# Strategic airspace capacity planning in a network under demand uncertainty
(COCTA project results)

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SESAR JOINT UNDERTAKING

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# COCTA Overview 1/3

**COCTA** – Coordinated capacity ordering
and trajectory pricing for a better-performing ATM

**Objective: Incentivize more cost-efficient outcomes!**

In a **re-designed ATM value-chain**,
propose and evaluate
**coordinated economic measures**
aiming to pre-emptively
**reconcile air traffic demand and airspace capacities**,
by acting on both sides of the inequality.

Focus:

- Strategic and pre-tactical phases, i.e. up to and including D-1
- En-route airspace (mindful of airport capacity and terminal airspace constraints)

# COCTA Overview 2/3

**COCTA** – Coordinated capacity ordering and trajectory pricing for a better-performing ATM

## **Coordinated capacity ordering** (capacity management)

Network Manager (NM) aims at minimizing total cost (sum of costs of capacity provision and costs of insufficient capacity, i.e. delays and re-routings – ‚displacement in time and in space‘)

NM concludes contracts with ANSPs on capacity provision

## **Trajectory pricing** (demand management)

NM offers several ‘trajectory products’ to Aircraft Operators (AOs), leaving different degrees of flexibility for assigning trajectories with the NM (i.e. lower charge involves more flexibility for the NM)

# COCTA Overview 3/3

**COCTA Process Overview**

| | |
|---|---|
| 5 years | Network Manager (NM) orders nominal **capacity profile** from ANSPs |
| 6 month | NM orders **capacity** (measured in sector-hours) from ANSPs and starts to offer trajectories to Aircraft Operators (AOs) |
| 6 month - 1 week | AOs order trajectories, NM can re-order capacities or modify charges (prices non-decreasing with time) |
| 1 week | NM assigns specific trajectories to AOs and decides on **Sector Opening Scheme** |
| Day of | operation |

**Key Element of today's presentation**

Strategic decision on capacity order **under uncertainty** (linked to **volatility**)

# Basic COCTA model

**Simplified optimization model (Strauss et al. 2017 – SID website):**

- Centralized decision making regarding ANSPs‘ capacities and AOs‘ routes (trajectories) **reduces overall costs** of ATC provision

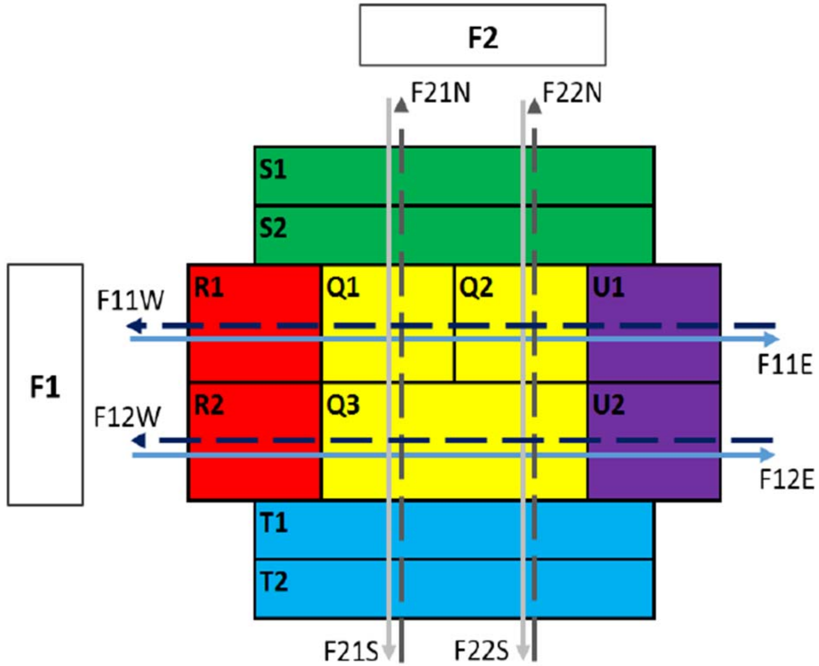



*Figure 4-1 Airspace structure for the case study*

<u>Decisions made by Network manager</u>:

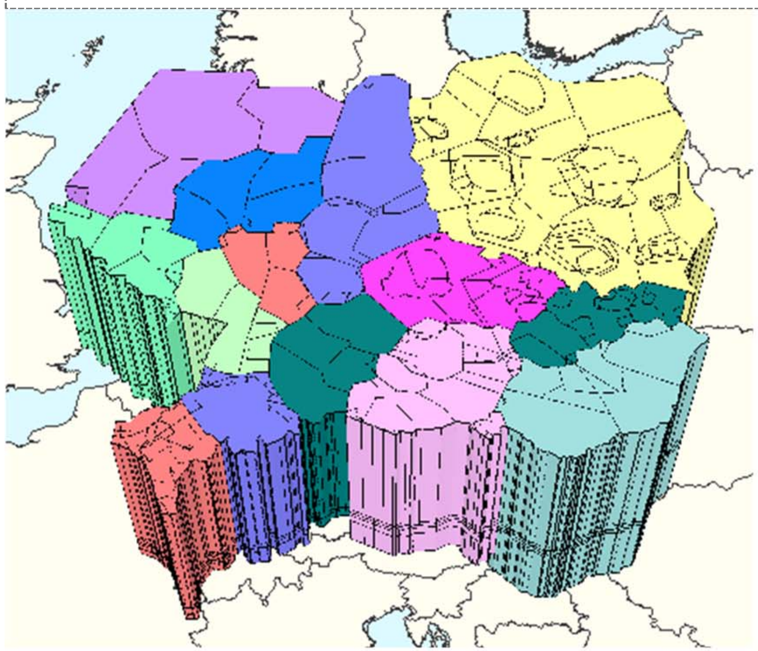
- Order (maximum) capacity from five ANSPs (Q, R, S, T, U)
- Decide on sector opening scheme and allocate flights within network (including displacement in time (delays) and space (re-routing))

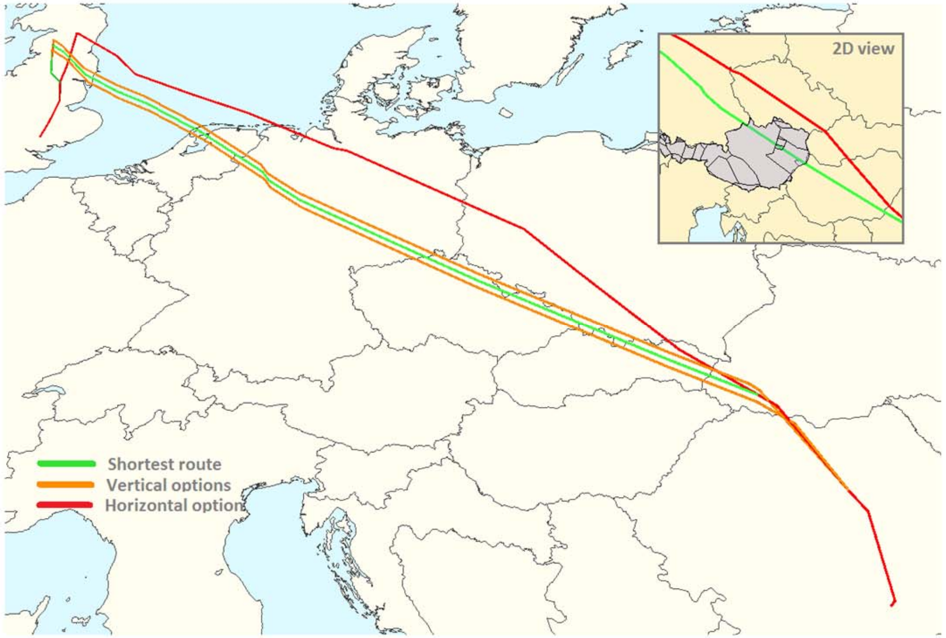
# Large scale case study 1/2

**Eight ANSPs** (with 15 ACCs/sector groups) in central and western Europe – in total 173 possible configurations for en-route traffic.

