UNDERGRADUATE REPORT

National Aviation System Congestion Management

by Sahand Karimi
Advisor:

UG 2006-8

Introduction:

This report will mainly talk about three different projects, all of which focus on the theme of improving the operation of the national airspace system in order to make it more efficient. All of these projects contain a common component which is to *predict delays and cancellations*. In my research, I have performed significant amounts of statistical analysis & modeling with detailed data collected from air carriers nationwide. My part of work (Queuing delays) is a part of predicting delays and cancellations.

Overview:

1) **Allocating slots/designing auction at LaGuardia airport (LGA).**

   - Economic Benefits of operating at LGA
   - Design an auction mechanism
   - What is the right level of operations?
   - Allow new entry competition and prevent anti-competitive behavior.
   - *Predict delays and cancellations*

2) **Building a new airport.**

   - Facility design (runways, terminals, gates, etc.)
   - Airspace issues
   - Forecast demand and revenue
   - Carrier strategies (hubbing, cargo, etc.)
   - *Predict delays and cancellations*

3) Collaborative scheduling at O’Hare airport (ORD).

- Establish an impartial broker.
- Broker collects proprietary data from actors.
- *Predict delays and cancellations.*
- Give back aggregate results.
- Reiterate until and acceptable solution is found.

1) Allocating slots at LaGuardia airport.

The New York City region is the nation's largest population center with the nation's most congested airports and the world's most complex airspace. Combined, LaGuardia (LGA), Kennedy (JFK) and Newark (EWR) airports (all owned and operated by the Port Authority of New York and New Jersey) handle over 90 million passengers, 2.8 million tons of cargo, and over 1.4 million aircraft operations annually.

LaGuardia, the smallest and most congested of the three airports, is located seven miles from midtown Manhattan. It is surrounded by Flushing Bay, an arterial highway and densely populated neighborhoods. LGA is located on only 680 acres and operates two 7,000-foot perpendicular runways. Even in good weather, LGA's scheduled operations exceed capacity 12 hours a day. (Air Traffic Congestion …).

New York area airports have a history of severe congestion. In 1968, the Federal Aviation Administration (FAA) adopted the High Density Rule (14 CFR part 93, Subpart K, 33 FR 17896; December 3, 1968) as a temporary measure to deal with the problem of congestion and delays at LGA. The HDR limits the number of flights per hour at each of these airports during specific times of day. Under the HDR, all aircraft require a "slot" to either take-off or land during the restricted period. Airlines acquire slots through an administrative action by the Secretary of Transportation or through a purchase or lease transaction. (Air traffic congestion …)

In order to allocate slots and design an auction for them at LaGuardia airport it is necessary to take certain steps. First of all, we should determine the economic benefits of operating at this airport to let all the air carriers (potential bidders) know about their future operations and their probable benefits or loses.

Design of an auction mechanism is a fundamental part of slot allocation. The high demand for LGA slots indicates that many airlines consider service to this airport to be a valuable part of the service they offer to their travelers. This mechanism has to allow new entry competition and prevent any anti-competitive behavior. Due to the sporadic availability of slots, entrants often find it difficult to establish a viable service pattern in a city pair. A viable service pattern often requires multiple flights during the day to offer convenient alternatives to passengers, particularly if the entrant must compete with an incumbent offering multiple flights. The advantage of slot/auction approach is that it provides a high level of control over congestion and delays.

In order to come up with reasonable models for these steps it is necessary to be able to predict the future delays and cancellations which will occur at LaGuardia airport. The process of prediction will be covered at the end of this report.

2) Building a new airport.

The planning of an airport is such a complex process that the analysis of one activity without regard to the effect on other activities will not provide acceptable solutions. In the past airport master plans were developed on the basis of local aviation needs. In more recent times these plans have been integrated into an airport system plan which assessed not only the needs at a specific airport site, but also the overall needs of the system of airports which service an area, region, state or country (Planning & Design …).

The elements of a large airport are divided into two major components, the airside and the landside. The terminal buildings form the division between the two components. Within the system, the characteristics of the vehicles, both ground and air, have a large influence on planning. An airport master plan is a concept of the ultimate development of an airport. The term development includes the entire airport area, both for aviation and nonaviation uses, and use of land adjacent to the airport.

An airport plan must be developed on the basis of forecasts. From forecasts of demand an evaluation of the performance effectiveness of the various airport facilities can be established. Forecasts are usually needed for the short, intermediate and long ranges, or approximately 5, 10 and 20 years. Analysis of capacity, delay and cancellations is an essential step in forecasting and also airport planning.

