Vista (SESAR 2020 Exploratory Research project)
A multi-layer model for long-term KPI alignment forecasts

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SESAR Innovation Days
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University of Westminster
Goals and objectives

Vista aims to study the main forces (‘factors’) that will shape the future of ATM in Europe at the 2035 and 2050 horizons

More specifically:

- trade-off between, and impacts of, primary regulatory and business (market) forces;
- trade-offs within any given period;
- trade-offs between periods;
- whether alignment may be expected to improve or deteriorate as we move closer to Flightpath 2050’s timeframe

Focus on five stakeholders: airlines, ANSPs, airports, passengers, and environment.
Scenario definition
Scenario definition in Vista

Vista model is a ‘what-if’ simulator

• *What happens if I do something in the system?*

And **not:**

• *What will happen in 2035 or 2050?*

**=> Scenario definition.** Aim is **not** to compute the likelihood of a given scenario.

**=> Factors** entering scenario subdivided into two main categories:

• **Business factors:** cost of commodities, services and technologies, volume of traffic, etc. => demand and supply

• **Regulatory factors:** from EC or other bodies, e.g. ICAO, => ‘rules of the game’
## Scenario definition in Vista

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Short description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current</strong></td>
<td>‘Current’ situation (SEP 2014)</td>
</tr>
<tr>
<td><strong>L35 baseline</strong></td>
<td>Baseline environment in 2035 (slow economic growth and slow technological advancements)</td>
</tr>
<tr>
<td><strong>H35 baseline</strong></td>
<td>Baseline environment in 2035 (high economic growth and high technological advancements)</td>
</tr>
<tr>
<td><strong>Non-supportive 2035</strong></td>
<td>Using L35 baseline plus a poor emphasis on environmental and passenger protection and very a high price for fuel</td>
</tr>
<tr>
<td><strong>Supportive 2035</strong></td>
<td>Using L35 baseline plus a poor emphasis on environmental and passenger protection and very a high price for fuel</td>
</tr>
<tr>
<td>L50, H50, Non-supportive 2050, Supportive 2050</td>
<td>As per above, for 2050</td>
</tr>
</tbody>
</table>

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## Scenario definition in Vista

### Foreground factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEO1 – Fuel prices</td>
<td>HHH – 4 €/kg</td>
</tr>
<tr>
<td></td>
<td>HH – 2 €/kg</td>
</tr>
<tr>
<td></td>
<td>H – 1 €/kg</td>
</tr>
<tr>
<td></td>
<td>M – 0.5 €/kg</td>
</tr>
<tr>
<td></td>
<td>L – 0.3 €/kg</td>
</tr>
<tr>
<td>BTS5 – 4D trajectory operations</td>
<td>L – Current</td>
</tr>
<tr>
<td></td>
<td>M – Moderate improvement of capacity en-route and airport</td>
</tr>
<tr>
<td></td>
<td>H – High improvement of capacity</td>
</tr>
<tr>
<td>BTO4 – Passenger management tools</td>
<td>L – Current rule of thumb operations</td>
</tr>
<tr>
<td></td>
<td>M – Passenger reaccommodation improved with wait-for-passenger rules</td>
</tr>
<tr>
<td></td>
<td>H – Passenger reaccommodated to any suitable flight, advanced wait-for-passenger rules</td>
</tr>
<tr>
<td>ROR1 – Passenger provision schemes</td>
<td>L – Current R261</td>
</tr>
<tr>
<td></td>
<td>M – Enhanced R261 and duty of care</td>
</tr>
<tr>
<td></td>
<td>H – Enhanced R621 and duty of care with automatic compensation</td>
</tr>
<tr>
<td>ROR3 – Emission schemes</td>
<td>D – Current, low price only C0, charged</td>
</tr>
<tr>
<td></td>
<td>CO2_H – High price only C0, charged</td>
</tr>
<tr>
<td></td>
<td>CO2_HH – Very high price only C0, charged</td>
</tr>
<tr>
<td></td>
<td>CO2_NOx_H – High price NOx also charged</td>
</tr>
<tr>
<td></td>
<td>CO2_NoX_HH – Very high price NOx, also charged</td>
</tr>
</tbody>
</table>

Grouped into **supportive** and **non-supportive** cases
Vista Model
Objectives of the model

- Vista model:
  - Simulates a typical day of traffic in Europe to the level of individual passengers
  - Changes the operational environment and see their impact on several stakeholders and at several levels
- Vista model takes a holistic approach:
  - Because the behaviour of the system is not a simple sum of the individual behaviours.
  - Because the heterogeneity of behaviours among actors shapes the system.
Airlines: choose flights, react to delay, etc.

Airports: deliver departure and arrival capacity, create congestion, etc.

ANSPs: deliver ATC capacity, create regulations etc.

Passengers: choose best itineraries based on fares and other parameters, make their trips with possibility of disruption, etc.

Environment: is passively impacted by NO\textsubscript{x} and CO\textsubscript{2}
Economic model: take into account macro-economic factors to forecast the main changes of flows in Europe.

