# The challenge of allocating scarce resources

Lorenzo Castelli, University of Trieste

2nd Engage thematic challenge 4 workshop
Nommon, Madrid, 12NOV19

Founding Members

# Scarce resources – NM’s view

EUROCONTROL

## Network Manager Annual Report

2018

SUPPORTING EUROPEAN AVIATION

FOUNDING MEMBER SESAR JOINT UNDERTAKING

NETWORK MANAGER

TABLE OF CONTENTS



**Network Manager** Annual Report 2018 7

# Scarce resources ?

## 6. SCARCE RESOURCES

The Radio Frequency Function (RFF) and Transponder Code Function (TCF) were established in 2012. The NMB approved the CDM arrangements that govern both functions.

### Radio Frequency Function

The implementation of 8.33 kHz below FL195 has again enabled NM to satisfy all requests for new aeronautical voice frequencies in Europe in 2018.

Even though only around 70% of the 8.33 kHz conversions planned for 2018 were completed before January 2019, these conversions provided spectrum capacity enabling the National Frequency Managers together with RFF to satisfy all the 2018 frequency requests. This high request satisfaction rate confirms the NM assessment of the benefits of the deployment of 8.33 kHz radios below FL195.

The NM Radio Frequency Function (RFF) has launched activities to maximise the benefit from the 8.33 kHz conversions in order to ensure they enable the satisfaction of all frequency requests for many years to come. This will be achieved via the development of new software tools supporting enhanced frequency management procedures agreed by the Radio Frequency Function group (RAFT) and, when applicable, applied in the whole ICAO EUR region via the cooperation with the ICAO EUR Frequency Management Group.

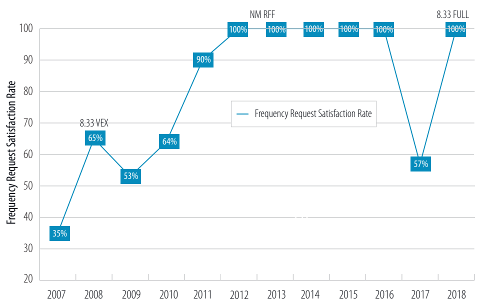
In 2018, the Radio Frequency Function also provided support to the National Frequency Managers by coordinating monitoring activities, analysing and contributing to the resolution of reported radio interferences and by performing local studies to satisfy complex frequency requests.

### Transponder Code Function

Transponder code usage in Europe has improved through the introduction or extension of multiple technologies. There were enough transponder codes available to users to avoid allocating wrong or conflicting codes.

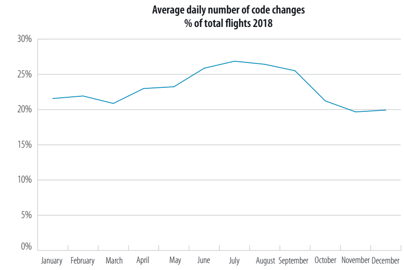
One of the main enablers for TCF is the Centralised Code Assignment and Management System (CCAMS), a pan-European solution to overcome the current and future shortages of the SSR codes used by Air Traffic Control for radar services. CCAMS provides a unique SSR code to each flight operating in the countries using the service.

By the end of 2018 seventeen States implemented CCAMS namely: Austria, Bulgaria, Croatia, Denmark, Estonia, Finland, Ireland, Lithuania, Moldova, Montenegro, Poland, Portugal, Norway, Serbia, Sweden, Ukraine and the United Kingdom.




*8.33 VEX - the Vertical EXpansion down to FL195 from FL245 and*
*8.33 FULL - the 8.33 kHz implementation in all the airspace of EU States plus Norway and Switzerland*






CCAMS also benefits non-CCAMS States as it reduces the number of code changes due to crossing different participating areas (see the graph; these figures are based on the current radar data provision to NM that have the SSR code included).

Approximately 59.3% of the daily flights receive an SSR code from CCAMS.

No cases of wrong codes assigned by CCAMS were detected by the monitoring tools or reported by the operational users. On average 29 code conflicts were detected daily for the NM area.

