NEXTOR Conference Abstracts

Monday, June 2, 2003

Plenary I: Charles Keagan, FAA.

ATM Session I Papers

Title: Resource Rationing and Exchange Methods in Air Traffic Management: Parts I & II

Authors: M. O. Ball and T. Vossen, University of Maryland (Email: MBall@rhsmith.umd.edu)

Abstract: The Federal Aviation Administration (FAA), and the airline community within the US, have recently adopted a new paradigm for air traffic flow management called Collaborative Decision Making (CDM). In this seminar we present a comprehensive analysis of the CDM resource allocation procedures. The CDM procedures consist of three components: a resource (arrival slot) allocation step, an intra-airline resource optimization step and an inter-airline exchange step. We model the first step as a fair resource allocation problem. We define a set of fair allocation axioms and then derive those allocation rules that satisfy these axioms. We investigate the problem of determining an actual allocation as close as possible to an "ideal" allocation produced by an allocation rule. We show that this problem is related to certain just-in-time scheduling problems. Based on this analysis, we show how certain inequities in the treatment of long-haul vs. short-haul air carriers can be substantially mitigated through the use of the new optimization procedures.

We also analyze the resource exchange process known as compression (Step 3). We show that it can be interpreted as a mediated 1-for-1 exchange process. Using this interpretation we propose an extension to the use of 2-for-2 exchanges. We develop an efficient integer programming model that solves the mediator's problem. We also show that, while the system-wide performance of the current exchange process (based on 1-for-1 exchanges), can yield results substantially below system optimal, the new procedure (based on 2-for-2 exchanges) can come very close to produced system optimal results.

Title: Exploratory Study of Auction-based Arrival Slot Allocation

Authors: S. Kholfi, L. Le, G. L. Donohue, and C-H. Chen, George Mason University, (Email: Gdonohue@gmu.edu)

Abstract: Auctions have been successfully used for radio spectrum allocation and energy distribution. In this paper we explore arrival time-slot auctions to balance demand and supply at slot-constrained airports. Our approach attempts to assure safe aircraft separation, optimize passenger enplanement opportunities, and equitably allocate a limited supply of landing opportunities.

Title: Evaluation of Airspace Metrics for New ATM Concepts

Authors: A. Yousefi and G. L. Donohue, George Mason University, (Email: Gdonohue@gmu.edu)

Abstract: The existing airspace Sectorization is not an efficient design to safely control the growing air traffic. To enhance the airspace design, it is necessary to accurately estimate airspace measures such as sector complexity, controller workload, and density. We discuss several metrics and how they can be used to evaluate new concepts in air traffic management.

ATM Session II Papers

Title: Evidence for the Safety-Capacity Trade-off Relationship in the Air Transportation System

Authors: G. L. Donohue, R. C. Haynie, and D. Wang, George Mason University, (Email: Gdonohue@gmu.edu)

Abstract: Much of the FAA modernization program has focused on technology to increase the air transportation system capacity. Although safety is stated as the FAA's primary mission, the maintenance of safety margins has always been taken as a given for most new technology insertion investment analysis. Rarely has the effect of operating the system at very high capacity fractions (as defined by aircraft arrival demand/maximum safe separation capacity) been considered as a primary reason for new operations procedures requiring the insertion of new technology. This presentation presents new data on operational practice at ATL and LGA compared to FAA wake vortex separation and runway occupancy time standards. This data is compared to historical safety data reports on accident precursors (i.e. Near Mid-Air Collisions, Loss of Separation and Runway Incursions) as a function of demand to capacity ratios. Calculations using the NLR safety modeling methodology for wake vortex encounters are shown as an example of a formal method to estimate operational hazard Target Levels of Safety for a wide range of system modernization programs.

Title: The Big Iron

Authors: A. Williams, S. Mondaloni, D. Liang, S. Bradford, and R. Jehlen, CSSI, Inc., Washington, DC (Email: awilliams@cssiinc.com)

Abstract: There are research activities in the United States evaluating various concepts of Free Flight. One such concept looks at autonomous flights for fully equipped aircraft operating in the National Airspace System. The flight deck of such aircraft will be fully equipped to uplink and downlink data (such as traffic, weather, etc.) and will be equipped with decision support tool(s) to process information for conflict detection and resolution and communicate with other flight decks and the service provider.

