Arrival trade-offs considering total flight and passenger delays and fairness

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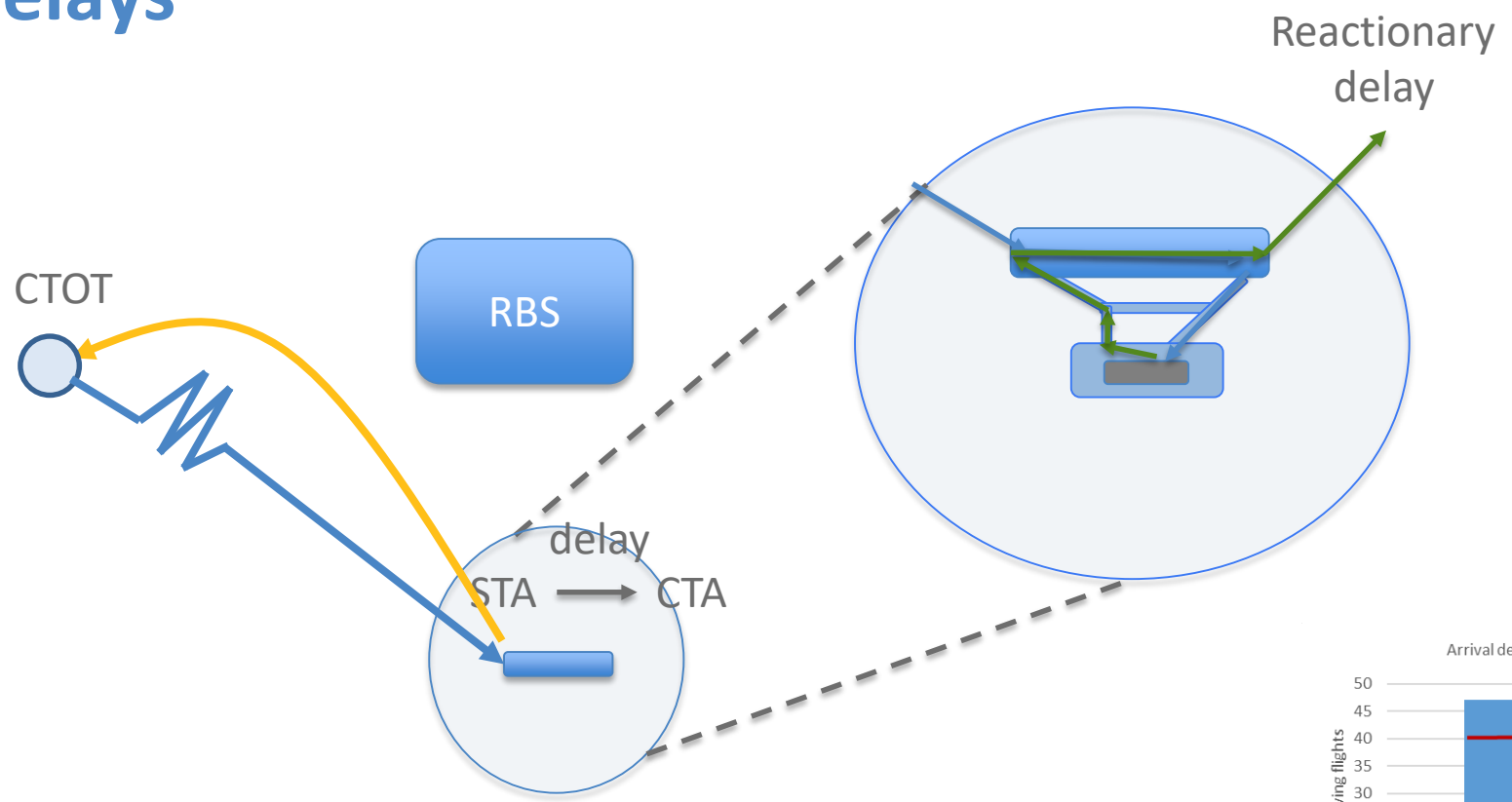
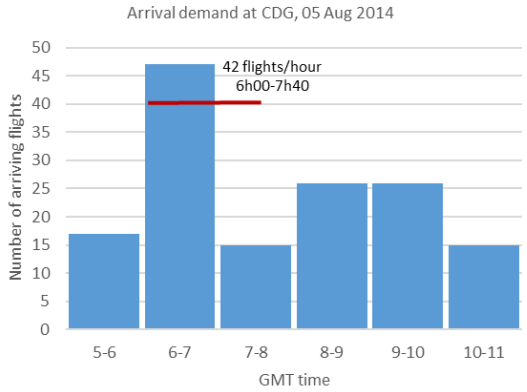
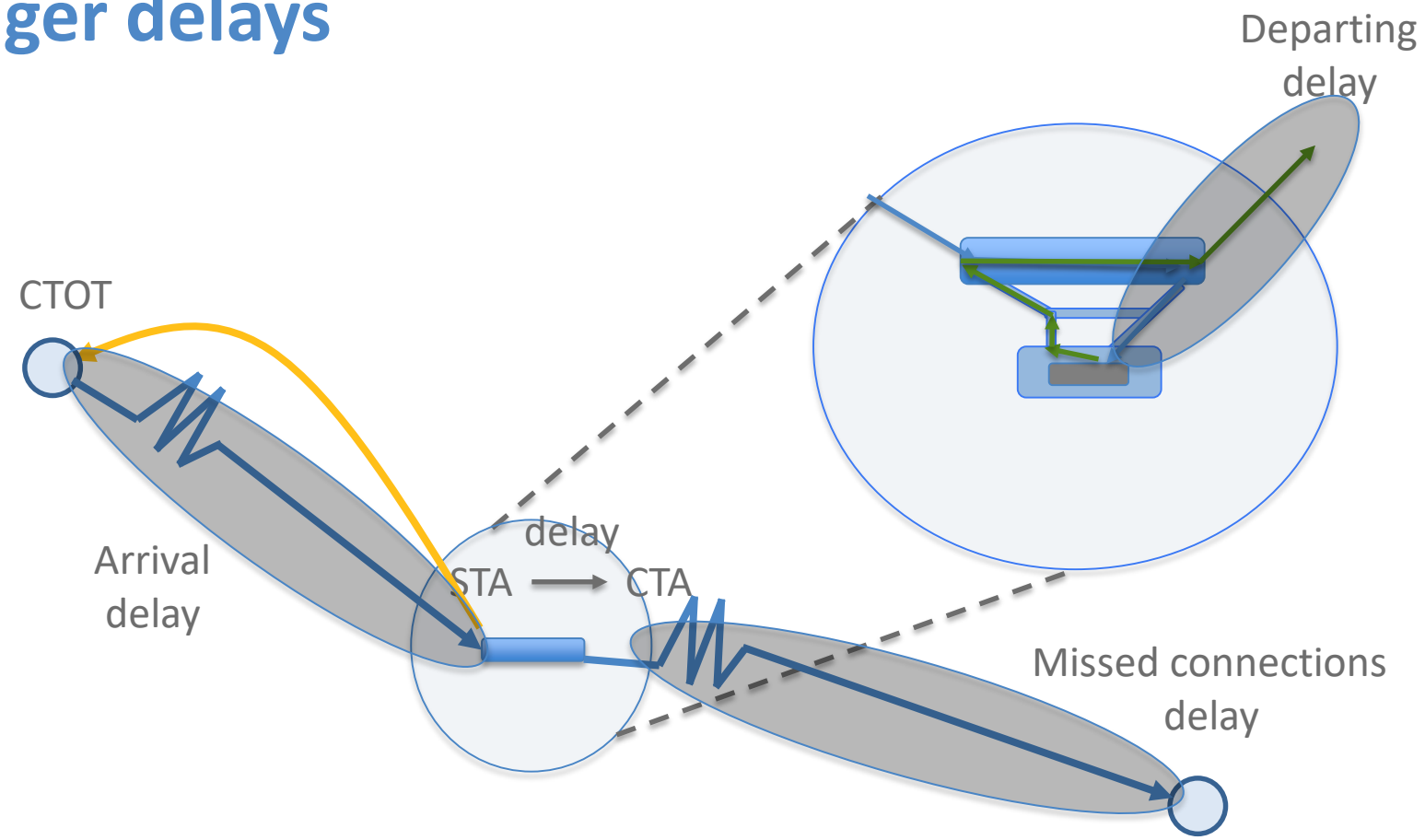
Total flight delays



