

An innovative safety-neutral slot overloading technique to improve airspace capacity utilisation



9th SESAR Innovation Days

Innovative enhancements for CASA to optimise the network delay

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Outline

1. Enhanced CASA (ECASA): Introduction, Motivation & Objectives
2. Enhancement 1: Mitigation of Interacting Regulations (MIR)
 - ❑ The “interacting regulations” problem
 - ❑ MIR optimisation heuristic
3. Enhancement 2: Resourceful Overloading of Slots (ROS)
 - ❑ The “wasted capacity” problem
 - ❑ ROS optimisation heuristic
4. Early simulations results
5. Conclusions and next steps



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What airspace capacity is?

➔ Nowadays, **airspace capacity** is (often) constrained by **operational capacity**, i.e., by the *maximum number of flights that the ATCOs can manage safely with an acceptable & sustainable level of workload*.

- Airspace capacity can potentially be limited by many different factors (e.g. physical capacity, weather, separation standards, CNS infrastructure, etc.).
- At airports usually the bottleneck is the runway throughput

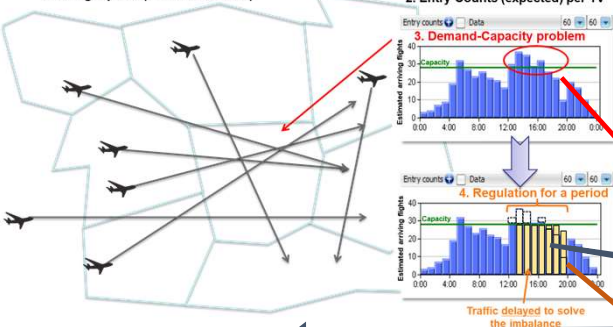


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Computer-Assisted Slot Allocation (CASA)

1. NM makes predictions of 4DTs from flight plans (hours in advance)



Introduction to:

- Demand & Capacity Balancing with CASA
- Our graphical representation of the CASA slot sequences
- Key properties of CASA

In a regulation, 'ATFM slots' are allocated by CASA to time-separate ("smooth") the traffic following the FPFS policy

Regulation



Planned sequence: A,B,C, D,E,F,G,H,I, J,...

CASA sequence (FPFS):

A	B	C	D	E	F	G	H	I	J	...
---	---	---	---	---	---	---	---	---	---	-----

Delay:

0	2	4	5	5	6	8	10	11	13	...
---	---	---	---	---	---	---	----	----	----	-----

FPFS is considered *fair* because it preserves the original order

FPFS minimises the *delay* in a single regulation

Potential bunch of flights (safety risk)

Time: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 ...



Motivation & objectives of this research

Motivation:

With today's congestion levels, CASA performance is largely affected by:

- 1) The ***Interacting Regulations problem***
- 2) The ***Wasted Capacity problem***



Enhanced CASA (ECASA) is proposed with two enhancements:

- 1) The **MIR** mechanism (*Mitigation of Interacting Regulations*)  Presented in the ATM Seminar, 2019 (Wien)
- 2) The **ROS** mechanism (*Resourceful Overloading of Slots*)  Main focus of this paper

Objectives:

The final goals of ECASA are:

- 1) To reduce the **ATFCM network delay** and its **impact on AUs**
- 2) To make it **rapidly deployable** (min change & max value)



