

ROLE OF OPTIMIZATION MODELS IN FUTURE AIR TRAFFIC MANAGEMENT SYSTEM

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ABSTRACT

Primary objective of Air Traffic Flow Management (ATFM) is to mitigate demand – capacity imbalance in various parts of the National Airspace System (NAS). In the United States, ATFM is performed on a national basis by the Air Traffic Control System Command Center (ATCSCC), commonly referred to as the “Command Center”. Time varying demand and capacity levels at different airports and en route sectors is monitored and decisions are taken to restrict the flow of traffic whenever there is a shortfall of capacity at any resource(s).

The goal of ATFM decisions such as ground delay programs (GDPs), rerouting of aircraft across convective weather zones, airborne holding of aircraft, flow metering at en route fixes, etc. is to distribute an unavoidable delay in the system among the users in a way that causes minimal disruption and inconvenience. Ideally, theory and principles of optimization methods can be used in making these decisions, but in reality this is seldom done. In practice, lot of collaboration takes place among the airlines, FAA-Command Center, and the individual air traffic control (ATC) facilities, to achieve a reasonable solution to the problem of managing the flow of traffic through a congested region in the NAS.

There are certain factors that make the task of optimizing ATFM decisions challenging. Prime among all is that the aviation community is very diverse, with each member (user or controller) having their own objectives to achieve, and therefore it is very difficult to obtain optimal solutions that are acceptable to all stakeholders. Moreover there exists a wide range of uncertainty in the system both in terms of the NAS resource capacities and different users’ plans and actions.

Most of the existing optimization models for ATFM suffer certain limitations that make them unusable in the real world application. Many of them are Integer programming models with high computational complexity. User priorities are not well addressed by the existing literature. Moreover, there is almost no model or algorithm for allocating en route resources among the stakeholders in an equitable way. Uncertainty is another issue that is not well addressed. Most of the optimization models that account for en route congestion are deterministic.

Nevertheless, there are potential benefits of applying optimization techniques in ATFM. In this paper we present a case study that illustrates the benefits of using optimization models to exploit advanced information on convective weather available through new technologies such as CIWS. The CIWS-Echo Tops product provides the information on location and altitude of convective weather. In some cases where the storm echo tops are below certain altitude, aircraft can fly over the weather-affected zone and utilize the available capacities of the high altitude sectors. We selected the convective weather event in the northeast region over Pennsylvania on August 24, 2002 as our case study. CIWS-NEXRAD products were used to obtain the weather information. The value of advanced information exhibited by the results of our study justifies the need of investment in developing such new technologies and tools for decision support in future.

There are potential benefits, in terms of delay savings, that can be gained by blending optimization models and algorithms within the ATFM decision-making process. Several studies show that delays in the NAS can be reduced significantly through efficient use of the resources. In the future year, with advent of new technologies and tools, it will be possible to apply optimization techniques in ATFM. There exists a fair amount of literature on this subject. Most of the models suffer certain limitations that make them unsuitable for practical implementation. Research is required developing such tools with a goal of practical use. The high level of complexity in the aviation system will continue to be a critical barrier. In this paper, we discuss the types of optimization model required in future years and illustrate certain techniques and theory that can be used to develop them.

In the future years, ATFM will be performed in a decentralized setting. A high level of participation of airlines will take place in the decision making process. There will be lot of information sharing among the users and controller of the NAS, leading to a collaborative decision-making. Common situational awareness will exist among the airlines and FAA. Optimization models and algorithms must assume the role of equitable resource allocation to various stakeholders.

In order to be implemented in real world, optimization models must be computationally tractable and must address the high level of uncertainty in the system. Aggregating the demand of various resources can lead computationally easier models and algorithms. Methods of stochastic optimization and achieving robustness in solutions can be useful to deal with uncertainty. Ability to dynamically reassess decisions based on updated information on the operating conditions of NAS must be adopted by the optimization models.