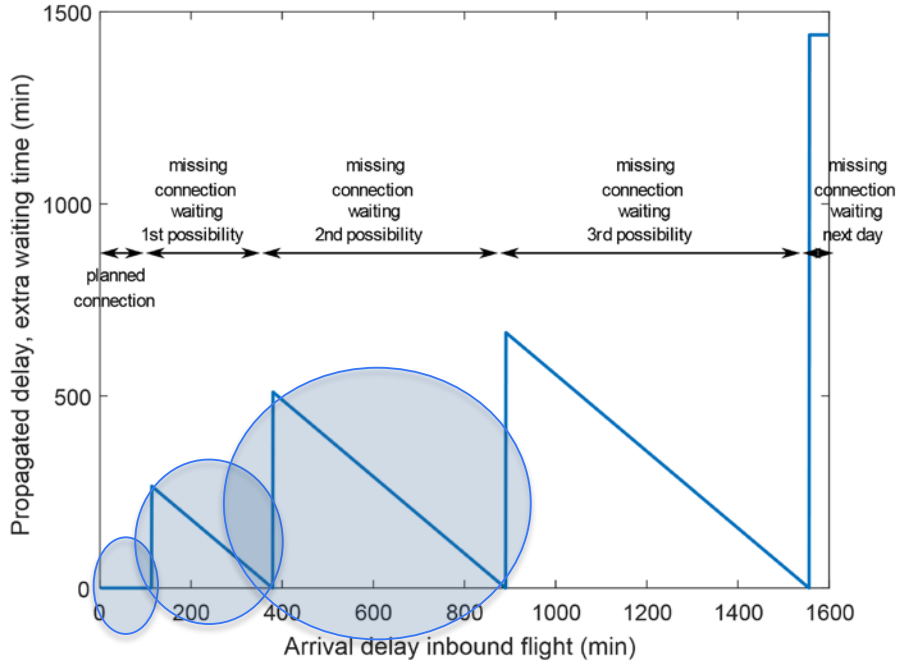


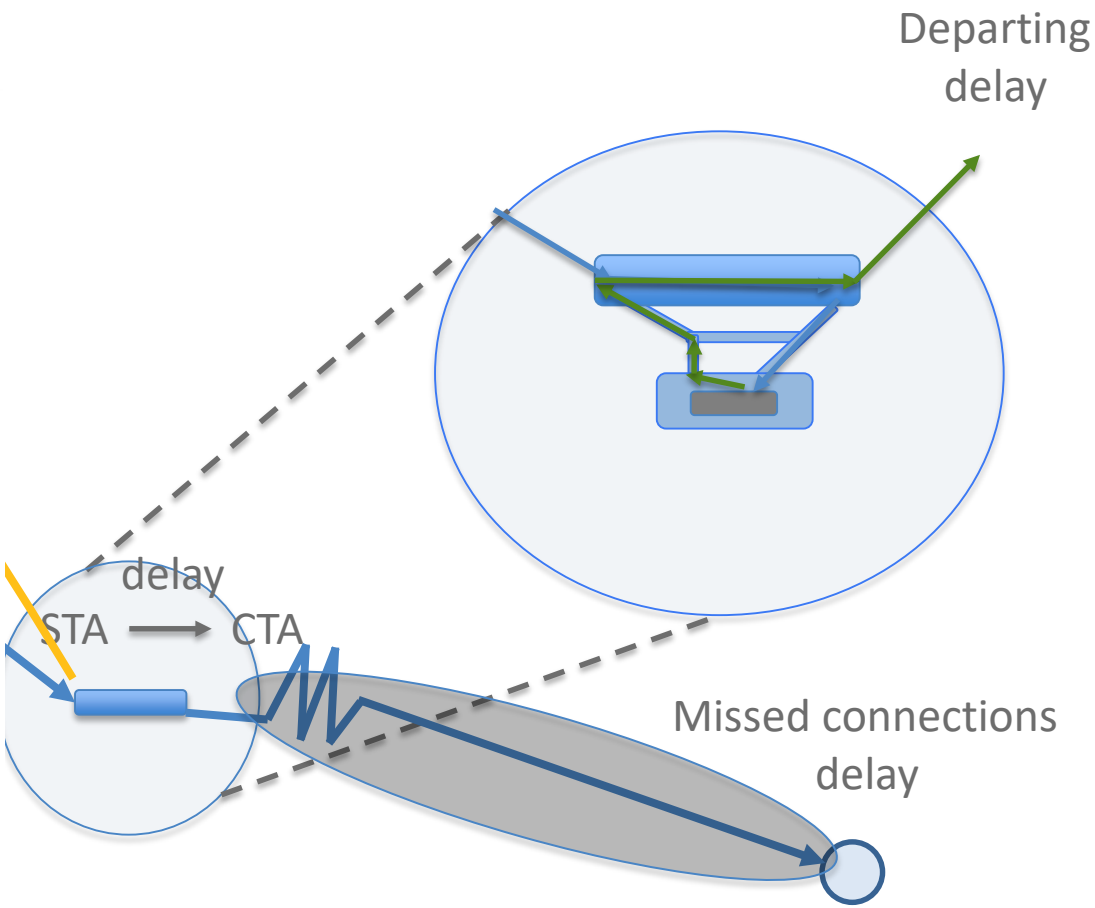
$$D_{Flight} = \sum_f \underbrace{(CTA(f) - STA(f))}_{\text{Primary delay}} + \underbrace{1.8(CTA(f) - LTA(f))}_{\text{Reactionary delay}}$$

Total passenger delays



Total passenger delays





$$D_{PAX} = \sum_f (PAX_{arr}(f)(CTA(f) - STA(f)) + PAX_{connec}\, PropagDelay(f, CTA(f)) + PAX_{dep}(f)(CTA(f) - LTA(f))$$

Arrival delay | Missed connections delay | Departure delay

Montlaur, A. and Delgado, L. 2017. Flight and passenger delay assignment optimization strategies. Transportation Research Part C: Emerging Technologies, Vol. 81, pp. 99—117

Fairness

- Fairness as total deviation with respect to RBS

$$D_{RBS} = \sum_f (|CTA(f) - RBS(f)|)$$

Overview of presentation

- Multi-objective optimisation
    - Flights and passenger trade-off
    - Fairness trade-off
- Fairness vs. efficiency trade-off
    - Price of fairness
    - Price of efficiency
- Discussion of results
- Conclusions and future work

Multi-objective optimisation

- Problem defined as GHP solved with integer programming

$$Obj(\alpha,\beta,\gamma) = \alpha D_{RBS} + \beta D_{PAX} + \gamma D_{Flight}$$

Fairness Passenger Flight

- Convex combination to provide Pareto for *a posteriori* articulation of preferences

$$\alpha + \beta + \gamma = 1 \qquad 0 \leq \alpha, \beta, \gamma \leq 1$$

Multi-objective optimisation

- $Obj_{PAX}(\alpha, \beta, \gamma)$: total passenger delay → optimal with $\beta = 1$ → Opt_{PAX}
- $Obj_{Flight}(\alpha, \beta, \gamma)$: total flight delay → optimal with $\gamma = 1$ → Opt_{Flight}
- $Obj_{Fair}(\alpha, \beta, \gamma)$: total deviation from RBS → optimal with $\alpha = 1$ → Opt_{Fair}

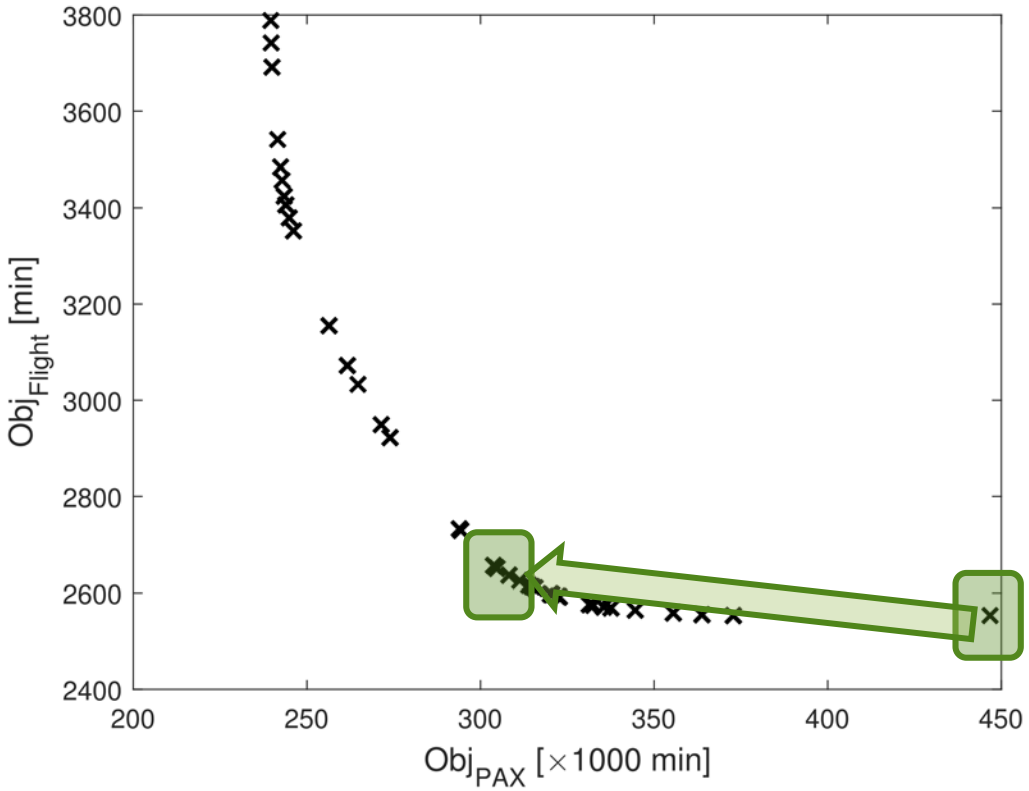
Multi-objective optimisation

- Arrivals at Paris CDG 12SEP14 5h00 – 11h00 GMT
- ATFM regulation 6h00 – 8h00 GMT

(min)	Obj_{Fair}	Obj_{Flight}	Obj_{PAX}
α =1	0	3 774.8	589 102
β = 1	2 601	3 788.4	239 594
γ = 1	2 057	2 553.4	446 760

