Two SESAR Exploratory Research perspectives (COCTA, Vista)

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Engage thematic challenge 4 workshop
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Coordinated Capacity Ordering and Trajectory Pricing for Better-performing ATM

COCTA

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COCTA project – formal overview

- H2020-SESAR-2015-1 call – topic **Economics and legal change in ATM**;
- Exploratory research project; TRL1
- April 2016 - September 2018

European Commission and SESAR Joint Undertaking		Project Officer **Alessandro Prister**	ATM expert **Andreas Hasselberg**
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COCTA objective

__Problem__: **substantial extra cost to users of the European airspace**, arising from:

- **divorced planning horizons** of ANSPs and AOs - > mismatch between *predictability* for ANSPs and *flexibility* for AOs - > capacity buffers…
- **inadequate capacity delivery** (vs. demand profile); supply-driven
- **an inadequate** (average-cost) **pricing** of air navigation services.

COCTA Objective: __Incentivize more cost-efficient outcomes__!

In a **re-designed ATM value-chain**, propose and evaluate
coordinated economic measures
aiming to pre-emptively
reconcile air traffic demand and capacity supply,
by acting on both sides of the inequality.

COCTA approach overview

Current situation	Proposed changes
1. The Network Manager has limited influence on capacity and demand.	1. **Strengthen the role** of the Network Manager**.**
2. Limited coordination between ANSPs on capacity provision combined with decentralized average cost pricing	2. **Network capacity coordination** between ANSPs and **overall trajectory pricing** to improve **efficiency**.
3. ANSPs plan their capacity provision rather early, Aircraft Operators (AOs) prefer short-term decisions.	3. NM-ANSP **capacity provision** contracts to optimize **network performance** in line with **policy goals**.
4. No incentives for AOs to deviate from their individual optimum, even if that would improve overall efficiency.	4. **Incentives** tailored to AOs' business needs/goals, aiming at **system optimum**.

COCTA institutional settings

The future Network Manager

Contracts!

Air Navigation Service Providers

Aircraft Operators

Capacity provision:
1) Long-term capacity requirement
2) Strategic capacity profile
3) Pre-tactical sector opening scheme

Capacity management

Trajectory products:
1) Standard – ST
2) Discounted – DT
3) *Premium - PT*

Demand management

Equity

Environment

Cost-efficiency

Delays

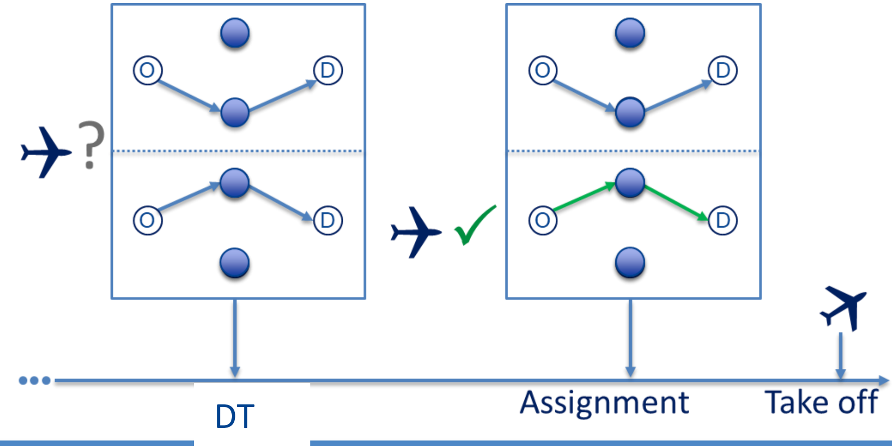
Re-routings

COCTA demand management (1/3): Airport-pair charging

Current charging scheme	Airport-pair charging
1. Airspace based: charging zones and corresponding unit rates are determined.	1. Charges are set on airport-pair basis: **any route (2D) between the two airports has the same base charge.**
2. In some cases, longer routes lead to cost reductions for AOs (airspace charges *vs* fuel cost trade-off).	2. By design, there is **no need to plan longer routes.**
3. Negative impact on the environment.	3. Shorter-route planning incentives should help **reducing emissions** and **improve predictability**.

