

Delay assignment optimization strategies at pre-tactical and tactical levels

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Overview

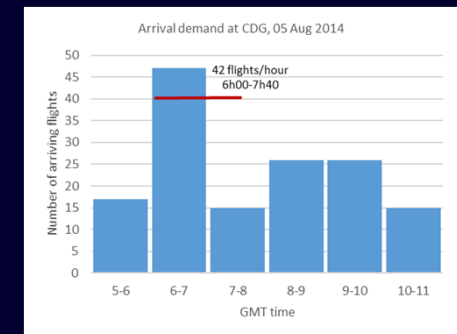
- Background
- Optimization models
 - System overview
 - Stakeholders
 - General ground holding problem formulation
 - Cost functions
- Scenario
- Results
 - Tactical
 - Pre-tactical
- Conclusions and further work

Background

Background

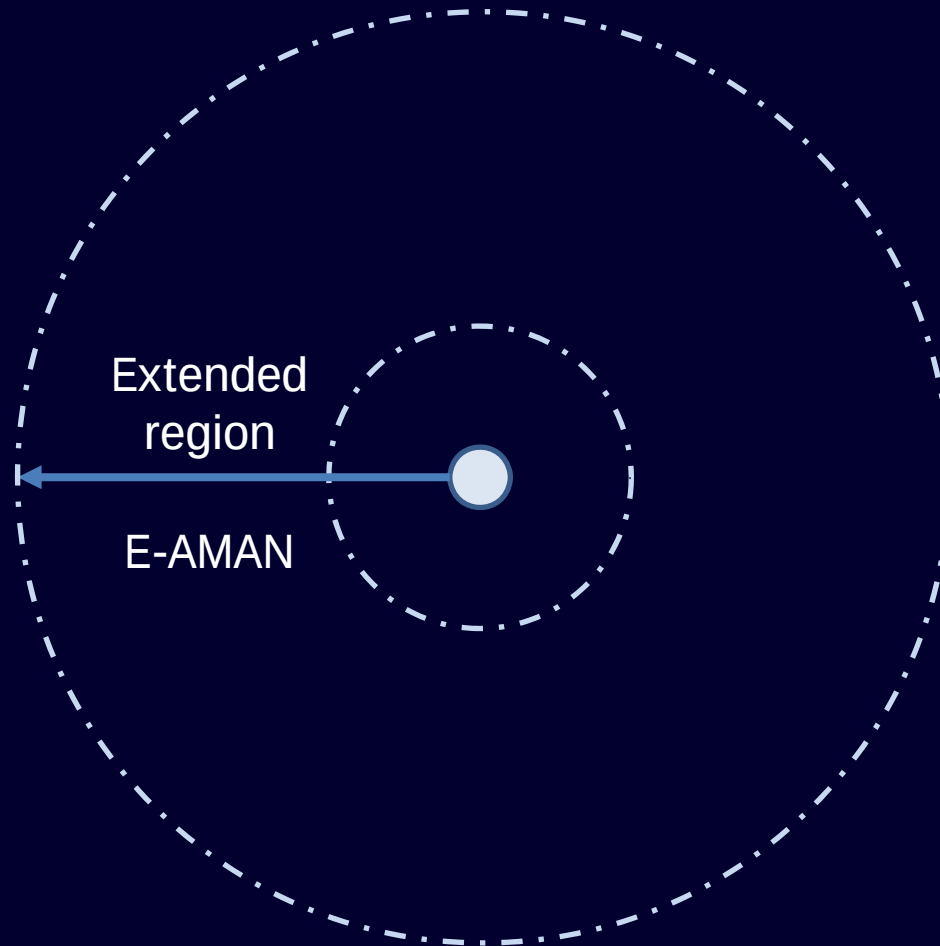