Traffic data: Busiest day in 2016 with **11,211 flights** in case study region

**ANSP cost data** from ACE reports (with assumptions on share of 'variable cost' – ATCO costs) / **AO cost data** from literature (A/C dependent)





# Large scale case study 2/2

## Key assumptions

- The majority of flights are known in advance
  (scheduled flights ≈85%),
  up to ***15% of flights appear at short notice***
  (e.g. charter, all cargo, business aviation, military).
- Model uses **‘sector hours’** as measure of capacity.
- Airport-pair charges provide incentives for using **shortest trajectory**.
- Only one demand management measure applied per flight
  (either delay **or** rerouting)

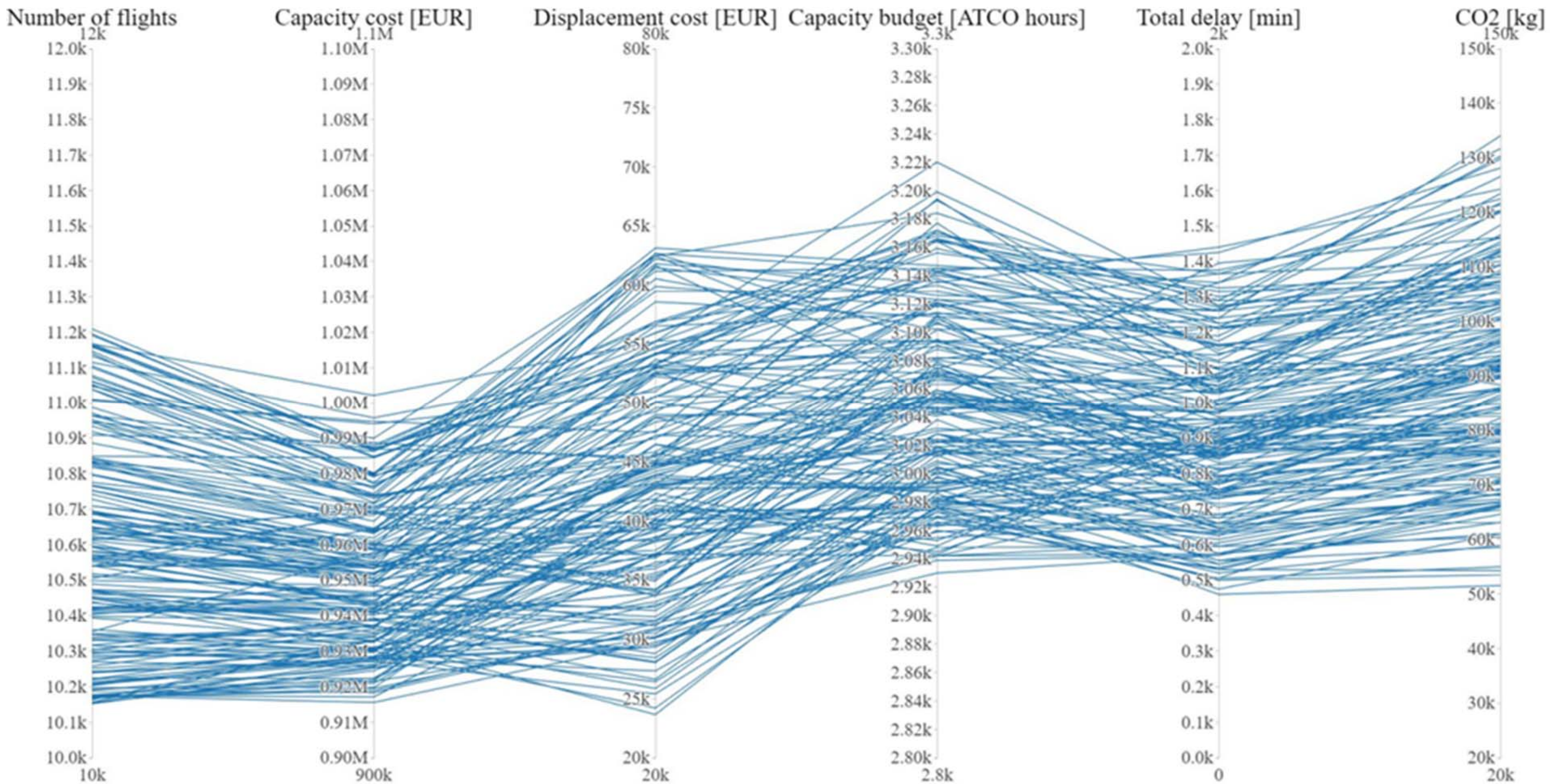
# Capacity ordering under uncertainty

## Two steps in modelling

1. **Scenario identification (SI)**
   Run a large number of simulations with (up to 15 %) random flights and **identify specific network optimum** (based on key performance indicators).
   **Result:** Different optimum scenarios for different traffic materializations

