



Optimal Dynamic Airspace Configuration (DAC) based on State-Task Networks (STN)

M. Florencia Lema-Esposto, Manuel Ángel Amaro-Carmona, Natividad Valle-Fernández, Enrique Iglesias-Martínez and Adrián Fabio-Bracero

7th December 2021



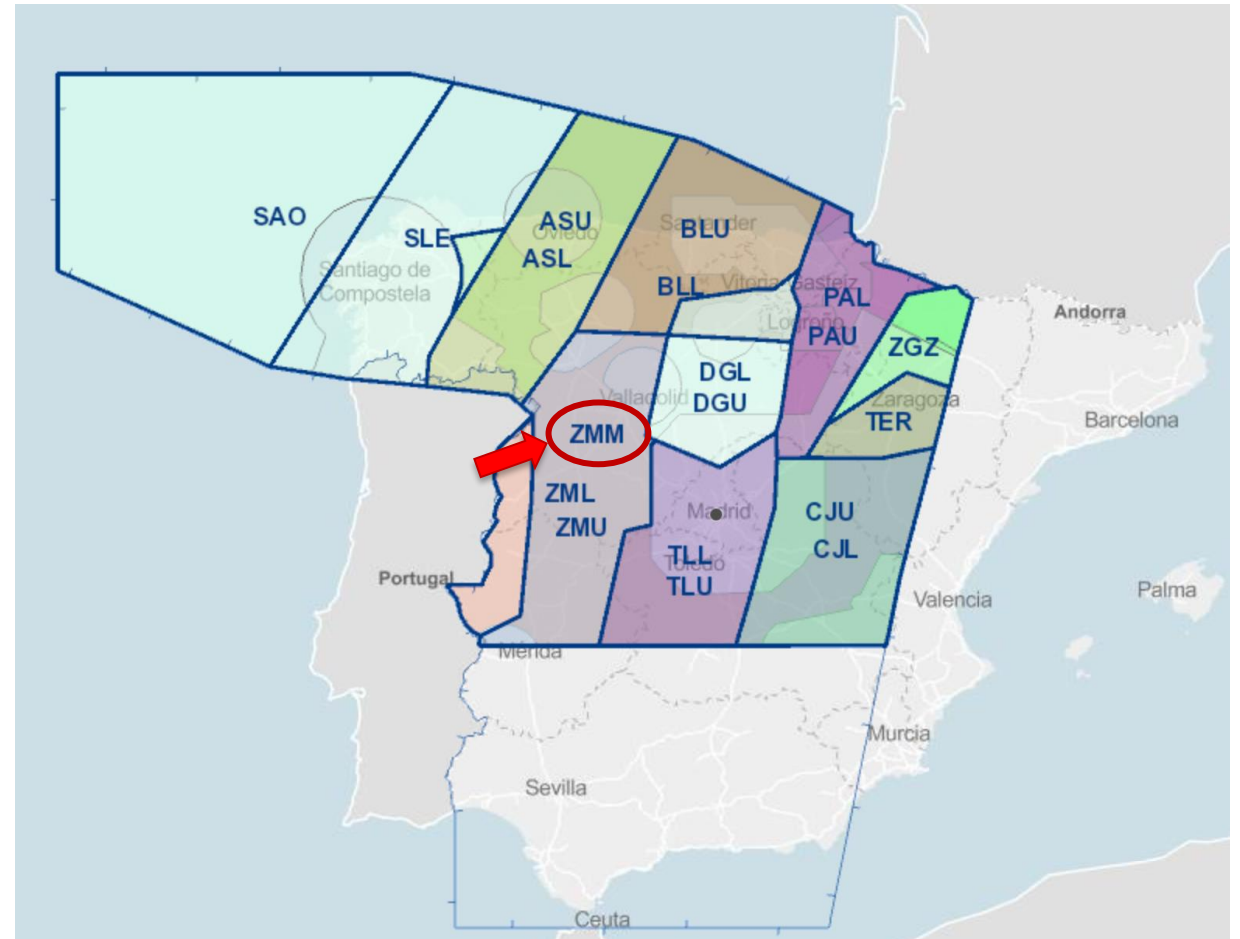
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Madrid ACC

- High levels of air traffic demand
- High complexity environment
- Use of pre-defined Elementary Sectors
- More flexibility

