Understanding KPI trade-offs - key challenges of modelling architectures and data acquisition

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Understanding KPI trade-offs

Key challenges of modelling architectures and data acquisition

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EASA, Cologne

SESAR JOINT UNDERTAKING

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Vista - 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.

Vista - 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.

Vista – How to produce a trade-off analysis

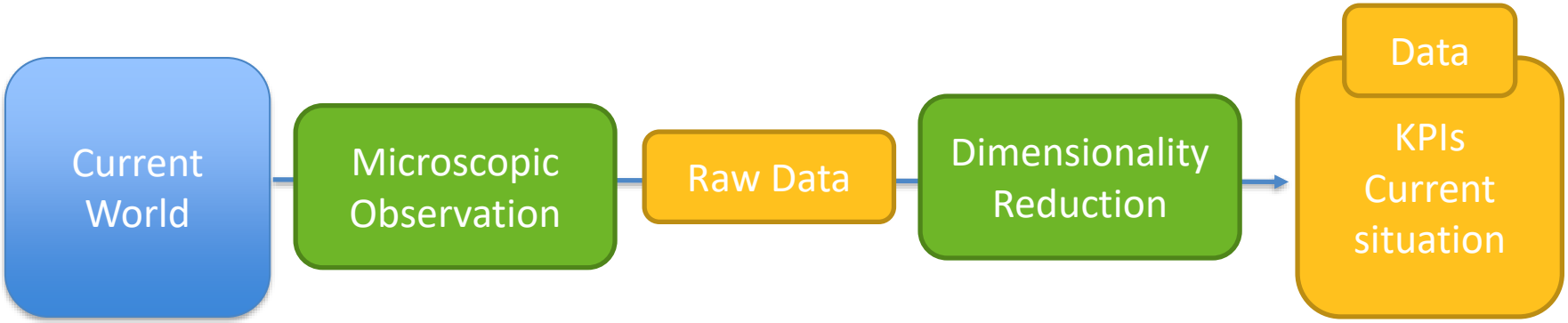
Trade-off: inverse relationship between two indicators. When one improves, the other worsens.

Two types of trade-off:

- Correlation with time series:
    - Past time-series: usually not enough data for macro indicators
    - Future time-series: need a model
- Causal relationship: with a model.

What about a change in the system? How to compute the relationship between metrics in totally new environment?

How to produce quantitative knowledge for the future?



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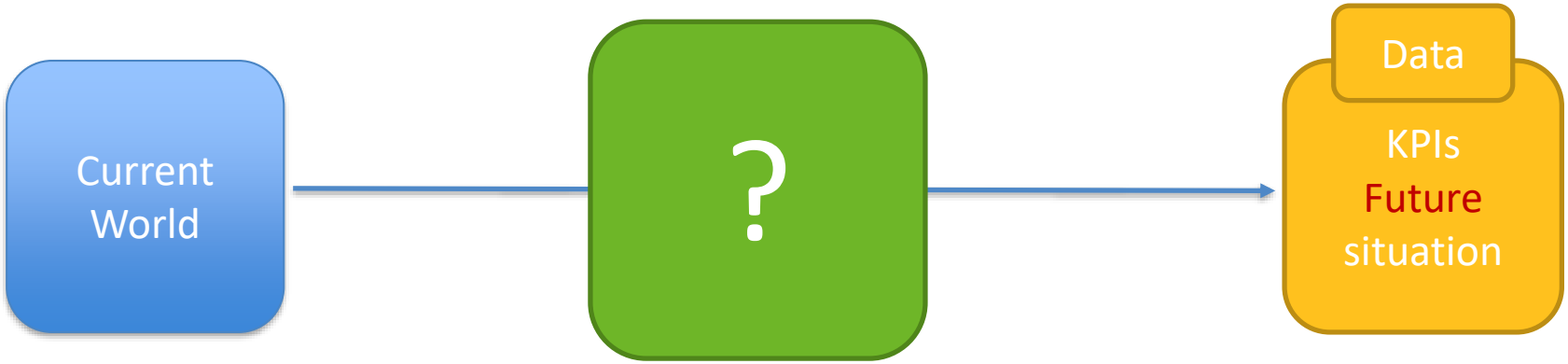

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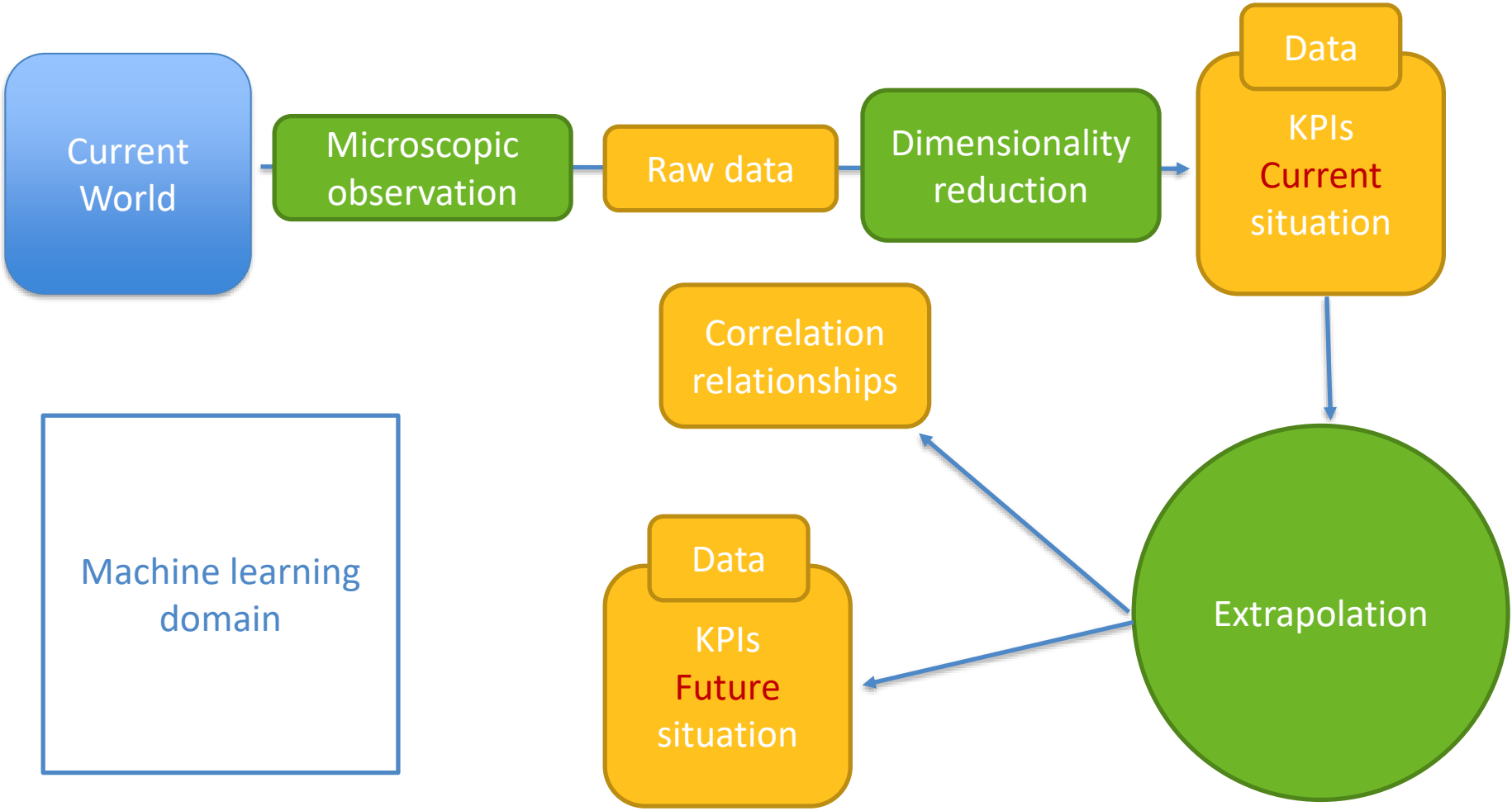

