Trajectory prediction to assess ATM performance: Challenges and limitations identified in SESAR ER project APACHE

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Thematic Challenge 2: Data-driven trajectory prediction
Castelldefels, Barcelona. Nov 6th 2018
APACHE Doc: DIS_WP6-16

Founding Members

EUROPEAN UNION EUROCONTROL

Introduction

The APACHE Project

Assessment of Performance in current ATM operations and of new Concepts of operations for its Holistic Enhancement

- SESAR Exploratory Research (ER) Project
- Topic ER-11-2015 (ATM performance)
- Grant Agreement: 699338
- 9th May 2016 – 8th May 2018

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

ALG TRANSPORTATION INFRASTRUCTURE & LOGISTICS

DIVISION OF AIRPORTS AND AIR TRAFFIC SAFETY
FACULTY OF TRANSPORT AND TRAFFIC ENGINEERING
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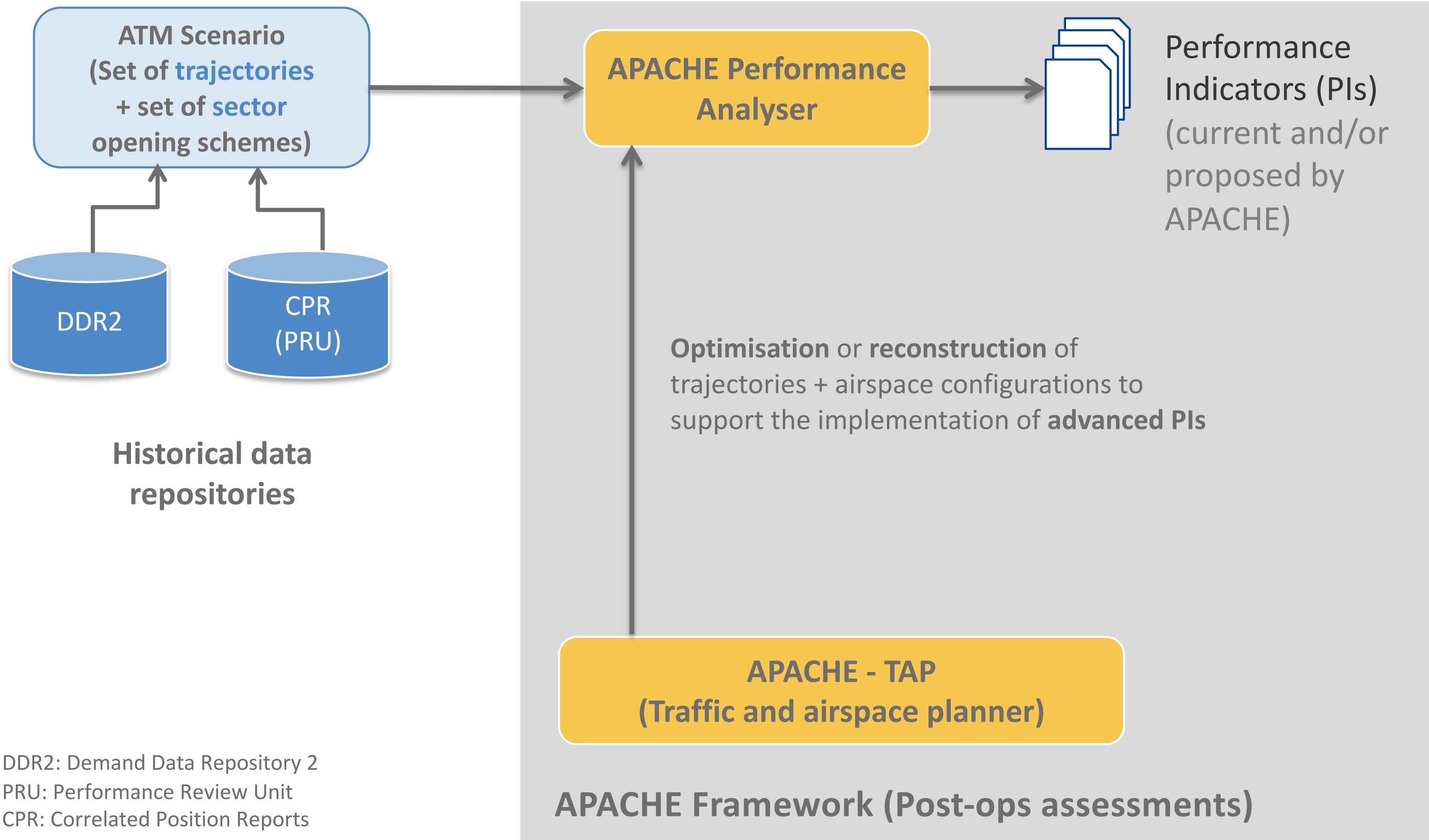
Objectives of the APACHE project

