OptiFrame
validation and assessment

The OptiFrame Consortium

Brussels, February 14th 2018

Founding Members

EUROPEAN UNION EUROCONTROL

SESAR JOINT UNDERTAKING

OptiFrame

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OptiFrame

Validation objectives

Compliance:

1. Assess compliance of OptiFrame solutions to all applicable constraints (capacity constraints of sectors/airports, separation constraints, etc.)
2. Assess OptiFrame support to flight prioritisation (e.g. flight delay apportionment)
3. Assess OptiFrame support to route preferences

Performance:

4. Assess whether solutions can be generated within reasonable computation time

Scalability:

5. Assess solutions for the ECAC-wide area for an entire day
6. Assess solutions generation for a future day of ops with 25% increase in traffic
7. Assess (scientific purposed only) whether solutions can be generated for +100% traffic

KPA/KPI Impact:

7. Assess the impact of the system on relevant Key Performance Areas

Resilience:

8. Assess the resilience of the system to a representative set of typical disturbances and determine the impact of these disturbances on relevant KPAs

Key performance areas

- Capacity (maximum number of flights handled by ATC)
- Costs (variable costs of AUs for fuel, ANSP charges, delay,...)
- Punctuality (DEP/ARR close to scheduled times of flight)
- Flexibility (ability of AUs to modify flight trajectories)
- Equity and Fairness (equal access to airspace or services, without benefiting any actors over others)

Operational Scenarios

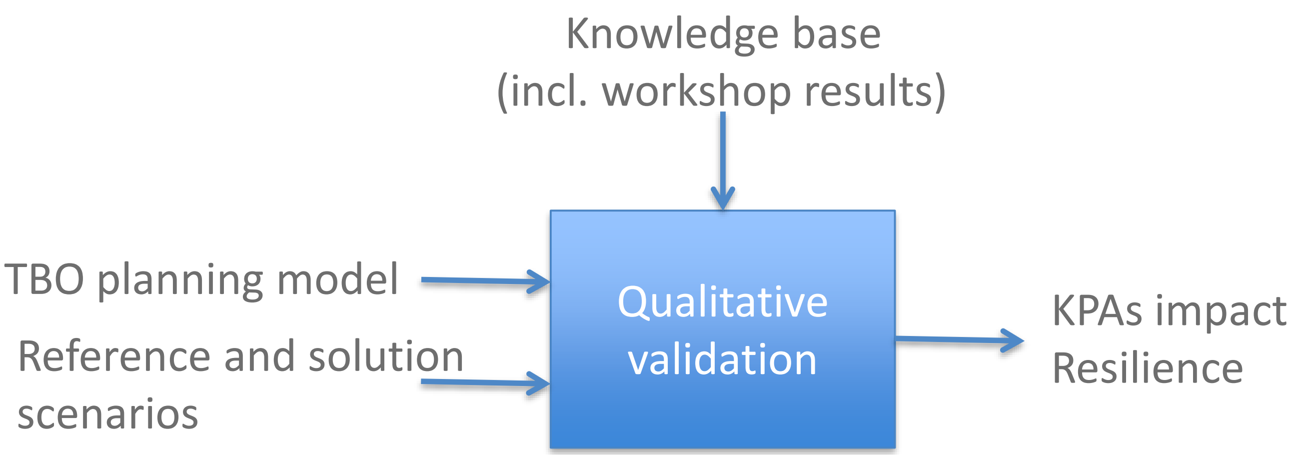
1. Baseline scenario

- Current-day traffic (summer 2016)
- Forecasted busy day with +25% traffic

2. Disturbance scenarios

- Unforeseen wind changes
- Airspace restrictions
- Airport restrictions
- Aircraft turnaround delays
- Airport closure
- Aircraft performance variations
- Insufficient synchonisation

Qualitative Assessment



Process

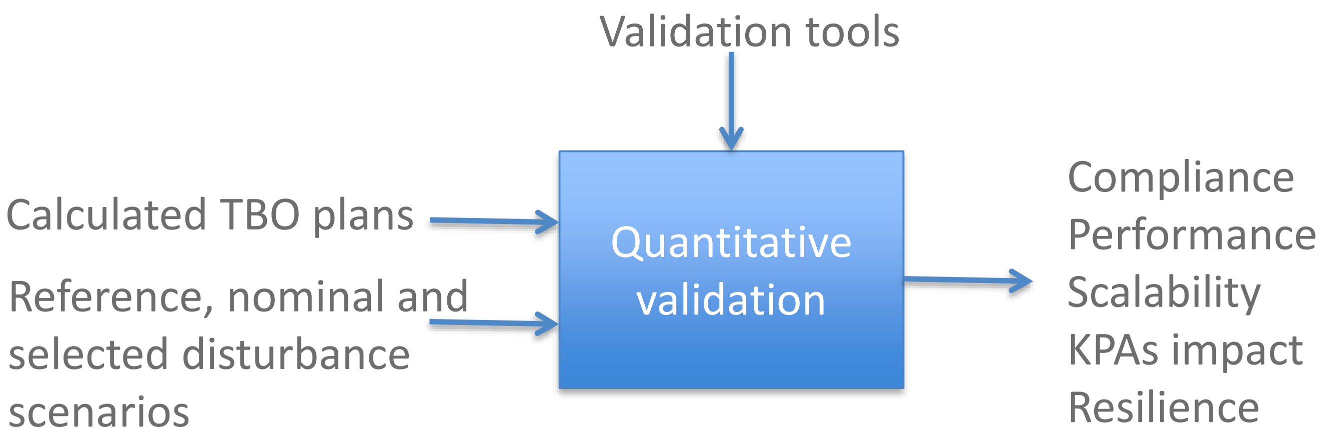
Qualitative reasoning about the operational impact of the OptiFrame TBO planning models on relevant KPAs:

- Reference/nominal scenario
- Disturbance scenarios

Results

- Impact on KPAs, insight into model resilience
- Feedback to planning model development
- Input for scoping of quantitative validation

