A Method to Assess Economic Effects of Different Air Traffic Management Scenarios Using Fast-time Simulations

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Background & motivation

- Novel concepts developed and tested to cope with the present and upcoming challenges in the ATM system
- Pre-implementation testing tools (*inter alia*): fast-time (FTS) and real-time simulations (RTS), main focus: capacity, safety and operability aspects; less visible – economic suitability of innovative ATM concepts
- EPISMAS project (Economic Performance Indicators in Support of Mathematical ATC Simulations), commissioned by EUROCONTROL CRDS, November ’07 – May ’09
- Objective: to investigate the capabilities of FTSs to address economic aspects of an ATM scenario, from different stakeholders’ perspectives

Fast-time simulations

- Computer simulation, (simulation time/real process time)<1, no interactive human involvement in simulated conditions
- Rule-based decisions control the interactions between simulated actors
- Typical uses: in early stages of concept validation – to preliminarily assess potential benefits, by analysing system capacity, safety and efficiency, e.g.:
  - Airspace sectorisations: capacity and delay aspects
  - ATCO workload analysis
  - Validation of new procedures
  - Conflict detection and resolution…
- Lots of outputs generated during simulations (traffic distribution, delays, W/L analysis, sector capacity ,etc.), which could be of use in economic evaluations

Fast-time simulations (2)

- FTS advantages:
  - Rapid evaluation of a large number of combinations of airspace and traffic
  - Relatively few resources required
  - Fairly accurate results in early evaluation stages
- Only a few attempts to use FTS outputs for economic evaluation: INTEGRA (2001), Fogari (2006), Condoleo (2009)
- Platform used: RAMS Plus® (Reorganised ATC Mathematical Simulator) – widely used for airspace design and capacity estimation, and aiding in environmental aspects' assessment

Methodology

1. Identification of ATM-related economic interests of main stakeholders: airspace users, ANSPs and passengers
2. Identification of relevant economic indicators for each of the stakeholders
3. Analysis and identification of potentially useful RAMS outputs (and inputs)
4. Conjunction of steps 2. and 3. to identify/compose/construct economic indicators measurable in RAMS
5. Application of identified indicators, to compare economic suitability of different ATM scenarios (e.g. airspace sectorisations), using credible (standard) cost inputs

Relevant airline economic indicators

- The quantity of fuel burned: impact on fuel cost and emissions
- Flying time (fl-hr) in the area of interest – scheduled vs. actual: impact on maintenance, crew, charges, pax delay costs
- Aircraft type: charges, pax delay costs, crew costs
- Airport of departure/destination: charges, fuel, maintenance, pax delay costs
- Airspace route network (entry/exit points): ANS charges

Relevant ANSP economic indicators

- Number of active sectors (sector-hr): impact on ATCO number (ANSP a labour-intensive business)
- Number of flight-hours controlled: better to process the given traffic sample faster, *ceteris paribus*
- ATCO workload, no straightforward economic implications, but an important aspect in decision-making, *ceteris paribus*

Relevant passenger economic indicators

- Flight delay: impact on passenger costs
- Aircraft size (number of seats)
- Airport of departure/destination: number of connecting passengers, affecting costs in case of delay (pax losing connection)
- Flight duration: the shorter, the better (opportunity costs), *ceteris paribus*

Cost to airlines – an illustration

Row mark	**Call sign**	AB0123	CD4567	EF8901
	Aircraft type	**A321**	**B733**	**AT72**
(1)	**Scheduled duration (min)**	25	15	35
(2)	**Actual duration (min)**	23	15.2	38
(3)=min{(1)+0.33, (2)}	**“Normal” duration (min)**	23	15.2	35.3
(4)	**Fuel burned (kg)***	1100	600	400
(5)=(4)x0.6	**Fuel cost** ($)**	660	360	240
(6)	**Unit BHOC*** ($/min)**	29.3	19.8	27.2
(7)=(3)x(6)	**OC other than fuel ($)**	673.9	301	960.2
(8)	**Unit cost of delay*** ($/min)**	77.6	61.6	34.0
(9)= [(2)-(3)]x(8)	**Cost of delay ($)**	0	0	91.8
(5)+(7)+(9)	**Total cost to airline ($)**	**1333.9**	**661.0**	**1292.0**