COCTA demand management (2/3): Trajectory pricing

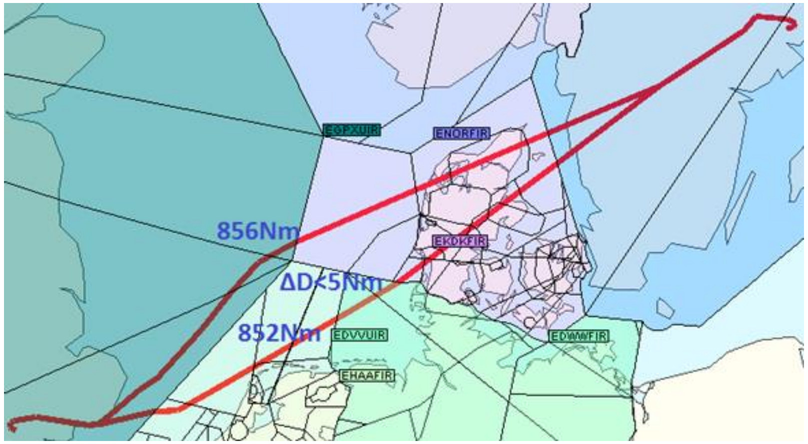
- Differentiation of charges as an instrument for incentive-based demand management (when needed)!
- Different charges for different trajectory products:
    - *Ex ante discount* (compensation) for a potential delay or re-routing (DT);
    - *Standard* trajectory product (ST).
    - *Premium* product (model testing ongoing) – AUs buying an option for last minute trajectory changes, in space or time, within agreed margins
- Incentivise utilisation of available airspace;
- Incentivise AOs to reveal their flight intentions earlier (as an option).



COCTA demand management (3/3): Trajectory products

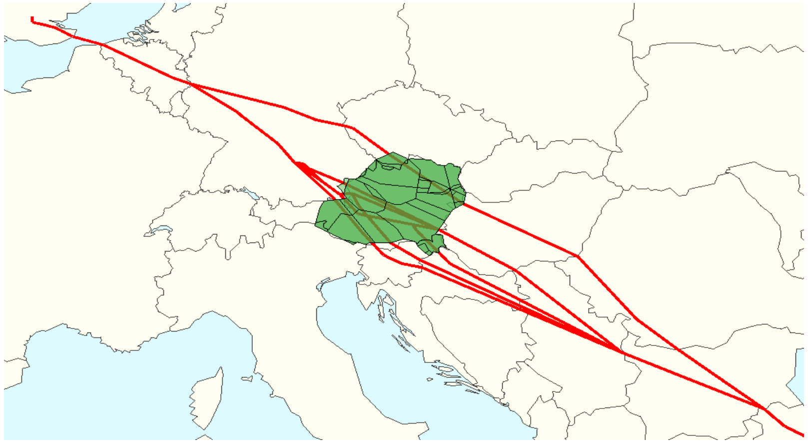
Standard (ST), example:

- Up to 5’ concerning the time of departure or
- Up to 5nm deviation from shortest path in horizontal plane or/and
- Up to 2,000ft deviation from the preferred cruise flight level.



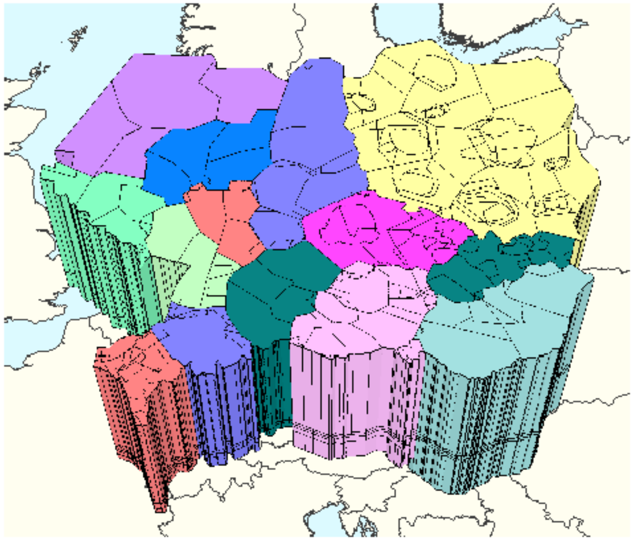
Discounted (DT), example:

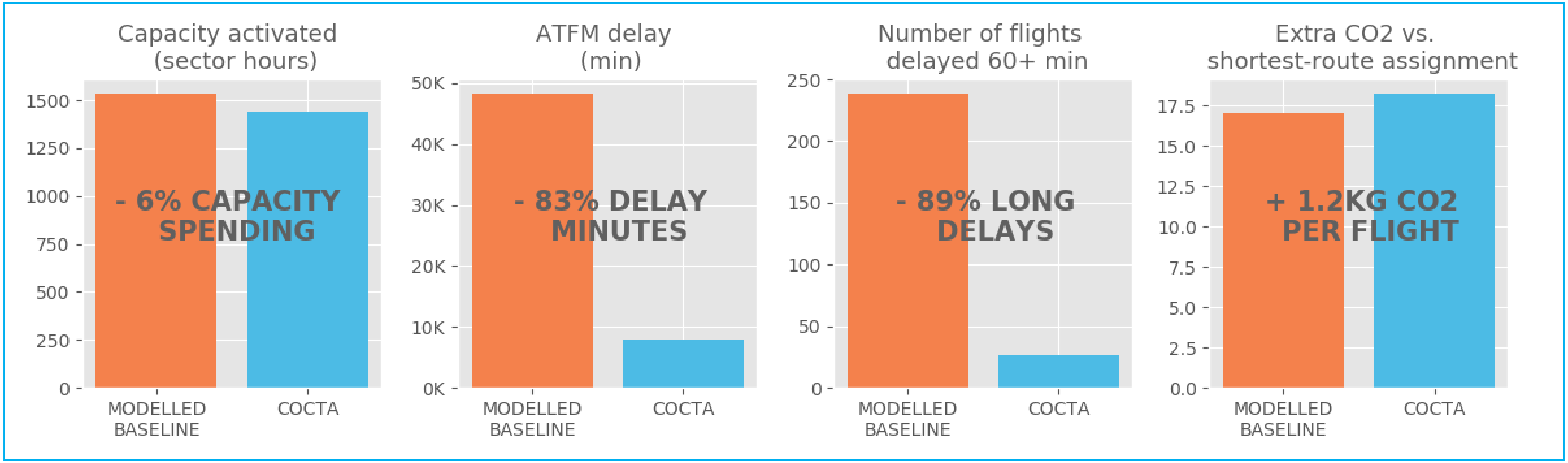
- Up to 20’ concerning the time of departure or
- Up to 20nm deviation from shortest path in horizontal plane or
- Up to 4,000ft deviation from the preferred cruise flight level.



Case study & some results

- **Eight ANSPs** in central and western Europe; 173 possible configurations enabled for en-route traffic.
- NEST/DDR data.
- Busiest day in 2016 with **11,211 flights** in the case study region.





Key modelling challenges: an overview

- **Demand**:
  - Choice behaviour?