Quantitative Assessment



Process

Quantitative evaluation of the operational impact of the optimized TBO plans, using suitable validation tools, on selected KPAs:

- Reference scenario
- Nominal scenario
- Selected disturbance scenarios

Results

- Compliance / Performance / Scalability / KPAs impact / Resilience
- Input for final evaluation of the Optiframe methods

Qualitative assessment

Report D13: Qualitative assessment of OptiFrame models for normal and disturbance cases

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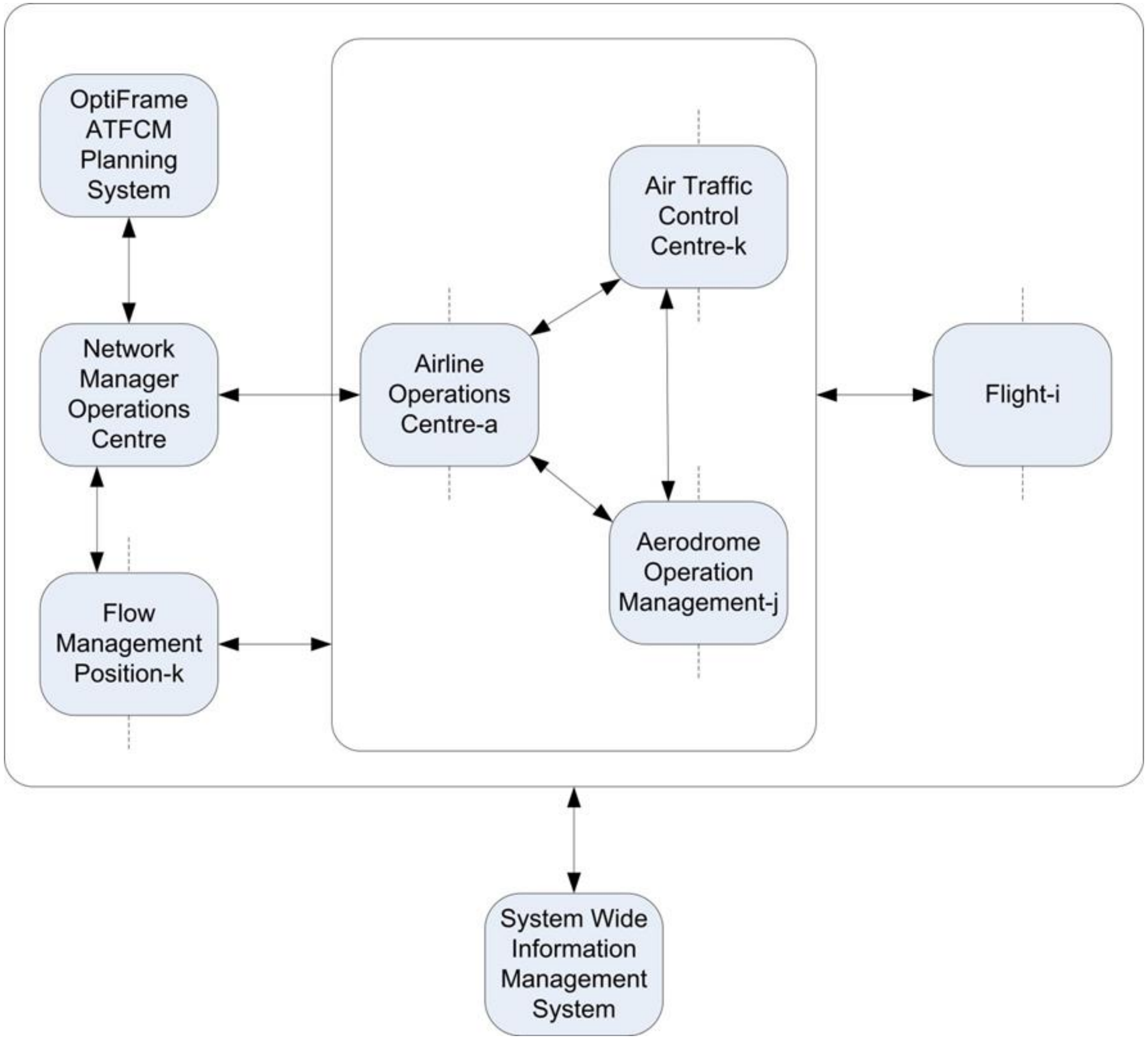
Reasoning by a qualitative agent-based model of TBO & planning

Identification of agents
- See diagram
- Low-cost carriers
- Main-line carriers

Optimization objectives
- Delay
- Route deviations
- Route charges
- Airline operating costs

Strategies of agents
- Unforeseen wind changes
- Airspace restrictions
- Airport restrictions
- Turnaround problems
- Airport closure
- Aircraft performance variations



Conclusions

Optimization objectives

- Differences in KPA impact (costs, punctuality) between mainline carriers and low-cost carries
- Pre-tactical flight planning on the basis of optimization objectives that do not take into account direct airline costs, are a relative disadvantage of mainline carriers with respect to low-cost carriers

Disturbance scenarios

- Six types of disturbance scenarios were evaluated qualitatively
- Largest implications are for the scenarios
  (1) Airport restriction
  (2) Airspace restriction
  (3) Airport closure

Quantitative assessment

Report D14: Detailed assessment of the OptiFrame computational framework for normal and disturbance cases

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AU expectations

Stakeholder expectations

Minimal deviation from the user-requested flight trajectory

- Delays
- Horizontal and vertical deviations
- Route charge changes

OptiFrame objectives

Objective functions:

- Departure delay proxy
- Horizontal + vertical deviation proxy
- Route charge proxy