- Propose a new framework to assess European ATM performance based on **simulation** and **optimisation** tools.
- **Fill some gaps in state-of-the-art** methodologies for ATM performance assessment aiming to better capture and understand:
  - the impact of ATM operations :
    - considering a **wide range of KPAs***
    - proposing a set of **new** or **enhanced PIs**
    - focusing in current AND future SESAR 2020 **ConOps** (SESAR solutions)
  - the **interdependencies** and **trade-offs** among different KPAs
  - the theoretical **limits** for certain KPAs.

(*) Equity, Capacity, AU Cost-efficiency, ANSP Cost-efficiency, Environment, Flexibility and Safety.

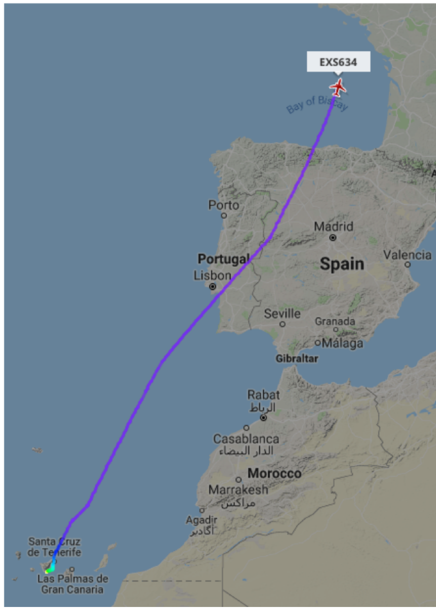
ATM: Air traffic management – KPA: Key performance area – PI: PI: Performance indicator –
ATS: Air traffic services – AU: Airspace User – ANSP: Air navigation service provider

APACHE Framework (Post-ops)



DDR2: Demand Data Repository 2
PRU: Performance Review Unit
CPR: Correlated Position Reports

Trajectory Prediction in APACHE



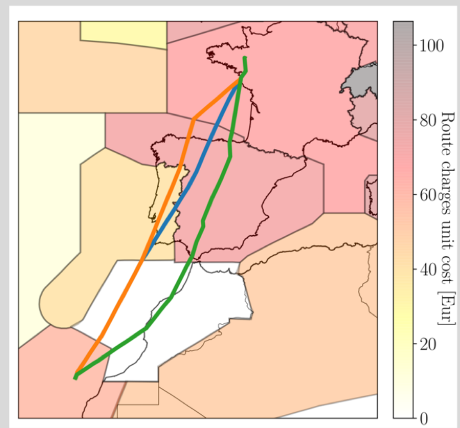
Historical (4D) Trajectory

TP to reconstruct the trajectory and estimate trip **fuel** and **cost**

TP/optimisator to generate the optimal trajectory baseline

APACHE Performance Analyser

Advanced ENV and AU-CE PIs



Optimal (4D) trajectory baselines

- min *Distance*
- min *Fuel*
- min *Cost* = min *(Fuel + CI·Time + Charges)*

APACHE - TAP
(Traffic and airspace planner)

APACHE Framework (Post-ops assessments)

