Visual Analytics and Machine Learning for Air Traffic Management Performance Modelling

Rodrigo Marcos
Data Scientist, Nommon Solutions and Technologies

Delft 8th of November 2016
INDEX

1. The Challenge of ATM Performance Modelling
2. INTUIT Project
3. ATM Data Quality Assessment
4. Proposed Research Questions
5. Case Study 1: Visual Analytics for ATFM Delay Analysis
ATM Performance Modelling: Challenges

SESAR performance orientation:
- Policy – qualitative performance objectives
- Objectives – measurable indicators
- Management actions – indicator trends

European ATM performance governed by SES Performance Scheme:
- Performance targeting
- Benchmarking

Needs:
- Analyse interdependencies/trade-offs between KPAs
- Characterise performance drivers
- Effective target setting and benchmarking
Data Science: Opportunities

Data Science:
• Discover patterns and extract knowledge from data
• Variety of techniques: statistics, machine learning...
• Synonym for Business Intelligence, Data Analytics...

Opportunities:
• Increasing availability of data
• Big data technologies
• New data analysis and visualisation techniques

How can we apply these ideas to ATM performance modelling?
What is their potential for ATM performance monitoring and management?
The INTUIT Project

Explore the potential of visual analytics, machine learning and systems modelling to improve our understanding of the trade-offs between ATM KPAs, identify cause-effect relationships between KPIs, and develop new decision support tools for ATM performance monitoring and management.

- Start March 2016, duration 24 months
- Website: www.intuit-sesar.eu
- Partners:
The INTUIT Project

ATM Performance Data

- Data Analysis
  - Patterns, Trends, Regularities...
  - Model Building (Hypothesis)
    - Model Calibration
      - Model Validation
        - Performance Models

- Performance Modelling
  - Policy Objectives Policies & Scenarios
    - Visual Analytics for Sensitivity Analysis
      - Multi-criteria Decision Support Tool
        - Interactive Dashboard

- Performance Monitoring Tool
  - Visual Analytics for Performance Monitoring
    - Early Warning System
      - Performance Monitoring Tool
        - Performance monitoring

- Performance Management Decision Support Tool
  - Performance Optimisation Engine
    - Alternatives (Pareto-optimal Solutions)
      - Performance Optimisation Engine
        - Policy Objectives Policies & Scenarios
          - Visual Analytics for Sensitivity Analysis
            - Multi-criteria Decision Support Tool
              - Interactive Dashboard

- Performance management decision-making
INTUIT Approach

1. Multiscale characterisation of ATM performance data:
   • Data collection and quality assessment
   • Qualitative analysis of performance drivers and trade-offs
   ⇒ INTUIT reference datasets + set of research questions

2. Data analysis and performance modelling
   • Visual analytics of performance data: exploratory data analysis
   • Machine learning and statistical analysis: identification of patterns and relationships between indicators
   • Models of KPI evolution explaining and/or reproducing the observed patterns and trends
   ⇒ ATM performance analysis techniques

3. Performance monitoring and management tools
   ⇒ Interactive dashboard
**Data Sources**

- **ANS performance monitoring** online dashboard developed by the PRU
- Delay analysis data from the Central Office for Delay Analysis (**CODA**)
- Network operations monitoring and reporting (public reports and **ATFCM Statistics**)
- Data about network events disrupting the network from Network Operations Portal (**NOP**)
- Air traffic demand from the Demand Data Repository (**DDR2**)
- Data on capacity, labor and cost per air traffic control centre, as provided in the yearly ATM Cost-Effectiveness (**ACE**)
- **Performance plans** and reports elaborated by EU Member States and approved by the PRB
- Statistics and forecasts on expected levels of air traffic in Europe produced by EUROCONTROL’s Statistics and Forecast Service (**STATFOR**)
- Base of Aircraft Data (**BADA**)

**EUROCONTROL Public Airport Corner**
Data Sources Classification

Low granularity
- ACE reports
- PRR
- ANS Performance Monitoring Dashboard
- National Performance Plans
- Public Airport Corner

High granularity
- DDR2
- ATFCM Statistics
- NOP
  - ANM
  - AUP
  - AIM
  - Events
- CODA
- STATFOR
Definition of Research Questions

Research questions obtained from:

- Desk research: research papers and policy studies
- Consultation: ATM stakeholders (PRU, NM, EASA, ANSPs, airports, airlines)

Selection criteria:

- Availability of data
- Relevance to INTUIT
- Interest of stakeholders
Performance Frameworks: Relationships

SESAR is focused on accidents measurements, whilst in SES more on their prevention (safety management).