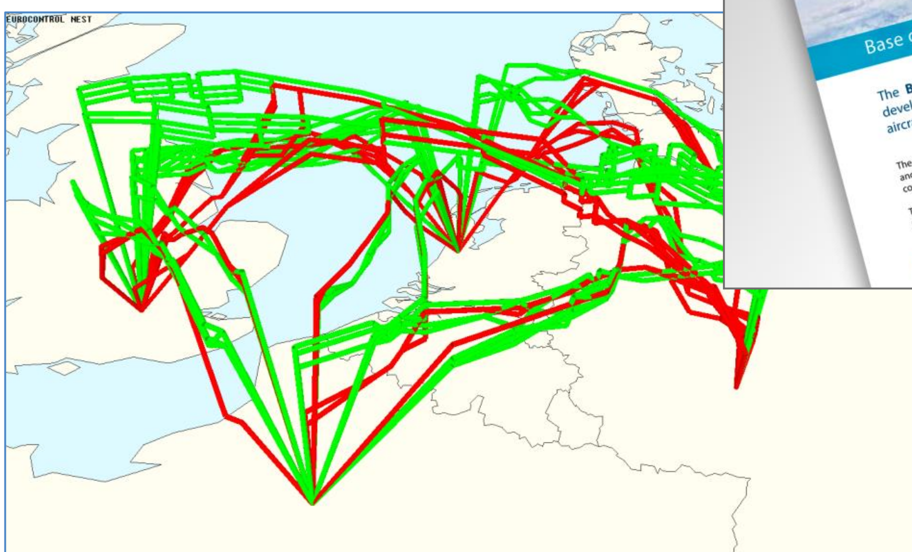
Performance of 4D-trajectories

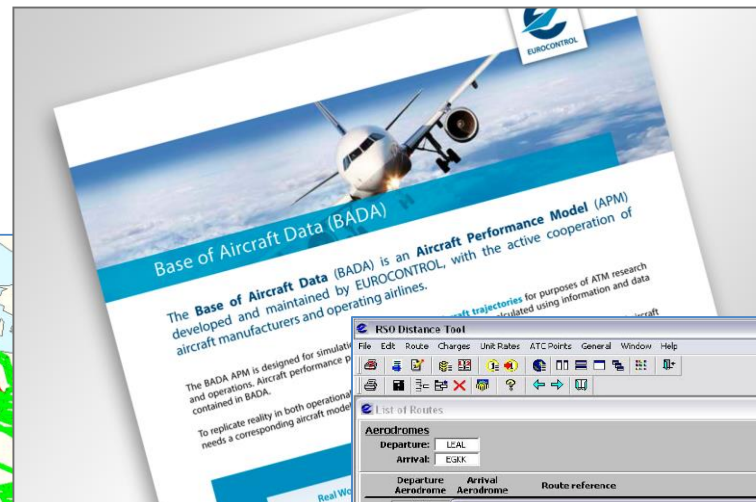
Key Performance Indicators:

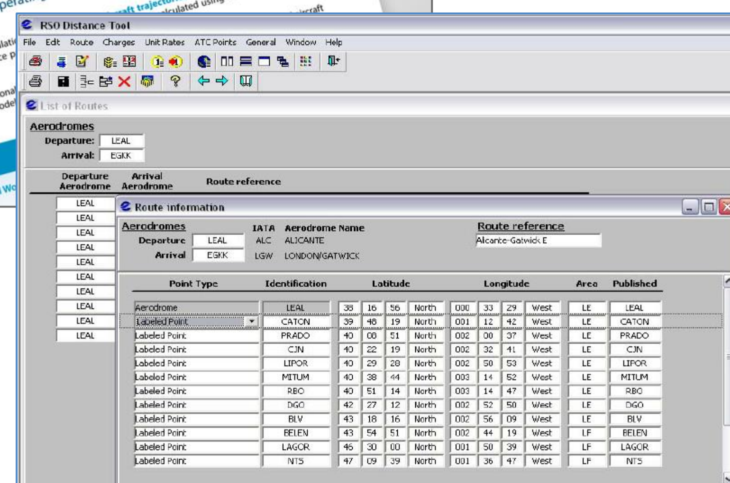
- Departure and arrival delays
- Trajectory length
- Flight time
- Fuel consumption
- Route charges

Analysis tools

- Network Strategy Tool (NEST)
- Base of Aircraft DAta 4.1 (BADA)
- Route per State Overflown (RSO) distance tool







Scenarios

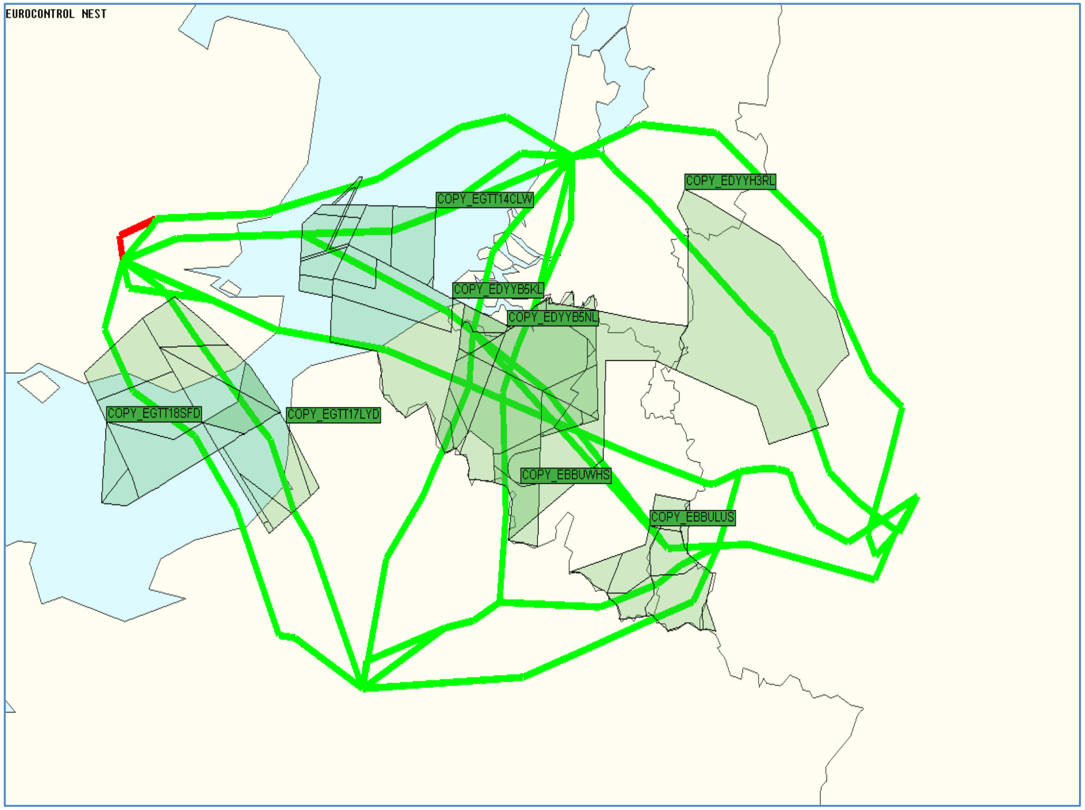
- Nominal scenarios
  - 2 airports / 10 flights and intermediate sectors
  - **4 airports / 49 flights and intermediate sectors**
- Increased connectivity scenarios
  - 4 airports / [49, 62, 74] flights and intermediate sectors
    - 25% connectivity
    - 80% connectivity
- Disturbance scenarios
  - Airspace restriction = Single busy sector at 50% capacity
  - Airport restriction = Single airport at 50% capacity
  - Airport closure = Single airport at 0% capacity