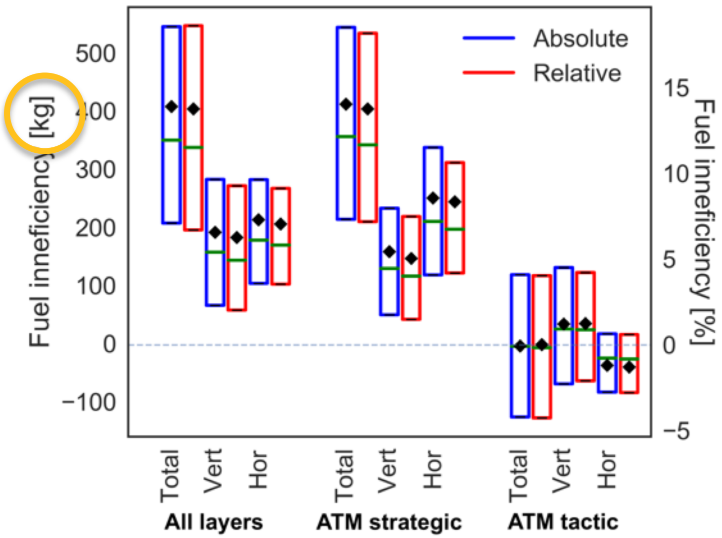
TP: Trajectory Predictor
PIs: Performance Indicators
ENV: Environmental Impact
AU-CE: Airspace User Cost-Efficiency

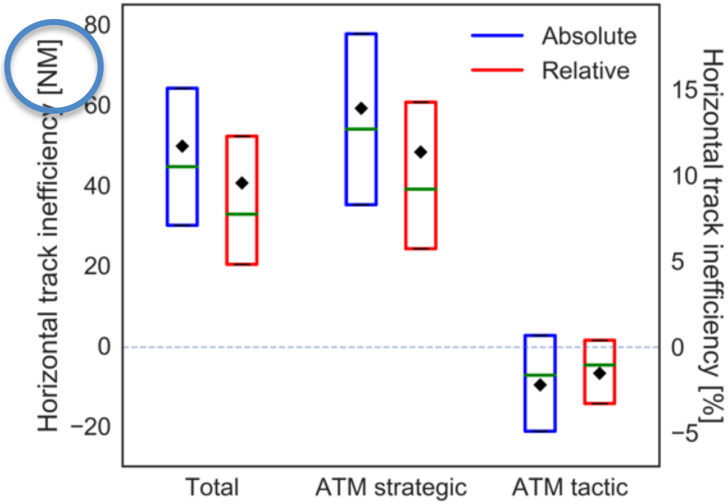
Main findings and results

Environment KPA

Main Contribution of APACHE: Optimal[1] trajectory as baseline reference to compute performance indicators (PIs)

Example: Actual and regulated trajectories crossing FABEC (Jul 28th 2016 **post-ops**)





Actual/Planned trajectory *estimated* **fuel**
minus
weather **optimal[1]** trajectory **fuel**

Actual/Planned route distance
minus
weather **optimal[1]** route distance

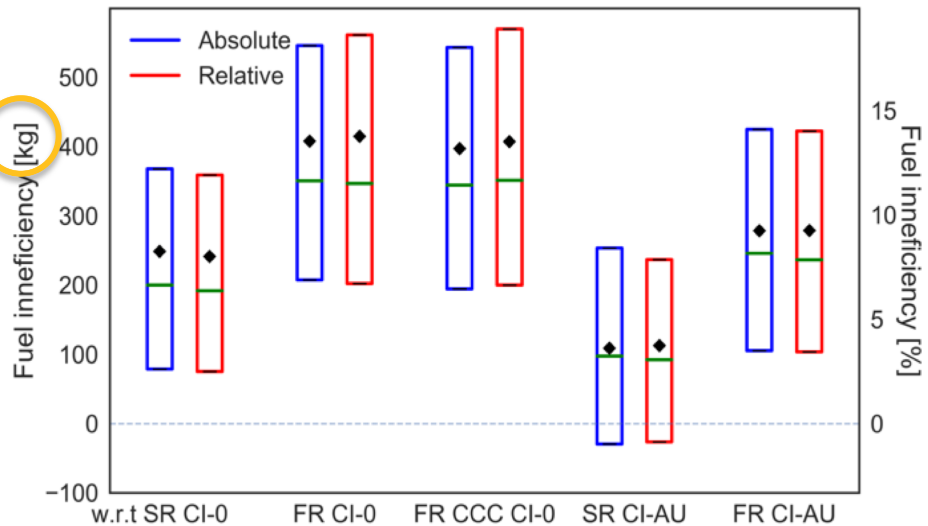
[1] Optimal baseline trajectories computed in full free-route airspace, flat-route charges scheme and maximum range operations (i.e. Cost Index = 0)

