Outline of Presentation

ENAC presentation

Air Transport Industry in numbers

AGIFORS

Survey:

Planning Air Transport Systems

Air Traffic Management

Planning Operations at Airlines

Airlines Revenue Management

Airport Operations

Conclusion
Ecole Nationale de l’Aviation Civile

- Initial Training
- Specialist diplomas
- Continuing Education
- Research activities
- International activities
Initial training at ENAC

2000 students

- French Civil Aviation Authority
- French and foreign companies in the aerospace field and associated sectors
Initial Training

- ENAC Engineer (Air Transportation, Electronics, Computer Science)
- Air Traffic Control Engineer
- Electronician
- Airport Technician
- Air Transport Pilot
- Airline Dispatcher
Master’s courses

- Air Operations and Air Traffic Management
- Satellite-based Communication, Navigation and Surveillance
- Aviation Safety, Aircraft Airworthiness
- Air Transport Management
- Airport Management
- Human-Machine Interactions
- Collaborative Avionics
Research activities

- Communication, navigation and surveillance systems-CNS
- Information Technology, Simulation
- Air Transport and ATC Economics
- Systems engineering
- Applied mathematics
  Mathématiques Appliquées, Informatique, Automatique de l’Aérien-MAIAA
International activities

- 450 foreign students and trainees from 5 continents.
- Exchanges with foreign universities: USA, Germany, UK, Finland, Italy, Spain, Sweden, Ukrain, Australia, Mexico, Viet Nam, Brazil, Singapore,
- Member of PEGASUS, the European network of the main aeronautical colleges and universities
- Cooperation with foreign Civil Aviation Training Centres and Universities
AIR TRANSPORTATION SECTOR

- AIRPORTS
- AIRLINES
- AIR TRAFFIC MANAGEMENT
- AERONAUTICAL INDUSTRY

Air Transport Service
Today, the global airline industry consists of over 2000 airlines operating more than 23,000 aircraft, providing service to over 3700 airports. In 2010, the world’s airlines flew almost 32 million scheduled flight departures and carried over 2.5 billion passengers.

35 millions of direct, indirect and induced jobs, 400 billion US$ in revenues in 2010, 40% of world trade in value.

The growth of world air travel has averaged approximately 5% per year over the past 30 years, with substantial yearly variations due both to changing economic conditions and differences in economic growth in different regions of the world. Historically, the annual growth in air travel has been about twice the annual growth in GDP.

Even with relatively conservative expectations of economic growth over the next 10-15 years, a continued 4-5% annual growth in global air travel will lead to a doubling of total air travel during this period.
Deregulation and Liberalization Worldwide

Since the deregulation of US airlines in 1978, the pressure on governments to reduce their involvement in the economics of airline competition has spread to most of the rest of the world. The US experience with airline deregulation can be perceived to be a success by some other countries, as overall benefits to the vast majority of air travellers have been claimed.

While US domestic air travel grew at rates significantly greater than prior to deregulation, average real fares declined since deregulation and today remain at less than half of 1978 levels. Despite worries at the time of deregulation that competitive cost pressures might lead to reduced maintenance standards, there is no statistical evidence that airline safety deteriorated.

At the same time, the US deregulation experience had some potentially more negative impacts: The pressure to cut costs, combined with increased profit volatility, mergers and bankruptcies of several airlines led to periodic job losses, reduced wages and airline labour unions with less power than they previously enjoyed.
Air Transportation System: A Highly Complex System
Main Characteristics of Air Transport Industry

High investment costs sector: infrastructures and aircraft fleets

High operational costs sector: fuel, wages, communications and control

Continuous Evolution of technology: Aircraft performances, communication and navigation systems (satellite based systems), air traffic management and control (NextGen, Sesar)

Vulnerability to Economy and Politics

Multi-Time-Scale systems

Multi-agent systems

On the short term vulnerable to Meteorology, social movements, etc
Recent Technological Developments:

- Global Satellite-based Navigation System for Aircraft
- Improved aircraft navigation and guidance systems
- Enhanced onboard computing capabilities
- High level of integration of ATC/ATM systems
- Collaborative decision making capabilities
- and …new Internet applications

lead to **new traffic control/management concepts** (NextGen, SESAR) designed for higher security and efficiency standards and to **new airports and airlines operational procedures** allowing increased robustness and flexibility towards economic return.
General Objectives for Air Transportation

SAFETY and EFFICIENCY

Complex constraints and optimisation criteria

Operations Research Models and Techniques appear essential to meet these objectives
The International Federation of Operational Research Societies (IFORS)

AGIFORS
The Airline Group of the International Federation of Operations Research Societies (AGIFORS) is a professional society dedicated to the advancement and application of Operational Research within the airline industry. The membership consists of Operational Research professional employed by recognized civil airlines and related industries and correspondents keenly interested in the application of Operations Research to aviation problems.

AGIFORS is the outcome of informal discussions between six airline Operational Research workers (from Trans Canada, Air France, Sabena, BEA, and Swissair) who were present at the second international conference in Operational Research at Aix en Provence, France, in 1960. These informal discussions led to the formation of a committee, which organized a Symposium on the use of Operational Research within the airline industry, at Spring Valley, New York in October 1961. This Symposium was deemed successful and resulted in the formation of AGIFORS as a professional society dedicated to the free exchange of ideas and new advances in Operations Research within the airline industry.
Today the AGIFORS membership exceeds 1,200 professionals representing more than 200 airlines, airline manufacturers and aviation related industries and associations.

**Annual Symposium of AGIFORS**

The Annual Symposium is the main focus of AGIFORS activities, and is held during September or October each year. AGIFORS members make presentations on various airline OR subjects. Guest speakers are invited from the academia and related industries, to present the latest state of-the-art OR practices. The Symposium also includes panel sessions, discussion groups and tutorials.

Participation in the Symposia and the nature of the subjects discussed, clearly show the international nature of AGIFORS, its growth and the wide range of interests of its members. The symposium also provides participants with the opportunity to make new contacts with people studying similar problems at airlines all over the world.
AGIFORS Study Groups

Cargo Study Group:

In recent years the Cargo business has taken on a new importance for many airlines. Following some discussions and a high level of interest in this area at the 1988 AGM, this group met in 1989 after a lapse of several years. Topics addressed include all aspects of the Air Cargo business of current interest to Operational Researchers.

Crew Management Study Group:

This group addresses planning and management topics related to cockpit and cabin crew. Discussion concentrates on topics related to planning crew pairings or rotations or pattern construction, and to crew assignments, crew rostering or development of bid lines. North American and European approaches to crew assignment both receive attention at this study group.
Airline Operations Study Group

**Flight Operations** - These including dispatch, flight planning, flight watch, weather data provision, operations control, ground to air communications and integration with crew, schedules and maintenance planning. Gate allocation, slot control, ATC and airport management can also be covered. There is increasing use of simulation and expert systems, for the management of irregular operations.

**Ground Resources** - The use of management science techniques in reducing costs or increasing the effectiveness of manpower has been the concern of this group. Topics addressed include determination of operational manpower requirements, optimal task allocation, production of efficient roster patterns, planning of employment, annual leave, training, reward systems and strategic planning of recruitment. There has been some considerable interest in personal computer applications with demonstrations of systems under development.