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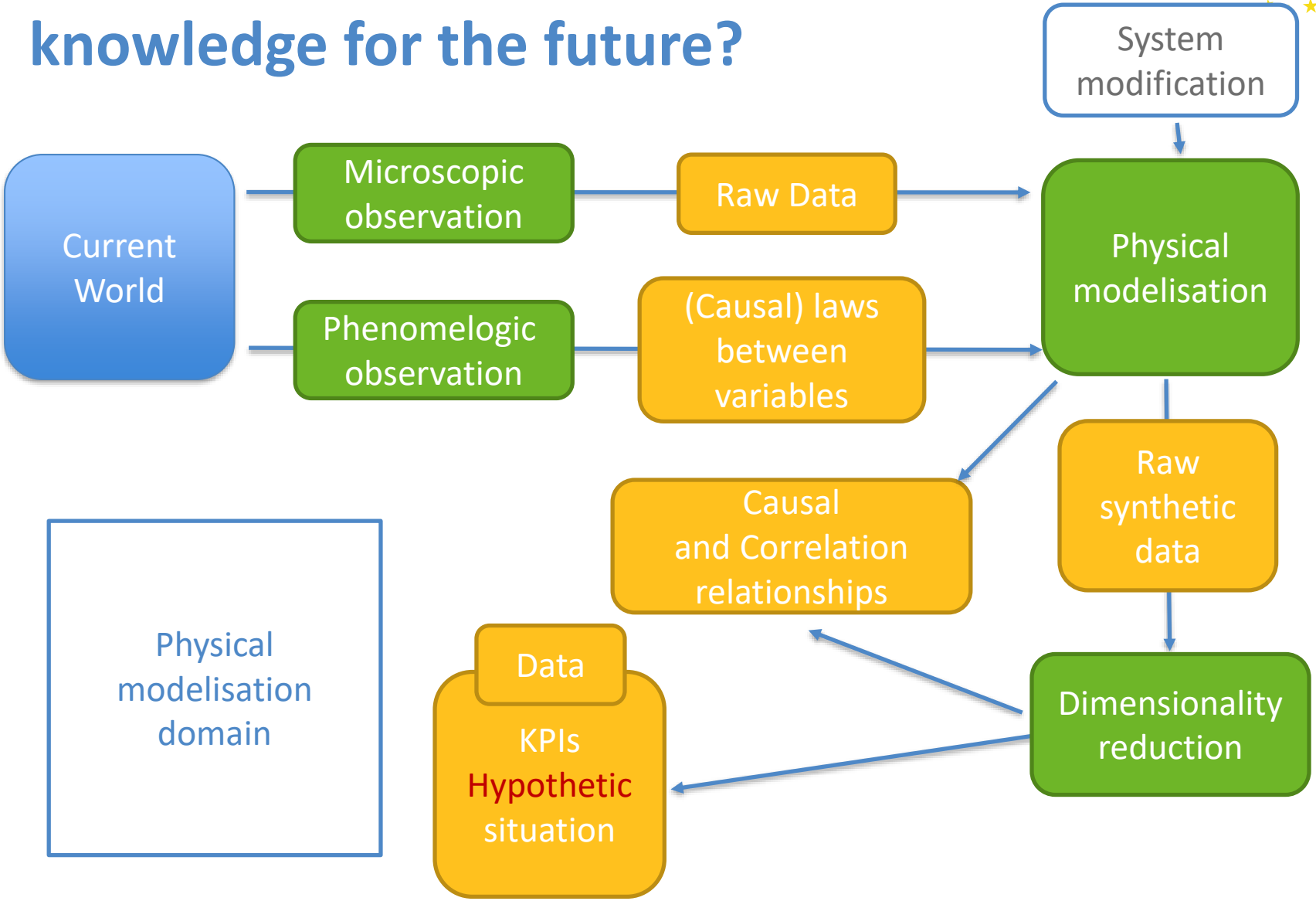


Challenges in data acquisition in Vista

'**Raw data**':

- Format (and sometimes content!) not consistent over time and over bodies providing them
- Openness: rarely open, usually expensive, or simply hard to get with very convoluted rules.
- Quality: individual projects redoing over and over the same quality checks on the same datasets.
- As many procedure to acquire data as number of datasets (at least): financial for airports, financial for airlines, financial for ANSPs, schedules, flight plans, real trajectories, itineraries, fares, etc.

'**Phenomenological laws**':

- Coming directly from theory and or other machine learning studies.
- Assumptions sometimes not clear, validity subject to other checks on the system
- Can be completely wrong, whereas raw data can lie only where recorded incorrectly!

Scenario definition in Vista

Vista is a **'what-if' scenario analyser.** Answers to:

- *What happens if I do this in the system?*

And not:

- *What will happen in 2035 or 2050?*

==> Scenario definition, where different external factors can influence the system. Aim is **not** to compute the likelihood of a given scenario.

Factors are 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'

Use in particular the different targets and high level views of SESAR to have a idea of the possible values of the parameters.

