Vista Project

Building a Holistic ATM Model for Future KPI Trade-Offs

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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.

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.

Scenario definition in Vista

Vista model is a ‘what-if’ simulator

- *What happens if I do this 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.

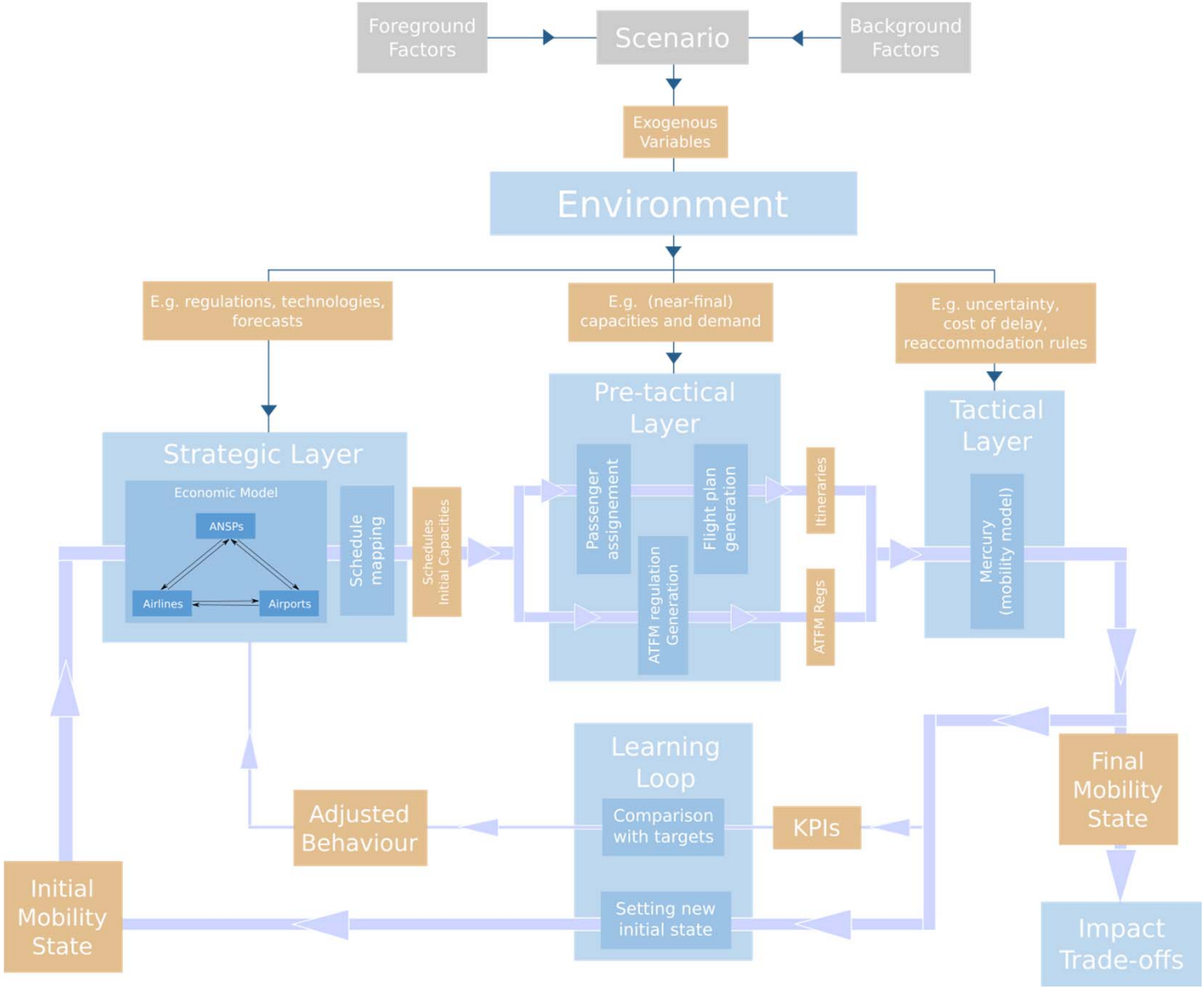
==> Factors entering scenario subdivided into two main categories:

- **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’