Another technology that contributed to the optimisation of the code usage was the Mode S radar technology that supported the capability to use the downlinked aircraft identification, which continued to progress in 2018. Approximately 13.65% of the daily flights used the conspicuity code A1000.

In coordination with the ICAO Paris Office, the Code Allocation List (CAL) for the complete ICAO EUR Region was produced and published in preparation for the summer season 2018. No cases of shortfalls (e.g. code shortages) in code allocations to States were reported.

# Infrastructure of the aviation system

The aviation system is composed of two main infrastructural elements

- Airports
- Air traffic management (ATM)

**There is not an unlimited availability of such resources**

- The ***runway complexes*** of major airports are among the scarcest resources of today's international air transport system and will continue to be so in the foreseeable future
- In Europe ***en route airspace*** also acts as a major "bottleneck"

Most delays are created by imbalances between demand and capacity resulting from airlines scheduling more flights than available capacity

# Delay mitigation actions
## (ref. #2)

- **Long-term. Infrastructural interventions**
  - increasing capacity through infrastructure expansion and the development of new ATM technologies
  - *difficult/expensive/environmental challenging*
- **Medium-term. Scheduling interventions** - ***Demand management***
  - Reduce the number of flights scheduled at peak hours by distributing flights more evenly over the day
- **Short-term** (**schedule is given**). **Improved capacity utilisation** – ***Capacity management***
  - Sequencing of runways configurations
  - Balancing of the arrival and departure service rates
  - ATFM regulations

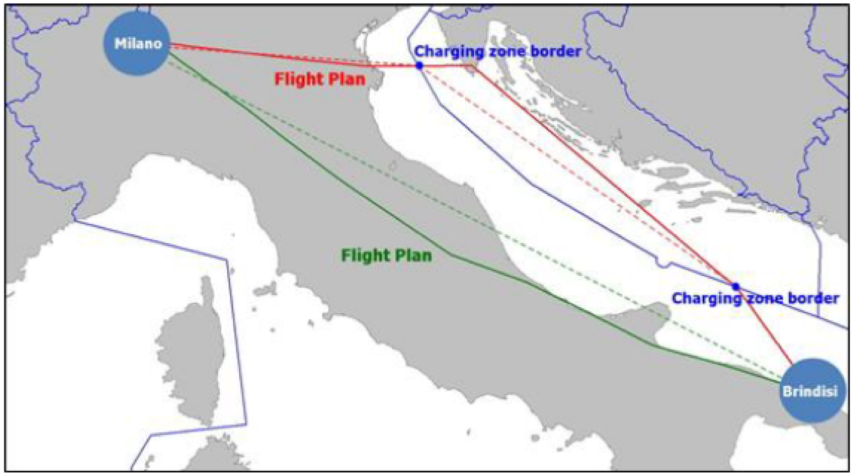
# Airport demand management
## (ref. #3)

- **Schedule coordination** – administrative, quantity-based
  - Airports declare a quantity of available slots per hour
  - Slots are then allocated through an administrative procedure *(IATA guidelines and EC Regulations)*
- **Congestion pricing** – economic, price-based
  - Congestions tolls are specified for access to the airport
  - Airlines then schedule their flights based on the resulting costs
- **Slot auctions** – economic, quantity-based
  - Airports declare a capacity, i.e., specify the number of available slots
  - Slots are then allocated through a market-based mechanism
- Alternative schemes
  - **hybrid mechanisms**, which allocate a fixed number of slots administratively and allocate the remaining slots through an auction or other economic scheme.
  - **secondary trading**, which allows buying and selling of slots after an initial allocation has been made
  - **non-monetary targeted scheduling interventions**, which adjust flight schedules taking into consideration airline scheduling requests and on-time performance objectives

**Airport slot:** the permission for a planned operation to use the full range of airport infrastructure necessary to arrive or depart on a specific date and time

# Airspace demand management

- When creating and subsequently submitting an initial flight plan, **airlines do not have the information on airspace nominal capacities** and do not need to consider it.
- *DCB solutions try to re-plan the demand*?
- Modulation of air navigation service charges (**no implementation so far**)
    - Users may fly longer routes to avoid "expensive countries" and still get an economic benefit
    - EC Regulation 393/2013 allows congestion pricing
    - Several Exploratory Research studies
        - SATURN: peak-load pricing
        - COCTA: trajectory pricing
        - VISTA, INTUIT, APACHE….



