Hub operations: delay recovery based on cost optimisation

- dynamic cost indexing and waiting for passengers strategies

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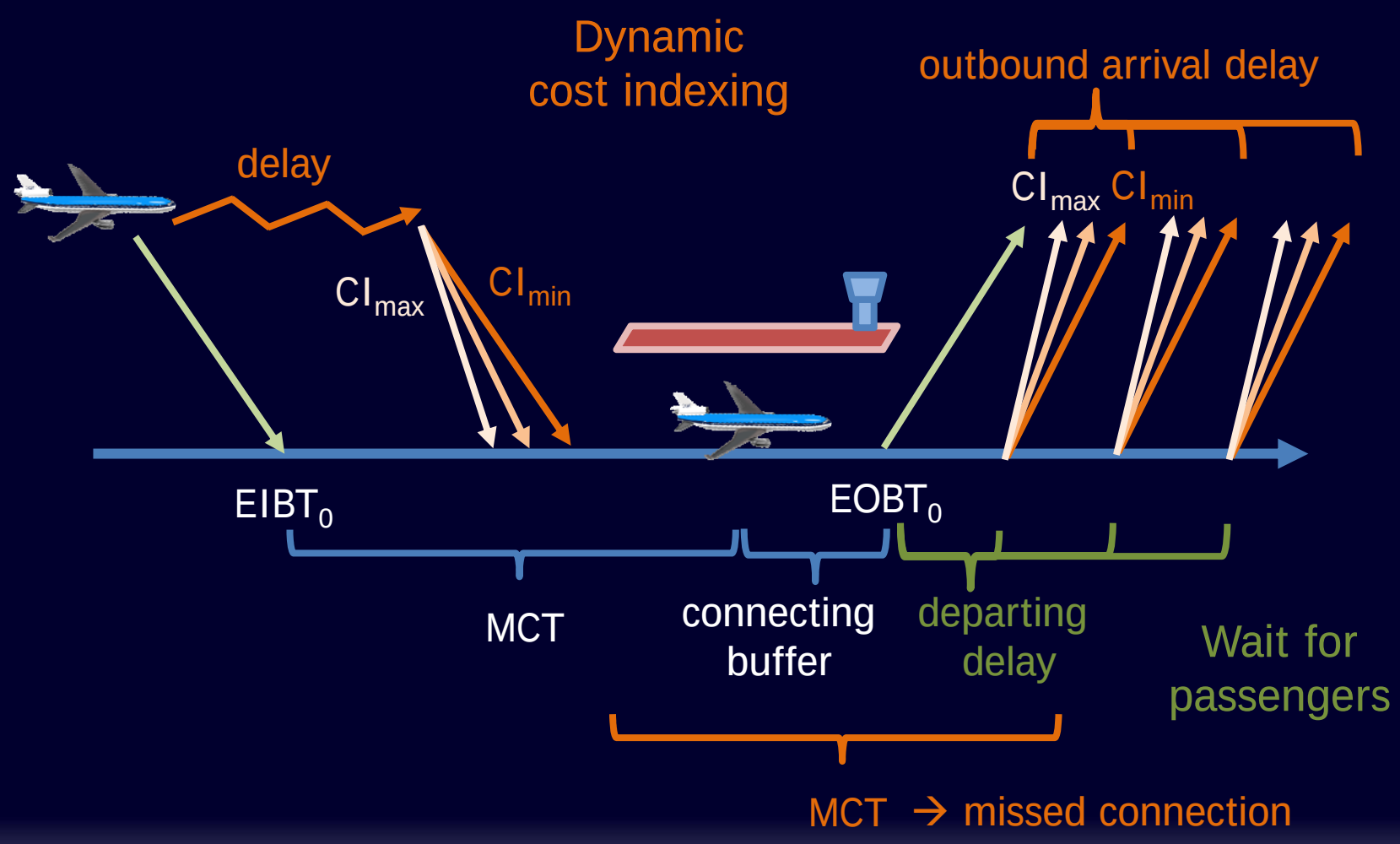
Overview

