“Efficiency and Automation”

Towards higher levels of automation in Air Traffic Management
HALA! Summer School
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Universidad Politecnica de Madrid
Introduction:
sustainable growth and efficiency challenges

- **Sustainable growth** of aviation whilst respecting the environment.
- ANSPs and Aircraft Operators (AO) have to improve the way they operate.

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“Efficiency and Automation in ATM”
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CHALLENGE

Effort and courage are not enough without purpose and direction

Diagram showing the relationship between Safety, Economy, Environment, and Security, with factors such as political and socio-economic expectations, airspace user needs and requirements, and service provider perspective/ATM contribution.
Introduction:
sustainable growth and efficiency

**SUSTAINABLE GROWTH**

balance between safety, economic, environmental and social constraints

**FLIGHT EFFICIENCY**

measures the difference between actual and optimum aircraft trajectories.

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**Lets talk about efficiency** ……. or effectiveness, or efficacy, or effectivity…?

- **EFFICIENCY**
  - doing things in the most economical way
    - (good input to output ratio)

- **EFFICACY**
  - getting things done
    - (meeting targets)

- **EFECTIVENESS**
  - doing "right" things,
    - i.e. setting right targets
    - to achieve an overall goal (the effect)
**What is difference between efficiency and effectiveness?**

<table>
<thead>
<tr>
<th><strong>EFFICIENCY</strong></th>
<th><strong>EFFECTIVENESS (effectivity)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- is a productivity metric!</td>
<td>- is a quality metric!</td>
</tr>
<tr>
<td>- is all about saving time, money, energy, material or effort.</td>
<td>- is all about getting the job done and getting the job done expeditiously.</td>
</tr>
<tr>
<td>- is a measure of speed and cost.</td>
<td>- is a measure of quality.</td>
</tr>
</tbody>
</table>

Efficiency is about doing the things right and effectiveness is about doing the right things

"Getting someone in here right away is more important than getting the right person later."

"Hiring the right person is more important than hiring someone right away."

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… a few examples to check…

... a company that has captured a 75% market share is very ........ \textit{EFFECTIVE}

... if two companies each had only a 0.1% rejection rate off the assembly line, they would be equally ........ \textit{EFFECTIVE}

...if the first company invested half as much as the second company in quality control, the first company is twice as ...... \textit{EFFICIENT} as the second company
• …… when talking about sustainability in air transport which one should we use?

– QUALITY APPROACH ? - Effectiveness
– PRODUCTIVITY APPROACH?- Efficiency

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**What Google says**

<table>
<thead>
<tr>
<th>Category</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air traffic control EFFECTIVENES</td>
<td>6 results</td>
</tr>
<tr>
<td>Air Transport EFFECTIVENES</td>
<td>4 results</td>
</tr>
<tr>
<td>Flight EFFECTIVENES</td>
<td>1,050 results</td>
</tr>
</tbody>
</table>

WHAT A SURPRISE!
Can automation effectively improve efficiency?
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Automation isn’t always the answer.

“Just because something is faster and easier to do doesn’t mean that it’s better”
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To improve efficiency though automation …

• Knowing the business
  – Where inefficiencies come from?

• Focusing the efforts
  – What are the highest inefficiencies?
Focusing the efforts

The Pareto Principle of Results

The “Trivial Many”
80% of the time expended

The “Vital Few”
20% of time

20% of results

80% of results

80% of the effects come from 20% of the causes
The point is focus the effort on the 20% that makes a difference, instead of the 80% that doesn’t add much.
Flight efficiency is a generic term that can refer to different concepts and definitions. Each actor involved in air transportation activities has its own perception of flight efficiency, but none of them, except may be Air Navigation Service Providers (ANSPs), do consider flight efficiency with a global viewpoint.

