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Airport-Airspace Simulations for Capacity Evaluation

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Editors
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Introduction

SALEH A. MUMAYIZ
MITRE Corporation
Committee Chair

The TRB Committee on Airfield and Airspace Capacity and Delay (A1J05) sponsored this workshop. The primary objective was to provide a forum to demonstrate and discuss airspace and airfield capacity evaluation studies and present state-of-the-art airport-airspace simulation models. Presentations of recent applications were made, and their findings discussed.

The workshop was designed to improve the understanding of airport capacity evaluation and elaborate on technical details and requirements of the analysis involved in these studies. The advantages of simulations to provide realistic and dynamic evaluation of the complex interactions of the system were highlighted and discussed. The workshop format contained sets of panels of software developers, with simulation users group representatives demonstrating the simulations and airport managers/planners with airport consultants presenting and discussing recent capacity studies. Discussions covered the assumptions, simulation logic, data requirements and management, modeling approaches, analytical techniques, evaluation methods, findings, and management of the conduct of airport simulation studies. Covered in this workshop were airport simulations, including SIMMOD-based simulation, the Airport Machine, and the total airport-airspace modeler as well as the detailed policy assessment tool for airport systems simulation.

The attendants of this workshop included airport managers, planners, and engineers; airport engineering/planning consultants; airlines' operations planners; aviation researchers; state airport/aviation planners; and FAA staff in aviation/airport planning, capacity, and air traffic management.

Acknowledgments

The TRB Committee on Airfield and Airspace Capacity and Delay and the workshop organizing subcommittee would like to express appreciation and gratitude to the individuals who contributed to the organization and success of this workshop. Without their tireless efforts, this activity wouldn't have been as successful as it was. In particular, acknowledgment is extended to Joseph A. Breen and Nancy Doten of the TRB staff for their timely contribution and attentive involvement throughout different stages of organization and to all the speakers and moderators of the workshop sessions.

Special appreciation goes to Jasenka Rakas, a member of the committee, who edited and produced this document in the new TRB format for E-Circulars. She provided tireless efforts and outstanding contribution to document this workshop and produce this TRB E-Circular. Without her work, the proceedings of this workshop would have otherwise gone undocumented and been lost.

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Role of Simulation in Airport Development Planning

GEOFFREY D. GOSLING
University of California at Berkeley

The presentation addresses the role of simulation in airport development planning from the perspective of several issues: objective of simulation analysis, selection of alternatives for analysis, experimental design considerations, design of future demand scenarios, projection of annual delay levels, and effect of new procedures or technology. Objectives of simulation analysis always have to be clearly defined and well understood. Simulation modelers/analysts usually deal with some of the following issues: evaluation of alternative concepts (looking for delay reduction benefits, aircraft flight and taxi time, and operational considerations), input to benefit-cost analysis, and input to noise/emissions analysis. They should also have a clear idea about the client's profile (i.e., who needs to be convinced: an airport board, FAA, metropolitan planning organizations, government agencies, or stakeholder groups?).

Selection of alternatives for analysis is central to the validity of results. The FAA's benefit-cost analysis requirements usually consider a broad range of alternatives (such as airfield configurations, runway separation and lengths, and new procedures and technology). The operational strategies should be tailored to alternatives, the baseline alternatives clearly defined, and an iterative approach conducted.

Experimental design considerations usually include many issues: projecting future traffic levels; modeling combinations of alternatives, conducting sensitivity tests on (*a*) traffic composition and peaking and (*b*) operational assumptions, handling saturated conditions, and presenting results.

Design of future demand scenarios should include the following: the proportional growth of current traffic, expected shifts in traffic composition, assignment of routes and runways, and airline market share considerations. Questions such as How many analysis days? What is the design day/annual ratio? and What is acceptable delay? should be considered to project annual delay levels.

New procedures or technology also needs to be considered in simulation modeling because they have a critical impact on analysis results. Because these procedures and technology are new, modelers should make reasonable assumptions and have good guidance.

Open architecture concepts should also be discussed. Some of the most important and critical concepts are better ways to define operational procedures, user access to intermediate data flows, interaction with user-developed modules, explicit modeling of human behavior, modeling of 4D aircraft flight paths, and link model inputs/outputs with other tools.

We always need to ask ourselves why we are conducting simulation modeling. In addition, we need to ensure that our modeling addresses the critical issues and that we pay attention to the importance of model assumptions. Modelers should also be able to (*a*) recognize uncertainty and limitations of a particular simulation model, (*b*) have technical guidance on use of models, and (*c*) continue to enhance capabilities of simulation tools.

Click here to see Gosling's slide presentation.

Issues and Challenges for Airports in the New Millennium

JAMES M. CRITES
Dallas/Fort Worth International Airport

This presentation provides a brief description of the Millennium Paper, Airspace and Airports in the New Millennium published by the TRB Committee for Airspace and Airport Capacity and Delay (A1J05) in January 2000. It covers topics such as changing roles in aviation, the most important questions for the 21st century, airport capacity, potential solutions, system technologies, decision support systems, and system performance. Aviation has changed its roles as a result of the following factors

1. Deregulation of the air transport industry,
2. United states 1990s focus on balancing the federal budget,
3. NASA strategic initiative to support commercial aviation, and
4. Airports transition from custodian/landlord to economic engine and service provider.

The presentation addresses the most important questions for the 21st century, such as What is the "end game" in the evolution of the new global air transport and civil aviation systems? What technologies, systems, and approaches will be or should be adopted? and What are the logical roles and responsibilities of the stakeholders in this new environment?

As major U.S. airports approach capacity limitations and experience tremendous delays, the airport capacity measures are divided into microlevel (airport) measures and a national airspace (NAS)-wide estimate of the impact of delays/improvements at specific airports. The microlevel (airport) measures deal with the following:

1. Traditional capacity improvements, that is, runways for independent arrivals/departures,
2. Procedural changes and technology innovation to allow simultaneous use of existing runways, and
3. Delay-driven demand management to reduce interarrival and interdeparture spacing.

To date, what is lacking is a NAS-wide estimate of the impact of delays/improvements at specific airports (a potential solution could be a mandatory publication of research funded by AIP/PFC).

Potential solutions to capacity enhancements suggested in this presentation fall into the following four categories.

1. Privatization of air traffic management (ATM),
2. FAA's focusing/funding of NAS architecture and operation,
3. FAA/NASA's focusing/funding of NAS research and development (R&D) and supporting regional ATM R&D augmented by airports, and
4. Airports' focusing/funding of regional ATM needs.

Privatization of ATM reduces strain on already constrained FAA budget and provides effective funding and fielding of new communications, navigation, and surveillance (CNS) technologies. To date, Civil Air Navigation Services Organization has achieved successes in the area of ATM privatization.

In September 1991, the International Civil Aviation Organization endorsed a transition to new CNS technologies, which included satellite, data link, and automation technologies. However, many issues remain unresolved, such as national sovereignty, industry regulations, and so forth.

In the United States, there is an emerging consensus on CNS technologies, with many issues to resolve [e.g., Global Positioning System (GPS) integrity, automatic dependent surveillance-broadcast (ADS-B) role in the airspace system]. The promising concepts include Free Flight Phase 1 and NASA/FAA's joint ATM research and technology development plan.

There is a greater need for comprehensive NAS/airport assessment and more effective reporting of performance. The current measures used in defining system performance are usually grouped into three categories.

1. Measures of performance, such as RAM, capacity (delay), and rates of return on investment;
2. Age of NAS equipment; and
3. New technologies [such as GPS, data link, ADS-B, Center TRACON (Terminal Radar Approach Control) Automation System, CASA, low-level wind shear alert system, integrated terminal weather system, low visibility landing and surface operations, and TAPS].

The presentation concludes that the implementation of (*a*) NAS architecture will lead to harmonization of current system and (*b*) free flight will cause the system to evolve into a more effective interactive airspace management. Regional air traffic control–airspace enhancement initiatives will be funded and supported by regional users. Air Transport Industry will continue to evolve from "global alliances" to global "seamless service" corporations. Airports will assume the role of on-ground customer service provider, ensuring effective developments of an economic asset.

Click here to see Airspace and Airports in the New Millennium.

Click here to see Crites' slide presentation.

Simulations for Redesigned Airspace Flight Procedures

WILLIAM DUNLAY, JR.
Leigh Fisher Associates

This presentation gives a brief description of a simulation study with the objectives to redesign airspace flight procedures and analyze their impacts on three busy and closely spaced airports in the New York Terminal Radar Approach Control (TRACON). The modeled airports in this simulation study are John F. Kennedy Airport (JFK), LaGuardia Airport (LGA), and Newark International Airport (EWR).

The basic study goals are to

1. Develop precision approach, departure, and missed approach procedures;
2. Reduce aircraft delays and flying times by permitting more simultaneous operations;
3. Define requirements for subsequent airspace restructuring; and
4. Provide incentive for the earliest possible implementation of emerging technology.

The simulation study undertakes several steps. Flight procedures are redesigned, and SIMMOD is then used to analyze the effects of new flight procedures on aircraft delays and flying times. The simulation study also considers capabilities of future navigation systems and uses 3D visualizations and video.