Pre-tactical traffic management



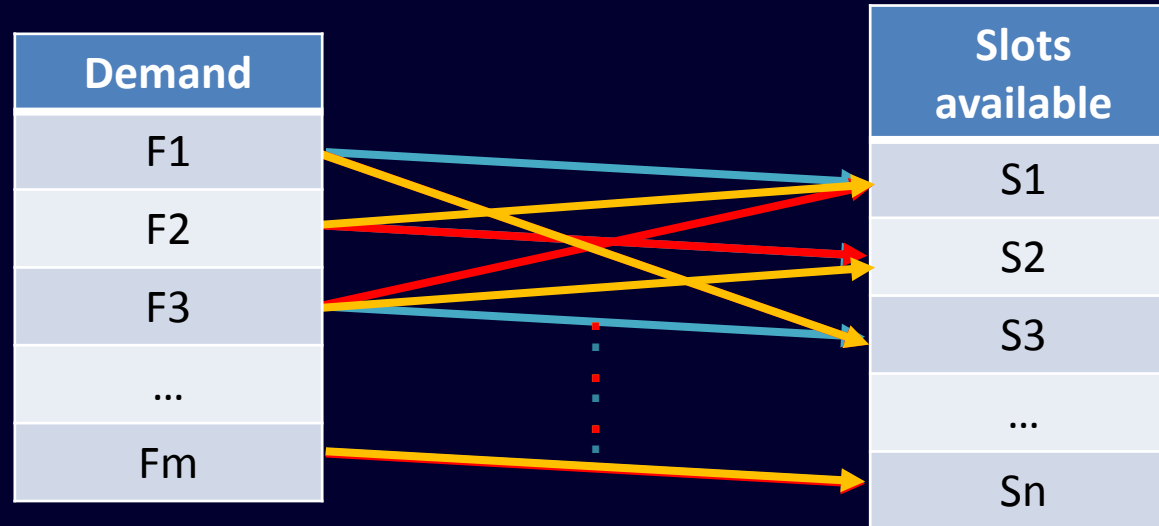
Background

Tactical traffic
management



Background

- RBS
- Minimising passenger delay
- Minimising delay considering turn-around



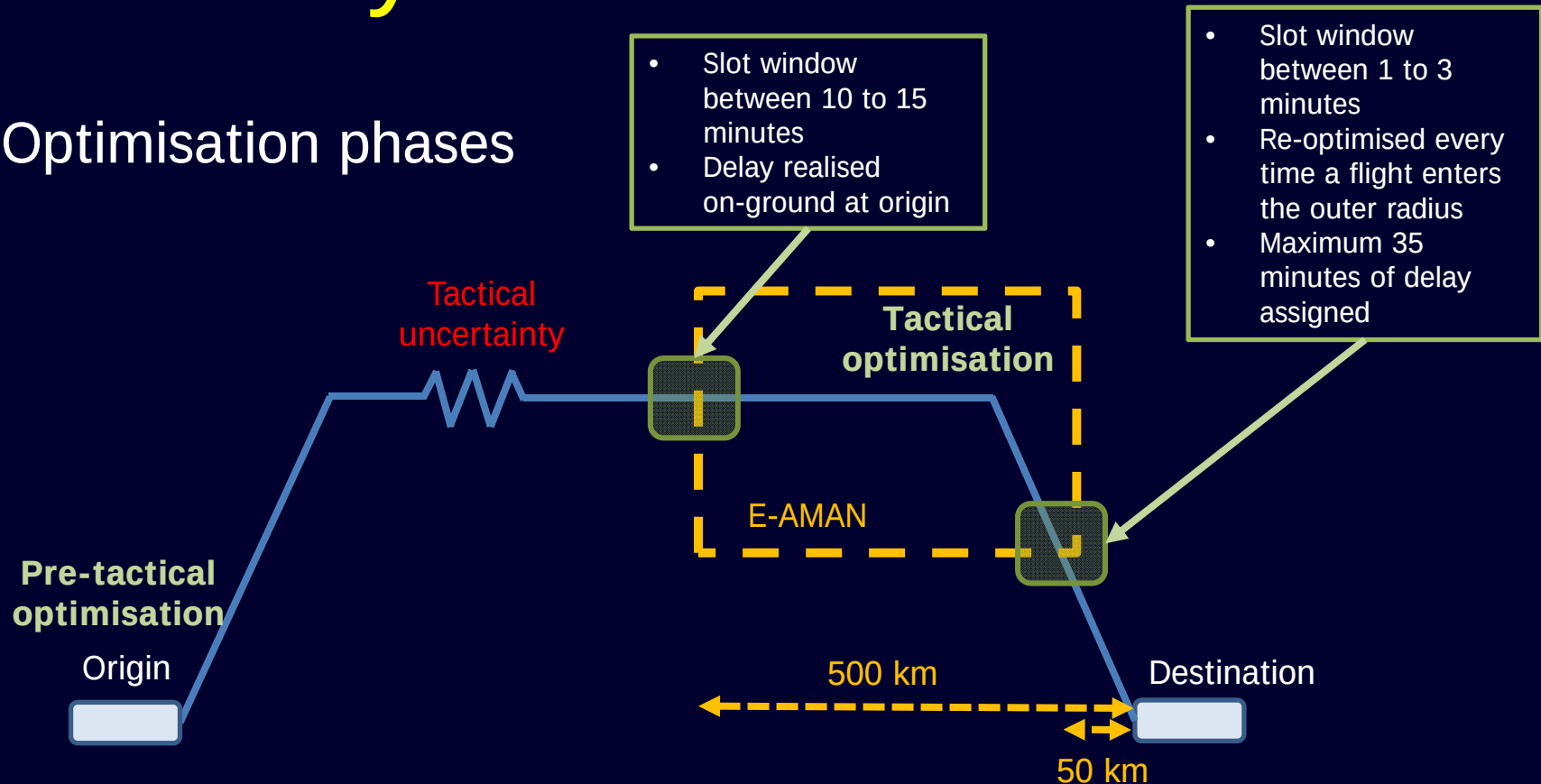
	Optimisation assignment ₁	Optimisation assignment ₂	Optimisation assignment _j
Metric ₁	V_{11}	V_{12}	V_{1j}
Metric ₂	V_{21}	V_{22}	V_{2j}
Metric _i	V_{i1}	V_{i2}	V_{ij}