2. **Scenario testing (ST)**
   **Test result(s)** of step 1 by running again a large number of simulations, this time with maximum capacity based on result of step 1.
   **Result:** Effects of specific capacity provision on KPIs under uncertainty

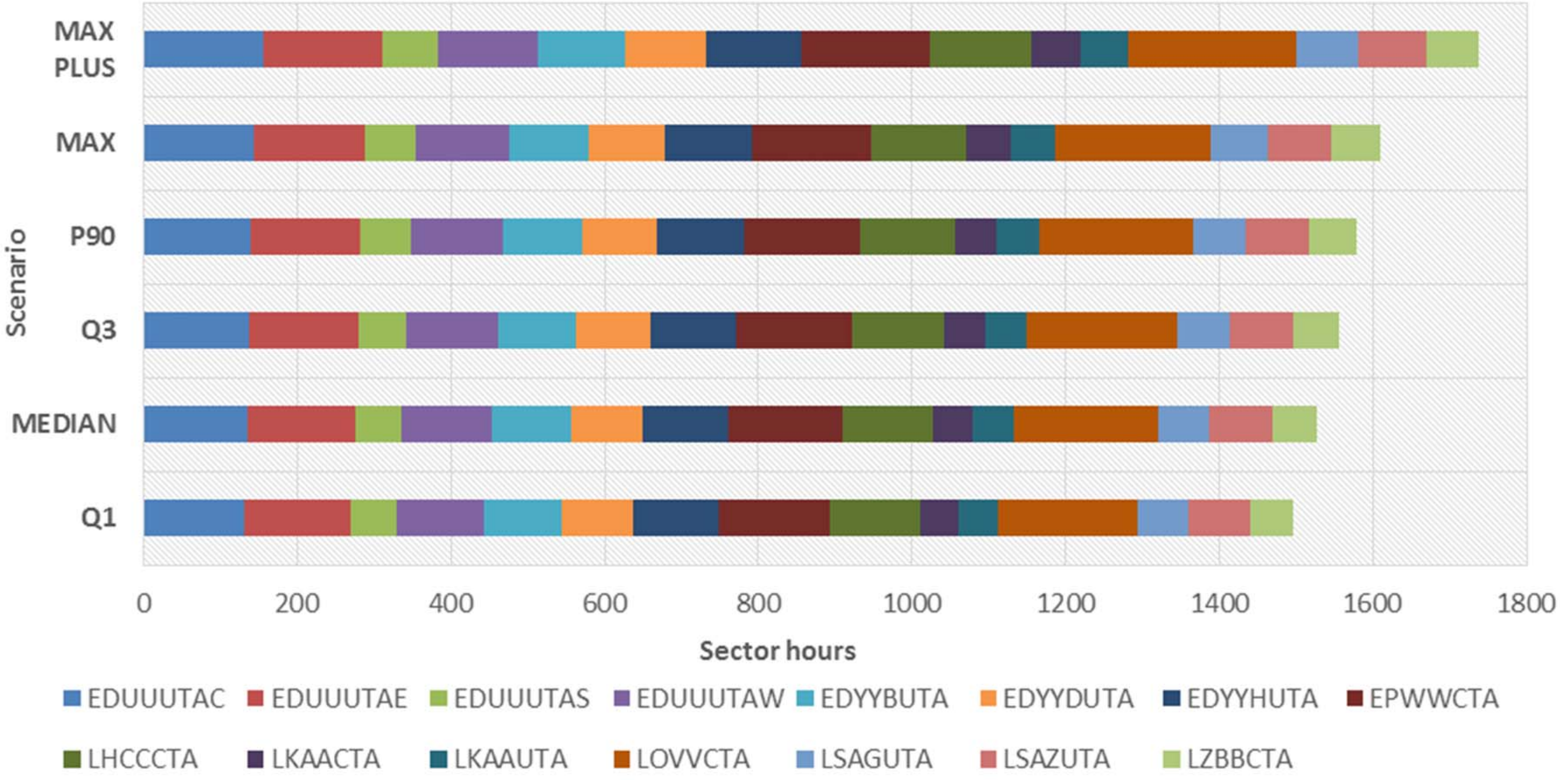
# Large scale case study – SI results




- 170 iterations
- Between 10,200 and 11,200 flights

KPIs:
- Capacity costs
- Displacement cost
- ATCO hours