As traffic in NY TRACON continues to grow and environmental constraints prohibit building new runways, potential capabilities of improved navigation technology need to be further explored. Some of the issues considered in this study are different levels of technology [flight management system with signals from very high frequency omnidirectional range/distance measuring equipment, Global Positioning System (GPS), differential GPS], curved or segmented procedures, reduced navigation and flight technical errors, instrument landing system-like navigation accuracy throughout the terminal area airspace ("aircraft on rails"), and instrument meteorological conditions procedures similar to visual meteorological conditions procedures.

With new Procedures C, D, and E involving JFK and LGA, the study has found that the annual savings at LGA would be $1.6 million in departure flying time, $0.3 million in departure delay, and $2.0 million in passenger time. These procedures would have short-term implementation, and the benefits would be expected for 20 percent of the year.

With Procedure F, the annual savings at JFK would be $3 million in departure delay, $5 million in departure flying time, and $8 million in passenger time. The procedures would have short-term implementation in visual flight rules (VFR) and long-term implementation in instrument flight rules. The benefits would be expected for 38 percent of the year.

With Procedures G and H, the annual savings at JFK would be $13.3 million in arrival delay and $19.1 million in passenger time. The annual savings at LGA would be $7.2 million in delay and $10.2 million in passenger time. It is also estimated that there would be 195 minutes savings in average arrival delay at LGA and JFK, with the expected benefits between 1 to 7 percent of the year.

New Procedures N and O, involving LGA, EWR, and Teterboro Airport (TEB), would bring the annual delay savings of $0.7 million at TEB and $0.2 million at LGA, with 21 minutes of average decrease in arrival delay and 19 minutes of average increase in departure delay at LGA. These procedures would require long-term implementation, and the expected benefits would be for 0.5 percent of the year.

Total annual savings in direct aircraft operating costs would have the (*a*) annual net delay savings of $39 million in 2002 (increasing to $94 million in 2007) and (*b*) annual flying time savings of $20 million in 2002 (increasing to $24 million in 2007). There would also be additional savings possible with airspace redesign.

While using SIMMOD to (*a*) manage large files with hundreds of overlapping nodes and links and (*b*) represent complex airspace interactions (such as alternating use of dependent runways at different airports, bi-directional flow on a single runway, and intersecting flight paths to multiple airports), the simulation modeling had to face many challenges. The top 10 challenges to implementation of procedures are listed as follows:

1. Fleet equipage and retrofits,
2. Accommodation of partially equipped fleet,
3. "Flyability" testing and blunder analyses,
4. Development of precision curved and segmented instrument procedures,
5. Restructured airspace,
6. Need to change air traffic control and procedural requirements and clearance criteria,
7. Evaluation of noise impacts,
8. Accommodation of foreign operators,
9. Redefining role of human controller, and
10. Pilot and controller acceptance.

Click here to see Dunlay's slide presentation.

Application of SIMMOD-Based Simulation
Users' Group Perspective

DOROTHY BRADY
HNTB

This presentation discusses the value of SIMMOD, activities of the North American SIMMOD User's Group (NASUG), and several SIMMOD applications.

SIMMOD is one of the oldest and most commonly used simulation modeling tools. It realistically models airport operations under different conditions and tests various "what if" scenarios with quantifying differing impacts. SIMMOD produces model animations that are understandable by nontechnical individuals.

The NASUG is an organization for the exchange of ideas and experiences among SIMMOD users, primarily working on North American airspace and airport projects. NASUG has more than 100 members from the aviation community that meet twice a year to discuss common modeling and programming problems. NASUG's website can be found at www.nasug.com.

SIMMOD applications could be classified into three basic groups: benefit-cost analysis, terminal/concourse layout, and construction phasing. Benefit-cost analysis deals with annualized SIMMOD results that may be used to help time the addition of new runways, taxiways, or gates. This analysis also uses the delay curve, showing average delay per operation as operations level increases. Terminal/concourse layout studies use SIMMOD to quantify ground movement impacts in apron areas. Construction phasing study involves modeling the impact of closing part of a runway at Minneapolis–St. Paul International Airport for reconstruction; demonstrates to airport management, airlines, and air traffic control that construction can be accommodated; provides airlines with necessary information to "fine tune" schedules and minimize delays; and helps an airport to "fine tune" the phasing of the project to reduce delays.

Click here to see Brady's slide presentation.

Development of Airport Simulations for SIMMOD and Beyond

TUNG X. LE
LeTech, Inc.

This presentation addresses LeTech's development issues for SIMMOD and airport simulation modeling tools in general. LeTech Incorporated has designed and developed the airport simulation model (LTI-ASM), previously called SIMMOD Turnkey System. The LTI-ASM model is based on SIMMOD users' needs and requirements. A recent joint-venture program with the International Air Transport Association (IATA) has resulted in the development and testing of modules for gate management and terminal simulation, which are being applied to IATA's actual projects, and are exclusively licensed to IATA for marketing, training, and support.

This latest model is affordable and cost effective, easy to use, reliable, and fast.

The developer's goals were to (*a*) easily maintain the model (C++), (*b*) minimize support (more internal validation), and (*c*) have flexibility in adding new features and sharing features between modules. The model (i.e., system) has a network editor, gate management, events generator, simulation engine, animator, and reports modules.

The network editor is simple and easy to use because of many user-friendly features, such as visual editing and selecting the system network; undo and redo functions; computer assisted design (CAD) object layout design; background display support [CAD with layers control (DXF import), CAD objects, National Flight Data Cener (NFDC) data, and demography]; and instant validation of input data with self repair. Gate simulation features include

1. Gate requirements analysis,
2. Gate assignment,
3. Flights cloning,
4. Standard network data and logic for gate selection,
5. Preprocessor for events generator, and
6. Simulation engine logic.

Events generator features include route assignment, taxi path assignment, and scenario builder (runway closing, flow control, and traffic shift).

LeTech's new and advanced simulation engine is compatible with most SIMMOD data inputs. Some of the enhanced features include

1. Individual aircraft tracing for debugging,
2. Air traffic controller delay actions, and
3. Air traffic control actions (by providing time between actions).

Other advanced features for generating queuing information of special locations deal with runway crossing operations, departure queue, and de-icing operations. Additional simulation enhanced features include procedure blocking (full matrix blocking, cross runways, and parallel dependent arrivals), de-icing special logic, de-icing areas and pads with movements control, and gate de-icing (variable runway threshold and taxi speed, patterned runway and airspace closing, gate preferences, and runway switching).

Animation, which is fast and easy to use, can handle multiple scenarios (four for NT/2000 and two for 95/98), multiple PCs replay (no limit), and background display support (CAD, CAD objects, NFDC data, demography, INM, and terrain).

The reporting features can be broken into several categories:

- Text and graphical output,
- Graphical point-and-click analysis,
- Graphs and charts, and
- 24-hour data collection/analysis.

The reports provide information on general delays, deicing operations and delays, airline delays, departure queues delays, gate statistics, flight statistics, ground and airspace statistics, and sector delays and statistics.

The backup features include daily or temporary backup onto a network or floppy drive, data transfer or delivery, and ability to fully regenerate a study and its cases.

Current LeTech's developments include demo/training features, CAD object layout design, report analysis enhanced features, and 3D graphics. The future development will be primarily focused on modeling terminal building operations. LeTech's primary goals are to provide the most efficient, productive, reliable, and peace-of-mind systems and tools while keeping up the latest technology in hardware and software.

Click here to see Le's slide presentation.

Application of SIMMOD-Based Simulation
Consultants/Airport Operators' Perspective

Dallas/Fort Worth Case Study

BELINDA HARGROVE
TransSolutions

This presentation discusses SIMMOD applications from consultants' and airport operators' perspectives. It also underlines general airport/airline questions that can be answered using SIMMOD and particular questions SIMMOD has helped answer at Dallas/Fort Worth International Airport (DFW). The presentation also discusses the benefits and usefulness of SIMMOD.

General problems faced by airports/airlines can be grouped into many different categories.

- Capacity (airfield constraints, runways, departure queues, taxiways),
- Terminals,
- Airspace routings/altitude separations, and departure headings, and
- Airline scheduling.

TransSolutions has undertaken a variety of SIMMOD studies at DFW airport to improve terminal operations, change airline hubbing schedules, or improve airfield design. Studies related to terminal improvements tried to solve some of the following questions:

- Is there enough taxiway access planned?
- Given the schedule increases with the additional gates, are the delays acceptable?
- Will we need a new runway?
- How many new runways?

Questions related to the change in airline hubbing schedules at DFW are usually related to the impacts of "on-to-in" and "out-to-off" times or if the arrival airspace delays are acceptable.

To improve airfield design, some of the following questions are being considered at DFW.

- What are the delay savings of a new departure queue holding area?
- What is the delay saving of a new runway?
- Are the improvements cost justified?

When dealing with airspace changes, modelers face some of the following questions.

- Will the new airspace structure accommodate demand?
- Are the delays acceptable?
- What are the delay savings of additional departure headings off the runways?

In the analysis of the runway usage, questions about the departure delay savings of alternative runway usage assignments and the change in the noise contours are usually asked. When dealing with the analysis of the FAA rule changes or impacts of new technologies, modelers are concerned with the delay effect of wake turbulence reclassifications and the operators' benefits from new landing aids and associated procedures.