Multi-objective optimisation

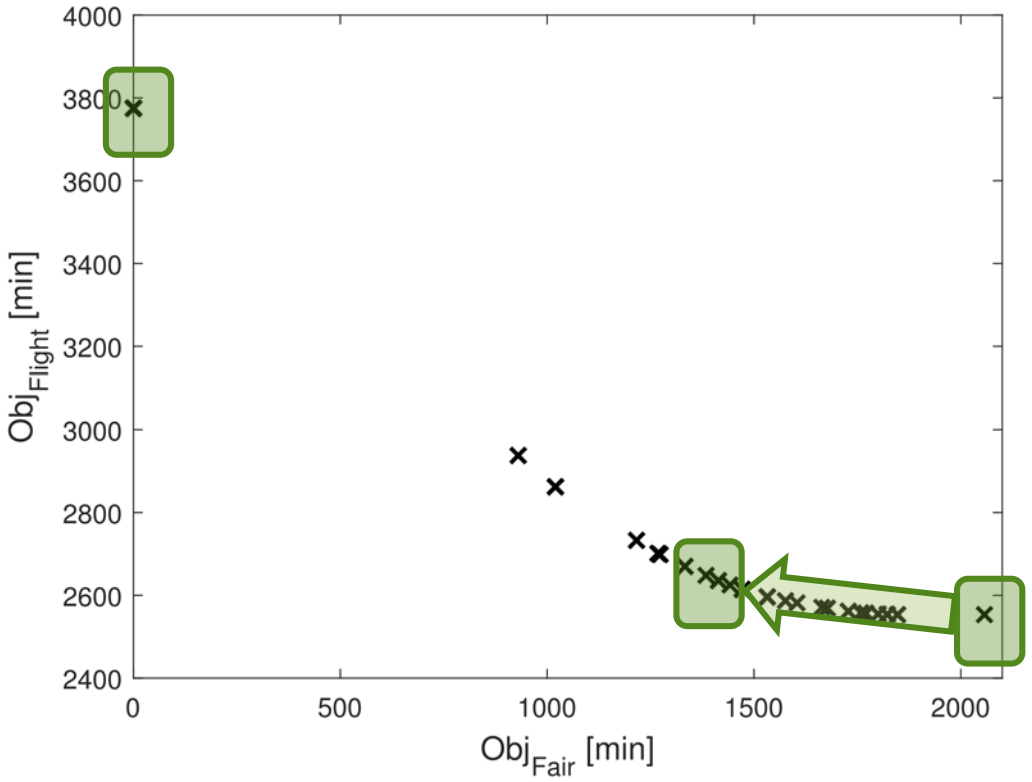
- Flight vs Passenger trade-off



$\alpha = 0$ – Only flight and pax delay considered

Multi-objective optimisation

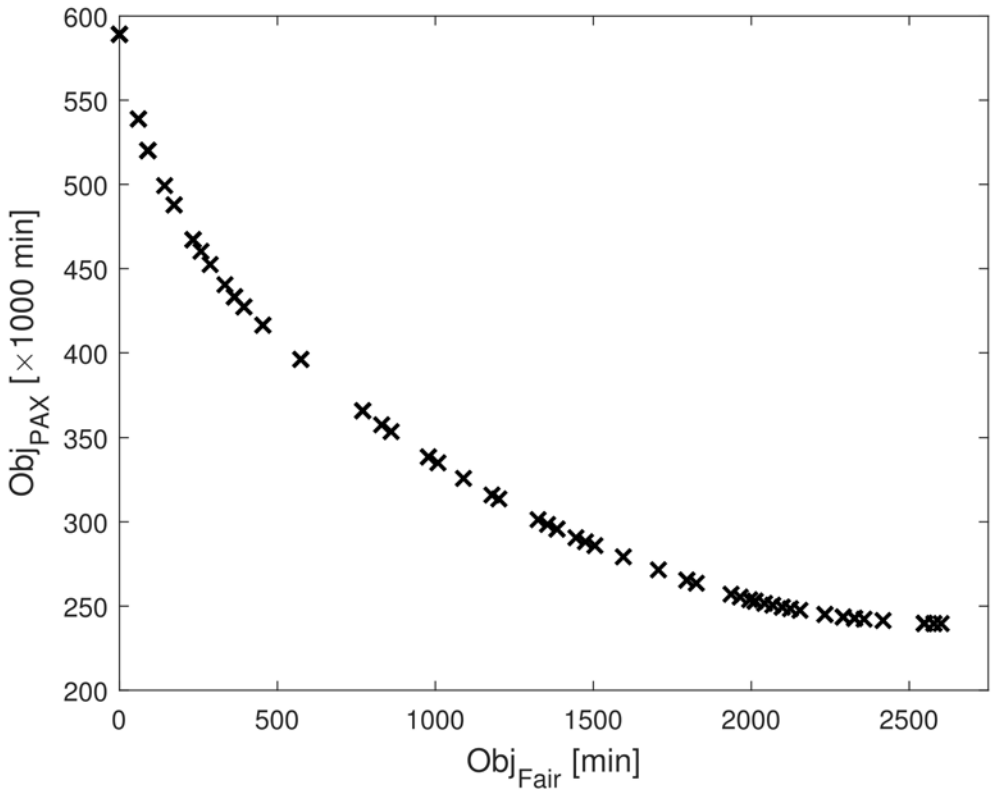
- Flight vs Deviation RBS trade-off



$\beta = 0$ – Only flight and deviation RBS considered

Multi-objective optimisation

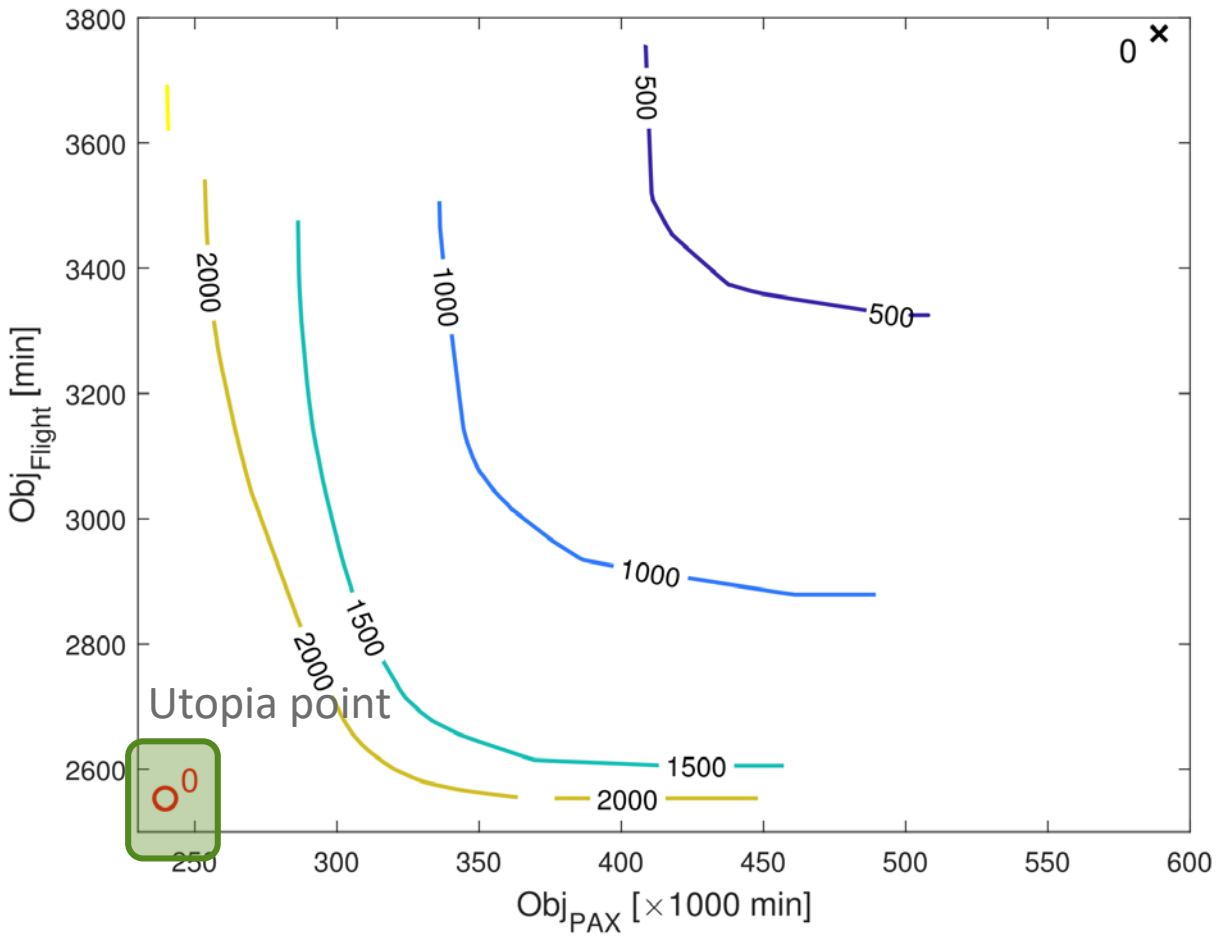
- Passenger vs Deviation RBS trade-off



$\gamma = 0$ – Only pax and deviation RBS considered

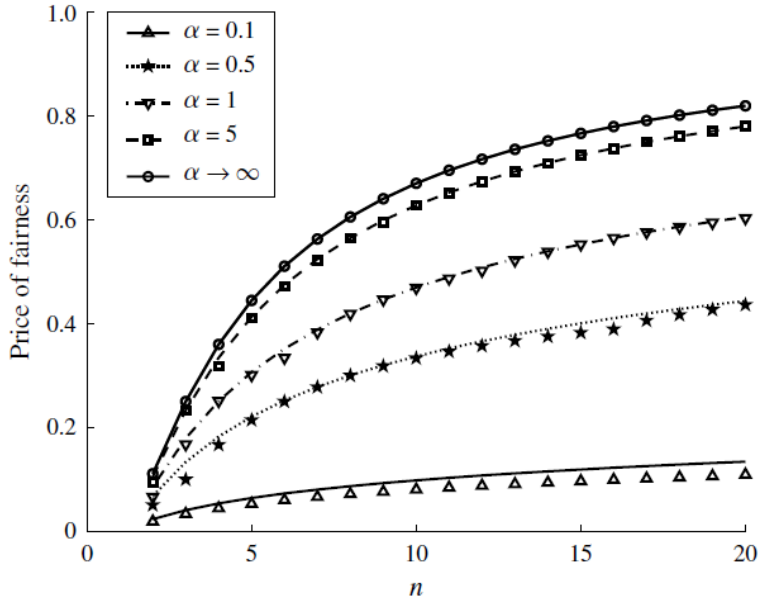
Multi-objective optimisation

- Flight vs Passenger vs Deviation RBS



Fairness vs efficiency trade-off

$$POF(U,\alpha) = \frac{SYSTEM(U) - FAIR(U,\alpha)}{SYSTEM(U)}$$



Bertsimas, D., Farias, V.F., Trichakis, N., 2012. On the Efficiency-Fairness Trade-off, Management Science, Vol. 58, No. 12, pp. 2234-250