Scenario definition in Vista

Regulatory factors:

- Regulations affecting gate-to-gate phase
  - SESAR development and integration (RSI): e.g., SES, Common projects.
  - Performance based regulations (RPB): e.g, Performance review body
  - ANSP requirements (RAR): e.g., Common requirements
- Regulations affecting airports
  - Airport demand (RAD): e.g., slots
  - Airport processes (RAP): e.g., ground handling market
  - Airport access / egress (RAA): e.g., airport access policies
- Regulations affecting other areas
  - Other regulations (ROR): e.g, passenger provision schemes, emission schemes

22 factors in total

Some of the regulatory factors are enablers of business factors

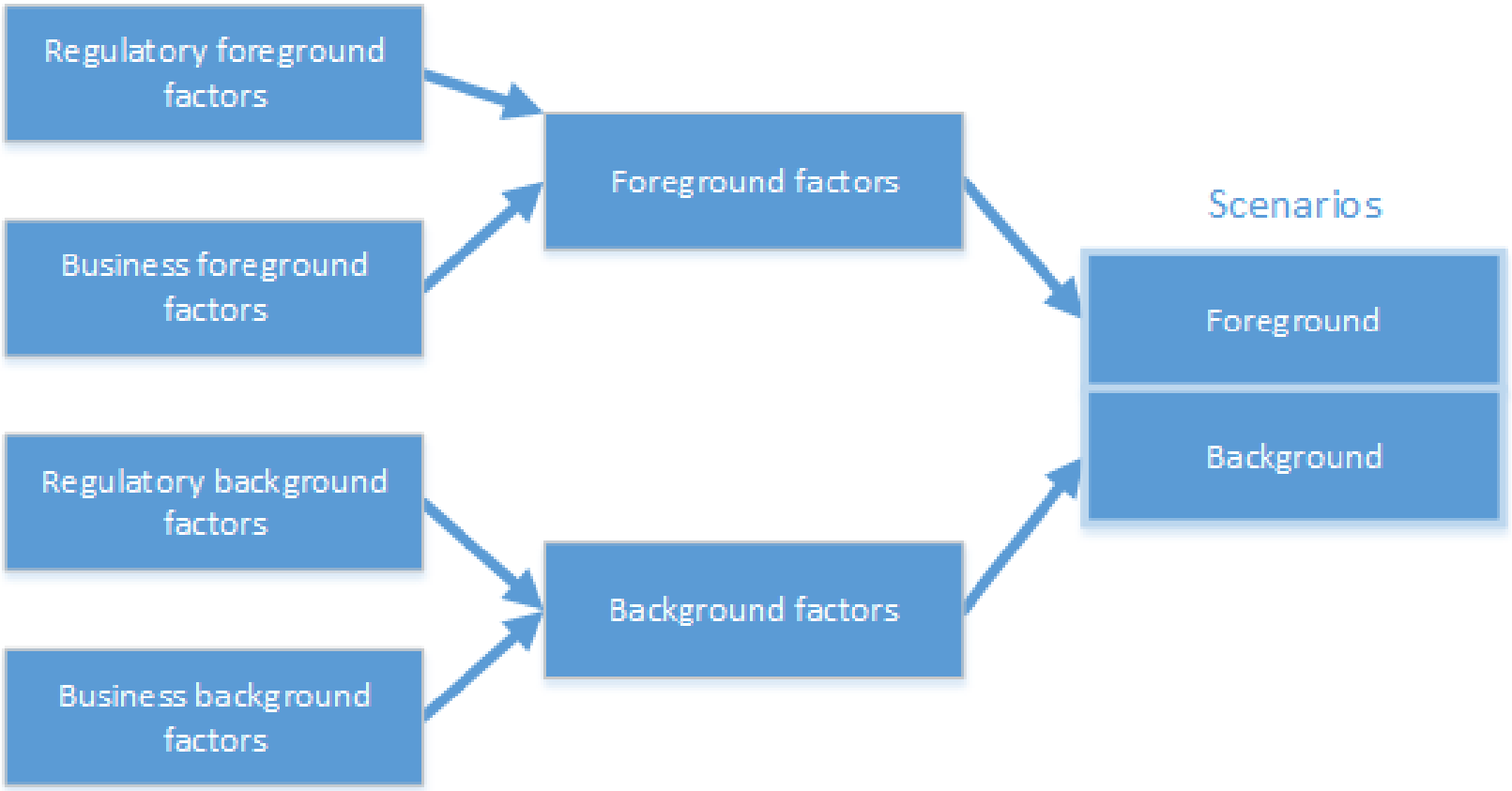
Scenario definition in Vista

Business factors

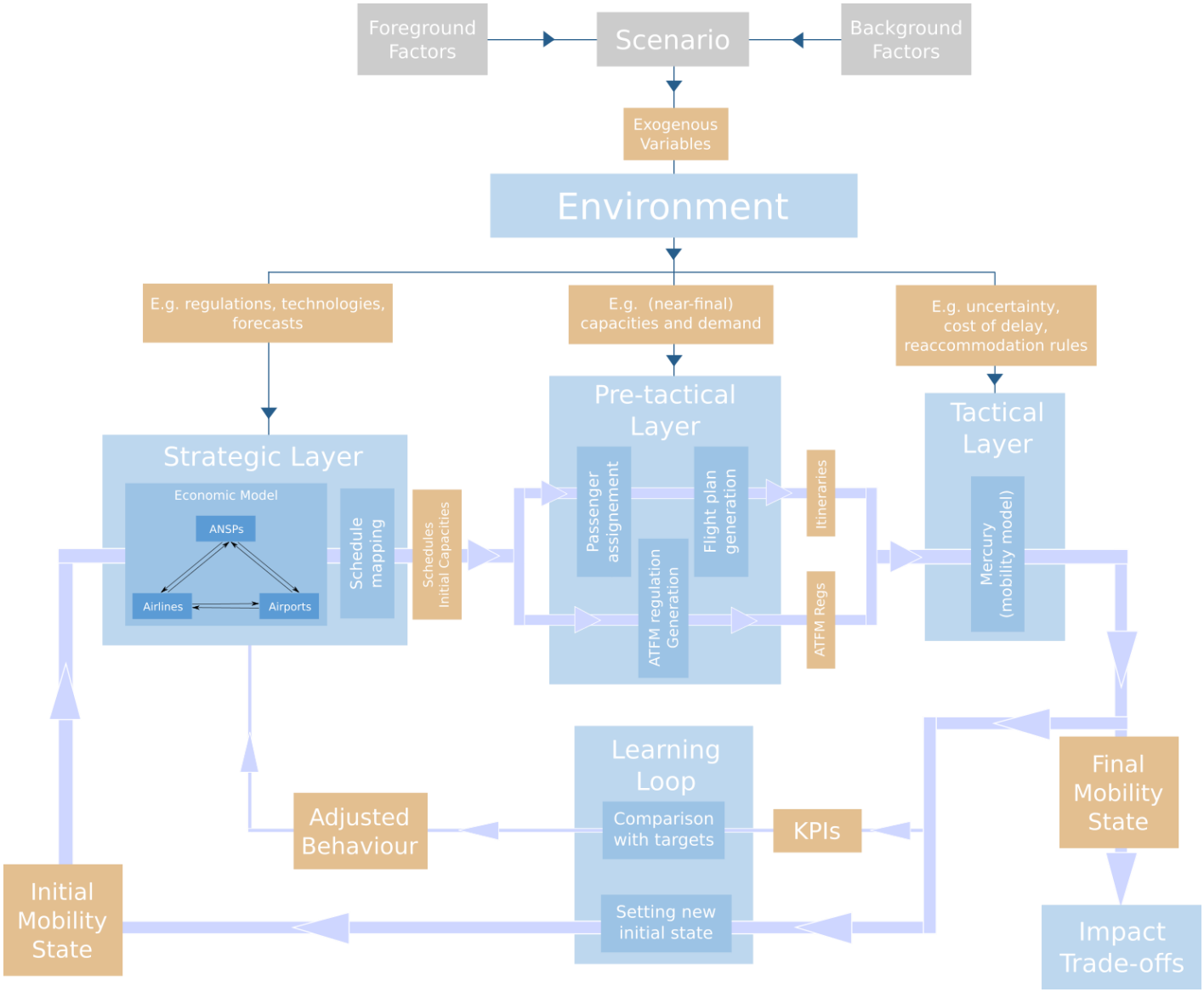
- Factors affecting gate-to-gate phase
  - SESAR operational changes (BTS): e.g., Free-routing
  - Other operational and technical changes (BTO): e.g., Passenger reaccomodation tools
- Airport processes and accessibility
  - Airport access / egress (BAA): e.g., multimodality
  - Airport processes (BAP): e.g., self-processing
- Demand and other economic factors
  - Demand evolution (BED): e.g., economic development
  - Other economic factors (BEO): e.g., fuel price

