Interactions between Operations and Planning in Air Traffic Control

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Different Layers of the Air Traffic Management

Different layers corresponding to different time horizons:

1. Airspace management filter:
   - define the structure of the route network
   - define navigation rules
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   - file flight plans a few hours before planned take-off
   - regulate traffic to enforce sector capacities with ground-holding (CASA)

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   - file flight plans a few hours before planned take-off
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3. Air Traffic Control (ATC) where controllers:
   - monitor sectors;
   - ensure safe transitions between sectors;
   - maintain separation between aircraft at all times.

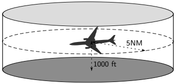

Figure 1: Vertical and horizontal separation

Present and future: what is at stake?

1. Present situation:
   - airspace congested in Europe
   - costly delays crucial to companies
   - few conflicts to solve for controllers

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Present and future: what is at stake?

1. Present situation:
   - airspace congested in Europe
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   - few conflicts to solve for controllers
2. Questions needing answers for the future:
   - what will future traffic look like?
   - how will regulations adapt to this future traffic?
   - what economic outcomes can be expected?
   - how to be better prepared?

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Our contributions

Based on a air traffic simulator we:

- simulate future French traffic up to 2035
- design different regulation scenarios
- compute ground-holding costs and ATC costs
- perform a traffic and cost analysis

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The whole picture

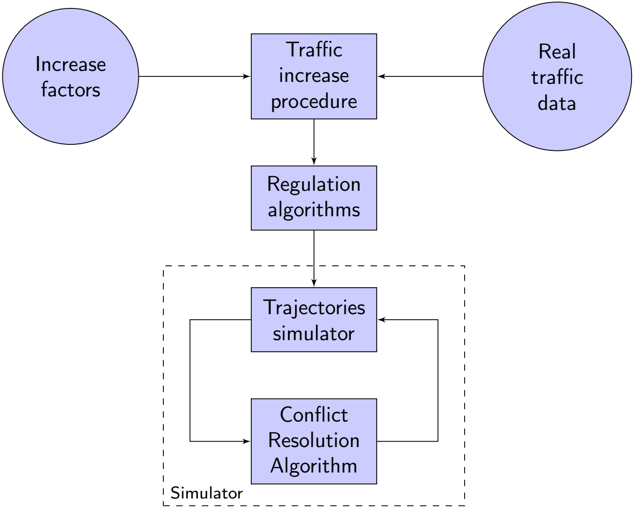

Figure 2: Experimental design

Traffic increase

Procedure parametrized by a multiplying factor f (i.e 40%):

- go from n flights to $n_+ = n(1+f)$ flights:
    1. choose random flights to be duplicated
    2. apply a small perturbation on departure time
- same random seed used: consistent increase
- maintain a similar temporal distribution of flights

Ground-holding regulation: CASA Algorithm

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Computer Assisted Slot Allocation (CASA)

- Allocates slots for take-off
- Greedy heuristic (FIFO fashion)
- one delay value for each overflown regulated zone
- assigned delay: maximum delay over all overflown regulated zones

Traffic simulation and conflict resolution

Traffic simulator: Complete Air Traffic Simulator (CATS)

- time-discretized execution model
- aircraft specifications and performances extracted from BADA tables
- detailed outputs: traffic statistics, sector occupancy, conflicts data

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Air conflict resolution used:

- genetic algorithm from Durand(1996)[4]
- embedded in CATS

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Traffic predictions

Data extracted from EUROCONTROL forecasts[2, 1]

	Annual growth			
Scenario	Global Growth	**Regulated Growth**	Happy Localism	Fragmented World
2012-2019	3.4%	2.3%	2.3%	0.9%
2019-2020	3.7%	2.2%	1.5%	0.6%
2021-2025	2.5%	1.9%	1.5%	0.8%
2026-2030	2.2%	1.5%	1.2%	0.4%
2031-2035	1.9%	1.2%	1.1%	0.7%