Optimization models

- System overview

System overview

- Optimisation phases



Optimization models

- Stakeholders

Stakeholders

- Airlines
 - Flight centric metrics
- Passengers
 - Passenger centric metrics
- Importance of optimization function focus

Optimization models

- General ground holding problem formulation

General GHP formulation

- Deterministic Ground Holding Problem (GHP)
- Constraints applied at destination
 - outer or inner radius

M. Ball, C. Barnhart, G. Nemhauser and A. Odoni, *Air Transportation: Irregular Operations and Control*, Handbook in OR & MS, Vol. 14, 2007.

General GHP formulation

- Set of intervals
- Set of flights
- Inputs defined
 - Capacity at each time interval
 - Scheduled time of arrival for each flight
- Decision variables
 - If a flight is assigned to arrive at a given time interval
(starting at the earliest possible arrival time for that flight)
- Problem formulation
 - Assign flights to intervals minimizing cost
(all flights must be assigned, capacity not overpassed)

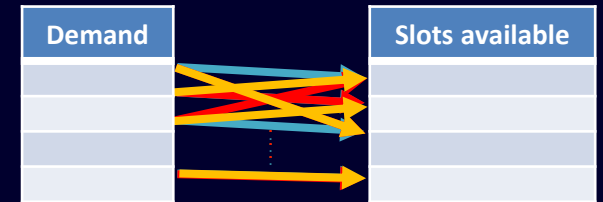
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Optimization models

- Cost functions

Cost functions

- Four costs models considered (c_{ft})
 - GHP Flight: Delay per flight minimised



$$c_{ft} = \underbrace{\text{Arrival time} - \text{Scheduled arrival time}}_{\text{Arrival delay}}$$

Cost functions

- Four costs models considered (c_{ft})
 - GHP PAX: Delay per passenger minimised

$$c_{ft} = \text{Number of passengers arriving} \times \text{Arrival delay}$$

Cost functions

- Four costs models considered (c_{ft})
 - GHP Reac: Delay per flight considering reactionary departure delay

$$c_{ft} = \text{Arrival delay} + 1.8 \times \text{Subsequent departure delay}$$

Subsequent departure delay is calculated as:

$$\text{Arrival time} - \text{Latest arrival time not generate departure delay}$$

Cost functions

- Four costs models considered (c_{ft})
 - GHP Reac Pax: Delay per passengers considering reactionary departure delay

$$c_{ft} = \text{Passenger arrival delay} + 1.8 \times \text{Subsequent passenger departing delayed}$$

The diagram illustrates the components of the cost function c_{ft} . It is structured as follows:

- $c_{ft} =$ [Passenger arrival delay] $+ 1.8 \times$ [Subsequent passenger departing delayed]
- The first term, [Passenger arrival delay], is calculated as: [Number of passengers arriving] $\times$ [Arrival delay]
- The second term, [Subsequent passenger departing delayed], is calculated as: [Number of passengers departure] $\times$ [Subsequent departure delay]

Cost functions

- Four costs models considered (c_{ft})
 - GHP Flight: Delay per flight minimised
 - GHP PAX: Delay per passenger minimised
 - GHP Reac: Delay per flight considering reactionary departure delay
 - GHP Reac Pax: Delay per passengers considering reactionary departure delay

Scenario and model uncertainty

Scenario definition and uncertainty

Model	Sub-model	Description	Times
Scenario	Flight demand	• Based on 12SEP14 at CDG • Between 5:00 and 11:00 GMT • Cancelled flight considered pre-tactically but not tactically • Flights within inner radius excluded	Once

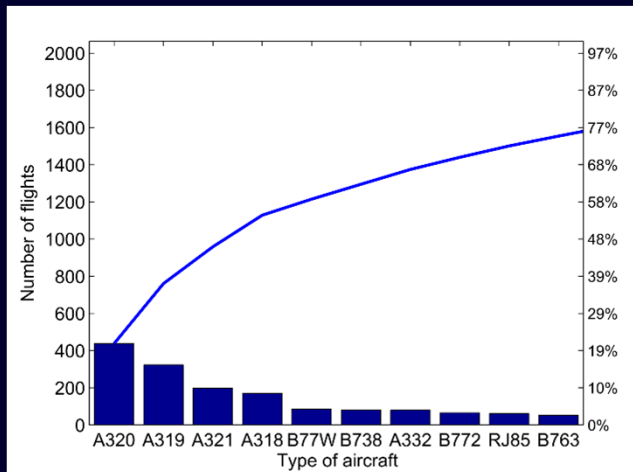
Demand Data Repository 2 (DDR2)