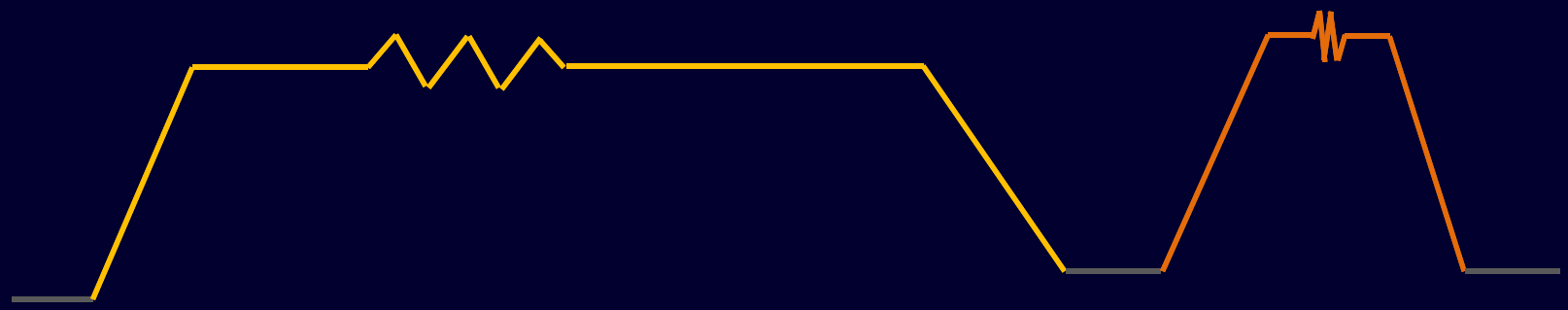
- Background and objectives
- Model description
- Datasets
- Case of study
- Results
- Conclusions and next steps

