Reducing Flight Delays by Managing Air Traffic Uncertainties

Even with the aid of the latest in forecasting tools, weather can be hard to predict. This causes no end of headaches for air traffic managers, who must weigh this uncertainty as they make decisions—often many hours ahead of takeoff—about flight routing and schedules. Just a single sudden storm in a major transportation hub such as Chicago or New York can trigger gridlock across the entire country, potentially throwing thousands of flights off schedule.

MITRE researchers are working with the Federal Aviation Administration to develop a model for managing weather uncertainties, allowing air traffic managers to respond with agility to rapidly changing weather conditions. Such techniques are critical to the development of decision-support tools that will help air traffic managers handle increasing numbers of flights. This will be especially important as the Next Generation Air Transportation System, also known as NextGen, becomes operational. The FAA describes NextGen as a "wide-ranging transformation of the entire national air transportation system."

"Air traffic management aims to control flow into airports and through airspace where the demand exceeds the capacity," explains Craig Wanke, a MITRE senior principal simulation modeling engineer. "The FAA has the tools to handle airport flows. But they don't yet have a good method for managing overcrowded airspace in the event of sudden weather changes.

"To do this, you need a quantitative way of estimating how many planes can use a sector of airspace where a weather disruption is moving through, so you can decide which aircraft to move and when. The idea is to provide a systematic way to make those decisions."

Weather or Not—Helping Make Better Decisions

Weather can cause significant variations in air traffic capacity. Strong winds may limit available runways, and poor visibility forces aircraft to maintain increased separation for safety reasons. And even unpredicted good weather can cause problems if plans are already in motion to deal with threatening conditions.

That's because air traffic managers, airlines, and the FAA's command center currently hold a teleconference several times a day to determine how flight paths should be managed. Strategic plans are drawn up in two-hour intervals, and traffic managers must commit to these plans for many additional hours. If expected weather disruptions fail to materialize, it's not quick or easy to alter previously settled flight paths to take advantage of suddenly clear skies.

With MITRE's model, traffic managers gain leeway to wait longer before ordering flight traffic changes—in effect waiting until weather outcomes can be predicted more accurately before reacting to them, Wanke explains. Also, the model enables traffic managers to react to weather changes by assigning new routes to individual flights instead of to large groups of flights, as is commonly done today.

Improving Air Traffic Data Analysis

"We've defined intervals when traffic managers will make decisions and then proposed actions they can take every 30 minutes," Wanke says. "You get a tree of decisions, including a variety of possible options. The model provides an analytical means of determining which solutions make the most sense, factoring in schedules, safety issues, emerging weather events, and cost concerns."

(continued...)

Decision support models developed at MITRE help air traffic flow smoothly even when weather turns bad.

Making More Accurate Traffic Flow Predictions

In a related effort, MITRE researchers have developed an air traffic sector capacity prediction model that uses information on previous patterns to more accurately model the intricacies of air traffic flow.

"Based on historical traffic patterns, you can determine different levels of complexity," explains Lixia Song, a MITRE lead simulation modeling engineer who developed the capacity prediction model. National airspace sectors typically exhibit certain common traffic flow patterns, and different patterns represent different levels of traffic complexity. In higher-complexity conditions, it takes fewer flights to generate high workload for the controller team, so the sector capacity is lower. Using the model, traffic managers can assign a proper sector capacity for each predicted type of traffic pattern, she explains.

"One goal of this research is to generate sector capacities that account for the inherent complexity of established traffic flow patterns, rather than simply counting the number of aircraft and ignoring their orientation," says Song's fellow researcher, Daniel Greenbaum. "To do this we've analyzed months of historical data to identify periods in which traffic started to back up into the sectors," he adds. "We were able to infer that the effective capacity in the congested sector had been reached when the paths in the feeder sectors began to significantly lengthen."

The capacity prediction model gives air traffic managers the ability to compensate, to some degree, for the time it takes to make the complex computations involved in managing sector capacity.

"One of the most difficult challenges related to this problem is acknowledging that in the real world, decisions are made in multiple stages based on forecasts that become more accurate over time," Greenbaum says. "Unfortunately, the computational complexity of large, multi-stage decision problems makes them very hard to solve."

This project—along with other, related MITRE efforts—is aimed at helping the FAA develop a unified decision-support toolset that will support incremental, flight-specific solutions to reduce flight delays across the entire national air traffic system. As Greenbaum notes, for air traffic managers, "Multi-stage decision making is key."

Through this work—which began in MITRE's internally funded research program but is now directly funded by the FAA—we've developed techniques for comparing the effectiveness of aggressive and conservative traffic flow planning strategies. The model evaluates various options using Monte Carlo simulations, which allow for detailed analysis of random variations. Information gleaned from such analyses can be used to study a range of possible outcomes.

These processes, called "probabilistic congestion management" techniques, take advantage of sophisticated algorithms for analyzing large-scale air traffic congestion problems. The goal of this work is to eventually provide the FAA with automated tools to help traffic managers make timely, effective decisions when severe weather occurs (or doesn't), ultimately reducing air travel delays.

What's more, these techniques could also save the FAA a huge amount of money, adds Daniel Greenbaum, a MITRE lead software systems engineer who also worked on the project. "The FAA has devoted most NextGen resources to efforts such as improving the accuracy of flight and weather information and improving information technology and integration," he says. "But there will always be uncertainty in a system as large and complex as the national airspace system."

No one knows exactly how much money could be saved by using decision analysis principles to identify long-term strategies for dealing with this uncertainty. "But given that the U.S. airline industry spends close to $200 billion in operating costs each year, the potential benefit of even a small percentage reduction in such costs is very large," Greenbaum says.

—by Maria S. Lee

Contact: For more information on this and other MITRE programs, see **www.mitre.org/news/digest.**

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