- The airline’s viewpoint
- The ATM viewpoint
- The airport’s viewpoint
- The passenger’s viewpoint
AO’s priority minimize direct operating cost

The total cost related to flight efficiency (cost of ATFM delays not included) breaks down to about **one third fuel costs** and **two third cost of time** (Aircraft utilization, maintenance and staff cost)

<table>
<thead>
<tr>
<th>Cost in Million Euro</th>
<th>Time</th>
<th>Fuel</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal flight efficiency</td>
<td>1550</td>
<td>850</td>
<td>2400</td>
</tr>
<tr>
<td>Vertical Flight efficiency</td>
<td>~0</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>TMA transit (airborne delays)</td>
<td>700-1700</td>
<td>500-1400</td>
<td>1200-3100</td>
</tr>
<tr>
<td>Taxi delays</td>
<td>350-1000</td>
<td>60-200</td>
<td>400-1200</td>
</tr>
<tr>
<td>Total flight efficiency</td>
<td>2600-4300</td>
<td>1600-2500</td>
<td>4000-7000</td>
</tr>
</tbody>
</table>

Considering a Delay Cost to an airline (1) AFTM en-route was estimated to be 950-1900 Million Euros.

(1) Evaluating the True Cost to Airlines of One Minute of Airborne or Ground Delay, University of Westminster, May 2004.
...the Airlines' view point

- For airlines, flight efficiency could be summarized by a minimization of total operating costs.

  - of wind,
  - speed,
  - altitude,
  - aircraft weight,
  - vertical profiles.

  - distance,
  - speed,
  - ATFM constraints, and
  - value of operating costs varying with flight time.

Airlines operating cost drivers

COST INDEX = ratio between the airline value for time and price of fuel.
Airlines' view point: Optimum Flight Planning

• One of the fundamental requirements for achieving fuel economy and the reduction of operating costs is a quality flight planning system.

• A quality flight planning system:
  – produce optimized route, cruising speed and altitude that meet the operator's economic criteria
  – based on accurate data
  – incorporates constraints of ATC and aircraft performance
  – flight profile must be realistic and achievable in operations
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Airlines' view point:
Optimum Flight Operations and Flight Planning

How optimum flight planning, aircraft routes, flight operations and aircraft performance are related to each other?
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Optimum Flight Operations and Flight Planning

1. Optimum Flight Operation
2. Optimum Flight Planning
3. Optimum Aircraft Performance
4. Optimum Route

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We should always aim to achieve Optimum Flight Operations.

We should understand that this requires Optimum Flight Planning which can only be achieved using Optimum Routes and taking Optimum Aircraft Performance into account.
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Why is the route with the shortest distance not always the optimum route?
Optimum Flight Planning:
Some Flight Planning Considerations

• Why does flying a longer route sometimes result in a shorter flight time?

• Why would an aircraft climb, only to maintain its cruising altitude for a few minutes?

Factors AOs need to take into account to achieve optimum flight operations?
Airlines’ view point: 
Optimum Route for a Flight

SPEED
DISTANCE

OPTIMUM ROUTE

COMERTIAL SCHEDULE
WIND CONDITIONS
Airlines' view point:  
Optimum Aircraft Performance

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Airlines' view point:
Optimum route - influence of speed

- True Air Speed (TAS)
- Ground Speed (GS)

\[ GS = TAS + \text{Tailwind} \]
\[ GS = TAS - \text{Headwind} \]

GS is one factor used when computing the flight time.
Airlines' view point: Optimum route - Wind Effect

- Wind and its impact can change on a seasonal, daily or hourly basis.
- Wind average component is used to estimate ground speed along the route.

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Airlines' view point: Optimum route - Distance Definition

• The Ground Distance (GD) is the sum of all the Loxodromic segments measured between way points and expressed in NM.

• GD is another factor used when computing flight time
Airlines' view point: Optimum route - EEFT

- **Estimated Elapsed Flight Time (EET)** is the estimated time needed to fly at the intended cruising speed between two points along a route.

- This calculation takes forecast wind conditions into account.

\[
EET = \frac{\text{GROUND SPEED}}{\text{GROUND DISTANCE}}
\]

- EET is important as it specifies how long the aircraft engine will be running and therefore how much fuel will be consumed.

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“Efficiency and Automation in ATM” 31-53
How is EET related to optimum flight operations?

