The Vista model: the challenges of building a holistic model across the strategic, pre-tactical and tactical phases of ATM

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Details of the workshop are available at:

http://vista-eu.com/

Vista
Vista consultation workshop

23 October 2017

Frequentis, Vienna

SESAR JOINT UNDERTAKING

Founding Members

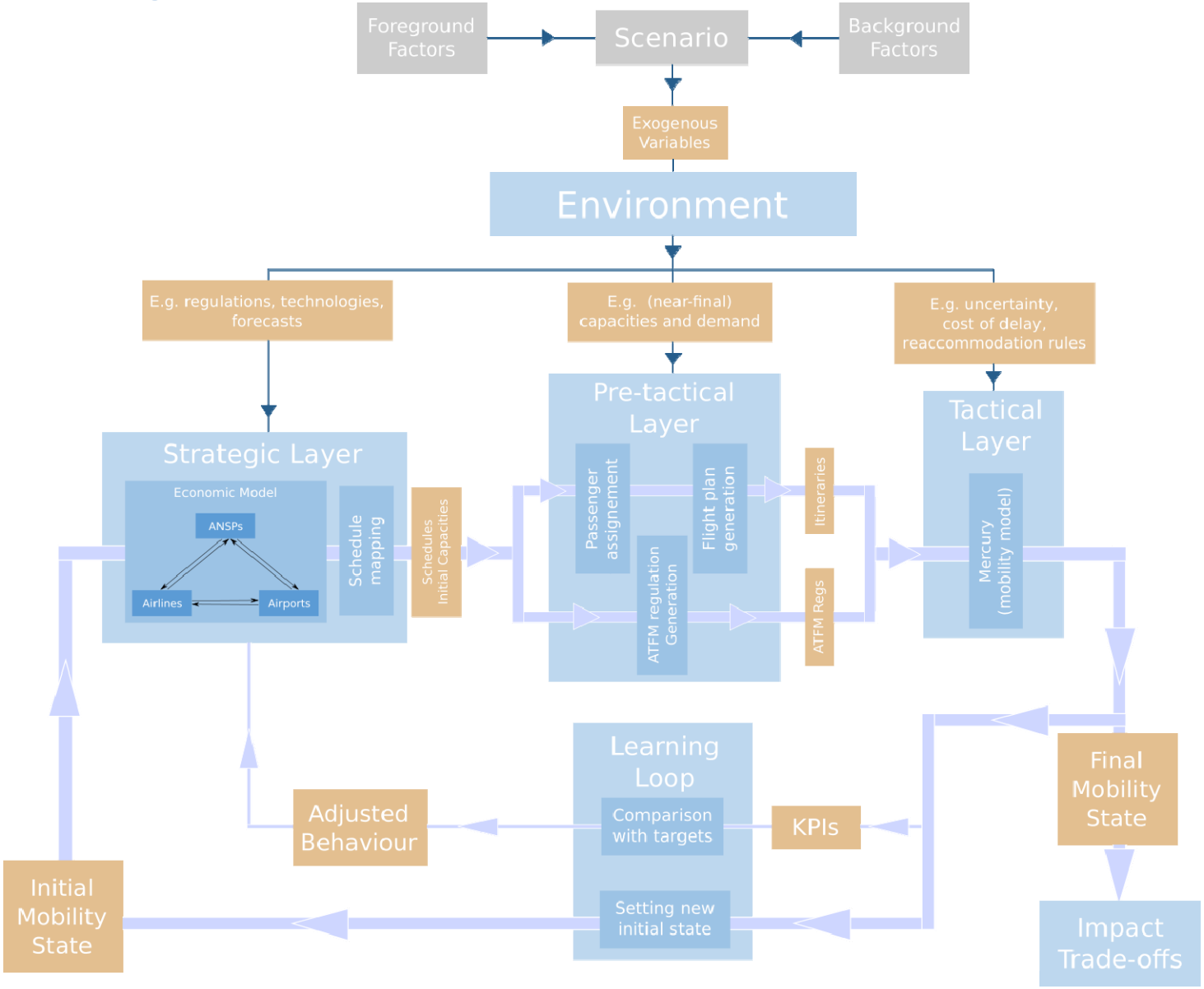
EUROPEAN UNION EUROCONTROL

Objective of the model

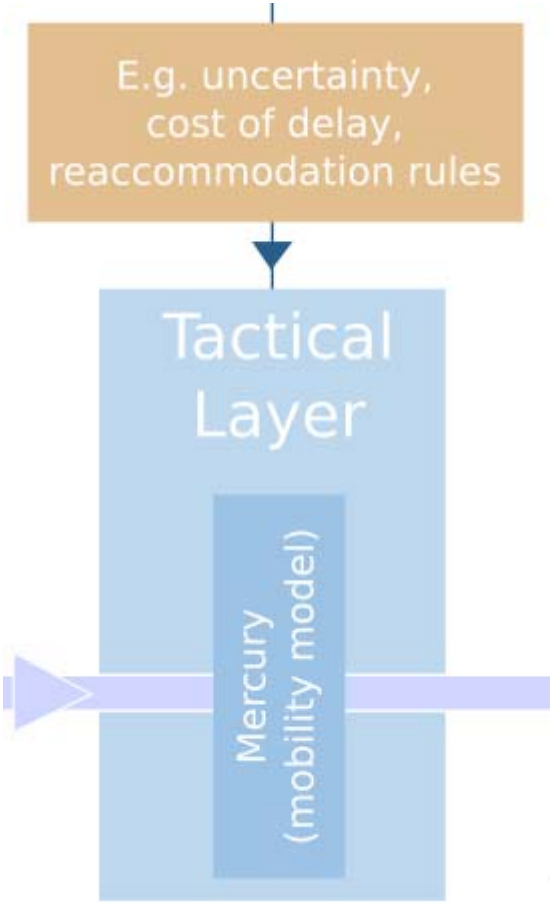
- Vista model aims at:
  - Simulating one day of traffic in Europe to the level of individual passengers
  - Being able to change the operational environment and see their impact on several stakeholders and at several levels
