures point in the Pareto diagram.
b) Find the delay cost to airlines if the average hourly cost for arrivals is $3,300 per hour based on the fleet mix operating at the airport. Also consider that the departure hourly cost to the airline is $1,500 instead.

Problem 2

This problem is a follow-up to Problem 1.

a) **Now solve the problem using the following rationale**: assume that small changes to the operating procedures at the airport are possible every two hours to move around the boundary of the Pareto diagram. For example, during periods of heavy arrival flows and low volume of departures, ATC controllers would direct aircraft to have in-trail arrival separations closer to the minimum feasible. Similarly, during heavy departure flows and low arrival flows, the arrival gaps will be increased (since arrival demand is low) allowing a maximum number of takeoffs. Solve the problem again and compare your solution with the 50/50 operating point. Compare and comment on the new answer obtained using this method. State the rationale of your selection and the iterations needed to arrive to your optimal solution. Remember, the idea is to minimize the delays for both arrivals and departures **simultaneously**.
b) Suppose that after a simulation study you convince the airport authority to add a second close parallel runway spaced 2,500 feet from the existing one. The airport installs a PRM system. If simultaneous dependent arrivals are possible at the airport and if the increase in arrival capacity is 9 per hour, explain how will this infrastructure improvement reduce delays.

Problem 3

An international airport in the Northeast has pre-designated de-icing areas to service aircraft operating at the airport during winter operations. Before departure, an aircraft has to be de-iced and a Glycol-based fluid applied to protect against ice formation in flight. A diagram of such system is shown in Figure 2.

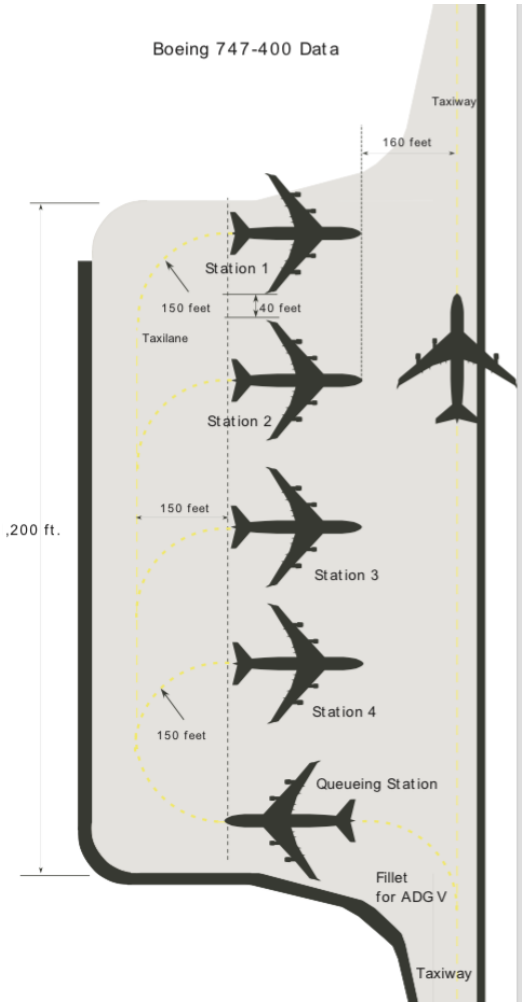

Figure 2. Deicing Stations at a Busy International Airport.

The de-icing is done by ground vehicles that spray the fluid to the aircraft. A commercial airliner takes 7.5 minutes on average to be de-iced. Service times are negative

exponential. Airlines schedule 28 departures per hour. The arrivals to the departure queue area, have shown to be Poisson (i.e., random).

a) Determine the average utilization of the cranes in the baseline year (2014).
b) Determine the standard measures of effectiveness of the queueing system (Lq, L, W, and Wq).
c) Find ands plot the probabilities that one day, more than 5, 6, 7 and 8 aircraft queue outside the deicing area. Explain.
d) The airport authority expects an increase in the number of flight operations at the airport at a rate of 3% per year (baseline) until the year 2025. Find the year when new de-icing equipment and stations would have to be procured if the airport authority wants to keep the delays in the waiting line to be less than 9 minutes in the future.