It is essential in the planning and design of an airport to have realistic estimates of the future demand to which the airport will be subjected. This is a basic requirement in developing either an airport master plan or an aviation system plan. These estimates determine the future needs for which the physical facilities are designed.

The development of accurate forecasts requires a considerable expense of time and monetary resources because of complex methodologies which must be used and the extensive data acquisition that is often required.

The operations at other airports in the area must be carefully analyzed when a site for a new airport is selected or when additional runways are provided at an existing airport. Airports should be located at a sufficient distance from each other to prevent aircraft which are maneuvering for a landing at one airport from interfering with the movements of aircraft at other airports. This step is called the airspace issues or the presence of other airports and availability of airspace. (Planning & Design…)

The last important step in planning and building a new airport is to be able to predict delays and cancellations in an accurate way. These predictions will allow us to build and design the facilities in a way that can support the future need.

3) Collaborative Scheduling at Chicago's O'Hare airport.

Chicago O'Hare International Airport is one of the world's busiest and one of the nation's most delayed. It is the only U.S. airport to serve as a domestic hub for more than one major airline. There were over 30 million enplaned passengers in 2003. It is currently ranked number one in the world in terms of total annual operations (operations defined as total number of arrivals and departures, which for O'Hare totaled 928,691 in calendar year 2003).

As our nation's commercial aviation industry experienced a marked increase in activity throughout the 1990s, O'Hare experienced a 15% increase in operations between the years 1990 and 2003. According to the FAA's Air Traffic Operations Network, which collects data on air traffic activity counts, 490,987 flights arrived at and departed from O'Hare during the first six months of 2004.

From January through July 2004, the total airport operations at O'Hare increased approximately 8.7% over the same period in 2003. Following the events of September 11, 2001, while commercial aviation activity in general declined and experienced a slow recovery, O'Hare rebounded to pre-9/11 levels by late 2003, and it is projected that O'Hare will handle approximately 990,000 operations during calendar year 2004.

When flights are delayed at O'Hare, the results are felt throughout the national system. This is due to the presence of two large airline hubs, American and United Airlines. It is also due to the geographic location of the airport. When flights are delayed at Chicago, connections are missed and the national airspace system is impacted.

More recently, the FAA has implemented various efficiency enhancement initiatives, including Collaborative Decision Making and the "Growth without Gridlock" initiative, intended to address delays at O'Hare and throughout our nation's aviation system. In addition, in recent months, the FAA worked with airlines serving O'Hare to agree upon voluntary limitations for scheduled arrivals during peak hours (Delay Reduction Efforts…).

American and United have managed to cooperate to reduce demand at O'Hare whenever FAA officials get involved. There are some situations that the airlines can not agree and this is when an outside mediation or an impartial broker is necessary.

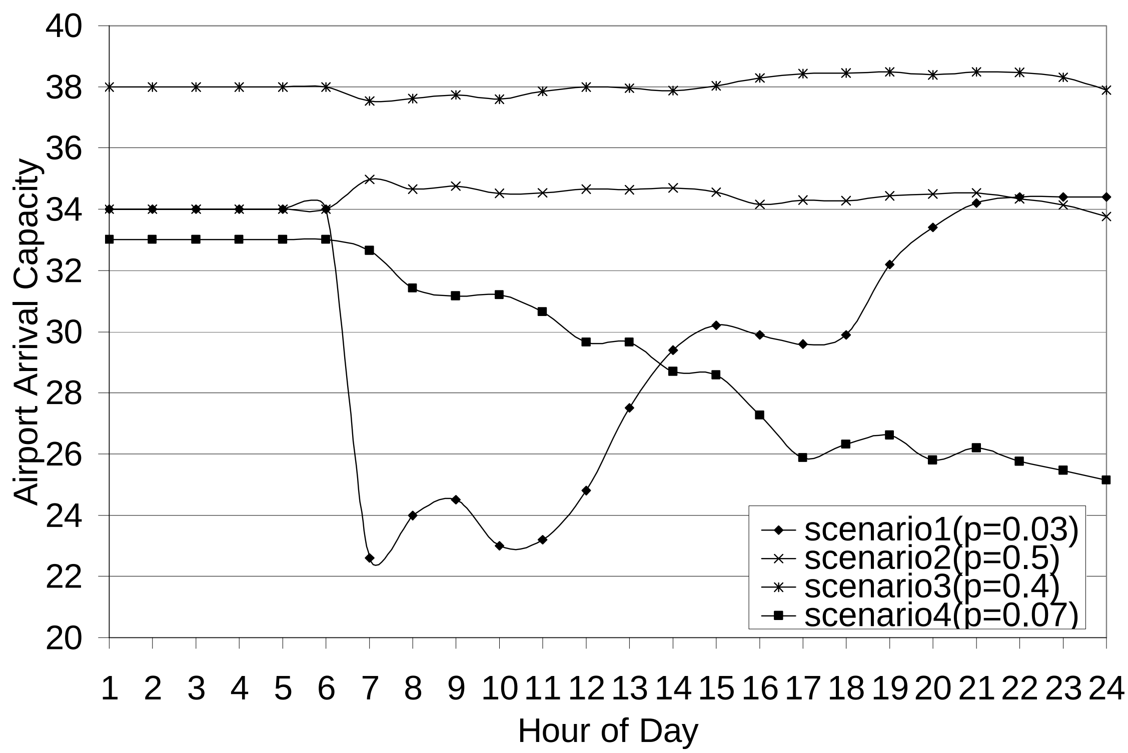
This hypothetical broker should collect the proprietary data from actors (American and United in this case) and based upon the collected data the broker starts to predict the delays and cancellations for a specific period of time. After determining the right level of operations (demand and capacity) at the desired airport, the broker gives back the aggregate results to each party. This process reiterates until an acceptable solution is found.