# Airport capacity management
## (ref. #3)

- For runway systems, the **maximum throughput capacity** is defined as the "*average number of aircraft movements that can be processed per unit of time under continuous demand*". It depends on:
    - number of runways
    - physical layout of the runway system
    - runway configuration - *can be controlled*
    - separation requirements
    - weather and other operating conditions - *subject to uncertainty*
    - mix of arrival and departures - *can be controlled*
    - aircraft mix - *can be controlled*

# Airspace capacity management

- Tactical demand-capacity imbalances in the airspace are managed by assigning pre-departure delays according to the **First-Planned First-Served** principle
  - traffic regulations – CASA algorithm, Europe
  - ground delay - ration by schedule, US
  - *It's better to have an aircraft waiting on the ground than in the air*
- User driven prioritisation (UDPP) approach
  - Flexibility to AUs to redistribute the delay across its fleet, through prioritisation of flights with high economic value over flights with relative low cost of delay
- Market-based approach
  - Minimise the total cost of delay by swapping FPFS-allocated slots (ref. #1)

- **Air Traffic Flow and Capacity Management (ATFCM) slot**: a period of time within which take-off has to take place, namely between 5 minutes before and 10 minutes after the *controlled take-off time* (CTOT).

# Demand and capacity management approaches

| | Airport | Airspace |
|---|---|---|
| **Demand management** | • **Schedule coordination**<br>• Congestion pricing<br>• Slot auctions | • Modulation of air navigation service charges |
| **Capacity management** | • Runway configuration<br>• Mix of arrival and departures<br>• Aircraft mix | • **CASA algorithm**<br>• UDPP<br>• Market-based ATFM slot trading |

**Currently in use – administrative approach**

# Airport demand management

## Schedule coordination – slot allocation process (ref. #4)

Before the beginning of the season

| | | |
|---|---|---|
| 1 year | **Capacity declaration** | Slot coordinator<br>Airport |
| 5 months | Slot requests | Airlines |
| 4 months | **Initial slot allocation** | Slot coordinator |
| 4 months | Slot conference | Airlines<br>Slot coordinators |
| 2 months | Slot return deadline | Airlines |
| Up to 1 day before operations | Changes and new requests | Airlines |

# Airport demand management

## Initial slot allocation (ref. #5)

**Primary criteria**

- grandfathered (20%-80% rule)
- change-to-historic
  - CL and CR
- new entrants
- others

**Mathematically formulated and solved !!**

**Secondary criteria**

- Year-round
- type of route
  - Existing vs. new route
- type of service
  - Scheduled, charter, cargo
- type of market
  - Domestic, regional, long-haul
- size of aircraft
  - Narrow-, wide-body

# Mathematical model - Formulation
## (Refs. #5, #6, #7)

- Minimise a weighted sum
  - Maximum displacement imposed on any slot (w1)
  - Total displacement across all flights of the season (w2)
  - Total number of slot displaced (w3)
  - Assumption: w1 >> w2 >> w3 = 1
- Long list constraints including
  - Airport capacities (departure, arrival, total) – apron and terminal
  - All four primary criteria
  - Connectivity and turnaround constraints
  - Series of slots (interdependencies between the different days)
- No secondary criteria considered

# Mathematical model – Results
## (Refs. #5, #6, #7)

- Computational tests on real data – provided by ANA Portugal
- Entire summer season 2014/2015
- Madeira (3.2 M pax), Porto (11 M pax) and Lisbon (27 M pax) airports
- Enormous benefits from the optimisation tool
- E.g., in Porto, reduction of
    - maximum displacement by 31%,
    - total displacement by 27%
    - the number of displaced slots by7%.
- Sensitivity analysis, e.g.,
    - an increase in the total hourly capacity by one slot (from 20 to 21 movements per hour) would reduce the total displacement by 20%.
    - displacing just 18 historic slots during the entire season by only 5 minutes each reduces CH displacement by 45%.

