Assessing ATM performance with simulation and optimisation tools: The APACHE Project

Xavier Prats, Cristina Barrado (UPC)
Andrija Vidosavljevic, Daniel Delahaye (ENAC)
Fedja Netjasov, Dusan Crnogorac (UB-FTTE)

7th SESAR Innovation days
Belgrade (Serbia)
November 29th 2017
APACHE Doc: DIS_WP6-09
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
• May 2016 – May 2018

http://apache-sesar.barcelonatech-upc.eu/
@Apache_SESAR
Objectives of the APACHE project

• New framework to assess European ATM performance based on simulation, optimisation and performance assessment tools.

• Fill some gaps in current state of the art methodologies in ATM performance assessment aiming to better capture:
  • the performance impact of ATM operations on different stakeholders taking into account a wide range of KPAs
  • the complex interdependencies and trade-offs among different KPAs

ATM: Air Traffic Management
KPA: Key Performance Area
Objectives of the APACHE project

- The specific objectives of the APACHE project are:
  - To propose **new metrics and indicators** capable of effectively capturing European ATM performance under either **current or future concepts of operation**.
  - To make a preliminary **impact assessment** of some SESAR 2020 solutions (PJ06, PJ07-01, PJ08 and PJ09) using the new APACHE Performance Framework along different KPAs.
  - To **analyse the interdependencies** between the different KPAs by capturing the **Pareto-front of ATM performance**, and finding the theoretical optimal limits for each KPA.
Methodology and Approach

ATM Scenario (Set of trajectories + set of opening schemes)

APACHE Performance Analyser

Performance Indicators (PIs)

Weather optimal trajectories + airspace configurations to support the implementation of new and advanced PIs

Data repository

Different configurations to synthesise representative European traffic and airspace scenarios

TAP: Traffic and Airspace Planner

Prats et al.– 7th SESAR innovation Days (SIDs 2017) – (APACHE Doc. DIS_WP6-09)
Assessing ATM performance with simulation and optimisation tools: The APACHE Project – 5

© 2017 APACHE consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions

Belgrade (Serbia)
November 29th 2017
New Performance Indicators (PIs)

APACHE new (or enhanced) PIs:

- 40 PIs and 18 variants initially proposed
- 25 PIs and 17 variants finally selected for implementation

- Access and Equity: 5 PIs
- Capacity: 3 PIs
- Cost-effectiveness: 3 PIs + 3 variants
- Environment: 2 PIs + 10 variants
- Flexibility: 4 PIs
- Safety: 7 PIs + 4 variants
- Participation: 1 PI

More details in Deliverable D3.1 available in the APACHE public web site:
http://apache-sesar.barcelonatech-upc.eu/
APACHE trajectory and airspace planner (APACHE-TAP)

More details in Deliverables D2.1 and D3.2 available in the APACHE public website: http://apache-sesar.barcelonatech-upc.eu/
APACHE trajectory and airspace planner (APACHE-TAP)

TP: Trajectory Planner

- “Current ConOPS” → Current route including FRA
- “Future ConOPS” → Full free route from origin/destination (theoretical limit of PJ06) + eventually CCC

TP uses network and FRA definition data from Eurocontrol’s DDR2

FRA: Free Route Areas
CCC: Continuous Cruise Climbs
APACHE trajectory and airspace planner (APACHE-TAP)

TP: Trajectory Planner

Optimal trajectories considering realistic cost for Airspace Users:
- The whole route
- Weather forecast(s)
- Route charges
- Cost of time (in terms of CI)

\[ \text{min } \text{Distance} \]
\[ \text{min } \text{Fuel} \]
\[ \text{min } \text{Cost} = \text{min } (\text{Fuel} + \text{CI} \cdot \text{Time} + \text{Route Charges}) \]

CI: Cost Index
**APACHE trajectory and airspace planner (APACHE-TAP)**

**TP: Trajectory Planner**

**Optimal trajectories considering realistic cost for Airspace Users:**
- The whole route
- Weather forecast(s)
- Route charges
- Cost of time (in terms of CI)

---

- Current route structure + FRA
- Full free route from Origin to Destination
APACHE trajectory and airspace planner (APACHE-TAP)