**Maintenance** - Information systems for Maintenance & Engineering and Materials functions have been the focus of this study group. Areas of current interest include component control, aircraft records, maintenance planning, inventory systems, initial provisioning and parts tracking.
AGIFORS Study Groups

Strategic and Schedule Planning Study Group

Delegates study the process of schedule development with an emphasis on developing techniques and systems to minimize fleet requirements and other scheduled related costs, maximize revenues and analyze punctuality profiles of proposed flight schedules. This group now includes Corporate Planning, which is concerned with strategic decision making, fleet selection, fleet assignment, route planning and medium to long term financial planning, as well as airspace and airport capacity issues.

Revenue Management and Distribution Study Group

All topics in the area of reservations systems activities are covered by this group. These include revenue optimization, overbooking management, demand forecasting, price demand elasticity, waitlist processing and some marketing issues.
Survey objectives:

- Classification of research themes
- Reference papers
- Contributions
  - Problem characteristics
  - Available OR Tools
  - Achieved results
  - Trends
Applications of Operations Research in the Air Transport Industry

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This paper presents an overview of several important areas of operations research applications in the air transport industry. Specific areas covered are: the various stages of aircraft and crew schedule planning; revenue management, including overbooking and leg-based and network-based seat inventory management; and the planning and operations of aviation infrastructure (airports and air traffic management). For each of these areas, the paper provides a historical perspective on OR contributions, as well as a brief summary of the state of the art. It also identifies some of the main challenges for future research.

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Computational Models, Software Engineering, and Advanced Technologies in Air Transportation: Next Generation Applications

Li Weigang (University of Brasilia, Brazil), Alexandre de Barros (University of Calgary, Canada) and Italo Romani de Oliveira (Atech Tecnologias Cricas, Brazil), IGI Global, 2010.

Table of Contents and List of Contributors

Challenges Ahead for European Air Traffic
Dave Young (EUROCONTROL, France), Nadine Pilon (EUROCONTROL, France), and Lawrence Brom (EUROCONTROL, France)

The SYNCROMAX Solution for Air Traffic Flow Management
Antonio Pedro Timoszczuk (Funadação Aplicações de Tecnologias Cricas – Atech, Brazil), Walter Nogueira Pizzo (Fundação Aplicações de Tecnologias Cricas – Atech, Brazil).

Balance Modelling and Implementation of Flow Balance for Application in Air Traffic Management
Bueno Borges de Souza (University of Brasilia), Li Weigang (University of Brasilia), Antonio Marcio Ferreira Crespo (CINDACTA I, Brazil), and Victor Rafael Rezende Celestino (TRIP Linhas Aereas S/A, Brazil).

Cooperative Control for Ground Traffic at Airports
Felipe Man Galvão França (Universidade Federal do Rio de Janeiro, Brazil), and Félix Mora-Camino (Ecole Nationale de l’Aviation Civile, France)

Critical Review and Analysis of Air-Travel Demand: Forecasting Models
Matthew G. Karlaftis (National Technical University of Athens, Greece)

Using the Continuum Equilibrium Approach to Solve Airport Competition Problems: Computational and Application Issues
Becky P.Y. Loo (The University of Hong Kong, China), H.W. Ho (The Hong Kong Polytechnic University, China), S.C. Wong (The University of Hong Kong, China), and Peng Zhang (Shanghai University, China)

Real-Time Non-Destructive Evaluation of Airport Pavements Using Neural Network Based Models
Kasthunran Gopalakrishnan (Iowa State University, USA)

Advances in Data Processing for Airlines Revenue Management
Félix Mora-Camino (French Civil Aviation Institute (ENAC), France), and Luiz Gustavo Zelaya Cruz (Universidade Federal Fluminense-Rio das Ostras, Brazil)

Commercial Aircraft: A Holistic and Integrated Model of the Flux of Information Regarding the Operational
José Lourenço da Sáide (State University of Beira Interior, Covilhã, Portugal), and Jorge Miguel Reis Silva (State University of Beira Interior, Covilhã, Portugal).

A Case Study of Advanced Airborne Technology Impacting Air Traffic Management
Italo R. de Oliveira (Atech Tecnologias Cricas, Brazil Henk A.P. Blom (Air Transport Safety Institute, National Aerospace Laboratory NLR, The Netherlands).

A Global Optimization Approach to Solve Multi-Aircraft Routing
S.P. Wilson (Numerical Optimisation Centre, University of Hertfordshire, UK), M.C. Bartholomew-Biggs (Numerical Optimisation Centre, University of Hertfordshire, UK).

Collaborative Decision Making and Information Sharing for Air Traffic Management Operations
Osvander Alves Martins (Aeronautics Institute of Technology (Instituto Tecnológico de Aeronáutica – ITA)), Denis Silva Loubach (Aeronautics Institute of Technology (Instituto Tecnológico de Aeronáutica – ITA), Brazil.
Operations and Planning Challenges in Air Transportation

Source Anna Norin, Linköping University, 2008
Considered Application Domains

Air Transport System Planning
- Long Term Air Transportation System Planning
- Pricing of Air Traffic Control Services
- Airport Airside Capacity Estimation
- Airport Noise Capacity

Airline Operations
- Airline Fleet Scheduling
- Airline Crew Management
  - Crew Pairing Problem
  - Crew Rostering Problem
- Airline Revenue Management

Airport Operations
- Systematization of Balanced Approach for Noise Abatment
- Security management at airports
- Ground Service Fleets Operations at Airports
Planning Air Transport Systems
Long Term Planning of an Air Transportation Network: A Two Level optimization Approach

By

Amadou Handou, WFP, Aïcha Alou Oumarou, LARA
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Journées de l’Optimisation
Montréal, Québec, Canada, 7 au 9 Mai 2007
LONG TERM PLANNING OF AN AIR TRANSPORTATION NETWORK: AN OPTIMIZATION APPROACH

SUPPLY OPTIMIZATION MODEL
(Problem I)

\[
\begin{aligned}
\max \; & \sum_{i=1}^{N} \sum_{j \in \Gamma_{pax}} \sum_{n=1}^{N_{ij}} \pi_{ij}^n \theta_{ijn} / (1 + \tau) - \\
& (c_{cf} + c_{cv} F_c + \sum_{i=1}^{N} \sum_{j \in \Gamma_{c}} c_{ij}^{cv} f_{ij}^c) + (c_{Lf} + c_{Ll} F_L + \sum_{i=1}^{N} \sum_{j \in \Gamma_{c}} c_{ij}^{Ll} f_{ij}^{Ll}) \\
& + \sum_{i=1}^{N} \sum_{j \in A_c(i)} f_{ij}^c d_{ij}^c \leq D_c F_c \\
& + \sum_{i=1}^{N} \sum_{j \in A_l(i)} f_{ij}^L d_{ij}^L \leq D_l F_L \\
& + \sum_{n=1}^{N_{ij}} \theta_{ijn} \leq T_{ij}^{*(k-1)} + \frac{\partial T_{ij}}{\partial \pi_{ij}} \left( \sum_{i=1}^{N_{ij}} (\theta_{ijn}^{(k-1)} \pi_{ij}^n) / T_{ij}^{*(k-1)} - \pi_{ij}^{(k-1)} \right) \quad i, j \in A
\end{aligned}
\]

Aircraft and Passengers Flows Positivity, Conservation and all Capacity Related Constraints

F.Mora-Camino XVI ELAVIO
DISTRIBUTION OF DEMAND (Problem II)

Local cost elasticities

Adopted Elastic Model:
\[ T_{ij}(\pi_{ij}) = T_{ij}(\pi_{ij}^0) e^{-\lambda_{ij}(\pi_{ij} - \pi_{ij}^0)} \]