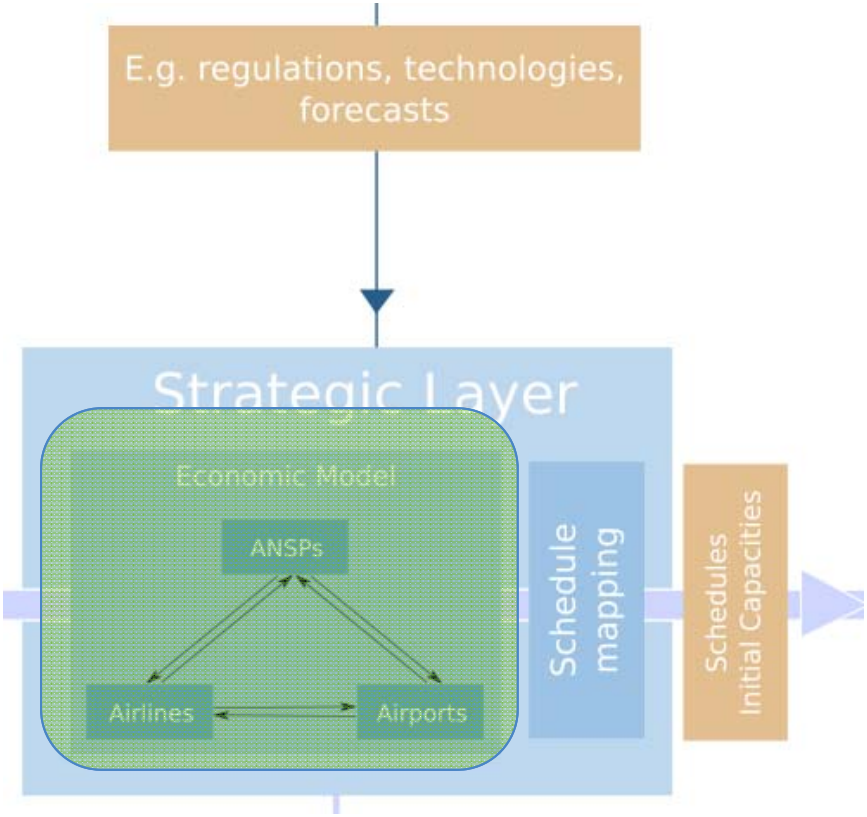
Objective of the model

- 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.