Prediction of Delays and Cancellations

As mentioned before, all three of the hypothetical/real applications that were discussed in this report share a common step in their process which is to predict delays and cancellations.

In order to come up with a reasonable prediction it is necessary to analyze the data from the past and come up with different kinds of scenarios that can happen in an arbitrary day. Each scenario, based on the delays and cancellations occurred, will have a possibility of occurrence which will be multiplied by the specified time interval.

The figure below demonstrates four possible scenarios for LGA airport:



My work was to come up with a code that could calculate the total delay at LaGuardia airport at any given day of year 2005.

First I had to define the Demand and the Capacity. Each of these quantities is reported in the Aviation System Performance Metric (ASPM) data base and the time interval for each of them is 15 minutes. The demand for every quarter of an hour is found under the METRIC ARR (Arrivals) and the capacity is listed under AAR (Airport Arrival Rate). The total delay in one delay is calculated by the given formula of:

$$Delay = 1/2(QL_{t-1} + QL_t)\Delta t$$

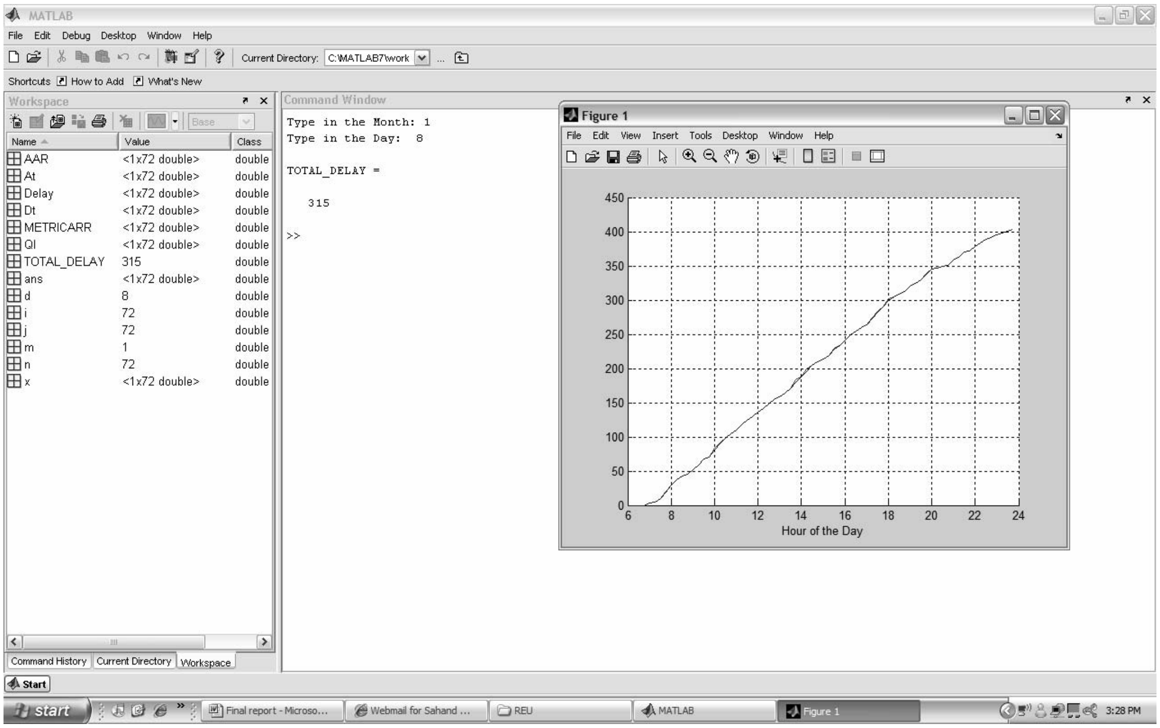
Where: $QL = D_t - A_t$

D_t or the total demand is the sum of demands for every 15 minutes.