Main findings and results

Environment KPA

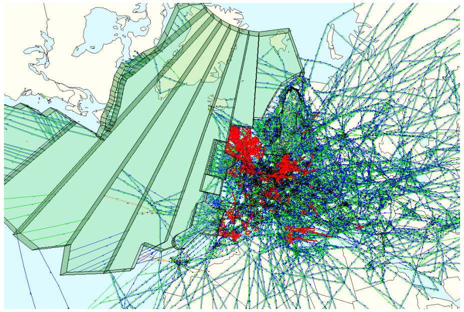
Main Contribution of APACHE: Optimal[1] trajectory as baseline reference to compute performance indicators (PIs)

Example: Actual and regulated trajectories crossing FABEC (Jul 28th 2016 **post-ops**)



Actual trajectory *estimated* **fuel** *minus* weather **optimal[1]** trajectory **fuel**

- *[1] But… what is the "best" trajectory?*
- *And what about environmental inefficiencies **due** to the Airspace User (AU)?*



[1] **Different optimal baseline trajectories computed in the following conditions:**

- **FR CI=0**: Full free route airspace and maximum range operations (Cost Index =0)
- **SR CI=0**: Current structured route airspace and maximum range operations
- **FR CCC CI=0:** Full free route airspace, continuous cruise climbs and maximum range operations
- **SR CI-AU**: Current structured route airspace and Cost Index chosen by the Airspace User
- **FR CI-AU**: Full free route airspace and Cost Index chosen by the Airspace User

Main findings and results

Environment KPA

Main Contribution of APACHE: Optimal trajectory as baseline reference to compute performance indicators (PIs)

- **Distance-based** performance indicators:
  - ✓ Easier to compute
  - X Cannot capture the inefficiencies in the vertical domain
  - X The same ground distance inefficiency could represent different air distance inefficiency and, therefore, different fuel (and CO_2) inefficiency.
- **Fuel-based** performance indicators:
  - X More difficult to compute →
    - require fuel estimation from surveillance data
    - require cost index estimation from surveillance data
  - ✓ Directly capture inefficiencies in fuel consumption and therefore CO_2.
  - ✓ Possibility to de-couple vertical and horizontal trajectory inefficiencies.

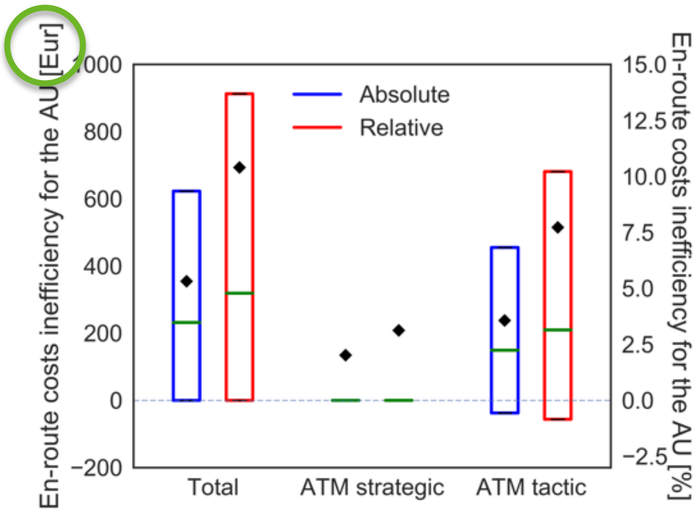
Trajectory Prediction Challenge

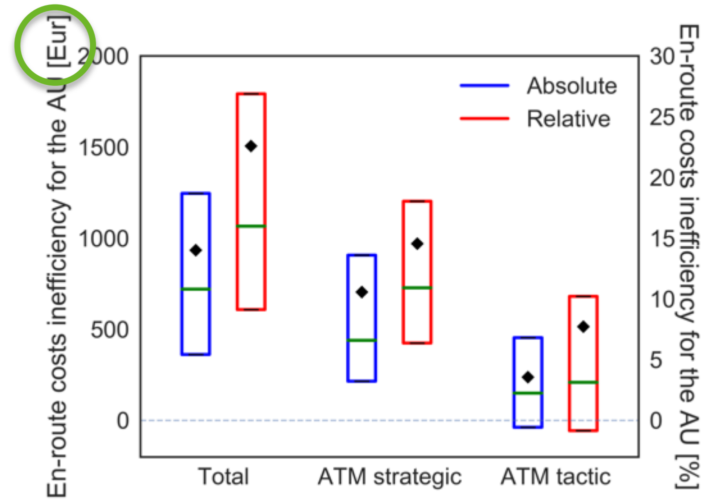
Main findings and results

AU cost-efficiency focus area

Main Contribution of APACHE: Optimal trajectory as baseline reference to compute performance indicators (PIs)