37 factors in total

Scenario definition in Vista



Multi-layered architecture of Vista



Multi-layered architecture of Vista

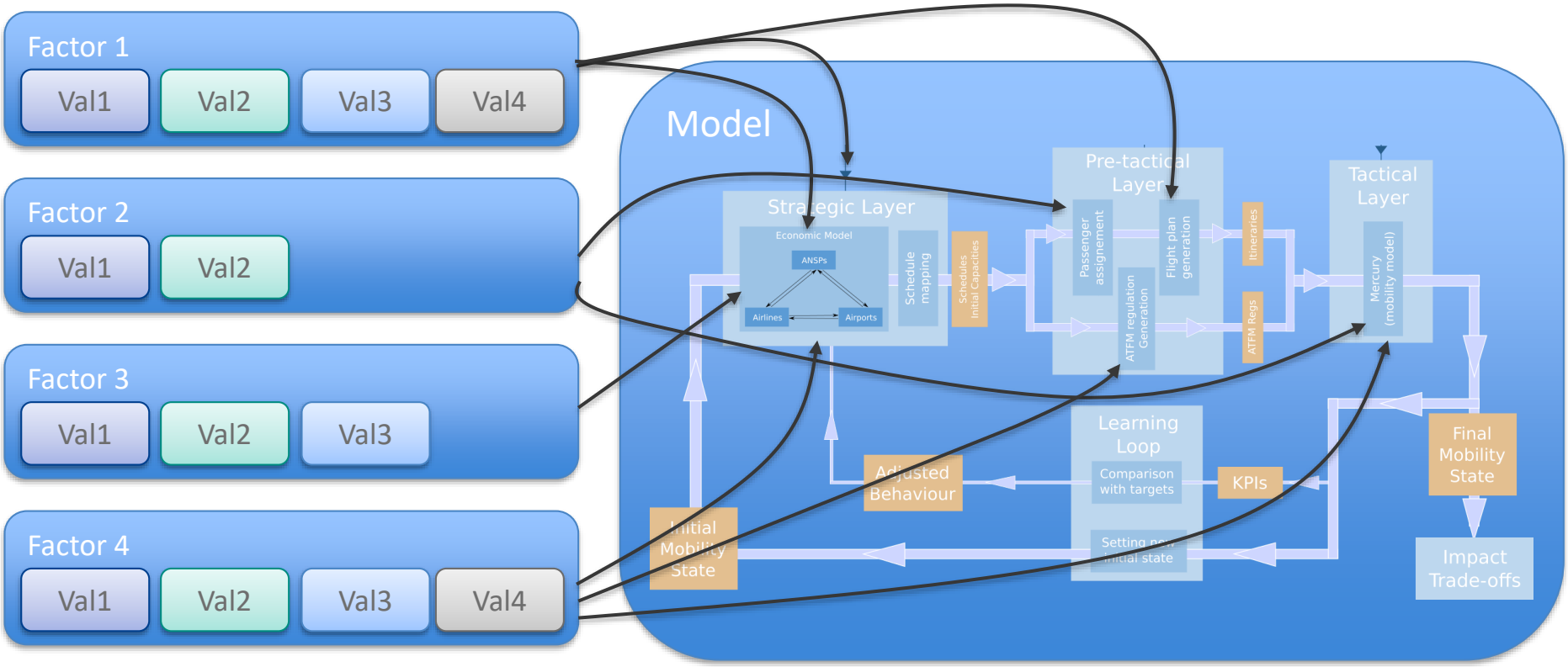
Three main layers correspond to:

- Strategic:
  - Producing main flows in Europe based on macro-economic variables
- Pre-tactical:
  - Producing flights plans (and disruptions).
- Tactical:
  - Simulating a real day of operation with microscopic pax tracking.

Transversal layers consist of stakeholders:

- 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 NOx and CO2

Multi-layered architecture of Vista



Data management in a multi-layered architecture

Data need to be:

- Consistent among layers,
- Easily accessible (for computing power),
- Traceable between the different blocks

==> All data are based on a single database, accessible to all the blocks. This ensures consistency, traceability and reproducibility.

More challenges come with this data architecture:

- How to enforce consistency between input and output of two block?
- How to take into account the multiple runs of the stochastic layers?
- What is the right balance between flexibility (NoSQL) and consistency (SQL)?

==> Now use a MySQL database.