When analyzing DFW's interaction with other neighboring airports, the following questions are being asked: Can the airspace accommodate increased traffic at nearby airports? What is the effect on DFW flights' airspace delays?

The three most common questions at DFW are associated with the fleet mix changes in relation to (*a*) the impact on departure queue delays, (*b*) the existing airspace and its ability to accommodate the projected fleet, or (*c*) changes in the airspace design or procedures to ensure that delays remain in an acceptable range.

Benefits of SIMMOD are numerous because

1. One model can be used to answer different questions for different clients,
2. The base model can be expanded or modified quite easily to evaluate various issues, and
3. Detailed statistics can be obtained on each flight to examine why and where delays occurred.

The presentation concludes that SIMMOD helps solve design and operational problems by providing estimates of delay and other measures of performance. However, keep in mind that the result based on simulation modeling with SIMMOD is only one of many considerations in decision making. Thus, airport consulting companies require experienced planners who can ensure that their simulation scenarios are feasible and interpret results to make appropriate recommendations.

Click here to see Hargrove's slide presentation.

Application of SIMMOD-Based Simulation
Consultants/Airport Operators' Perspective

Montreal Dorval (YUL) Case Study

NATHALIE MARTEL
Aéroports de Montréal International Inc.

This presentation offers a review of SIMMOD studies for Montréal Dorval airport, discussing the simulation input needs and output results.

Since 1997, all simulation studies at Montréal Dorval airport have been conducted using LeTech's version of the SIMMOD model. Runway capacity studies conducted at Montréal Dorval airport with SIMMOD include one study started in 1991, a second one in 1995, and the last one (still in progress) in 1999. The current study takes into account the new fleet mix at the airport and NavCanada's Engineered Performance Standards.

Several studies were conducted for apron configuration analysis. The first, in 1995, examined the traffic on current apron versus a modified apron with single and dual taxi lane. A second set of analysis was made in 1997 to determine the impact of a new international pier on the circulation of aircraft. The third study, completed in 1999, dealt with another terminal configuration. Other studies include

1. Centralized de-icing area analysis (1992),
2. Site location and de-icing center capacity (1997),
3. De-icing center layout and pads configurations analysis (1998),
4. Impact analysis of the size and number of trucks in the operator's fleet, and
5. Number of pads used for de-icing and entrances to the center.

The presentation also offers a brief review of capacity definitions for practical and theoretical capacity. It emphasizes the fact that the modeling approach varies with the type of analysis and compares two types of analysis: runway capacity [which requires aircraft classification according to the weight, paying close attention to air traffic control (ATC) procedures and examining runway operating configurations] and apron configuration (which requires aircraft classification according to the wing span, paying attention to the push backs, tow movements, and circulation on the apron).

Also presented are data for Montréal Dorval airport on aircraft classification, runway occupancy times, landing and take off roll distances, aircraft speed, unloading and boarding times, push back and power up times, reaction delays to ATC actions, and de-icing times. Runway capacity assumptions for SIMMOD modeling are

1. Airspace extends 10 nautical miles from the airport,
2. Simplification of airspace structure (consequently requiring detailed procedures),
3. Bare and dry runway conditions,
4. Instrument flight rules (IFR) operations,
5. Gate capacity not a problem (boarding and unloading = 1 minute), and
6. No turnaround (split flights for enplane and arrival only).

The analytical approach for runway capacity analysis requires

1. Identification of runway operating configurations;
2. Selection of typical days (one for each configuration);
3. Consideration of aircraft mix, visual flight rules versus IFR operations, commercial versus general aviation movement profiles (daily and hourly), and movements distributions per runway;
4. Modeling of existing conditions and calibration with respect to hourly runway throughput and taxi times;
5. Cloning using small and constant increments (e.g., 5 percent); and
6. Comparison of delays for each cloning scenario with those of best case scenario.

In a figure that depicts the evolution of delays compared with the best case scenario, we see how the total delay increases with the increase in the aircraft operations.

Outputs considered in runway capacity analysis include ground times (taxi and delays), total system delays, and runway throughput. On the other hand, when accomplishing a de-icing capacity analysis, one needs to examine the following outputs: hold over times (time from start of de-icing to release for departure), taxi times and delays, and departure queue length and delays.

In conclusion, SIMMOD is an effective, inexpensive planning tool for airport analysis. The flexibility offered by the model allows the user to represent most situations well. The inputs required to the model and the outputs generated from the model will vary in nature depending on the problem examined.

Click here to see Martel's slide presentation.

MORNING SESSION

Discussion

Panel Moderators
GEOFFREY D. GOSLING
University of California at Berkeley and NEXTOR

JAMES M. CRITES
Dallas/Fort Worth International Airport

Panelists
WILLIAM DUNLAY, JR.
Leigh Fisher Associates

DOROTHY BRADY
HNTB

BELINDA HARGROVE
TransSolutions, Inc.

TUNG X. LE
LeTech, Inc.

NATHALIE MARTEL
Aéroports de Montréal International Inc.

Geoffrey D. Gosling: I hope you all appreciated listening to our speakers this morning. We see a lot of "on the cutting edge" thinking of airport and airspace simulation. But now is the opportunity for the audience to ask these experts questions.

Question: There is quite a bit of planning ahead of the game when you look at changes to the airport. But when you have changes to the aircraft like the regional jets (RJs) presented in the last decade, did you all have an opportunity to examine those aircraft prior to their arriving into the system, or was it sort of a surprise to planners that it would have such a dramatic impact?

William Dunlay, Jr.: I think there were indications that slowly evolved realization of the impact of these aircraft. I think people were caught by surprise. But as it evolved, it has snowballed in terms of a huge concern.

Gosling: I think that is typical to see when you ask the airlines what they're going to do, and they tell you this is their plan for the next 5 years, and then the next day it changes. So it is kind of hard to always account for everything that is going to happen at the airport because you don't know what those airlines are going to do.

James M. Crites: I would like to add one comment at the start of this discussion. We are going to have another session later to present the TRB Millennium Paper for our committee (A1J05) that was written by a group of excellent experts in the respective areas. The Millennium Paper tries to address major issues from a larger perspective, namely that there have been traditional roles in the aviation industry, whether that be with the FAA and the roles that they play or the airlines, the airports, or other users. Also, the issue of what capacity of the airport, airspace, and the system really means, particularly from the larger context of systems interactions. George Donohue is presenting a timely paper on this particular issue. I suggest that you all look at these two very important papers.

I know that TransSolutions, when they were part of the Sabre group before, were able to get an early view of RJs as American Airlines considered internally what was going to take place within that airline. But airports [and Dallas/Fort Worth International Airport (DFW) being one of them] in a traditional custodial role say: “Tell me what you need and I will try to facilitate the acquisition of those assets that you, the airlines or the FAA, require.” We see a potentially changing set of roles here in that the airline horizon is much shorter in terms of what they’re forecasting. You see them looking at 6 months out instead of even 1 year. Obviously it takes, as it is well known, much longer to bring on assets to satisfy that demand, and this is why the urgency with regard to RJs.

So airports are starting to ask themselves the questions—when we see NLAs coming online or the potential for new technologies coming on board from the research the FAA or NASA is conducting? Should we, as airports, proactively ask the “what if” questions, given how we operate today? What do we think or how should we think these technologies, or new assets, should be applied? What might be the effect to all of us now and in the future so that we might be able to highlight potential issues before they become, for lack of a better term, a crisis?

Dr. Jon Simons: Mr. Dunlay explained all new investments about flying into and flying out of New York. We have already known for 20 years about the development of these systems. My question is Why wasn’t it possible to implement some of these systems and techniques 20 years ago? I’m astonished why it is in the year 2000 that you have developed such techniques in New York and not 20 years ago?

Dunlay: If I knew the answer to that, I would be worth a lot more money than I am today! As I mentioned in my presentation, these entanglements among the airports and the issues of runway dependencies in New York have been very well known for 30 years. The lack of solutions to it has been primarily just a lack of progress being made in increasing aircraft navigation accuracy and trying to take advantage of that technology and technology and air traffic control (ATC) improvements. So I think it is a matter that we have an ATC system that is designed to accommodate the least-equipped aircraft in the fleet. Here, we are talking about an air traffic control system that we designed to accommodate the most-equipped aircraft in the fleet—one with flight management system (FMS) computer capability enhanced by differential Global Positioning System (DGPS) signals—that is a big change. But until we show the real benefits of that to the airlines and the chief executive officers of the airlines and top management at the FAA, nothing is going to happen.

So this question is a good one. Why? For microwave landing system (MLS), 10 years ago, you could pick up a study almost exactly like this about what MLS was going to do for the New York airspace. The same procedures are in there that we have in this report, and nothing happened. So I wish I could answer your question.

Gosling: I would like to follow-up with just a couple of comments following on from what Dunlay has said. I think this question, Dunlay's response, and some of Crite's comments earlier touch on a very critical issue that we in the airport planning community need to think very carefully about. We are at the confluence of two very conflicting and serious dilemmas. The first dilemma is that the FAA is criminally underfunded in terms of its research and development (R&D) budget. So one of the reasons why a lot of these issues are not being pursued as vigorously as they ought to be is simply because the FAA doesn't have the R&D funding to do the studies it needs to do.