Model presentation



Strategic layer – economic model



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

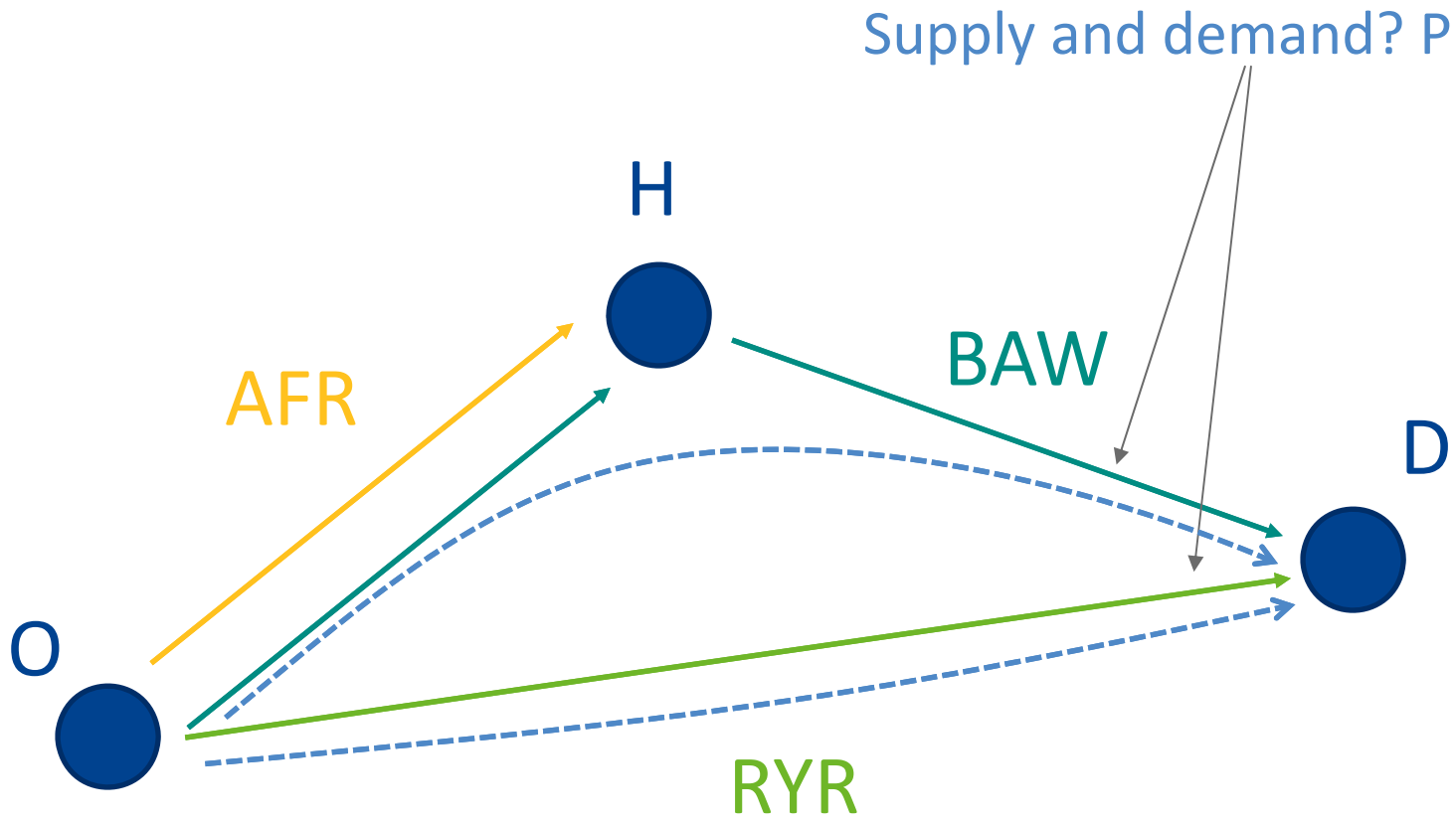
Deterministic agent-based model

In a nutshell:

- Step-by-step multi-agent model
- Individual agents are currently:
  - Individual airports
  - Individual airlines, part of alliances (or not)
  - Passenger aggregated at an OD level per airline
  - Individual ANSPs
- 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)

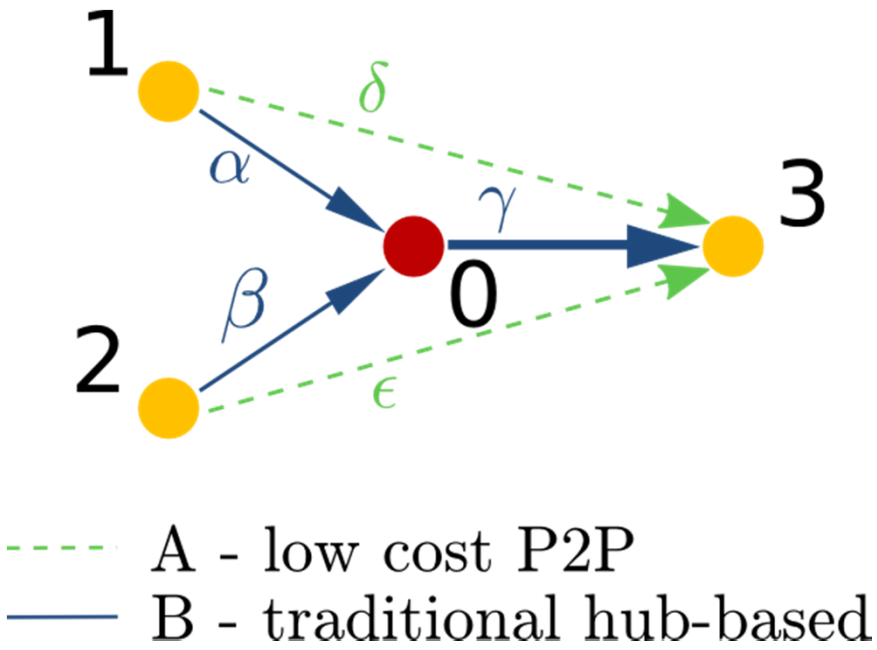


ABM flow

- Airlines choose their supply, based on cost and price of tickets,
- Passengers choose between different itineraries, based on prices,
- Supply and demand are compared, prices evolve,
- Agents compute profit and form expectations,
- Short-list of airports assess a potential capacity extension,
- ANSPs choose their capacity based on target and set their unit rate.