Background and objectives

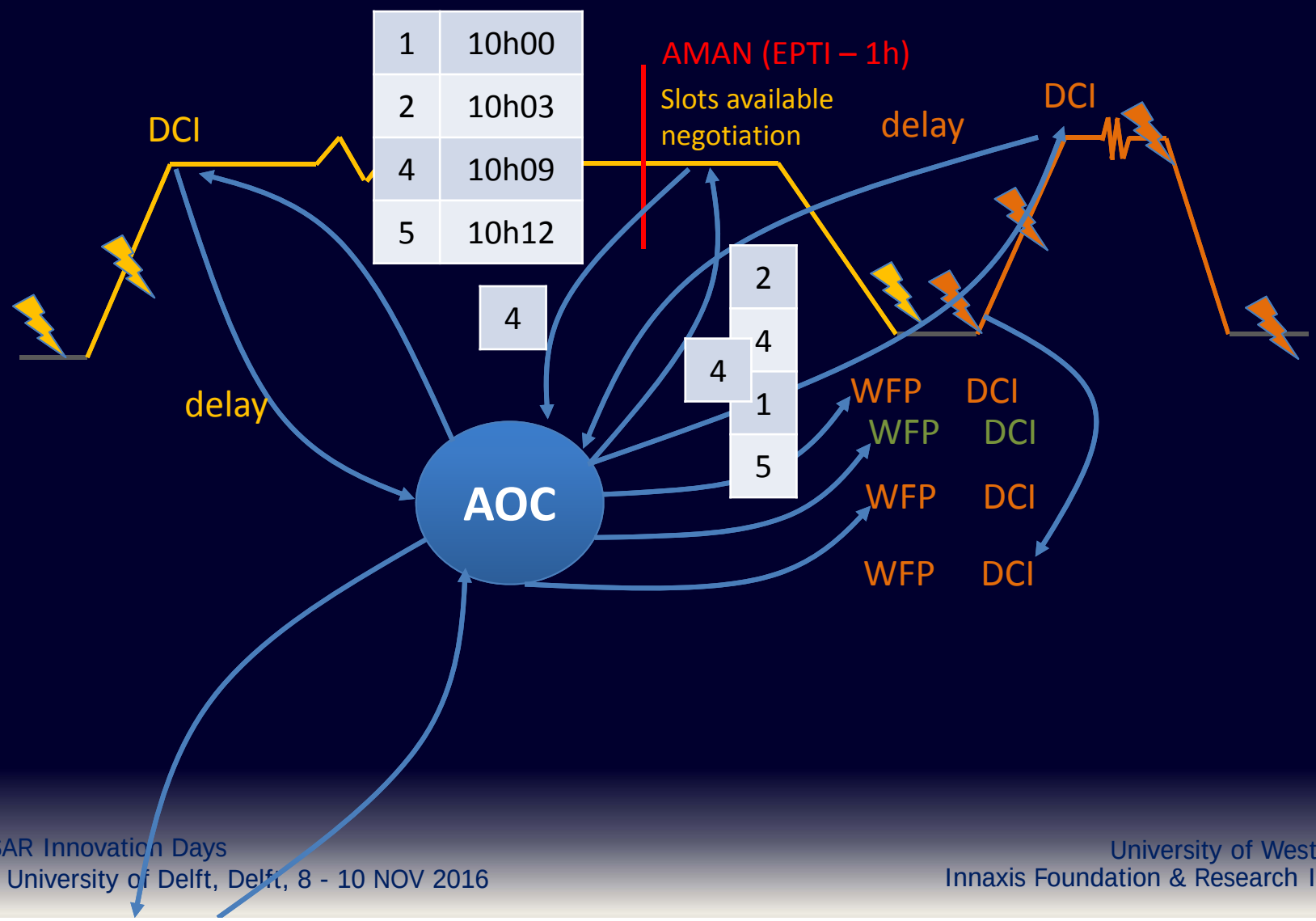
Background and objectives



Background and objectives



Background and objectives



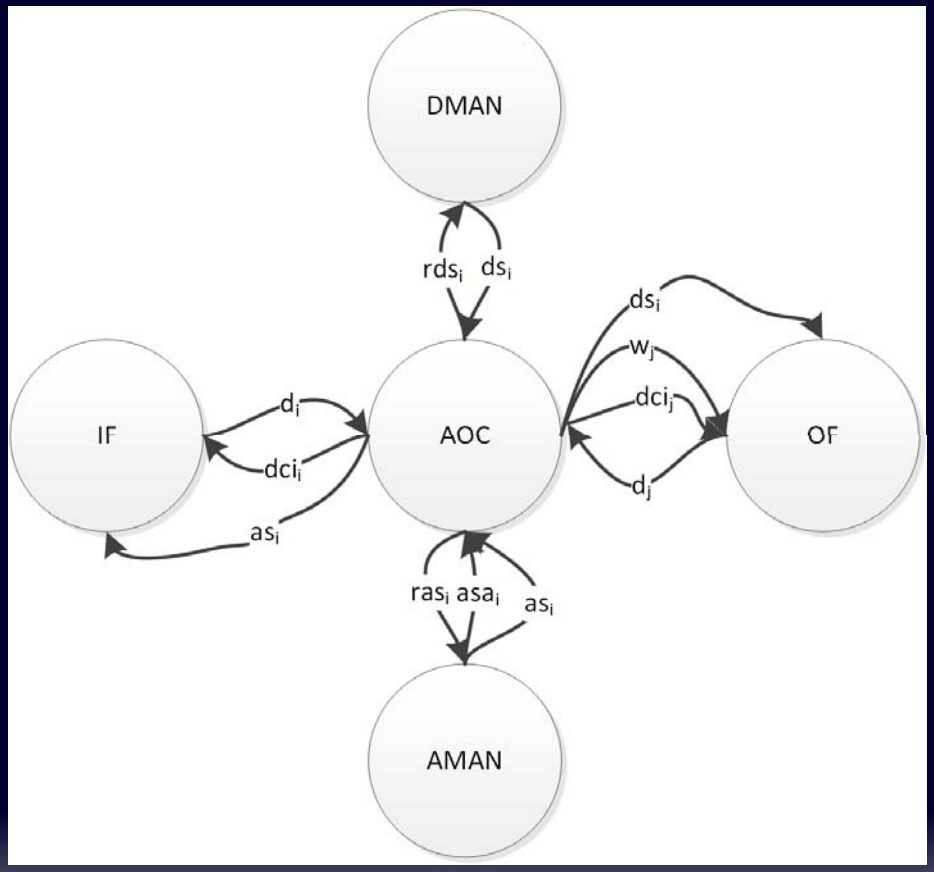
Background and objectives

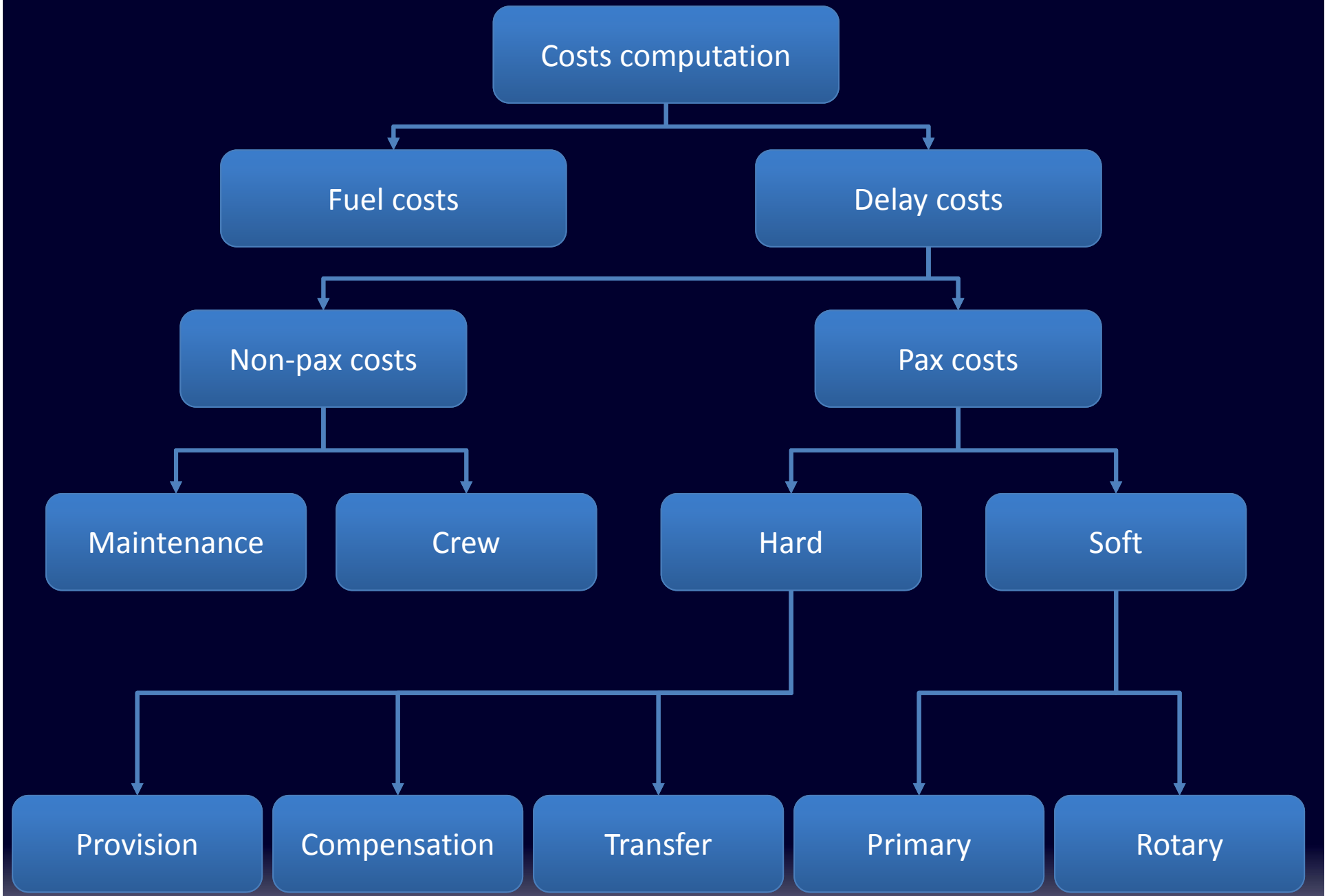
- Model operations at a hub allowing two strategies
  - Dynamic cost indexing (DCI)
  - Wait-for-passengers (WFP)
- Analyse effect of these strategies considering
  - Delay and uncertainty at different phases
  - DCI for inbound and outbound flights at TOC
  - E-AMAN with slot negotiation capabilities