ASP: Airspace planner: ”current ConOps”

- Replicate the work done by FMP for each ACCs
- Given a traffic demand and time period → optimal opening scheme minimising the number of open sectors and providing the best overall load balance
- Minimize sector underloads; while limiting (avoiding) overloads and considering a comprehensive set of operational constraints
- Existing set of airspace configuration is used
- Existing collapsed sectors – no new sector groupings

FMP: Flow Management Position
ACC: Area Control Centre
APACHE trajectory and airspace planner (APACHE-TAP)

ASP: Airspace planner: "current ConOps"
APACHE trajectory and airspace planner (APACHE-TAP)

ASP: Airspace planner: "future ConOps"

- **SESAR solution PJ08**: Dynamic airspace configuration (DAC)
- Given a traffic demand and time period \(\rightarrow\) optimal grouping of the Sector Building Blocks (SBB) providing the best overall load balance in terms of traffic complexity
- Minimize number of open sectors, traffic transfer between active sectors, and considering a comprehensive set of operational constraints
- In APACHE, existing elementary sectors are used as SBB
APACHE trajectory and airspace planner (APACHE-TAP)

ASP: Airspace planner: ”future ConOps”
APACHE trajectory and airspace planner (APACHE-TAP)

ASP: Airspace planner: "future ConOps"
APACHE trajectory and airspace planner (APACHE-TAP)

TCP: Traffic and Capacity Planner
- “Current ConOPS” → ATFM with delays (CASA algorithm)
- “Future ConOPS” → Advanced DCB (theoretical limits of PJ09)

• Advanced DCB algorithm:
  • Minimises the total system cost (sum of all trajectory costs), such that the maximum capacity at all sectors is not exceeded.
  • Considering cost of fuel and cost of delay.
  • Considering for each concerned flight:
    o Original trajectory (+ delay)
    o Horizontal re-route (+ delay)
    o Vertical “re-route” (+ delay)
APACHE trajectory and airspace planner (APACHE-TAP)

TCP: Traffic and Capacity Planner

- **Advanced DCB algorithm**: The APACHE TP (trajectory planner) provides to the TCP with optimal re-routing and optimal flight level capping trajectories (minimising total trajectory cost).
Illustrative examples

Pre-ops assessment (demand for Feb 20\textsuperscript{th} 2017 crossing FABEC)

- ENV-1.1: Strategic ATM inefficiency on the horizontal track

FR: full free route
SR: current (structured) network

Current network + FRA

Full free-routing
Illustrative examples

Pre-ops assessment (demand for Feb 20th 2017 crossing FABEC)

- ENV-1.1: Strategic ATM inefficiency on the horizontal track
- ENV-2.3: Strategic ATM inefficiency on the trip fuel

FR: full free route
SR: current (structured) network

FR-C10: Cost Index = 0
CIAU: Same Cost Index than chosen by the Airspace User
Illustrative examples

Pre-ops assessment (demand for Feb 20th 2017 crossing FABEC)

<table>
<thead>
<tr>
<th>PI</th>
<th>Description</th>
<th>Current network</th>
<th>Full free route</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAF-1</td>
<td>Number of Traffic Alerts warnings</td>
<td>300</td>
<td>131</td>
</tr>
<tr>
<td>SAF-2</td>
<td>Number of Resolution Advisories issued</td>
<td>73</td>
<td>1</td>
</tr>
<tr>
<td>SAF-3</td>
<td>Number of Near Mid Air Collisions (NMACs)</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>SAF-4</td>
<td>Number of Separation Violations</td>
<td>1376</td>
<td>939</td>
</tr>
<tr>
<td>SAF-7</td>
<td>Risk of conflicts/accidents</td>
<td>5.5 \times 10^{-3}</td>
<td>3.0 \times 10^{-3}</td>
</tr>
</tbody>
</table>

Full free Route

Current route structure
Illustrative examples

Pre-ops assessment (demand for Feb 20\textsuperscript{th} 2017 crossing FABEC)

• ASP validation (compared with NEST ICO tool).

![Sector load distribution graph]
Illustrative examples

Pre-ops assessment (demand for Feb 20th 2017 crossing FABEC)

- **ASP validation** (compared with NEST ICO tool).