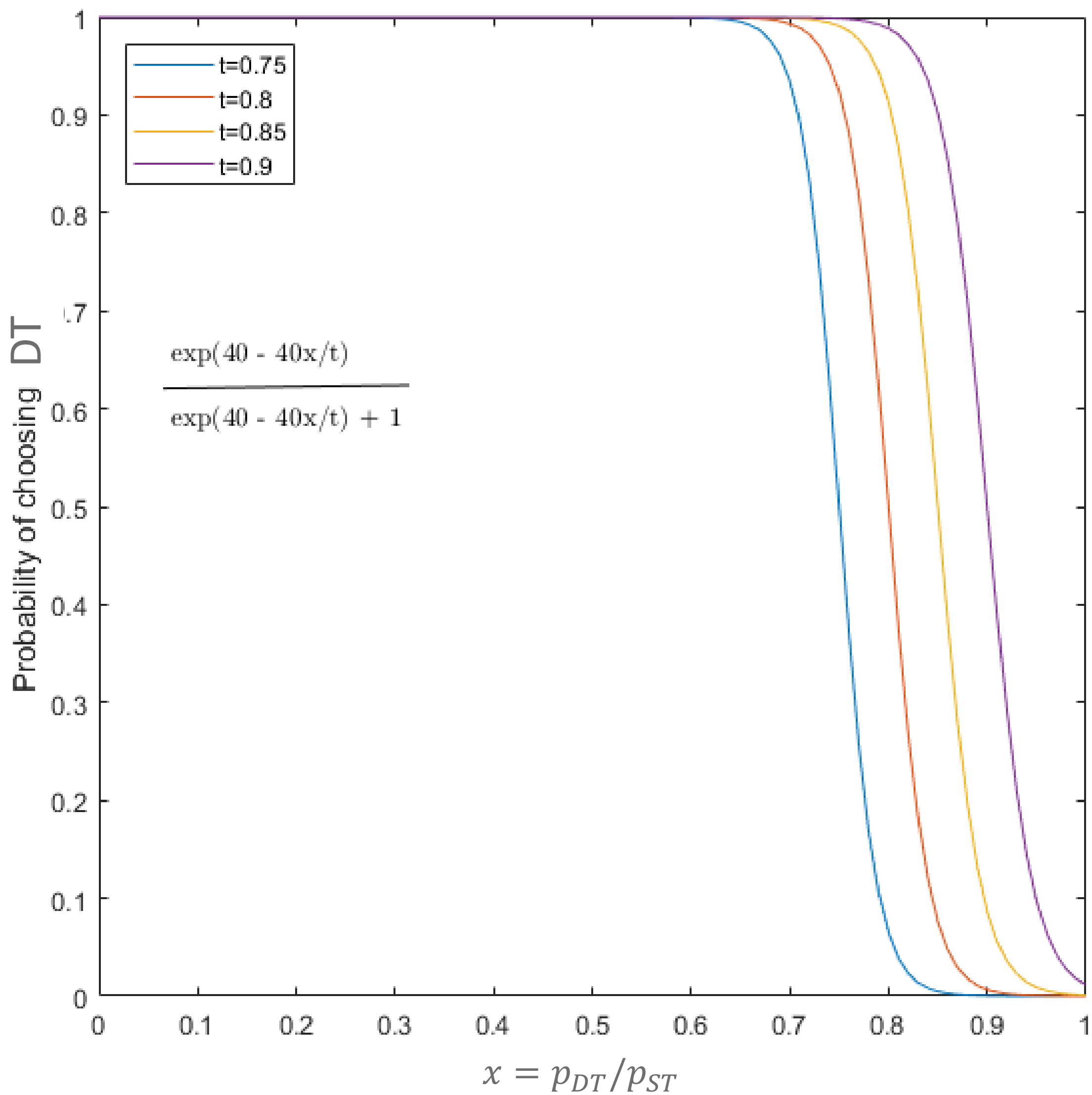
    <u>Assumption</u>: rational airlines, minimising their costs.
  - Uncertain flights?
- **Supply**: Modelling capacity?
- **Decision problem:** Complexity?

Trajectory pricing decision in the model

- Standard Trajectory (ST): OD-based price pre-determined in strategic phase (based on estimated capacity provision cost)

- Discounted Trajectory (DT):
  - DT price is expressed as discount over ST
  - Choice between ST and DT only offered to flights where flexibility is expected to help reduce the system costs
  - Total discounts given are aimed to broadly correspond to estimated flexibility savings
  - Choice model incorporated in price decision

Examples of Choice Probability Functions



Challenges – choice behaviour

- Absence of relevant (purchase/transaction) data to analyse and calibrate the model, re. elasticity of airlines to trajectory charge changes
- Various influential specific aspects/circumstances, concerning e.g.:
    - Airline business model
    - Airport-pair involved (hubs, directions, ...)
    - Time of departure (e.g. first morning flight or ...)
    - Timing of the trajectory purchase decision
    - etc.