SES establishes «ATFM delay» as target, while SESAR focuses on throughput, which is linked.

SES targets are based on flight efficiency and SESAR addresses fuel efficiency directly.

Partial consistency between DUC and Technology Cost per flight and ATCO productivity.

---

*Source: D108 SESAR 2020 Transition Performance Framework ed. 00.01.00*
Literature Review

Macro focus:
• Broad geographical scale
• Multiple KPAs
• Simplified assumptions

Literature threads:
• Prediction accuracy
• Spill-over effects
• Unit costs

Micro focus:
• Small number of sectors
• Two KPAs
• Detailed case-study

Literature threads:
• Optimisation of ATCO workload
• External drivers of cost-efficiency
• Capacity-flight efficiency trade-off
Literature Review: Interdependencies

**Capacity**
- Percent of maximum traffic (ACC level)
- Sector “criticality”
- Cost of delay
- Delay due to ATFM regulation

**Environment**
- Flight inefficiency

**Cost-efficiency**
- Sector “efficiency”
- Cost of adding extra ATCO working hours
- Flight delay costs
- DUC (determined unit cost)
- Planning eff & sector utilization rate
- “Total economic value”

**Safety**
- Aircraft overdelivery in specific sector
- Traffic level
- Seasonal variation

**Howell 2003**
- SIDs 2016

**PRB 2012**
- Tobaruela 2015

**Delgado 2015**
- Negrete 2003

**Cook 2011**
- Bujor 2016
- Castelli 2013

**Grebensek 2012**
- Fin. Cost-effectiveness
- ATCO productivity

**SIDs 2016 - Visual Analytics and Machine Learning for Air Traffic Management Performance Modelling**
Research Areas

Interdependencies
- ATCO workload: demand – capacity drivers
- Cost of delay vs environment
- Uncertainty impact: ATOT – en-route – arrival
- Safety trade-offs

Decision-support tools
- Spatial disaggregation of metrics
- Different time-scales visualisation
- New metrics:
  - demand constraints
  - gate to gate indicators
  - safety
  - predictability
Case Study 1: Visual Analytics for ATFM Delay Analysis

Objective: airport network bottleneck identification

Metric:

ATFM delayed outgoing flights - ATFM delayed incoming flights
Case Study 1:
Visual Analytics for ATFM Delay Analysis

Objective: external impact of regulations on the airport

Metric:
flights delayed by external regulations
Case Study 2:
Navigation Charges Visual Analysis

Objective: charges vs traffic interdependency

Metrics:
- number actual ODs / number great circle ODs flying over each area
- normalized unit rate
Case Study 2: Navigation Charges Visual Analysis

Objective: route efficiency vs traffic interdependency

Metrics:
- average flown distance / average distance factor
- normalized unit rate
Conclusions & Future Steps

• INTUIT approach:
  Machine Learning + Visual Analytics
  ATM Performance Modelling + Decision Support

• Preliminary results:
  • Research challenges
  • Potential of visual analytics

• Future activities:
  • Visual analytics exercises for pattern discovery
  • Study a sub-set of research questions through machine learning and statistical analysis techniques
Thank you very much for your attention!
Macro approaches

• Bujor & Ranieri (2016): Assessing air traffic management performance interdependencies through Bayesian networks: Preliminary applications and results
• Castelli, Labbé & Violin (2013): A network pricing formulation for the revenue maximization of European ANSPs. Transportation research part C: emerging technologies
• EUROCONTROL PRB (2012): Proposed regulatory approach for a revision of the SES performance scheme addressing RP2 and beyond
• Negrete, Urech & Saez-Nieto (2003): ATM system status analysis methodology

Micro approaches

• Cook & Tanner (2011): Airline delay cost reference values
• Delgado, Cook, Cristobal & Plets (2015): Controller time and delay costs – a trade-off analysis
• Grebensek & Magister (2012): Effect of seasonal traffic variability on the performance of air navigation service providers
• Tobaruela, Schuster, Majumdar & Ochieng (2015): Framework to assess an area control center’s operating cost-efficiency: a case study
• Howell, Bennett, Bonn & Knorr (2003): Estimating the en-route efficiency benefits pool