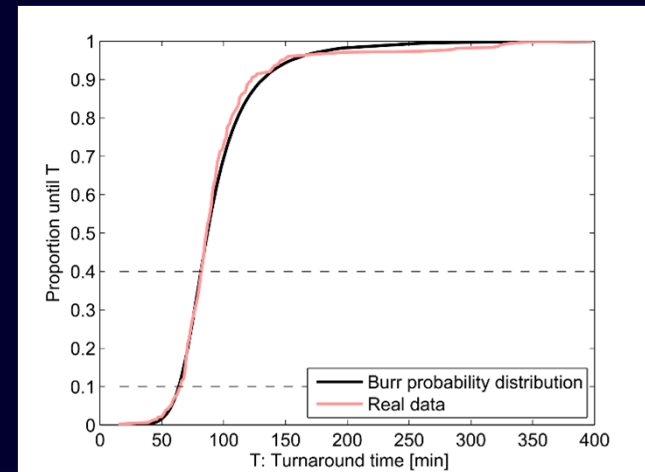
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	Turnaround		

Top 10 AC types



A320 turn around times



Scenario definition and uncertainty

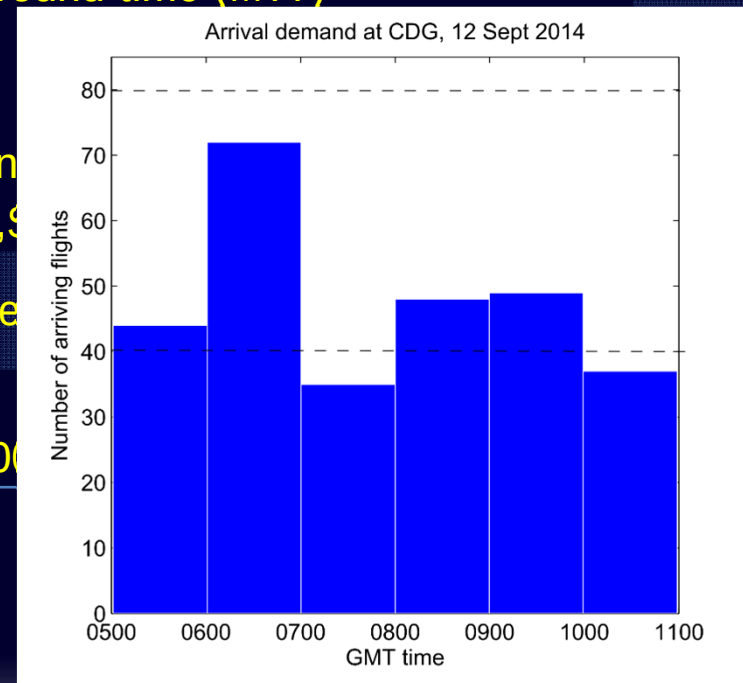
Model	Sub-model	Description	Times
Scenario	Flight demand	- Based on 12SEP14 at CDG - Between 5:00 and 11:00 GMT - Cancelled flight considered pre-tactically but not tactically - Flights within inner radius excluded	Once
	Turnaround	- AC type for minimum turnaround time (MTT) - AC types top 10 used - AC categories otherwise - Burr and Weibull distribution fitting $MTT(f) = \text{Max}(\text{rand}(0.1, 0.4), STT(f))$	

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	Passenger demand	Triangular distribution between 60-95% centered at 85%	

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	Passenger demand	Triangular distribution between	
	Capacity	80 acc/h nominal 40 acc/h regulated from 6:00	