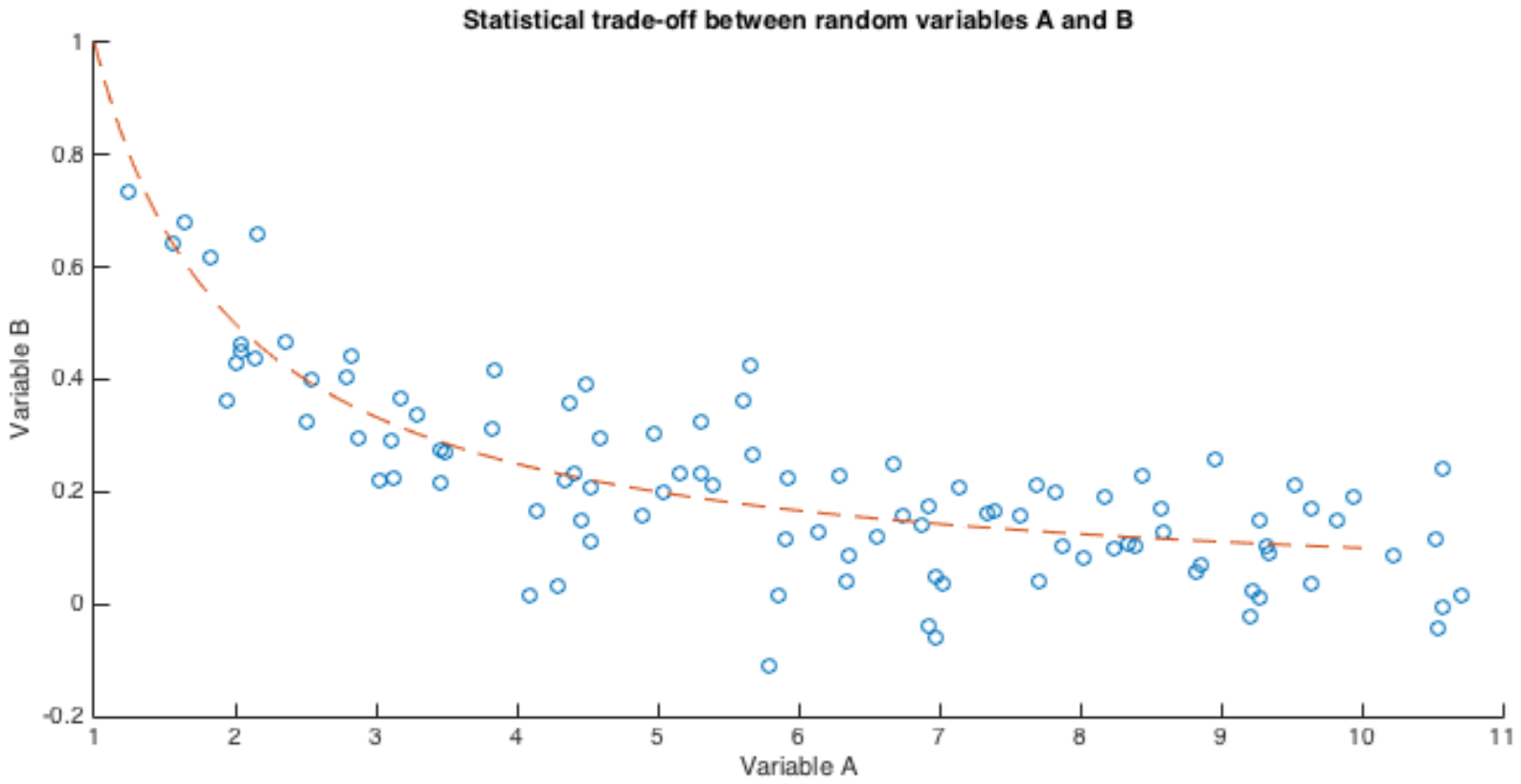
Calibrating the model

Calibration is done in several steps:

- **Direct calibration**:
  - Extract some values from historical data (including literature) and set them directly in the model:
    - E.g.: price elasticity for passengers
  - Put some phenomenological relationships obtained otherwise:
    - E.g.: cost of delay for airline as a function of delay.
- **Indirect calibration**:
  - Supervised learning: a parameter is swept (in a smart way) in order for another one to reach a value extracted from data.
    - E.g.: cost of capital for airlines is calibrated to have the historical flows of passengers between airports.
  - Reinforcement learning: for instance, agents in the model modify their behaviour in order to be self-consistent across layers.
    - E.g.: cost of delay used to compute main flows should be the same as the actual cost of delay during the tactical phase.

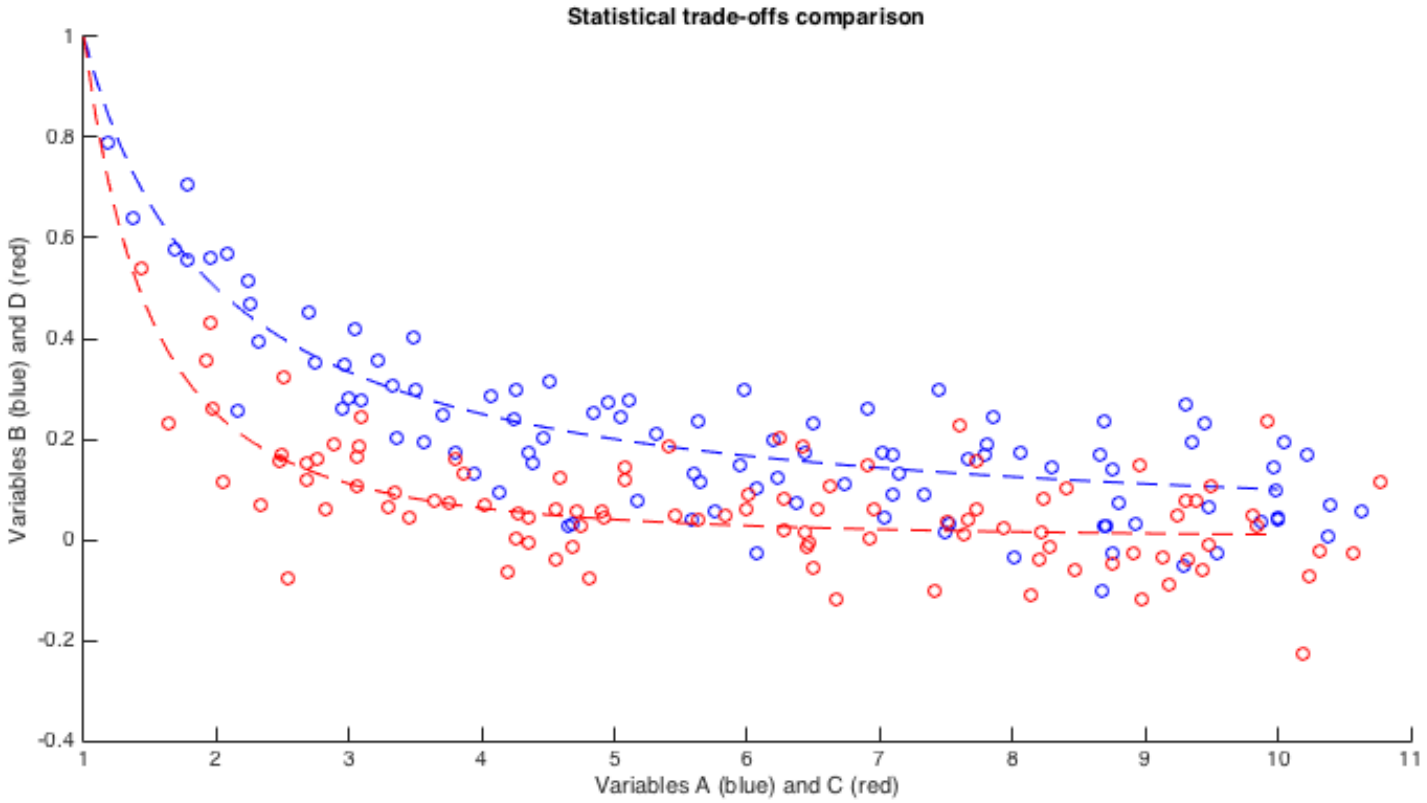
Studying the output: how to recognise a trade-off?