The federal government is trying to get around that problem in part by having NASA do more work. But there is a very serious issue that is still not being addressed, and that is we have all these technologies that are being developed. Many of you may be familiar, for example, with the demonstration that was run in November at Minneapolis under a NASA-sponsored program, looking at the use of automatic dependent surveillance-broadcast (ADS-B) -equipped aircraft for close-operating, closely coupled arrivals to runways that would normally require staggered separations. The FAA now has to deal with the sorts of questions of how you certify procedures to handle this technology, which airlines can purchase today, and in fact, as mentioned earlier, this technology was installed 2 years ago at New York airports. This technology is already available off the street. If you are not familiar with the experiments that were conducted last year in the Ohio Valley by the Cargo Airlines Association using ADS-B technology, I would urge you to become familiar with that work. This is the shape of the future, and the FAA has still not begun to address the question of how they are going to decide what the operating procedures are to allow those technologies to be taken full advantage of. So that is one set of problems.

Against that, we have another set of issues, which is that we're trying to figure out what all this means for a capacity of 10 and 20 years hence. So that presents a very real issue for the planning when we're essentially working with tools and procedures. If we look in the FAA orders, we can find that there is nothing in there that speaks to how these technologies will be used in the future. The problem is that we don't know whether this technological capability will become available in 3-years' time, in 8-years' time, or in 15-years' time. There is no guidance on how to answer these questions.

As a result, airports are faced with a dilemma that they may spend hundreds of millions of dollars pouring concrete in the next 5 years. Even before they have cut the ribbon, there may be technologies available and certified at that time that will make all that investment unnecessary. So I'm not sure how we deal with this, but I think it is an issue that we need to grapple with as a profession.

George Donohue: I think this is a very interesting session and a number of your simulations are showing that if you can space aircraft closer together, either in the terminal airspace or on the arrival, that you can have a significant increase in capacity. This is largely coming due to the fact that the FMS and DGPS and so forth provide much higher surveillance accuracy than we have had before. So 3-mi buffers and so forth really are not as important in the future as they were in the past.

The comment about the FAA not having adequate funding to move in this area I find somewhat interesting. This is primarily an aircraft equipage issue. There is really very little that the FAA would invest itself in getting the benefits of these new technologies. It seems to me that the whole discussion that we've had within the Radio Technical Commission for Aeronautics free-flight discussions and internationally about an economic driven modernization begs the issue of that you have to give the benefit to the people who provide the investment. If we continue with a first-come, first-serve, going to the least common denominator of equipage, then I don't see any reason to start the modernization of this system under that kind of philosophy.

My comment to some of the people in the FAA is even without any money, if they changed the rules in, let's just say, Class B Airspace, which is the most complex and probably the most high-density airspace, the changing of a rule basically doesn't cost them any money. But it would require a specific equipage date for the fleets. I think the kind of economic analysis Dunlay did for New York shows that there are some very large benefits to the airlines. I've done some similar analyses for the United Parcel Service (UPS), and I get very large benefits if they are equipped.

So that is the preface to the question that I would like the panel to address, that is, should the FAA be more proactive in requiring equipage of this new technology as opposed to taking the least-fair option when they will be equipped if they see there is a benefit?

Dunlay: I think this is a really good comment. I think the FAA could do two things. They can provide some indication that with the equipage, there will be a benefit or a change in procedures and criteria that will result in a benefit to the carriers. The FAA has not been forthcoming in this regard. It is a slow process because you have to have lots of flight testing to reduce, for example, the FAA TERPS for the obstacle clearance requirements for aircraft that can navigate more precisely than we have today.

The FAA can also develop a large database to implement that. There is really no effort in that regard that is underway. So part of it is for the FAA to give a strong signal that with the equipage, benefits will follow. If they would do that, then perhaps they are on solid ground at some point in time, which requires equipage to operate in the system, which will then provide benefits to those who are equipped.

Crites: If I could just add one more point regarding the NASA Ames experiment last month. A very interesting chart that was presented earlier showed technology R&D and their obsolescence curve. I would dare say that, where we are with new technology today, in particular, new technology on board an aircraft that could have a significant revolutionary increase in safety and capacity? This is an issue that the FAA currently either has not yet, due to time or resources, had the opportunity to identify their role in or the rules on how we are going to address it. But we have existing technology, standard concrete, standard runways, and standard systems. We also have this "revolutionary" potential capacity, which calls for all parties to come together and resolve how we should establish the rules. As Dunlay points out, the mandates that control who is that controlling entity that allows us to take advantage of this revolution should also be resolved.

Donohue: If I could add to what Crites mentioned, I think the FAA is actually doing more than most people are aware in looking at new TERPS and so forth. Alaska Airlines has equipped almost their entire fleet with GPS/FMS equipment, and they are getting better accuracy. They are flying into Juneau, Alaska, using new TERPS criteria on a commercial basis. The Ohio Valley experiments are showing what ADS-B can do, and the general consensus is that those were pretty successful experiments. So this data is actually coming into the archives and is being built today. I think the issue is, is the community ready to ask the FAA or demand the FAA to set a date to start the regulation process that says there will be a date? My recognition is to let the airlines pick that date. If they say 2002, 2003, or 2005, I really don't care what it is! They should set it and say by that date airlines' fleets will have to be equipped, and the FAA will give them time to do that equipage. In the meantime and in parallel with that, the FAA can continue doing the kinds of things that Alaska is doing in Juneau and UPS and FedEx are doing.

William Swedish: Gosling had a couple of thoughts in his presentation that I wish could be expanded on a little bit more.

Talking about the results of future simulations, you said we should look at more than just the impacts of delays, but should there be other measures to consider as well?

Faced with high levels of delays, the airlines are going to respond with flight cancellations, or they may not expand in a particular airport and establish a hub somewhere else. Any idea on how we could reflect that in simulation? I would like to hear what you have to think about that.

Gosling: Let me speak to the second one of the two issues because I think, as Hargrove indicated earlier, the primary product we get out of the simulations is the delay information on flight times and other performance measures. All other considerations fold into the planning process, but they are not directly an output of the simulation analysis itself. However, when the simulation analysis is looked on in its entirety, one of the issues of interest to the research community here is how the airlines would respond to levels of delay at different airports. Some of those changes—the flight cancellation scenario, which is the one I used just for purposes of illustration—is somewhat of an extreme case. You hope that isn't how they are going to manage it and that we're not going to be in a situation where the airlines are going to have to cancel lots of flights on a routine basis.

Rather what we're looking at are perhaps the example of using airports in a multi-airport region. What is the point at which an airline decides to expand service at other airports within a reasonable travel time of a congested airport? This is an issue we are particularly struggling with at the moment in California because we have a number of military air bases in our metropolitan areas that are being considered for either joint use or use as replacement airports. El Toro in Southern California is one such case. What is the function that is going to cause Airlines X, Y, or Z to start serving El Toro rather than adding more flights to Los Angeles World Airport (LAX), for example?

Aircraft size is another interesting issue. Airlines could significantly increase the number of passengers they get through an airport without increasing the number of aircraft operations proportionately if they used larger aircraft on their busier routes. But there are significant competitive and airline operational considerations—can't just simply turn a 737 into a 757 for one segment of its daily itinerary. So they have to reschedule the way their whole aircraft flows through their network to do that. There are costs associated with that. How are the airlines in the future going to deal with those trade-offs between the cost to their network of reassigning fleets so they have larger aircraft at busier airports versus taking the delay costs at those airports and just living with those delay costs.

These are issues which I certainly don't have an answer to, but I think they are issues that are researchable and need to be looked at to provide guidance to the kind of studies that we've been talking about this morning.

Stephen Quilty: Since we are a small university, we get to represent small communities. I'm a little bit curious about the models that have been presented, where there seems to be an assumption or a bias going for the airlines. When we look at the new technology of installing FMS and its due date, that Donohue discussed, to what extent in requiring that type of equipment are we precluding the use of general aviation to include corporate and business access to these same airports? I'm a little bit curious as to what extent any of the panelists have incorporated business and general aviation use into modeling those airports, or is your vision one of excluding them, and have you addressed those social and political impacts?

Crites: Sometimes corporate and private airplanes are the best equipped airplanes in the fleet. As an airport authority, I will tell you we welcome everyone to come in. I fully appreciate your concern, and it is a concern that is expressed on the part of the smaller aircraft operators being excluded. I think these are very large community issues in terms of looking strategically at the regional airspace capacity. It is another one of the issues we really have to sit down and grapple with because today everyone is entitled to fly everywhere. As we see demand far exceeds capacity, it is going to become an issue of do we require aircraft of any size to be equipped with certain fundamental systems and technologies to operate out of certain airports or not? I think there are social implications right now that would preclude that out of hand. But it is an issue that we have to start grappling with, especially if we start bringing on these new technologies to enhance capacity.

Gosling: There are some areas in the country, like Southern California and Northern California, which have airspace users' working groups. I dealt with one working group, Southern California, a couple years ago. Out of the 15 or 16 people that are most active in that working group, there are only about 2 or 3 who represent the airlines. So it is very much geared toward business jets, general aviation, and the training flights, which have taken a very active role in some of the airspace considerations in the Southern California region.