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Outline

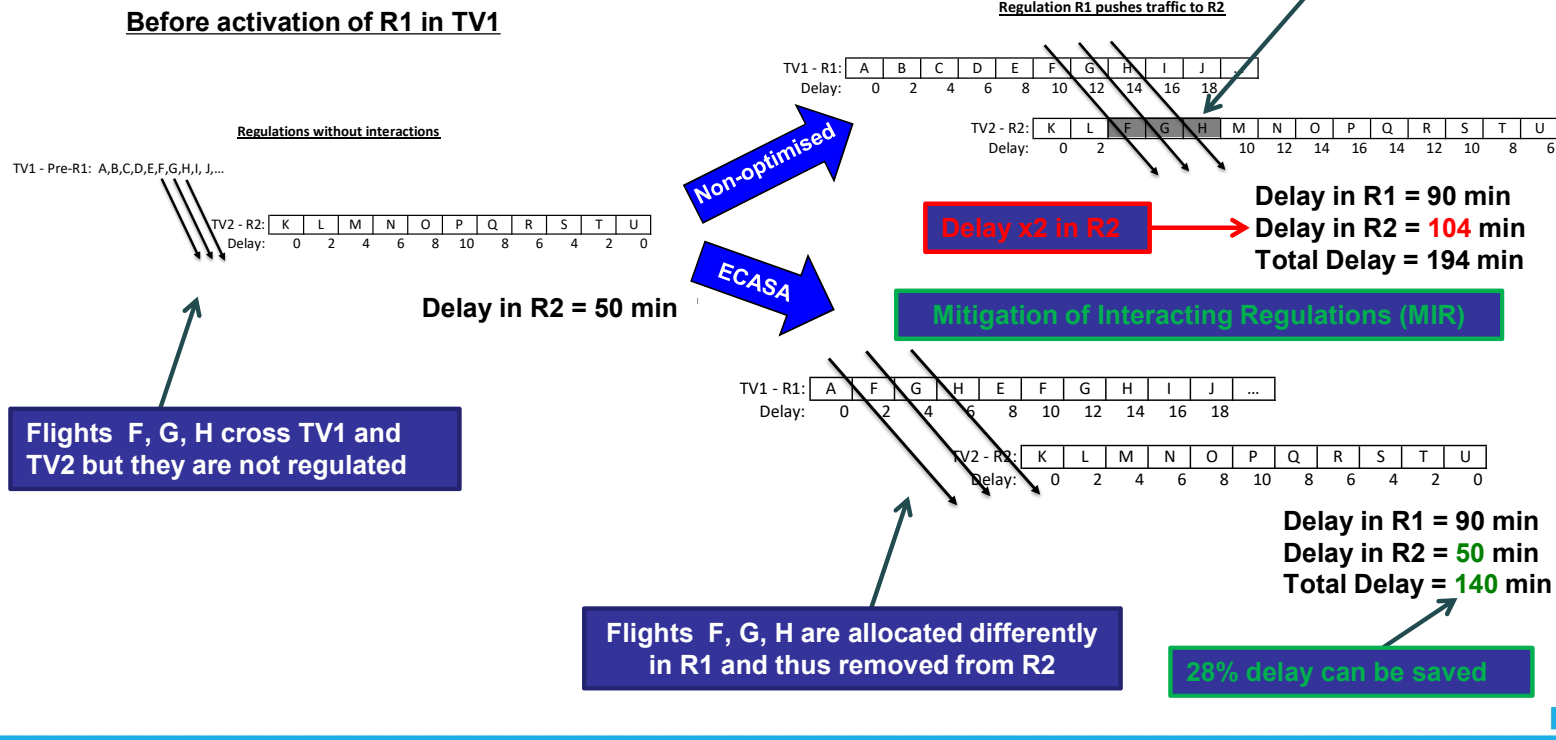
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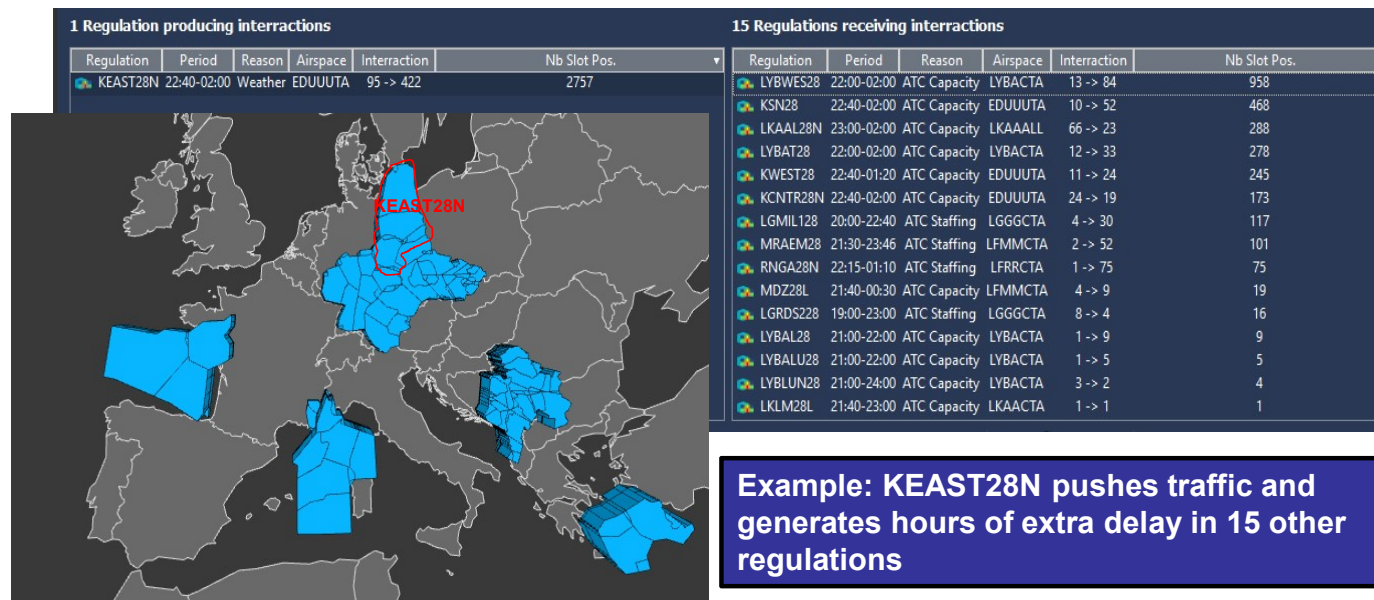


