Analysis of Relationship between Air Traffic Demand, Safety and Complexity in FABEC Airspace

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Introduction

• By 2021 over 12.3 million operations in European sky

• Challenge for the safety, the en route sector capacity and impact on the environment

• FRA and FAB concepts - crucial ‘tools’ for solving those issues
Objective of the Study

• Having in mind changes in the European airspace (such as introduction of FRA and FABs) and constantly growing traffic demand, the following research questions emerged:

• Is there any relationship between traffic demand, air traffic complexity and safety?

• Are there any differences in those relationships between seasons?
Study Approach (1)

• A showcase methodology on the analysis of FABEC:
  
  • how performance indicators (existing and the new ones) could be used to assess operational and safety performance,

  • advantages and benefits of operational changes/concepts such as FRA,

  • to set a benchmark for further assessment of potential benefits of operational environment changes in airspace due to implementation of FRA.
Study Approach (2)

- Use Case: FABEC airspace
- Traffic: Actual M3 trajectory - EUROCONTROL DDR2
  - above FL195,
  - 2 weeks of 2017 operated traffic:
    - Summer (July 3–9, 2017, with 131,268 flights) and
    - Fall (November 13–17, 2017, with 94,947 flights)
Study Approach (3)

- **Complexity**
  - a macroscopic view
  - EUROCONTROL methodology:
    - Adjusted density (*assesses the potential interactions resulting from density, including uncertainty in the trajectories and time*)
    - Structural index (*balances the density metrics according to the interaction geometry and aircraft performance differences*)
  - Complexity score
Study Approach (4)

- **Conflict Risk / Safety**
  - Conflict Risk Assessment Tool
    - Separation violation detection module
      - used for the calculation of duration, severity and number of PLoS
    - Risk of Conflict assessment module
      - simulation of flights
      - comparison of the actual separation of a/c with a given separation minima in order to detect PLoS
Safety performance indicators

• **Potential losses of separation (PLoS)** represent the area of potential safety concern
  • both vertical and horizontal separation minima breached
  • 5NM horizontally and 1000ft vertically, but minima were relaxed for 10% (4.5 NM and 900 ft) to deal with potential position and altitude inaccuracies

• **Risk of Conflict / Conflict Risk**
  • calculation of "elementary risk" for each conflicting a/c pair considering duration and severity of PLoS
  • Calculation of total risk
Complexity and safety indicators overall analysis (1)

- No PLoS per 1000 flights is lower in winter
Complexity and safety indicators overall analysis (2)

- Daily changes in complexity are following the changes of daily traffic demand
- The changes in daily number of PLoS and conflict risk do not follow strictly the changes in daily traffic demand

<table>
<thead>
<tr>
<th>Season</th>
<th>Traffic</th>
<th>Complexity</th>
<th>No PLoS</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer vs. Winter</td>
<td>↑ 22 to 37%</td>
<td>↑ 17 to 29%</td>
<td>↑ 33 to 63%</td>
<td>↑ 28 to 65%</td>
</tr>
</tbody>
</table>
Complexity and safety indicators overall analysis (3)

<table>
<thead>
<tr>
<th>Season</th>
<th>Total no of interactions</th>
<th>No of interactions per hour of flight</th>
<th>No PLoS per hour of flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer vs. Winter</td>
<td>↓</td>
<td>↑ 23% (0.224 vs 0.172)</td>
<td>↑ 13% (0.015 vs 0.013)</td>
</tr>
</tbody>
</table>

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**Summer vs. Winter**

- **No of interactions per hour of flight**: Increased by 23% (0.224 vs 0.172)
- **No PLoS per hour of flight**: Increased by 13% (0.015 vs 0.013)
• the probability of separation losses in FABEC is reducing in winter

15,11 in 1000
PLoS per 1000 flights

13,07 in 1000
PLoS per 1000 flights
Correlation between traffic, complexity and safety indicators (1)

• Increase in traffic ➔ the higher complexity ➔ higher number of PLoS and conflict risk

<table>
<thead>
<tr>
<th>Both Seasons ($R^2$)</th>
<th>Complexity</th>
<th>PLoS</th>
<th>Risk of Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Flights</td>
<td>+0.9807</td>
<td>+0.8819</td>
<td>+0.8008</td>
</tr>
<tr>
<td>Complexity</td>
<td>-</td>
<td>+0.9138</td>
<td>+0.8296</td>
</tr>
</tbody>
</table>

• ATCo task load will increase, leading to a higher ATCo workload
Correlation between traffic, complexity and safety indicators (2)