Daniel Peterson: My question concerns the general market penetration of SIMMOD and similar tools within the planning communities. I have a question to the members of the panel: What is the degree of utilization of these simulation tools for airport operations by the airport operator-owner side and within the airline side? What is the breadth and number of major airports that use some type of a simulation-based planning, and how current and what is the quality of that planning? In other words, it is one thing to create a simulation, but not update it for 5 years. If someone could comment on just where we are in terms of state-of-the-art.

Dorothy Brady: Well, for one thing, the FAA has the Airport Capacity Task Force in the Tech Center doing airport capacity enhancement plans, and that is covered by the FAA. Other than that, airports generally in their master plans would use a form of a simulation for their capacity section if they are a pretty large airport. There are some simpler models that you would do before getting to the level of simulation, but eventually if you are going to be planning for a new runway or doing a major study, you would get to the level of simulation for some of those alternatives.

Peterson: But you said on-going though—is it pervasive! All major airports in North America have the ongoing up-and-running simulation models?

Brady: I think it happens about as often as there is a change at the airport or a master plan at the airport.

Peterson: I guess it came out of the New York airports, where the changes are continuous—it never ends!

Belinda Hargrove: If I can add something here. That is why you might say that we've been doing DFW capacity studies for 12 years. There are certainly some airports where there are a lot of studies going on. I'm not sure if you were asking the airports themselves to do the analysis. In the United States, that is what we find. It is interesting that in Europe, it is the airports themselves that are doing the capacity analysis studies—it is not the consulting community that much. But there are some airports in the United States, like DFW, O'Hare in Chicago, and LAX, that seem to have simulations going on almost every day or every month. There are other airports they do it for a master plan, and then it sits there until the master plan update occurs in however many years.

Response: Do you see a much broader consulting community involvement in this field?

Hargrove: We like it just the size it is! The issue of the use of simulation by airlines was mentioned earlier. I think the use of simulation by and for airlines is increasing, where they are using it more for scheduling purposes and to increase operational performance.

Saleh Mumayiz: That about wraps up the time for the panel discussion. We would like to thank all of the panelists. I think we have heard really informative discussion reflecting the state-of-the-art in this field and have had very stimulating conversation from the experts in the field, with some challenging questions from the audience.

The Airport Machine
BWI Airside Capacity Evaluation

ALAN YAZDANI
KEN SCARBOROUGH
Edwards & Kelcey, Inc.

This presentation gives a brief overview of the airside capacity evaluation for the Baltimore–Washington International Airport (BWI), using the Airport Machine simulation model. This simulation model was developed by Airport Simulation International and is utilized by U.S. airports, the FAA, and in Canada and Europe. It is an interactive, PC/Windows-based model, with 2D or 3D versions, and is used in modeling airfield and airspace operations.

The presentation further offers a background on changes in traffic volumes at BWI between 1970 and 2020 (for passengers, cargo, and operations) and discusses the total passenger forecast from the perspectives of expected and high passenger growth.

Evaluation of the BWI capacity improvement alternatives is managed by the Capacity Task Force, whose members include:

- FAA (headquarters, Eastern Region, Technical Center, Airports District Office and Airway Facilities);
- User groups (airlines, Air Transport Association, Regional Airline Association, Aircraft Owners and Pilots Association, and National Business Aircraft Association); and
- BWI airport support (planning and engineering divisions, operations, and Edwards & Kelcey consultant support).

This task force is concerned with (*a*) airfield improvements (that determine when a new runway is needed, where a runway should be located, and what are the runway length requirements) and (*b*) air traffic control operational and procedural improvements.The presentation also discusses the BWI capacity issues because the capacity of this airport is constrained by runway configuration and requires an additional parallel runway for independent operations if BWI is to meet the traffic demand increase. At the end of this presentation, the speakers offered a live demonstration of BWI operations using the Airport Machine model.

Click here to see Yazdani and Scarborough's slide presentation.

Airspace and Airport System Simulation with DPAT

LEONARD A. WOJCIK
MITRE Corporation

The presentation addresses issues in airspace and airport system simulation studies using the detailed policy assessment tool (DPAT) by giving an overview of

1. The definition of DPAT,
2. Samples of recent studies using DPAT,
3. Excerpts from a sample DPAT study (1997), and
4. Current DPAT applications.

The DPAT is an ultrafast time, global air traffic simulation that can model current and future air traffic for any world region. The tool can represent airports and airspace as a network of finite-capacity resources.

DPAT applications include

1. Systemwide airport and airspace planning,
2. Prediction of system-wide effects of weather and traffic flow management restrictions (such as ground delay programs and miles-in-trail restrictions),
3. Assessment of economic benefits of proposed system improvements, and
4. Identification of total-system effects of future traffic growth.

DPAT and its predecessor, the national airspace system performance analysis capability (NASPAC), have been used as planning tools by the FAA since the 1980s. Both of these tools have been improved continuously to better reflect air traffic control operations. However, DPAT achieves far shorter run times than NASPAC through more efficient coding and parallel processing and can simulate a full day of U.S. air traffic in under 1 minute (Official Airline Guide) plus nonscheduled traffic] on a four-processor Unix workstation. With regard to its performance implications, DPAT can be run hundreds of times overnight for analysis across many days of traffic and weather or for sensitivity analysis (with appropriate pre- and postprocessing software). This tool has the potential for use in real-time air traffic management operations.

In the study on the automatic dependent surveillance-broadcast/cockpit display of traffic information benefit assessment, which was completed recently using DPAT, the annualized benefit of reducing delay using improved separation standards in moderately poor weather conditions was computed. In this study, there were 730 runs (365 × 2) representing weather and traffic conditions for each day in 1997. Other DPAT studies dealt with problems of

1. Miles-in-trail restrictions into operational requirements document from the southeast,
2. Separation reduction impact analysis [of the effectiveness of reduced separation standards and how that would interact with other national airspace (NAS) components],
3. Impact of regional jets on congestion in the NAS, and
4. Taipei (Taiwan) instrument flight rules delay analysis.

The Pacific Rim DPAT Study, conducted in 1997, took into consideration the major airport infrastructure investments planned for the Pacific Rim over the next 20 years. This study analyzed the system demand and capacity relations over the next 20 years, considering

1. If the infrastructure is completed on time and demand grows as expected,
2. If the infrastructure is not completed on time or demand does not grow as expected, and
3. Interactions between airports.

The results indicate that at some airports there will be capacity/demand problems if schedules are not well designed. In addition, some of the problems will propagate to other airports.

Current DPAT applications at MITRE Corporation focus on the following topics.

1. Analysis of future benefits of possible improvements to the U.S. NAS,
2. Prototype integration of DPAT with sector design and analysis tool (SDAT) using Department of Defense high-level architecture (HLA), and
3. Exploration of real-time operational DPAT used to aid traffic flow management (TFM) decision making.

In addition to current DPAT applications, the presentation addresses other very important concepts, such as operation for SDAT/DPAT prototype integration using HLA, collaborative flow management, and exploration of NAS modeling for impact assessment. Collaborative flow management, as an operational concept, assumes that the FAA moves toward more strategic flow planning and that the airlines are willing to participate in a meaningful way.

The role of NAS modeling for impact assessment is complex because it is not always clear what is meant by “traffic prediction.” The impact assessment tools are a necessary but not sufficient condition for achieving the goal of overall system performance improvement. There are (at least) two ways to look at the traffic prediction problem, as illustrated in the presentation.

Click here to see Wojcik’s slide presentation.

Analysis Requirements for Airport Performance Studies

PETER F. KOSTIUK
Logistics Management Institute

This presentation addresses three types of analysis requirements for airport performance studies, used at the Logistic Management Institute (LMI): quantification of the benefits of specific investments in airport capacity (technology infusion and physical expansion), runway arrival and departure throughput (flight delay reduction and increased revenue potential), and benefits of the NASA Terminal Area Productivity program at 10 U.S. airports.

Airport performance could be analyzed in a number of ways, but the following analysis components are being used at LMI: modeling of airport capacity and delay, technology impacts, demand forecasts, cost analysis (delays and investments), and sensitivity of benefits.

The analysis steps developed at LMI consist of a series of interrelated models with many dependent and independent variables (i.e., inputs and outputs). For example, technology parameters, air traffic controller procedures, weather, and current and future demand directly influence an airport delay, which, in return, serves as a base for estimation of economic benefits. On the other hand, the economic benefits also depend on airline operations. In the last analysis step, we obtain the benefit/cost (measure of performance) as a function of economic benefits and technology life-cycle costs.

LMI's capacity model consists of 79 (or 96) sets of input parameters, runway configurations, and air traffic controllers' characteristics; the output consists of 19 capacity curve files (with one per technology). The delay model consists of the inputs such as (*a*) the capacity model, (*b*) hourly demand for the day of the week and season [multiplied by the terminal area forecast (TAF) factor for the demand year], and (*c*) weather (35 years of hourly data). This model produces 19 output cases of annual arrival delay, average arrival delay per flight, annual departure delay, and average departure delay per flight for each demand year.

Input parameters for LMI's airport capacity model are:

1. Inefficiency buffer [nautical miles (NM)],
2. Heavy aircraft flag,
3. Aircraft mix (fraction: small, large, b757, and heavy) in a minimum arrival separation matrix (NM),
4. Approach and departure speeds (knots),
5. Approach and departure speed standard deviations (knots),
6. Position uncertainties (NM) through the length of a common path (NM),
7. Standard deviation of wind speed (knots),
8. Arrival runway occupancy time (rot) and standard deviation of arrival rot (minutes),
9. Departure rot and standard deviation of departure rot (minutes),
10. Minimum distance to departure turn (NM),
11. Mean and standard deviation of communications delay (minutes),
12. Maximum history (count of arrivals in stream tracked for parallel runway calculations), and
13. Second arrival separation matrix (duplicate of first or aircraft vortex spacing system).