Scenario definition and uncertainty

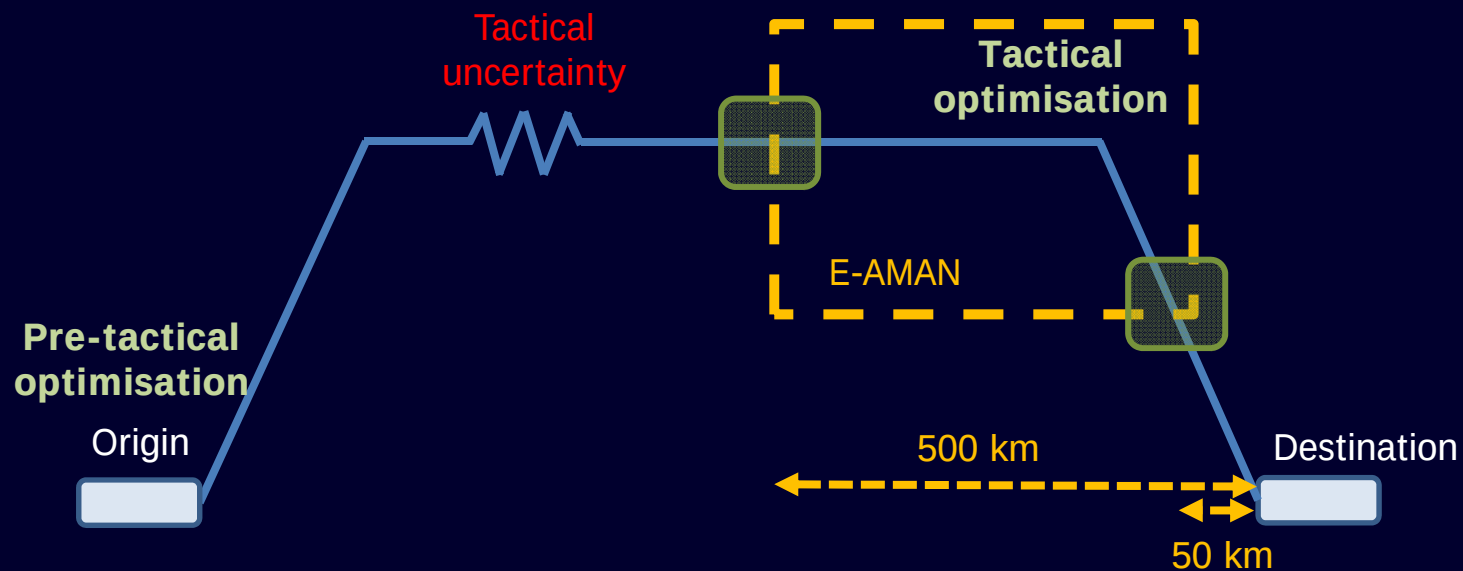
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	Passenger demand	Triangular distribution between 60-95% centered at 85%	
	Capacity	80 acc/h nominal 40 acc/h regulated from 6:00 to 8:00 GMT	
	Radii	- Outer 500 km (270 NM) - Inner 50 km (27 NM)	

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	Passenger demand	Triangular distribution between 60-95% centered at 85%	
	Capacity	80 acc/h nominal 40 acc/h regulated from 6:00 to 8:00 GMT	
	Radii	- Outer 500 km (270 NM) - Inner 50 km (27 NM)	
	Optimisation window	15' pre-tactical (20 acc/15' nominal, 10 acc/15' regulated) 3' tactical (4 acc/3' nominal, 2 acc/3' regulated)	

Scenario definition and uncertainty

Model	Description	Times
Tactical noise	• Difference scheduled actual • Burr distribution	Monte Carlo 50 times