- Total delay
- $CO_2$ emissions

# Large scale case study – SI results




**Six scenarios for capacity budget (for each ACC):**

- 1st/2nd/3rd quartile
- 90th percentile
- Maximum (as result of SI)
- MAX PLUS (i.e. Maximum plus 8% ATCO hours – delay averse with capacity supply structure based on COCTA model, i.e. including coordination effects)

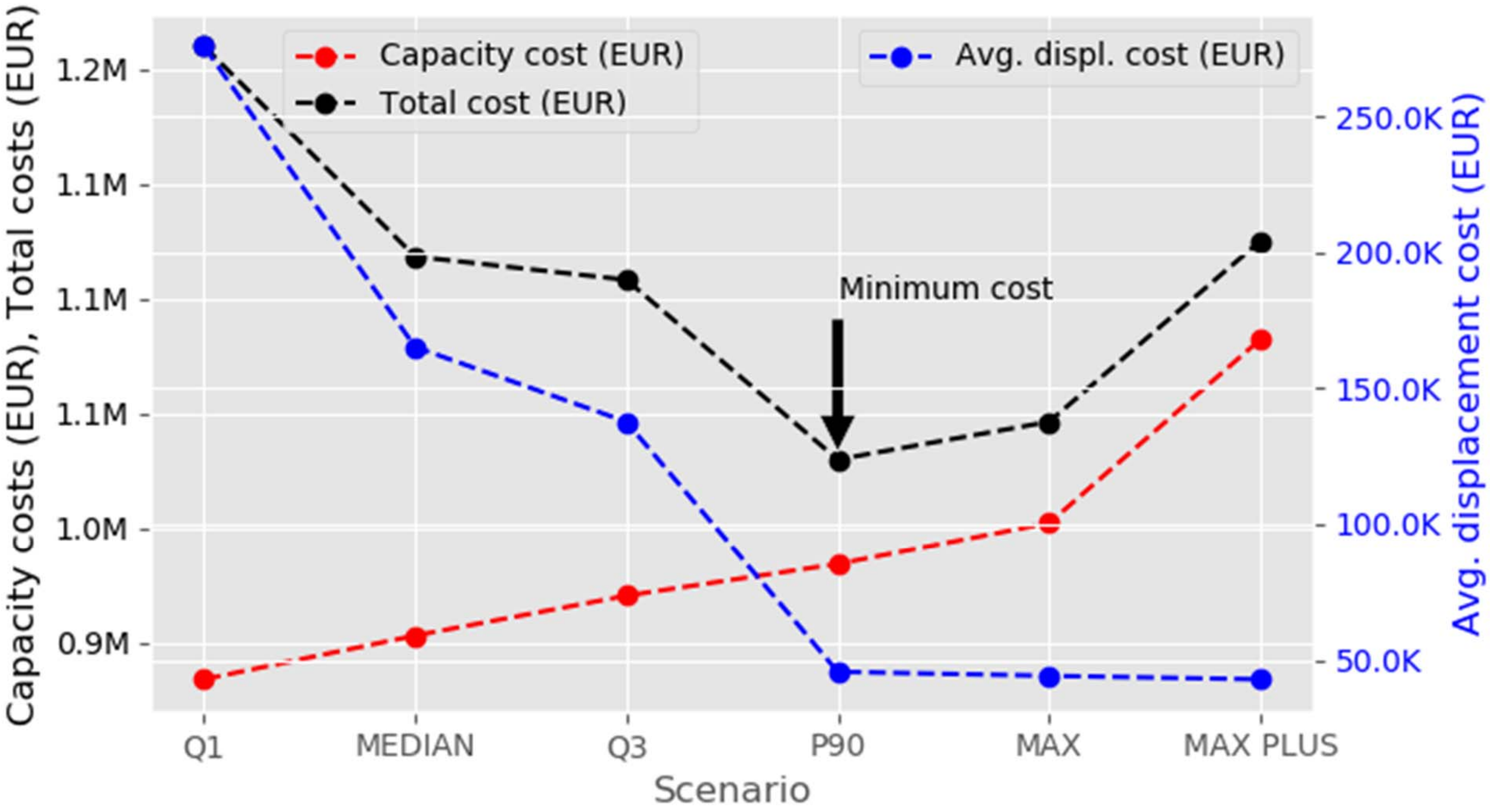
# Large scale case study – Evaluation 1/3

