Objective of the model

• Vista model aims at:
  • Simulating one day of traffic in Europe to the level of individual passengers
  • Being able to change the operational environment and see their impact on several stakeholders and at several levels
  • Vista model does not aim at predicting the likelihood of the changes of operational environment in the future.

Vista model is a ‘what-if’ simulator
Tactical layer - Mercury

- E.g. uncertainty, cost of delay, reaccommodation rules

Tactical Layer

- Mercury (mobility model)

- Flight plans
- ATFM delay
- Passengers itineraries

Tactical delays, reaccommodations, etc
Tactical layer - Mercury

- A framework EU-mobility performance and assessment
- Flexible to implement almost any scenario
- Focus on passengers, not flights
- Produces a wide range of metrics, not only delays
- Drawn from a wide range of sources; including airlines, airports and air navigation service providers
- Developed and tested over 7 years of research under several initiatives (SESAR, H2020)
Tactical layer - Mercury

- Data-driven mesoscopic approach, stochastic modelling
- Individual passenger DOOR-TO-DOOR itineraries
- Regulation 261/2004 Flight compensation regulation
- Disruptions, cancelations, re-accommodations, compensations costs
- Airline decisions based on costs models or rule of thumb
- Full Air Traffic Management model, demand/capacity balance
Pre-tactical layer

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

### Schedules

<table>
<thead>
<tr>
<th>Fid</th>
<th>From</th>
<th>To</th>
<th>SOBT</th>
<th>SIBT</th>
<th>Capacity</th>
<th>GCD</th>
<th>Ac type</th>
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<td>1234</td>
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<td>954</td>
<td>A320</td>
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<td>D</td>
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### Flight plans

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<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>
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<td>00:29</td>
<td>504</td>
<td>1:07</td>
<td>445N (0.77M)</td>
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<td>34</td>
<td>201</td>
<td>00:35</td>
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<td>0</td>
<td>218</td>
<td>00:36</td>
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</tbody>
</table>

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Pre-tactical layer – flight plan generation

- Flight plans need enough information to model flying time and fuel usage
- Allow model of mechanism which might impact tactical operations

![Graph showing kg fuel/km vs % speed min-max]

- AC type
- FL
- Weight
- Nominal speed
Pre-tactical layer – flight plan generation
Objective of the economic model: take into account macro-economic factors to forecast the main changes of flows in Europe.

Desired output:
- Main flows in Europe,
- Market share of different airline types
- Capacities of ANSPs and Airports
- Average prices for itineraries.
Strategic layer – economic model

Should take into account:

• **Main changes in demand:**
  • volume
  • types of passengers

• **Major business models changes:**
  • Point-to-point vs hub-based (airlines)
  • competition vs cooperation (ANSP)
  • privatization vs nationalisation (ANSP and airports)

• **Capacity restriction:**
  • Congestion at airports
  • ATCO limits

• **Major changes of prices in commodities:**
  • Fuel,
  • airport and airspace charges, etc
Model description

Deterministic agent-based model

In a nutshell:

• Step-by-step multi-agent model

• Individual agents are currently:
  • Individual airports
  • Individual airlines
  • Passenger aggregated at an OD level per airline
  • Coming soon: ANSPs

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

- **Airlines choose the capacity** to provide on each OD pair based on their supply function (including their costs, e.g. fuel, airspace charges, etc) and the predicted price of the ticket on this leg.
- **Passengers choose between different itineraries** for the OD pair based on the latest prices.
- **Supply and demand are compared**
- **Prices evolve** in each leg of each itinerary based on the discrepancy between supply and demand.
ABM flow

• All agents compute revenues and costs.

• Airlines estimate the future price based on their latest estimates and the current price.

• After a certain number of iterations, airports assess their expected profits based on traffic forecast and choose to expand, or not, their capacity.

• (Coming soon) After a certain number of iterations, ANSPs can change their charges. Airlines can choose between different ANSPs to fly.
Network Based Model

- Supply: origins/destinations
- Demand: itineraries

Supply and demand?
Passenger demand

- Pax demand: given all the possibilities (itineraries) to go from i to j with associated prices, travel times, etc, how to choose one?

\[
D_k = D_k^0 (1 - \alpha \Delta p_k + \beta \Delta i_k + ...) C(p_k, \{p_l\}_{l \neq k})
\]

- Volume term
- Competition term

\[
C(p_k, \{p_l\}_{l \neq k}) = 1 - \frac{1}{s} \left( \Delta p_k - \sum_{l=1, l \neq k}^{n} \frac{\Delta p_l}{n-1} \right) + ...
\]
**Airline supply**

- **Airline supply**: profit maximizer, choosing their capacity on each branch.

\[ r = S\hat{p} - c(S) \]

\[ c(S) = c + c_o S + c_c S^\alpha \quad \alpha > 1 \]

- Overhead, constant
- Cost of capital, superlinear
- Operational cost, linear

\[ S^* = \left( \frac{\hat{p} - c_o}{c_c} \right)^{\frac{1}{\alpha-1}} \]
Airline supply

• Operational cost depends on a lot of parameters:

\[ c_o = \chi \Delta \delta t_o + \chi \Delta \delta t_D + c_f(d) + c_{ATC} + \ldots \]

Cost of delay
Cost of fuel
ATC charges
Market clearing and convergence

• Demand disaggregated itineraries -> airport pair
• Demand and supply are compared on each edge, price is updated:

\[ p_{t+1}^k = p_t^k \left( 1 + \lambda \left( \frac{S_k - D_k}{(S_k + D_k)/2} \right) \right) \]
Airport delay management

- Airports compute their total traffic, which produces an extra level of delay given by

\[ \delta t = \delta t_0 + \frac{T}{C} \]

- Airports try to maximise their profit by increasing (or not their capacity):

\[ r = T\hat{P} - c(C) \]

Traffic

Capacity (fitted)

Cost of capacity (linear in the model)
Simple example: LLC vs trad

- Simplified setup: four airports, two airlines LLC/trad

Simple scenario:
- Increase in demand (higher income) on 0->3
- Increase of capacity of airport 3
- Increased fuel price for everyone
Number of passengers

Income increase

Capacity increase

Price of fuel increase

Number of passengers

Simulation step

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Airport profit

- Income increase
- Capacity increase
- Price of fuel increase

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Next steps

Airlines:

• **Integrated cost function** to catch network effects (hub, etc):

\[ r(S_1, S_2) = S_1 p_1 + S_2 p_2 - c_1 S_1 - c_2 S_2 + c(S_1 + S_2)^\alpha \]

• **Opening new routes**: based on master cost function compared to cost for a similar airport pair

• **Operational cost includes ATC charges.** Airlines can choose different options.

ANSPs:

• Compute traffic in their area, **fix their unit rate** to cover their costs
Conclusions

Overall model:

- Aim at simulating what happens a typical day of if you change something in the system.
- **Macro to micro** model in different layers of increasing detail

Economic model:

- **High-level description**, dependence of main flows on macro-economic parameters.
- **Deterministic agent-based model**, featuring ANSPs, airlines, airports and passengers
- **Complex economic feed-back**, emerging phenomena coming from network-based interactions
Questions

• What are the pros and cons of having a hub-based network for airlines?

• What are the pros and cons of being part of an alliance, for small and big companies?

• How much are neighbouring ANSPs in competition for traffic?

• How much do airports lose from high speed trains due to increased competition versus how much do they gain due to increased catchment areas?