Vista (SESAR 2020 Exploratory Research project)

A multi-layer model for long-term KPI alignment forecasts

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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.

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

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

Scenario definition in Vista

Foreground factors

Grouped into **supportive** and **non-supportive** cases

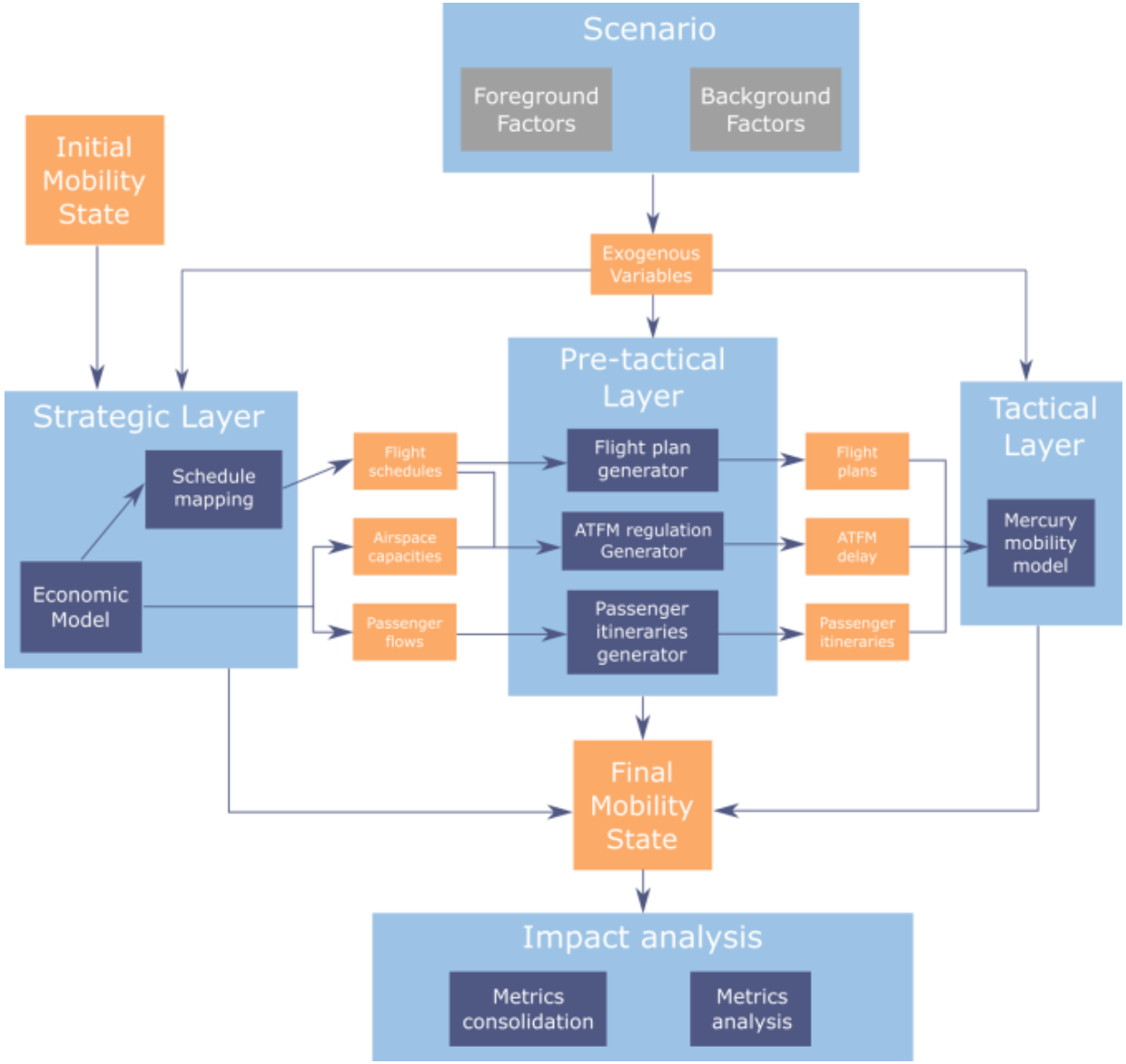
Factor	Values
BEO1 – Fuel prices	HHH – 4 €/kg HH – 2 €/kg H – 1 €/kg M – 0.5 €/kg L – 0.3 €/kg
BTS5 – 4D trajectory operations	L – Current M – Moderate improvement of capacity en-route and airport H – High improvement of capacity
BTO4 – Passenger management tools	L – Current rule of thumb operations M – Passenger reaccommodation improved with wait-for-passenger rules H – Passenger reaccommodated to any suitable flight, advanced wait-for-passenger rules
ROR1 – Passenger provision schemes	L – Current R261 M – Enhanced R261 and duty of care H – Enhanced R621 and duty of care with automatic compensation
ROR3 – Emission schemes	D – Current, low price only $C0_2$ charged CO2_H – High price only $C0_2$ charged CO2_HH – Very high price only $C0_2$ charged CO2_NOx_H - High price NO_x also charged CO2_Nox_HH – Very high price NO_x also charged

Vista Model

Objectives of the model

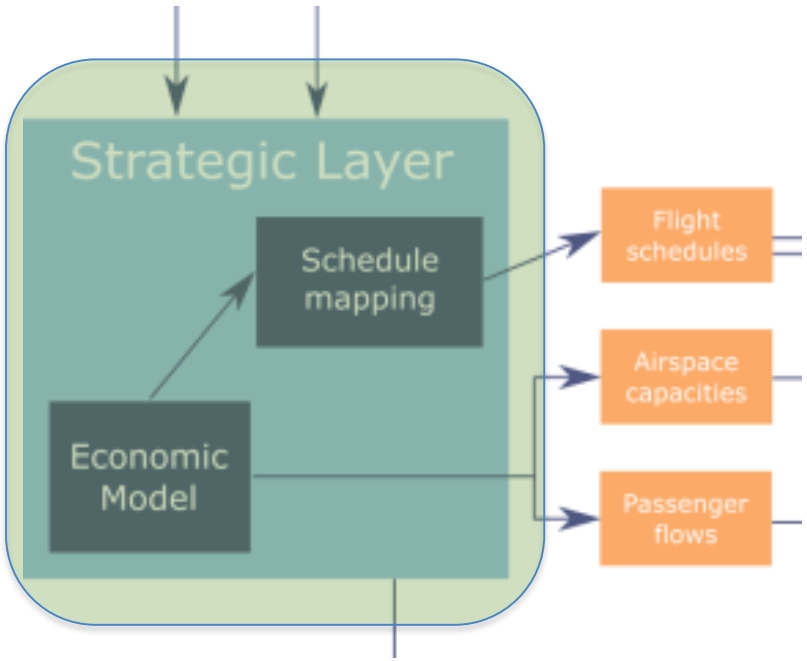
- Vista model:
  - Simulates a typical day of traffic in Europe to the level of individual passengers
  - Changes the operational environment and see their impact on several stakeholders and at several levels
- Vista model takes a holistic approach:
  - Because the behaviour of the system is not a simple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

Multi-layered architecture of Vista



- **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_x and CO_2

Strategic layer – economic model



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:

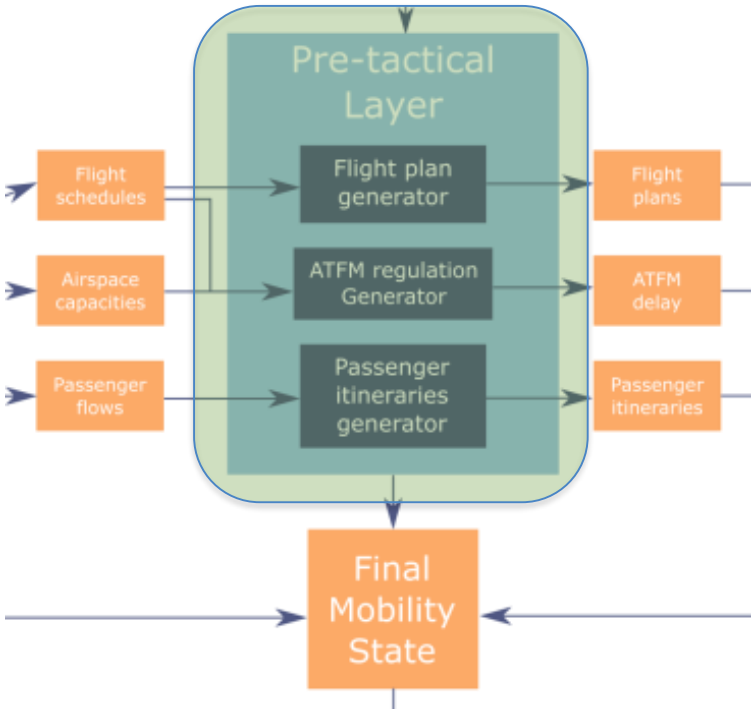
- Step-by-step multi-agent model
- Individual agents are currently:
  - 823 Individual airports,
  - 326 Individual airlines, part of alliances (or not), with 15 209 OD pairs,
  - 31 430 Passenger agents, aggregated at an OD level per airline,
  - 88 individual ANSPs (but only the ECAC ones are active).
- Agents compete with peers, try to predict different values (delays, future demand, prices) and act accordingly