Nominal scenario

Main characteristics

- 4 airports
- 60 sectors
- 694 waypoints
- 49 flights
- 9:00 – 15:00 UTC

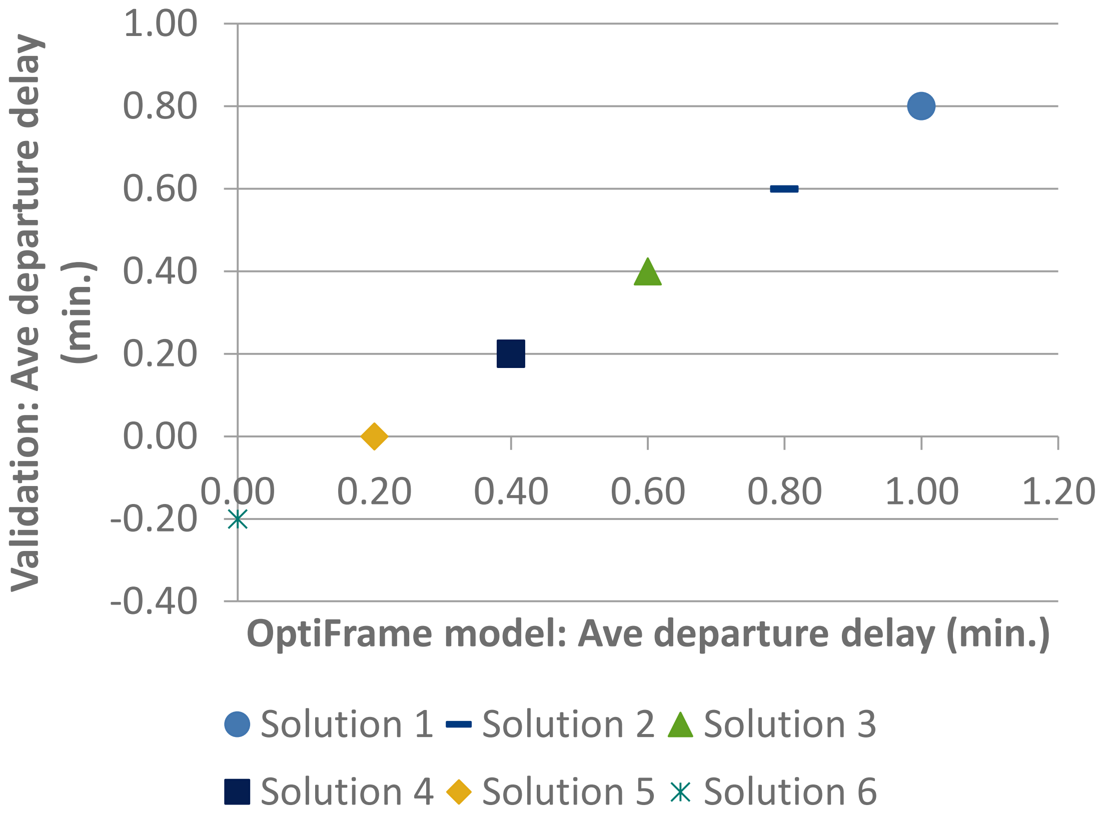
- Preferred trajectories (input to OptiFrame model)
- 6 non-dominant OptiFrame solutions (Exact model):
  - Solution 1 (Delay ↑)
  - Solution 6 (Deviation ↑)