The Interacting Regulations problem and the MIR mechanism



The size of the Interacting regulations problem: a common ECAC-wide problem

In a tightly connected and congested network the probability of multiple crossed-interactions is very high

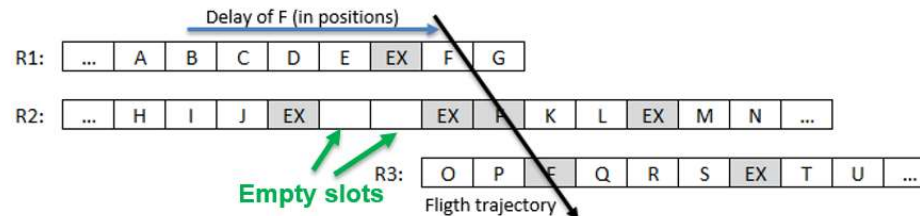


The Mitigation of Interacting Regulations (MIR) mechanism

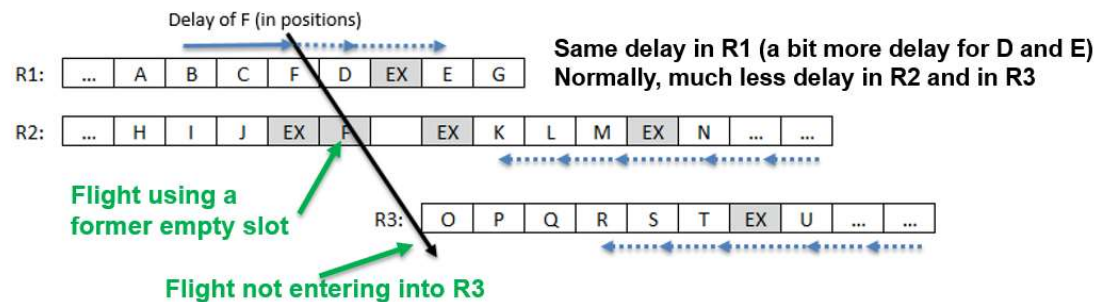
For more info about MIR:

- S. Ruiz, H. Kadour & P. Choroba. "A Novel Air Traffic Flow Management Model to Optimise the Network Delay", ATM Seminar, 2019

Before optimisation (default CASA sequences)



After optimisation (enhanced sequences)



In a nutshell, the MIR heuristic removes regulated flights from periods of congestion of other sectors



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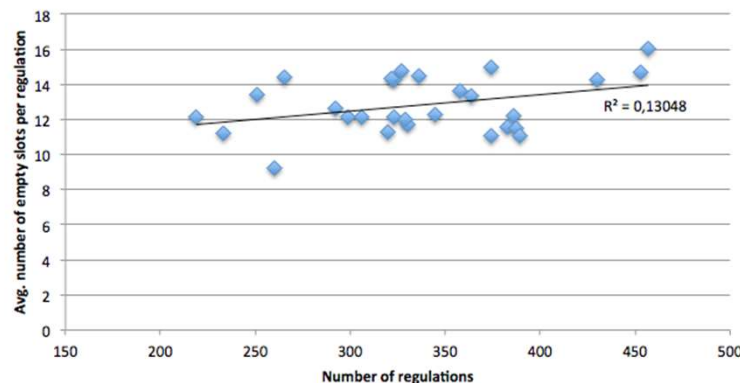




The “wasted capacity” problem

- CASSA sequences often contain **empty/unused slots** (i.e. **wasted capacity**), due to different reasons, e.g.: lack of demand, missed slots, interactions between regulations...
- In the Technical Report ‘*Analysis of Unused ATFM Slots*’ (EUROCONTROL, 2000) it was **estimated** that around **21% of the delay** could be due to unused slots.

Avg. number of empty slots per regulation vs.
number of regulations (AIRAC 1808)



The number of empty slots (capacity inefficiencies) increases with congestion.

The share of delay caused by unused slots could potentially be larger than 21%.



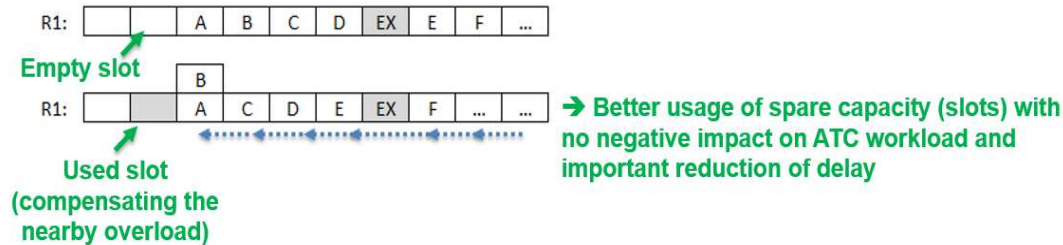
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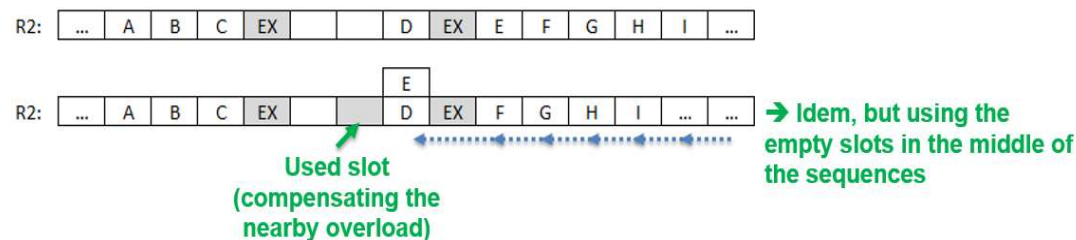


The Resourceful Overloading of Slots (ROS) mechanism

Case 1:



Case 2:



ROS mitigates the wasted capacity problem and reduces the total delay

Overloaded slots nearby empty slots is considered acceptable for ATC



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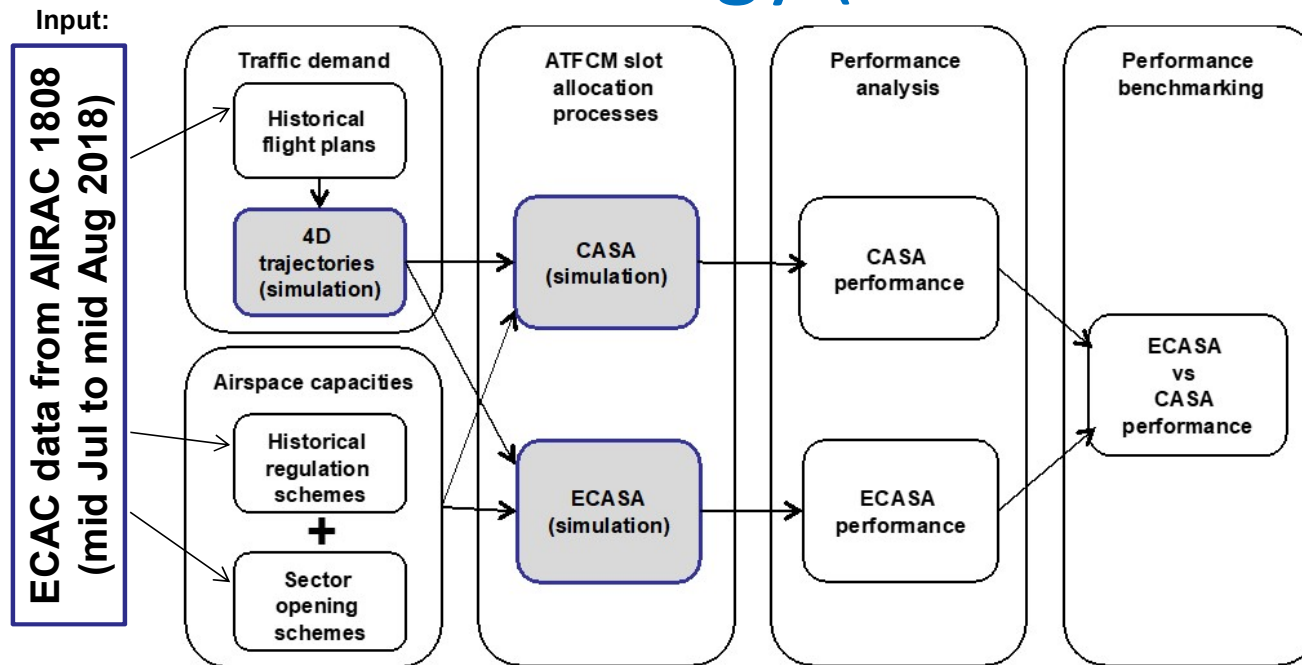
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Research methodology (with R-NEST)



ECASA performance has been analysed with these KPIs:

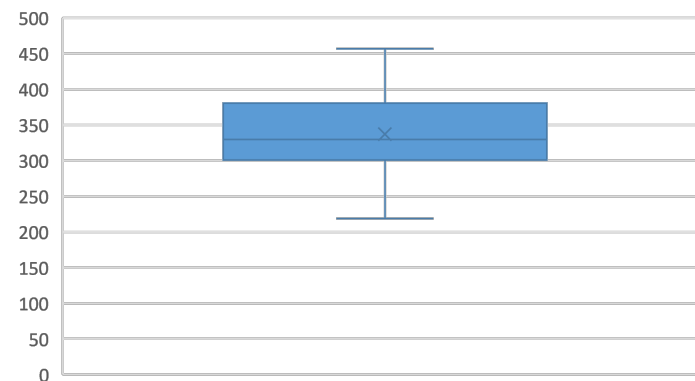
1. Delay in the network
2. Impact to AUs (#flights with delay >15 min.)