EET is important as it specifies how long the aircraft engine will be running and therefore how much fuel will be consumed.

**EET** = \( \frac{GD}{GS} \)

*ROUTE WITH TAILWIND*

*ROUTE WITH HEADWIND*

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Airlines' view point:
Aircraft Performance and Fuel Consumption

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Airlines' view point: Aerodynamic Performance – Drag

\[ \text{total drag} = \text{induced} + \text{parasitic} \]

Which will be the best speeds to fly for optimum fuel consumption?
Aerodynamic Performance: Maximum Endurance Speed and Maximum Range Speed

The goal is Optimum Fuel Consumption

**Situation:**
the longest time in the air is required e.g. holding

**Maximum Endurance Speed:**
(absolute minimum drag)

**Situation:**
the greatest distance must be flown with the fuel available e.g. long distance flights

**Maximum Range Speed:**
(best fuel vs. distance ratio)
Airlines' view point: Trust and Engine Performance

- TSFC will be minimum if the engine is operated at its **design speed**.
- The design speed produces the maximum thrust for the minimum fuel flow.
- For a given thrust, there is only one **optimum altitude** that will allow the engine to operate at its design speed.
- Aircraft Operators plan flights in a way that ensures TSFC will be at a minimum during the cruise.
Airlines' view point: Cruise Performance

- In terms of saving fuel, the cruise phase of the flight is the most important. For example, during long haul flights, significant amounts of fuel can be saved by proper cruise management.
- The two variables that most influence fuel consumption are **cruise speed** and **cruise altitude**.

For a typical two engine widebody aircraft on a 3000NM trip, with 30000 kilos payload, the table below gives you an example of costs (EET/FUEL/CO₂) for typical FLs and Cruising Speeds.

<table>
<thead>
<tr>
<th>M.82 CRUISING SPEED</th>
<th>INITIAL FL (FILED BY AO) FL 350</th>
<th>FINAL FL (ATC CLEARANCES) FL 270</th>
<th>EXTRA COSTS (EET/FUEL/CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EET (min)</td>
<td>395</td>
<td>385</td>
<td>-10 min</td>
</tr>
<tr>
<td>FUEL REQUIRED</td>
<td>37,5T</td>
<td>44,8T</td>
<td>+7,3T/22,9T CO₂</td>
</tr>
<tr>
<td>M. LONG RANGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EET (min)</td>
<td>405</td>
<td>450</td>
<td>+45min</td>
</tr>
<tr>
<td>FUEL REQUIRED</td>
<td>37T</td>
<td>41,5T</td>
<td>+4,5T/14,17T CO₂</td>
</tr>
</tbody>
</table>
Airlines' view point - Cruise Performance: Specific Range and fuel consumption optimization.

Optimizing fuel consumption means maximizing **Specific Range** (SR).

Specific Range = \( \frac{\text{Distance (NM)}}{\text{Fuel Consumed}} \)

The best SR is achieved when the aircraft has the lowest drag when aircraft flies at the optimum altitude.

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Airlines' view point - Cruise Performance: Cruise Altitude Optimization

- The optimum altitude for cruising is the most suitable altitude for both aerodynamic performance and engine efficiency.
- There is only one optimum altitude for a given aircraft weight.

- During cruise, as weight decreases (fuel burn), the optimum altitude increases. In order to maintain an optimum altitude the flight crew needs to climb along with the fuel burn. This is called the Step Climb Technique.

For each weight there is only one altitude where SR is maximum. This is called the Optimum Altitude.
Airlines' view point - Cruise Performance:
Cruise Speed Optimization

For the AO, the selection of cruising speed is the choice between maximum distance covered and minimum flight time for minimum fuel.

\[
\text{TOTAL COST} = \text{FUEL COST} + \text{TIME COST} + \text{FIXED COST}
\]

\[
\text{COST INDEX} = \text{COST OF TIME} / \text{COST OF FUEL}
\]

The Cost Index for each flight on each route depends on the aircraft type, the predicted payload and the constraints of that route.