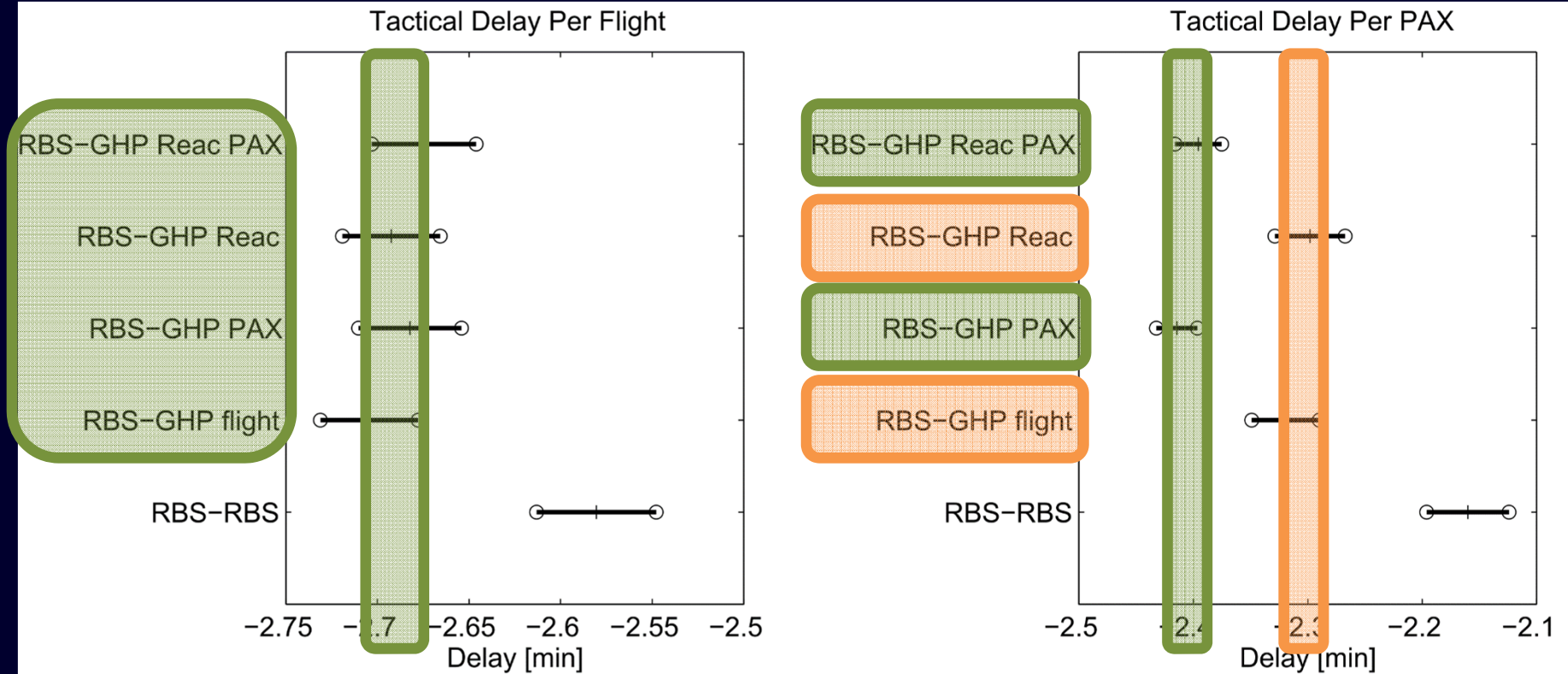


Results

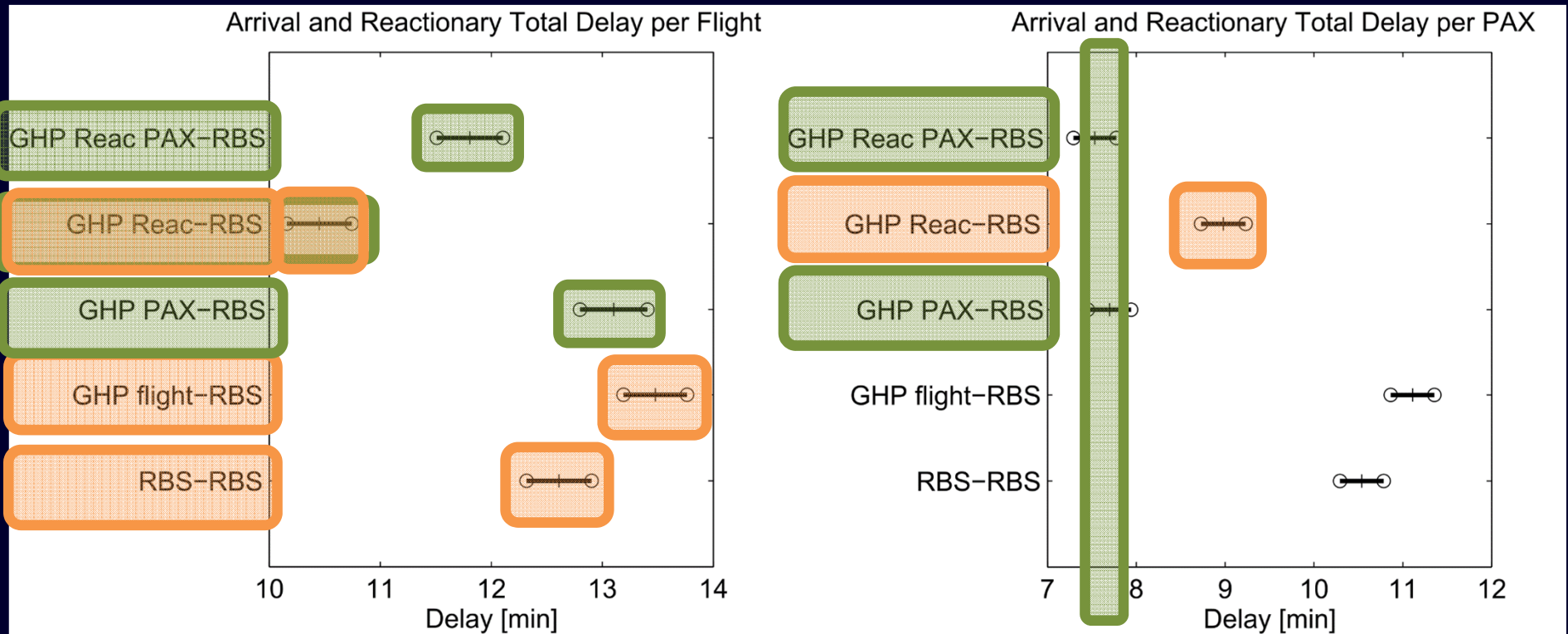
Results

- Per flight and per passenger
 - Mean arrival delay
 - Mean tactical delay, i.e., delay generated at the E-AMAN
 - Mean reactionary delay
 - Mean total delay (arrival and reactionary)
 - Number of flights with reactionary delay
 - Maximum reactionary delay