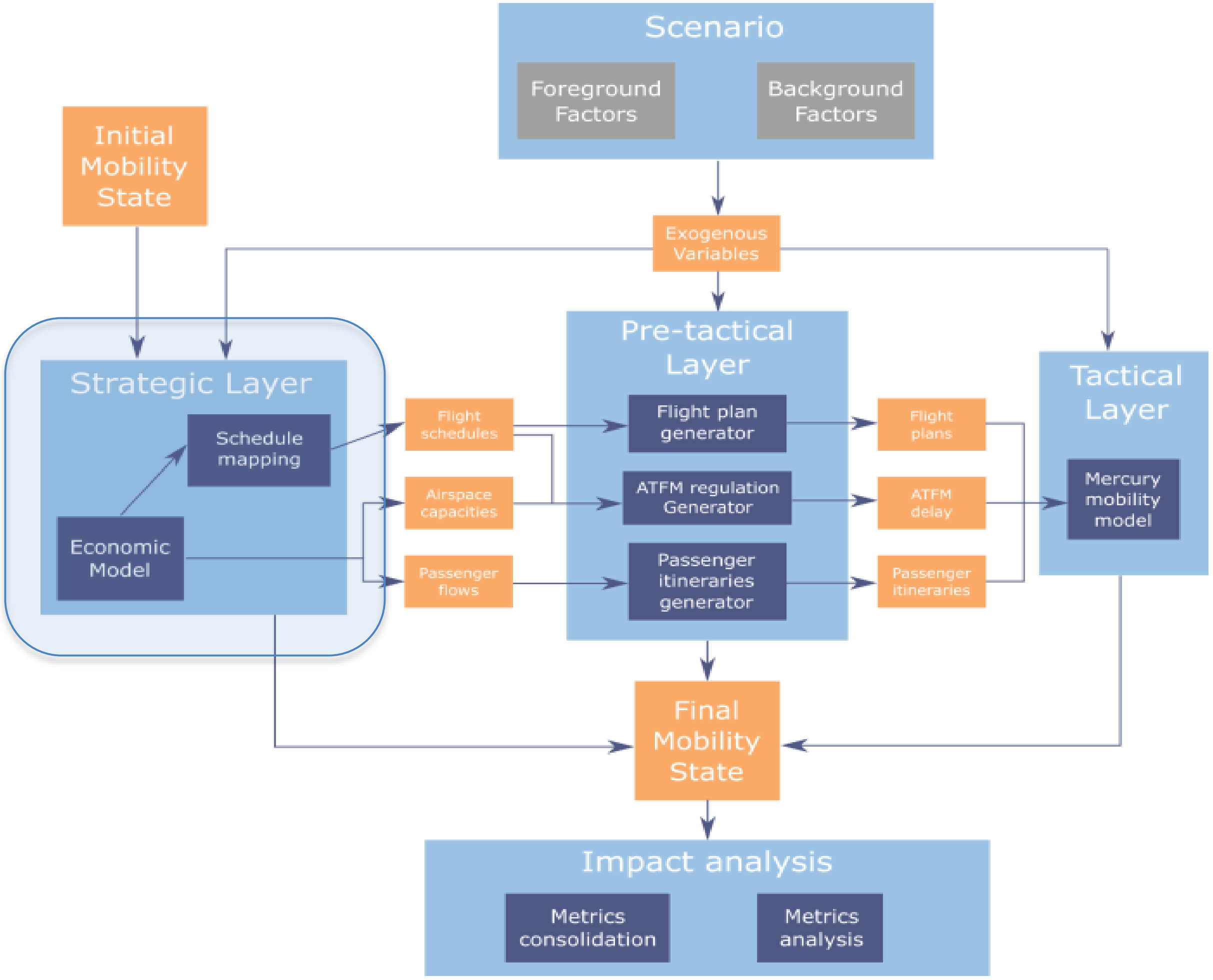
Vista

Vista – project overview

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

Focus on five stakeholders:

- airlines,
- ANSPs,
- airports,
- passengers,
- environment.



Objectives of the model

- Vista model aims at:
    - Simulating a typical 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 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.