- Strong correlation between the daily No flights and Complexity
- Positive correlation between No flights and conflict risk is not significant in both seasons

<table>
<thead>
<tr>
<th></th>
<th>Complexity</th>
<th>Summer ($R^2$)</th>
<th>Winter ($R^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Flights</td>
<td>+0.7163</td>
<td>+0.9022</td>
<td></td>
</tr>
<tr>
<td>Complexity</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>PLoS</th>
<th>Risk of Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Flights</td>
<td>+0.3716</td>
<td>+0.5144</td>
</tr>
<tr>
<td>Complexity</td>
<td>+0.6980</td>
<td>+0.5144</td>
</tr>
<tr>
<td>Complexity</td>
<td>+0.5640</td>
<td>+0.2843</td>
</tr>
</tbody>
</table>
PLoS severity and duration

• PLoS severity (related to the breach of separation) depends on the minimum spacing between the pair of aircraft ($S_{\text{min}}$) and the applied separation minima ($\text{Sep}_{\text{min}}$)

\[
\text{Severity} = \frac{\text{Sep}_{\text{min}} - S_{\text{min}}}{\text{Sep}_{\text{min}}}; \text{ where } 0 \leq \text{Severity} \leq 1
\]

• in 80% of cases severity is 1, which means that both aircrafts were at either the same flight level or at the same point in the horizontal plane

• Results of PLoS duration analysis show that majority of PLoS are short, up to 30 sec (roughly two-thirds)
  • almost 90% do not last more than 1 min
Traffic seasonality is influencing higher complexity values; moreover, the number of PLoS evidently contributes to higher complexity values.
Geometrical characteristics of PLoS (1)

• In summer sample percentage of overtaking and crossing PLoSs is almost similar (51 vs. 46%) while in winter there are more overtaking PLoSs (71%)

• overtaking (difference between headings is ±70°)
• crossing (difference between headings is in a range between ±70 and ±160°) and
• head-on encounters (difference between headings is in a range between ±160 and 180°)
Geometrical characteristics of PLoS (2)

- Daily values show that share of encounter types are more stable during the winter which could be related to more uniform traffic flows during winter months (e.g. no seasonal and charter flights)
Conclusions and Further work (1)

- Small-scale analysis showed that changes in traffic demand do influence complexity and safety performance

- **Set a benchmark** for future monitoring of safety and operational performance during FRA implementation
Conclusions and Further work (2)

• Further analysis will investigate whether dispersion of traffic after FRA implementation
  • is enough to create complexity decrease and
  • whether change in complexity have not compromised safety and ATCo workload

• Further improvement will include:
  • increased traffic sample, complexity per sector, traffic type, vertical profiles, workload, etc.
Thank you!

See you hopefully in Rome with new results
Back Up slides
Analysis of potential losses of separation (1)

- Results of PLoS duration analysis show that majority of PLoSs are short, up to 30 sec (roughly two-thirds, i.e. 372 cases), while almost 90% do not last more than 1 min.
Analysis of potential losses of separation (2)

- Results of PLoS severity analysis show that in 80% of cases severity is 1, which means that both aircraft were at either the same flight level or at the same point in the horizontal plane.
Analysis of potential losses of separation (3)

- The results of the distribution of minimum vertical separation at the CPA show that almost 80% of PLoSs are at the same flight level or are separated vertically up to 100 ft.
Analysis of potential losses of separation (4)

- The results of horizontal distribution show that roughly 50% of PLoSs have breach of less than 3 NM.
Summer 2017
y = 3E-07x - 0,0051
$R^2 = 0,6891$
\[ y = 2 \times 10^{-5}x - 0.1108 \]
\[ R^2 = 0.8509 \]
$y = 0.0159x - 0.0024$

$R^2 = 0.5717$
Winter 2017
$y = 6 \times 10^{-8} x - 0.0003$

$R^2 = 0.7016$
9th SESAR Innovation Days
2 – 6 December 2019, Athens, Greece

\[ y = 1E-05x + 0.0254 \]
\[ R^2 = 0.9428 \]

Complexity

# flights
$y = 0.0052x - 0.0004$

$R^2 = 0.589$
Summer+Winter 2017

Red dots – Winter

Blue dots - Summer
y = 6E-08x - 0.0003

$R^2 = 0.7799$
$y = 7 \times 10^{-6}x + 0.059$

$R^2 = 0.9676$
$y = 0.0076x - 0.0007$

$R^2 = 0.809$