- Stochastic context, correlative trade-offs



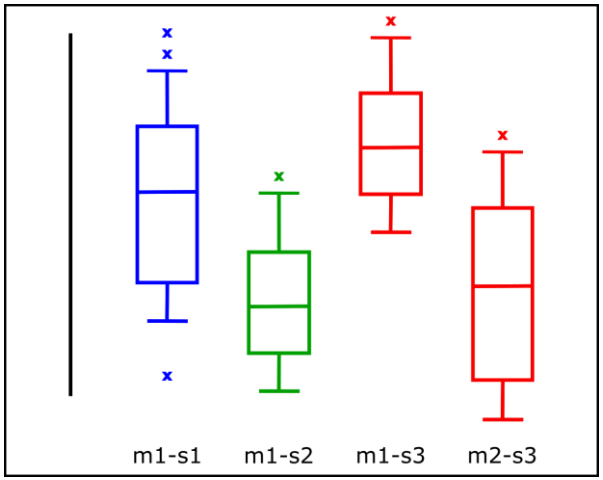
Studying the output: how to recognise a trade-off?

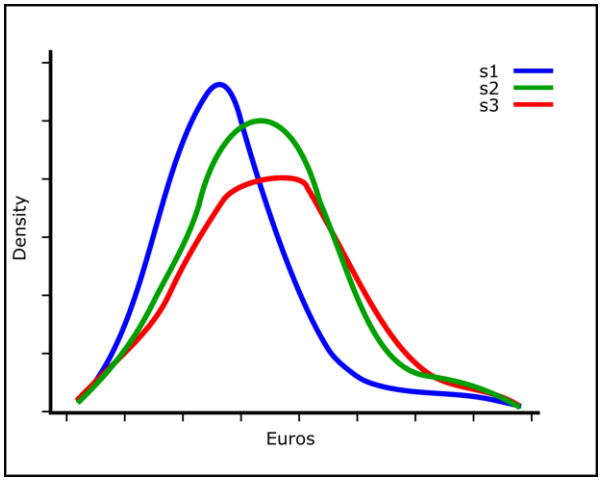
- Stochastic context, trade-offs comparison

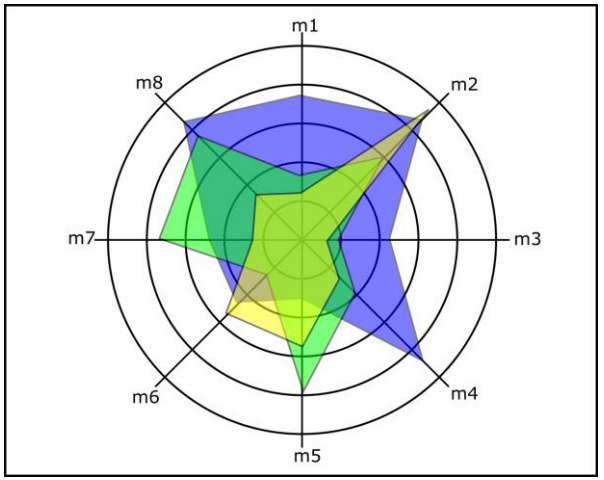


Studying the output: how to recognise a trade-off?

- Deterministic trade-off: dependence of distribution over deterministic parameter