Elastic Generation and Attraction Constraints
\[
\begin{align*}
\sum_{j=1, j\neq i}^{N} T_{ij} e^{\lambda \pi_{ij}} &= O_i & i = 1 \text{ à } N \\
\sum_{i=1, i\neq j}^{N} T_{ij} e^{\lambda \pi_{ij}} &= D_j & j = 1 \text{ à } N
\end{align*}
\]

Consistency:
\[ \sum_{i=1}^{N} O_i = \sum_{j=1}^{N} D_j = T \]
Pricing of Air Traffic Control Services: A Dual Inverse Approach to Bilevel Programming

Rabah Guettaf¹, Moussa Larbani², Félix Mora-Camino¹

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² Kuala Lumpur University, Malaysia
moussa.larbani@gmail.com
Maximisation of passengers flows:

\[ \max_{v_u \geq 0} \sum_{u \in U} \phi_u + \sum_{e \in E} \phi_e \]

Under revenue constraints:

1) Airlines sector:

\[ \sum_{u \in U} (\pi_u^{\text{int}} \phi_u - (c_u + v_u) f_u^{\text{int}}) - C_{ALN}^F \geq R_{ALN} \]

2) ATC sector:

\[ \sum_{u \in U} ((v_u - \sigma_u^{\text{int}}) f_u^{\text{int}} + \alpha \lambda_u^{\text{int}} \pi_u^{\text{int}} \phi_u^{\text{int}}) \]
\[ + \sum_{e \in E} ((w_e - \sigma_e^{\text{ext}}) f_e^{\text{ext}} + \alpha \lambda_e^{\text{ext}} \pi_e^{\text{ext}} \phi_e^{\text{ext}}) - C_{ATC}^F \geq R_{ATC} \]
The airlines capacity offer is given by the solution of the following maximization problem:

$$\max_{\pi_u, f_u} \sum_{u \in U} \left( \pi_u \phi_u - \left( (c_u + v_u) f_u \right) - C_{ALN}^F \right)$$

with

$$\phi_u = \max \{0, \min \{ q_i f_u, D(\pi) \} \} \quad u \in U_i, \ i \in I$$

$$0 \leq \sum_{u \in U_i} L_u f_u \leq \left( \sum_{u \in U} L_u \right) f_{\max} \quad i \in I$$

$$D_u(\pi) = D_0^u - \rho_{uu} \pi_u (1 + \lambda_u) + \sum_{v \neq u} \rho_{uv} \pi_v (1 + \lambda_v) \quad u \in U$$
Solution of pricing for public ATC

The ATC tariffs optimization problem can be rewritten as:

\[ \min_{\nu, w} \ m' \nu + n' \pi^{ext} + r \]

under quadratic constraints:

\[ \nu' \ N_{ATC} \nu + M_{ATC} '\nu + P_{ATC} 'w + z_{ATC} \geq 0 \]

\[ \nu' \ N_{ALN} \nu + M_{ALN} '\nu + P_{ALN} 'w + z_{ALN} \geq 0 \]

\[ w_e f_{e}^{ext} \leq \eta_e \phi_{e}^{ext} \pi_{e}^{ext} \quad e \in E \]
The above optimization problems can be considered to be such as:

$$\min \ c^t z$$

under an LMI constraint:

$$M(z) \geq 0$$

where $c \in \mathbb{R}^m$ is given and where:

$$M(z) = M_0 + \sum_{i=1}^{m} z_i M_i$$

$M_j, j = 0 \text{ to } m$ are symmetric matrices.
Here the feasible domain is given by the non convex domain $F$. Level curves are here given by parallel straight lines such as $\Delta$ and the optimal solution is at point $A$. 

Solution of pricing for public ATC
A HEURISTIC APPROACH TO 3D ESTIMATION OF AIRSIDE CAPACITY AT AIRPORTS

ICORAILD-ORSI
Bengalore, December 27-29/2005

Dragos Stoica, Félix Mora-Camino,
Luiz Gustavo Zelaya Cruz
ENAC and UT2, Toulouse, France, COPPE/UFRJ,Rio de Janeiro, Brazil

F.Mora-Camino XVI ELAVIO
Terminal de passageiros e patio do aeroporto de Congonhas
Airport Capacity

- **Theoretical Capacity**: the maximum number of aircraft that the airport is able to process per unit of time without considering the quality of service.

- **Potential Capacity**: the maximum number of aircraft that the airport is able to process per unit of time for given levels of demand (arrivals).

- **Practical Capacity**: The maximum number of aircraft which can be processed per unit of time for a given mean delay level.

- **Operational capacity**: The maximum number of aircraft which can be processed per unit of time for a given maximum delay.

Operational $\leq$ Practical $\leq$ Potential $\leq$ Theoretical
Airside Capacity Computation
Assignment of flows

Chosen criterion

\[ f(\varphi) = \sum_{u \in U} l_{u} \varphi_{u} + \sum_{l \in L} \sum_{u \in \omega^{-}(l)} \sum_{v \in \omega^{-}(l), v \neq u} c_{uv} \varphi_{u} \varphi_{v} \]

\[ P_{op}(\Phi_{a}, N^{0}, \Phi^{d}) \]

\[ \min f(\varphi) \quad \text{given (} \Phi^{a}, \Phi^{d}, N^{0} \text{) inside practical capacity limits} \]

\[
\begin{aligned}
0 \leq \varphi & \leq \varphi_{\text{max}} \\
A\varphi & = 0 \\
(A_{L}\varphi)\theta & \leq T \\
0 \leq N^{0} + \Psi^{a} + \Psi^{d} & \leq S \\
A_{\Omega}\varphi & \leq Z
\end{aligned}
\]

\[
\begin{aligned}
A_{I}\varphi^{a} & = \Phi_{I}^{a}, A_{I}\varphi^{d} = \Phi_{I}^{d} \\
A_{J}\varphi^{a} & = \Psi^{a}, A_{J}\varphi^{d} = \Psi^{d} \\
\Psi^{a}1^{T} & = \Phi^{a}, \Psi^{d}1^{T} = \Phi^{d} \\
0 \leq \Psi^{a} & \leq \Psi^{a}_{\text{max}}, 0 \leq \Psi^{d} \leq \Psi^{d}_{\text{max}}
\end{aligned}
\]
$$P_{op}(\Phi^a, N^0, \Phi^d)$$

**Airside Capacity Computation**

**Optimal assignment of flows**

- **Algorithm (increasing load)**
  - **Entries**: $\Phi a$, N0, $\Phi d$, T, Q
  - **Output**: $f^*$ - quasi-optimal
  - **FOR** $k = 1, \ldots, T$
    - **FOR** $i = 0, \ldots, Q$
      - **IF** $i == 0$ **THEN**
        - Solve $P_{op}^0(\Phi^{a_0}, N^0, \Phi^{d_0})$
        - $f^0(\varphi) = \sum_{u \in U} l_u \varphi_u$
      - **ELSE**
        - Solve $P_{op}^i(\Phi^{a_i}, N^0, \Phi^{d_i})$
        - $f^i(\varphi) = \sum_{u \in U} l_u \varphi_u + \sum_{l \in L} \sum_{u \in \omega^{-} (l)} \sum_{v \in \omega^{+} (l)} c_{uv} (\varphi_u^{i-1} \varphi_v + \varphi_u \varphi_v^{i-1})$
      - **ENDIF**
    - **END FOR**
  - **END FOR**

$$f^* = \min_{k} \max_{i} f^i_k$$
Airside Capacity Computation

Network loading scheme

Criterium value during network loading (until $\Phi^a = \Phi^d = 18$)
Airside Capacity Computation