Dynamic Airspace Configuration
+
State-Task Networks optimization



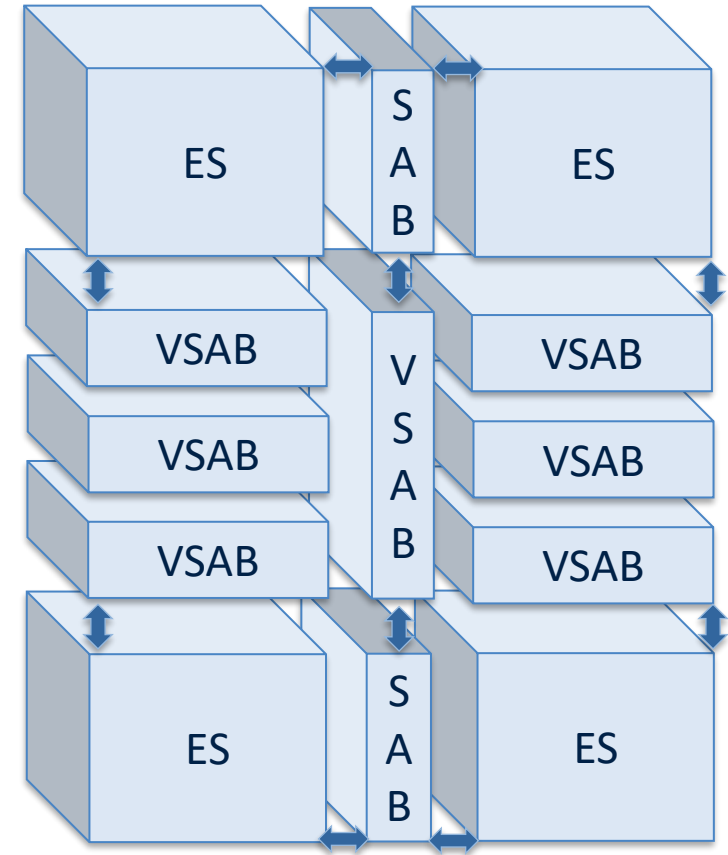
Dynamic Airspace Configuration (DAC)

- More flexible sectors configuration
- Adaptable to air traffic demand
- Creation of multiple smaller combinable airspace volumes

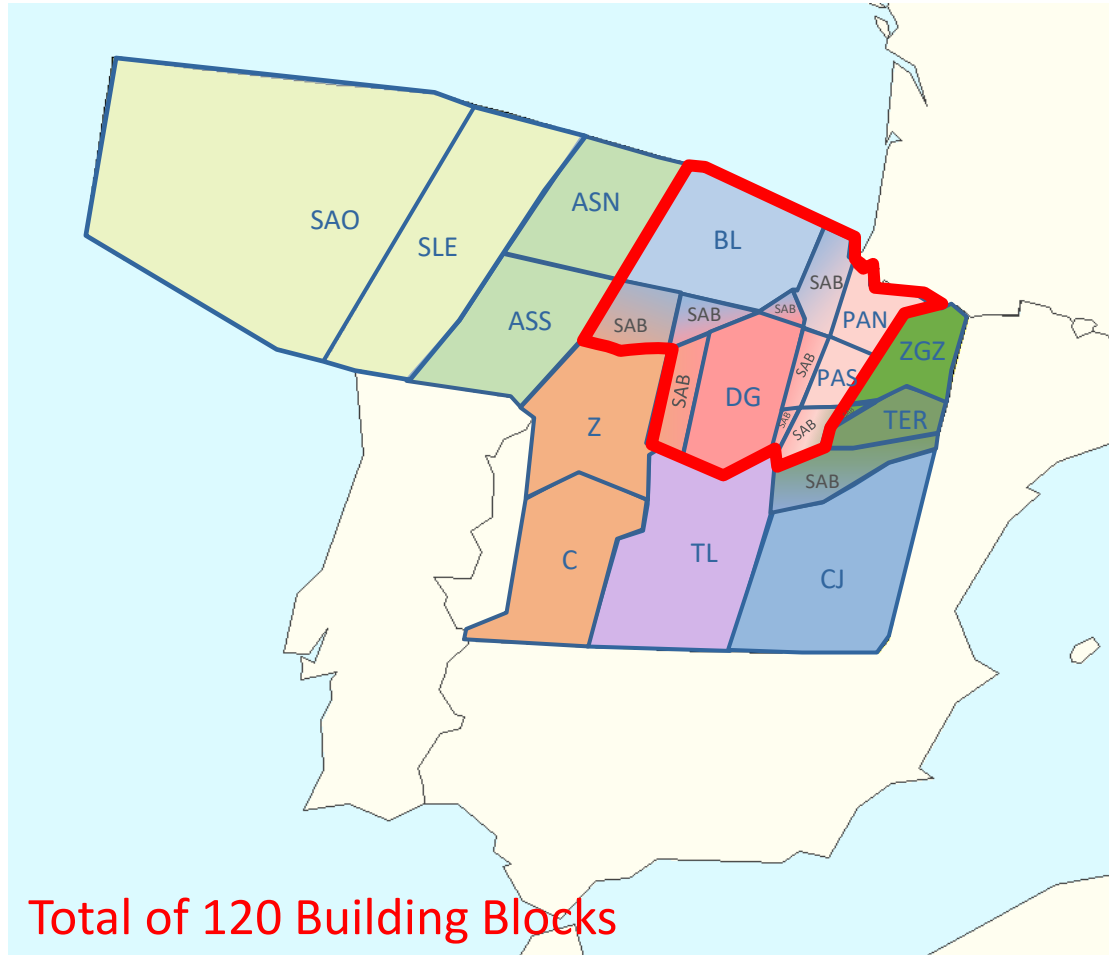
Elementary Sector (ES)