Economic model

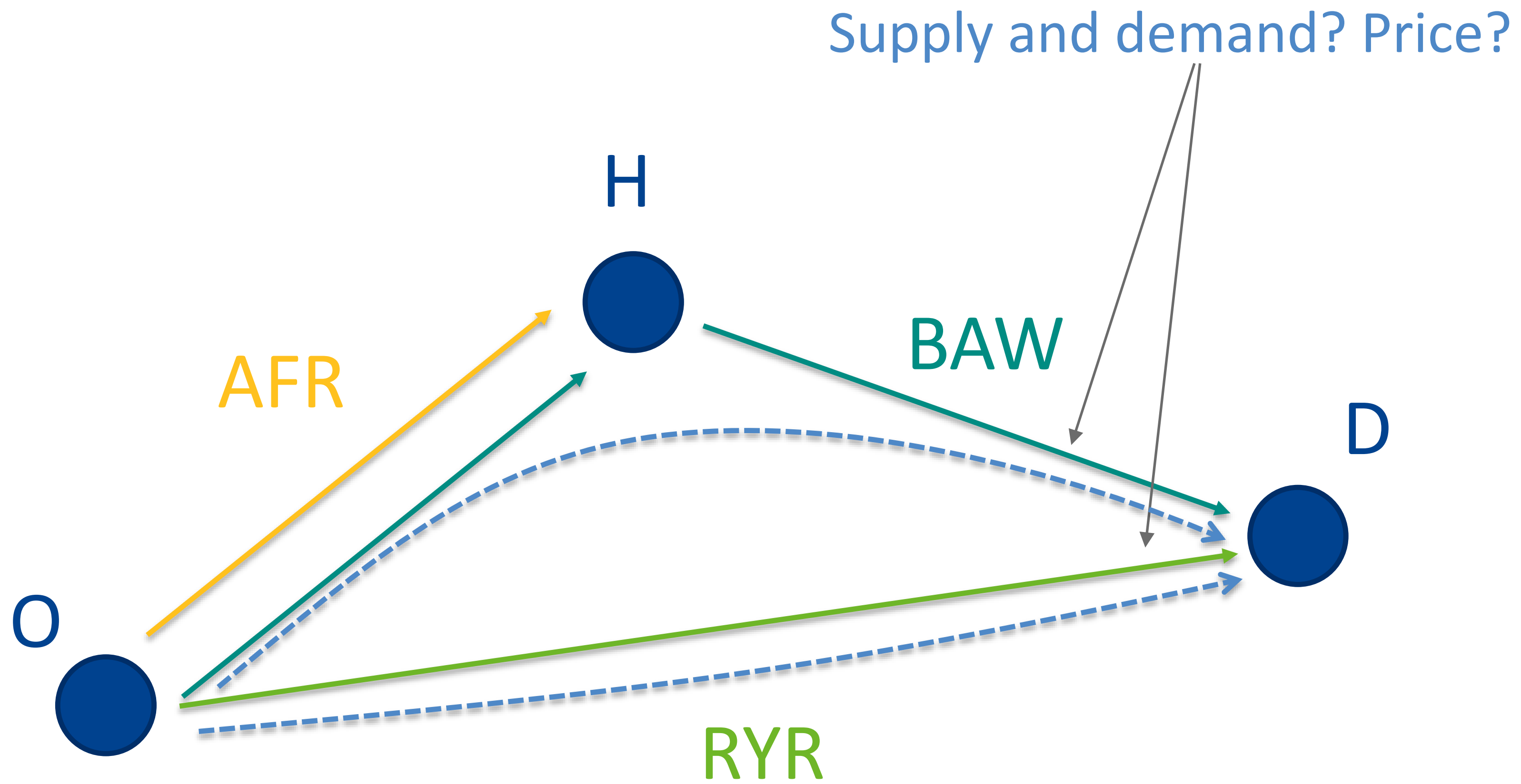
Deterministic agent-based model

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 15209 OD pairs,
    - 31430 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.