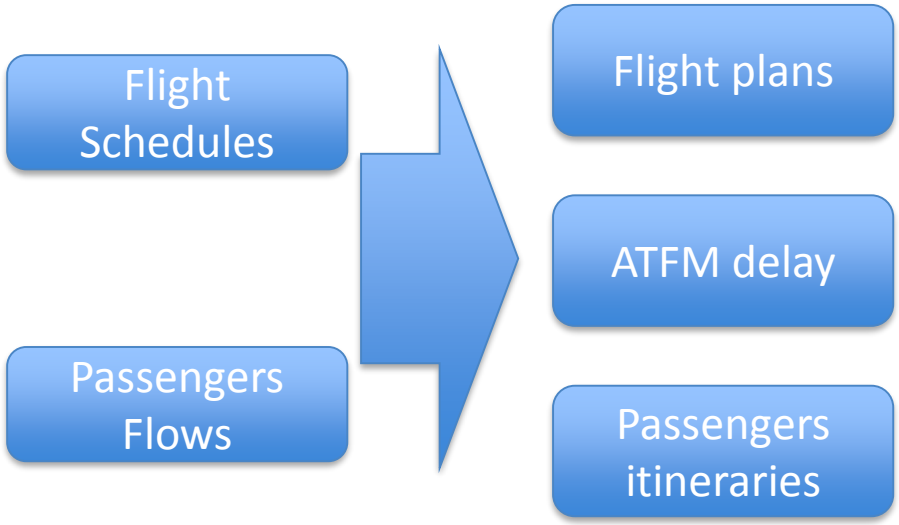
ABM flow

- Airlines choose their supply, based on predicted costs (maint., crew, fuel, emissions (CO_2, NO_x), 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

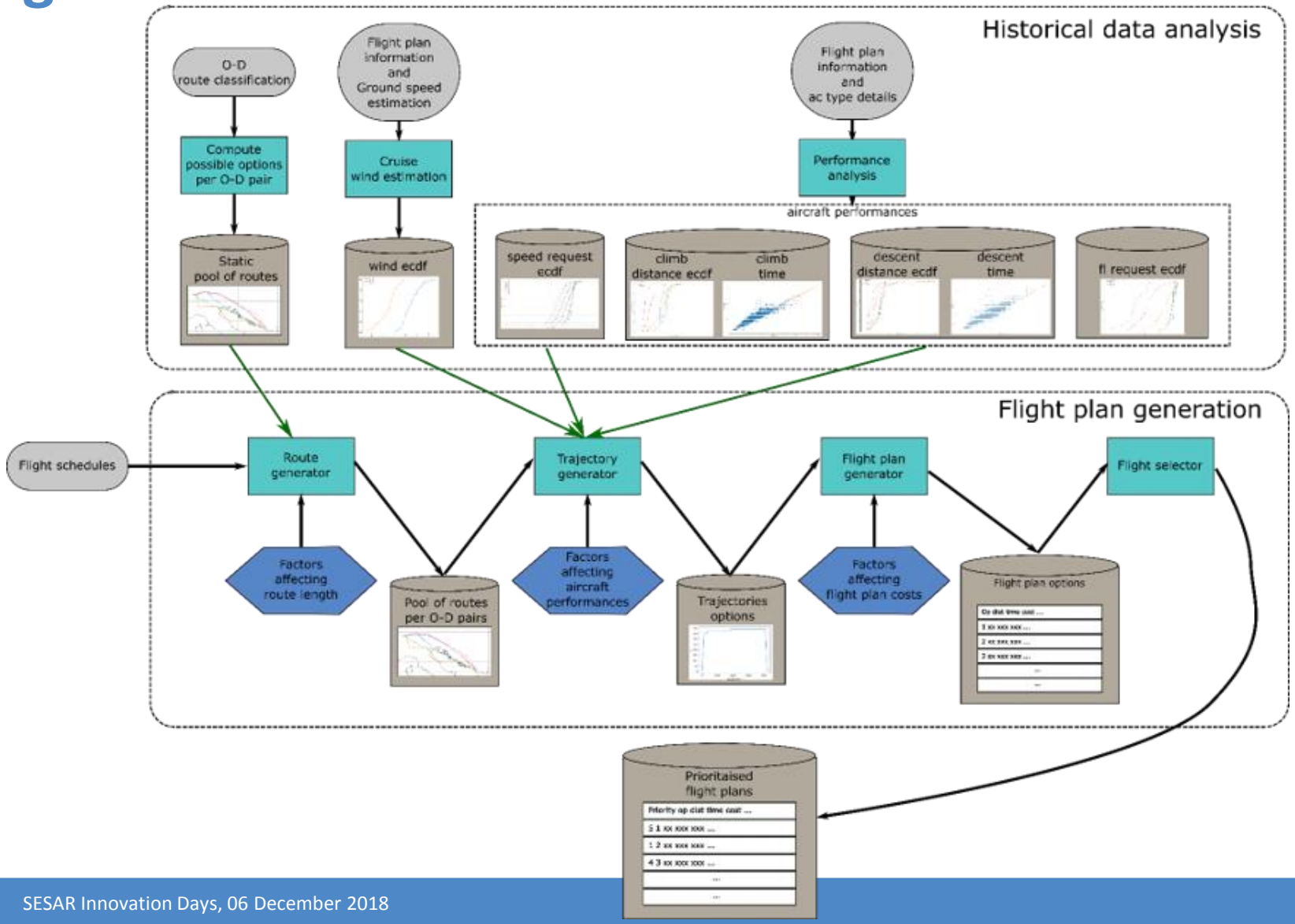
Schedules

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	
…								

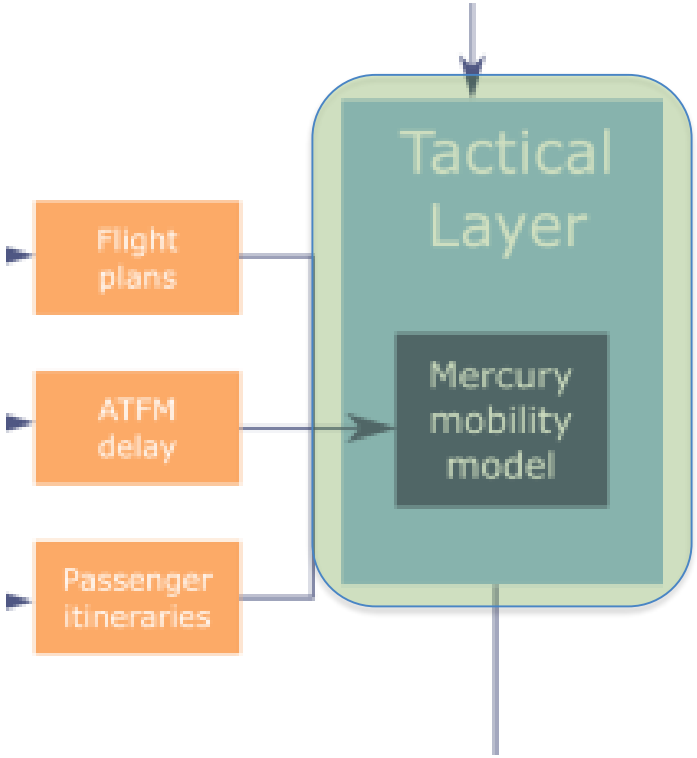
Flight plans

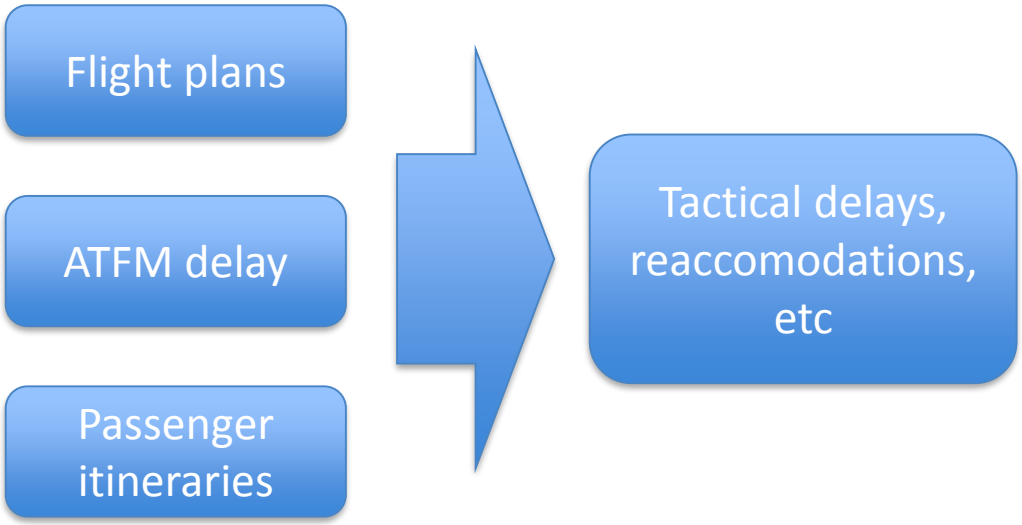
Fid	Flight plan type	Climb dist	Climb time	Cruise dist	Cruise time	Cruise speed	Cruise avg Fl	Cruise avg weight	Cruise avg wind	Descent dist	Descent time
F_{AD1}	0	208	00:29	504	1:07	445N (0.77M)	380	66500	34	201	00:35
F_{AD1}	1	213	00:31	442	1:00	450N (0.78M)	360	67000	-9	224	00:36
F_{AD1}	2	194	00:29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