The presentation also offers an example of technology alternatives and an example of airport results. In addition, LMI proposes several extensions to airport modeling and suggests areas where some type of improvement is needed, such as queuing network modeling, integration of operational and economic analysis, demand forecasting (as the airport-airspace system nears capacity limits), forecasts that explicitly include behavioral feedback. This enables direct evaluation of alternatives, and technology impact analysis (better understanding of the role of technology in the air traffic management system).

The issues of integration of operational and economic analyses are also discussed in this presentation. Integration of operational and economic analyses is a complex process that involves two interrelated models.

1. The national airspace system model (consisting of the delay model and capacity model, which interrelate), and
2. The air carrier investment model (consisting of the air travel demand model and airline cost model, which also interrelate).

The presentation concludes that analytical modeling of airport capacity and delay offers a quick, credible method for evaluating airport improvements under a wide variety of scenarios and that integration of operational and economic models enables a better understanding of system interactions and agent responses (with more realistic forecasts of system demand and delay).

Click here to see Kostiuk's slide presentation.

Airport Capacity Enhancement Through Fast-Time Simulation

PETER CRICK
EUROCONTROL

This presentation discusses EUROCONTROL's efforts to enhance airport capacity through fast-time simulation modeling. The lack of European airspace and airport capacity and increase in delays has led to the use and development of more comprehensive simulation modeling tools.

EUROCONTROL is a governmental agency comprising of 28 European states established 30 years ago to better manage the en-route airspace. In 1997, EUROCONTROL further extended its functions and included "gate-to-gate" operations. Being truly a European organization, this agency has its headquarters Brussels, Belgium; operational air traffic control centers in Maastricht, Netherlands; a training institute in Luxembourg; and experimental center in Bretigny, France.

The experimental center's main activities in the simulation area include two types of simulation modeling: real-time simulations (human in the loop) and fast-time simulations. Because EUROCONTROL uses the FAA's SIMMOD for airport simulation studies, the agency maintains a close cooperation with the FAA in the areas of fast-time simulations (SIMMOD, RAMS) and environmental studies.

A joint FAA/EUROCONTROL Research and Development (R&D) Committee has objectives to ensure systems interoperability and to pool scarce R&D resources. It is cochaired by the FAA and EUROCONTROL (meeting four times a year) and addresses future air traffic control concepts, architecture, modeling, applications, procedures, validation, and human error issues.

The air traffic modeling of operational concepts (AP9) was signed by FAA/Eurocontrol/NASA in June 1999 and is actively pursued by FAA, NASA, seven European states, and NavCanada. Their objective is to define and develop a system for the validation of future operational concepts and the development of decision tools. The characteristics of such modeling include a flexible research tool and utilization of object-oriented techniques that could eventually replace SIMMOD, RAMS, or TAAM.

The presentation also pays attention to the problem of capacity limitations and suggests several alternative solutions to increase capacity: constructing new runways, high-speed exits, taxiways, and terminals; adopting best practice procedures or new procedures; maintaining capacity in bad weather conditions (A-SMGCS); and minimizing costs and environmental impact (such as noise and emissions). In addition, the presentation addresses and summarizes common problems that simulation modelers face in the light of

1. Many ways of defining and assessing airport capacity and delay,
2. Lack of agreement on validity of results,
3. Lack of user requirements,
4. Models' user-unfriendliness,
5. Incompatibility of outputs and inputs, and
6. Lack of ability to easily upgrade models.

It is suggested that an integrated airport modeling system be developed, which would consist of a number of interrelated models and would include an analytical tool, rapid airport capacity analysis package, fast-time simulator, and environmental model. The suggested envisioned improvements would focus on the following developments: a commonly recognized system to estimate airport capacity and analyze delays, single integrated system for the user, simplified traffic generator, automatic syntax/semantic checks, better format translation between elements, and state-of-the-art software techniques to permit substitution.

The last part of the presentation offers three application examples. The first example deals with the introduction of partial (Phase 1) and full (Phase 2) parallel taxiways at Malta airport. The benefit-cost analysis annualizes and compares delay savings between the proposed alternatives (i.e., phases). The second example analyzes the cross wind prediction and models three cases: the worst case (no cross wind), with standard in-trail separation between 2.5 and 6 nautical miles (NM); the best case (crosswind all day), with in-trail separation at 2.5 NM on final approach, and typical case (historical cross winds), with standard and reduced separations. The third example analyzes the perceived beneficial effects of wake vortex tracking, A-SMGCS, reduced separation on parallel runways, optimization of arrival and departure routes, and segregated airspace.

Click here to see Crick’s slide presentation.

Application of TAAM Simulation

Developers' Perspective

ALEXANDER KLEIN
The Preston Group

This presentation offers from The Preston Group's (TPG's) perspective, a review of the year 1999 in terms of finances, total airport-airspace modeler (TAAM) development, new customers, and new projects. In summary, 100 percent of TPG stock was purchased by Boeing, and the year ended with excellent financial results. TAAM Plus Version 1.0 was released on time and many new TAAM customers joined the World Wide TAAM Users Group (WWTUG). In addition, TPG continued the intensive simulation project work and started the research and development project with MITRE CAASD.The fact that Boeing purchased TAAM was an excellent sign of a high value of TPG technology. Even though Boeing purchased 100 percent of TPG's stock, the company continues as an independent entity, without changes to management or operation. By becoming a giant parent company with a strategic focus to the TPG, Boeing is further strengthening TPG's growth and the long-term stability and is helping to obtain new exciting projects. The TAAM Plus Version 1.0 was also released as the result of a year's work. This new version has

1. Open systems platform,
2. Client/server architecture, and
3. Runs on Sun's top-of-the-range workstations and on Intel machines under Linux.

The proposed 2-year development program approved by WWTUG will offer some of the following capabilities.

- Major enhancements to functionality,
- New level of flexibility for TAAM rule base,
- Gradual migration to object-oriented architecture;
- Growing "after market" of pre- and postprocessors, and
- Stepping stone for the next wave of TPG tools.

TPG was also successful in selling TAAM to many new customers. The new TAAM license sales in 1999 include FAA and MITRE (4 licenses), with the FAA now being the largest TAAM user, with a combined total of 6 licenses. Other airports or airlines who purchased TAAM include Vienna International Airport (first airport license); NavCanada (2 licenses); Brazil (first license in Latin America); Finnish Civil Aviation Authorities (CAA) (long-term lease); ENRI Japan (second license); Swisscontrol (second license); and Virginia Tech, George Mason University, and Aachen Technical University (academic licenses). TPG is also expecting three major airlines, more universities, and CAA to come on board in the following year and more additional licenses to be ordered by existing users.

TAAM is an airport and airspace model supporting gate-to-gate fast-time simulation. Because these two "worlds" are tightly interconnected, there is a need for complete, single software that supports airport, airline, CAA, and aviation research and development (R&D) users on five continents, such as TAAM. This model is scalable, and its studies range from modeling a small airport to an entire NAS. Its flexibility is achieved through a sophisticated rulebase and the use of options and parameters.

TPG's simulation project work is very productive. The company completed

- Three projects for United Airlines;
- MSP runway construction study for Northwest Airlines in Louisville, Kentucky;
- Inbound flow improvements for the United Parcel Service;
- St. Louis, Missouri, airport study for Trans World Airlines;
- Johannesburg master plan alternatives analysis for ATNS/ACSA (South Africa);
- Dallas/Fort Worth International Airport impact on American Airlines' regional jets;
- Sydney, Australia, airport expansion study;
- Ground capacity study for Adelaide International Airport, Australia; and
- Helsinki Vantaa third runway study (Finland).

These projects have enriched TAAM developers' perspective from a different (i.e., customer's) angle.

TAAM has proved itself as a rapid-development tool for airport and terminal airspace simulations. On average, a baseline development from scratch averaged at 4–5 weeks and then would require 1–3 weeks per major study alternative. (A complete day of operation for largest U.S. airport took 25 minutes to run.) Thus, the total study duration was typically 9–10 weeks.

TPG, together with MITRE, started a 3-year R&D project with the objective to increase TAAM's computational performance by at least an order of magnitude. This research includes joint analysis and optimization of TAAM libraries and algorithms and further work on applications of parallel processing, enabling TAAM to run on multiprocessor machines. For example, a Northeastern U.S. simulation (with 34,000 flights in a 24-hour period, 40 airports, 6 centers, 315 sectors), which currently takes TAAM 8 hours to complete on an Ultra10 computer, should be reduced to about 30–40 minutes.

The company is also improving TAAM for better operational decision support, while improving the traffic forecast accuracy. TPG is working on a reasonably realistic simulation from a real-time starting point; continuous tactical "probe;" better and faster insight into the nearest future (2 hours), better judgment on how the traffic and weather situation is likely to evolve, improved decision making in mitigating impact of weather and other disruptions, and better traffic flow on a routine daily basis.