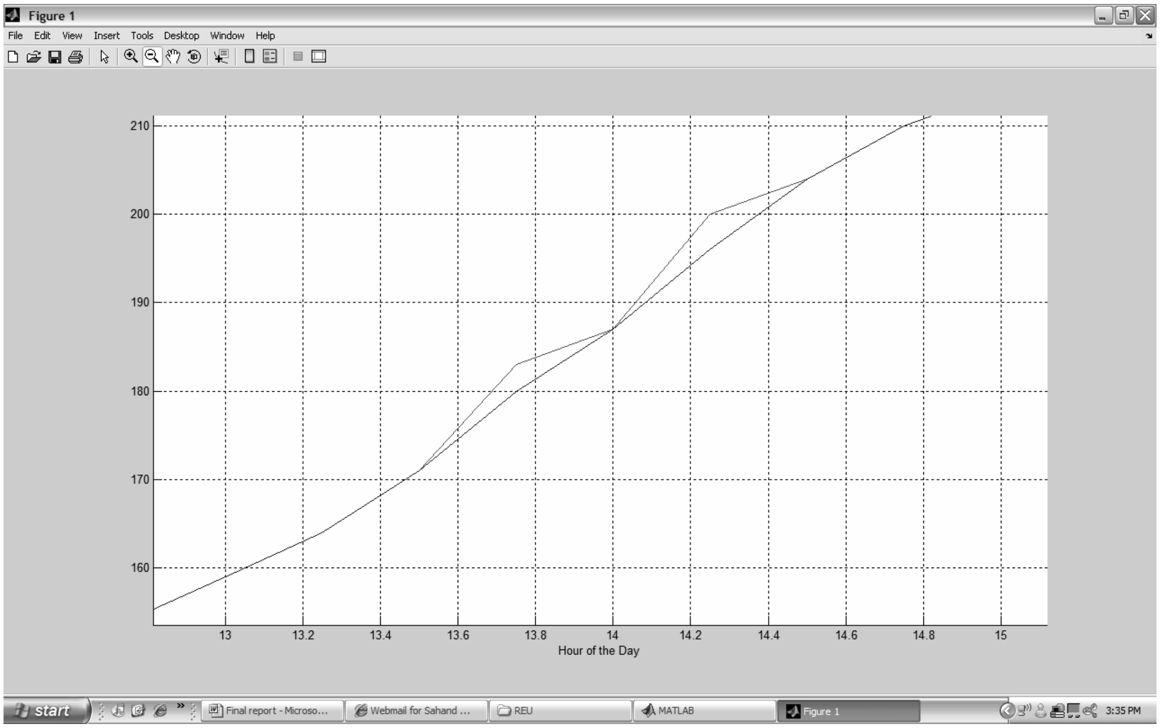
A_t or the total arrival can be calculated by this formula : $A_t = \min(A_{t-1} + AAR, D_t)$

Below you will see the result for 8th day of January in year 2005:

The first picture shows the total delay (315 minutes) and the curves of D_t and A_t



I have zoomed on the graph to show the difference between D_t and A_t.



The red line demonstrates the total demand and the blue line shows the total arrival. The surface between these two lines is the Q_L which leads us to calculate the total delay.

References

1)Horonjeff, Robert / Francis X.McKelvey , Planning & Design of Airports , 3rd Edition.

2)Hearing on Air Traffic Congestion in the New York City Area, Subcommittee on Aviation. http://www.house.gov/transportation/aviation/07-16-01/07-16-01memo.html

3)Hearing on Reduction Efforts at Chicago's O'Hare Airport, Subcommittee on Aviation.

http://www.house.gov/transportation/aviation/09-09-04/09-09-04memo.html

4) Smith, Aidan D, LaGuardia Slot Allocation a Clock-Proxy Auction Approach.

5)Potential Air Traffic Congestion Solution: Slot Allocation by Auction Method.