![Sector load distribution per period](image)

Prats et al.– 7th SESAR innovation Days (SIDs 2017) – (APACHE Doc. DIS_WP6-09)
Assessing ATM performance with simulation and optimisation tools: The APACHE Project – 22

© 2017 APACHE consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions

Belgrade (Serbia) November 29th 2017
Illustrative examples

Pre-ops assessment (demand for Feb 20th 2017 crossing France)

• TCP example

With CASA algorithm (only delays):
  • 2,510 aircraft delayed
  • 406,042 min total delay
  • 55 min of average delay

With ADCB algorithm:
  • 301 aircraft delayed
  • 821 min total delay
  • 0.11 min of average delay
Conclusions

• ATM is progressively transitioning to a performance based system with many Key Performance Areas (KPAs).
• New tools and methods are needed to overcome current limitations in performance assessment to better capture:
  o the impact of new concepts and solutions; and
  o the complex interdependencies among KPAs.
• APACHE aims at filling some of existing gaps by providing a framework that combines simulation, optimisation and performance assessment tools.

http://apache-sesar.barcelonatech-upc.eu/

@Apache_SESAR
Assessing ATM performance with simulation and optimisation tools: The APACHE Project

Thank you very much for your attention!
Assessing ATM performance with simulation and optimisation tools: The APACHE Project

Backup Slides

This project has received funding from the SESAR Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement No [number]

The opinions expressed herein reflect the author’s view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.
Methodology and Approach

TAP: Traffic and Airspace Planner
Scope of the research

Real data (coming from ANSPs, network manager, etc.)

SESAR2020 ConOps
- Executed RBT
- RBT¹
- SBT²

Current ConOps
- Actual trajectory
- Regulated trajectory³
- Last filled trajectory⁴

Post-ops (monitoring)

New PIs  Current PIs

Synthesized data with the APACHE-TAP

SESAR2020 ConOps
- Executed RBT

Current ConOps
- Actual trajectory
- Regulated trajectory³
- SBT²
- Last filled trajectory⁴

Pre-ops (planning)

New PIs  Current PIs

Legend:
- Out of scope of the APACHE Project because SESAR2020 ConOps is not yet deployed and real data is not available.
- Out of scope of the APACHE Project because the tactical ATM layer is not modelled in the APACHE system. Therefore, the synthesized trajectories are only RBT or ATFM regulated trajectories.
- Done in the APACHE Project to demonstrate the utility of the APACHE system for post-ops analysis and to benchmark current ConOps with new PIs in the current ConOps.
- Done in the APACHE Project to benchmark current ConOps with future ConOps (initial assessment of some SESAR2020 solutions and capturing ATM Pareto front) and to benchmark current ConOps with new PIs when assessing SESAR2020 operations.

¹ Referring to the “first” RBT (i.e. the “last” SBT)
² Referring to the “first” SBT (as submitted initially by the AU before starting the negotiation process with the NM).
³ It comes from the regulated flight plan, which includes ATFM re-routings and/or ATFM delays (if any).
⁴ It comes from the last filled flight plan from the AU (without considering ATFM re-routings, if any.).
APACHE trajectory and airspace planner (APACHE-TAP)

TP: Trajectory Planner

Current network + FRA

Full free-routing

Conventional
CCC

Prats et al.– 7th SESAR innovation Days (SIDs 2017) – (APACHE Doc. DIS_WP6-09)
Assessing ATM performance with simulation and optimisation tools: The APACHE Project – 29
© 2017 APACHE consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions
Post-ops results

Baseline trajectories: Current network  
Baseline trajectories: Full Free-route

ENV-1: ATM inefficiency on the horizontal track (*using M3*)
ENV-1.1: **Strategic** ATM inefficiency on the horizontal track (*using M2*)
ENV-1.2: **Tactical** ATM inefficiency on the horizontal track
**Post-ops results**

**Baseline trajectories: Current network**

**Baseline trajectories: Full Free-route**

**ENV-1**: ATM inefficiency on the horizontal track *(using M3)*

**ENV-1.1**: Strategic ATM inefficiency on the horizontal track *(using M2)*

**ENV-1.2**: Tactical ATM inefficiency on the horizontal track