

Chapter 8

Summary, Conclusions, and Recommendations for Future Research

8.1. Summary of Contributions

We have presented a detailed airspace collaborative decision making model that significantly enhances a preliminary formulation APM [47]. Specifically, we have first incorporated two alternative representations of randomized aircraft trajectory errors into the model, in contrast with using deterministic flight paths, recognizing that aircraft are subject to pilot, navigation, and wind-induced errors. By studying various conflict risk thresholds, this construct can also offer new insights that can be used for investigating possible revisions to FAA's aircraft separation standards. Second, we have employed a continuous time consideration of conflict risk incidents to provide a more flexible means to study sector conflict resolution capacities. Third, we have proposed two new model representations of conflict resolution constraints via suitable valid inequalities that serve to tighten the linear programming relaxations, and thereby potentially improve the solvability of the developed large-scale mixed-integer optimization problem.

Finally, we have proposed a novel collaboration equity formulation that more effectively scrutinizes the distribution of individual airline schedule costs relative to the overall cost, and takes better account of the dispersion of relative airline cost efficiencies than previous modeling efforts that focused mainly on ranges and extremal values of equity functions. This formulation includes an improved set of flight plan cost factors for investigating such fairness issues. In addition to fuel and delay costs, we

have examined flight dependencies occurring in hubbed operations, as well as market factors such as schedule convenience, reliability, and the timeliness of connections. To model this issue, we introduced a concept of collaboration efficiency as the difference between individually optimized decisions and the optimal CDM solution. This concept was used to develop an equity formulation that assesses the distribution of collaborative efficiencies achieved by each airline. In addition to a linear representation, we also presented an alternative representation that maps such collaboration efficiencies and equities to respective exponential utility functions. This equity formulation allows us to consider the significance of risk attitudes revealed by airline decision makers with respect to cost decisions, and to examine scenarios where these decision makers might “game” their decisions in the CDM process.

The APCDM can be used in practice for various tactical decision making purposes as well as for strategic planning studies. Potential tactical contexts include decisions pertaining to air traffic control diversions and delays during spacecraft launch operations or during severe weather conditions, military theater operations (such as damage assessment, search and rescue, ground support, and counter-operations), and the generation of alternative flight plans. Strategic applications include air traffic control policy evaluations, homeland defense contingency planning, spaceport location planning, military theater air campaign planning, and the construction of *a priori* plans to respond to various disruption scenarios (e.g., augmenting the FAA’s *National Playbook*). Furthermore, the model can be used to study the incorporation of the Small Aircraft Transportation Systems (CATS) into the NAS, and evaluate possible revisions to aircraft separation standards.

8.2. Recommendations for Further Research, Development, and Testing

We shall continue our research by first examining several specific airspace management scenarios. These scenarios will include an examination of airspace closures required for the safe passage of space launch vehicles from Cape Canaveral Air Force Station, Florida. Other scenarios will include dynamic time-dependent airspace closures resulting from severe weather systems as they progress across the Florida peninsula. Using ETMS data, and generating appropriate surrogates for both of

these cases, we shall explore, via column generation techniques as depicted in the outer loop of Figure 2-13, whether there might exist combinations of flight plans, not previously identified, that might yield a more efficient and less costly use of the airspace under such constrained conditions. Additionally, we will investigate dynamic resectorization strategies as an alternative means to more efficiently allocate ATC resources to various regions of airspace, particularly during periods of high traffic density or severe weather disruptions over certain sections of the airspace.

Next, we shall address the actual C++ programming used to execute the APCDM. The various programming models are functional, but need to be made more accessible (e.g. “user friendly”) to accommodate testing and evaluation by FAA personnel who are not necessarily familiar with C++ codes. We plan to adopt a “black box” approach, where users can input a set of proposed flight plans, select several parameter settings, and receive appropriately formatted APCDM outputs. This effort will require added efficiencies in the coding and the merging of the different modules. We will also require a more powerful processing platform to accommodate the increased memory storage and computing requirements associated with building a robust APCDM user interface.

We shall explore related applications for the APCDM, specifically, with respect to two areas rich in potential. Military theater campaign planning is a complex process that requires close coordination and deconfliction between diverse mission requirements such as Close Air Support, Strategic Interdiction, and Military Airlift. The APCDM model, appropriately modified, might be useful to gain new insights into this planning process.

Using the non-linear utility function CDM representation developed in Chapter 5, we shall compare decision outputs from the corresponding piecewise linear representation to the present APCDM formulation to determine the efficacy of using such an enhanced representation of risk attitudes, at the expense of added model complexity. We shall explore whether concepts of collaboration efficiency and equity, along with these utility functions will be useful in other decision models, and in particular, we will explore whether such concepts can be applied towards developing adequate representations of group utility functions.