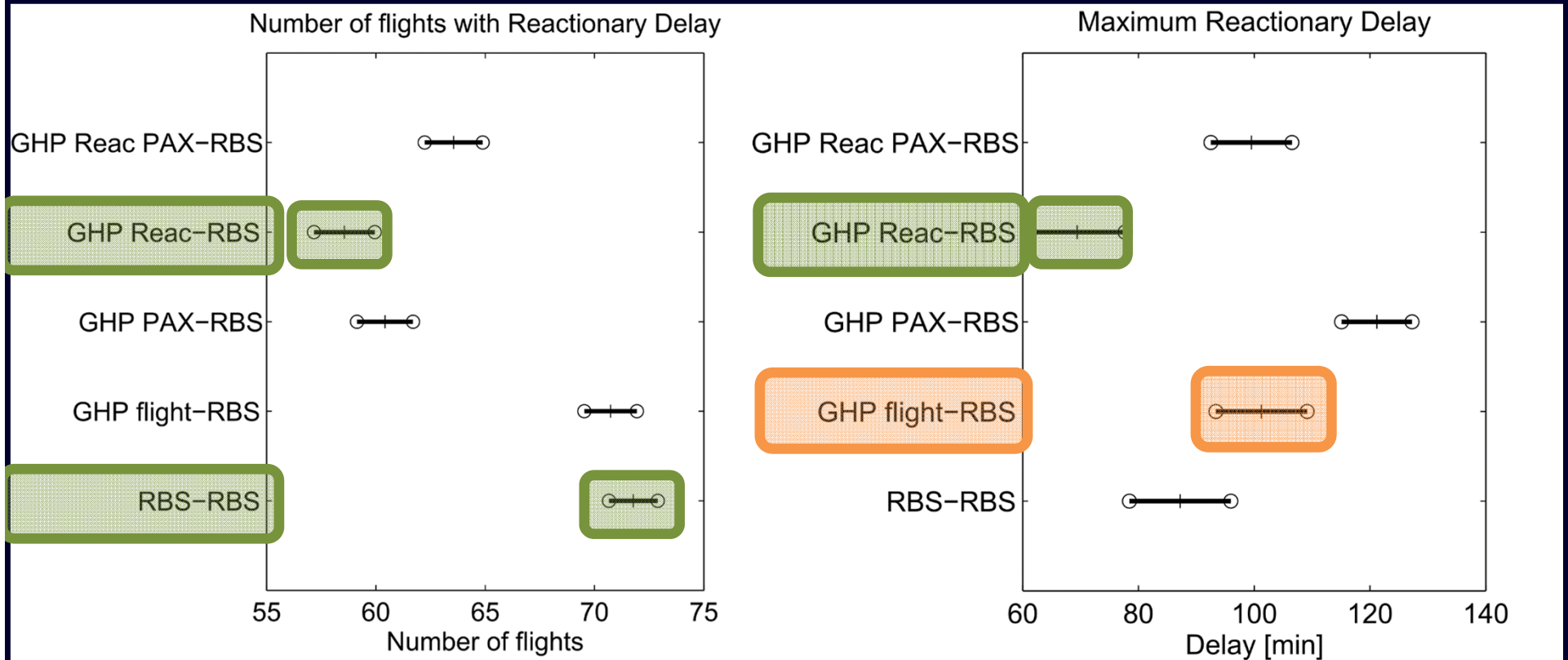
Tactical results



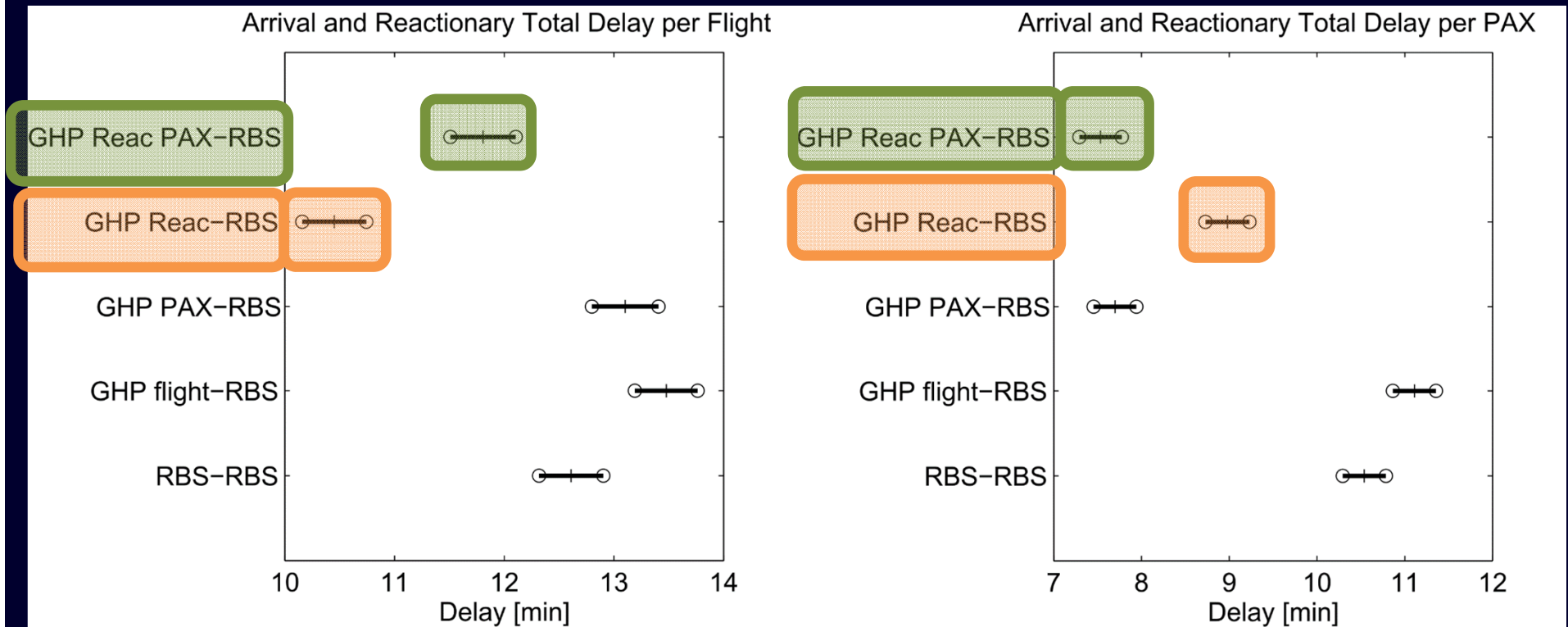
Pre-Tactical results



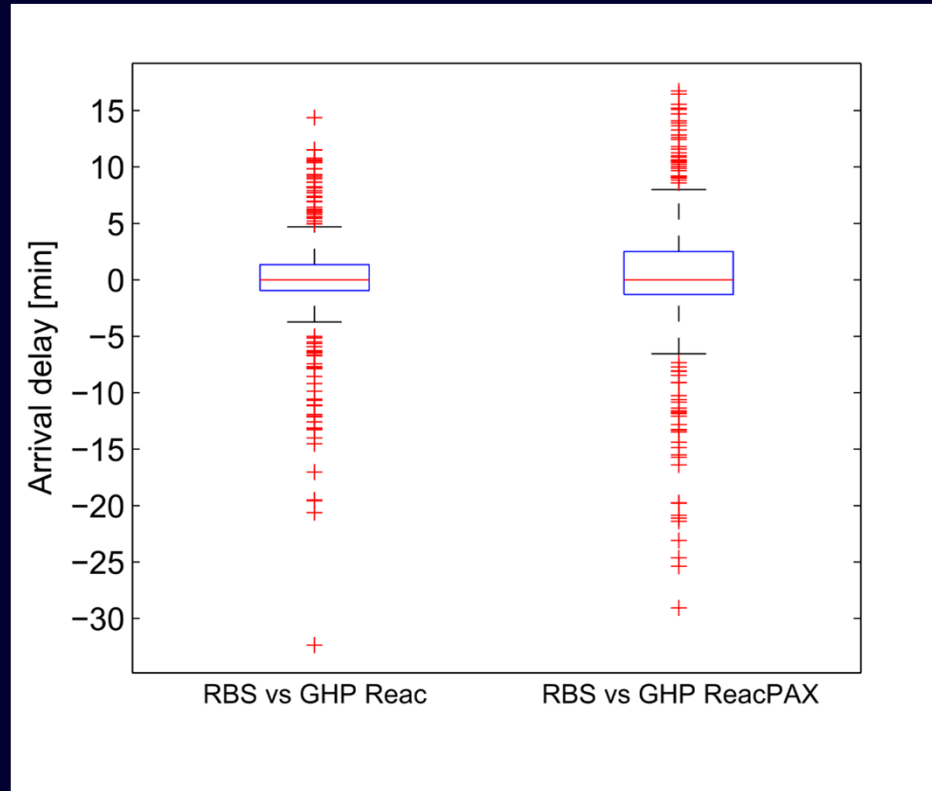
Pre-Tactical results



Pre-Tactical results



Pre-Tactical results



Conclusions and further work

Conclusions

- Flight and passenger centric metrics might lead to different results
- Four optimization functions considered
 - Arrival delay for flight
 - Arrival delay for passengers
 - Total delay for flight
 - Total delay for passengers

Conclusions

- Tactical management and delay is required to adjust arrivals
 - All strategies represent benefit with respect to RBS, benefit very small and there are not different between strategies
 - At the E-AMAN scope a more sophisticated strategy rather than RBS is not justified
 - E-AMAN allows to manage delay more efficiently leading to benefits in terms of fuel consumption, reduction of holdings, etc.

Conclusions

- Pre-tactical management (ATFM delay)
 - Other strategies rather than RBS might lead to better results for flights and passengers
 - If optimisation only focus on arrival delay, counter-productive effects might be generated
 - Minimising total delay considering turnaround the best strategies
 - Passenger centric might lead to higher reactionary delays and less *fair* delay assignment

Further work

- Passenger delay values are preliminary
 - Values highly correlated with aircraft size
 - Need to incorporate itineraries with connections
 - We expect to find strategies that will benefit passengers without impacting flight metrics significantly
- Propagation of delay should consider other sources of delay
- Cost of delay incorporated

Thank you