Shareable Airspace Block (SAB)

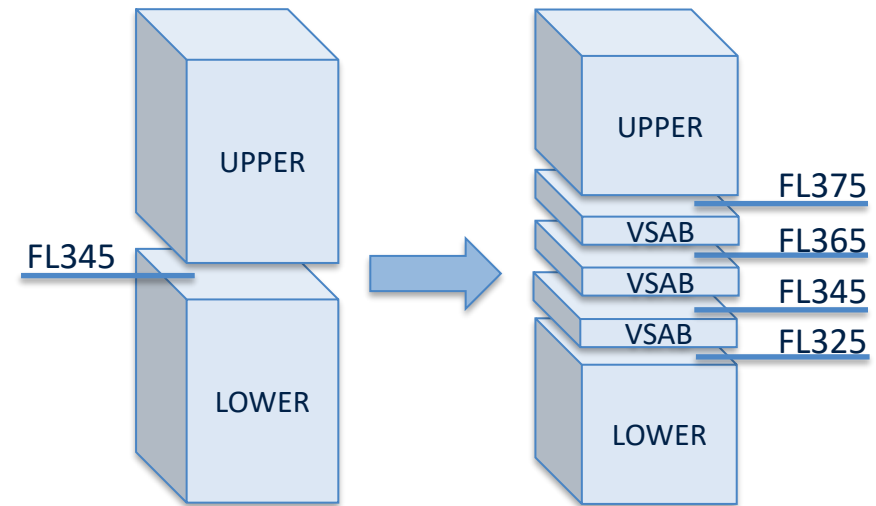
Vertical Shareable Airspace Block (VSAB)



Dynamic Airspace Configuration (DAC) in Madrid ACC



✓ Free Route Airspace



✓ 28 Elementary Sectors (ES)

✓ 20 Shareable Airspace Blocks (SABs)

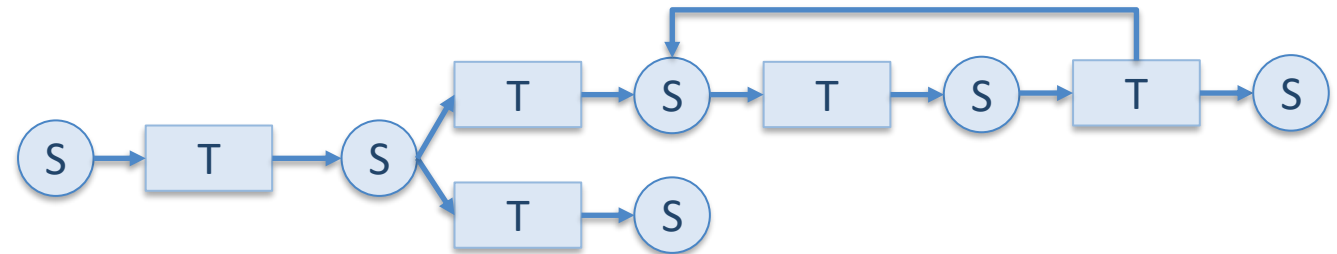
✓ 72 Vertical Shareable Airspace Blocks (VSABs)