Distribution of performance at full loading ($\Phi^a = \Phi^d = 18$)
Airside Capacity Computation

Example of tridimensional representation of airport capacity
Towards the Concept of Airport Noise Capacity

Teo Revoredo¹ Walid El Moudani² and Felix Mora-Camino³

Abstract

The aim of this paper is to introduce the concept of airport noise capacity. According to the preliminary choice of a noise metric, a matrix providing elementary noise impacts for each type of flight operation at selected receptor points around an airport is introduced. Acceptable maximum noise levels at a reduced set of receptor points are also considered. Then is formulated the problem of dispatching in-bound and out-bound flights on different approach and departure trajectories such that for a given level of traffic, a global index of noise impact is minimized. This problem can be solved using classical combinatorial techniques such as branch and bound or dynamic programming, however, considering air traffic control operational constraints, a simplified version is proposed, resulting in a continuous linear programming problem of easy solution. For a given composition of aircraft fleet, the above problem is solved for different increasing levels of in-bound and out-bound traffic until maximum noise levels are reached and no more feasible solutions are available. The comparison of the maximum level of traffic with actual traffic at a given airport produces an estimation of practical remaining capacity with respect to noise, while the same comparison with the solution of the above problem with current traffic volumes produces an estimation of theoretical remaining capacity. The capacity estimation process can be then restarted with different composition of the operating aircraft fleet.

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² Lebanese University, Fac. of Business, Dept. of Business Information System, Lebanon. wmoudani@ul.edu.lb
³ MAIAA, Ecole Nationale de l’Aviation Civile, ENAC, Toulouse, France, felix.mora@enac.fr
Integrated Noise Model (INM)

DNL: Day-Night average sound level at a given point:

\[
DNL(dB) = 10 \log_{10} \left( \frac{1}{3600 \times 24} \left[ \int_{10am}^{10pm} L_A(t) \, dt + \int_{7am}^{10am} L_A(t) \, dt \right] \right)
\]

where \( L_A(t) \) is the instantaneous sound level
Aeronaves | 737300 | 737700 | 737800 | A319 | ATR42 | EMB120 | EMB190 | F10065 | GASEPEV
 Nº de vôos | 8,452 | 25,032 | 5,903 | 31,323 | 3,387 | 2,774 | 5,839 | 8,032 | 7,258
(média p/dia)

<table>
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<th>DNL</th>
<th>LAeqD</th>
<th>LAeqN</th>
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<tr>
<td>Gloria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>82,0</td>
<td>93,3</td>
<td>83,5</td>
</tr>
<tr>
<td>G2</td>
<td>85,5</td>
<td>96,8</td>
<td>86,6</td>
</tr>
</tbody>
</table>

G2 85,5 96,8 86,6 80,9 82,3 78,7
Aircraft Assignment Problem

\[
\max_{x_{v,n}} \quad C_v \cdot x_{v,n} \\
\sum_{n \in N} x_{vn} = 1 \quad \forall v \in V
\]

\[
\sum_{n \in N} \alpha_{np} \sum_{v \in V} r_{p,v} \cdot x_{vn} \leq C_p \quad p \in P
\]

\[
10 \log \left( \sum_{n \in N} \sum_{v \in V} x_{vn} \cdot 10^{\sigma(n,v,r)/10} \right) \leq B_r^{\text{max}} \quad r \in R
\]

\[
x_{vn} \leq \delta_{vn}, \quad x_{vn} \in \{0,1\}, \quad v \in V, n \in N
\]
Air Traffic Management
Abstract

In this paper, we show how genetic algorithms can be used to solve en-route aircraft conflict automatically to increase Air Traffic Control capacity in high density areas. The ATC background and the model are presented. The complexity of the problem is then discussed. The author then justifies the choice of GAs. After a brief description of genetic algorithms, the author describes the improvements that were used for solving the conflict resolution problem. Several numerical applications are then given justifying the choices that were made and illustrating the interest of the research.

Automatic aircraft conflict resolution using Genetic Algorithms

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Optimization strategy for air traffic flow in multi-airport network

Yu JIANG*, Honghai ZHANG and Hongshan XIA
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Scientific Research and Essays Vol. 6(31), pp. 6499-6508, 16 December, 2011

A Mixed Integer Linear Programming method is used for creating sectors in Fort Worth, Cleveland, and Los Angeles centers based on several days of good-weather traffic data. The performance of these sectors is studied when they are subjected to traffic data from different days. Additionally, the advantage of using different sector designs at different times of day with varying traffic loads is examined.

To avoid the airport congestion and reduce flight delays, the paper studied the airport traffic balance from a system perspective at the strategic level. By considering the single-airport approach and departure as well as the correlation between the multi-airport connecting flights, the paper proposed network system on traffic flow which is open and has a direction in multi-airport; the paper set up multi airport open network assignment model which was based on constraint capacity and multiple connecting flights and which minimized the total delay of all flights in the network within the target.

Air Traffic Sector Configuration Change Frequency

Gano B. Chatterji* and Michael Drew†
University of California Santa Cruz, Moffett Field, CA, 94035-1000

GNC – AIAA 2010
Trajectory Generation For Relative Guidance of Aircraft

Baba Ouattara* and Félix Mora-Camino#

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bouattara@eamac.ne
# LARA, Département Transport aérien, ENAC, Toulouse, France,
felix.mora@enac.fr
Problem Formulation

**Minimum time convergence problem**:

\[
\min_{r_P} \int_0^{t_f} dt \quad \text{with} \quad \begin{aligned}
\dot{d} &= V_L \cos(\theta - \psi_L) - V_P \cos(\theta - \psi_P) \\
\dot{\theta} &= \left\{-V_L \sin(\theta - \psi_L) + V_P \sin(\theta - \psi_P)\right\}/d \\
\dot{\psi}_P &= r_P
\end{aligned}
\]

and with constraints:

- \[\phi_{\min} \leq \phi_P \leq \phi_{\max}\]
- \[d_{\min} - d \leq 0\]

Initial conditions:

- \[d(0) = d_0 \quad \text{with} \quad d_0 \geq d_{\min}, \quad \theta(0) = \theta_0, \quad \psi_P(0) = \psi_{P0}\]

Final conditions:

- \[\psi_P(t_f) = \psi_L\]
- \[\theta(t_f) = \psi_L\]
- \[d(t_f) = D\]

Control variable:

- \[r_P = \frac{g}{V_P} \cdot \tan \phi\]
Characterization of Convergence Trajectories

Regular trajectory of the $n^{th}$ order:

A trajectory composed of a sequence of $(n - 1)$ pairs of straight line segments and maximum bank angle turns is here called “regular trajectory” of order $n$.