Output:
- Flows in Europe,
- Market share of different airlines
- Capacities of ANSPs and Airports
- Prices of itineraries.
Model description

Deterministic agent-based model

In a nutshell:

• Step-by-step multi-agent model

• Individual agents are currently:
  • 823 Individual airports,
  • 326 Individual airlines, part of alliances (or not), with 15 209 OD pairs,
  • 31 430 Passenger agents, aggregated at an OD level per airline,
  • 88 individual ANSPs (but only the ECAC ones are active).

• Agents compete with peers, try to predict different values (delays, future demand, prices) and act accordingly
ABM flow

- Airlines choose their supply, based on predicted costs (maint., crew, fuel, emissions (CO₂, NOₓ), CRCO charges, delay, uncertainty) and predicted price of tickets,
- Passengers choose between different itineraries, based on prices, frequencies, and their income,
- Supply and demand are compared, prices evolve,
- Agents compute profits and form expectations,
- ANSPs choose their capacity based on their target delay (but can't go further than a technology-fixed max. capacity) and predicted traffic,
- ANSPs set their unit rate to have zero profit.
Pre-tactical layer

• From strategic high-level to tactical executable detail
Pre-tactical layer – flight plan generation

| Fid | From | To  | SOBT | SIBT | Capacity | GCD  | Ac type | ...
|-----|------|-----|------|------|----------|------|---------|------
| $F_{AD1}$ | A    | D   | 9:00 | 10:30| 120      | 1234 | A320    |      
| $F_{AD2}$ | A    | D   | 10:45| 12:20| 240      | 954  | A320    |      
| $F_{AD3}$ | A    | D   | 10:50| 12:20| 120      | 2521 | B737    |      
| $F_{CD1}$ | C    | D   | 8:30 | 12:00| 70       | 3213 | B737    |      
| ...      |      |     |      |       |          |      |         |      |

Schedules

<table>
<thead>
<tr>
<th>Fid</th>
<th>Flight plan type</th>
<th>Climb dist</th>
<th>Climb time</th>
<th>Cruise dist</th>
<th>Cruise time</th>
<th>Cruise speed</th>
<th>Cruise avg FL</th>
<th>Cruise avg weight</th>
<th>Cruise avg wind</th>
<th>Descent dist</th>
<th>Descent time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{AD1}$</td>
<td>0</td>
<td>208</td>
<td>00:29</td>
<td>504</td>
<td>1:07</td>
<td>445N (0.77M)</td>
<td>380</td>
<td>66500</td>
<td>34</td>
<td>201</td>
<td>00:35</td>
</tr>
<tr>
<td>$F_{AD1}$</td>
<td>1</td>
<td>213</td>
<td>00:31</td>
<td>442</td>
<td>1:00</td>
<td>450N (0.78M)</td>
<td>360</td>
<td>67000</td>
<td>-9</td>
<td>224</td>
<td>00:36</td>
</tr>
<tr>
<td>$F_{AD1}$</td>
<td>2</td>
<td>194</td>
<td>00:29</td>
<td>472</td>
<td>1:07</td>
<td>446N (0.77M)</td>
<td>380</td>
<td>66000</td>
<td>-24</td>
<td>201</td>
<td>00:35</td>
</tr>
<tr>
<td>$F_{AD1}$</td>
<td>3</td>
<td>208</td>
<td>00:29</td>
<td>466</td>
<td>1:02</td>
<td>450N (0.77M)</td>
<td>340</td>
<td>67500</td>
<td>0</td>
<td>218</td>
<td>00:36</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Flight plans
Pre-tactical layer – flight plan generation

Historical data analysis

- O-D route classification
- Flight plan information and Ground speed estimation
- Cruise wind estimation
- Performance analysis

Flight schedules

- Route generator
- Trajectory generator
- Flight plan generator

Factors affecting route length

Factors affecting aircraft performances

Trajectories options

Factors affecting flight plan costs

Flight plan options

Prioritised flight plans

- Initial up climb time cost...
- 2 x x x x...
- 1.2 x x x x...
- 4.3 x x x x...
- ...

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Tactical layer – Mercury

Flight plans
ATFM delay
Passenger itineraries

Mercury mobility model

Flight plans
ATFM delay
Passenger itineraries

Tactical delays, reaccommodations, etc
Tactical layer – Mercury

- Data-driven mesoscopic approach, stochastic modelling
- Individual passenger **door-to-door** itineraries
- Regulation 261/2004 – pax care & compensation
- Disruptions, cancelations, reaccommodations, compensation costs
- Airline decisions based on costs models or rule of thumb
- Full air traffic management model, demand/capacity balance
Vista results – overview
Strategic metrics
Strategic metrics

Operational cost per flight

Low baseline for 2035,
Low eco. dev.
Low tech. dev.