State-Task Networks (STN)

✓ Introduced by Kondili et al. (1993) as a general algorithm for scheduling chemical multipurpose batch operations

✓ Interconnected nodes: “States” and “Tasks”

✓ Simple representation of a flowsheet



✓ Define the value of binary variables (Tasks) to optimally transform material from one state to another

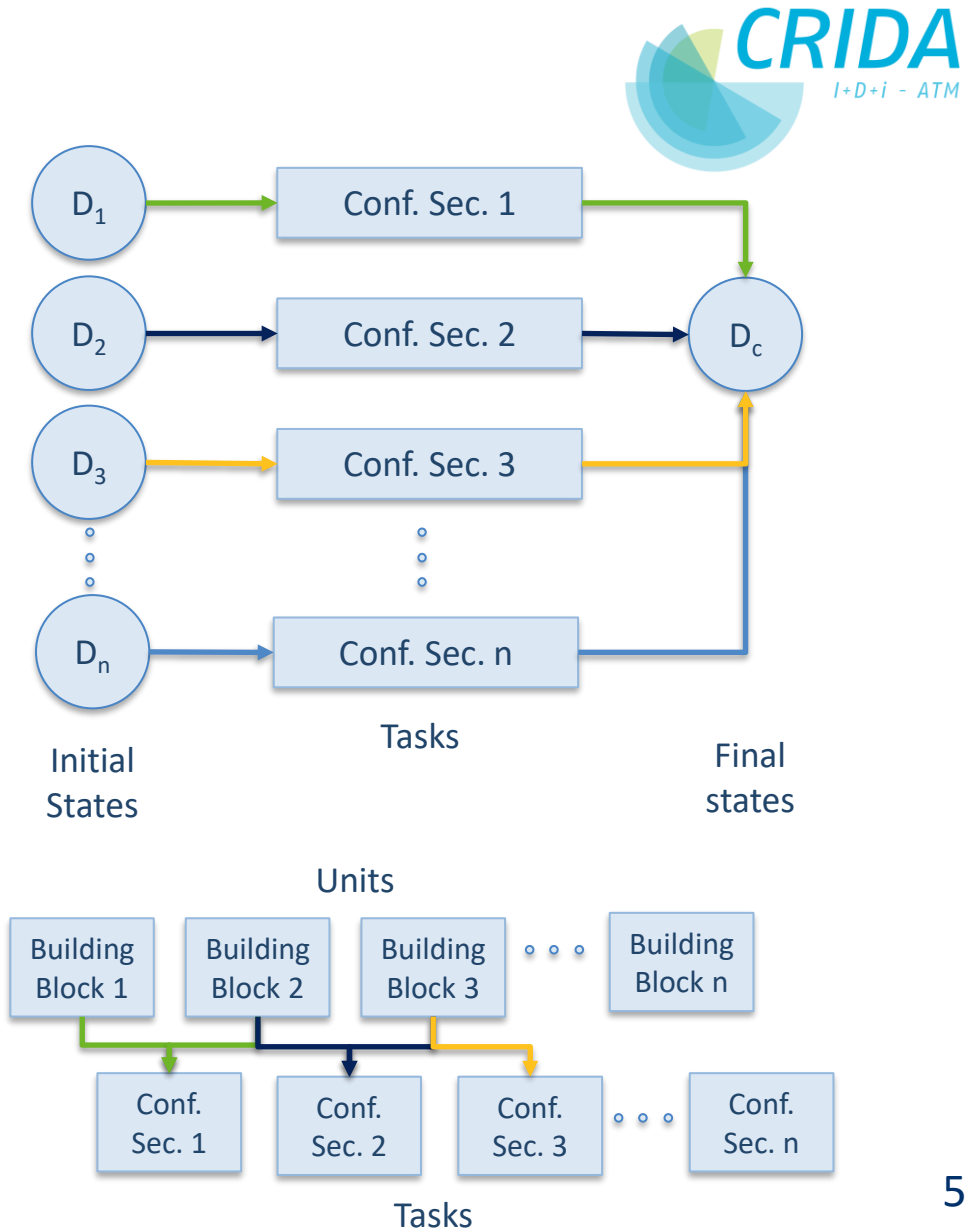
Model

- ✓ Simple representation of DAC interconnected elements
- ✓ Novel approach to address DAC problem