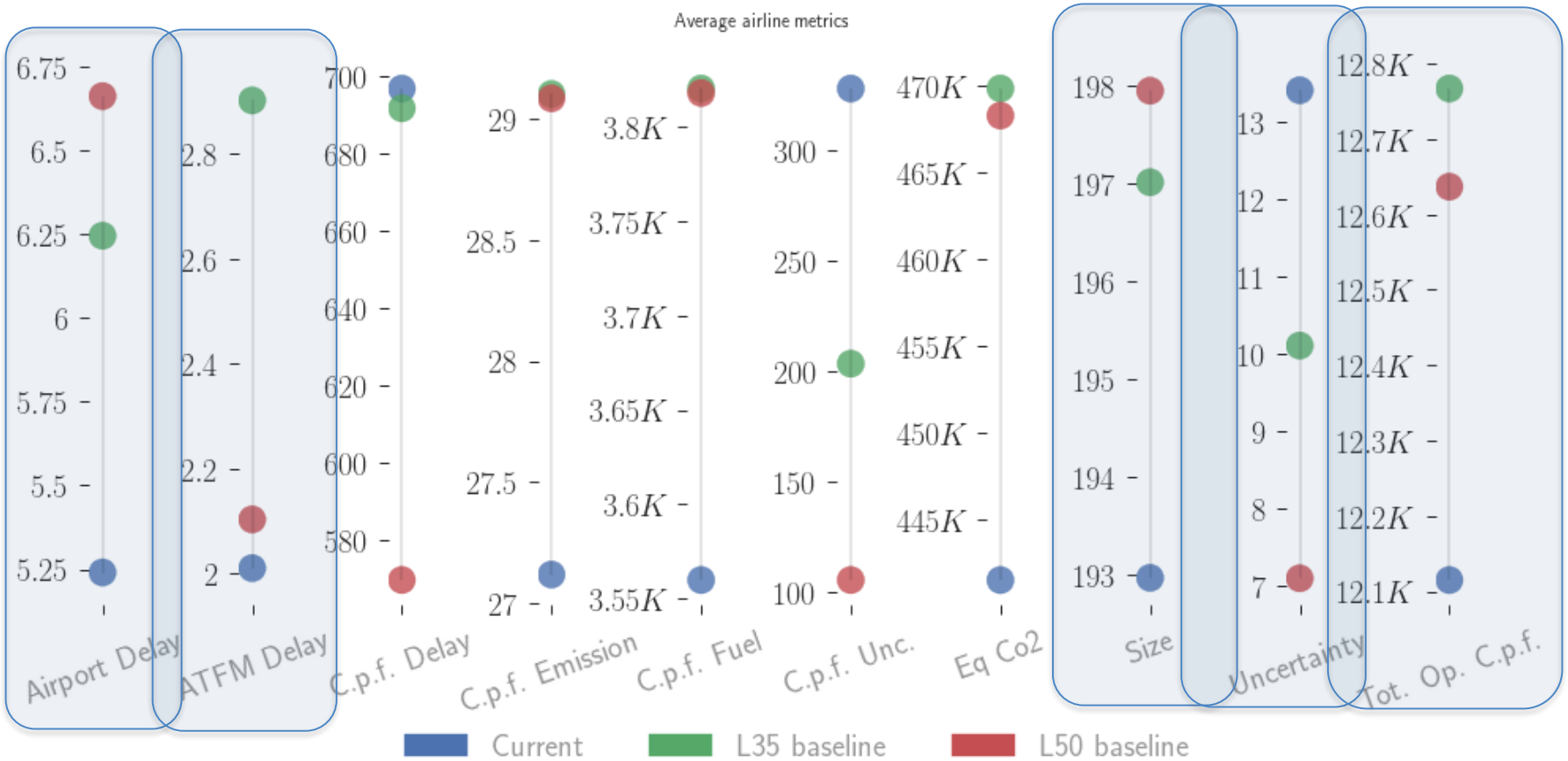


Tactical layer – Mercury

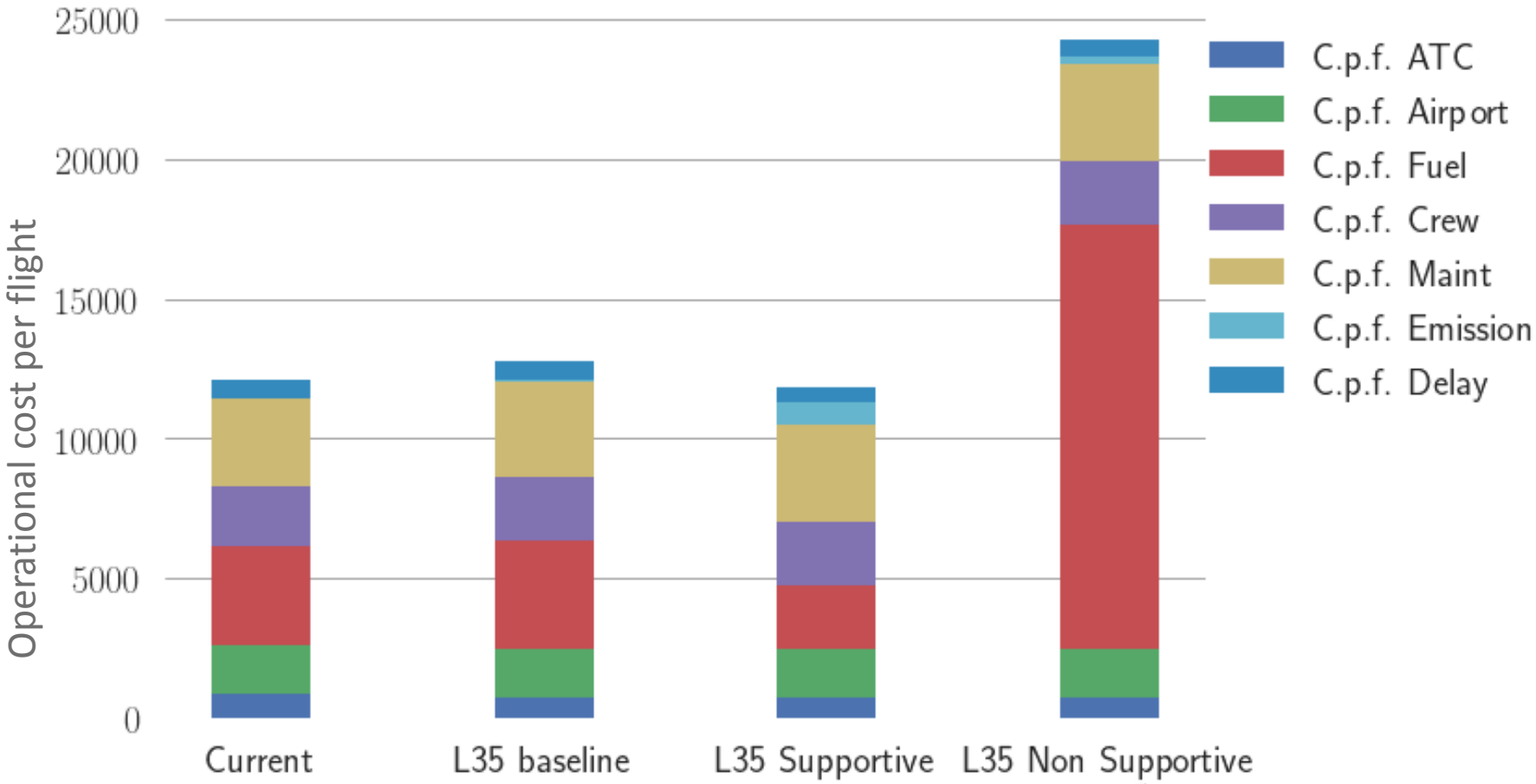
- Data-driven mesoscopic approach, stochastic modelling
- Individual passenger **door-to-door** itineraries
- Regulation 261/2004 – pax care & compensation
- Disruptions, cancelations, reaccommodations, compensation costs
- Airline decisions based on costs models or rule of thumb
- Full air traffic management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