Simple example: LLC vs trad

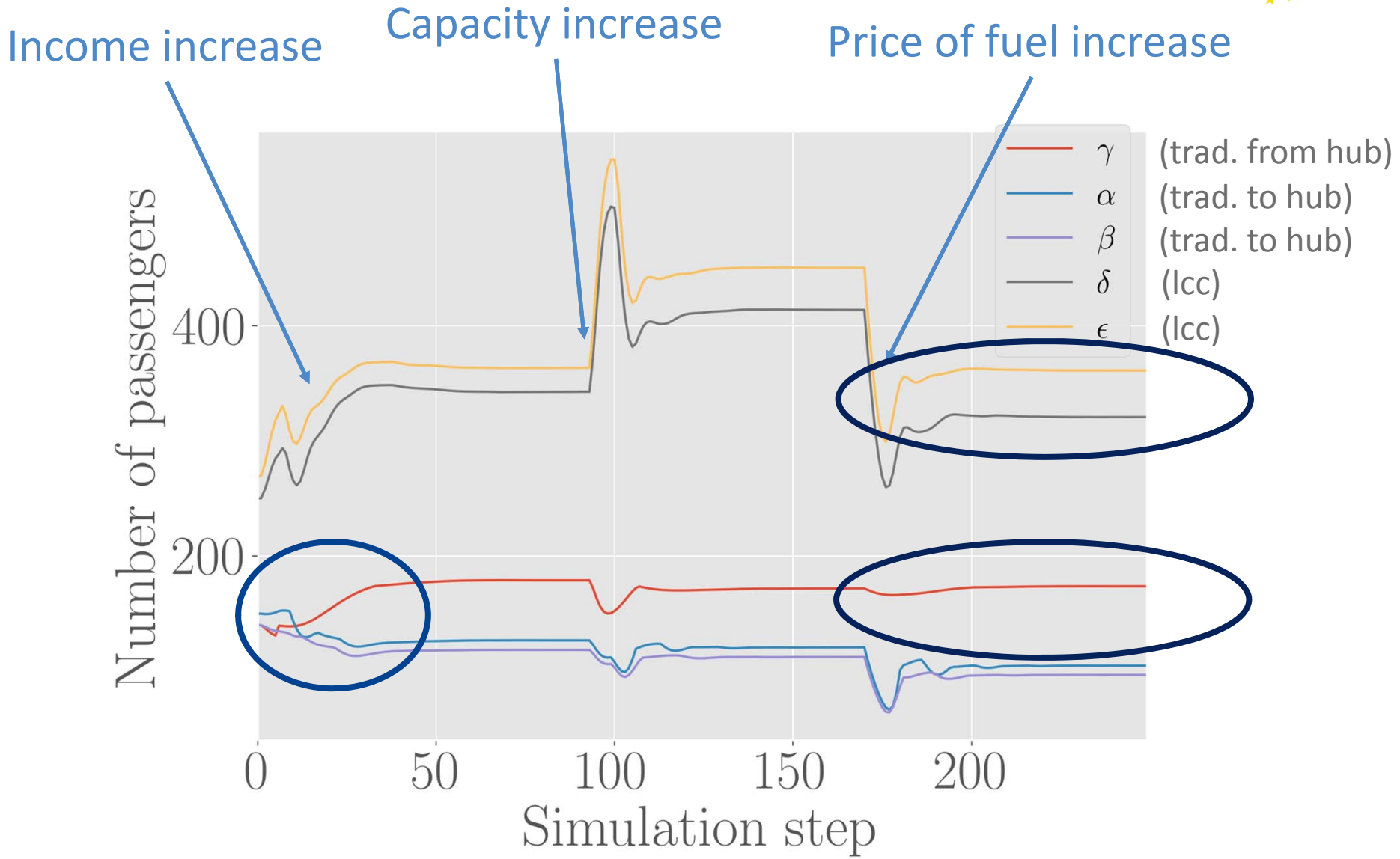
- Simplified setup: four airports, two airlines LCC/trad