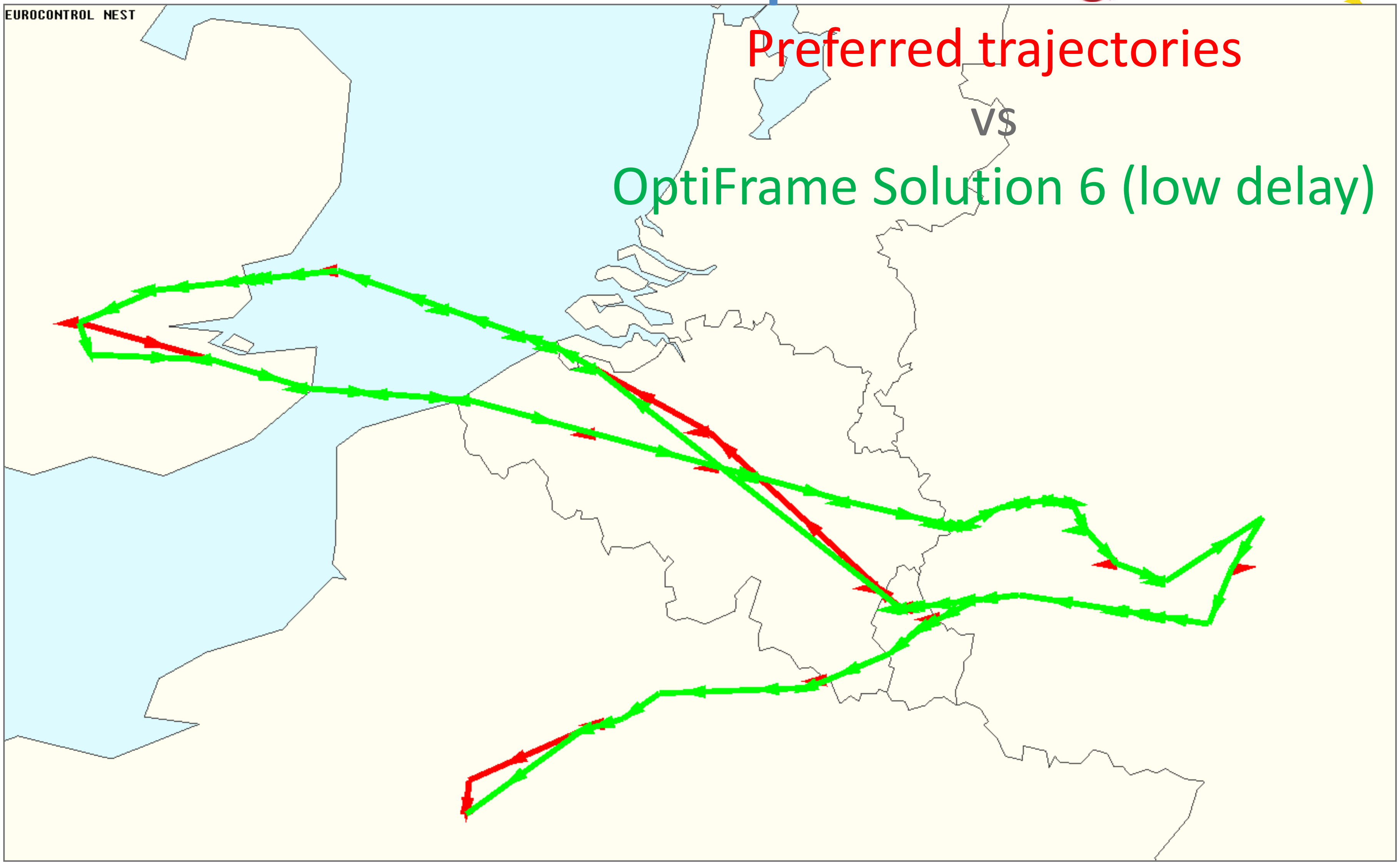
Departure delay

Main findings

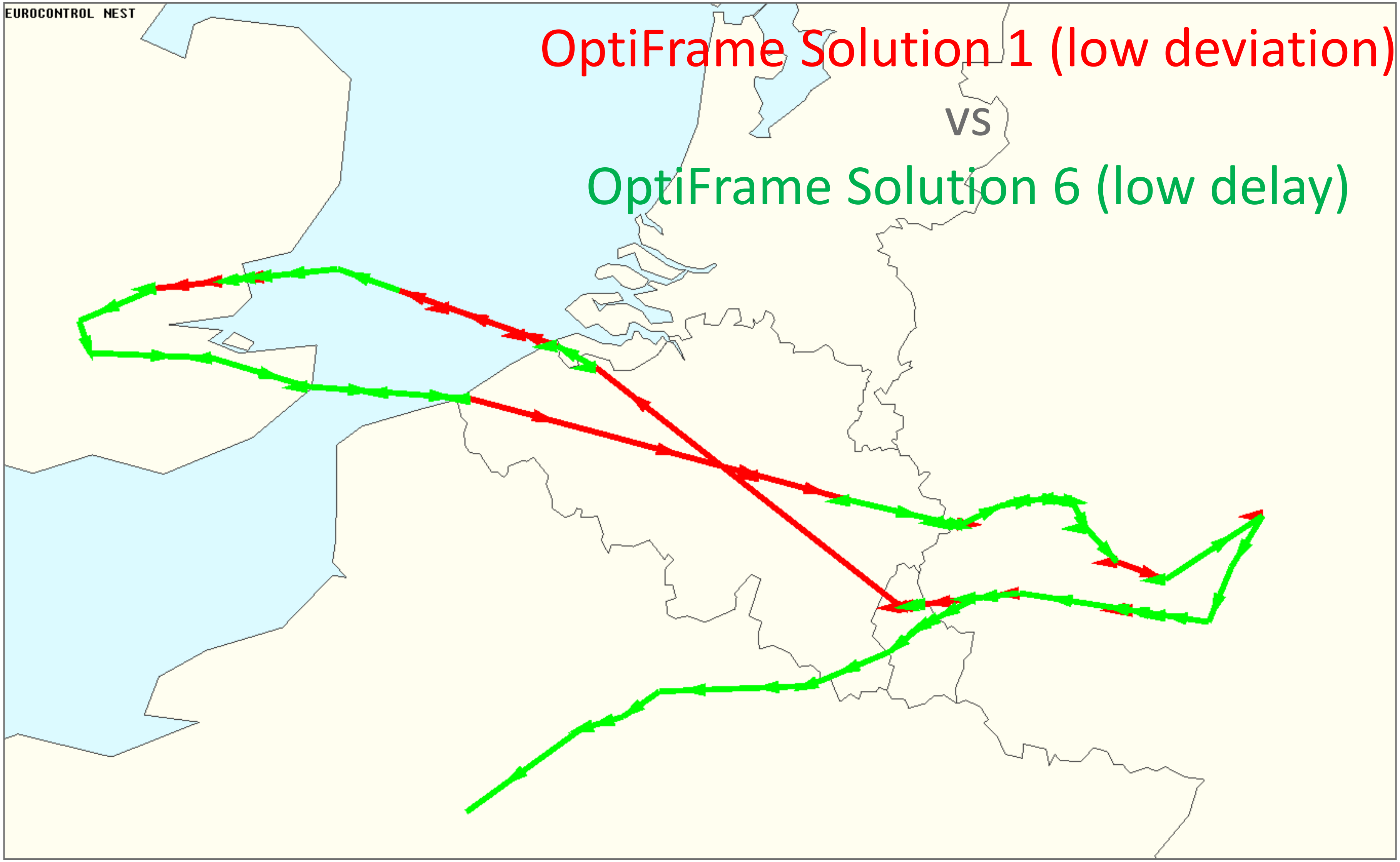
- OptiFrame model takes departure delay correctly into account
- Stakeholders have the option to choose for solutions with a low departure delay, but with costs in other areas