Vista results – overview

Strategic metrics



Strategic metrics

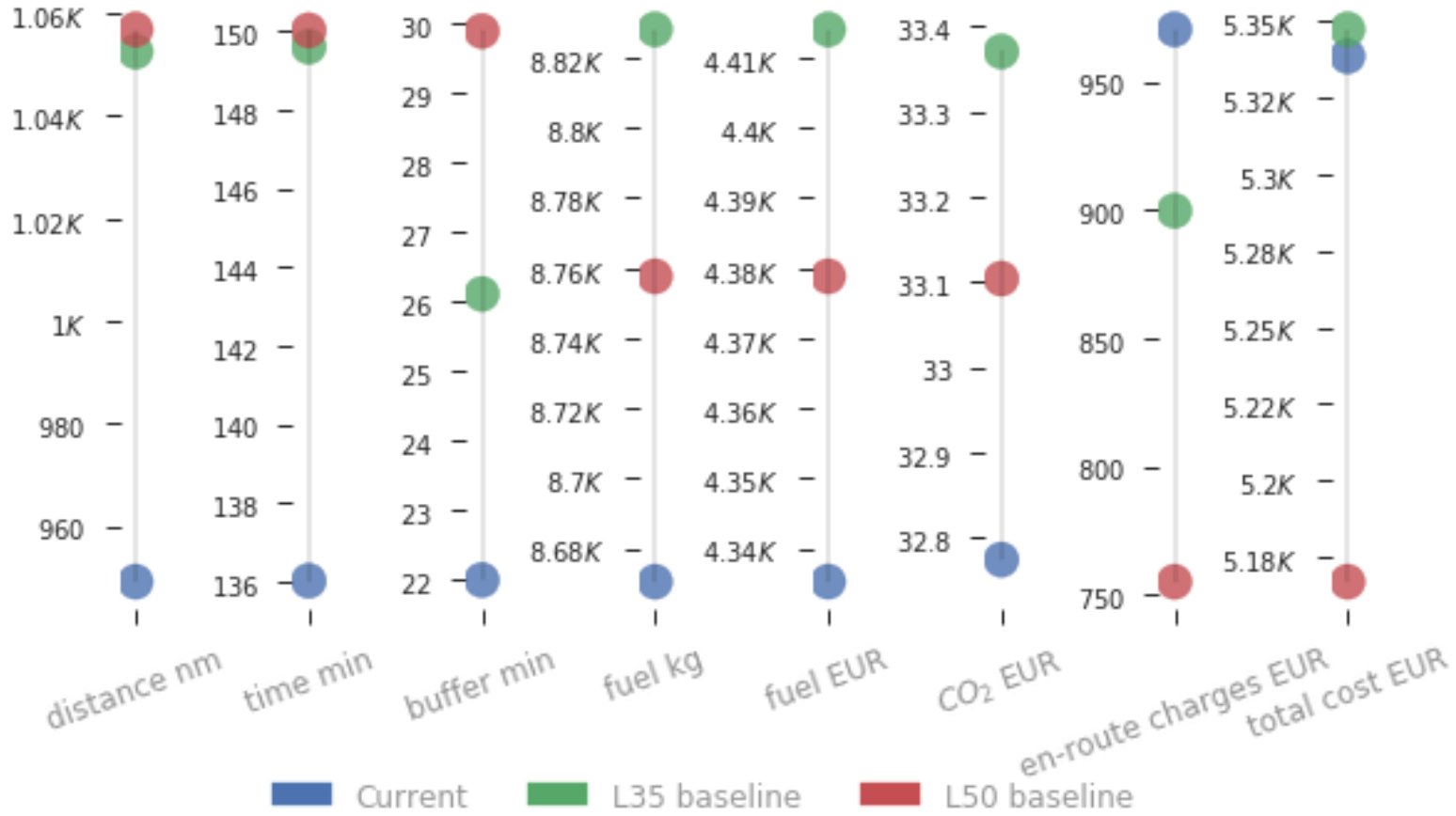


Low baseline
for 2035,
Low eco. dev.
Low tech. dev.

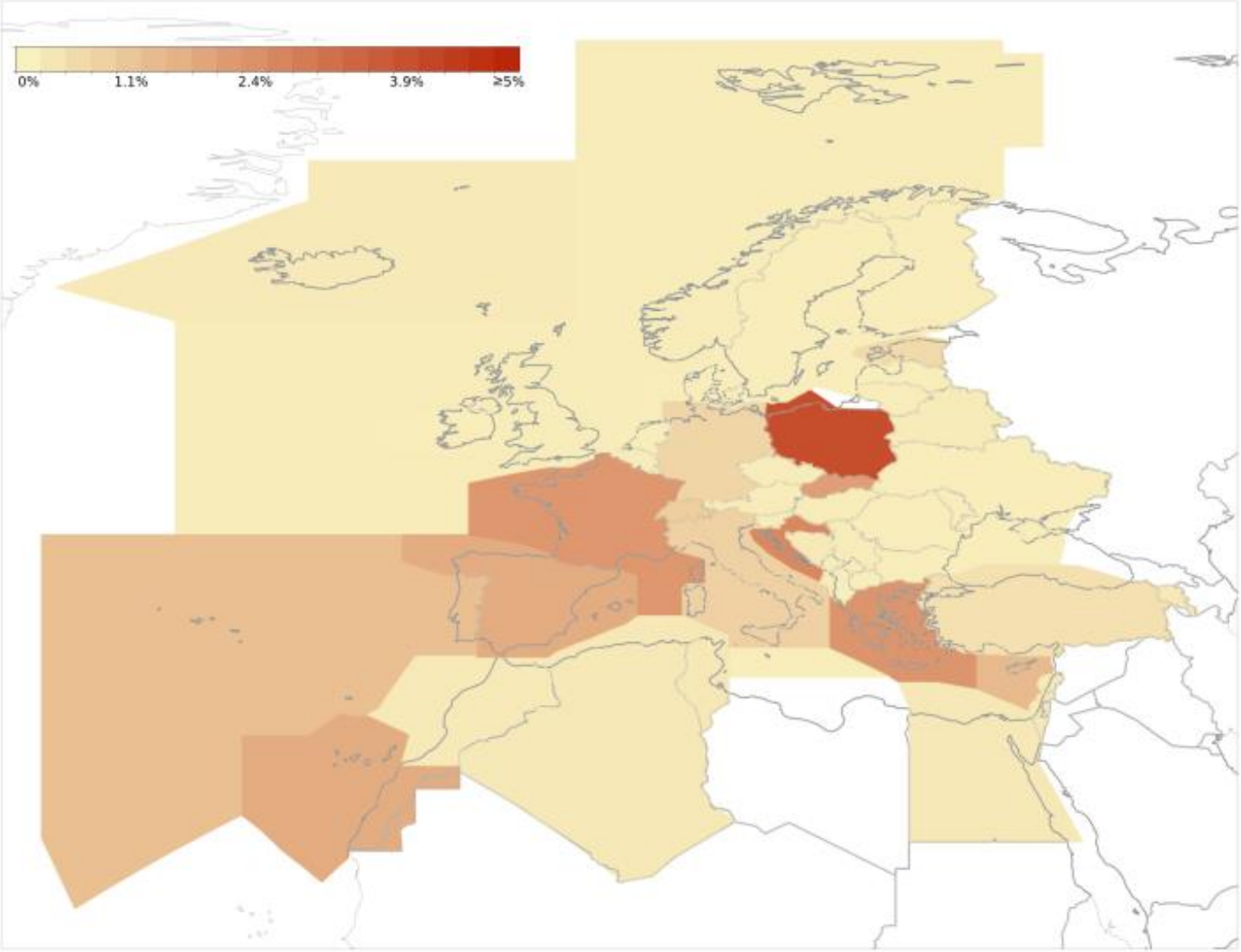
+ Low fuel price + eco-tax
+ better 4DT + pax protection