- Vista model does not aim at predicting the likelihood of the changes of operational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

Vista model is a ‘what-if’ simulator

Model presentation



Tactical layer - Mercury



Flight plans

ATFM delay

Passengers itineraries

Tactical delays, reaccomodations, etc

Tactical layer - Mercury

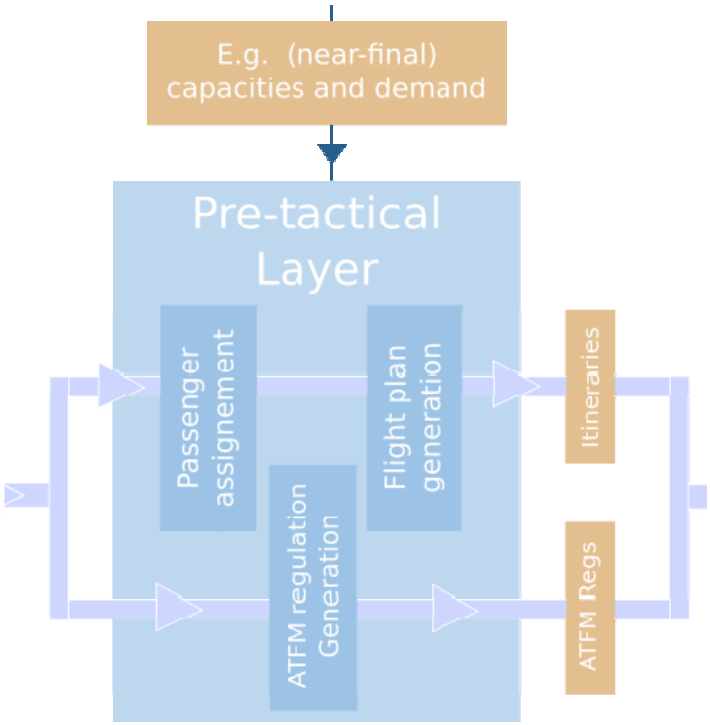
- A framework EU-mobility performance and assessment
- Flexible to implement almost any scenario
- Focus on passengers, not flights
- Produces a wide ranges of metrics, not only delays
- drawn from a wide range of sources; including airlines, airports and air navigation service providers
- Developed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