Horizontal deviation examples



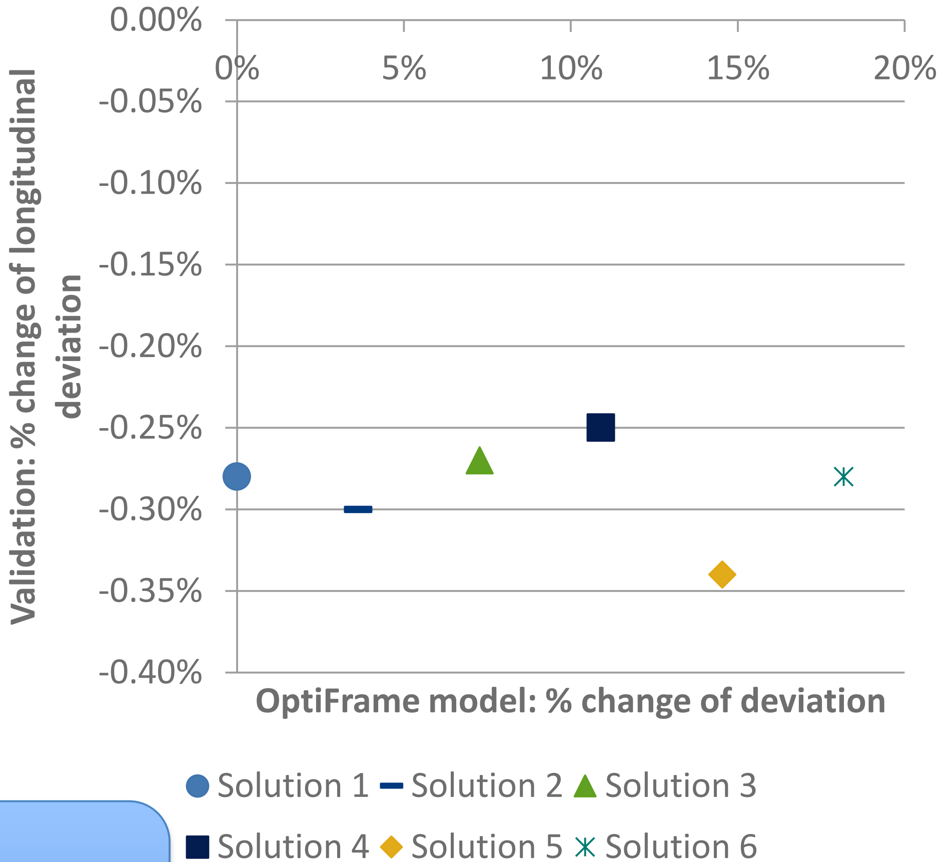
Horizontal deviation examples



Lateral deviation

Main findings

- The OptiFrame solutions show minimal effect on the longitudinal deviations
- Why:
  - OptiFrame model makes minimal use of lateral deviations
- Conclusion:
  - Small lateral deviations are not effective in changing the arrival time to sectors such that the sector throughput may be altered.