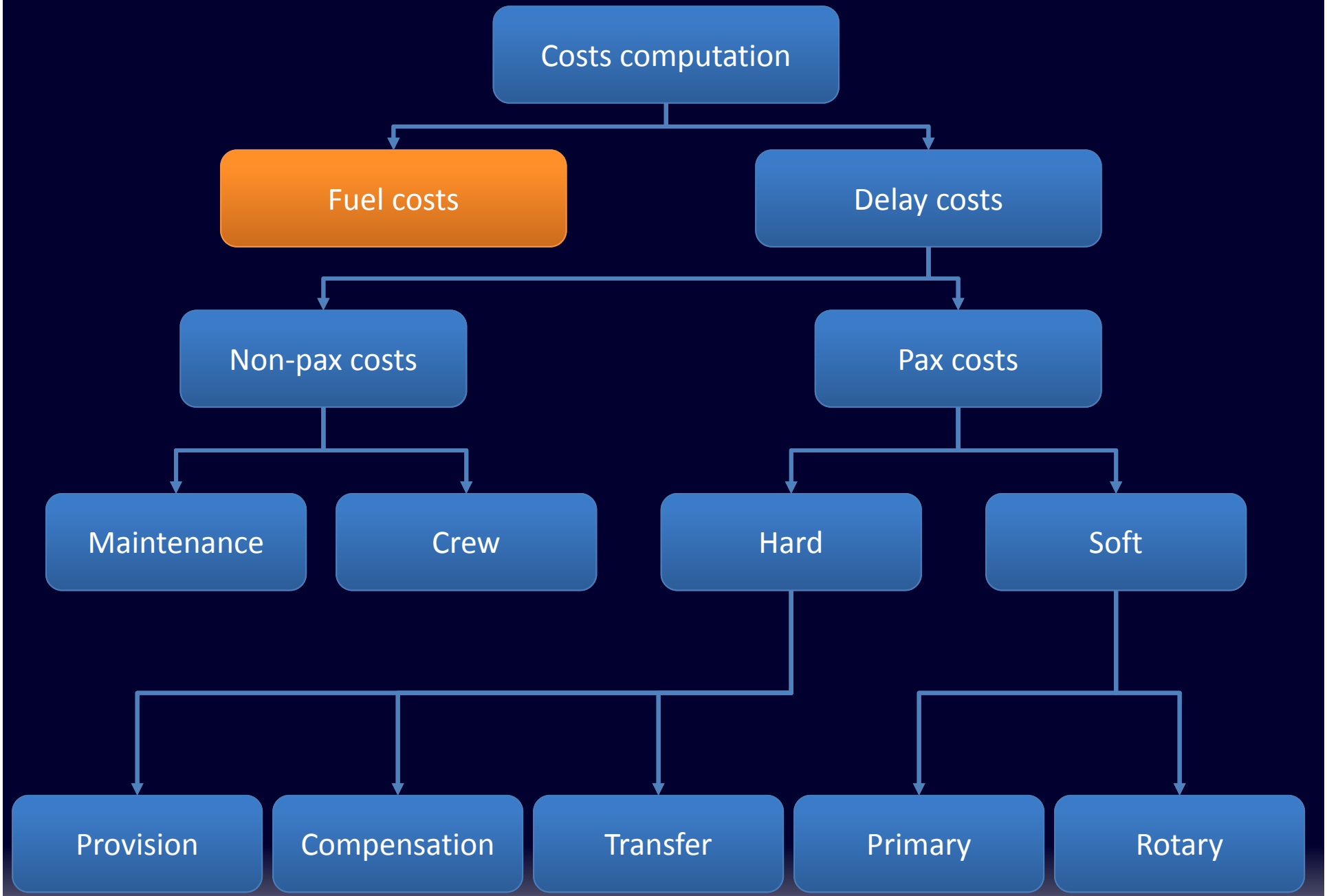
Model description

Model description

- Agent Based Model




Costs computation
Fuel costs
Delay costs
Non-pax costs
Pax costs
Maintenance
Crew
Hard
Soft