# Mathematical model – Comments

- It is possible
  - to perform a slot allocation with significant lower schedule displacement (i.e., airlines' requests are more closely met), in a very short computational time up to 200000 movements per year
  - to quantitatively determine (or at least estimate) the effect of modifications in some procedures or parameters that are currently considered as boundary conditions (and thus unchangeable) in the slot allocation process.
- These results cannot be determined without the support of an optimisation tool.
  - Largely manual procedure in place today
- The larger the airport, the larger the benefits from optimisation

# Airspace capacity management
## CASA algorithm (ref. # 9)

- FPFS policy
- Exempted flights
- True revision process (once a minute)
- Most penalising regulation (MPR)
- Compression
- Capacity of slots (one flight per slot is allowed)
- Overloaded slots (two flights per slot in some cases. One empty slot 'nearby')
- Manual slot amendments

# CASA enhancements

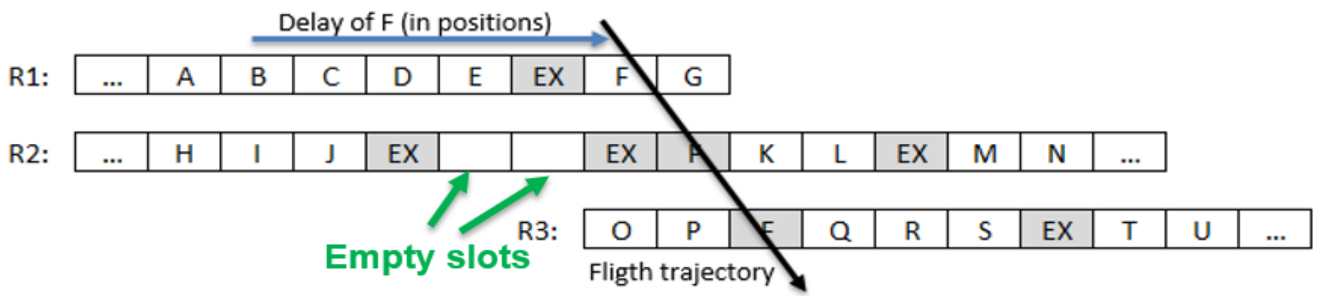
## Mitigation of Interacting Regulations – MIR (ref. #9)

- Higher priority if anticipating a flight reduce overall delay
    - FPFS rule ‘slightly’ broken !
    - Slots now left empty by CASA are used.
    - Only for flights affected by more than one regulation
- Heuristic optimisation approach
    - Flights delayed by their MPR and generate ‘large negative’ impacts on other regulations are identified
    - The priority of those flights is increased
- Results through simulation (R-Nest), not analytical approach
- AIRAC 1808 (mid-July to mid-August 2018)