- D.O.C. = Direct Operational Cost (The Sum of all costs)
- ECON = Economical speed
- M_{MR} = Mach number for Max Range
- M_{LR} = Mach number for Long Range
- M_{MO} = Mach number for maximum operational speed
The ATM view point

There is no a global unique metric for determining ANSP’s flight efficiency.

• Upstream ATFM arrival delays (at gate)
• Additional time within the ASMA (Airborne)
• Pre-departure delays (at gate)
• Additional time in the taxi-out phase (ground)

En-route Flight Efficiency
• tactical control maneuvers
• network Design
• air traffic flow management

ATFM Delays

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The ATM view point: En-route flight efficiency

- The horizontal en-route flight efficiency indicator takes a single flight perspective.

- **En-route extension** is defined as the difference between the length of the actual trajectory (A) and the Great Circle Distance (G) between the departure and arrival terminal areas (radius of 30 NM around airports).
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The ATM viewpoint: Components affecting en-route flight efficiency

- **En-route design component** relates the shortest available route (S) to the direct course (D)

- **Route utilisation** relates the Filed Route (F) to the shortest available route (S)

- **ATC routing** relates the actual flown routes (A) to the routes filed by the airspace users (F)

Strategic design and use of airspace are the main origins of route inefficiencies.
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The ATM view point: En route design

- concept of most constraining points:
  - 2000 city pairs or 150 more constraining point

50% of the flight inefficiencies are generated by 2100 origin-destination

50% of the flight inefficiencies are generated by 150 points
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The ATM view point: Route utilization

Filed flight plan compared to shortest route filed

Airspace structure
En-route congestion
Route charge differentials

on shortest route 35%
longer route 43%
only one route used 22%

higher route charge 12%
same route charge 24%
lower route charge 7%

50% 45% 40% 35% 30% 25% 20% 15% 10% 5% 0% 5%

Additional distance compared to the shortest route
The ATM viewpoint: ATC routing

- ATC routing concerns ATC providing aircraft with direct tracks, when traffic and airspace availability permits, in the tactical phase.

- It relates the actual flown routes (A) to the routes filed by the airspace users (F).

- In 2010 Direct ATC routings are estimated to have reduced the flight distance by 0.7%, on average. The fewer number of direct routings is most likely related to the complex capacity situation in 2010.

- ATC shortcuts given on a tactical basis are usually associated with the flexible use of shared airspace.
The ATM view point: ATFM delays

Overall assessment of ATFM performance:
- ATFM slot adherence;
- ATFM over-deliveries; and,
- Avoidable ATFM regulations.

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Estimated costs of ANS-related inefficiencies in the horizontal flight profile.

Estimated costs of ATFM delay [>15 minutes]

<table>
<thead>
<tr>
<th>Year</th>
<th>Total ATFM delays (min.)</th>
<th>ATFM Delays &gt; 15 minutes</th>
<th>Estimated cost of ATFM delays (€2009 Prices)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>En-route</td>
<td>Airport</td>
</tr>
<tr>
<td>2004</td>
<td>14.9 M</td>
<td>5.2 M</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>17.6 M</td>
<td>6.3 M</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>18.4 M</td>
<td>7.7 M</td>
<td></td>
</tr>
</tbody>
</table>

Breakdown of estimated total economic costs of en route ATM in 2010.

The cost of en-route ANS provision account for the main share (63.8%) followed by costs of en-route extension (23.2%) and ATFM delays (13%).
Final Summary

Flight efficiency concept and definitions:
• The airline’s viewpoint
• The ATM viewpoint
• The airport’s viewpoint
• The passenger’s viewpoint

Operational Efficiency trade-offs
– When there is an en route delay, AOs will make a judgement based on the cost difference between a delay and alternative solutions (re-route proposals, scenarios, FL capping).

• Factors AOs take into account to achieve optimum flight operations

\[
\text{TOTAL COST} = \text{FUEL COST} + \text{TIME COST} + \text{FIXED COST}
\]

\[
\text{COST INDEX} = \frac{\text{COST OF TIME}}{\text{COST OF FUEL}}
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