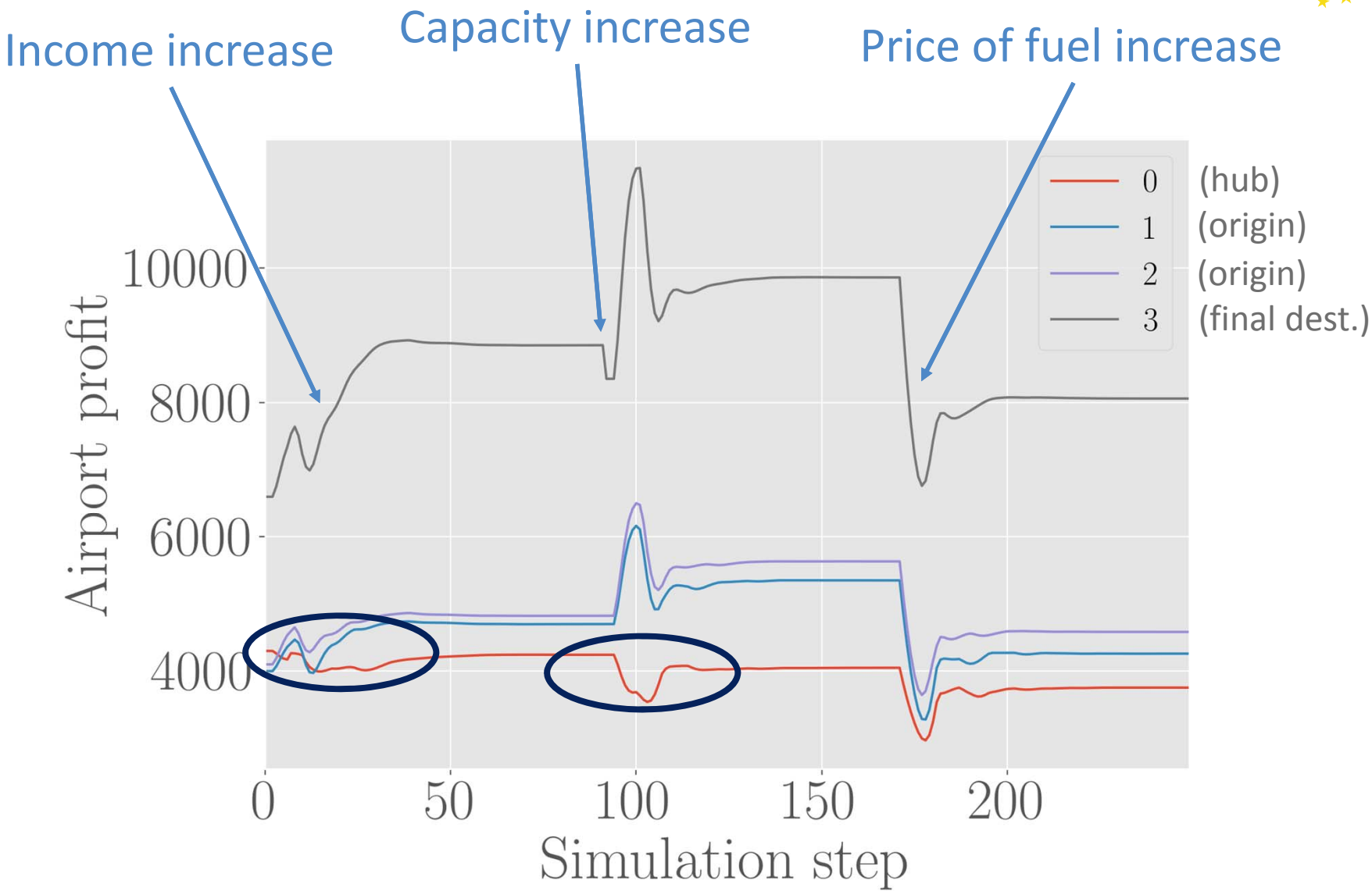
Simple scenario:

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

Number of passengers

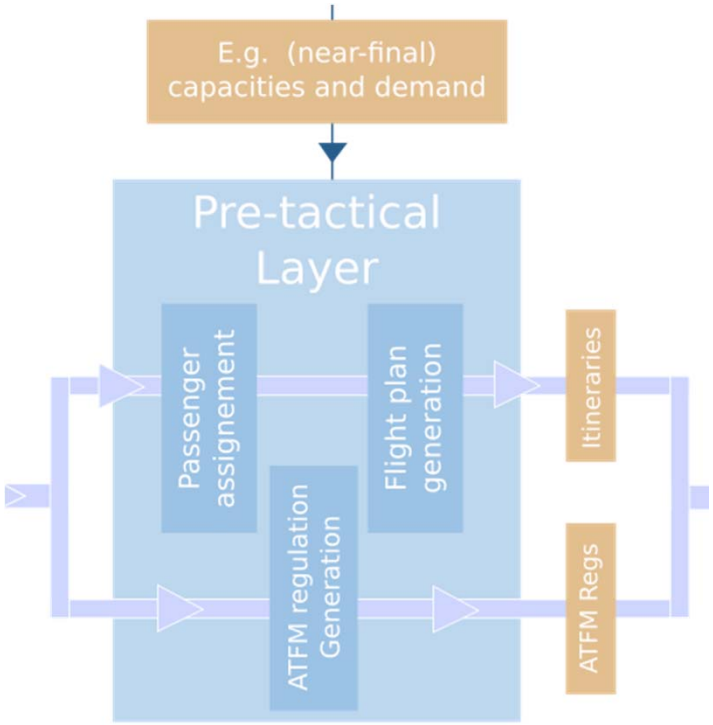


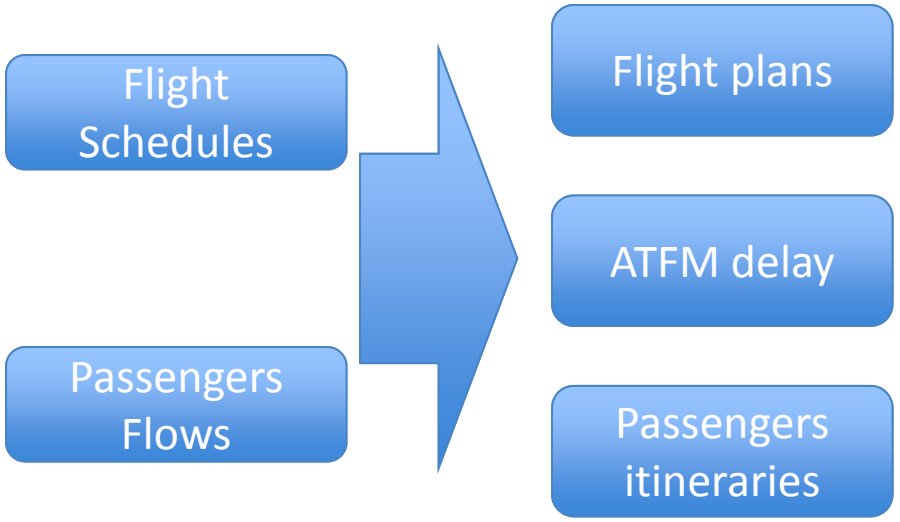
Airport profit



Pre-tactical layer

- From strategic high-level to tactical executable detail





Pre-tactical layer – flight plan generation

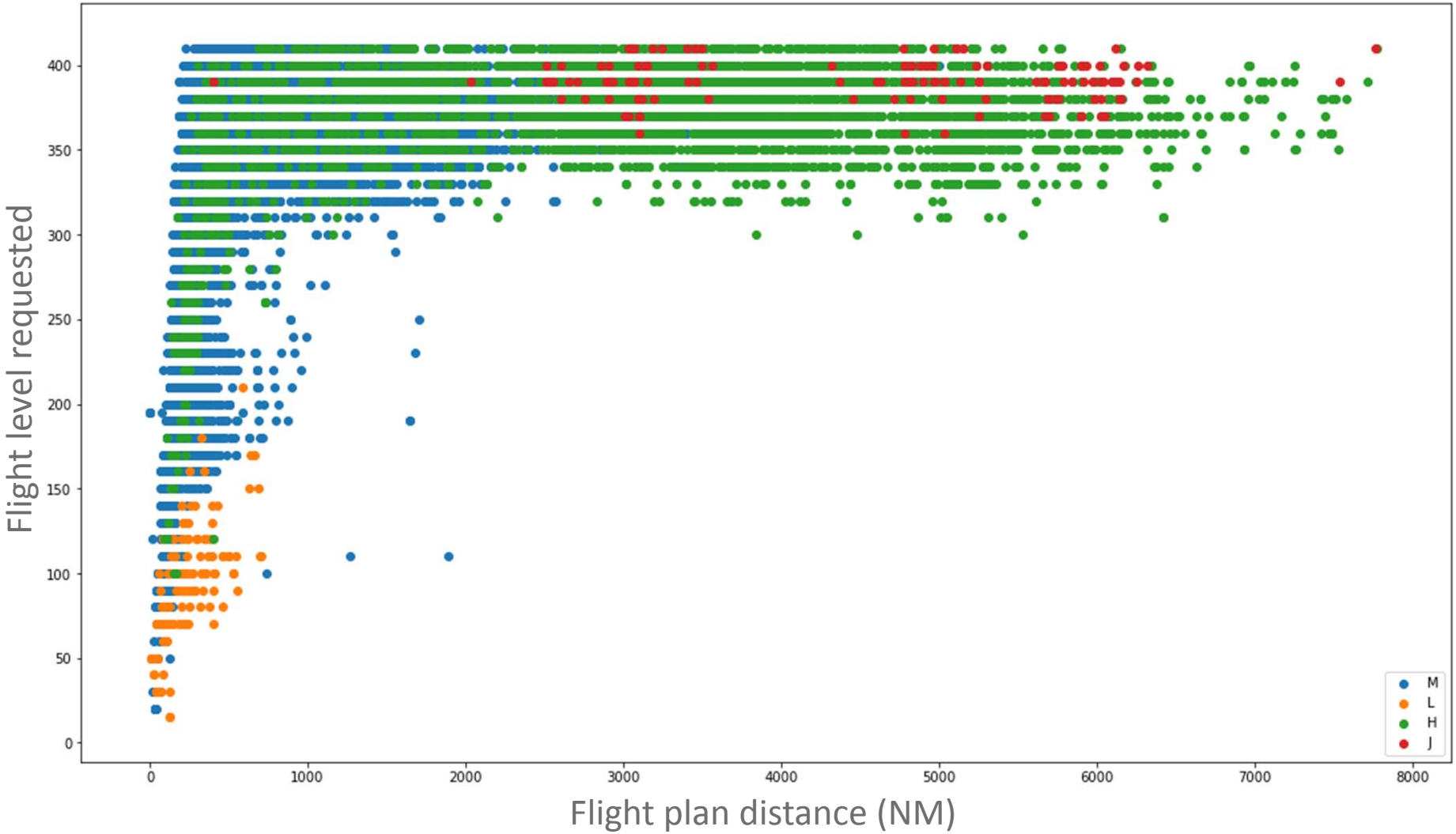
Schedules

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	
…								

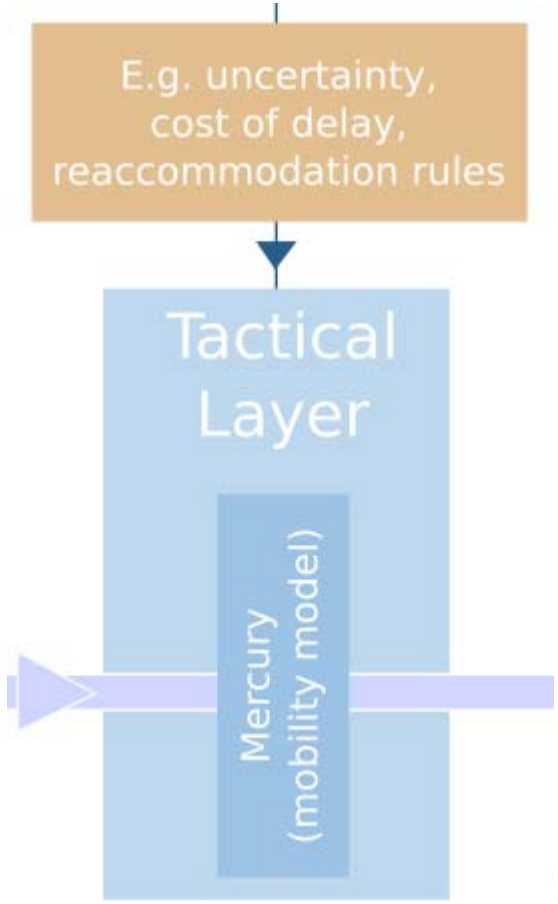
Flight plans

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

Pre-tactical layer – flight plan generation



Tactical layer -- Mercury



Flight plans

ATFM delay

Passengers itineraries

Tactical delays, reaccomodations, etc

Tactical layer -- Mercury

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

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

Potential next steps

Academic developments:

- Study of emergent phenomena related to more specific changes in the model, for instance introduction of different drone management systems
- Refinements of the economic side of the model by extending the financial aspect: capital of companies, loans, etc.
- Refinements of the strategies used by agents, game theory.