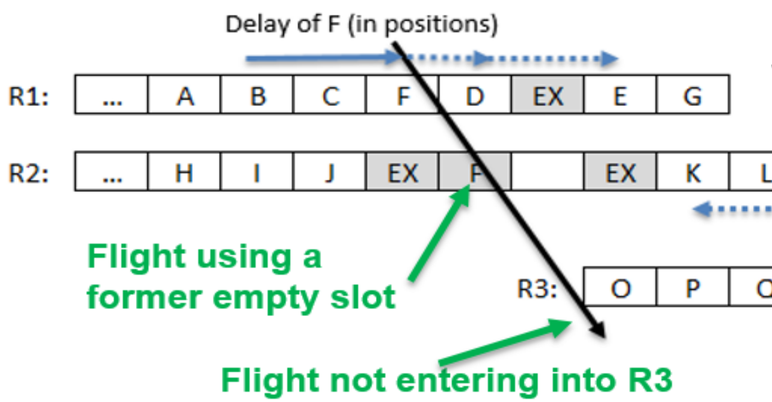
# CASA enhancements

## MIR mechanism (ref. #9)

**Before optimisation (default CASA sequences)**



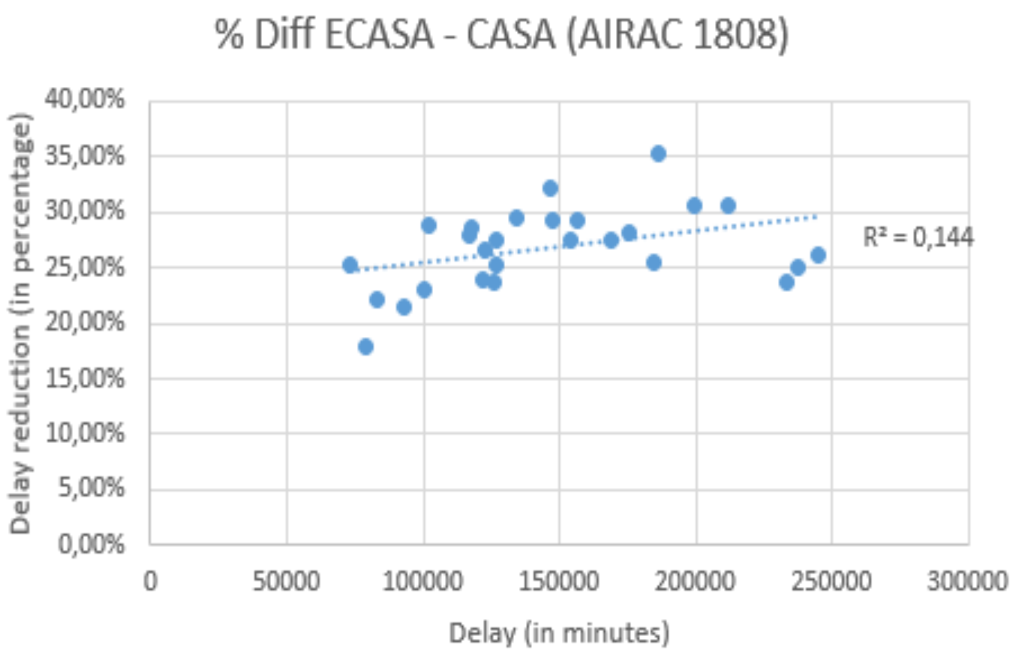

**After optimisation (enhanced sequences)**




**Same delay in R1 (a bit more delay for D and E)**
**Normally, much less delay in R2 and in R3**

# CASA enhancements
## MIR results (ref. #9)

- About 1500 flights amended
- **Av. daily delay reduction 27%** (min 18% - max 35%)