Table 1: Summary of flight forecast for Europe until 2035

Year	2014	2017	2020	2025	2030	2035
Increase	+5%	+12%	+20%	+32%	+42%	+50%

Table 2: Traffic predictions with Regulated Growth

Airspace Capacity

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Nominal sector capacities for France were used:

- different from actual regulation
- remains a valid indicator

Two scenarios of simulations:

- S_1: the actual regulation is applied with unchanged capacities
- S_2: no ground regulation is applied

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Extreme situations to challenge both :

- ground regulation: assigning take-off slots under high demand (S_1)
- ATC regulation: conflict resolution with numerous aircraft (S_2)

Choice of historical data

Week of French traffic from 2012:

- high volumes, especially on 6/8
- consistent differences between computed delays and actual delays

Date	Number of flights	Computed delays (min)	CFMU delays (min)
6/6	8656	1835	4503
6/7	8723	1875	8845
6/8	**9053**	**16086**	**15505**
6/9	8469	5708	13215
6/10	8786	11075	10924
6/11	8817	5507	11449
6/12	8618	4739	8006
Average	8731.7	6689.3	10349.5

Table 3: Traffic statistics from 2012/6/6 to 2012/6/12

Delay costs

Delay costs need to account for:

- passenger costs
- crew costs
- maintenance costs
- subsequential delays

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Data used: model designed by EUROCONTROL and Westminster University[3]

- cost function of delay magnitude and type of aircraft involved
- data stored in tables

Delays (min)	15	60	120	240
B744	1230	20760	120940	213950
A320	410	6800	35280	63530

Table 4: Tactical costs (euros, total) of ground holding delay

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Maneuvers costs

Three types of maneuvers issued:

- speed changes
- heading changes
- ascent interruption or descent anticipation

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Costs computed as extra fuel cost:

- define nominal speed with BADA performances
- compute fuel consumption on original flight plan at nominal speed C_{nom}
- compute fuel consumption during the maneuver C_{man}
- the extra cost is the difference $C_{\text{nom}} - C_{\text{man}}$

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Simulations without conflict resolution (1/2)

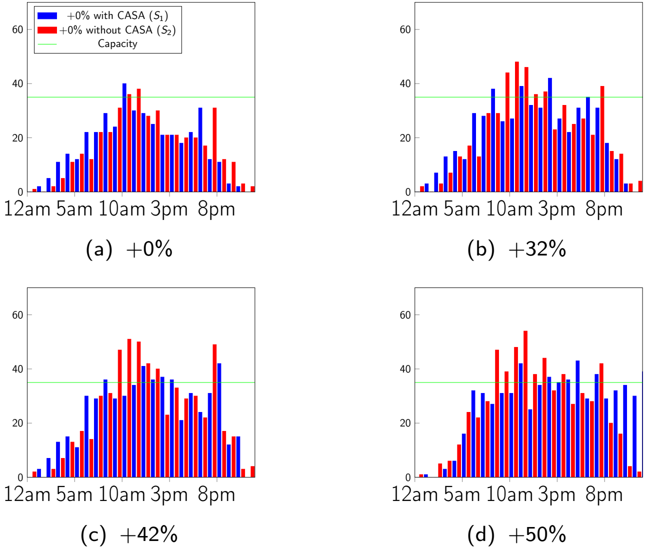

Figure 3: Entering flow per hour for different traffic volumes on KR

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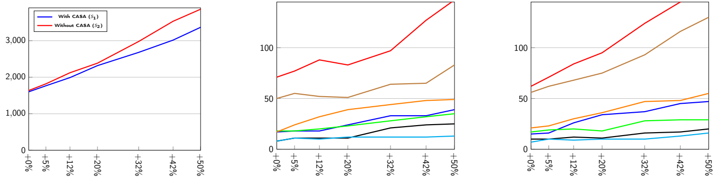
Impact of ground-holding regulation