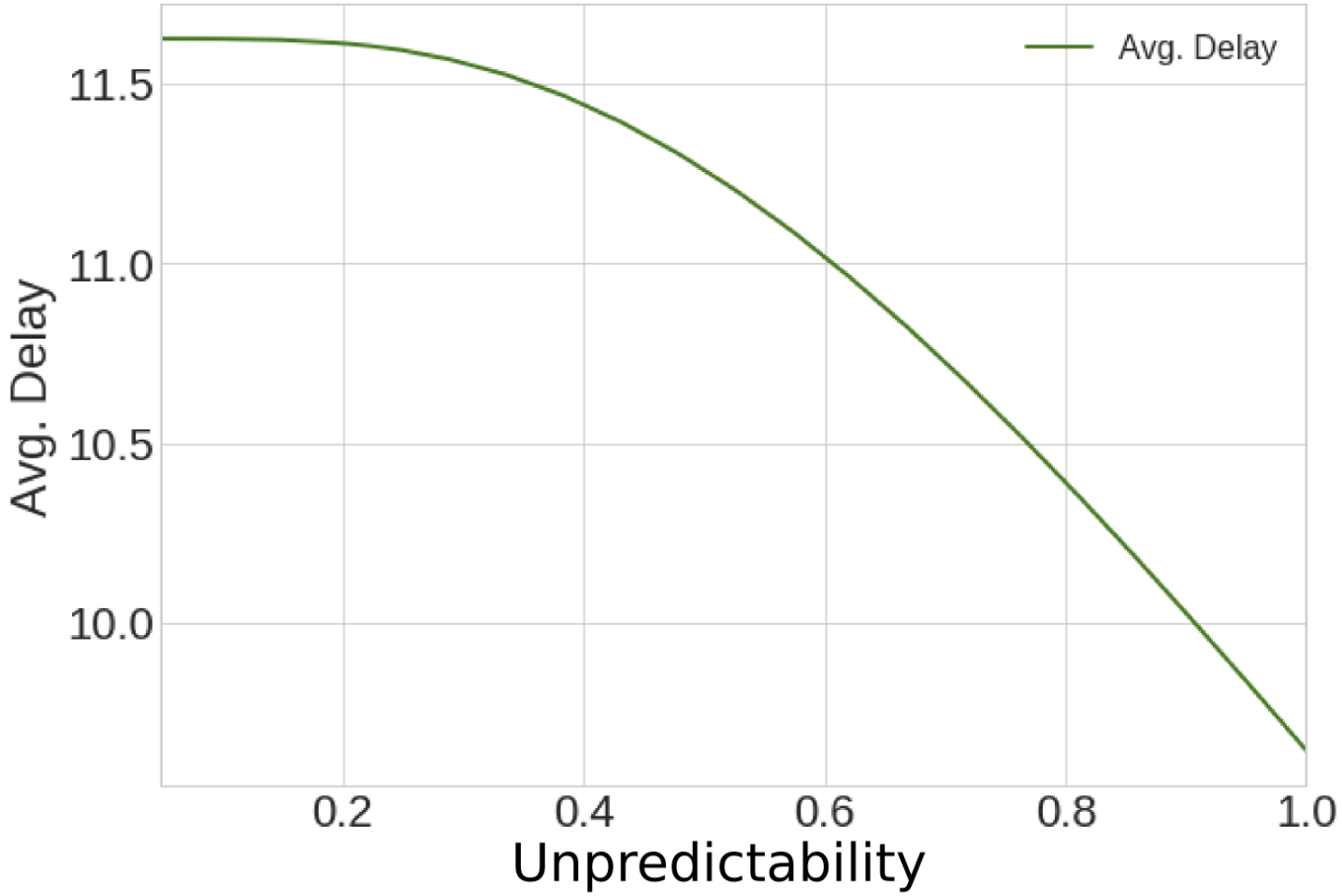






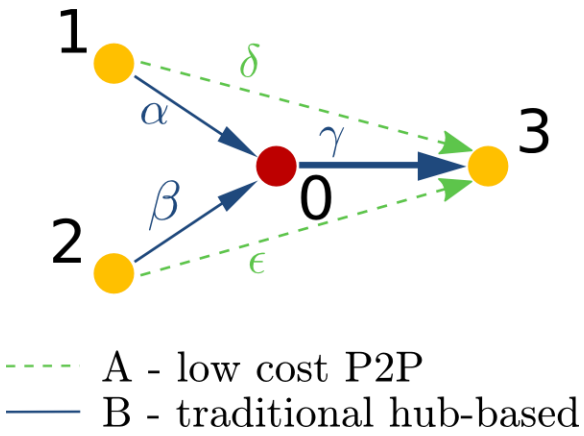
Trade-off example: predictability vs punctuality

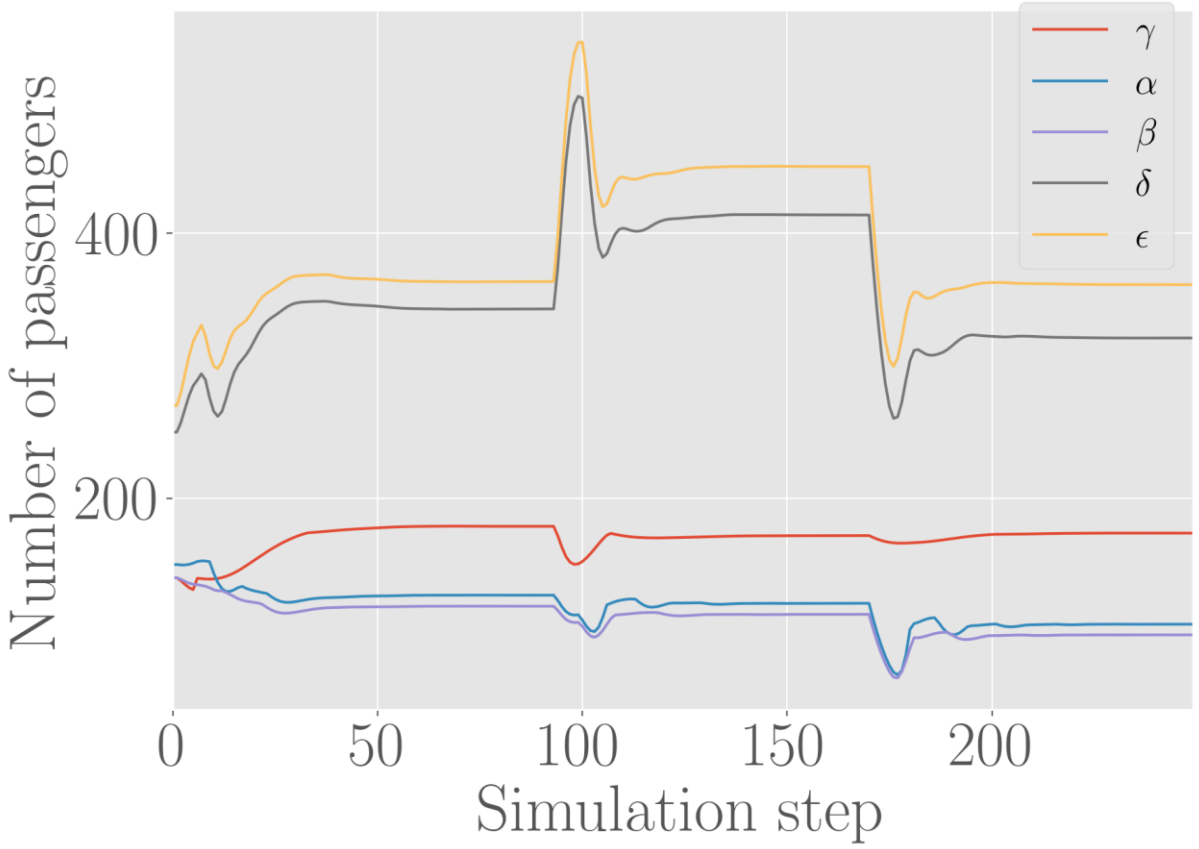
- One airport, unpredictability of departure delay is changed artificially