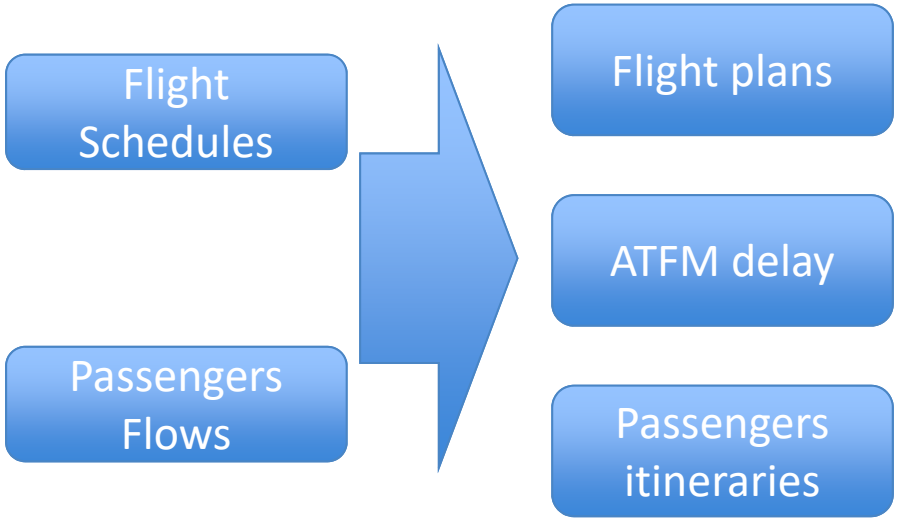
Tactical layer - Mercury

- 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

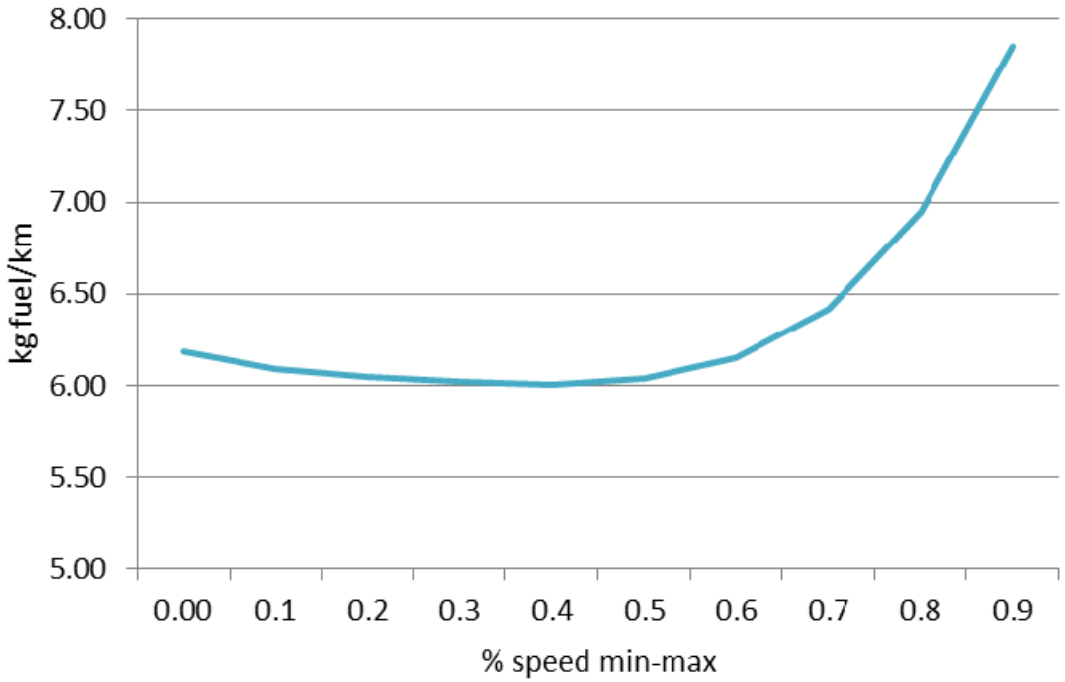
Fid	From	To	SOBT	SIBT	Capacity	GCD	Ac type	…
F_{AD1}	A	D	9:00	10:30	120	1234	A320	
F_{AD2}	A	D	10:45	12:20	240	954	A320	
F_{AD3}	A	D	10:50	12:20	120	2521	B737	
F_{CD1}	C	D	8:30	12:00	70	3213	B737	
…								