Parametric representation of a regular trajectory of order 4
Characterization of Convergence Trajectories

Time optimal convergence trajectories: MP Formulation

$$\min_{(l_i, \varepsilon_i, \theta_i)_{i=1 \text{ a } n-1}} \sum_{k=1}^{n-1} (l_k + R_{\min} \theta_k)$$

with\n
\[ l_i \geq 0, \theta_i \geq 0, \varepsilon_i = \pm 1 \quad i = 1 \text{ a } n-1 \]

with the constraints

- initial conditions \[ x_n = x_0^P, \quad y_n = y_0^P \text{ and } \psi_n = \psi_0^P \]

- final convergence

\[
\begin{align*}
x_1 & = x_L(0) + \alpha \sum_{k=1}^{n-1} (l_k + R_{\min} \theta_k) - D \\
y_1 & = 0 \\
\psi_1 & = \psi_L \\
d & \geq d_{\min}
\end{align*}
\]

- minimum separation

From the point of view of Mathematical Programming this problem presents major difficulties:

- it is a **mixed variables** programming problem ($\varepsilon_i$ are binary variables while angles $\theta_i$ and lengths $l_i$ are real positive variables),

- the admissible domain generated by the different constraints is **non convex** and its complexity grows explosively with an increasing value of $n$,

- the minimum separation constraints depend on **logical conditions**.
The Proposed Solution Approach

Minimum time trajectory generation:

by Reverse Dynamic Programming

Generation of a new point
Verification of the separation constraint
If point is already stored, selection of the minimum time trajectory
Storage of its parameters and

Example of Training Grid

Solutions memorization within Neural Network Structures and On Line Interpolation of current Situations

Trajectory parameters

Example of Training

F.Mora-Camino XVI ELAVIO
The Proposed Solution Approach

On line Neural Networks Operation

Current relative position and speed

Neural Networks

Convergence trajectory prediction

Generation of instant guidance directives
Planning Operations at Airlines
Airline cost elements

Domestic Airline

Intercontinental Airline
Airline scheduling consists of the following four planning stages:

1. **Flight Scheduling:** A schedule consisting of all flights to be flown is constructed. The construction is typically based on market demands for the flight segments.

2. **Fleet Assignment:** In this stage, available aircraft are allocated to flight legs. The revenue from a flight leg depends on the market for the flight leg and the size of the aircraft that is used for the leg. The objective is to maximize revenue with the constraint that requires all the flight legs to be flown using the fleet that is available.

3. **Aircraft Routing:** The aircraft routing problem involves the routing of aircraft such that maintenance constraints are satisfied, all flights flown by the fleet are covered and through revenues are maximized.

4. **Crew Assignment** to scheduled flights.
Interdependent Decision Processes at Airlines
Network Fleet, and Schedule Planning
Classroom and In-Company Course

Contribute to your company’s success by developing a profitable network fleet plan and effective flight plan.

This course develops your skills with a hands-on approach that includes exercises and case studies for individuals and groups.

Duration
3 days (24 hours)

Requirements
None

Goals
• Understand how company revenues and profitability depend on the network and fleet plan
• Learn basic market and route forecasting
• Schedule effectively to maximize company aircraft resources
• Improve aircraft and fleet utilization
• Implement better scheduling strategies
• Learn the tools and data required in the planning function, including passenger traffic demand data and data sources, flight schedule data, network planning, and optimization tools

Who will benefit
• Network, fleet, and schedule planning staff
• Those seeking to understand network planning
• Staff seeking to understand the airline’s planning process

Dates and registration online
www.iata.org/training/courses/pages/iatm28.aspx

Key topics
• Consider processes involved in optimizing an actual route network
• Airline economics and costs; supply and demand dynamics; passenger traffic demand and market estimation
• Route profitability
• Passenger traffic flow: point-to-point versus true origin-destination
• Route and network determinants
• Scheduling design and planning
• Airline capacity and route
• Network strategies and optimization
• Fleet planning and management; operational constraints in the planning process
• Strategic and operational analysis related to fleet

Activities
• This course provides you with practical experience utilizing interactive exercises and role playing.

Certificate awarded
You will earn an IATA Certificate upon successful completion of this course.

You may also apply this course toward a diploma:
• Airline Management
• Cargo Management

F.Mora-Camino XVI ELAVIO
Airline Fleet Assignment Problem

\[ \min \sum_{k=1}^{K} \sum_{i \in I_F} c_{ki} x_{ki} \]  
\[ \sum_{i \in I_{IN_v}} x_{ki} = \sum_{i \in I_{OUT_v}} x_{ki}, \quad \forall k = 1, 2, \ldots, K, \; v \in V; \]  
\[ \sum_{k=1}^{K} x_{ki} = 1, \quad \forall i \in I_F; \]  
\[ \sum_{h \in H} \sum_{i \in I_{OUT_{s_h}}} x_{ki} \leq n_k, \quad k = 1, 2, \ldots, K; \]  
\[ \sum_{i \in I_{IN_{t_h}}} x_{ki} = \sum_{i \in I_{OUT_{s_h}}} x_{ki}, \quad \forall k = 1, 2, \ldots, K, \; h \in H; \]  
\[ x_{ki} \in \{0, 1\}, \quad \forall k = 1, 2, \ldots, K, \; i \in I_F; \]  
\[ x_{ki} \geq 0, \quad \forall k = 1, 2, \ldots, K, \; i \in I. \]

Indices:
- \( k \), index for fleet types;
- \( v \), index for nodes;
- \( i \), index for arcs;
- \( h \), index for airports;

Input parameters:
- \( K \), number of fleet types;
- \( V \), set of all nodes;
- \( I \), set of all arcs;
- \( I_F \), set of flight arcs;
- \( n_k \), number of available aircraft for fleet \( k \);
- \( H \), set of all airports;
- \( s_h \), the node associated with airport \( h \) and the beginning
- \( t_h \), the node associated with airport \( h \) and the end of the
- \( c_{ki} \), cost of assigning fleet \( k \) to flight arc \( i \);

Decision variables:
- \( x_{ki} \), indicating whether fleet type \( k \) is assigned to arc \( i \);

In the model, \( 1 \) is the objective function which minimizes the total cost of fleet assignment; \( 2 \) states the conservation of flows at each node for each fleet type; \( 3 \) makes sure that each flight segment is flown by one and only one aircraft; \( 4 \) enforces the resource constraint for each fleet type; \( 5 \) is the aircraft balance constraint: the number of aircraft of any particular fleet flying out from any particular airport in the beginning of the day must be the same as the number of aircraft of that fleet flying back to the same airport at the end of the day; \( 6 \) is the integral 0-1 constraint on each flight arc; and \( 7 \) is the non-negative constraint on each arc.
This paper introduces a new type of constraints, related to schedule synchronization, in the problem formulation of aircraft fleet assignment and routing problems and it proposes an optimal solution approach. This approach is based on Dantzig-Wolfe decomposition/column generation. The resulting master problem consists of tight covering constraints, as in usual applications, and of schedule synchronization constraints. The corresponding sub problem is a shortest path problem with time windows and linear costs on the time variables and it is solved by an optimal dynamic programming algorithm. This column generation procedure is embedded into a branch and bound scheme to obtain integer solutions. A dedicated branching scheme is devised in this paper where the branching decisions are imposed on the time variables. Computational experiments were conducted using weekly fleet routing and scheduling problem data coming from an European airline. The test problems are solved to optimality. A detailed result analysis highlights the advantages of this approach: an extremely short sub problem solution time and, after several improvements, a very efficient master problem solution time.
A heuristic approach based on shortest path problems for integrated flight, aircraft and passenger rescheduling under disruptions, Rapport LAAS N°10183, Mars 2010, 17p.
Airline Crew Management

I Introduction
II Operations costs with Airlines Crews
III Mathematical Formulation
IV Airlines crew pairing
V Airlines crew rostering
VI On Line Crew management

IATOM 2009
Elaboration du planning

Généralement, l’élaboration du planning se fait de façon progressive durant les mois qui précèdent le mois courant. Soit « M » le numéro du mois de planning à élaborer. L’élaboration du planning peut être décomposée en quatre phases (figure II.2).