Network Based Model

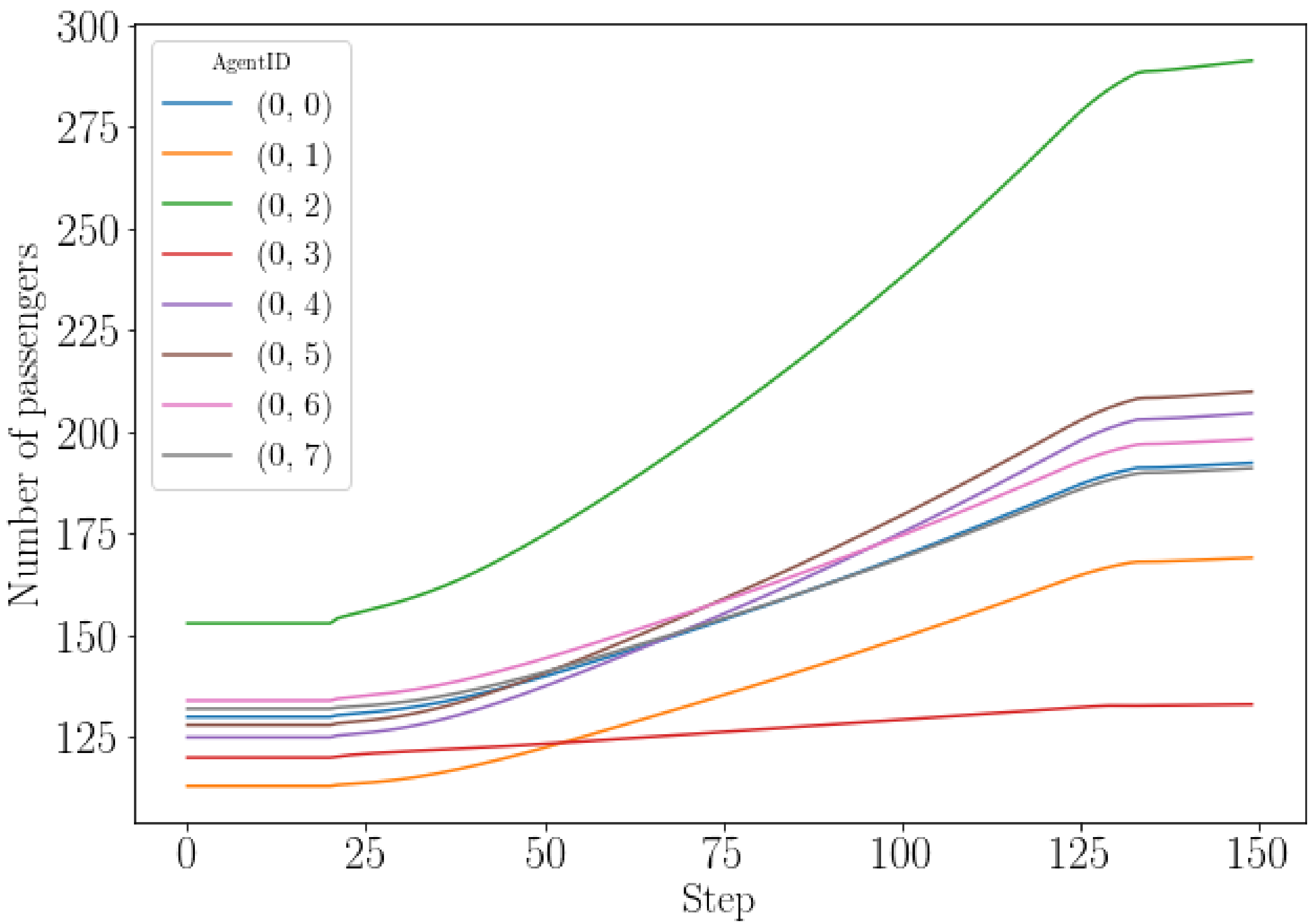
- Supply: airport pairs (edges)
- Demand: itineraries (collection of edges)