Model

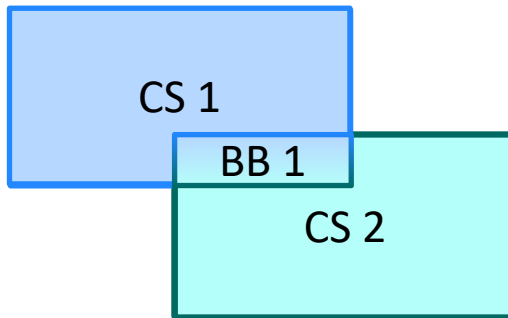
1. Single feed layer of initial “states” → Air traffic demand
2. Layer of “tasks” → Configured sectors
3. Single layer of final “state” → Controlled air traffic demand

Optimization objective: find the optimal “unit” (building block) allocation to each configured sector for passing the air traffic demand from its initial to its final state.

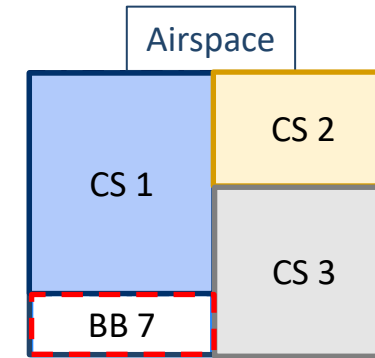


Constraints

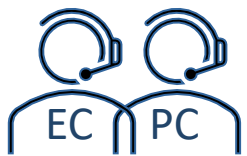
Building blocks simultaneity



Building blocks allocation

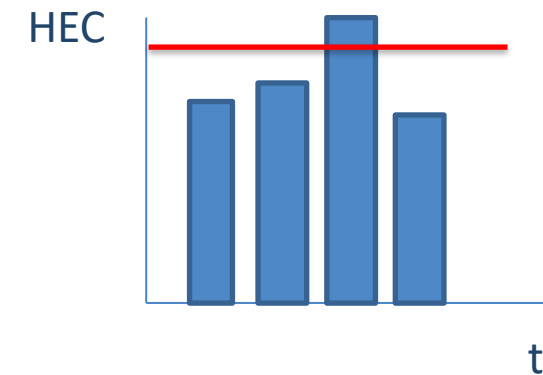


Maximum number of configured sectors



$\times 6 = 6$ Configured Sectors

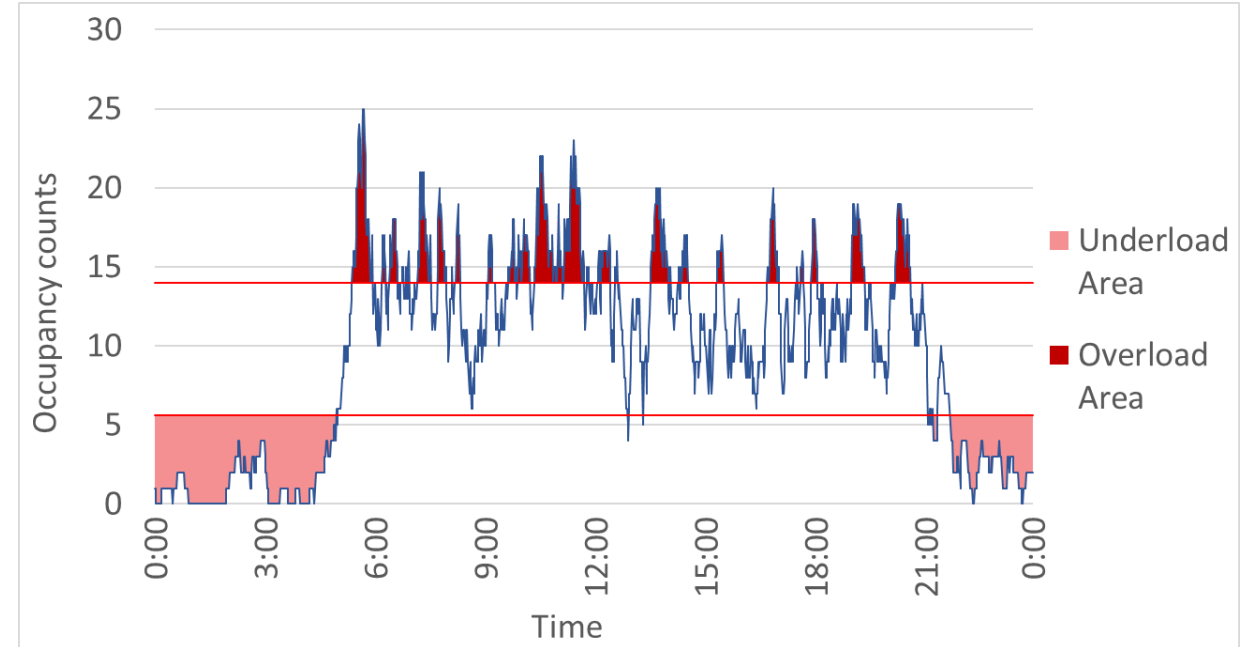