+ High fuel price
+ No eco tax

Pre-tactical metrics

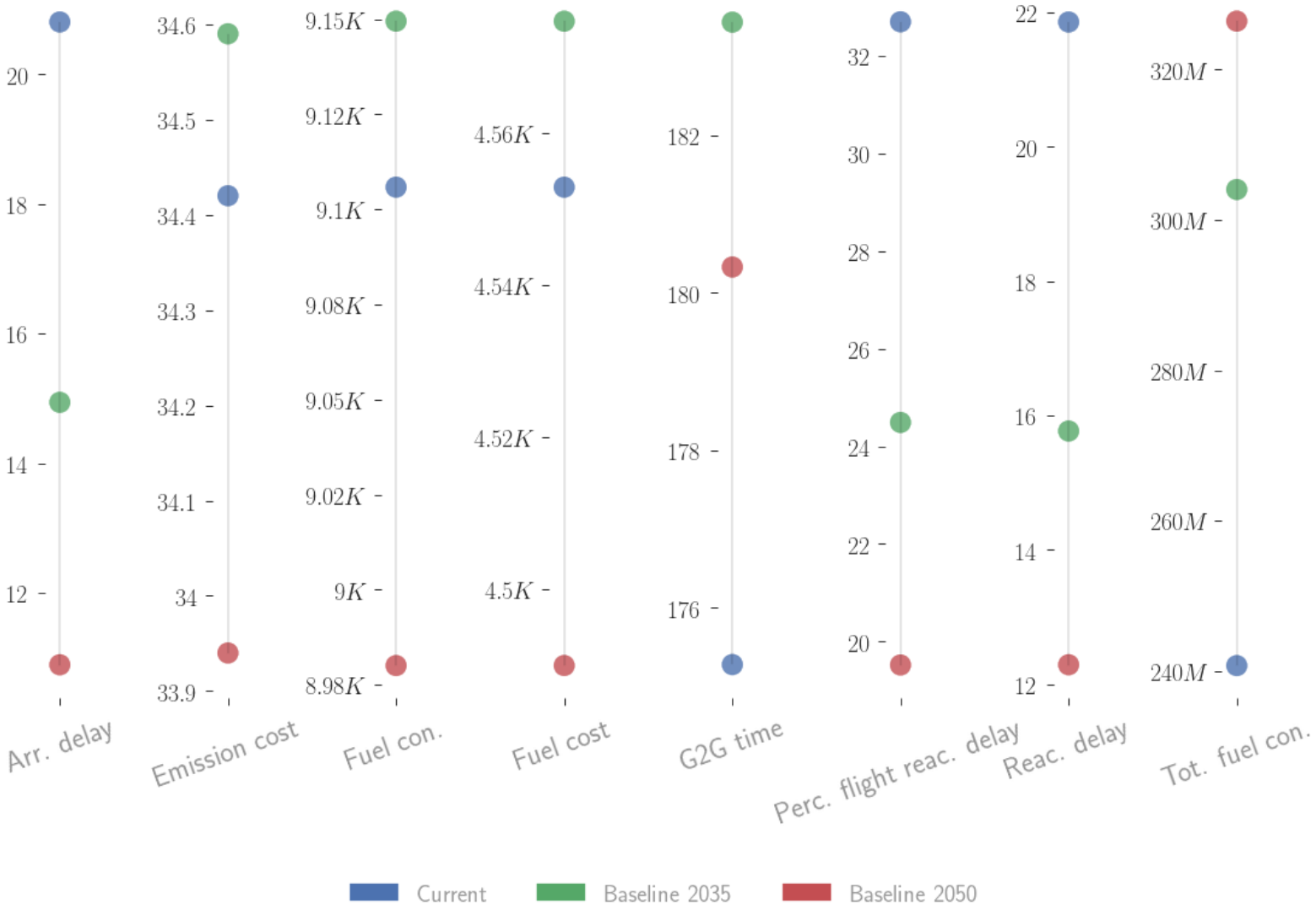


Pre-tactical metrics

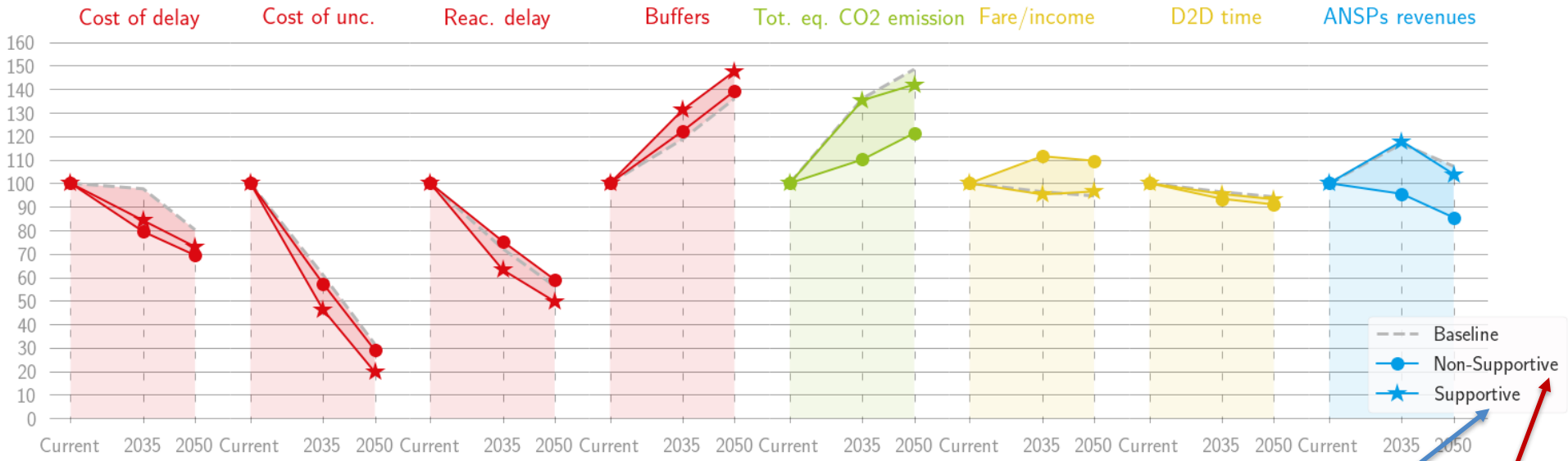


Low 2050

Tactical layer



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.

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

+ High fuel price
+ No eco tax

Conclusions

Key results:

- Main high-level driver: demand and **price of fuel**
- Cost of emissions has an impact only if **NO_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**

Vista project

Thanks for listening!

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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

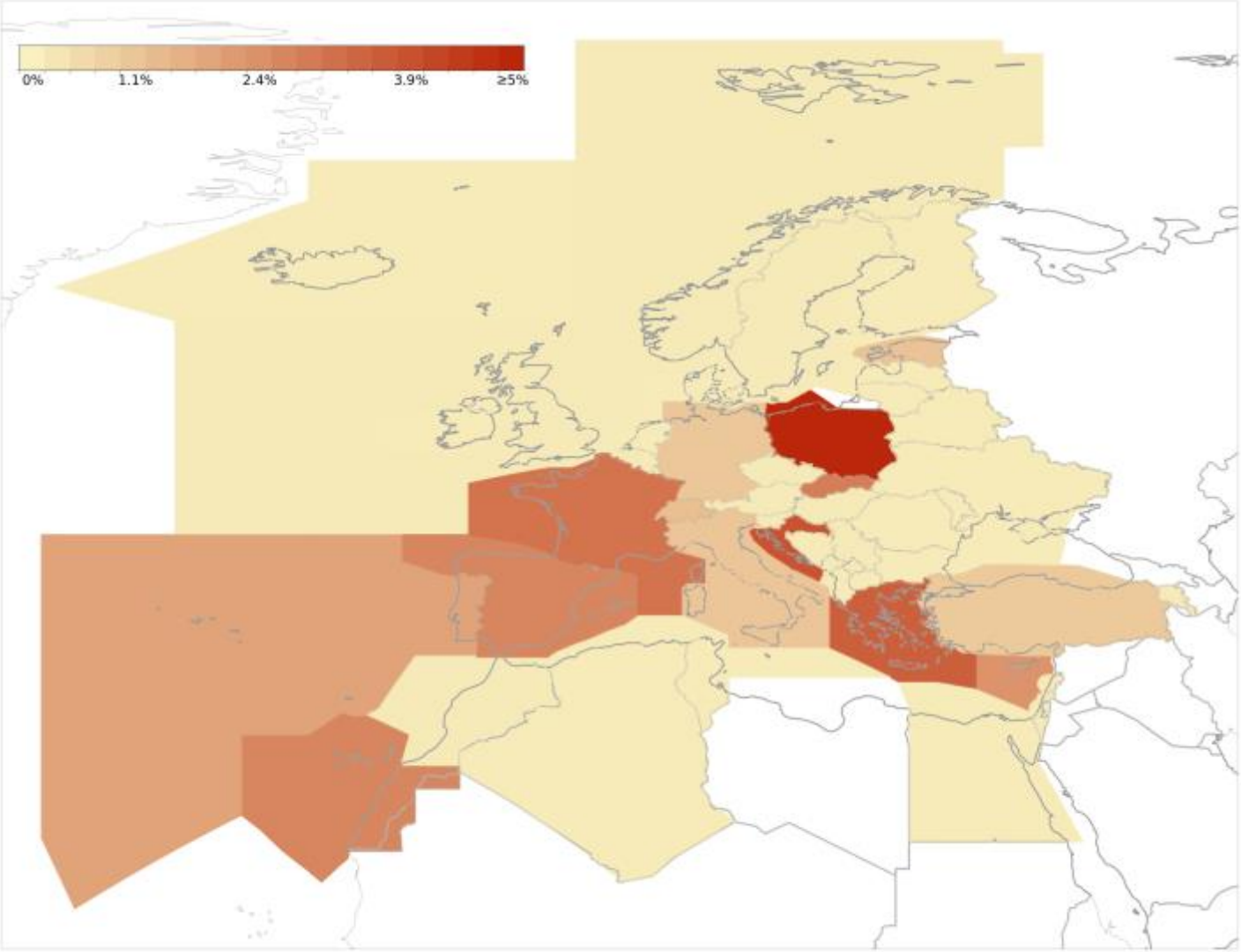
Overview

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.
- Pax: airport delay, ATFM delay, **ticket price**, income, **fare to income ratio**, **frequency**, volume, **gate-to-gate time**, **door-to-door time**, number of missed connections, waiting times at airport.
- Environment: CO_2 emissions, NO_x estimation, environmental **impact in CO_2 equivalents**.