EUROCONTROL is conducting a 6-month TAAM evaluation process with teams in Bretigny [airspace/traffic management advisor (TMA)] and Brussels (airport/TMA). This is a joint EUROCONTROL/TPG project aiming to examine TAAM's usefulness as a tool for EUROCONTROL's simulation analyses.

TPG is continuing its massive investment in TAAM software development, working toward a more user-friendly, flexible, faster, more open software, with advanced visualization and data extraction capabilities, taking advantage of the client/server environment. The company will continue to maintain a single software version but will diversify TAAM use and pricing for different markets, which will make TAAM more affordable for a wider circle of users.

Click here to see Klein's slide presentation.

Using TAAM in Airline Operations and TAAM Analysis of EWR Capacity for Parallel Arrivals

TIM STULL
Continental Airlines

PAT MASSIMINI
MITRE Corporation

This presentation discusses the airline applications for total airport-airspace modeler (TAAM) and reviews the study of Newark International Airport (EWR), New Jersey, airport capacity for parallel arrivals.

In general, Continental Airlines (COA) uses TAAM in the facilities design to validate design concepts before they are built and to support studies for regulatory projects. The model is also used for CDM/CR (as a test-bed for potential solutions), scheduling (to schedule integrity or impact studies), and operations scenario analysis. MITRE uses TAAM for the analysis of airport capacity and delay; in this particular study, the software is used for the analysis of airport capacity for parallel arrivals at EWR airport. The objectives of the particular study are (*a*) to determine the effect of the new procedure on EWR airport delays and capacity and (*b*) to provide inputs to the FAA's report to Congress regarding feasibility of the new procedure.

In the study, dual arrivals were examined by adding a second arrival stream. This alternative scenario would eliminate arrivals from runway 29 (shifting them to runways 4L or 4R) and would shift departures to runway 29. Under this scenario, it is assumed that visual approaches or SOIA/PRM procedures to runways 4L and 4R are available.

Some of the most important questions were

- How much improvement would the new procedure provide with respect to arrival delay?
- To what extent would additional arrivals effect EWR departures?
- Would there be sufficient gate, taxiway, and parking capacity at EWR to handle additional arrivals? and
- Would an increase in traffic change these results?

The study uses TAAM to model runways, taxiways, gates, and 2003 airport configuration (additional terminal building and changes to taxiways and parking areas); simulate runway operations for both scenarios without gate and taxiway operations as constraints; and adds taxiway and gate usage to identify their impact separately from the runway constraints.

There are seven demand scenarios, several design alternatives, and assumptions regarding the wind flows, runway operations, airport configurations for 2003, airspace constraints on arrivals or departures, interactions with any other airport, traffic flow intervention to balance flow to airport, noise restrictions, and visual separation.

COA, FAA, and MITRE made a team effort in this study, providing the necessary data and analyses. For example, COA provided 2003 airport layout, COA schedules for 1999 and 2003, gate service times for COA flights, and restriction on use of runway 29 (aircraft type, range, and fix). (COA has a hub at EWR, and thus a large involvement in EWR's operations and planning.) The

FAA provided the current automated radar terminal system data; provided historical, current, and future traffic counts; and provided validation of runway, taxiway, gate and parking area usage. MITRE provided data coordination synthesis, analysis, and interpretation of TAAM results.

The metrics consist of (*a*) arrival and departure rates by runway and (*b*) arrival and departure delays (average per aircraft and cumulative over the 24-hour period).

The TAAM simulation results for observations for 2003 traffic level indicate that the alternative scenario reduces delays significantly as compared with baseline operations (24 to 31 percent reduction). On the basis of these results, it is concluded that adding gates and taxi operations to the runway model adds delay but not an unusually large amount (8 to 18 percent increase).

Simulation results for observations for 2003 traffic increase for over 10 percent indicate that delays increase significantly from 2003 traffic levels (37 to 53 percent increase), that the alternative scenario still reduces delays as compared with baseline operations but not as much (15 to 19 percent reduction), and that ground operations contribute significantly to delay at this traffic level (40 to 42 percent increase).

At the end, this presentation makes observations on the use of TAAM and summarizes TAAM's capabilities for modeling runway capacity and ground operation and for interacting with controllers and a study team.

Click here to see Stull and Massimini's slide presentation.

FAA Air Traffic Airspace Laboratory

BARRY DAVIS
Federal Aviation Administration

The main objectives of this presentation are to provide information on the FAA Air Traffic Airspace Laboratory's purpose and support, present the lab's data, and outline the airspace analysis tools available in the lab.

The main purpose of the lab is to assist in airspace problem identification and visualization through data collection, while providing mechanisms to get the data (through web interfaces and data repositories) and offering adequate analysis tools [such as ArcView and sector design and analysis tool (SDAT)].Data collection could involve different functions: defining the type of data needed for an analysis (traffic data, airspace configuration data); defining and computing metrics; and visualizing airspace, air traffic, and problem solving alternatives.

The lab's primary contribution is to give day-to-day operational support to the FAA headquarters' field facilities and projects. The lab's projects include the national airspace redesign, cost accounting, Y2K problems, commercial airspace, aviation policy, environmental issues, and many others.

Lab data makes it possible to store, manipulate, and retrieve through the operational laboratory network. The network, consisting of an enhanced traffic management system (ETMS) server, SMA server, and an automated radar terminal system server, is an input into the network. The data from the operational network are parsed and inserted into the Oracle production database, which provides data for archiving, tools [such as ArcView, spatial data engine, SDAT, and structured query language (SQL)], analysis and special projects.The distribution of data is web based and could be obtained through the FAA Intranet web access and user download of flight data. The airspace analysis tools available at the lab include the SQL, geographic information systems (GIS), and SDAT.

The lab's Oracle/SQL has over 2 years of historical ETMS data with the additional data sources continuously being added. "Canned" queries can be automated and web enabled (metrics). GIS at the lab consists of tools such as ArcView (containing maps, traffic flows, flight replay, spatial/3D analysis, and spatial data integration); MapObjects (including the web/GIS application development); and spatial database engine (containing the FAA airspace spatial database, boundary crossings, flight statistics, and track generation). SDAT is currently being used in the analysis of the Baltimore–Washington/Washington National/Dulles International airports' terminal traffic. SDAT's capability to group air traffic flows is helping to better identify problems at this location and to better visualize and evaluate proposed alternatives.

In summary, we can say that the Air Traffic Airspace Laboratory contributes to airspace analyses through offering the (*a*) historical database with several years of ETMS data, (*b*) visualization tools, and (*c*) central repository of airspace configuration data. Access to the lab is possible through FAA sponsorship.

Click here to see Davis' slide presentation.

Discussion

Panel Moderators
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Logistics Management Institute

ANDRE MURPHY
MITRE/CAASD

Panelists
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Federal Aviation Administration

ALEXANDER KLEIN
The Preston Group

PAT MASSIMINI
MITRE Corporation

TIM STULL
Continental Airlines

LEONARD A. WOJCIK
MITRE Corporation

ALAN YAZDANI
Edwards & Kelcey, Inc.

Peter F. Kostiuk: I will make a couple of comments based on what we've seen this afternoon. I think there is no doubt that we have several excellent modeling tools that are now available to us for evaluating airport operations and performance enhancements. Clearly, most of these tools have all been based on evaluating operational changes in some way. So there has been a little bit of work done on bringing in the economics, but I think, a lot more needs to be done in that area. As Tim Stull mentioned earlier, economics is what drives this business. Air transportation systems are not designed simply to develop air traffic control technologies or airports. The system as a whole is designed to move people by air efficiently, safely, and economically. So unless it is economically viable and makes sense from a passenger and airline perspective, things aren't going to happen.

The other thing that was interesting is that there are really only a few tangential comments about noise, which is one of the major constraints on airport operations these days. Certainly, as we look into the future, we try to accommodate the growth that is expected within this industry; it is going to become more of a problem, and to try to make the operations more efficient, we are going to bump into some of those noise constraints. Certainly those of us who have traveled over to Europe to talk to some of the airport operators and airlines over there, know how significant a problem it is worldwide. You've got operations caps at airports, unless that problem can be tackled. Therefore, as far as the modeling and simulation community is concerned, we need to find some better ways for incorporating those types of constraints into the models as we develop them.

The other issue not covered today is that I don't think we mentioned any models for evaluating the safety of any of these operational changes and certainly any of the advanced systems that are being opposed.

Those are my brief comments. I'll just go down and spend 5 minutes to have each of the panel members perhaps say something if they want to, and then we will open up the floor to questions.

Andre Murphy: My brief comment is in reference to the comments that Klein and Stull made about model testing. What are the real operational requirements for simulation tools like total airport-airspace modeler (TAAM) and others, as they are used in a more tactical environment? In the coming months and years, we will need to understand better what the operational usage is of all these tools and what the operational demand would be like.

Leonard A. Wojcik: I think one of the areas where we could go further in modeling is with respect to adaptation. When any change is made, either on the time scale of 1 day or longer, we need to understand how it is that the different parties involved in the system, namely, the airlines, the FAA, and the other airspace users, would adapt. At MITRE/CAASD, we have done some research work in this area, but I think that is an excellent area where more research needs to be done to understand these kinds of adaptations better, which will result in a more realistic and more useful utilization of simulation.