Provision
Compensation
Transfer
Primary
Rotary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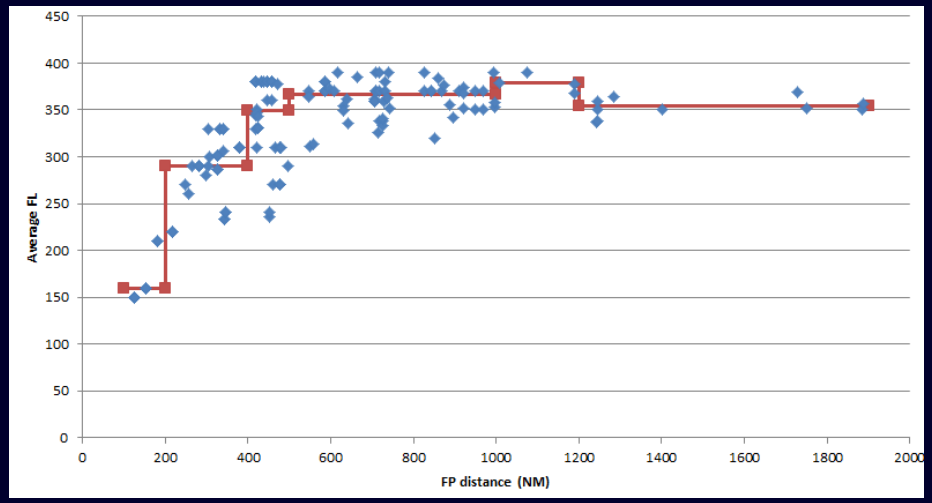
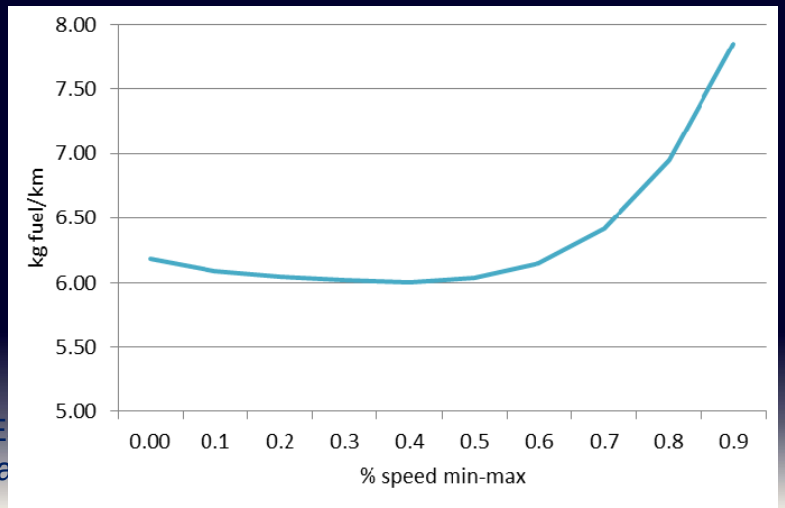
Costs computation