Fairness vs efficiency trade-off

$$POF(U,\alpha) = \frac{SYSTEM(U) - FAIR(U,\alpha)}{SYSTEM(U)}$$

$$POE(U,\alpha) = \frac{max_{u \in U} min_{j=1,\dots,n} u_j - min_{j=1,\dots,n} z_j(\alpha)}{max_{u \in U} min_{j=1,\dots,n} u_j}$$

Bertsimas, D., Farias, V.F., Trichakis, N., 2012. On the Efficiency-Fairness Trade-off, Management Science, Vol. 58, No. 12, pp. 2234-250

Fairness vs efficiency trade-off

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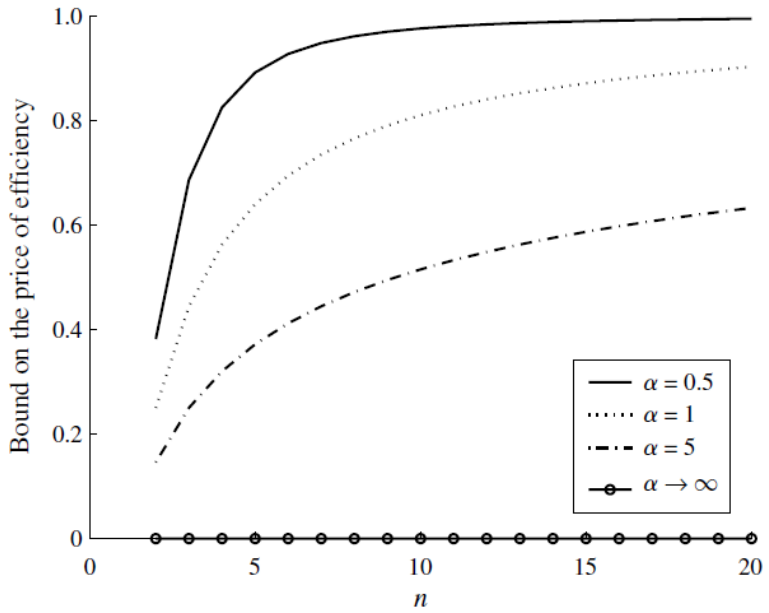


Bertsimas, D., Farias, V.F., Trichakis, N., 2012. On the Efficiency-Fairness Trade-off, Management Science, Vol. 58, No. 12, pp. 2234-250

Fairness vs efficiency trade-off

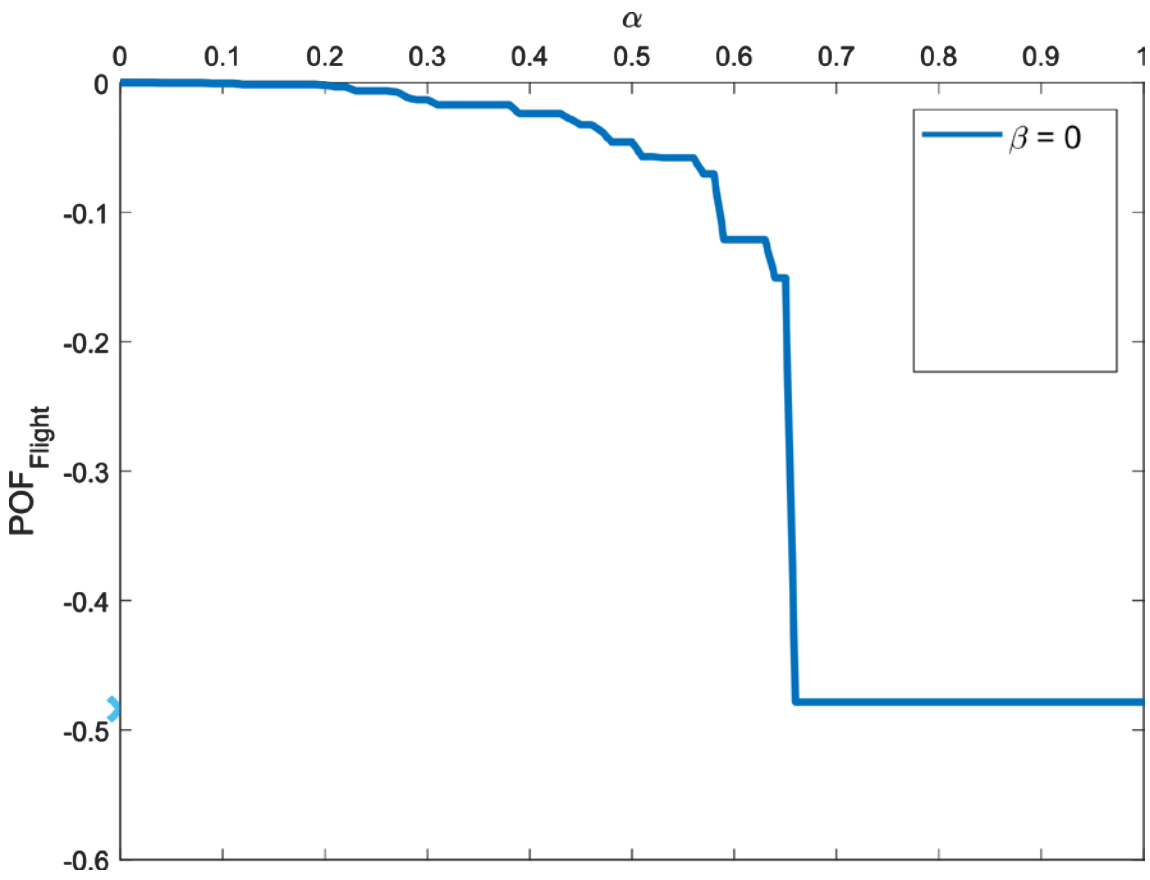
$$POF_{Flight}(\alpha,\beta,\gamma) = \frac{Opt_{Flight} - Obj_{Flight}(\alpha,\beta,\gamma)}{Opt_{Flight}}$$

Price of trade-off

$$POF_{PAX}(\alpha,\beta,\gamma) = \frac{Opt_{PAX} - Obj_{PAX}(\alpha,\beta,\gamma)}{Opt_{PAX}}$$

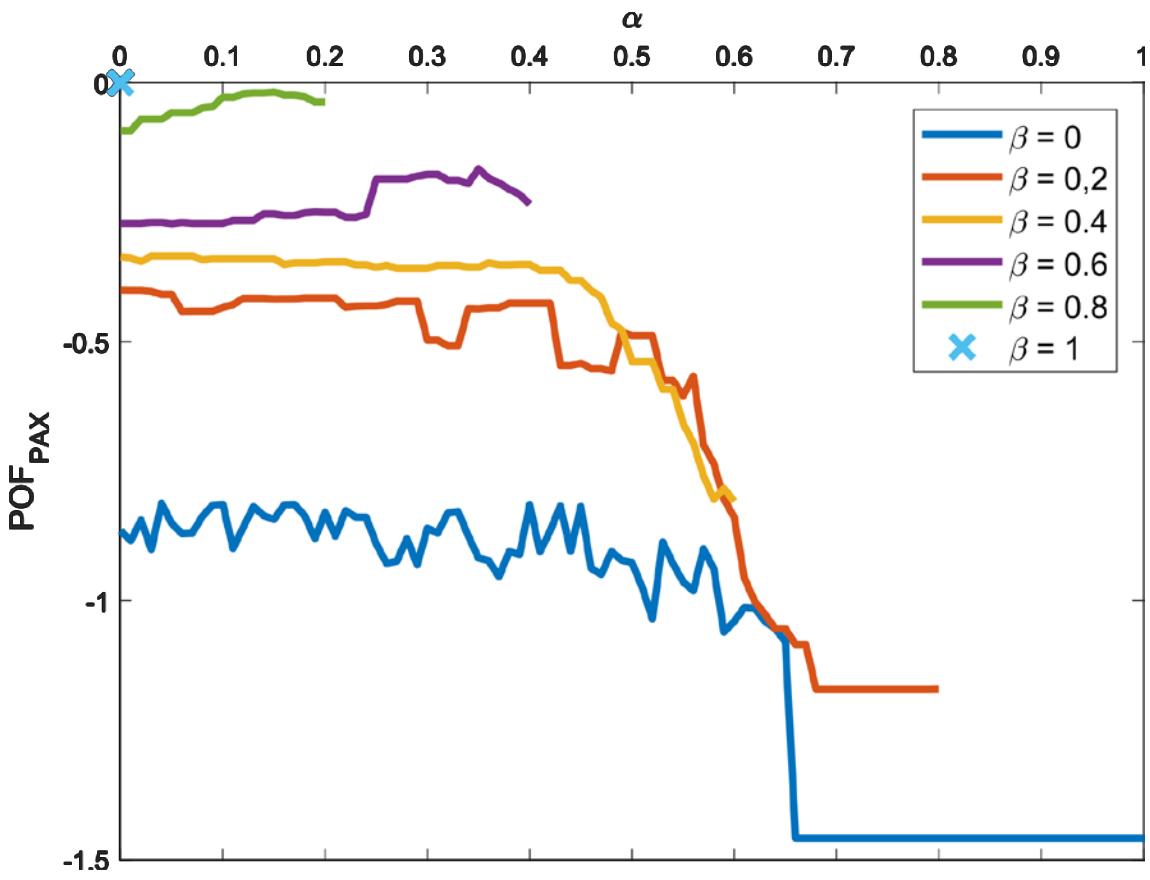
$$POE(\alpha,\beta,\gamma) = \frac{|Opt_{Fair}| - |Obj_{Fair}(\alpha,\beta,\gamma)|}{\max(|Obj_{Fair}|)}$$