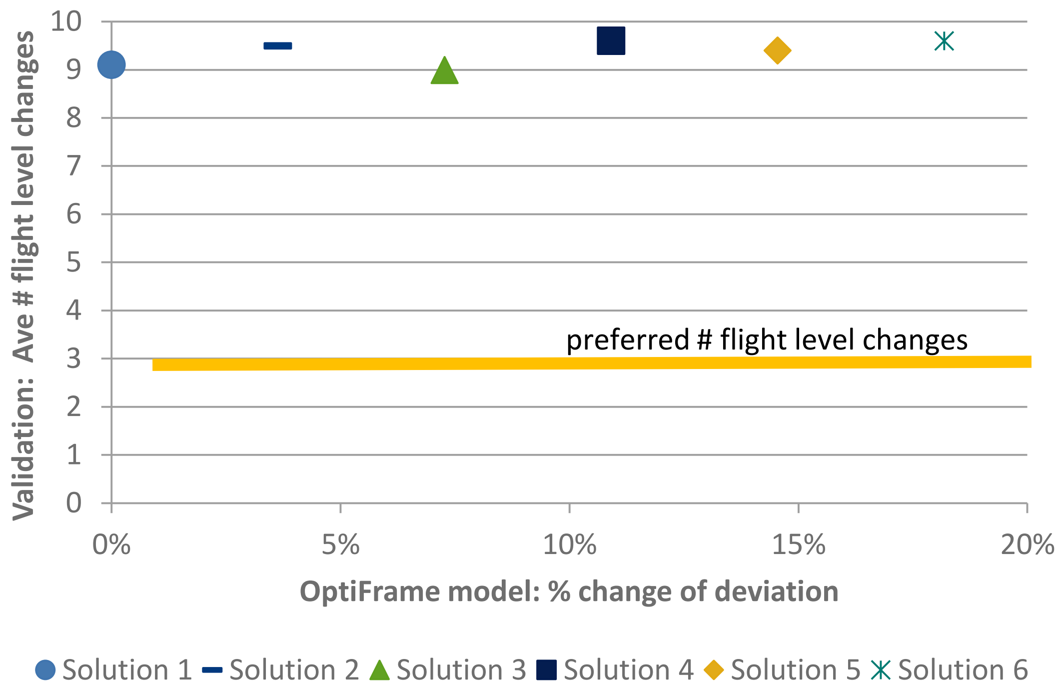


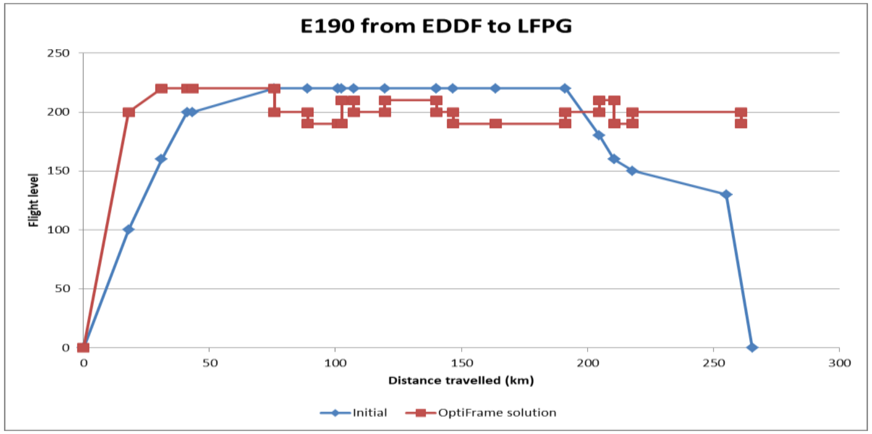
Discussion point:
Should lateral deviations be limited to specific flight phases? Should larger lateral deviation be considered so flights pass through sector adjacent to busy sector?

Step changes

Main findings

- The OptiFrame model shows great preference for vertical step changes in all solutions
- Why:
  - Step changes seem to be the easiest way to finding feasible solutions
- But:
  - A lot of step changes is not desirable for both ATC and Flight Crew (e.g. Workload? Traffic interaction?)



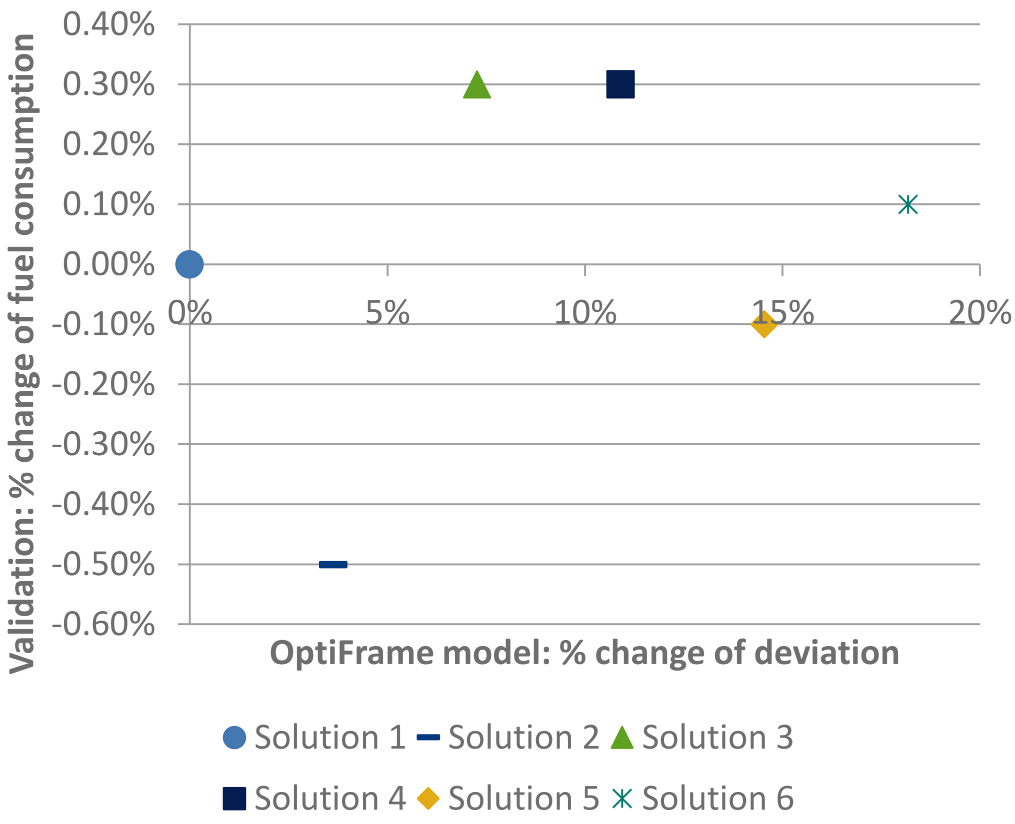


Discussion point:
What is an acceptable behaviour in respect to step changes? And how to inforce this behaviour? What about flight time changes due to changes in flight level?