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
…											

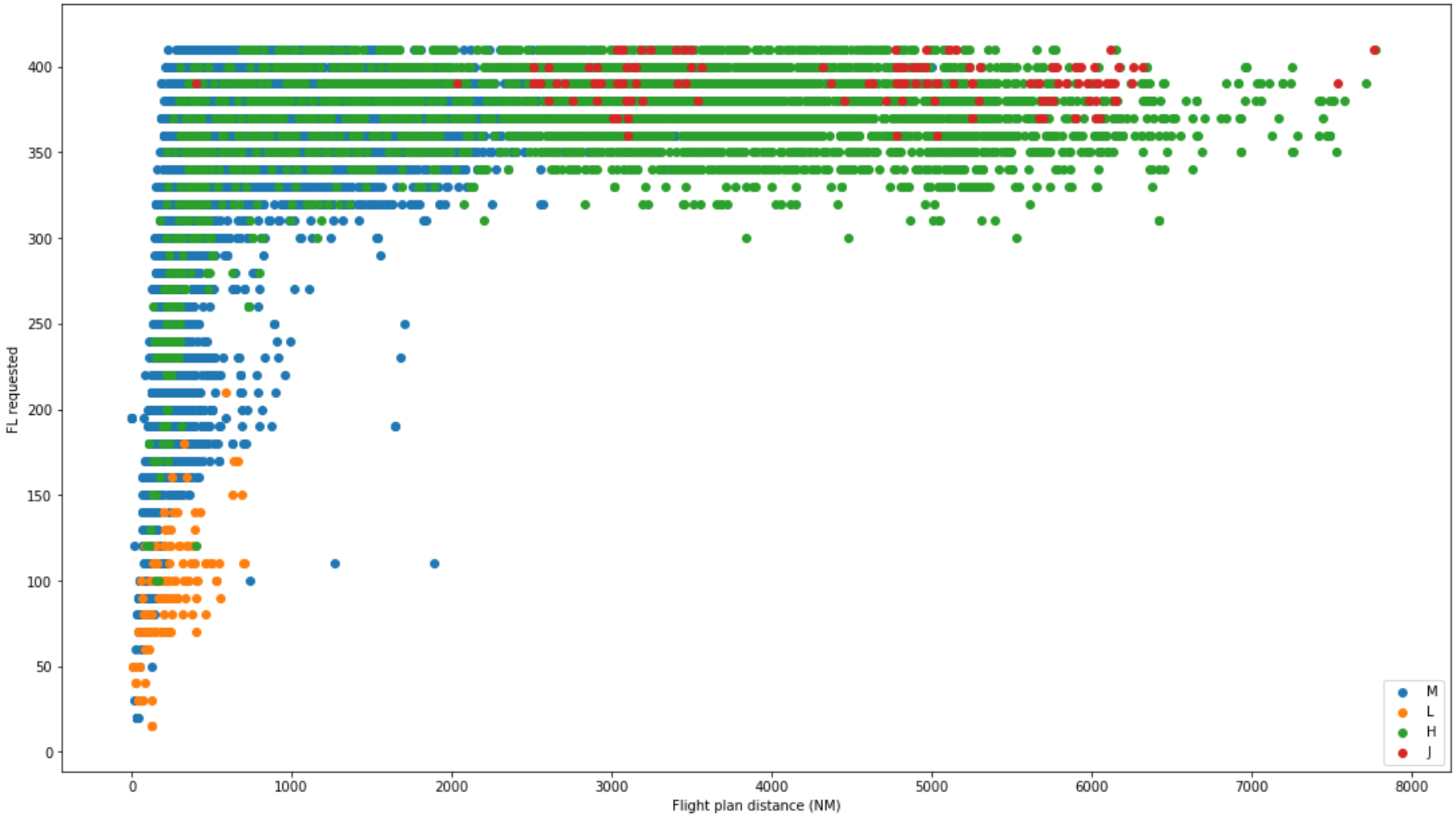
Pre-tactical layer – flight plan generation