Example: Actual and regulated trajectories crossing FABEC (Jul 28th 2016 **post-ops**)





Actual trajectory *estimated* **cost**
minus
SBT *estimated* **cost** (*)

Actual trajectory *estimated* **cost**
minus
Estimated **cost** of **full free route** with *estimated* Cost Index (*)

(*) Assumptions:

- Cost of fuel: fixed fuel price for all AUs
- Tactical cost of trip time given by the Cost Index
- Cost of delay: model proposed by (Eurocontrol, 2017)

➢ *But… what is the "best" trajectory from the Airspace User (AU) point of view?*

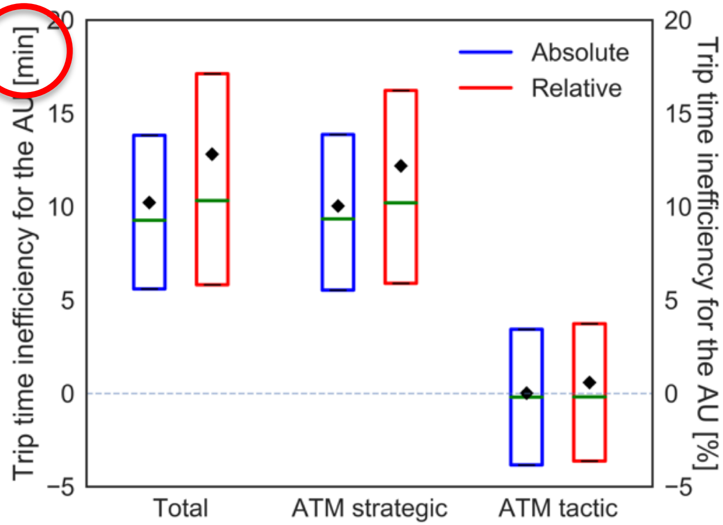
Eurocontrol, 2015 (nov). **Standard Inputs for EUROCONTROL Cost-Benefit Analyses**. *Technical Report* Ed. 7.0.

Main findings and results

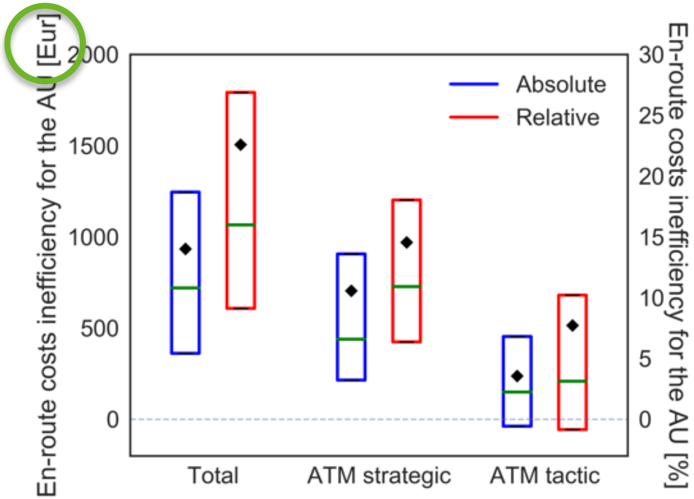
AU cost-efficiency focus area

Main Contribution of APACHE: Optimal trajectory as baseline reference to compute performance indicators (PIs)

Example: Actual and regulated trajectories crossing FABEC (Jul 28th 2016 **post-ops**)



Actual trajectory **time**
minus
Full free route trajectory **time** with *estimated* CI



Actual trajectory *estimated* **cost**
minus
Estimated **cost** of **full free route** with *estimated* Cost Index