This document presents an alternative architecture, a centralized information assembly and processing, and a decision support system called the "Big Iron" that can be implemented in long-term NAS operations under the Free Flight Concept. Such a system would provide a homogeneous decision support tool and homogeneous assembly of information coming from different communication means with differing levels of accuracy and latency. Consequently, appropriately equipped users would possess consistent common information.

There are two potential problems identified under this approach: (1) delay in receiving the decision support analysis and (2) added strain on communication links expressed through additional bandwidth requirements. Both problems stem from having to transmit solutions and/or requests as opposed to processing them locally. Assumptions were made regarding the types of services necessary to support the autonomous operations that will be available and their associated communication links. The purpose of this research is to determine how much and what kind of information can be transmitted in time to enable *safe and efficient operations under such* centralized information and decision support processing and the timeframe in which this could be realized.

Title: Using TOPAZ to Estimate Runway Incursion Probabilities

Authors: J. Shortle and Y. Xie, George Mason University (Email: jshortle@gmu.edu)

Abstract: The growth in air traffic operations has led to increased stress on the arrival and departure airspace near major hubs. We investigate whether this has also led to a decrease in safety. We use the NLR safety modeling methodology, TOPAZ, to estimate runway incursion probabilities, based on data collected for Atlanta airport.

Title: Current Analysis of Hazard Factors in U.S. Civil Aviation Midair Collisions, 1991-2000

Authors: C. C. Morris, US Department of Transportation (Email: craig.morris@bts.gov)

Abstract: Midair collisions in U.S. civil aviation average about 15 per year. Each collision involves two aircraft and usually results in substantial life and property loss. To identify hazard factors associated with midair collisions in U.S. civil aviation, I present a Haddon matrix analysis of National Transportation Safety Board data on U.S. civil aviation midair collisions from 1991 through 2000.

ATM Session III Papers

Title: Using Time Series to Model NAS Operational Correlations

Authors: L. Le, S. Kholfi, G. L. Donohue, and C. H. Chen, George Mason University, (Email: Gdonohue@gmu.edu)

Abstract: We analyze the space-time correlations among different variables in the NAS such as demand, capacity, delays, cancellations, and delay variability. We present a user-friendly tool to visualize the large, complex data sets of ASPM and BTS, and present a case study involving ORD and MSP.

Title: Toward Probabilistic Forecasts of Convective Storm Activity for En Route Air Traffic

Authors: B. Liu and M. Hansen, UC Berkeley (Email: mhansen@ce.berkeley.edu)

Abstract: Convective weather is one of the primary causes of delay in the US National Airspace System. Many of the advances in reducing this problem require estimates of the probabilities that convective weather will make certain routes un-flyable at some point in the future. We investigate the possibility of providing such probabilities using Markovian models of the "storm state" of an air route segment. We consider first the question of how to define such a state. Next various Markovian models are presented, with particular emphasis on hidden Markov models (HMM's). This model postulates the existence of unobserved weather states, such that the hidden weather process is assumed to follow a Markov chain, and the observable weather condition is assumed to be conditionally independent given the hidden weather state. We model the convective weather evolution at the Northeast Corridor in the US based on same day data of 46 time periods, each 5 minutes apart, for 611 geographic sectors. Preliminary results suggest that HMMs have promise as a modeling framework for the convective weather process.

Title: Building the Timetable from Bottom-up Demand: A Micro-econometric Approach

Authors: D. Bhadra, J. Gentry, B. Hogan, F. Moreno-Hines and M. Wells, The MITRE Corporation (Email: dbhadra@mitre.org)

Abstract: The aviation community has a rich collection of tools that simulate the operational flows of the National Airspace System (NAS). In nearly all cases, modeled operational flows of aircraft in the NAS begin with a schedule generated outside of the model. In the past, this schedule has been derived by translating Terminal Area Forecasts (TAF) into flights. The downside to this, however, is that NAS operations are made up specific airport-to-airport flows, which may be different from a simplistic extrapolation of terminal area growth attributable to those airports. The challenge is to move from a generic traffic count at a specific terminal to a schedule of flights that includes a "when" and a "where" dimension.

