Assignment 6: Deterministic Queueing Analysis

Date Due:November 28, 2011 Instructor: Trani

Problem 1

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

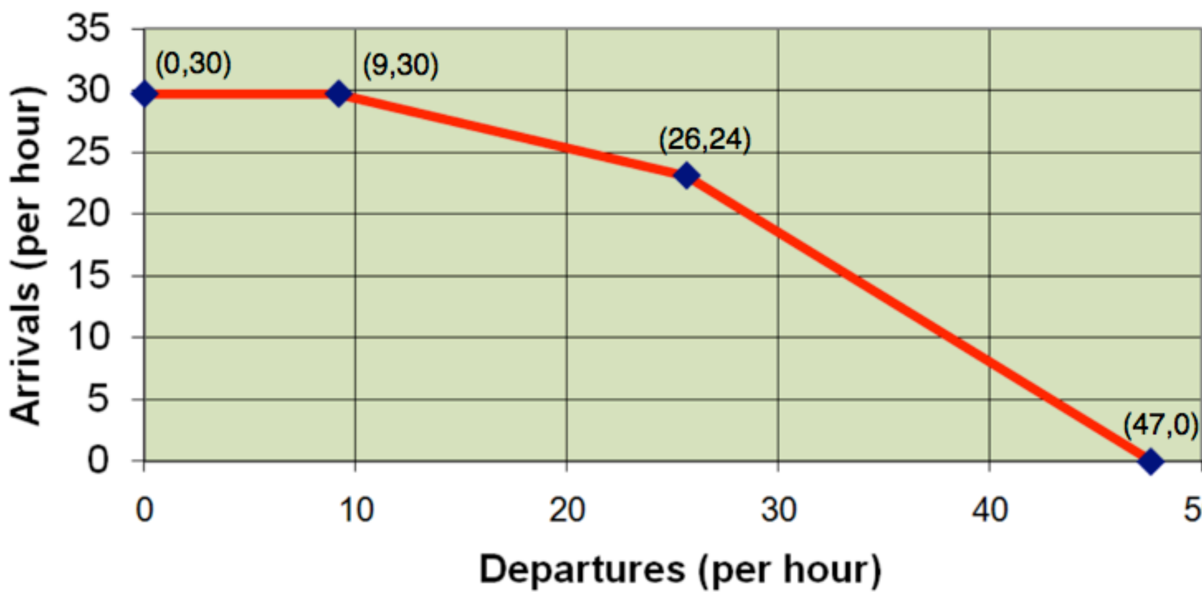

Figure 1. Single Runway Airport Pareto Diagram (IFR Conditions). Numbers in parenthesis indicate the arrivals/departure data points.

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 for the Airport.

Time (hrs) (Bin Center for Hourly Period)	Arrivals per Hour	Departures per Hour
0.5	18	1
1.5	20	5

Time (hrs) (Bin Center for Hourly Period)	Arrivals per Hour	Departures per Hour
2.5	19	8
3.5	21	23
4.5	26	30
5.5	17	32
6.5	16	29
7.5	27	30
8.5	29	33
9.5	28	22
10.5	20	24
11.5	23	18
12.5	21	25
13.5	22	34
14.5	34	30
15.5	35	28
16.5	23	27
17.5	18	25
18.5	19	20
19.5	14	14
20.5	9	11
21.5	6	7
22.5	16	6
23.5	24	3

a) Use a deterministic queueing model to find the **minimum** expected arrival and departure delays per flight at the airport under IFR conditions. In your solution consider the fact that ATC controllers at the control tower of the airport will coordinate arrival gaps (i.e., in-trail separations) with TRACON controllers to reduce arrival and departure delays. In your solution state what operating point in the Pareto diagram would likely be used by ATC controllers at a given point in time. 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**.

Assume that small changes to the operating procedures at the airport are possible every hour 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.

b) Find the delay cost to airlines if the average hourly cost is $3,550 per hour based on the fleet mix operating at the airport.
c) Describe a decision support tool for airport ATC tower controllers to minimize runway delays.

Problem 2

An international airport in the Providence (Rhode Island) has two fixed de-icing cranes to service aircraft operating at the airport. The de-icing operations are conducted during the winter months of the year to make sure all aircraft wing and control surfaces are free of ice before a flight. The de-icing cranes are able to handle 15 aircraft per hour (per crane) and have shown to exhibit negative exponential service times. During a busy period at the airport, airlines schedule 24 departures per hour. The arrivals to the departure queue area, have shown to be Poisson.

a) Determine the average utilization of the cranes in the baseline year (2011). Determine the standard measures of effectiveness of the queueing system (Lq, L, W, and Wq).
b) The airport authority expects an increase in the number of flight operations at the airport at a rate of 3.5% per year (baseline) until the year 2026. Find the year when new de-icing cranes would have to be procured if the airport authority wants to keep the delays in the queue to be less than 9 minutes in the future.