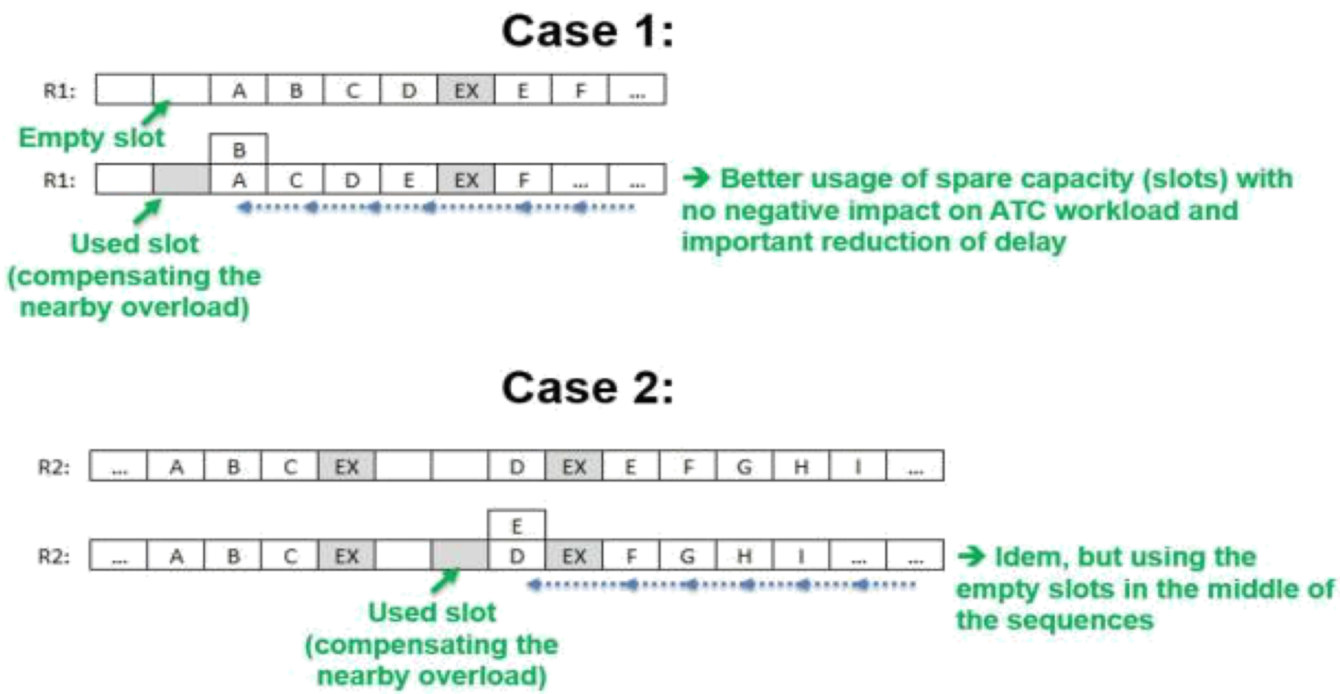

- **Number of delayed flights reduced by 13,7%** (9161 vs 10616)
  - + 12,7% number of delayed flights with delay < 15 min
  - - 42,0% number of delayed flights with delay > 15 min
  - Slight increase in the number of delayed flights with delay > 90 min
    - From 77 (0,7%) to 137 (1,5%) flights

# CASA enhancements

## Resourceful Overloading of Slots – ROS (ref. #10)

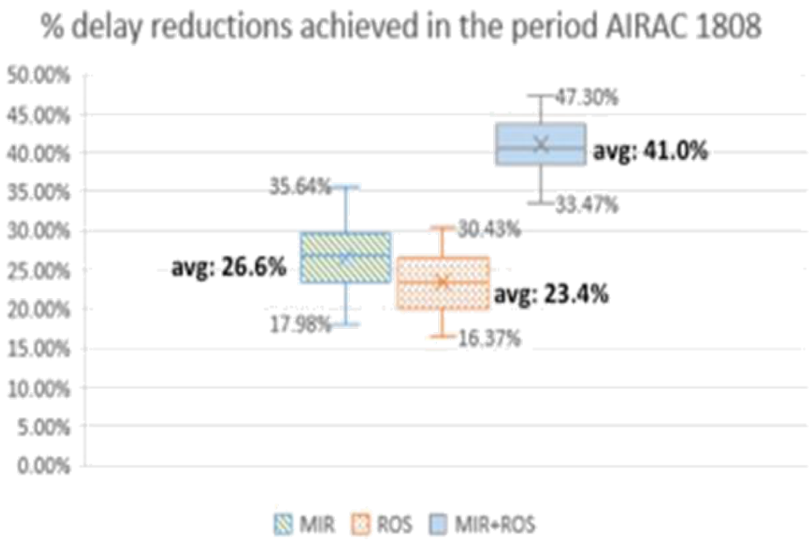
- If a non-forced empty slot is identified in the sequence, then a nearby non-overloaded slot could be overloaded with an extra flight.

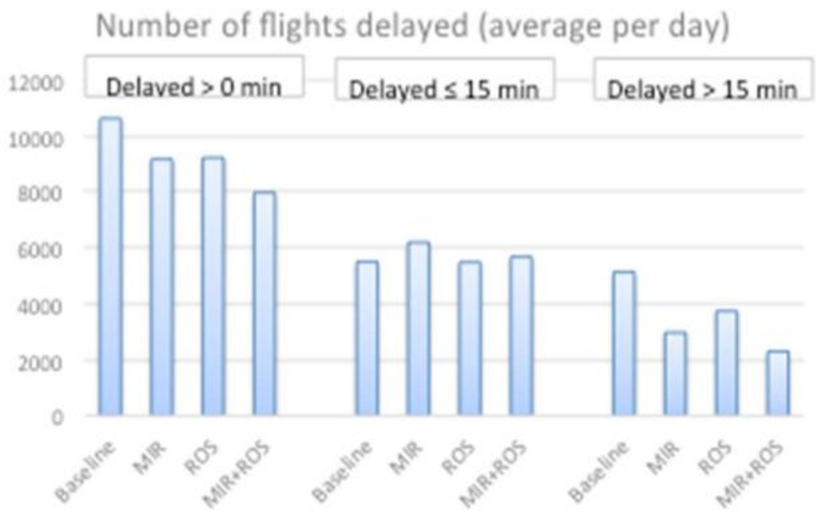
- On average 10 non-demanded/unused slots per regulation for AIRAC 1808