(a) **Total** (b) **With CASA (S_1)** (c) **Without CASA (S_2)**

Figure 4: Comparison of the number of conflicts observed with and without CASA

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Simulations without conflict resolution (2/2)

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Impact of ground-holding regulation:

- prevents flight aggregation into peaks $\leftrightarrow$ eases controller's task
- smoothes the flow over the day
- reduces the number of conflicts for heavily loaded sectors

Ground-holding regulation costs

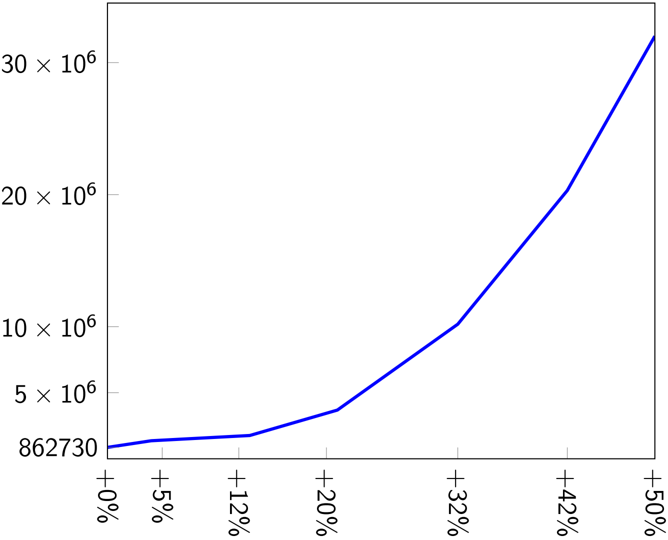

Figure 5: Cost of ground-holding regulation (in euros)

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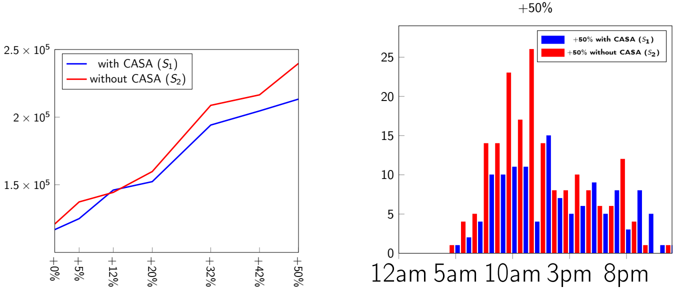
ATC costs



(a) **Deconfliction costs**

(b) **Maneuvers per hour - KR sector**

Figure 6: Deconfliction costs and maneuvers per hour

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Costs Analysis

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1. Regarding ground-holding regulation costs:
   - grow exponentially with traffic volume
   - due to larger peak periods, hence larger delays
   - millions of euros could be saved by removing capacities
2. Regarding ATC deconfliction costs:
   - remain small compared to ground-holding costs
   - removing capacities increase resolution costs by 15%
   - removing capacities dramatically increases workload
   - conflict situations more and more difficult to solve
3. How to take advantage of this information?
   - cf. SESAR project [5]
   - higher degree of automation
   - design a new regulation

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Scientific contributions

- Simulations on future traffic extrapolated from real-life data
  - increased traffic based on detailed forecasts
  - insight into future traffic conflict situations
- Study of interactions between ground-holding regulation and ATC:
  - Millions of euros can be saved daily by removing sector capacities
  - Additional ATC effort increases cost by 15%
  - Controllers' workload increases dramatically
- Have an insight into future solutions:
  - design a regulation better adapted to dense traffic
  - need of highly automated tools to decrease workload

Perspectives

Future work will focus on:

1. follow more detailed forecasts

2. introduce an hybrid scenario S_3:
   - determine new capacities
   - control ground holding regulation costs
   - control increase in controller's workload

3. perform the same study on direct routes

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