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

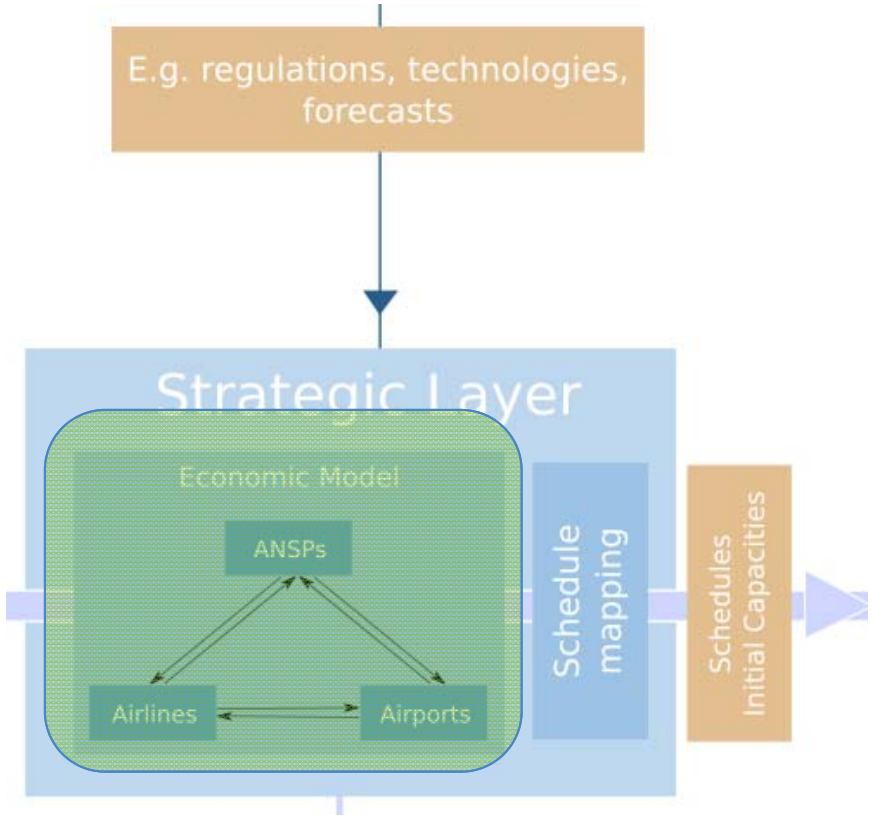


- AC type
- FL
- Weight
- Nominal speed

Pre-tactical layer – flight plan generation



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
  - 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

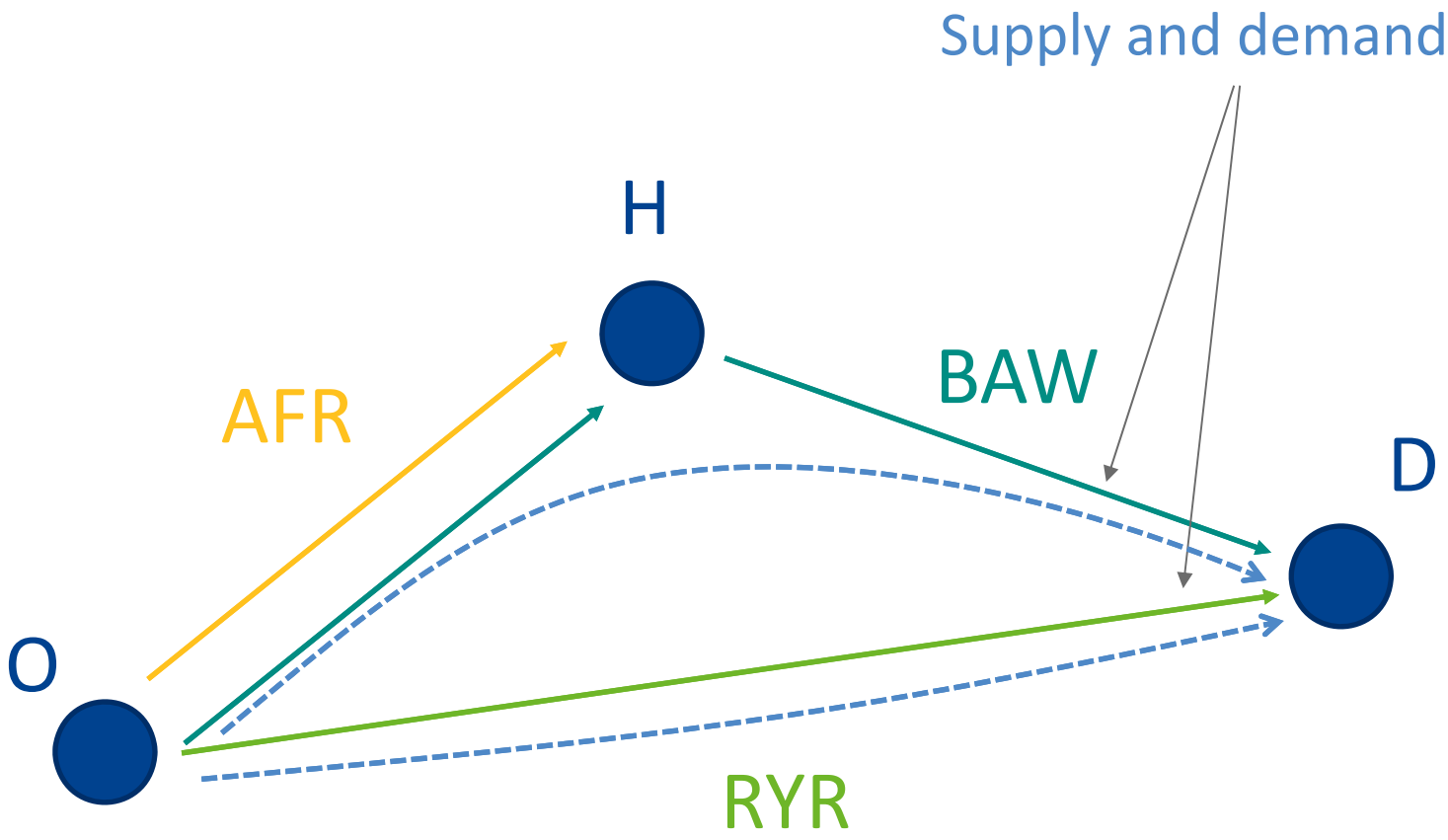
- Airlines choose the capacity to provide on each OD pair based on their supply function (including their costs, e.g. fuel, airspace charges, etc) and the predicted price of the ticket on this leg.
- Passengers choose between different itineraries for the OD pair based on the latest prices.
- Supply 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