Capacity threshold



Cost function

- ✓ Each configured sector has an associated cost
- ✓ Parameter that the optimizer uses to rank all the possible configurations
- ✓ Occupancy counts $\leftrightarrow$ ATCO workload
 - Interval: 5 min
 - Sliding window: 1 min

$$Cost = W_{OVLD}A_{OVLD} + W_{UNLD}A_{UNLD}$$



$$Cost\ of\ a\ configuration = \sum_i^O Cost_i$$

being O = set of configured sectors forming the configuration

Results

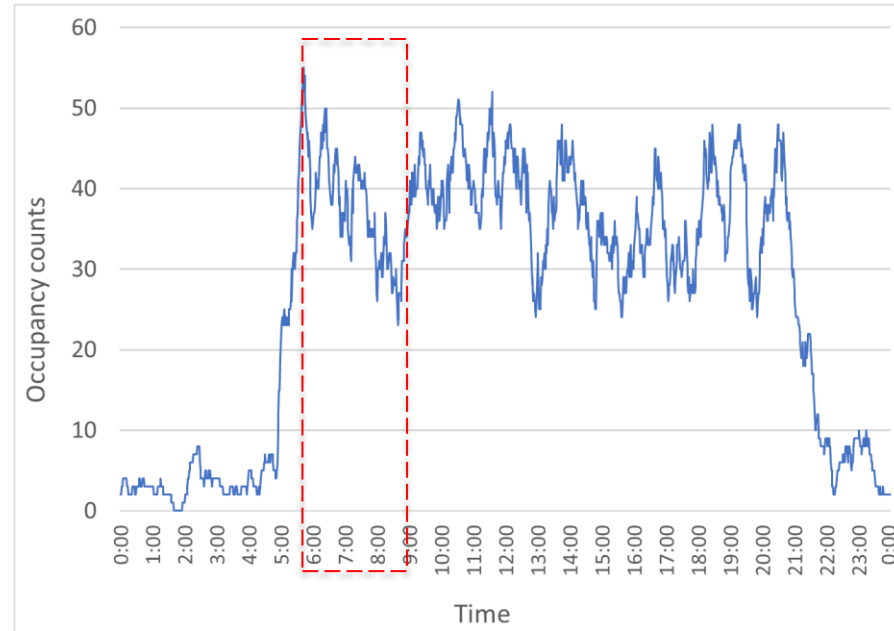
Use case: 21st of July 2019 → 6am to 9am

Reference scenario

LECMBLL	LECMBLU	LECMBLU
LECMBLU	LECMDGU	LECMDGU
LECMDGL	LECMPAL	LECMPAL
LECMDGU	LECMPAU	LECMPAU
LECMPAL	LECMBDL	LECMBDL
LECMPAU	LECMBDL	LECMBDL
6A	5A	5A
6am-7am	7am-8am	8am-9am