Fairness vs efficiency trade-off



α – Deviation RBS
β – Pax total delay
γ – Flights total delay

Fairness vs efficiency trade-off



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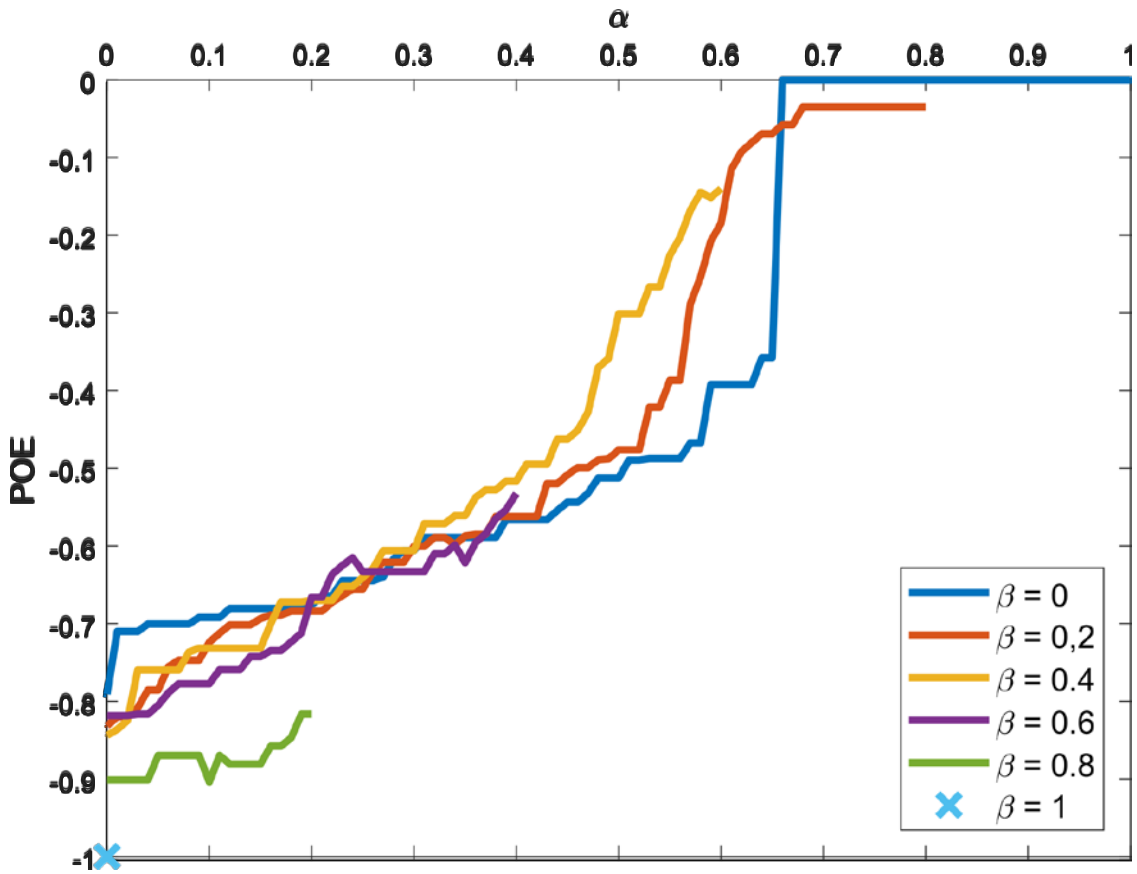
Fairness vs efficiency trade-off

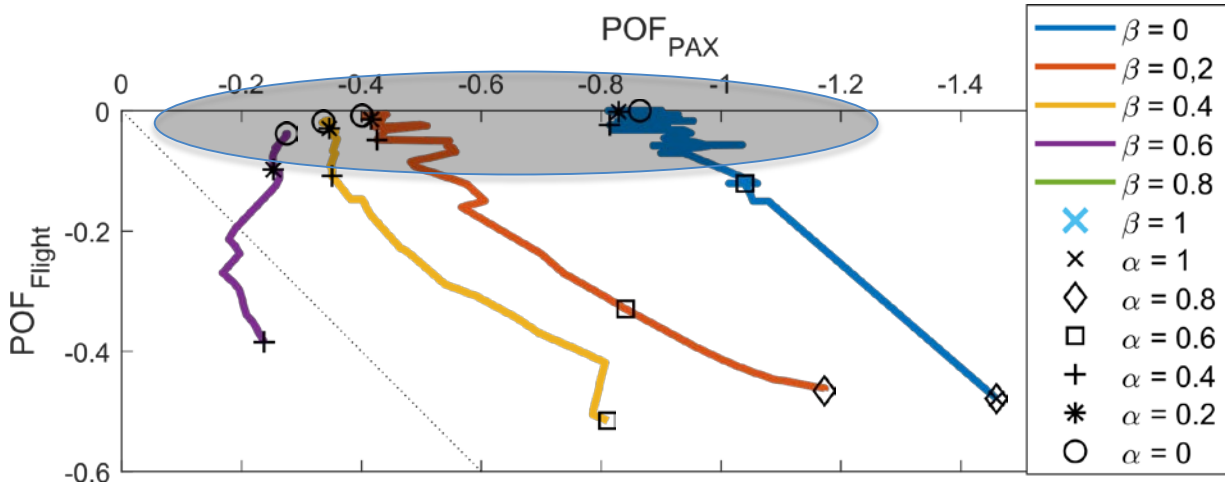


α – Deviation RBS
β – Pax total delay
γ – Flights total delay

Discussion of results

- Multi-objective selection of parameters
- Across objectives trade-offs

Discussion of results



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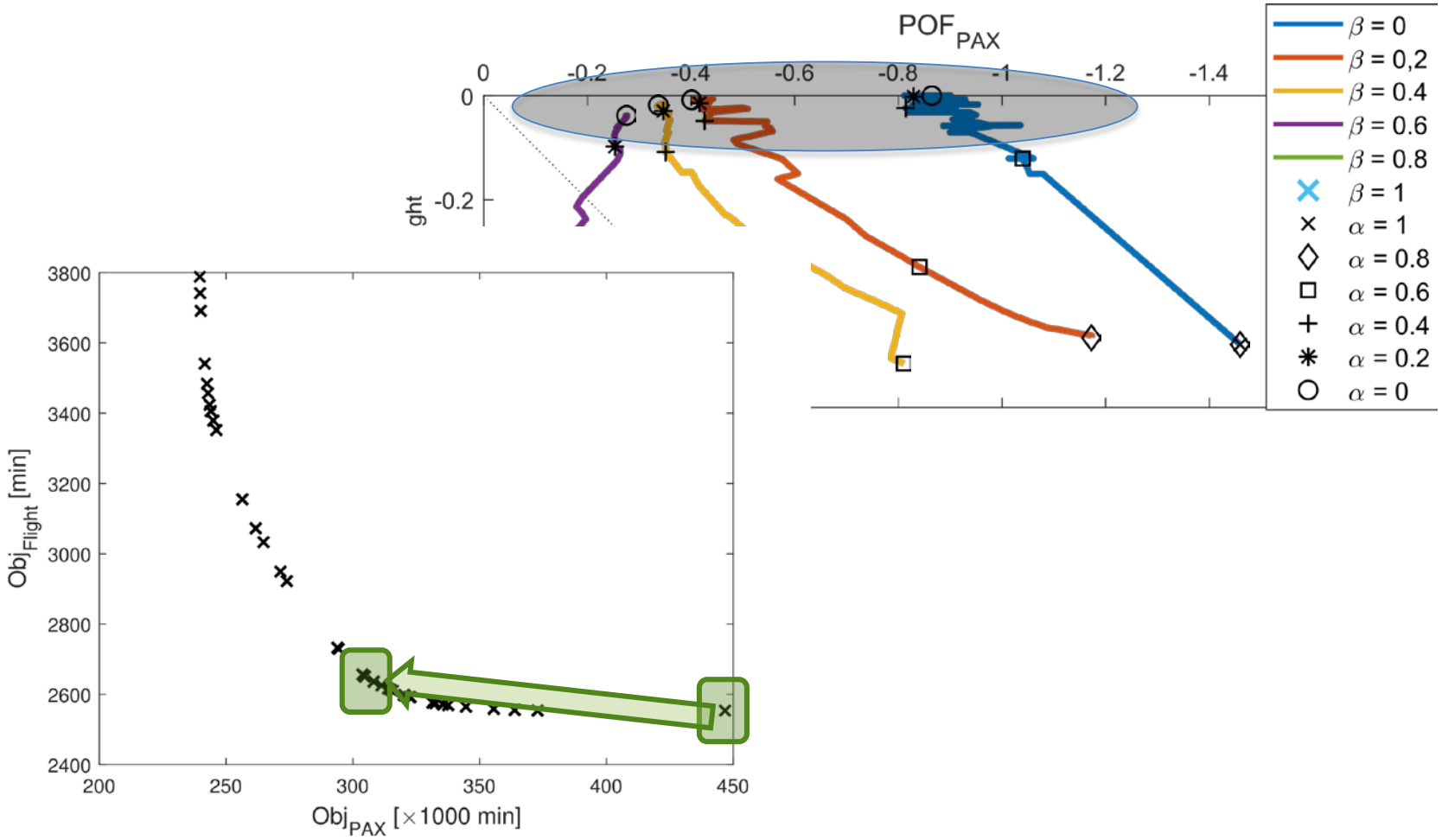
Discussion of results