M-3 : Prévision des rotations

M-2 : Pré-élaboration

M-1 : Elaboration

M : Suivi
Mathematical formulation

Minimiser \( \sum_{j=1}^{K} \sum_{i=1}^{N} (c_{ij} x_{ij} + \sum_{k=j+1}^{K} c_{ijk}^i y_{jk}) \)

sous les contraintes suivantes :

\[
\sum_{i=1}^{N} x_{ij} \geq 1, \quad \forall j \in \{1 \ldots K\}
\]

\[
(x_{j_1} + x_{j_2}) \leq 1 \quad \forall j_1 \in \{1 \ldots K\}, j_2 \in O_{j_1}, i \in \{1 \ldots N\}
\]

\[
\sum_{j=1}^{K} d v_{j} x_{ij} \leq v_{i}^{+} \quad \forall i \in \{1 \ldots N\}
\]

\[
d r_{jk} y_{jk}^{i} \geq \beta_{jk}^{+} \quad \forall i \in \{1 \ldots N\}, \forall j, k \in \{1 \ldots K\}
\]

\[
x_{ij}, y_{jk}^{i} \in \{0, 1\} \quad \forall i \in \{1 \ldots N\}, \forall j, k \in \{1 \ldots K\}
\]
Problem decomposition

- Crew Pairing Problem
- Crew Roastering Problem

Diagram:

1. **Programmation des vols commerciaux**
   - **Affectation des avions aux vols commerciaux**

2. **Contraintes dures liées à la législation et à la technique**
3. **Contraintes flexibles liées au service commercial de la compagnie**

4. **Génération d’un ensemble performant de rotations couvrant tous les vols commerciaux**

5. **Contraintes dures liées à la réglementation, aux accords contractuels, etc.**
6. **Contraintes flexibles liées aux désiderata du personnel navigant technique**

7. **Affectation efficace du Personnel Navigant Technique aux rotations**

Text (bottom of the page):

Relations entre les différents problèmes dédiés à l’organisation des opérations de transport aérien dans une compagnie aérienne
**Crew Pairings:** A pairing is a sequence of flight legs or segments that begin and end at a crew base such that in a sequence the arrival city of a flight leg coincides with the departure city of the next flight leg. It is also referred to by some as a trip or rotation. Each pairing has a cost associated with it. The objective is to find a subset of these pairings with minimal cost that covers all the flight legs in the schedule exactly once. A large number of regulations and other constraints apply during this stage.

**Airline Crew Scheduling: State-of-the-Art**
BALAJI GOPALAKRISHNAN, Institute for Mathematics and its Applications, University of Minnesota
ELLIS. L. JOHNSON, School of Industrial & Systems Engineering, Georgia Institute of Technology, Atlanta
Airline Crew Rostering

Rosters/Bidlines: a monthly schedule that can be flown by the crew is drawn using the optimal set of pairings generated from the previous stage. Monthly schedule is called a bidline (or roster) for the crew. It is called bidline because pilots can bid on the generated lines based on seniority and other considerations. This stage determines the exact number of cockpit crew members that the airline will require for the month.

ANNALS OF OPERATIONS RESEARCH
Airline Crew Rostering: Problem Types, Modeling, and Optimization
Niklas Kohl and Stefan E. Karisch
From the issue entitled "Staff Scheduling and Rostering: Theory and Applications, Part I"

EVOLUTIONARY MULTI-CRITERION OPTIMIZATION
A Bi-Criterion Approach for the Airlines Crew Rostering Problem
Walid El Moudani, Carlos Alberto Nunes Cosenza, Marc de Coligny and Félix Mora-Camino

A Dynamic Fuzzy Approach for the Evaluation of Airlines’ Crew Satisfaction
Moudani, W. E. & Mora-Camino, F.
Airlines Revenue Management
The impact of fare pricing cooperation in airline revenue management


This article addresses an airline revenue management strategy to jointly determine both the seat allocation and the fare price for a single leg flight in a duopoly market. Two game theoretic scenarios: non-cooperative and cooperative are considered. In non-cooperative game setting, existence of pure strategy Nash Equilibrium for the perfect competition between two airlines is shown. In cooperative scenario, two bargain games that differ in availability of side payment (SP) option while sharing of the gain of cooperation are studied.
AN ADVANCED AIRLINE RESERVATION CONTROL PROCESS USING DYNAMIC PROGRAMMING

Félix Mora-Camino
Carlos A.N. Cosenza

in Computational Models, software Engineering and Advanced Technologies in Air Transportation, IGI Global, 2010
The Revenue Management Problem

<table>
<thead>
<tr>
<th>Airline Company</th>
<th>Booking Request for Fare Class $i$</th>
<th>Potential Passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fare Class 1</td>
<td></td>
<td>Willingness To Pay</td>
</tr>
<tr>
<td>Fare Class 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>…</td>
<td></td>
<td>Accept/Reject</td>
</tr>
<tr>
<td>Fare Class $I$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Decision with respect to the booking request timing, fare class, number of available seats on the flight

Objective: Maximize the Expected Revenue
Demand Forecasting: process to update probability distributions

Start of the booking period

End of the booking period

Real demand

Remaining demand forecast ($\delta_n$)

$[p_{jk}^n]$ a priori distributions

$[p_{jk}^{n+1}]$ updated distributions

$N$ $n+1$ $n$ $n-1$ $...$ $0$ $1$

$\text{Real demand}$

$\text{Remaining demand forecast (}\delta_n\text{)}$

$\text{Start of the booking period}$

$\text{End of the booking period}$
Demand Forecasting: Geometric Program dual form

\[
\max \sum_{k=1}^{n-1} \sum_{j=0}^{J} \frac{p_{jk}^n}{n-1} \cdot \log \left( \frac{p_{jk}^{n+1}}{p_{jk}^n} \right)
\]

under

\[
\sum_{k=1}^{n-1} \sum_{j=0}^{J} \frac{p_{jk}^n}{n-1} = 1
\]

\[
\sum_{k=1}^{n-1} \sum_{j=0}^{J} \left( j - \frac{\delta_n}{n-1} \right) \cdot p_{jk}^n = 0
\]

\[
\sum_{j=0}^{J} p_{j1}^n - \sum_{j=0}^{J} p_{jk}^n = 0, \quad \forall k \in \{2, \ldots, n-1\}
\]

\[
p_{jk}^n \geq 0
\]

Probability updating process

\[
\delta_{i,k}^n = \left( \sum_{l=0}^{K-k} \sum_{m_i+m_{i+1}+\cdots+m_{i+l}=k+l} \prod_{i=1}^{l} p_{i,m_i}^n \right) \cdot \frac{k_i}{\sum_{m_i=0}^{K_i} m_i \cdot p_{i,m_i}^n}
\]

\[
k = 0 \text{ to } K = \sum_{i=1}^{I} K_i
\]

\[
\delta_{i,k}^n \quad \text{demand probabilities by period, by fare class, and by order of arrival}
\]
Inventory Control: Physically Unconfined Classes