# CASA enhancements

## MIR + ROS (preliminary) results  (ref. #10)




Number of delayed flights (delay > 15 min)

- ROS: -27%
- MIR: -42%
- MIR + ROS: - 55%

# CASA enhancements

## Comments

- Significant delay reductions from individual MIR and ROS use and from their combination
- ***UDPP equity***: *the action of one AU shall not generate a direct negative impact (i.e., increase the delay) of other AUs' flight(s).*
- ***FPFS fairness***: *the original sequence of flights is preserved*
- ROS: a simple idea that could potentially bring significant benefits to all stakeholders without penalising anyone.
    - *FPFS-fair <u>and</u> UDPP-equitable*
- MIR: it appears to provide higher delay reductions (than ROS')
    - *not UDPP-equitable, not FPFS-fair*
- Results do not rely on mathematical/analytical models but on heuristics + simulation

# Final comments

- There is unexploited capacity
- It is still possible to make better use of existing capacity without having to invent solutions that are radically different from those currently in use
- Mathematical/analytical models still of great use
    - CASA enhancements would benefit from math modelling
- 'Slightly' relaxing *immovable* rules could lead to significant benefits
    - Grandfather rights
    - FPFS
- Advances for more accurate setting of declared/nominal capacities could be envisaged (e.g., through the use of ADS-B data)
- The larger the problem (more movements, more congestion), the more optimisation potential

# References


1. Castelli, L., Pesenti, R., & Ranieri, A. (2011). The design of a market mechanism to allocate air traffic flow management slots. Transportation research part C: Emerging technologies, 19(5), 931-943.
2. Jacquillat, A., & Odoni, A. R. (2015). An integrated scheduling and operations approach to airport congestion mitigation. Operations Research, 63(6), 1390-1410.
3. Jacquillat, A., & Odoni, A. R. (2018). A roadmap toward airport demand and capacity management. Transportation Research Part A: Policy and Practice, 114, 168-185.
4. Odoni A. R. (2018). The context of the ASAP research project. https://drive.google.com/open?id=1olX6px9PKuYg687FwTI3KUBd8wUWdCcU
5. Ribeiro, N. A., Jacquillat, A., Antunes, A. P., Odoni, A. R., & Pita, J. P. (2018). An optimization approach for airport slot allocation under IATA guidelines. Transportation Research Part B: Methodological, 112, 132-156.
6. Ribeiro, N. A., Jacquillat, A., Antunes, A. P., Odoni, A. (2019), Improving Slot Allocation at Level 3 Airports, Transportation Research Part A: Policy and Practice, 127, 32-54.
7. Ribeiro, N. A., Jacquillat, A., & Antunes, A. P. (2019). A Large-Scale Neighborhood Search Approach to Airport Slot Allocation. Transportation Science, 53(6), 1772-1797.
8. Ruiz, S., Guichard, L., Pilon, N., & Delcourte, K. (2019). A New Air Traffic Flow Management User-Driven Prioritisation Process for Low Volume Operator in Constraint: Simulations and Results. Journal of Advanced Transportation.
9. Ruiz, S., Kadour, H., & Choroba, P. (2019) A novel air traffic flow management model to optimise network delay. 13th USA/Europe ATM R&D Seminar, Vienna, Austria.
10. Ruiz, S., Kadour, H., & Choroba, P. (2019) An innovative safety-neutral slot overloading technique to improve airspace capacity utilisation, 9th SESAR Innovation Days, Athens, Greece.

# The challenge of allocating scarce resources

# Thank you

This network has received funding from the SESAR Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 783287.



The opinions expressed herein reflect the author's view only.
Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.