Regulations and delay in July-August 2018 (AIRAC 1808)

19.0 M min
en-route ATFM delay
(↑ +104% vs. 2017)



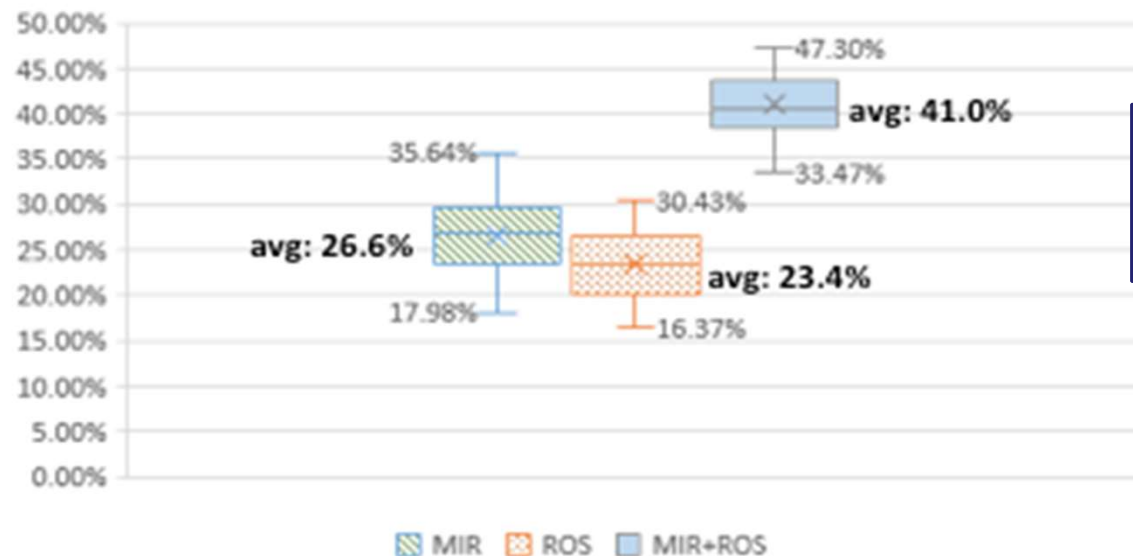
Number of Regulations (AIRAC 1808)



- **65%** more network delay vs 2017
- In en-route: **delay x2** vs 2017
- **337** regulations per day (max 450)

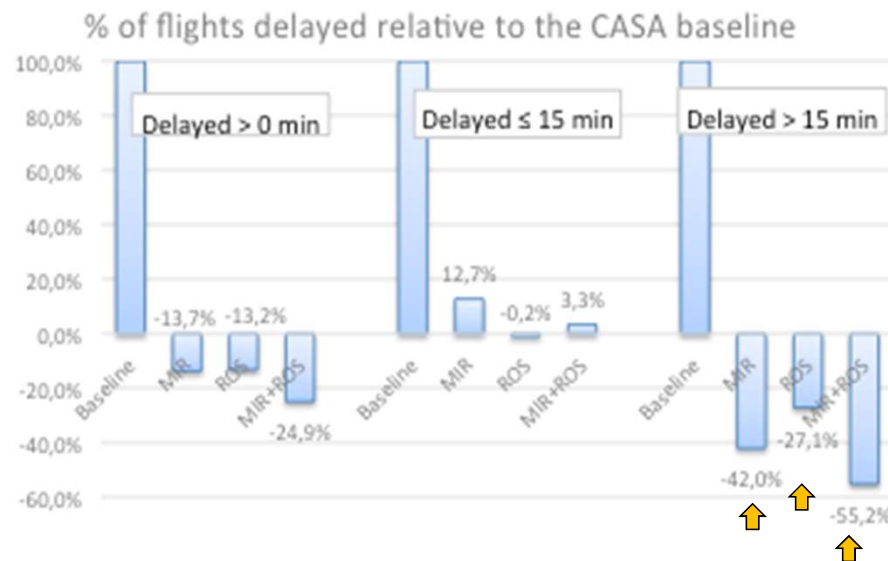
Fast Time Simulation results (with R-NEST)

% delay reductions achieved in the period AIRAC 1808



**Significantly less
network delay
compared to CASA**

Fast Time Simulation results (with R-NEST)