\( \varphi_{s}^{n,k} = \text{the maximum expected revenue} \) (to be obtained from the remaining time interval) when \( k \) demands may still arrive during the \( n^{\text{th}} \) decision period, and \( s \) seats are still available for booking

\[
\varphi_{s}^{n,k} = \left( 1 - \sum_{l=0}^{K-k} \sum_{m_{1}+m_{2}+\cdots+m_{l}=k+l} \prod_{i=1}^{l} p_{i,m_{i}} \right) \varphi_{s}^{n,k-1} + \sum_{i=1}^{l} \varphi_{i,k}^{n} \max \left\{ F_{i} + \varphi_{s-1}^{n,k-1}, \varphi_{s}^{n,k-1} \right\}
\]

The optimal decision policy is established:

- accept \( \iff \) \( F_{i} + \varphi_{s-1}^{n,k-1} \geq \varphi_{s}^{n,k-1} \)
- reject \( \text{otherwise} \)
Numerical Results: cumulated revenue vs. received requests

Comparison between the BRDP and FCFS decision policies applied on a single-leg flight with 3 fare classes, 15 seats still available for booking, 5 days before departure.
Planning Operations at Airports
Aircraft ground Traffic at Airports
Main Operations Issues at Airports

- Airport environment management
- Aircraft ground traffic control
- Service fleets management
- Airside Airport security management Landside
The Airport Ground Movement Problem: Past and Current Research and Future Directions

Jason A. D. Atkin, Edmund K. Burke, Stefan Ravizza*
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University of Nottingham, Jubilee Campus
Nottingham, NG8 1BB, UK
Email: {jaa,ekb,smr}@cs.nott.ac.uk

Abstract—Determining efficient airport operations is an important and critical problem for airports, airlines, passengers and other stakeholders. Moreover, it is likely to become even more so given the traffic increases which are expected over the next few years. The ground movement problem forms the link between other airside problems, such as arrival sequencing, departure sequencing and gate/stand allocation. This paper provides an overview, categorisation and critical examination of the previous research for ground movement and highlights various important open areas of research. Of particular importance is the question of the integration of various airport operations and their relationships which are considered in this paper.
Systematization of Balanced Approach for Airport Noise Abatement through Sensitivity Study

Jules Slama, Téo Revoredo, Félix Mora-Camino

Federal University of Rio de Janeiro, Brazil

and

ENAC, French Aviation Institute, Toulouse, France
ICAO/CAEP’s - Balanced Approach to Aircraft Noise Management

ICAO’s Balanced Approach consists of identifying the noise problem at an airport, and then analyzing the various measures available to reduce the noise using four principal elements, namely:

1. reduction of noise at source;
2. land-use planning and management;
3. noise abatement operational procedures; and
4. operating restrictions.

The goal is to address the local noise problems on an individual airport basis and to identify the noise-related measures that achieve maximum environmental benefit most cost-effectively using objective and measurable criteria.
Balanced noise minimization problem

\[
\min_{\varepsilon} \left\{ \sum_{s=0} \left( \sum_{l \in L} \left( \sum_{s=0} \left( \left( D \delta \alpha_{s,l}^0 + \varepsilon_{D \delta \alpha_{s,l}^0}^i \right) + \left( N \delta \alpha_{s,l}^0 + \varepsilon_{N \delta \alpha_{s,l}^0}^i \right) \right) c_{s,l}^i - C_{s,l}^0 \right)^2 \right) + \sum_{s=0} \left( \sum_{l \in L} \left( \sum_{s=0} \left( \left( D \delta \alpha_{s,l}^0 + \varepsilon_{D \delta \alpha_{s,l}^0}^i \right) + \left( N \delta \alpha_{s,l}^0 + \varepsilon_{N \delta \alpha_{s,l}^0}^i \right) \right) c_{s,l}^i - C_{s,l}^0 \right)^2 \right) + \sum_{s=0} \left( \sum_{l \in L} \left( \sum_{s=0} \left( \left( D \delta \alpha_{s,l}^0 + \varepsilon_{D \delta \alpha_{s,l}^0}^i \right) + \left( N \delta \alpha_{s,l}^0 + \varepsilon_{N \delta \alpha_{s,l}^0}^i \right) \right) c_{s,l}^i - C_{s,l}^0 \right)^2 \right) \right\}
\]

under constraints:

\[
\Phi(X + \varepsilon) \leq \Phi_{\text{min}}
\]

and

\[
c_{s,l}^k (X + \varepsilon) \leq K_{s,l}^k, \quad k \in \{1, 2, \ldots, N_{r,s} \}
\]

with \( \varepsilon \in \mathbb{Z}^n \)

where \( c_{s,l}^k \) is the occupancy of runway \( k \) under demand \( X + \varepsilon \).
Optimisation des opérations de contrôle des passagers dans une aérogare

Rakiatou Jackou-Kaffa*, Hadj Batatia#, Félix Mora-Camino¤

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rajaka65@yahoo.fr
# IRIT-INPT et ENSEEIHT, 2 Rue Charles Camichel, 31071
Toulouse, Hadj.batatia@irit.fr
¤ENAC, Département de Transport Aérien, LARA, felix.mora@enac.fr
Schéma d’organisation du terminal de passagers
Les événements pris en compte dans ce cheminement sont en ce qui concerne les situations de menace:

- E1 : terroriste détecté au comptoir d’enregistrement,
- E2 : terroriste non détecté au comptoir d’enregistrement,
- E3 : terroriste détecté au contrôle de sûreté,
- E4 : terroriste non détecté au contrôle de sûreté,
- E5 : terroriste détecté à la porte d’embarquement,
- E6 : terroriste non détecté à la porte d’embarquement.

Exemple de structure de contrôle

Flux de passagers à l’entrée du système de contrôle

Flux de passagers à la sortie du système de contrôle

C_1

C_2
On peut alors formuler le problème de **minimisation de la probabilité de non détection d’un danger, sous les contraintes d’un niveau maximum pour la probabilité de fausses alarmes** et de la disponibilité des postes de contrôle.

\[
\begin{align*}
\text{Min } & \sum_{m=1}^{M} \sum_{i=1}^{N} \left( \tau_m \left( \sum_{u=1}^{\mu} \pi_u \prod_{j \in C'_2} (1 - p_{uj}) \right) x_{im} \right) \\
\text{sous les contraintes} & \\
\sum_{i=1}^{N} \left( \prod_{j \in C'_2} (1 - q_j) \right) \sum_{m=1}^{M} (1 - \tau_m) x_{im} \leq P_{FA}^{\max}
\end{align*}
\]

où \( P_{FA}^{\max} \) est le niveau maximum de probabilité de fausse alarme retenu.

les contraintes de disponibilité temporelle des postes de contrôle de \( C_2 \) pendant la période \( T \):

\[
\sum_{i=1, j \in C'_2} \sum_{m=1}^{M} x_{im} \leq y_j^{\max} \quad j \in C_2
\]

les contraintes de proportion :

\[
\sum_{i=1}^{N} x_{im} = z_m \quad m = 1 \ \text{à} \ M \quad 0 \leq x_{mi} \leq 1 \quad i = 1, \cdots, N \quad m = 1, \cdots, M
\]
Solutions avec pré-filtrage pour différents niveaux de demande:

<table>
<thead>
<tr>
<th>D</th>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$x_3$</th>
<th>$x_4$</th>
<th>$x_5$</th>
<th>$x_6$</th>
<th>$x_7$</th>
<th>$P_{ND}$</th>
<th>$P_{FA}$</th>
</tr>
</thead>
<tbody>
<tr>
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Solutions avec pré-filtrage pour différents niveaux de $P_{FA}^{\text{max}}$