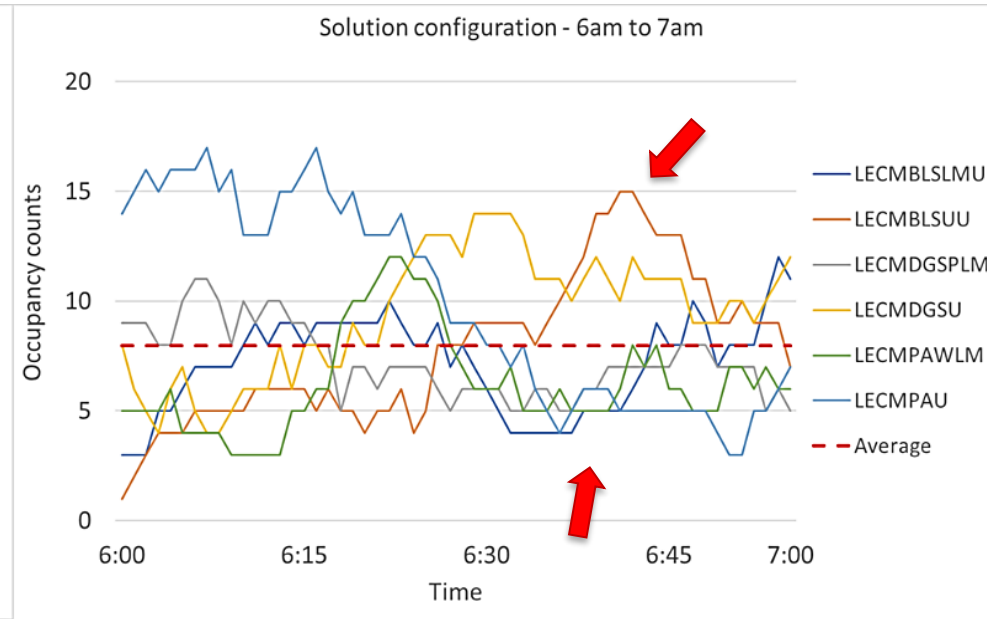
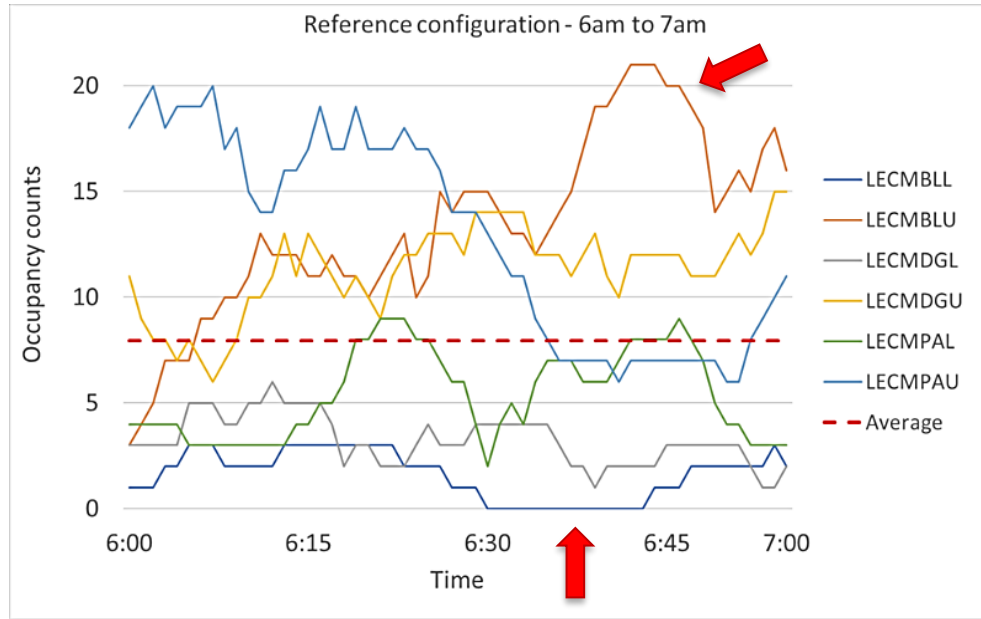
Solution scenario

LECMBSLMU	LECMBDPLL	LECMBSLI
LECMBSUU	LECMBSUML	LECMDGSLMU
LECMDGSPLM	LECMDGSPMMU	
LECMDGSU	LECMDGSPUU	LECMDPUU
LECMPAU	LECMPAWUML	LECMPALMU
LECMPAWLM	LECMPAWUML	
6A	5A	4A
6am-7am	7am-8am	8am-9am