Because modeled NAS operational performance is highly dependent on the characteristics of the forecast scheduled operations, it is critical that a schedule of traffic is created correctly. The top-down approach described above achieves its goal of replicating the intended volume of flights at each airport, but it does not

necessarily achieve the desired operational-level integrity. In other words, the existing method is not capable of forecasting route-specific growth in operational flows.

At CAASD, we are building a framework which attempts to fill in the gaps mentioned above using a bottom-up, demand-driven micro-econometric approach. Our ultimate goal is to produce a schedule of flights that is linked with origin and destination (O&D) operations via passenger route choice. It should thus be in sync with the Official Airline Guide (OAG), but not driven by it. Our method is comprised of eight basic steps, beginning with forecasts of traveler demand between O&D city pairs, and culminating with the creation of a forecast schedule that incorporates all major aspects of passenger demand.

Title: A Cluster Analysis to Classify Days in the National Airspace System

Authors: S. Penny, Metron Aviation (Email: penny@metronaviation.com)

Abstract: *Purpose:* Within the aviation community, there is a need to conduct simulations of the National Airspace System (NAS). In the validation process, NAS simulation output data is compared – in some statistical sense – to the real world data characterizing the natural operation of the NAS. How many different types of days should be used to validate a NAS simulation? We investigated this question.

Research: The NAS is complex. The amount of data that could be used to validate NAS simulations could be overwhelming. Because of this, we created a *NAS Feature Vector* that describes the natural state of the NAS. Using cluster analysis, we investigated 65 variables describing aggregate NAS data (Jan. 2000 through Sept. 2001) for states (e.g., arrival rates, weather, etc.), controls (Ground Delay Programs (GDPs), MIT restrictions, etc.) and performance (e.g., weather related delays, taxi delays, etc.), and identified eight key variables that naturally describe the NAS. The other variables were eliminated from our NAS Feature Vector as they are shown to be independent of the eight key variables.

Results: There is no single day of the year which could be described as a "typical" day in the NAS. One must select the "type" of day in the NAS first before identifying the most "typical" day of that type. Hence, we identify a total of six "typical" days in the NAS, one for each of six representative "types" of days in the NAS. When NAS simulations do not include weather (nor GDPs), then two types of days represent good simulation validation data sets. When weather and GDPs are modeled in a simulation, then another four types of days are important for NAS simulation validations. The results apply primarily to "low fidelity" NAS simulations; high fidelity simulations require further study.

Plenary II: Arnold Barnett, "Already Gone? Where is the Crisis in Airport/Airspace Congestion?" MIT (Email: abarnett@mit.edu)

Abstract: After 9/11, it was said that air traffic growth would be delayed for a year, after which normal growth trends would resume. There there is less traffic in 2003 than in 2002, and little prospect for a resurgence in 2004. Are we facing a changed world rather than a transient "breather" period? We will brood on the topic.

ATM Session IV Papers

Title: Adjusting Ground Delay Programs for Demand and Capacity Uncertainties

Authors: W. Kooiman and T. R. Willemain, Rensselaer Polytechnic Institute (Email: willet@rpi.edu)

Abstract: GDP planning might better account for uncertainties in the timing of arrivals to, and the actual landing capacity at, the destination airport. We model these demand and capacity uncertainties and then estimate how they affect the calculation of ideal ground delays.

Title: Agent-Based Computational Approach to Airline Competition and Airport Congestion Problems

Authors: J-H. Kim, D. Teodorović, and A. A. Trani, Virginia Tech (Email: duteodor@vt.edu)

Abstract: The number of passengers in air transportation, and the total number of flights have significantly increased in recent decades. At the same time, airport capacities have not kept up with this increase in demand. Airspace systems in many countries are overloaded. Today's air transportation problems are found in the complex interactions of social, economic, political, and engineering issues. This complex situation results in cancelled flights, delayed flights, greater airline and airport operating costs, inconvenience to passengers, decrease in the quality of air traffic service and potential decrease in airspace safety. Airlines are under the constant pressure to improve their operational efficiency and profitability.