α – Deviation RBS
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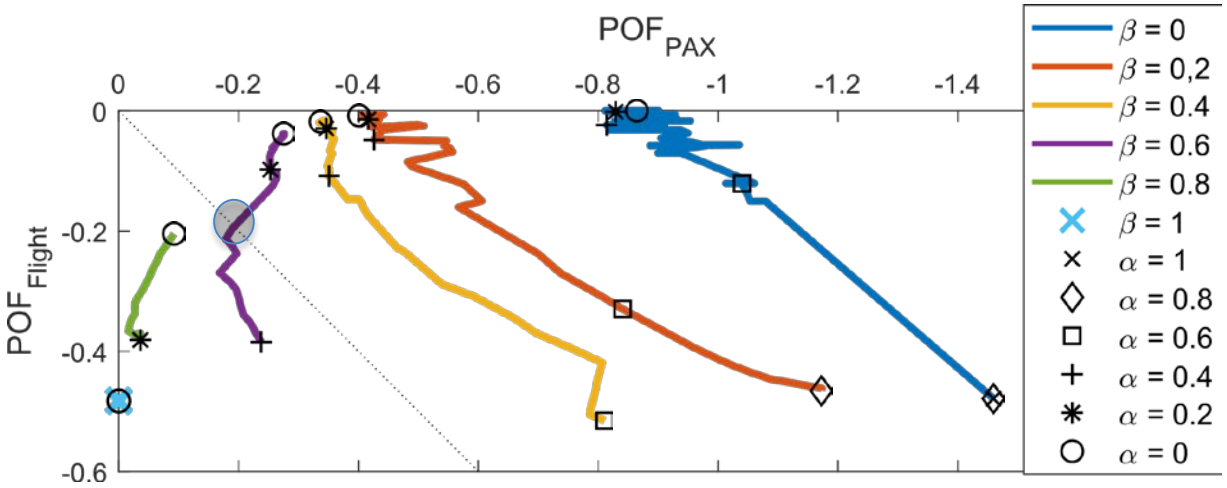
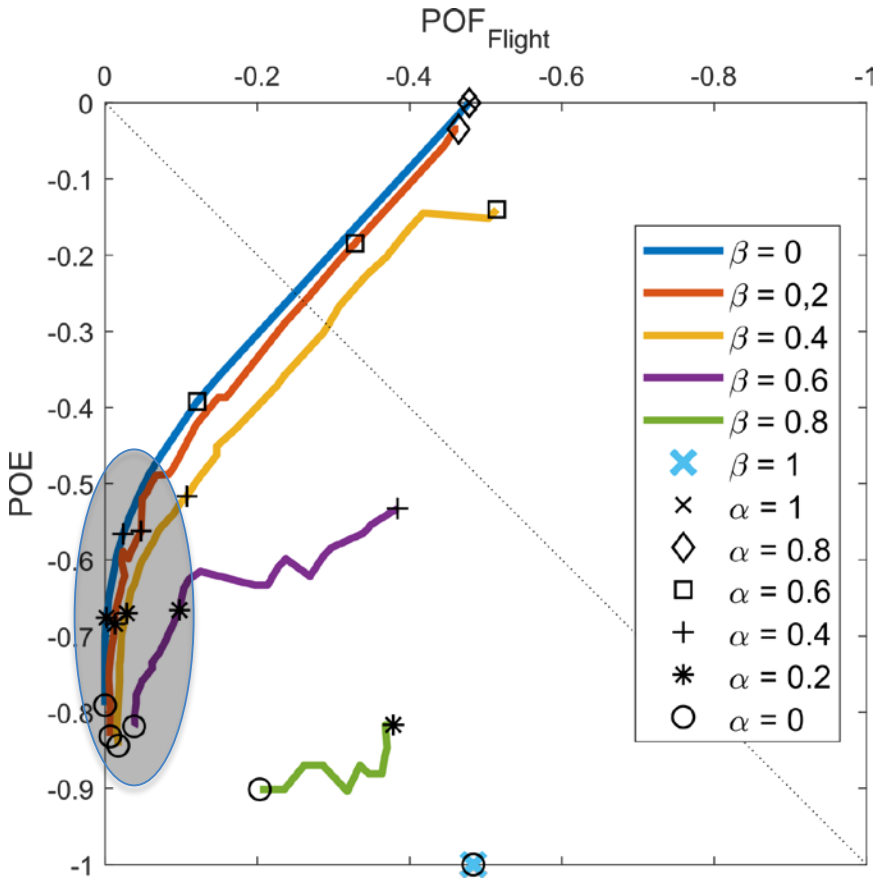
Discussion of results



$\alpha \approx 0.3$
$\beta \approx 0.6$
$\gamma \approx 0.1$

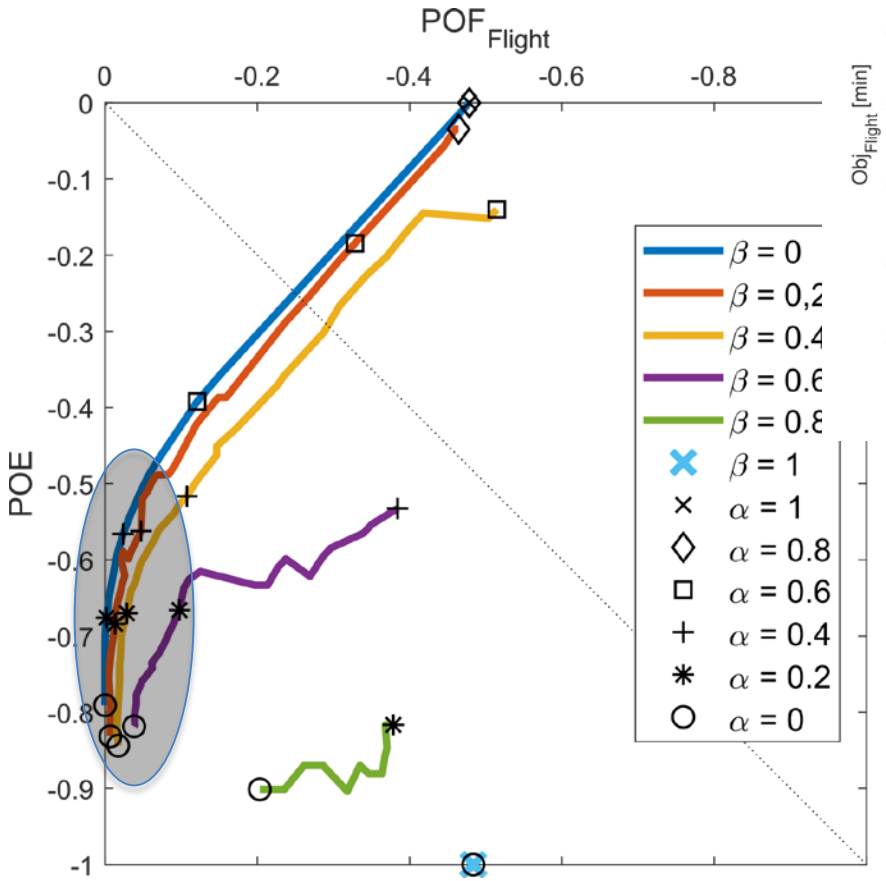
α – Deviation RBS
β – Pax total delay
γ – Flights total delay