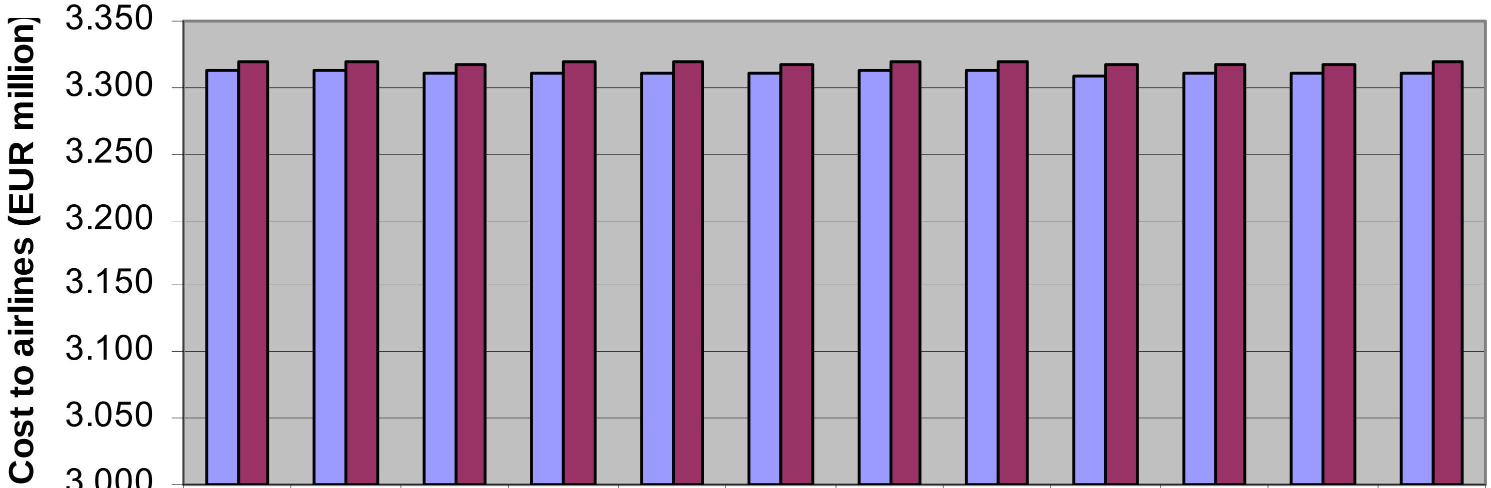
* Approximate quantities
** Fuel price assumed: 0.6 US$ per kg
*** Excluding fuel cost; approximate values based on ICAO and EUROCONTROL cost of delay model_(assumed conversion rate: 1EUR=1.3US$)

Case study

- 2004 HCAA (Hellenic Civil Aviation Authority) FTS study, CRDS
- Simulated airspace: HELLAS UIR, all en-route sectors included
- Focus on the ACC sectors in the northern and eastern part of the HELLAS UIR, where a new RNAV route network was implemented
- 24h simulation, 1921 flights
- Two scenarios compared – different sectorisations:
  - Reference scenario (RS): 12 en-route sectors (no vertical split)
  - Alternative scenario (AS): 15 en-route sectors, changes to original sectorisation in both horizontal and vertical plane
- Stochastic analysis: variation of flight entry times by up to (-5, +10) minutes
- Eleven iterations in each scenario, with identical traffic samples across both scenarios in any given iteration

Key results

- Airlines: relatively minor differences in total cost to airlines, but a consistent sign: AS more expensive than RS (on avg. 0.23%)



Iteration	1	2	3	4	5	6	7	8	9	10	11	Mean 1-11
RS	3.313	3.312	3.311	3.310	3.310	3.311	3.312	3.312	3.309	3.310	3.310	3.311
AS	3.320	3.319	3.318	3.319	3.319	3.318	3.319	3.318	3.316	3.318	3.318	3.318

Key results (2)

- ANSP: RS scenario unfeasible (!!), due to ATCO workload exceedences (70% threshold violations), economic comparison thus meaningless
- Passengers: Aggregate delay minutes compared, for delays longer than 5 minutes in the simulated ACC:
  RS performs consistently better than the AS (on average, 86 pax-hr of delay cumulated in the RS vs. 123 pax-hr in the AS)
- Sometimes implausible results generated by RAMS post-processor (e.g. unrealistic fuel burn values) – debatable credibility of the results, despite considerable data cleaning performed

Conclusions and a way forward

- There is certain potential to use the FTS outputs to assess the economic efficiency of different ATM solutions
- Proposed methodology aligned with the SESAR's performance-based framework
- The detected differences in economic performance typically fairly small compared to the precision that can be achieved by the FTS (error vs. cost differentials order of magnitude?)
- FTS platform integrity?
- Used cost inputs were conservative (US airline BHOC, delay cost, emission charges, pax costs) – may add to differentials
- Recommendations:
  - try FTS of another airspace
  - by-pass the RAMS post-processor, i.e. use original RAMS outputs for economic analysis
  - apply developed methodology (*mutatis mutandis*) to some other FTS simulator

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