Alan Yazdani: I want to add that the simulation modeling tools we use should be put in a perspective of a tool that we are able to use to answer, or try to answer, some of the problems that capacity at airports have today and into the future. But it is not the only solution to our problem. We are working with the FAA and other users, who make good use of the simulation models to answer some of the questions. But in the real world, we need to look at the big picture. What are other constraints that we need to be concerned with? As the moderator mentioned, noise is an issue—of course it is. We do need to have many of our improvements, when we look into options, consider how the community is going to react to noise implication of any of the improvement you will have and many others. But the bottom line is that we need to look at the whole picture and not just in terms of simulation modeling and the cost versus benefit to airlines.

There are many standards and other extra factors that come into play and if we just look at those components, I think we are shortchanging our clients or whoever we are working with. I encourage any of us planners who are doing modeling to consider these factors from the outset and not get in a situation where some improvements in runway extension, airspace, or new runways are suggested. These improvements will not be implemented simply because we are putting a runway right in the direction of somebody's house who happens to be a legislator—well, these plans are not going to go too far! So keep looking at the big picture and try to make more sense of all the good work we do in simulation modeling.

Pat Massimini: I would like to add just a comment about the noise modeling. We've seen what the FAA is doing right now with noise modeling as part of National Airspace Redesign (NAR) teams. I think they really have the right approach here. At Potomac, the NAR team has made a big part of their process to integrate the noise modeling right into their alternative design. They are using the noise-integrated routing system, which is not used very widely throughout the system (I think only in Chicago) before. But it is built on the same basic engine as the INM. It is a good multiple airport model, with good representation of noise profiles. That is a real important part of their community outreach in being prepared for noise issues.

The New York NAR team, which is very deeply involved in the airspace redesign effort, is at the planning stage right now in developing alternatives. It is their clear intention to do this iterative noise modeling and working very closely with the public. They have started environmental prescoping meetings already. They go three times a week, and they have some 20-odd meetings scheduled throughout New York, New Jersey, and the Philadelphia area before they have even defined a single alternative. So I think they are making a lot of progress in that respect.

The only other comment I would like to make is with respect to this integration concept that we live in a very interconnected, dynamic system, and cutting the problem up into little pieces and solving them locally is not necessarily the right answer nationally. A solution for Newark might be to the detriment of the other New York airports or even Chicago, Washington, or Atlanta. There really needs to be a continued effort to connect all of these up and to make sure that we understand the systemwide impacts. I think the tools collectively are there. It would be nice to see improvements in any one of them to make this a little easier. But I think, by packaging up a number of tools, we will be able to start building a bigger picture. We know there is a keen interest in that!

Alexander Klein: I just wanted to remind you that I think we all, as a simulation modeling community, have an obligation to continue to educate our customers and users, controllers, citizens groups, government officials, city authorities, airline pilots, and many others what a simulation model can and cannot do. You may recall only a few years ago, many people still believed that simulation really equals playback animation and that you can validate one model by the other. There wasn't even a notion of a simulation baseline really, or if there was, then we would take 1 day of operation as recorded in the day of actual traffic, and then you try to make sure your model replicates that exactly and precisely on that particular day. Fortunately, we are moving away from that limited kind of understanding. But there is a huge amount of work that needs to be done, and the theoretical base for the work that we are doing, I think, is very important.
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Tim Stull: With all that said, probably in the next 5–10 years, we're going to see more change in the national airspace and the environment that we all operate in and work around than we have seen in the last 30–40 years. That is going to present tremendous challenges to us all. It also means that we all have plenty of work.

I think I've seen a lot in the tools today that tell me there is merit to each one of the simulation tools out there. So that is certainly not the issue to me. The issue is more of where we are going to be 5–10 years from now in making all technology out there integrate nicely among the cockpit, the air traffic system, and other users. These "black boxes" that were a mystery to the system users for a long time are no longer black boxes. So with that, I definitely applaud the efforts of the people in this room to carry that forward and try to use simulation that can make the best possible decisions. Simulation is cheap compared with a bad decision. I will also applaud the FAA, that has finally really opened its doors and has made a lot more information available to simulation users, airlines, and others who try to make things better, do things better, and try to do the right thing. I really applaud their efforts to try and open their doors and make as much information available to us as they can to make things better for us.

Barry Davis: I couldn't ask for a better entry. I'm going to go a little slower than I went on the presentation. I wanted to address a couple of points. One, the point you made earlier on environmental. One of the things I didn't stress in my presentation that came out in a couple of different places is the interaction between all the tools. To do the job, you really have to put more than one tool together. It is important that the tools interact with each other and that you can move and pass data between them. I think that is one of the great things we learned out at Potomac. MITRE has been following through, and I know everybody else has been working on that.

The safety issue was mentioned. I can almost guarantee, without a question, that this comes up all the time at the FAA. I know specifically almost all of our models do conflict and workload, and we try to look at that all the time. I'm sure TAAM does exactly the same thing.

The last point was a point that I brought up in the presentation, and I really can't emphasize it any more. I think one of the keys to success, both in performing the analysis work correctly and the interaction of the models, is the standardization and the sharing of the data. I couldn't emphasize that any more. That is a big push we are putting forth in the lab. We're working with a lot of people. Whatever we have in the lab as far as data about particular airspace, we are willing to share with anybody, and we hope that everybody is also willing to share with us.

Kostiuk: I would like to thank the panelists for their comments. I'll open the floor up for questions now.

Robert Samis: In the New York presentation, I gather the alternative scenarios are using the crosswind runway much more than historically. Is that for both arrivals and departures?

Stull: In this case, it was for departures only. All the arrivals were routed over to the parallel runways. For departures on the crosswind runways, it was primarily jet usage.

Geoffrey D. Gosling: A number of the comments earlier have alluded to the fact that we need to start thinking about interactions at a system level, looking at networks of airports. Therefore, the propagation of delays across networks of airports is an important part of the issues we are struggling with. That, in turn, implies that we know something about the routing of individual aircraft to figure out where they are going to be later in the day. That can be done with current information for existing schedules, but it presents a challenge when we then are starting to look at 10 years or 20 years into the future. This is analogous to some of the things we were talking about this morning—the problem of forecasting future schedules. Except forecasting future aircraft routing, it strikes me as being even harder than forecasting future schedules. I would be interested in any comments that members of the panel have on that.

Stull: After having spent a few years up in airline scheduling doing just that, generally when we build a schedule that we are looking out, for example, in the 2002–2003 time frame, we tend to put together the bank structures, the basic city pairs, and the marketing side of it based on basic economic analysis. That flows upward into generic fleet type scenarios that we use. For example, my 737-300 and 500 class aircraft I can see as a single fleet type out of that level of everything. I can't quite pair my MD-80s up with my 737-800s, but it is really close if I am looking just at ASMs, the available seats that are there—I can do it. I can't do it on the cost side quite as efficiently. International travel I can do easily. The airline's wide-body fleet remains pretty much generic to what I'm looking at. Now across all the airlines, it would be a little more complex, but within my airline and my fleet types, it is pretty simple to do.

You do have to start, though, with that baseline economic data—where you think you are going to be. You do have to dovetail in a technology plan in terms of the system where you believe system capacity will be. You also have to bring in your facilities plan to make sure that your facilities can handle that level of capacity and where you think you're going to be. Integrate all that together, and you're well on the way.

Kostiuk: From the modeler and analyst perspective, we not only have to do that by the airline, but because there is no 2005 Official Airline Guide (OAG) database published right now, we have to create one. As Gosling just said, then the next step is how are these planes going to be flying? We are used to simulating, and this is really a bottoms-up analysis approach.

Wojcik: At MITRE, we have an algorithm for trying to make those kinds of estimates for the future. As with the basic principal—and we're doing it not for one airline but for the entire system—we start off with estimates of the growth rates that are expected for different airports individually and those growth rates would embody the economic drivers. Then, based on those growth factors, we connect different cities together, and using the current OAG as a starting point, we make the connections and try to derive the itineraries of the airplanes. But obviously it is imperfect. That is a method that we've used.

Gosling: Do you tend to just generate one scenario or a handful? As you mentioned, there are so many different assumptions that go into that, and we are sort of locked in, at least as a starting point to start out with the official FAA forecast of growth at individual airports—none of us has the expertise to generate that independently. But that is just one forecast scenario. For any of those who have done forecasting, we know we are going to be wrong when the future rolls around.

Yazdani: If I can add to that—not that it is the best way to do—we find that if we have information from the airlines and maybe the airport operations, we would probably have a better baseline to start your base case, where OAG might not have all the information or it becomes outdated in no time. When we have a timeline that might extend many months and forecast years for a few years, those data become updated quite fast. Normally, when using the schedule, we basically rely on our in-house economists that tell us what scenarios are most likely to occur over the next years or decades. They basically use city pairs and fleet mixes to make some of those judgmental calls. For example, regional jets (RJs) are good examples that we want to incorporate to the work we are doing with Baltimore–Washington International Airport (BWI). It looked at all the city pairs that RJs are able to use at BWI to serve these smaller communities, and that became one of the driving factors to make the future schedule, which basically is going to help us fit the schedules for modeling.

Saleh Mumayiz: I would like to thank the panel for their excellent presentations this afternoon and their very informative responses to the questions.

APPENDIX

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