Metrics

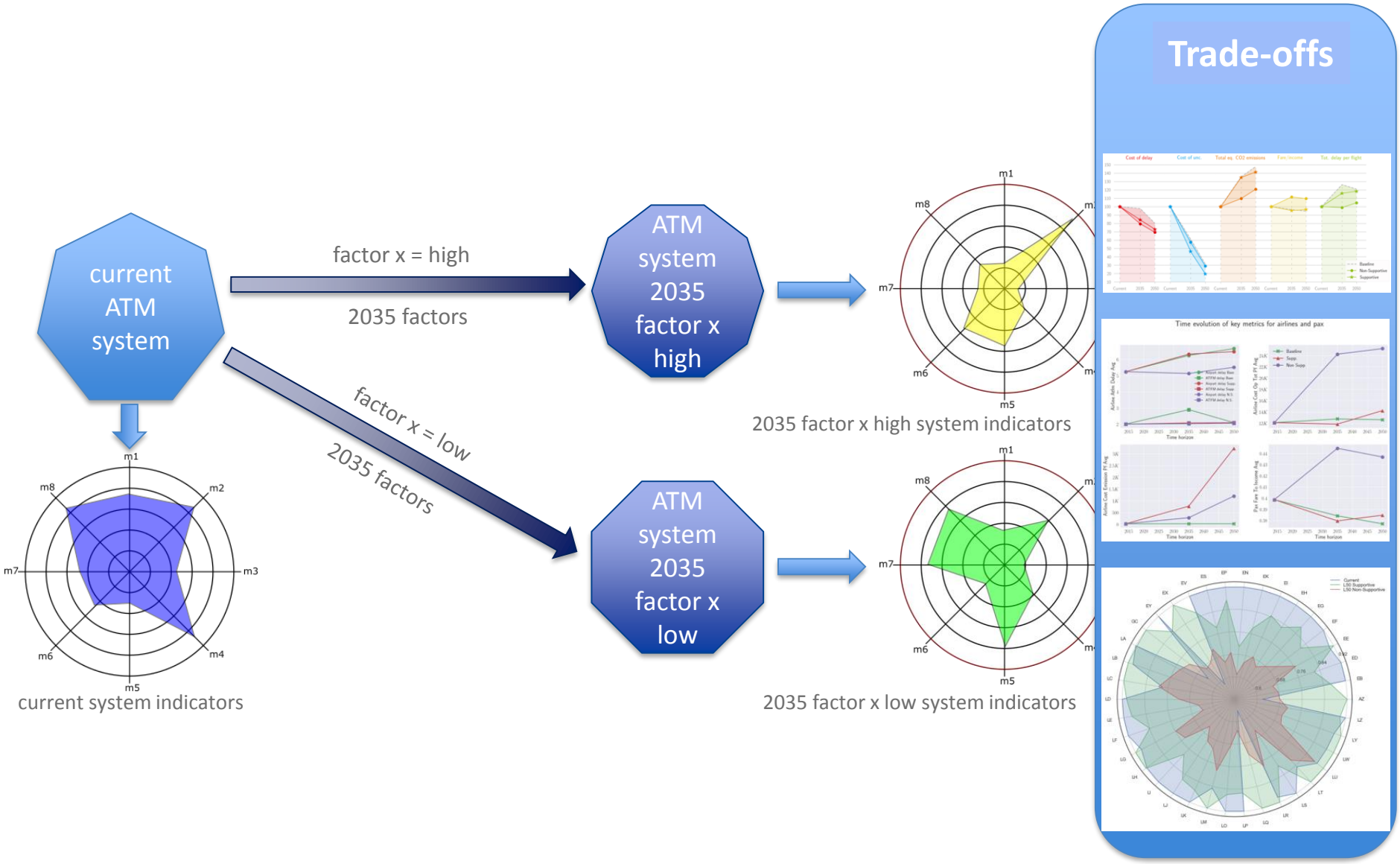
- Airports: **capacity**, **departure delay**, total costs, profit, revenues, traffic (for 24 hours), tactical arrival holding delay and departing queuing delay.
- Airlines: airport delay, ATFM delay, ATC cost , airport cost, **cost of delay** (strategic, tactical), emission costs, fuel cost, crew cost, 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

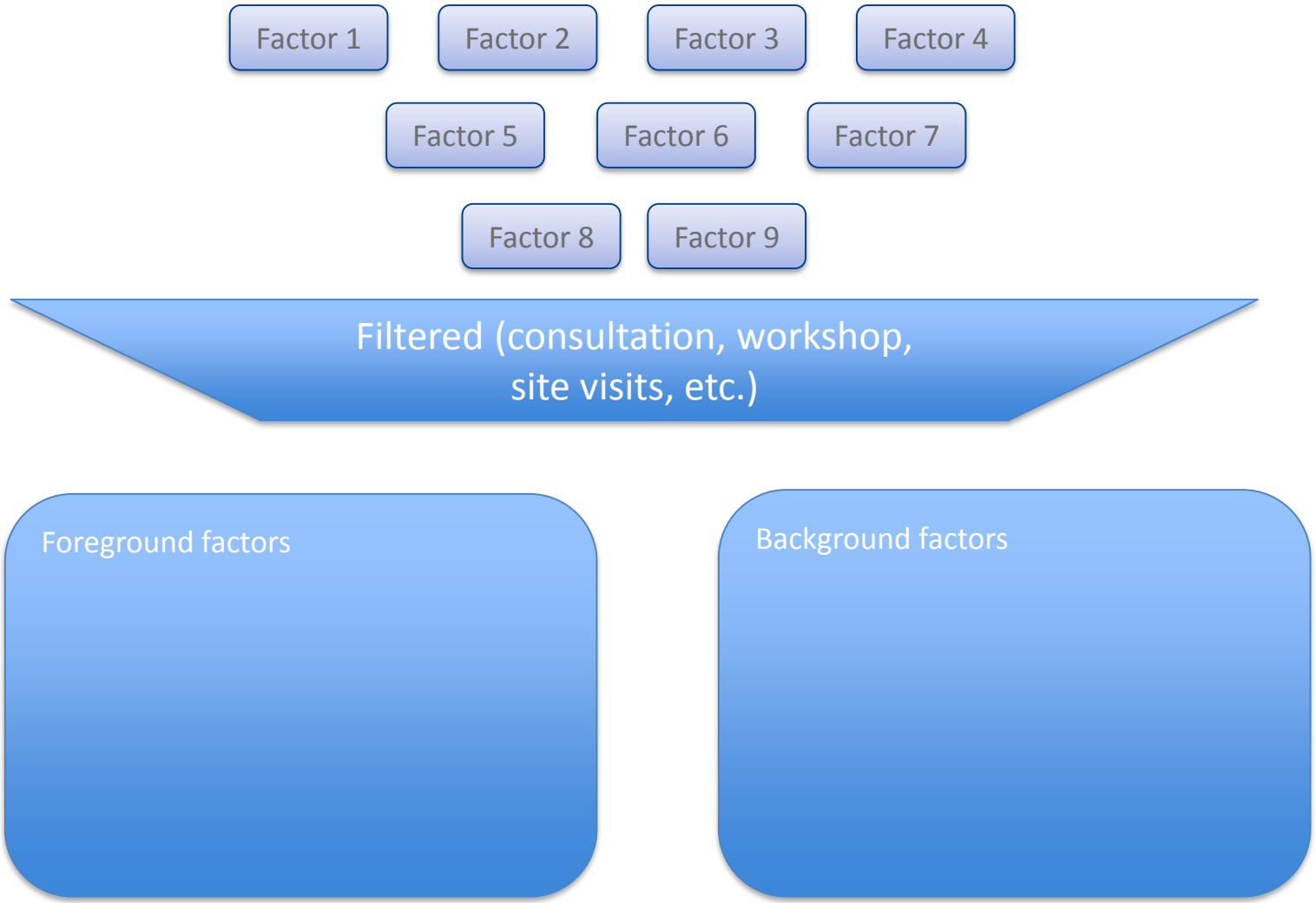
Workflow:

- 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



Scenario definition in Vista



Pe-tactical layer – Pax itinerarie

Schedules

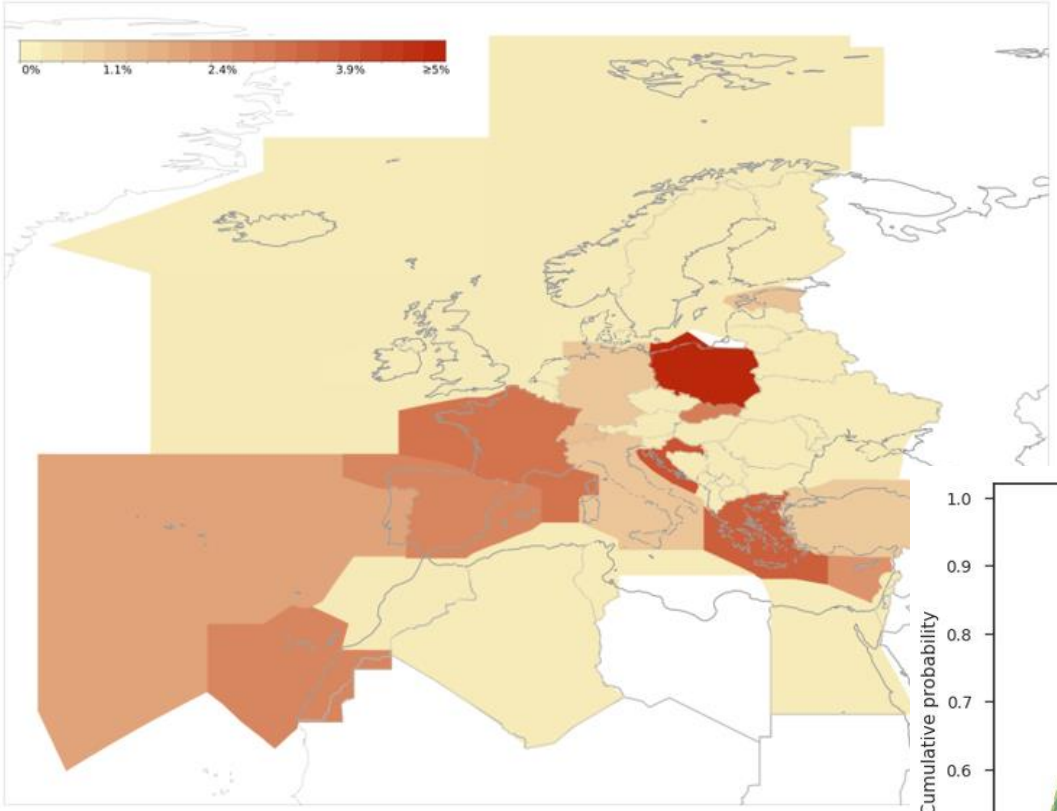
Fid	From	To	SOBT	SIBT	Capacity	…
F_{AD1}	A	D	9:00	10:30	120	
F_{AD2}	A	D	10:45	12:20	240	
F_{AD3}	A	D	10:50	12:20	120	
F_{CD1}	C	D	8:30	12:00	70	
…						

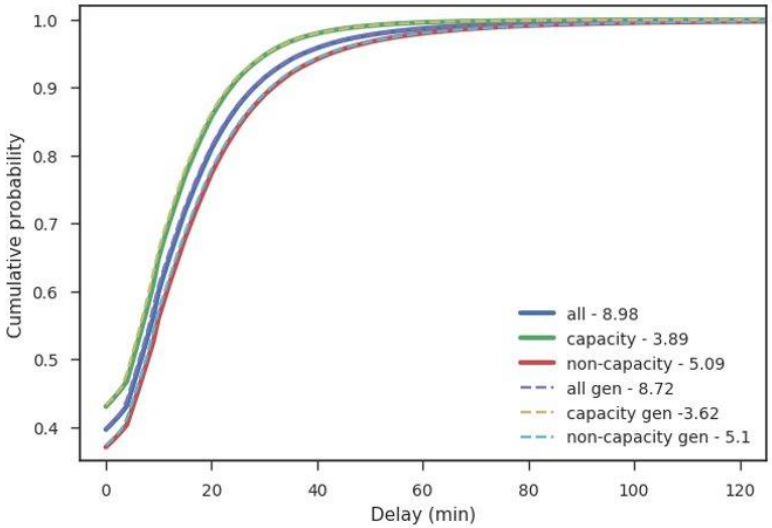
Passenger flows

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	$F_{BC1} – F_{CD2}$	
…				

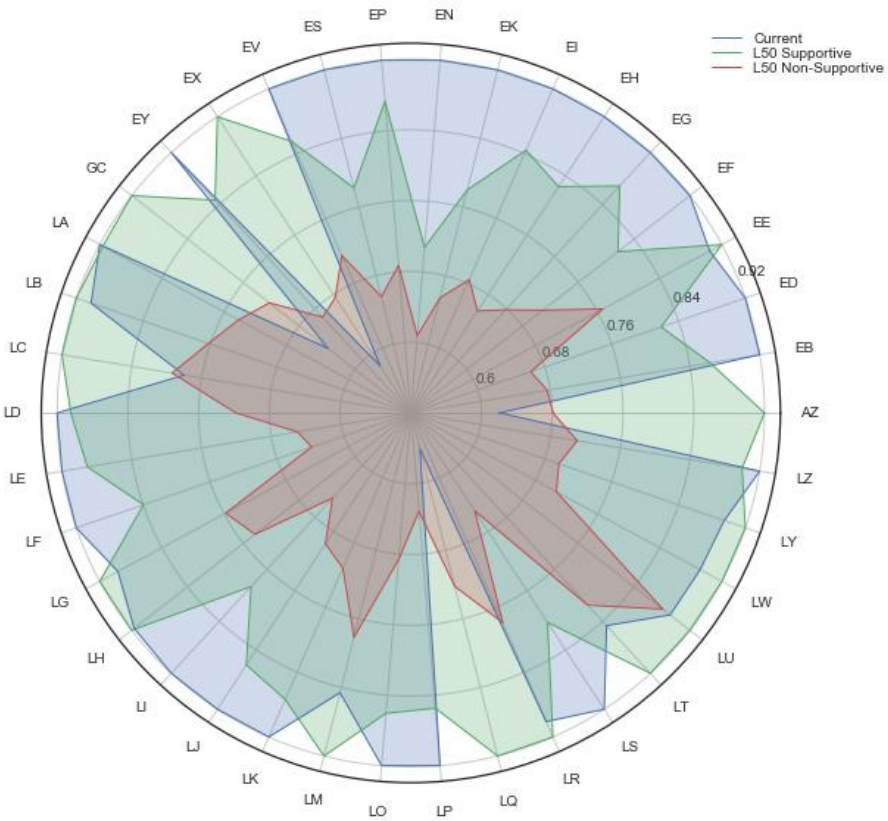
Pe-tactical layer – ATFM regulations





Pre-tactical metrics

ANSPs revenues



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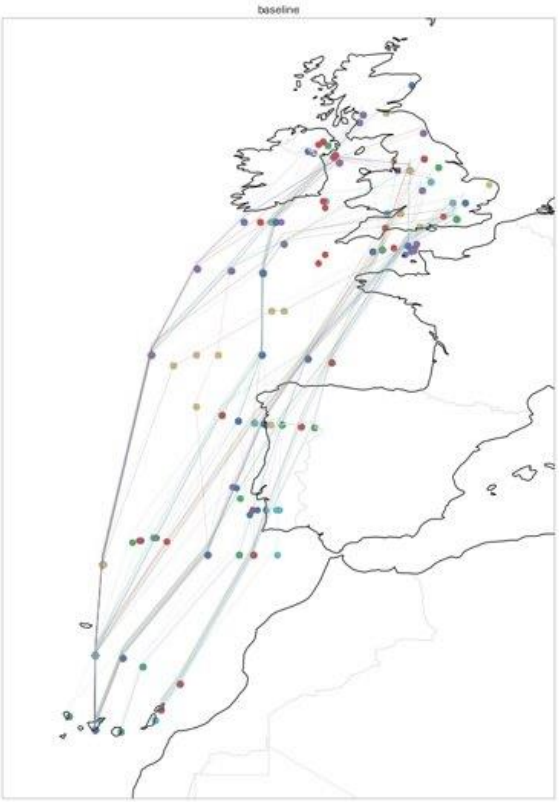
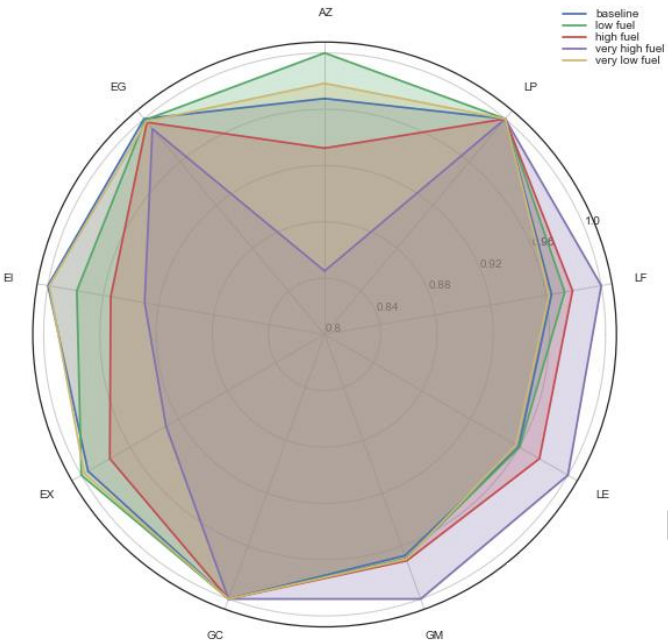
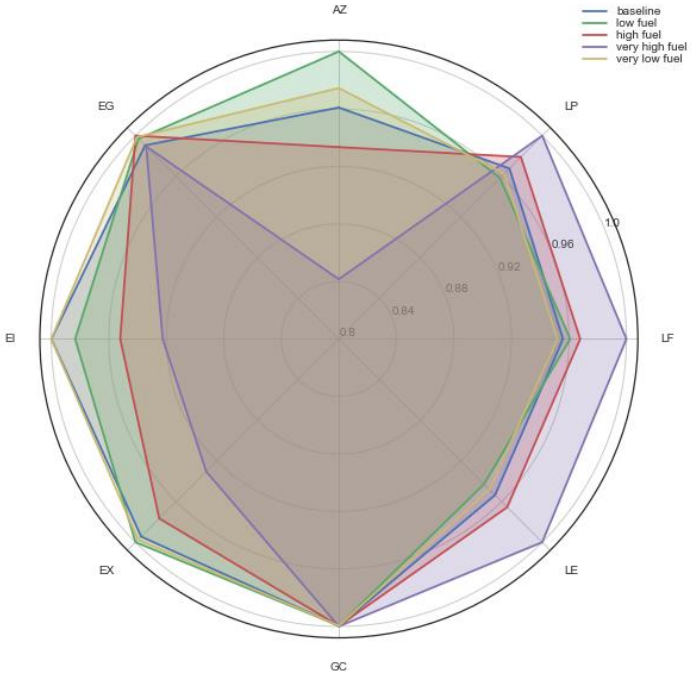