CI: Cost Index

Main findings and results

AU cost-efficiency focus area

Main Contribution of APACHE: Optimal trajectory as baseline reference to compute performance indicators (PIs)

- **Cost-based** performance indicators:
  - X Difficult to compute →
    - require fuel estimation from surveillance data
    - AU's cost/business model(s): cost of time, delay, fuel, etc.
  - ✓ Possibility to de-couple vertical and horizontal trajectory inefficiencies

Trajectory Prediction Challenges

- **Time-based** performance indicators:
  - ✓ Easier to compute although estimation of AU's CI is still needed.
  - ✓ In line with "Operational Efficiency SESAR ambition target" defined in the ATM master plan (flight time reduction)
  - X Not representative of the overall cost for the AU

CI: Cost Index

TP challenges

- Fuel estimation from surveillance data
- Cost Index (CI) estimation from surveillance data
  - Take-off (or landing) mass estimation from surveillance data
  - Thrust estimation from surveillance data
    - ❑ High sensitivity to noise in surveillance data (+ gaps in data)
    - ❑ A pure model-based approach is very sensitive to:
      - ❑ Accuracy/representativeness of aircraft performance model
      - ❑ Accuracy/representativeness of the weather input data
    - ➢ Could the estimation be enhanced with data-driven and/or signal processing approaches (e.g. estimating flight intents)?

- Fuel + CI + (mass + thrust) estimation of planned trajectories
  - ❑ FPL: very coarse description of the trajectory (difficulty to estimate CLB/DES)
  - ❑ SBT: 4D description, but still need to estimate hidden data (mass, CI,…)
  - ➢ Could the estimation be enhanced with data-driven and/or signal processing approaches?

SBT: Shared Business Trajectory – FPL: Flight Plan – CLB/DES: Climb/Descent

TP challenges

- **Estimation of AU's costs (tactical cost of time, cost of fuel, cost of delay, …)**
- **Better capture AUs preferences (CI, route choice, etc.)**
- **Better isolate the contribution of ANS to flight inefficiencies**
  - ❑ Is the initial SBT (or FPL) really what the AU would like to fly?
  - ❑ Is the AU always planning the "best trajectory"?
  - ❑ Could we identify AUs reactive/preventive behaviours?
  - ➢ Difficult to model, could be inferred with data-driven approaches?

SBT: Shared Business Trajectory – FPL: Flight Plan

Further reading

Project Deliverable D1.2: Final project results report

Project Deliverable D3.1: Review of current KPIs and proposal for new ones

Project Deliverable D3.2: Functional requirements and specifications for the ATM performance assessment framework

Project Deliverable D4.1: Report on the availability of the APACHE framework

Project Deliverable D5.1: Results from simulation and analysis of results

X. Prats, C. Barrado, A. Vidosavljevic, D. Delahaye, F. Netjasov and D. Crnogorac. 2017 (Nov). **Assessing ATM Performance with Simulation and Optimisation Tools: The APACHE Project**. *In proceedings of the 7th SESAR Innovation Days.* SESAR JU. Belgrade (Serbia).

F. Netjasov and D. Crnogorac. 2017 (Sep). **Assessment of safety performance indicators of future air traffic management system.** *In proceedings of the XLIV Symposium on operational research*. Zlatibor (Serbia).

Dalmau, R., Melgosa, M., Vilardaga, S. and Prats, X. 2018 (Jun). **A Fast and Flexible Aircraft Trajectory Predictor and Optimiser for ATM Research Applications**. Proceedings of the 8th International Conference on Research on Air Transportation (ICRAT). Castelldefels, Catalonia

Xu, Y., Dalmau, R., Melgosa, M., de Montlaur, A. and Prats, X. 2018 (Jun). **Alternative Trajectory Options for Delay Reduction in Demand and Capacity Balancing**. Proceedings of the 8th International Conference on Research on Air Transportation (ICRAT). Castelldefels, Catalonia.

Netjasov, F. and Crnogorac, D. 2018 (Jun). **Potential Safety Occurrences as Indicators of Air Traffic Management Safety Performances: A network based simulation model**. Proceedings of the 8th International Conference on Research on Air Transportation (ICRAT). Castelldefels, Catalonia

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Thank you very much for your attention!

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