The traditional approach to analyze transportation problems has been the "top-down approach." On the other hand, when considering complex air transportation problems, many issues are addressed simultaneously and the individual parts (passengers, airlines, airports, and Air Transportation authorities) have greater autonomy to make decisions, communicate and to interact with one another. Relatively minor change in individual behavior can cause significant change in while air transportation system. In other words, complex collective behavior can emerge from simple actions of individual agents (airlines, airports, and aviation

authorities). Congestion in air transportation could be viewed as emergent phenomena that is sometimes difficult to predict and that is even sometimes counterintuitive. It seems that the promising way for analyzing emergent phenomenon (congestion in air transportation) is the development of the simulation models that can simulate behavior of every agent (passengers, airline, airport, and air transportation authority).

In this paper the agent-based model for air transportation congestion has been developed. Our model considers that each part (airline, airport, passengers) act based on its local knowledge and cooperates and/or competes with other parts. The model developed allows agents that represent airports to increase the capacity, or to significantly change landing fee policy, while the agents that represent airlines learn all the time, change their markets, fares structure, flight frequencies, and schedules. The Agent based model developed in this paper, which represents a bottom-up approach to problem solving, is an appropriate tool that can help us to better understand complex nature of congestion in air transportation. In this way, it will become easier to predict and/or control the overall performance of a complex air transportation system.

Title: Conflict Resolution (CORA) Strategy

Authors: S. Kauppinen, EUROCONTROL (Email: seppo.kauppinen@eurocontrol.int)

Abstract: Three strategies were investigated in EUROCONTROL Human Factors Laboratory using a group of controllers from Europe. Controllers preferred Collaborative Strategy over User-driven and Automatic. Each strategy is described in this paper.

Title: An Airspace Planning and Collaborative Decision Making Model Under Safety, Workload, and Equity Considerations

Authors: H. D. Sherali, R. W. Staats, and A. A. Trani, Virginia Tech, (Email: hanifs@vt.edu)

Abstract: We develop a large-scale, mixed-integer programming Airspace Planning and Collaborative Decision Making Model (APCDM) to schedule a set of flights from among alternatives subject to flight safety, air traffic control workload, and airline equity constraints. Novel contributions of this research include three-dimensional probabilistic conflict analyses, the derivation of valid inequalities to tighten the conflict safety representation constraints, the development of workload metrics based on average (and its variance from) peak load measures, and the consideration of equity among airline carriers in absorbing the costs related to re-routing, delays and cancellations. The APCDM has potential use for both tactical and strategic applications, and can serve a useful role in augmenting the FAA's *National Playbook* of standardized flight profiles in different disruption-prone regions of the National Airspace.

ATM Session V Papers

Title: Estimating the True Extent of Air Traffic Delays

Authors: J. El-Alj and A. Odoni, MIT (Email: yelalj@mit.edu)

Abstract: Most air traffic delay measures assess delays relative to schedule. Over the past decades, however, airline schedules have been adjusted to take into account airspace congestion and yield better on-time performance. In that context, delay measures that are using scheduled times as a benchmark are of very limited use in assessing airport and airspace system congestion, since delay has already been built into the schedule.

The primary goal of this paper is to develop a measure that will estimate "true" delays that are not sensitive to schedule adjustments. In order to calculate "true" delays, we compute the difference between the actual gate-to-gate time and a theoretical benchmark, the "baseline." The baseline time to be used is O-D specific and is defined here as the gate-to-gate time from origin to destination under optimal (non-congested) conditions.

We choose the fifteenth percentile of reported statistics on gate-to-gate time as an estimator of the baseline. We then compute baseline times for 618 major O-D pairs. Using the baseline times, we compute "true delays" on these 618 O-D pairs and observe that they are about 40% to 60% larger than delays relative to schedule.

We also develop two methods to attribute O-D delays to the origin and destination airports. Using these methods, we determine that airports incurred about 5 to 13 minutes of delay per operation in 2000, depending on the airport under consideration. Airport rankings according to "true" delays are compared to airport rankings obtained from OPSNET delay statistics. The comparison suggests that, although OPSNET statistics underestimate the magnitude of delays, they yield very comparable airport rankings and can therefore be used to rank airports with respect to congestion.