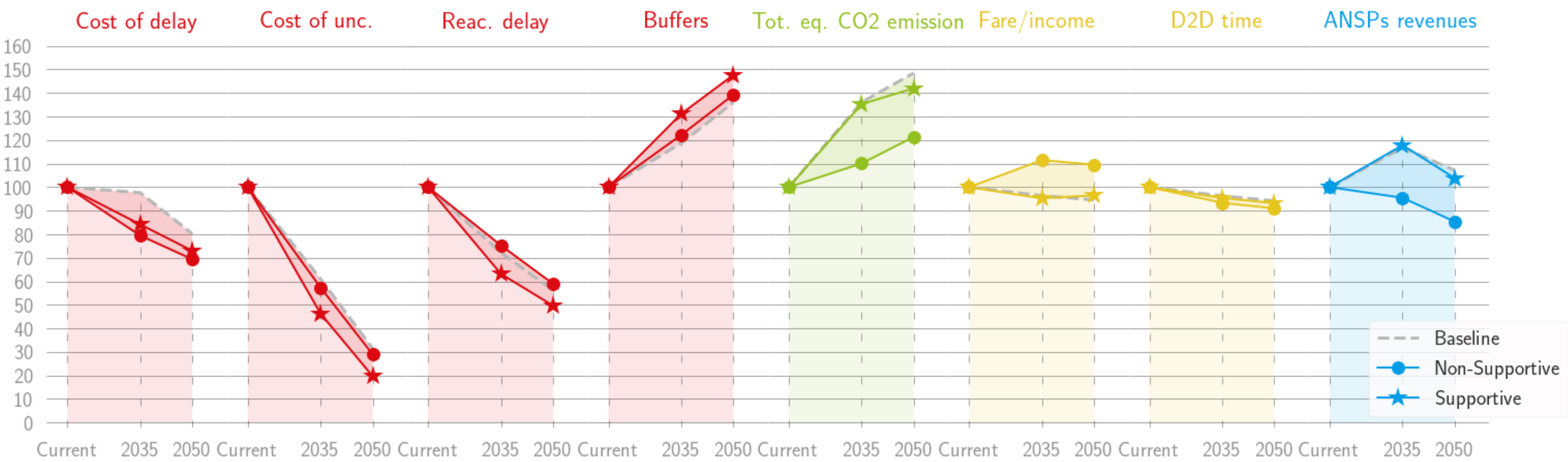
ABM flow

- Airlines choose their supply, based on predicted costs (maint., crew, fuel, emissions (CO_2, NO_x), CRCO charges, delay, uncertainty) and predicted price of tickets,
- Passengers choose between different itineraries, based on prices, frequency, and their income,
- Supply and demand are compared, prices evolve,
- Agents compute profits and form expectations,
- Air Navigation Service Providers (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.

Example of results



Example of results



ANSP decision

- ANSP tries to be profit-neutral when choosing their unit rate.
- Choice based on traffic forecast, set their expenses to cope with traffic (i.e. delay below target) and fix the unit rate to match revenues and expenses.
- **Not currently taken into account:**
  - Overestimation of costs, thus overestimation of unit rates,
  - Hysteresis: easier to stick to current operations than change them.
  - Airline 'real' behaviour, e.g.:
    - price elasticities w.r.t. en-route rates
    - 'cultural' effects
    - agent variabilities

(as flagged previously)

Airline decision

- Airlines choosing to expand/reduce their capacity on a leg.
- Choice purely based on their production function and projected price:
  - $S = \left(\frac{p-c}{(\alpha-1)c_c}\right)^{\frac{1}{\alpha-1}}$
- Taken into account: variance of airport and airspace delay to compute the expected cost (is not the cost of the average delay!).

Airline decision

- **Not currently taken into account:**
  - Hysteresis: easier to stick to current operations than change them.
  - Uncertainty of price and cost forecast, common issue.
    - Instead of expected profit, maximisation of a convex utility function:
      - variance is penalized
    - Can use self-reinforcement learning (but simulations need to be simple enough).

Airline decision

- **Not currently taken into account:**
  - Slot allocation problem: historical allocation for airport slots:
    - => Very strong path dependency
    - How to account for risk of letting a slot go?
      - In theory, cumulative $E[r] = p - c(S)$ over the years should be positive,
      - Problem: agents need to have long-term forward vision.
    - Other possibility:
      - $E[r] = p - c(S) + a$: a is an offset (asymmetric stickiness) that keeps the leg artificially open even if non profitable. Could be calibrated with long-time series if one knows roughly the kind of forecast used by the airlines (+other financial data).

Passenger decision

- Passengers choosing between options for their itinerary
- Choice based on changes in prices of tickets and relative frequencies, logistic function.
  - $p(\delta f_i, \delta p_i) = \frac{1}{\sum_j e^{(E_j - E_i)/s}}$, $E_i = \delta f_i - \delta p_i$
- **Not currently taken into account**:
  - Loss-aversion: asymmetric utility function (but how to calibrate it?)
  - Other terms potentially in E_i assumed constant: comfort, length of itinerary, etc
    - Rmk: no need to use value of time for passengers per se, travelling time constant for a given itinerary

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www.cocta-project.eu

www.vista-eu.com

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