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<th>$P_{FA}^{\text{max}}$</th>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$x_3$</th>
<th>$x_4$</th>
<th>$x_5$</th>
<th>$x_6$</th>
<th>$x_7$</th>
<th>$P_{ND}$</th>
</tr>
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<td>0.02845</td>
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<td>0.66531</td>
<td>0.0</td>
<td>0.00439</td>
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</tr>
</tbody>
</table>

Ainsi, on constate l’effet bénéfique du pré-filtrage sélectif qui pour un même niveau de fausses alarmes conduit à des niveaux de non détection de menace largement inférieurs.
Optimisation de la gestion des opérations d’escale

Salma Fitouri Trabelsi
Félix Mora Camino
École Nationale de l’Aviation Civile, Toulouse
ROADEF 2011
Disposition des véhicules d’assistance en escale autour du B777-300ER
\[
\min\left(\lambda \sum_{k=1}^{K} (T_k - d_k^P) + (1 - \lambda) \sum_{l=1}^{N} \sum_{i=1}^{n_i} L_i^l \right) \\

\text{subject to:}
\]

\[\begin{align*}
\sum_{l=1}^{n_i} \sum_{r=0}^{1} \sum_{k \in K_k} z_{ijl,k}^{1l} &= 1 & j &= 1, 2, \forall k \in K & (2) \\
\sum_{l=1}^{n_i} \sum_{k \in K_k} z_{ijl,k}^{1l} &= 1 & i &= 2, 3, 4, 5, \forall k \in K & (3) \\
\sum_{k \in K_k} z_{ijl,k}^{1l} &= \sum_{k \in K_k} z_{ijl,k}^{1l} & l &= \{1, 2, ..., n_i\}, \\
&= \sum_{r=0}^{1} \sum_{k \in K_k} z_{ijl,k}^{1l} & l &= \{1, 2, ..., n_i\}, \\
&= \sum_{r=0}^{1} \sum_{k \in K_k} z_{ijl,k}^{1l} & j &= 1, 2, \forall k \in K & (5) \\
\end{align*}\]

\[
\begin{align*}
C_{1k}^1 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \sum_{k \in K_k} \left( c_{1l}^{1k} + \frac{\delta_{1}^{1h(k)}}{\Delta_{1}^{1k} + \Delta_{3}^{1k}} \right) z_{ijl,k}^{1l} k' & & (6) \\
C_{1k}^1 \geq \frac{1}{2} \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{1}^{1k} . z_{ijl,k}^{1l} k' & & \forall k \in K \\
C_{1k}^1 \geq d_k^A & & \forall k \in K \\
\end{align*}\]

\[
\begin{align*}
C_{1k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \sum_{k \in K_k} \left( c_{1l}^{2k} + \delta_{1}^{2h(k)} \right) z_{ijl,k}^{2l} k' & & (7) \\
C_{1k}^2 \geq \frac{1}{2} \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{3}^{2k} . z_{ijl,k}^{2l} k' & & \forall k \in K \\
C_{1k}^2 \geq d_k^A & & \forall k \in K \\
C_{1k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{3}^{2k} . z_{ijl,k}^{2l} k' & & (8) \\
\end{align*}\]

\[
\begin{align*}
C_{2k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \sum_{k \in K_k} \left( c_{2l}^{2k} + \frac{\delta_{1}^{2h(k)}}{\Delta_{2}^{2k} + \Delta_{3}^{2k}} \right) z_{ijl,k}^{2l} k' & & (9) \\
\end{align*}\]

\[
\begin{align*}
C_{2k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \sum_{k \in K_k} \left( c_{2l}^{2k} + \frac{\delta_{1}^{2h(k)}}{\Delta_{2}^{2k} + \Delta_{3}^{2k}} \right) z_{ijl,k}^{2l} k' & & (10) \\
C_{2k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{2}^{2k} . z_{ijl,k}^{2l} k' & & \forall k \in K \\
C_{2k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{3}^{2k} . z_{ijl,k}^{2l} k' & & \forall k \in K \\
\end{align*}\]

\[
\begin{align*}
C_{3k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \sum_{k \in K_k} \left( c_{3l}^{3k} + \delta_{1}^{3h(k)} \right) z_{ijl,k}^{3l} k' & & (11) \\
C_{3k}^2 \geq \frac{1}{2} \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{3}^{3k} . z_{ijl,k}^{3l} k' & & \forall k \in K \\
C_{3k}^2 \geq \frac{1}{2} \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{3}^{3k} . z_{ijl,k}^{3l} k' & & (12) \\
\end{align*}\]

\[
\begin{align*}
C_{4k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \sum_{k \in K_k} \left( c_{4l}^{4k} + \delta_{1}^{4h(k)} \right) z_{ijl,k}^{4l} k' & & (13) \\
C_{4k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \sum_{k \in K_k} \left( c_{4l}^{4k} + \frac{\delta_{1}^{4h(k)}}{\Delta_{3}^{4k} + \Delta_{2}^{4k}} \right) z_{ijl,k}^{4l} k' & & \forall k \in K \\
C_{4k}^2 \geq \sum_{l=1}^{n_l} \sum_{r=0}^{1} \Delta_{3}^{4k} . z_{ijl,k}^{4l} k' & & \forall k \in K \\
\end{align*}\]

\[
\begin{align*}
\sum_{k \in K} \sum_{r=0}^{1} \sum_{l=1}^{n_l} \sum_{i=1}^{n_i} z_{ijl,k}^{1l} = 1 & & \forall l \in \{1, 2, ..., n_i\} & (17) \\
\sum_{k \in K} \sum_{r=0}^{1} \sum_{l=1}^{n_l} \sum_{i=1}^{n_i} z_{ijl,k}^{2l} = 1 & & \forall l \in \{1, 2, ..., n_i\} & (18) \\
\sum_{k \in K} \sum_{r=0}^{1} \sum_{l=1}^{n_l} \sum_{i=1}^{n_i} z_{ijl,k}^{3l} = 1 & & \forall l \in \{1, 2, ..., n_i\} & (19) \\
\sum_{k \in K} \sum_{r=0}^{1} \sum_{l=1}^{n_l} \sum_{i=1}^{n_i} z_{ijl,k}^{4l} = 1 & & \forall l \in \{1, 2, ..., n_i\} & (20) \\
\end{align*}\]
Airport COLLABORATIVE DECISION MAKING is the concept which aims at improving operational efficiency at airports by reducing delays, improving the predictability of events during the progress of a flight and optimising the utilisation of resources.

With Airport CDM more accurate take-off information is provided to the ATFM (Air Traffic Flow Management). As more airports implement Airport CDM, an airport network will be created and will be able to utilise available slots more efficiently and reduce the current buffer capacity.

The improved decision making by the Airport CDM Partners is the result of the sharing of accurate and timely information and by adapted operational procedures, automatic processes and user friendly tools.
Conclusions

Operations Research Models and techniques are widely used in Air Transport Industry and for classical OR problems as well as new ones. So, ATI is a rich source for the development of new practical decision tools as well as new theoretical problems.

Today ATI needs tools from OR which:

- provide efficient solutions with reasonable computational effort
- produce robust solutions to parameter changes,
- are able to take immediate advantage of new information,
- are able to integrate data from different sources,
- are able to react to new operational conditions,
- are able to generate data to connex sectors of Air Transportation

Human, Economics and Environmental constraints and objectives should be tackled in accordance with Air Transport regulations.
Relevant textbooks in Air Transportation
Operations and Planning