+ Low fuel price + eco-tax
+ better 4DT + pax protection

+ High fuel price
+ No eco tax
Pre-tactical metrics
Pre-tactical metrics

Low 2050
Tactical layer

[Graph showing data points for various metrics such as Arr. delay, Emission cost, Fuel cost, G2G time, Perc. flight reac. delay, Reac. delay, Tot. fuel con., with different values for Current, Baseline 2035, and Baseline 2050.]
Key results: trade-offs?

- Indicators can be aligned or go in different directions (trade-offs)
- Trade-offs between two given indicators can appear in some scenarios and disappear in others.
Conclusions

Key results:

• Main high-level driver: demand and price of fuel
• Cost of emissions has an impact only if NO\textsubscript{x} is taken into account and price of allowance is much higher
• The average size of the aircraft used by airlines is increasing
• Total emissions are expected to very substantially increase in the future
• The reduction of uncertainty in the departure time envisioned by SESAR is expected to an impact on the cost of delay to the airlines
• Buffers increase: reduction of tactical delay (but poor adaptation of agents)
• D2D time decreases
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The opinions expressed herein reflect the authors’ view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

Vista project

Thanks for listening!
Conclusions

• Fuel consumption per flight is flat over time as the (e.g. technological) benefits obtained by the system are offset by the use of longer routes with larger aircraft.

• There is an increase in the size of the buffers per flight: this may contribute to the reductions in tactical delay costs.

• An improvement in passenger door-to-door times does not necessarily imply an increase in the average emissions per flight.

• Reductions in flight arrival delay with passenger arrival delay map close to a 1:1.3 ratio.
Overview

Current
Overview

Low baseline 2035
Overview

Non-supportive 2035
Overview

Supportive 2035
Pre-tactical metrics

Current
Metrics

- **ANSPs**: *capacity*, *delay*, expenses, maximum capacity, *revenues*, traffic, *unit rate*, spare capacity, slack capacity.


- **Environment**: CO$_2$ emissions, NO$_x$ estimation, environmental impact in CO$_2$ equivalents.
Metrics

• **Airports**: capacity, departure delay, total costs, profit, revenues, traffic (for 24 hours), tactical arrival holding delay and departing queuing delay.

• **Airlines**: airport delay, ATFM delay, ATC cost, airport cost, cost of delay (strategic, tactical), emission costs, fuel cost, crew cost, maintenance cost, cost of uncertainty, cost of uncertainty per minute, emissions in CO$_2$ equivalents, ticket price, size of aircraft, fuel consumption, uncertainty, number of passengers, total operational cost, flight plan characteristics (length, time, profile, average wind), load factor, buffers, departing and arrival delay, gate-to-gate performance.
Project overview

Workflow:

• Build an extensive list of **business** and **regulatory** factors likely to impact the ATM system.

• **Classify the factors:** short-term/long-term, likelihood of occurrence, importance of their impact on the ATM system, etc.

• Build current and future **scenarios**.

• Building model requirements:
  • *consider as many (important) factors as possible in a flexible way*;
  • *produce level of detail required and achievable to capture relevant metrics*.

• **Iterative model development** in consultation with stakeholders.

• Trade-off analysis.
Goals and objectives

Current ATM system

- Factor x = high
- 2035 factors

- Factor x = low
- 2035 factors

ATM system 2035

Factor x high

ATM system 2035

Factor x low

2035 factors

Current system indicators

2035 factor x high system indicators

2035 factor x low system indicators

Trade-offs
Scenario definition in Vista

Filtered (consultation, workshop, site visits, etc.)

Foreground factors

Background factors
## Pe-tactical layer – Pax itinerary

### Schedules

| Fid  | From | To | SOBT | SIBT | Capacity | ...
|------|------|----|------|------|----------|------
| F_{AD1} | A    | D  | 9:00 | 10:30| 120      |      
| F_{AD2} | A    | D  | 10:45| 12:20| 240      |      
| F_{AD3} | A    | D  | 10:50| 12:20| 120      |      
| F_{CD1} | C    | D  | 8:30 | 12:00| 70       |      
| ...   |      |    |      |      |          |      

### Passenger flows

| Pax flow | Passengers | Route | ...
|----------|------------|-------|------
| PF_{AD}  | 800        | A - D |      
| PF_{BCD} | 35         | B – C – D |      
| PF_{ED}  | 1230       | E – D |      
| PF_{BCF} | 560        | B – C – F |      
| ...      |            |       |      

### Pax | Flow | Fare | Flights | ...
|-------|------|------|---------|------
| 3     | PF_{AD} | 130 | F_{AD1} |      
| 2     | PF_{AD} | 240 | F_{AD1} |      
| 1     | PF_{BCD}| 145 | F_{BC1} – F_{CD2} |      
| ...   |        |     |         |      

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*Image: SST Schedules}*
Pe-tactical layer – ATFM regulations
Pre-tactical metrics

ANSPs revenues
Pre-tactical metrics

Demand variation

Revenue variation
Strategic metrics
Pre-tactical metrics
Pre-tactical metrics
Buffer size vs flight plan distance