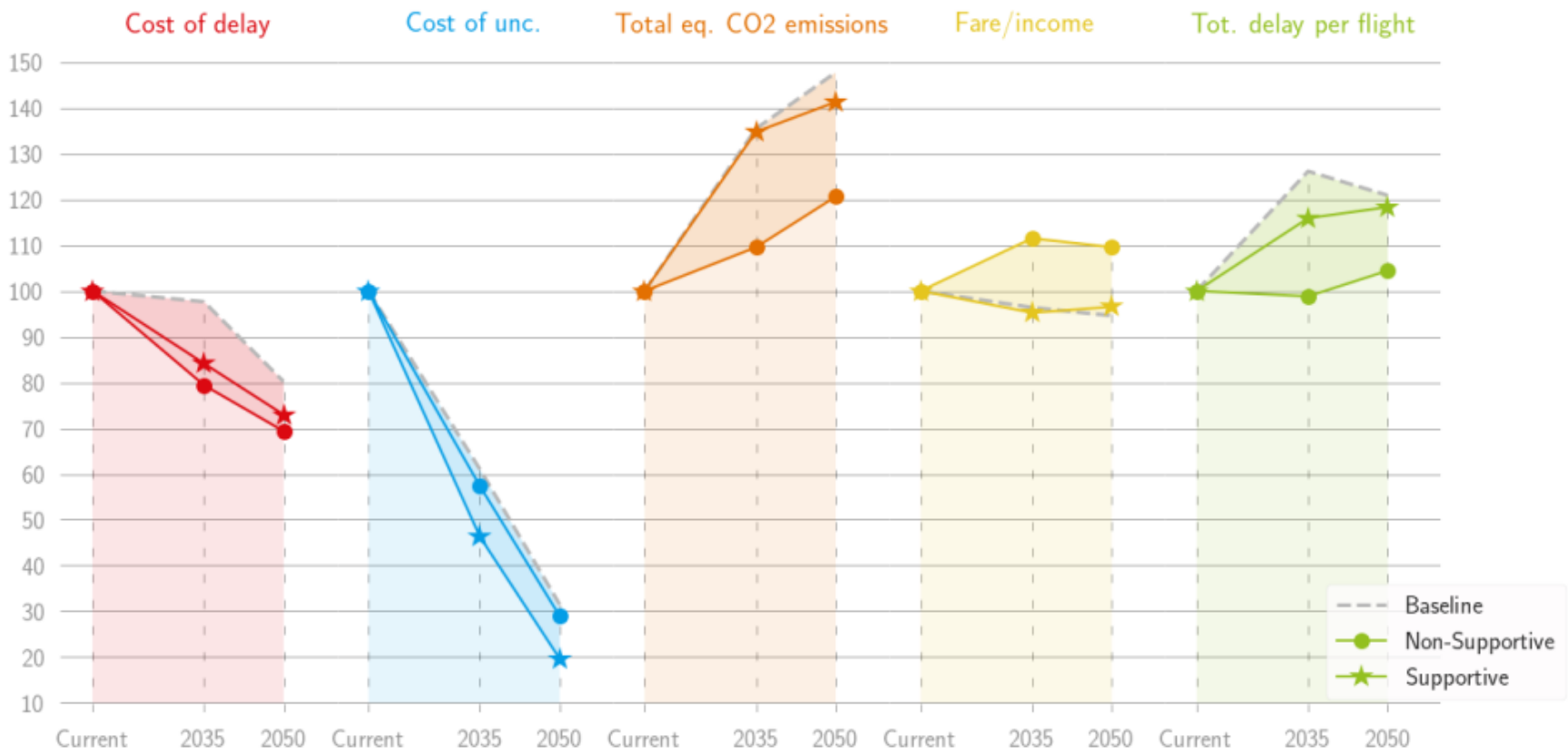
Demand variation



Revenue variation



Strategic metrics



Pre-tactical metrics

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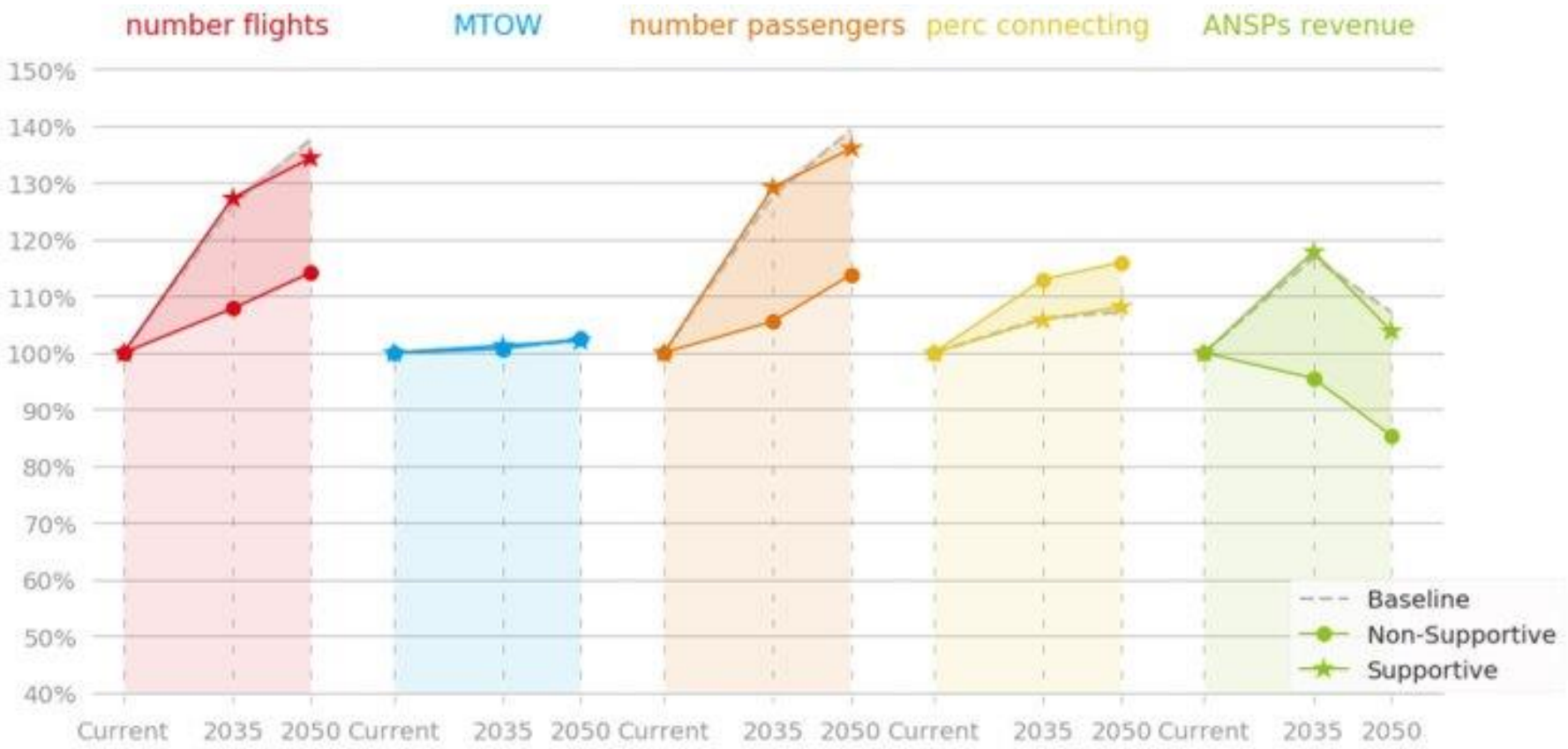

Buffer size vs flight plan distance