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.

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

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

Overhead, constant

Operational cost, linear

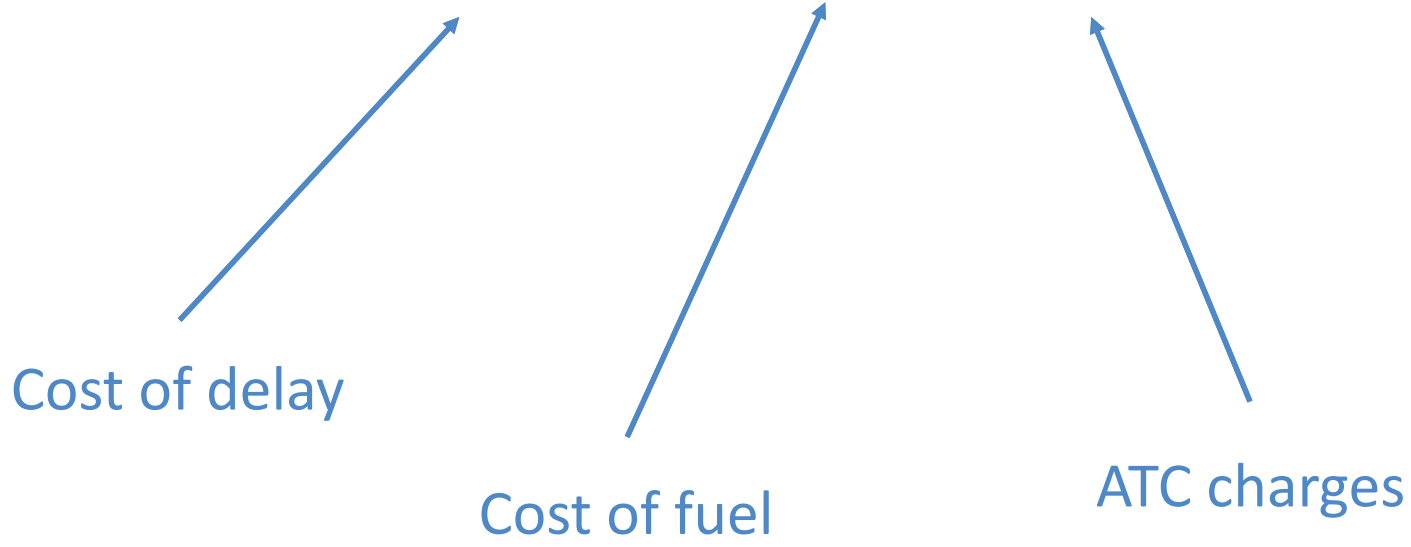
Cost of capital, superlinear

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

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)

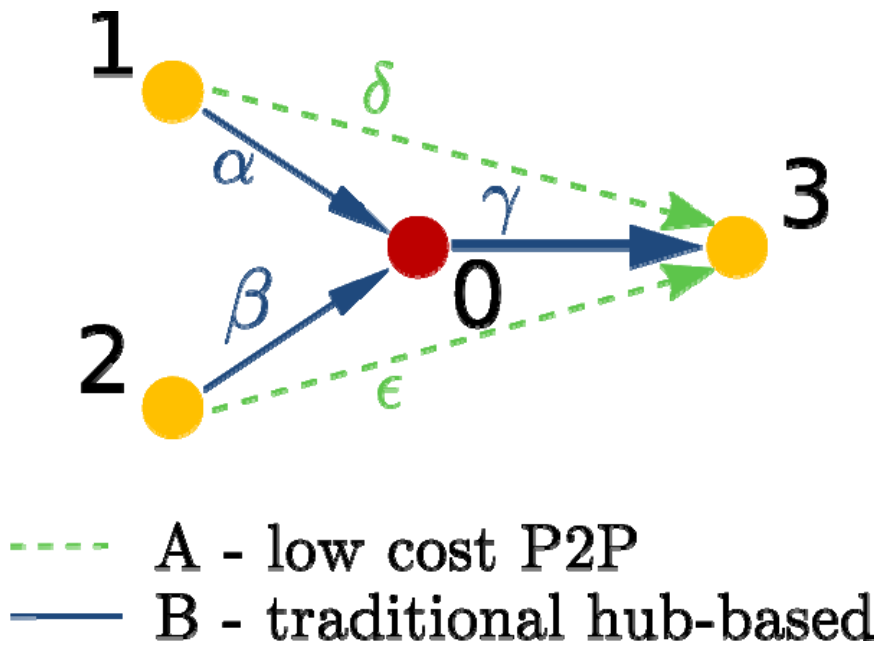
- Airports try to maximise their profit by increasing (or not their capacity):