Application-oriented development:

- Support to projects like PJ19, development of performance tools and general views like EATMA
- Support to projections of demand at the ANSP level (stakeholder demand)

Vista project

Thanks for listening!

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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?

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

Volume term

Competition term

$$\mathrm{C}(p_k, \{p_l\}_{l\neq k}) = 1 - \frac{1}{s}\left(\Delta p_k - \sum_{l=1, l\neq k}^{n} \frac{\Delta p_l}{n-1}\right) + \ldots$$

Airline supply

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

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

$$c(S) = c + c_o S + c_c S^{\alpha} \qquad \alpha > 1$$

Overhead, constant

Operational cost, linear

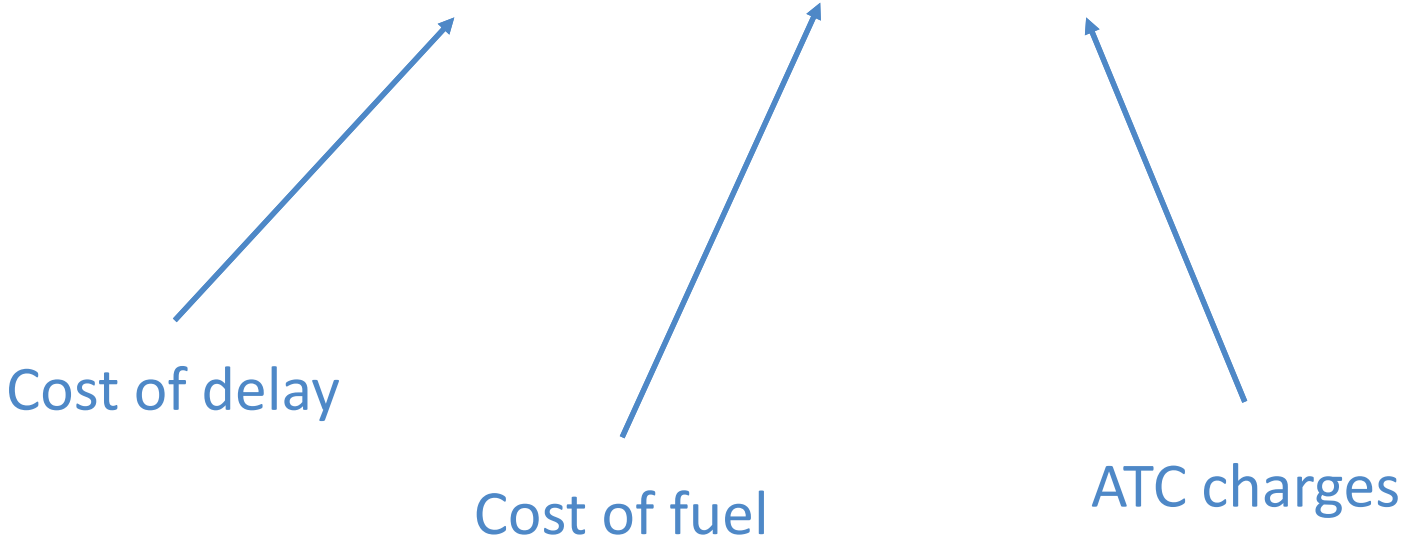
Cost of capital, superlinear

$$S^* = \left(\frac{\hat{p} - c_o}{c_c}\right)^{\frac{1}{\alpha - 1}}$$

Airline supply

- Operational cost depends on a lot of parameters:

$$c_o = \chi \Delta\delta t_O + \chi \Delta\delta t_D + c_f(d) + c_{ATC} + \cdots$$



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

$$\delta t = \delta t_0 + \frac{T}{C}$$

Traffic

Capacity (fitted)

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

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

Cost of capacity (linear in the model)