Trade-off example: LLC vs trad

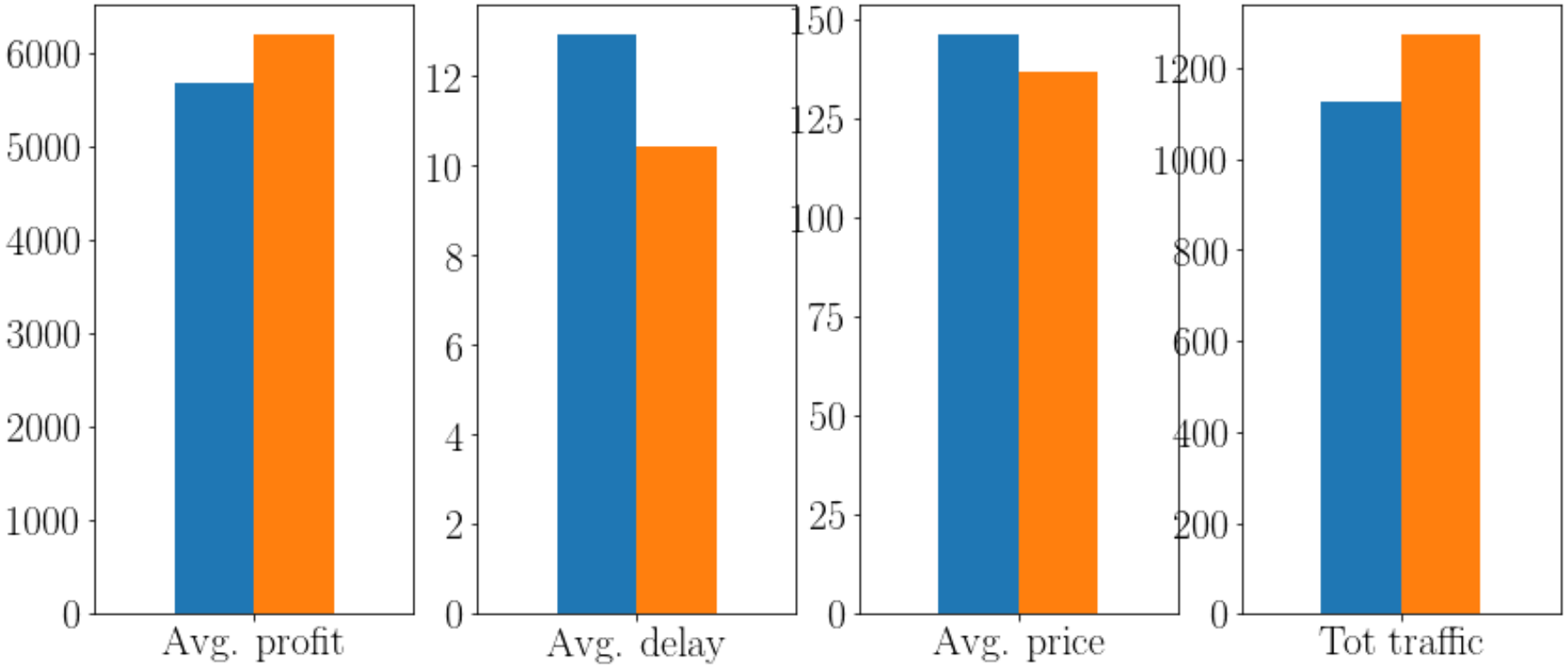
- Simplified setup: four airports, two airlines LLC/trad, capacity increase of airport 3





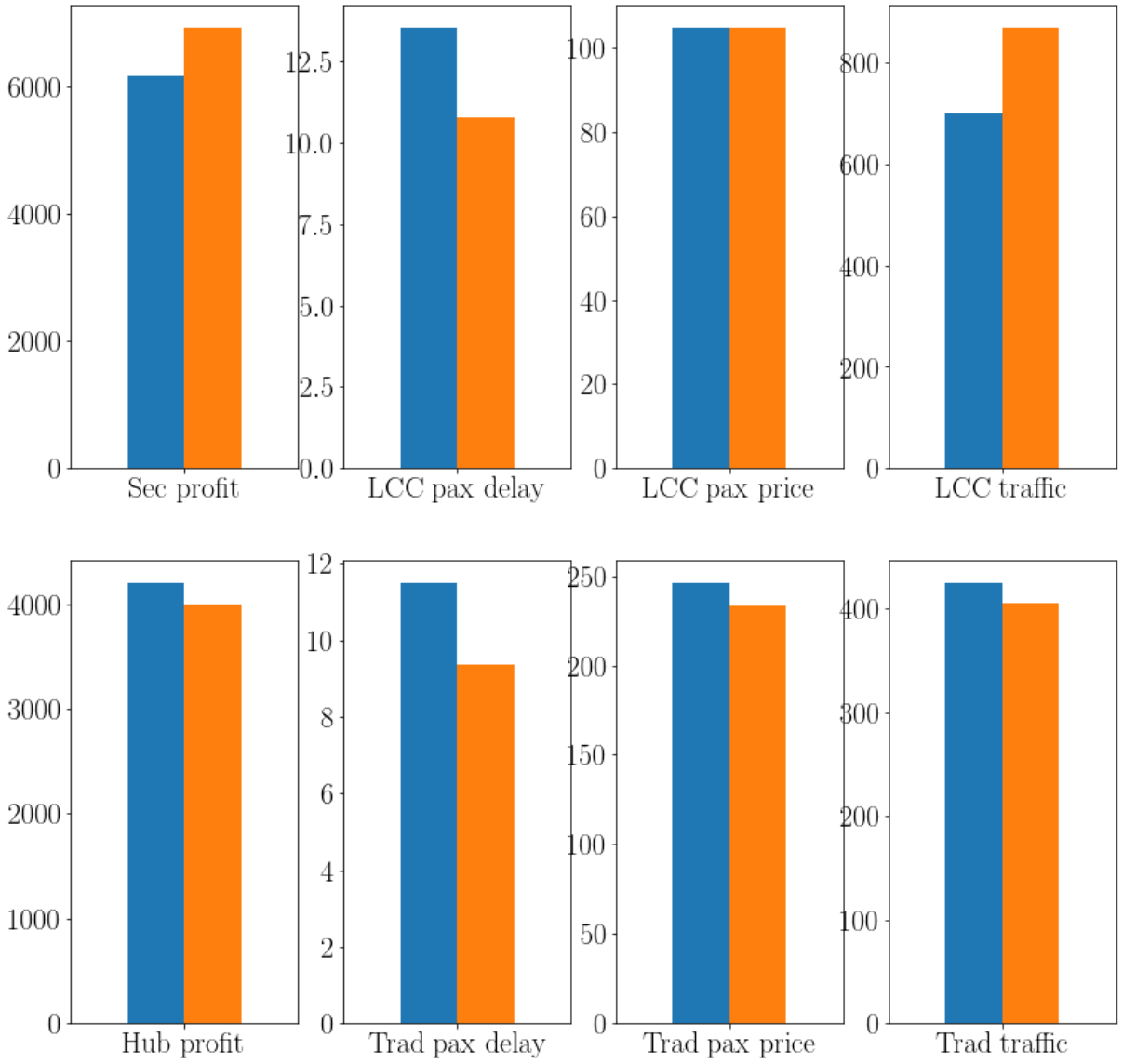
Trade-off example: LLC vs trad

- On average, everyone is better off after the capacity increase



Trade-off example: LLC vs trad

- But some agents are actually losing from the capacity increase!



Conclusions

- Vista aims at understanding the trade-offs (or synergies) between KPIs in (current and) the future (2035 & 2050) air transportation world.
- Requires forecasting the values of the KPIs, and also their relationships:
    - Either by pure machine learning.
    - Or by injecting other phenomenological laws into the model.
- Vista is based on a multi-layered architecture requiring very diverse types of data as input.
- Additionally, the different layers of the model need to communicate smoothly and reliably, thus requiring a central data repository.
- Calibration (or training) is a main issue in this type of model and requires several steps involving data reduction and internal optimisation.
- The trade-off analysis requires different techniques, including statistical regressions, and also careful data aggregation. Different tools can be used to help choose the best situation, including Pareto analysis etc.
- Trade-offs can appear between different types of stakeholders, among different actors of the same type, among periods, etc.

Vista

Thank you

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