- Results adhere to demand tendency
- Number of sectors is reduced

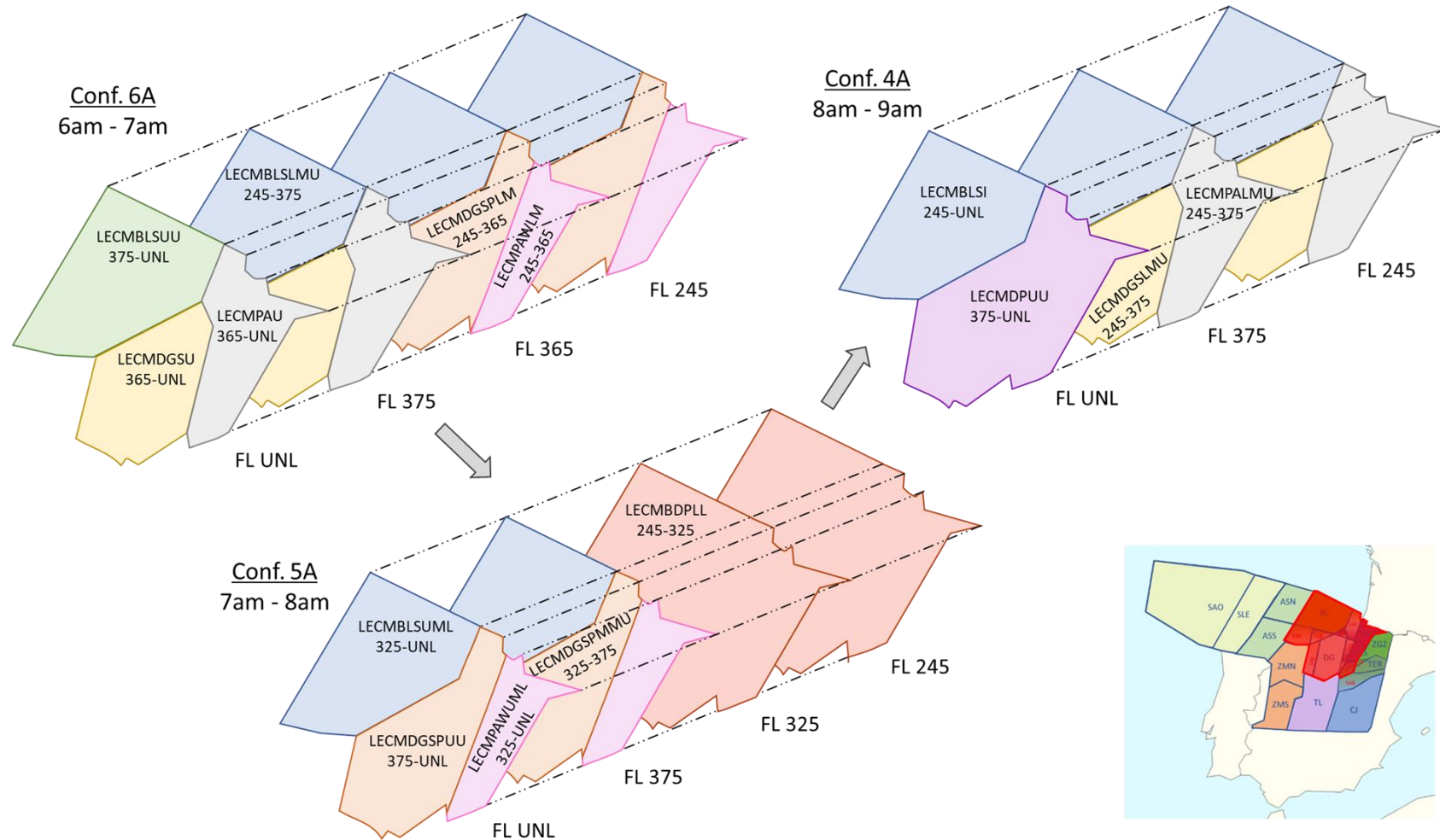
Results



Time Interval	Standard deviation (σ)	
	Reference scenario	Solution scenario
6am-7am	5.6	3.3
7am-8am	4.2	3.8
8am-9am	3.3	2.1

- ✓ Less peaks and troughs
- ✓ ATCO workload balanced
- ✓ Standard deviation decreases for Solution configuration

Results



Conclusions & Future work

- Implementation of Dynamic Airspace Configuration in Madrid ACC
- Application of State-Task Networks methodology to model the DAC problem
- Resolution of the optimization problem obtaining a configuration plan for a defined time interval and airspace based on occupancy counts
- ATCO workload is balanced, and the number of configured sectors required is reduced

Future Work:

1. Include the previous states of the airspace configuration in the modelling process
2. Include other variables for cost calculation



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Thank you for your attention – Q&A



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