| | Capacity budget (sector-hours) | Feasibility (%) | Variable capacity cost (EUR) | Avg. number of displaced flights [st. dev.] | Displacement cost (EUR) [st. dev.] | Average variable capacity cost per flight (EUR) | Average total cost per flight (EUR) | Average extra CO2 (kg) [st.dev.] | Average delay per delayed flight (minutes) | Average number of flights delayed 15-30 minutes | Average number of flights delayed 45+ min | Highest feasible demand observed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Q1** | 1,496 | 73.3 | 933,967 | 1,151 [440] | 275,879 [500,959] | 88.5 | 113.8 | 148,809 [77,434] | 10.1 | 68.8 | 38.2 | 10,974 |
| **MEDIAN** | 1,527 | 86.7 | 953,004 | 1,056 [406] | 165,209 [266,649] | 89.6 | 104.6 | 135,394 [75,991] | 8.5 | 48 | 13.6 | 11,207 |
| **Q3** | 1,556 | 96.7 | 970,377 | 981 [329] | 137,708 [419,814] | 90.8 | 103.3 | 116,263 [53,099] | 7.4 | 23.7 | 3.7 | 11,207 |
| **P90** | 1,579 | 100.0 | 984,230 | 881 [182] | 45,622 [12,906] | 92.0 | 96.2 | 95,148 [24,766] | 5.75 | 12.6 | 0.1 | 11,207 |
| **MAX** | 1,610 | 100.0 | 1,002,130 | 857 [156] | 44,143 [11,286] | 93.7 | 97.8 | 92,195 [21,207] | 5.61 | 10.5 | 0.1 | 11,207 |
| **MAX PLUS** | 1,739 | 100.0 | 1,082,150 | 850 [151] | 42,841 [10,712] | 101.1 | 105.1 | 88,402 [18,678] | 5.6 | 10.7 | 0.0 | 11,207 |

**Overview:**

- P90 scenario minimizes overall cost (capacity plus displacement)
- Q1 and Median scenario cannot always accommodate all flights (delays up to 90 minutes)
- MAXPLUS does not perform better than MAX (only small reduction in displacement costs but large increase in capacity costs)

# Large scale case study – Evaluation 2/3




**Trade-off between capacity costs and displacement costs**

# Large scale case study – Evaluation 3/3

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## KPI specific analysis (example):

- P90 scenario minimizes overall cost (capacity plus displacement)
- MAXPLUS best performance with respect to delays and $CO_2$ emissions

# Conclusions and outlook

1. **Suitable model for capacity decisions under uncertainty**
   Developed for COCTA model, but also applicable for non-coordinated capacity decisions.

2. **Positive effect of coordination**
   (esp. performance of P90 vs. MAX-PLUS scenario)

3. **(Selected) options for future modeling**
   - Sensitivity analysis with respect to cost values
     (ANSP costs / airline costs)
   - Strengthen the role of demand management
   - Add uncertainty with respect to aircraft take-off times
   - Add uncertainty with respect to capacity provision

**You are invited to our final project workshop:**

Brussels, 13 September 2018

For more information visit **www.cocta-project.eu**

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# Thank you very much for your attention!

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