Finally, we change perspective and look at the development of probabilistic models for designing flight schedules that minimize delays relative to schedule. We use the simple case of an airline scheduling an aircraft for a round trip to illustrate the complexities and uncertainties associated with optimal scheduling.

Title: Factors Influencing Estimated Time En Route

Authors: T. R. Willemain, H. Ma, N. V. Yakovchuk, and W. A. Child, Rensselaer Polytechnic Institute (Email: willet@rpi.edu)

Abstract: We investigated the influence of several factors on a flight's estimated time en route (ETE). We found much variation in ETEs. Some routes have ETE distributions that are well modeled by a mixture of lognormals; in simple cases, this pattern can be regarded as a mixture of regular and irregular operations.

Title: Estimating Sources of Temporal Deviations from Flight Plans

Authors: N. Yakovchuk and T. R. Willemain, Rensselaer Polytechnic Institute (Email: willet@rpi.edu)

Abstract: We analyzed temporal deviations from flight plans. We decomposed the average daily deviation for each OD pair as Deviation = System Effect + Origin Effect + Destination Effect + En route Effect. Applications include monitoring sources of delay in the NAS through creation of next-day reports on trouble spots.

Title: Post-deployment Analysis of Capacity and Delay Changes for an Airport Enhancement: Case of a New Runway at Detroit

Authors: M. Hansen, UC Berkeley (Email: mhansen@ce.berkeley.edu)

Abstract: We develop and demonstrate a new statistical method for estimating airport capacity and assessing the capacity and delay impacts of events such as the opening of a new runway, deployment of technology, or even transient events such as facility outages. The method is to estimate models of airport throughput using censored regression, recognizing that a given time the throughput is the minimum of the capacity and available demand. The method is demonstrated for the opening of a new runway, Runway 4L/22R, at Detroit-Wayne County (DTW) Airport. Results show, over the period studied, the main effect of the new runway was to increase departure capacity during IFR conditions. Another finding is that capacity is highly variable, even controlling for visibility condition. Results are then used to estimate arrival and departure delays at DTW, using a simple spreadsheet simulation. We find that simulated delays match observed delays quite well, and the new runway decreased departure delays about 20%, while having virtually no effect on arrival delays.

ATM Session VI Papers

Title: Ranking of Air Traffic Conflict Resolution (CORA) Advisories Based on Resolution Quality Index

Authors: S. Kauppinen, EUROCONTROL (Email: seppo.kauppinen@eurocontrol.int)

Abstract: A method was developed to rank resolution advisories based on quality index. CORA ranks resolution advisories based on workload and cost. The advisories are presented with their quality index, and after controller selection, converted into a system trajectory. Reminders are provided of any maneuver required for implementing the resolution.

Title: Medium-term Conflict Detection Field Trails in Europe

Authors: S. Kauppinen, EUROCONTROL (Email: seppo.kauppinen@eurocontrol.int)

Abstract: A series of field trials were organized in Area Control Centres in Europe to get feedback of MTCD concept using a trials platform connected to live ATC system. Two modes of operation were tried, shadow mode and active shadow mode. This paper presents results from two trials (Malmö and Rome).

Title: Virtual Reality Simulation for Airport Expansion

Authors: K. Christensen, NASA (Email: kchristensen@mail.arc.nasa.gov, nancy.s.dorighi@nasa.gov)

Abstract: Expanding existing airports and changing procedures quickly, correctly and safely requires assessments that include the human operators, not just the proposed airport layout. NASA Ames high fidelity simulation laboratories provide the unique ability to experience a future airport in a real-time simulation from both the tower and cockpit perspectives. The 360-degree tower integrated with a full motion transport aircraft simulator enable operational measurements on which to base better airport expansion decisions.

Title: Functional Analysis of Aviation-impacting Weather: A Unified Modeling Language (UML) Approach

Authors: D. J. Embt, CSSI, Inc. (Email: dembt@cssiinc.com)

Abstract: This paper discusses a Unified Modeling Language based methodology that was used for performing functional analysis of aviation impacting weather. The objective of this analysis is to identify National Airspace System-level requirements that affect the operational use of weather information by decision makers. The methodology was developed and applied using a commercially available UML tool, which offers a rich notation for describing systems using a variety of diagram types.