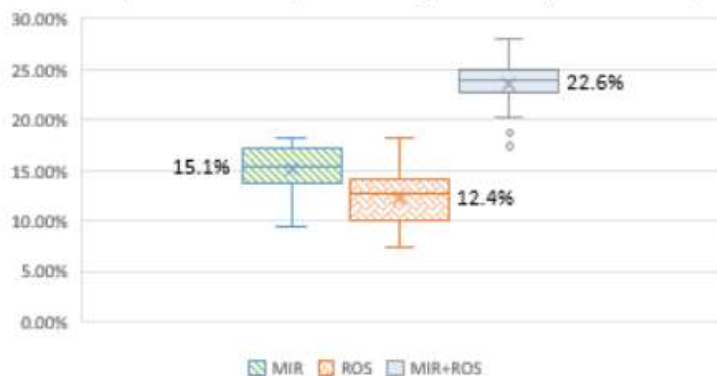


Significantly less
impact of delay

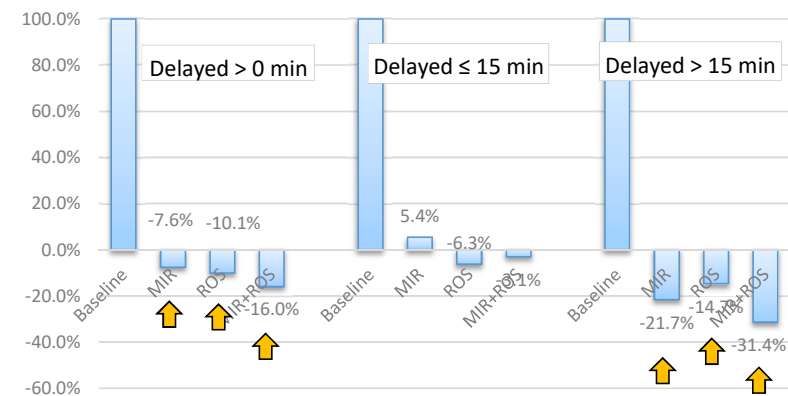
Recently updated results (not in the paper)

- We have added the *recorded dynamicity of the regulation scheme* (from *oplog* files)
- Results are highly sensitive to the inputs (reduction of benefits by 50%)
- Simulations with *recorded demand variability* (e.g. FPL updates) will be analysed soon (this could lead to important benefit reductions too)

ECASA optimisation - dynamic Reg. Scheme (AIRAC 1808)



% of flights delayed relative to CASA baseline





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Conclusions and future work

- ECASA has **3 key features**:
 - **Reconciliation of local constraints** (i.e. to mitigate the *Interacting Regulations problem*)
 - **Better utilisation of slots** (i.e. to mitigate the *Wasted Capacity problem*)
 - **Innovative approach** (i.e. quick improvements using the current system and rules and requiring minimal developments)
- ECASA could contribute to:
 - Significantly reduce **network delay** and **impact of delay**.
 - Possibly increase **ATCOs productivity** (less 'idle times').
 - **Equity** and **safety** in principle remain neutral (to be further validated).
- Currently we are exploring the **potential implementation of MIR in the Network Manager systems for real operations** and will be **followed by ROS**.
- Future research will include **new optimisation strategies for ECASA** to further reduce delays.



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Questions?



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Implementation aspects

ECASA follows an innovative approach (min change & max benefit)

ECASA-MIR algorithm:

At each CASA True Revision Process (every 1 minute):



- 1) Run **CASA** as usual (CASA is the core)
- 2) **Identify interacting flights** generating unnecessary delay
- 3) **Change the CASA priority** of the flights identified

ECASA steps

Note: Slot **amendments** are managed by **CASA** (in step 1)



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Implementation aspects

ECASA-ROS algorithm:

At each CASA **True Revision Process** (every 1 minute):



- 1) Run **CASA** as usual (CASA is the core)
- 2) **Identify unused slots & nearby slots** that could be overloaded
- 3) **Overload nearby slot & block the unused one**

ECASA steps

ECASA follows an innovative approach (min change & max benefit)



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