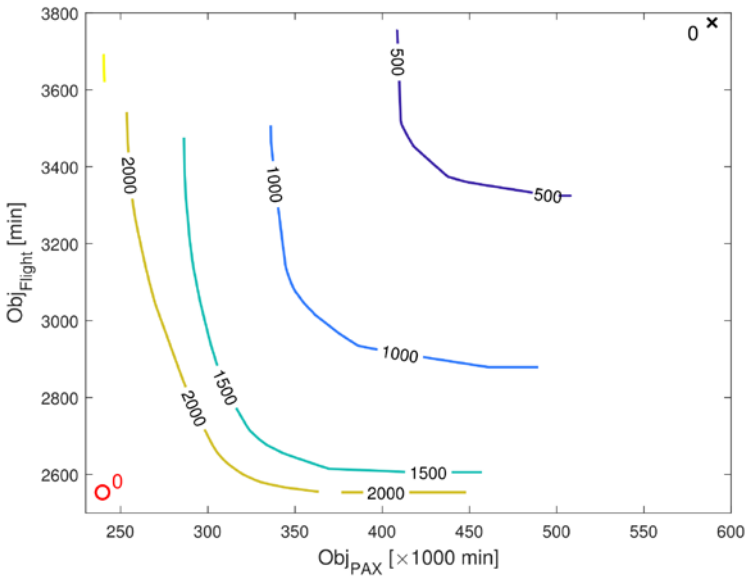
Discussion of results



α – Deviation RBS
β – Pax total delay
γ – Flights total delay

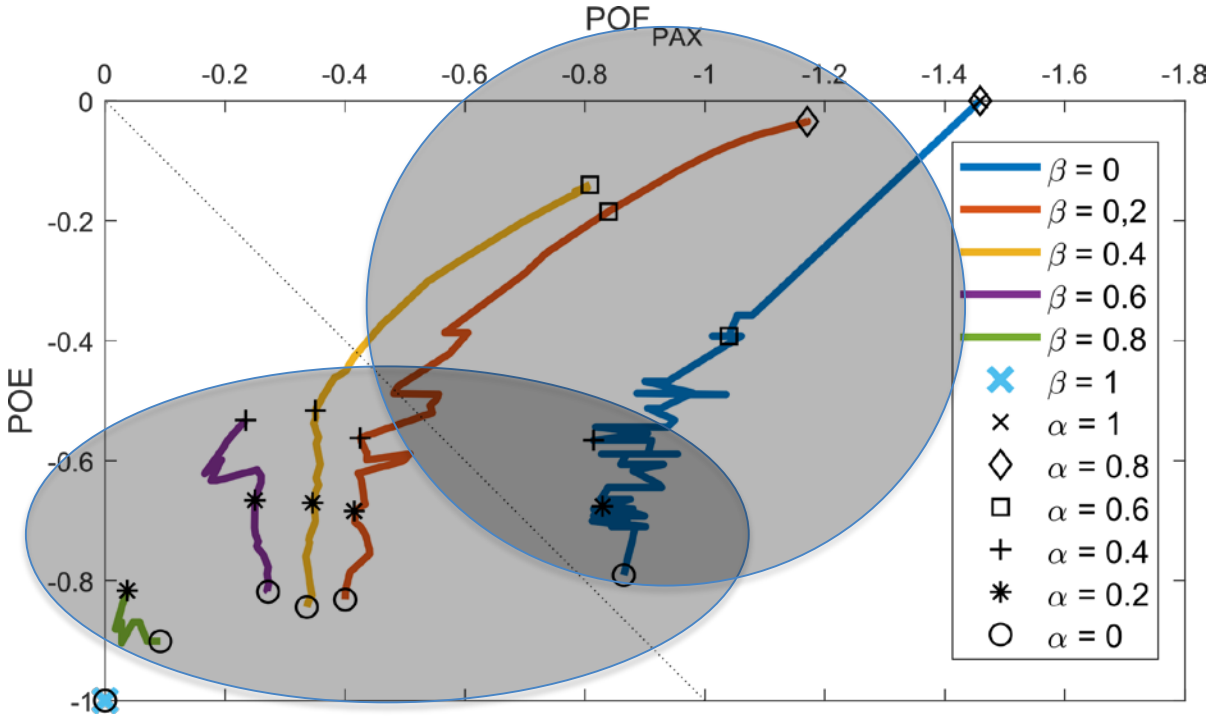
Discussion of results





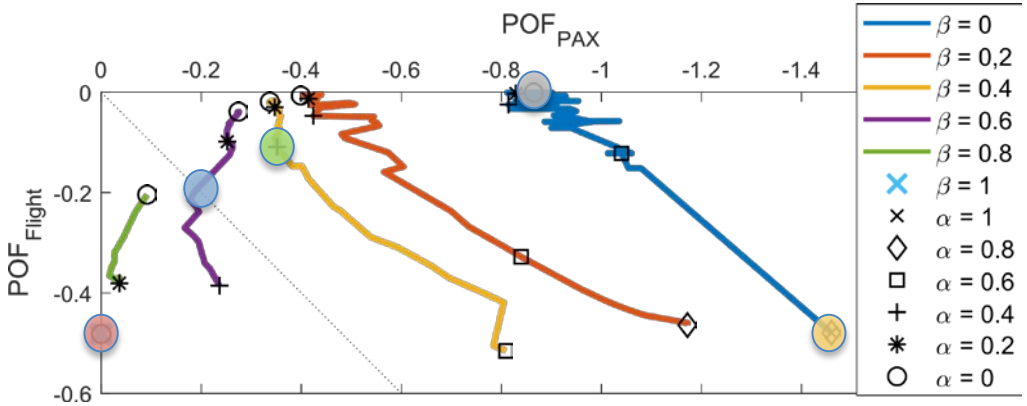
α – Deviation RBS
β – Pax total delay
γ – Flights total delay

Discussion of results



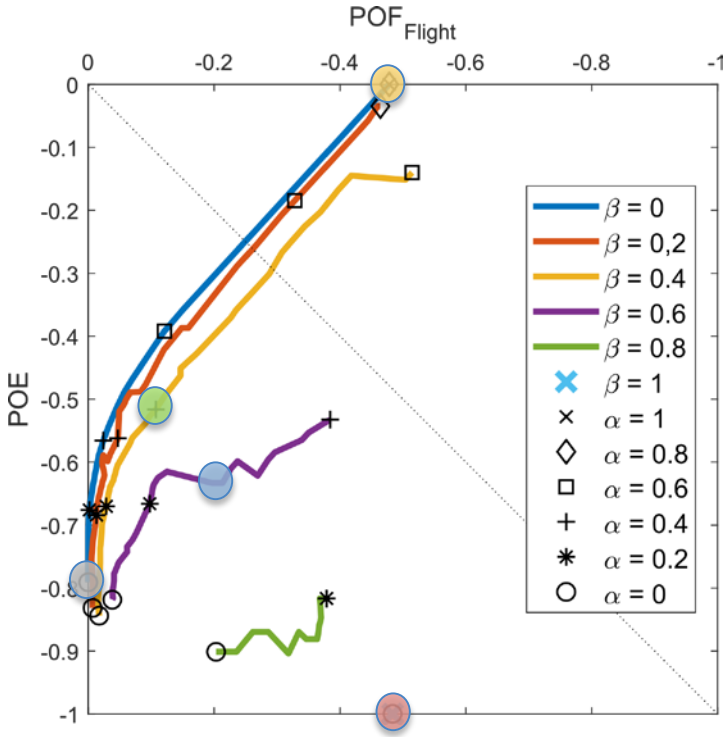
α – Deviation RBS
β – Pax total delay
γ – Flights total delay

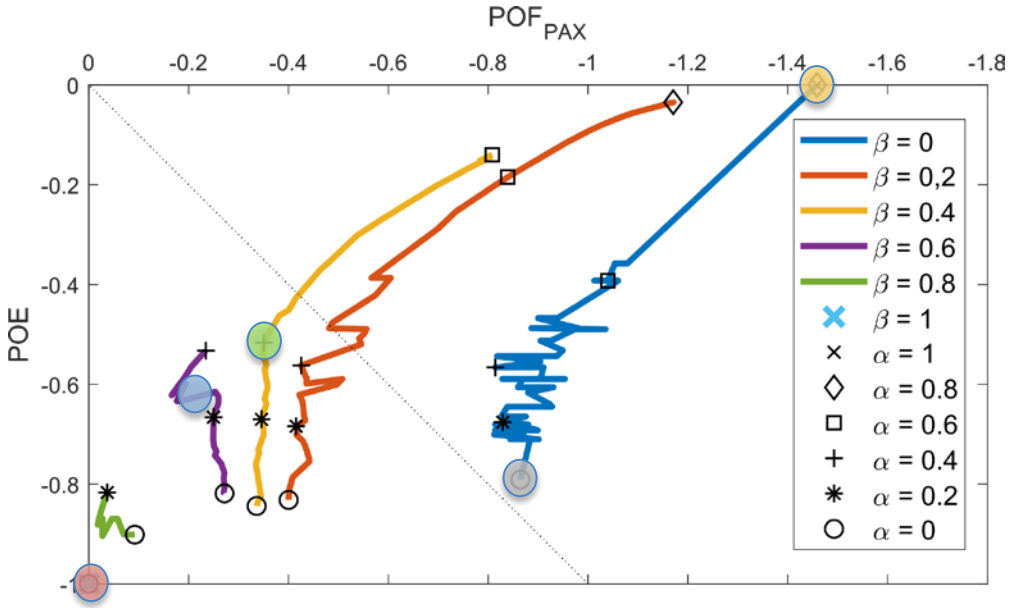
Discussion of results



RBS	Flight	Pax
$\alpha = 1$	$\alpha = 0$	$\alpha = 0$
$\beta = 0$	$\beta = 0$	$\beta = 1$
$\gamma = 0$	$\gamma = 1$	$\gamma = 0$

Flight/Pax	Flight/Pax/RBS
$\alpha = 0.3$	$\alpha = 0.4$
$\beta = 0.6$	$\beta = 0.4$
$\gamma = 0.1$	$\gamma = 0.2$





α – Deviation RBS β – Pax total delay γ – Flights total delay

Conclusions and future work

- Different stakeholders need to be considered when optimising
  - Improvements can be achieved for one stakeholder without significant reducing performance of another
  - But, might have impact on the fairness of the solution
  - **Think about the passengers!**
  - But, **how to share/consider the information?**
- Fairness defined as deviation from RBS
  - Still flight-centric approach
  - **Other solutions?**
- POE and POF allows modellers to ***a posteriori*** **identify the different trade-offs**
  - How to better present this information?
- Extend work to other airports/regulations to be analysed

Thanks for your attention

Multi-objective optimisation

- Problem defined as GHP solved with integer programming

$$Obj(\alpha,\beta,\gamma) = \alpha D_{RBS} + \beta D_{PAX} + \gamma D_{Flight}$$

Fairness Passenger Flight

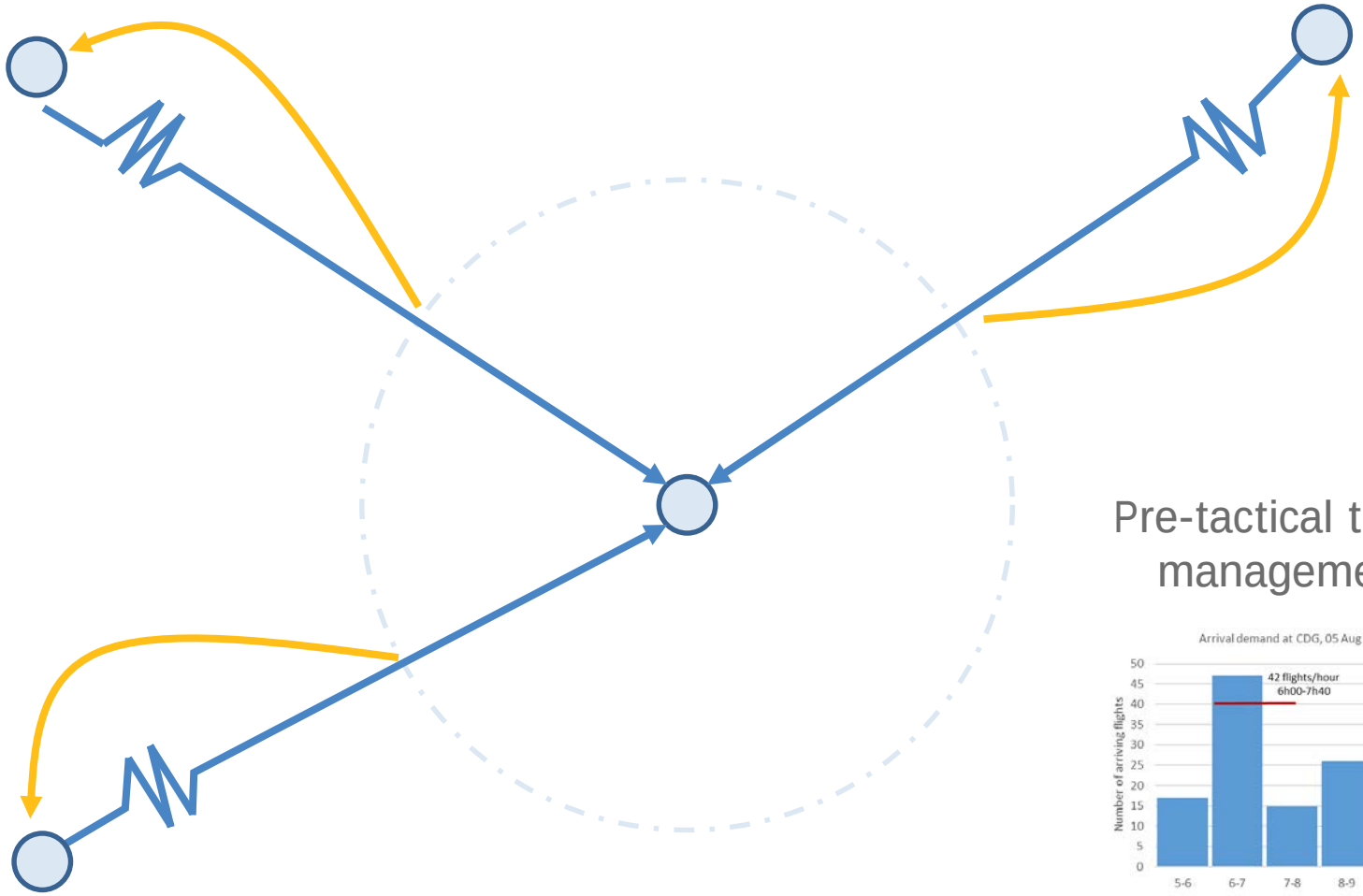
- Convex combination to provide Pareto for *a posteriori* articulation of preferences