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

Cost of capacity (linear in the model)

Simple example: LLC vs trad

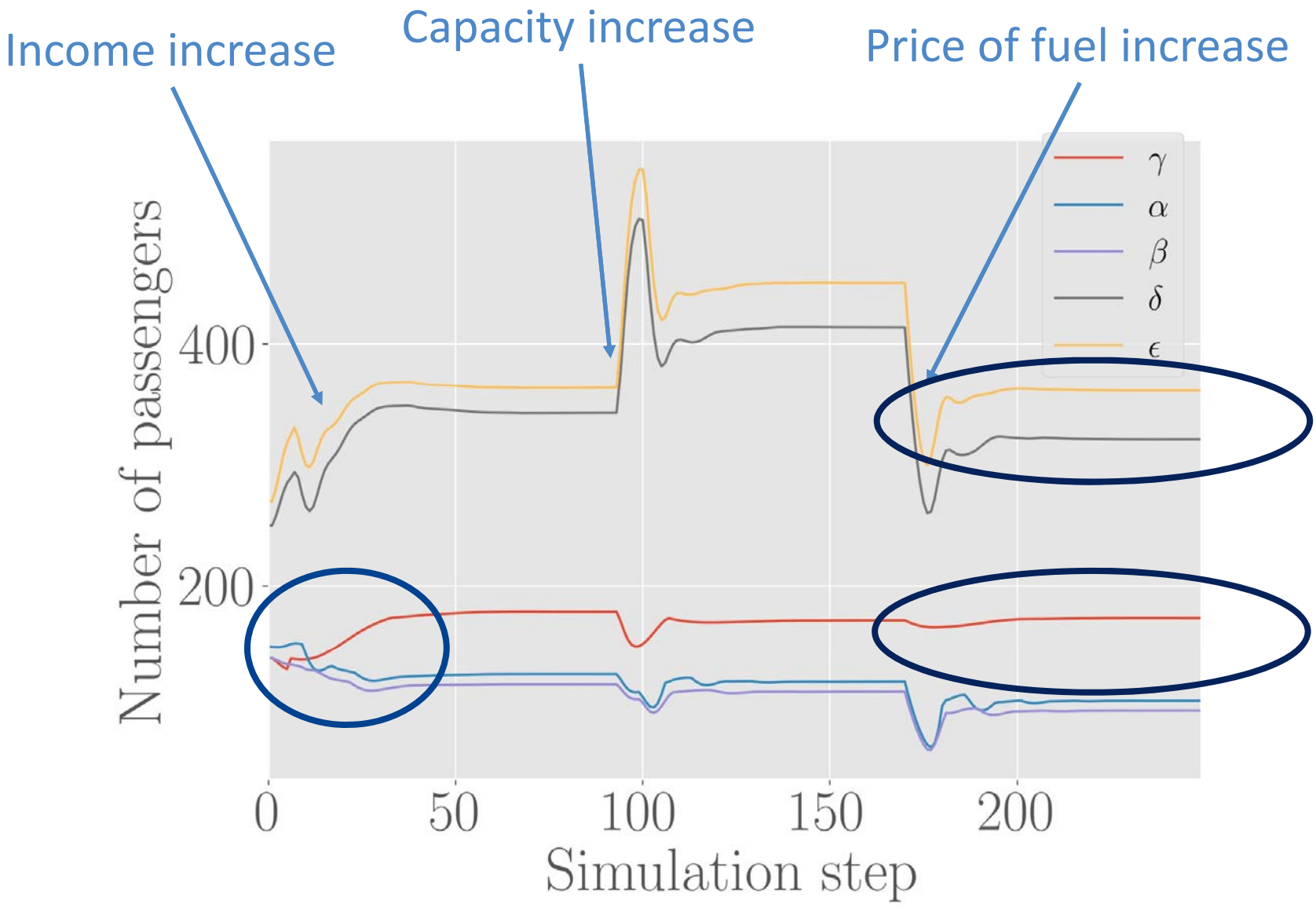
- Simplified setup: four airports, two airlines LLC/trad



