Using GIS to Support In-Flight Operations in the Event of an Airport Outage

A Case Study of the October 29th, 2011 Snowstorm

Extensive weather disruptions, current diversion practices, and the advent of NextGen expose the potential of GIS for disruption management in aviation. This tool helps to determine where planes should be diverted in the event that a destination airport becomes unavailable.

Mapping the Data

On October 29th, 2011, a snowstorm hit the American Northeast that caused major equipment failures at both John F. Kennedy (JFK) International Airport and Newark Liberty Airport. Since flights could no longer land at these airports, many were diverted to nearby airports. One of these airports was Bradley International. However, due to the unexpected diversions, Bradley International was not able to accommodate the diverted flights in a timely manner, and some were stuck on the tarmacs waiting for a gate for nearly 7 hours.

Diversion routes are currently handled on a plane-by-plane basis, which requires a lot of collaboration and can turn chaotic in the event of many flights needing diversion. This tool was created to optimize the diversion process by assuming that a regional air traffic control is using shared situational awareness to manage all flights in the airspace intended for an outage airport. This tool takes all diverted flights on October 29th, starting at 12pm and ending at 6pm, and routes them to JFK as efficiently as possible. The tool simulates a “closing pattern” for flights that must hold over JFK before being diverted.

Once the distance between each diversion point and each diversion airport is calculated, a table in which the data record is formatted in Excel so that it can be taken into a linear integer program. This integer program minimizes the total distance that flights travel to diversion airports, which simulates the use of shared situational awareness in the event of an airport outage.

Identifying Diversion Airports

The diversion airports were chosen according to their proximity and size to JFK. Since there is a high chance that a diverted flight will be forwarded, there is likely that many of the diverted aircraft will be wide-bodied. An airport that is wide-bodied must land on a runway of at least 9,000 feet. Additional landing requirements will be applied in the linear program. It is also desirable that the candidate diversion airports have the infrastructure to deal with a large number of enplanements as well as transportation back to JFK. The six candidate diversion airports for JFK are listed in Table 1 below.

<table>
<thead>
<tr>
<th>Airport Code</th>
<th>Airport Name</th>
<th>Orientation (degree) from JFK</th>
<th>Diversion Airport ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWR</td>
<td>Newark Liberty Int'l</td>
<td>61</td>
<td>2</td>
</tr>
<tr>
<td>BOS</td>
<td>Boston Logan Int'l</td>
<td>150</td>
<td>4</td>
</tr>
<tr>
<td>DCA</td>
<td>Washington Dulles Int'l</td>
<td>208</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 1

Creating the Network

The network in Figure 4 is created by combining the flight paths in Figure 2 and Figure 3. The network dataset is created in the same manner that a vehicle or freight network is created. Though there are an infinite number of possible flight paths that can be taken, the given flight paths in this network represents a “worst-case scenario” in which flights need to hold over JFK. While this is not ideal, the solution produced from this network gives an upper-bound to the true, optimal solution.

Optimizing the Solution

The final part of this tool takes all the flight distances created from the OD-Matrix and uses them to construct the objective function of the linear integer program (seen below). The first set of constraints forces each diversion airport to accept two or only one diversion airport. The second set of constraints forces each diversion airport to accept two or only one diversion. It should be noted that the right-hand side of the constraints can be modified at any time, and the numbers chosen are somewhat arbitrary. It should also be noted that if a flight only wanted to go to certain diversion airports, such as those in which the airline controls the gates, then these preferences can be expressed by using subsets of the second set of constraints.

Table 3 shows the solution from running the linear integer program. It is not surprising that Newark and Washington were two of the airports that receive the maximum number of diverted flights, as they are the closest airports to JFK. In future iterations of this model, these airports may also be represented as outliers, if desirable. This tool offers great flexibility in simulating different airport outages and adding different diversion airports, and demonstrates the strength of disruption management under shared situational awareness.