$$\alpha + \beta + \gamma = 1 \qquad 0 \leq \alpha,\beta,\gamma \leq 1$$

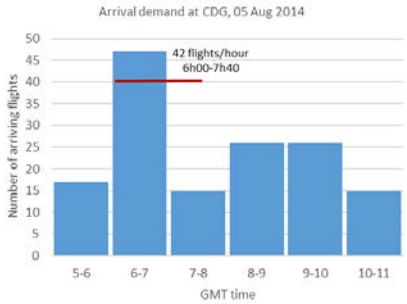
- Upper-lower-bound transformation

$$Obj(\alpha,\beta,\gamma) = \alpha \frac{D_{RBS} - D^0_{RBS}}{D^{max}_{RBS} - D^0_{RBS}} + \beta \frac{D_{PAX} - D^0_{PAX}}{D^{max}_{PXA} - D^0_{PAX}} + \gamma \frac{D_{Flight} - D^0_{Fliht}}{D^{max}_{Flight} - D^0_{Flight}}$$

Flights and passengers delays



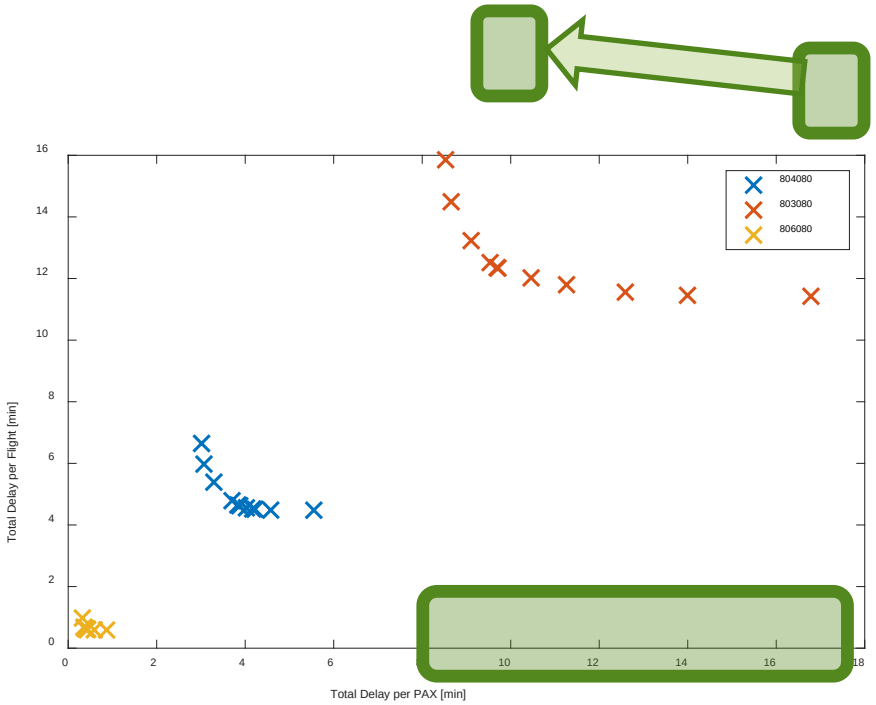
Pre-tactical traffic management

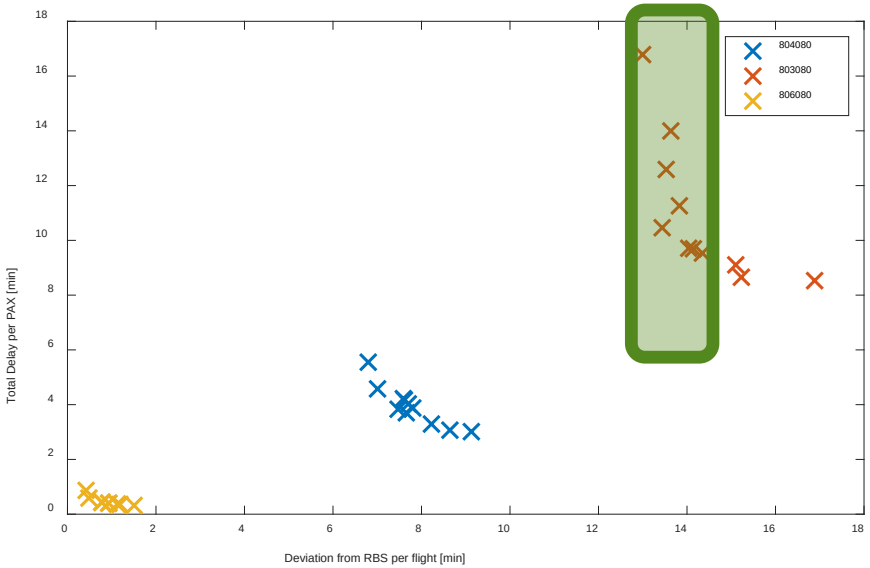


A. Montlaur, L. Delgado, Delay assignment optimization strategies at pre-tactical and tactical levels, SESAR Innovation Days 2015

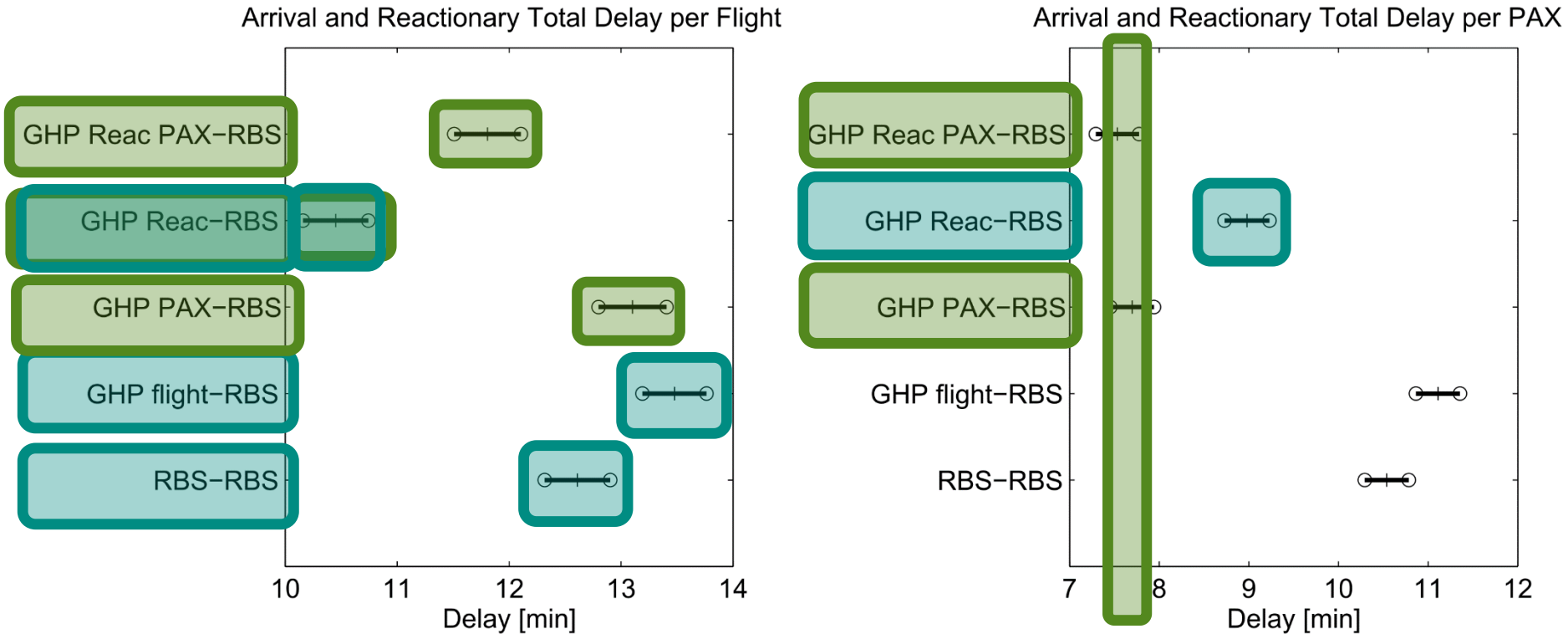
Flights and passengers delays

Obj = α Total delay per flight + (1-α) Total delay per passengers





Flights and passengers delays



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