Fuel consumption

Main findings

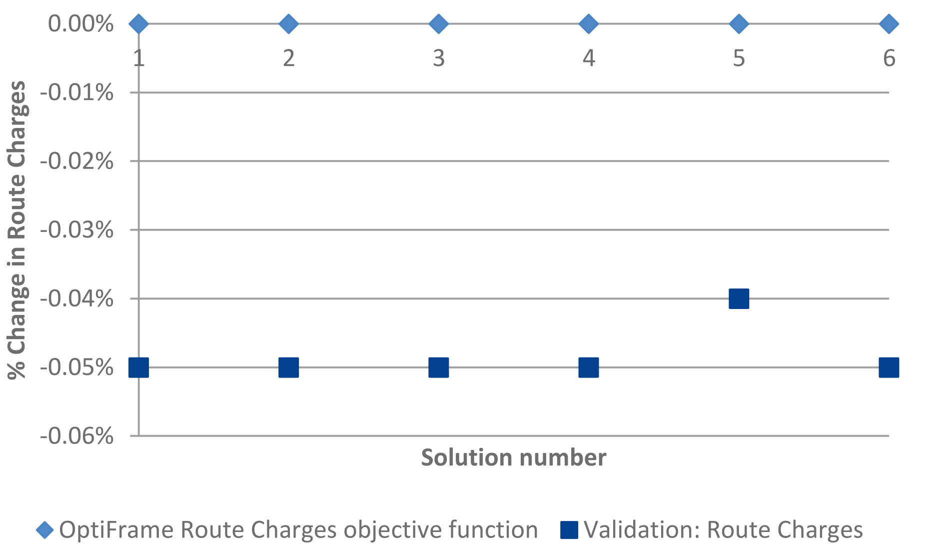
- Validation shows both decreases and increases in fuel consumption with an increasing deviation factor (=OptiFrame objective function)
- Recommendation:
    - improve/calibrate deviation cost function to become more in line with fuel consumption



Route charges

Main findings

- Both the OptiFrame objective function and actual route charges show minimal change
- Why:
  - Possibilities for lowering route changes have minimal effect on short travel distances
  - Deviation objective function also tries to keep lateral changes minimal



Discussion point:
Should route charges remain in the set of OptiFrame objective functions? What would happen without the route charges objective?

Capacity

- Capacity constraints are followed by the OptiFrame model

Discussion point:
With the high number of step changes proposed, is it still a valid assumption that the sector capacity remains the same?

Airport departure capacity

- Not every airport has a similar percentage of departure delays
- If the route network originating from a specific airport is complex then departure delays are more frequent

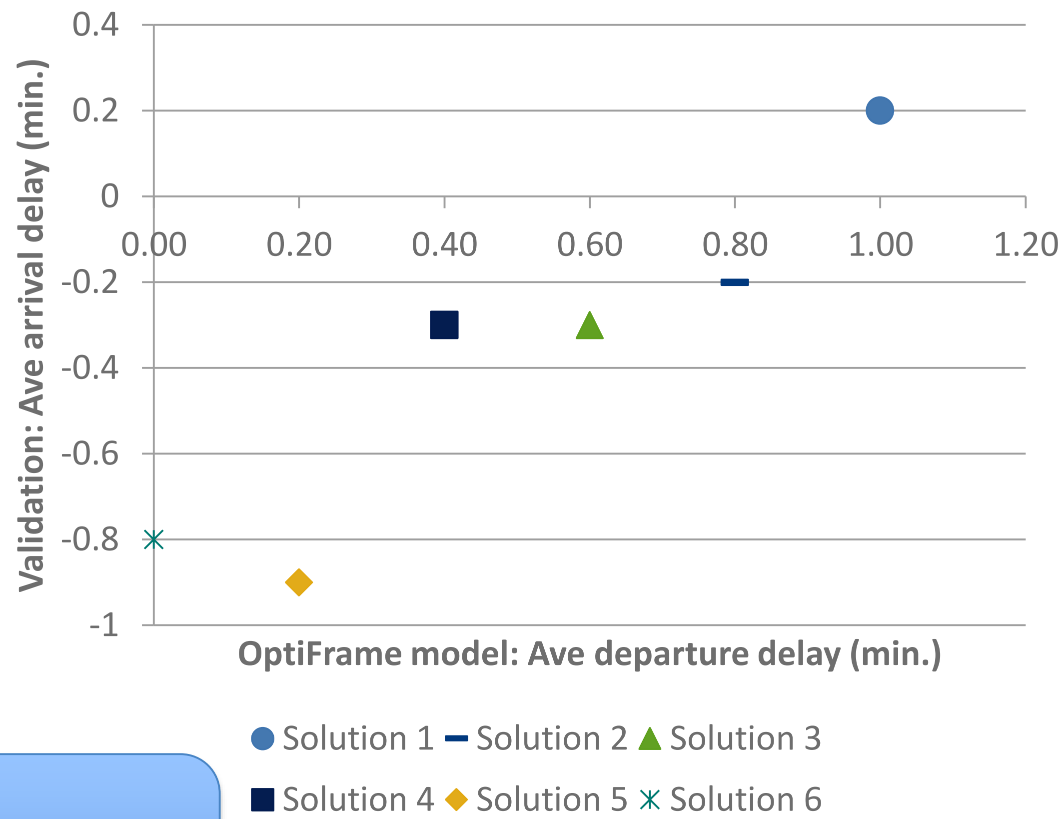
Airport arrival capacity

- Not every airport has a similar percentage of arrival delays
- Arrival time deviations vary more then departure time deviations

Arrival delays

Main findings

- Arrival delay is reduced with decreasing departure delay



Discussion point:
If arrival delay is more important then departure delay then maybe arrival delay should be considered as an alternative objective function.

Conclusions and recommendations

- Control variables of the OptiFrame framework:
  - Departure delay works
  - Lateral deviation works, but is used minimally. Maybe limit to specific flight phases.
  - Vertical deviation is used too frequent.
- Objective functions:
  - Stakeholders get the to option to choose between accepting departure delays or trajectory deviations.
  - Arrival delay should be considered as an alternative to departure delay.
  - Lateral deviation stays close to preferred route.
  - Vertical deviation: calibrate/update cost function to limit frequency
  - Route charges: has no significant effect over short distances. Lateral deviation points in the same direction.

Discussion points

1. Should lateral deviations be limited to specific flight phases? Should larger lateral deviation be considered so flights pass through sector adjacent to busy sector?
2. What is an acceptable behaviour in respect to step changes? And how to inforce this behaviour? What about flight time changes due to changes in flight level? With the high number of step changes proposed, is it still a valid assumption that the sector capacity remains the same?
3. Should route charges remain in the set of OptiFrame objective functions? What would happen without the route charges objective?
4. If arrival delay is more important then departure delay then maybe arrival delay should be considered as an alternative objective function?

OptiFrame validation and assessment

Thank you very much for your attention!

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