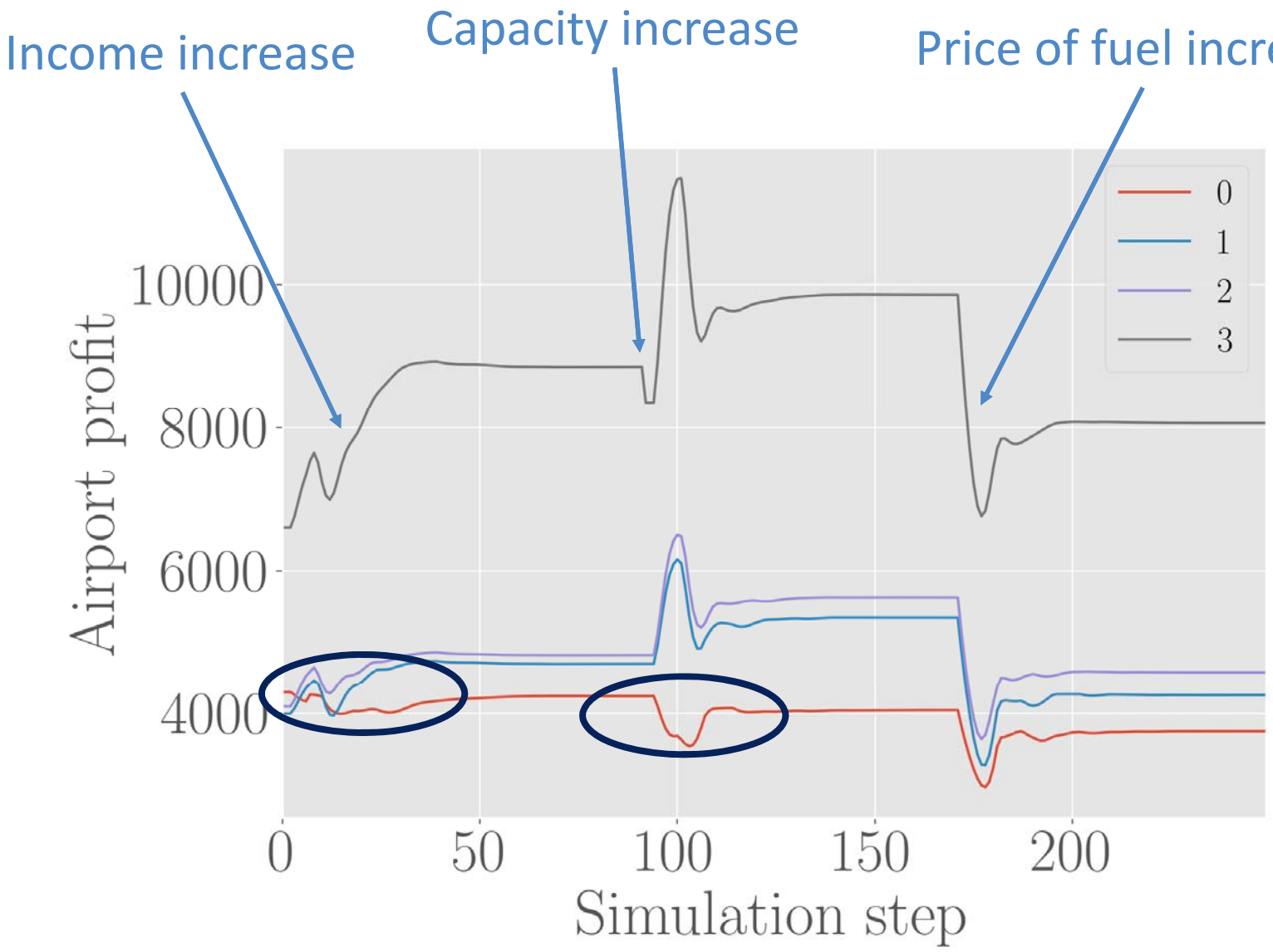
Simple scenario:

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

Number of passengers



Airport profit



Next steps

Airlines:

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

$$r(S_1, S_2) = S_1 p_1 + S_2 p_2 - c_o^1 S_1 - c_o^2 S_2 + c_c (S_1 + S_2)^{\alpha}$$

- 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?