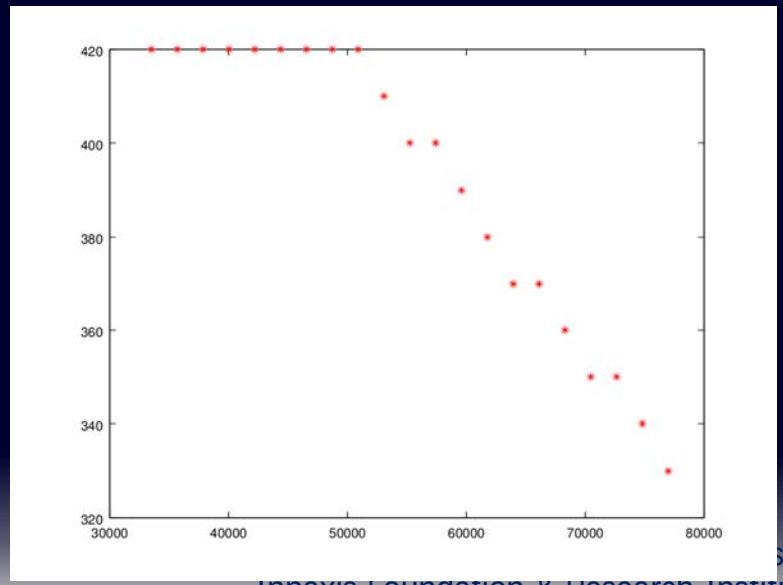
Fuel costs

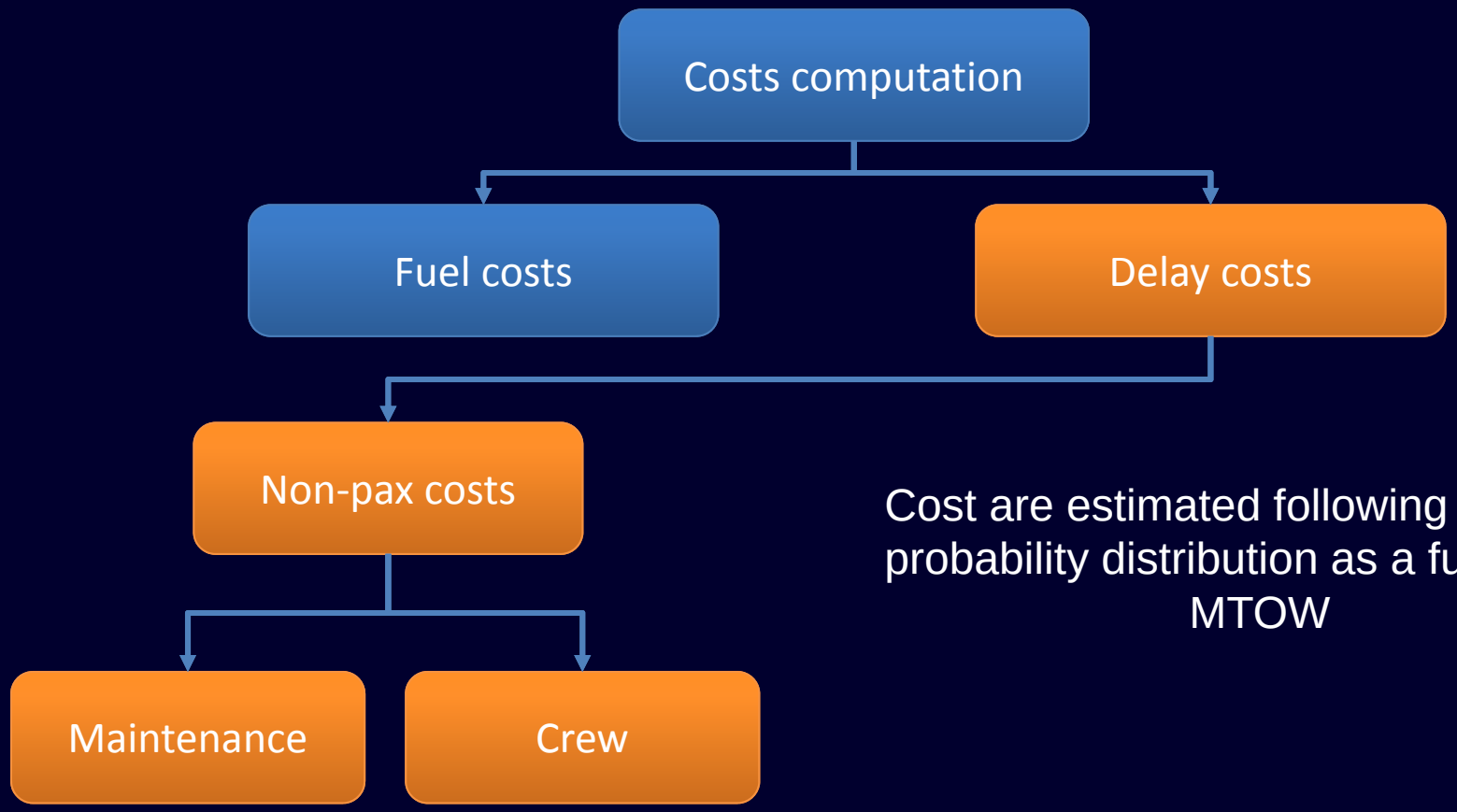
- Based on BADA 4

  (4th degree polynomial fitting)
  - Ac model
  - Considering FP length
  - Flight level based on historical analysis
  - Reference speed for the aircraft from BADA
  - Mmin and Mmax (load factor 1.3g)
  - Estimation of reference weight considering specific range consumption



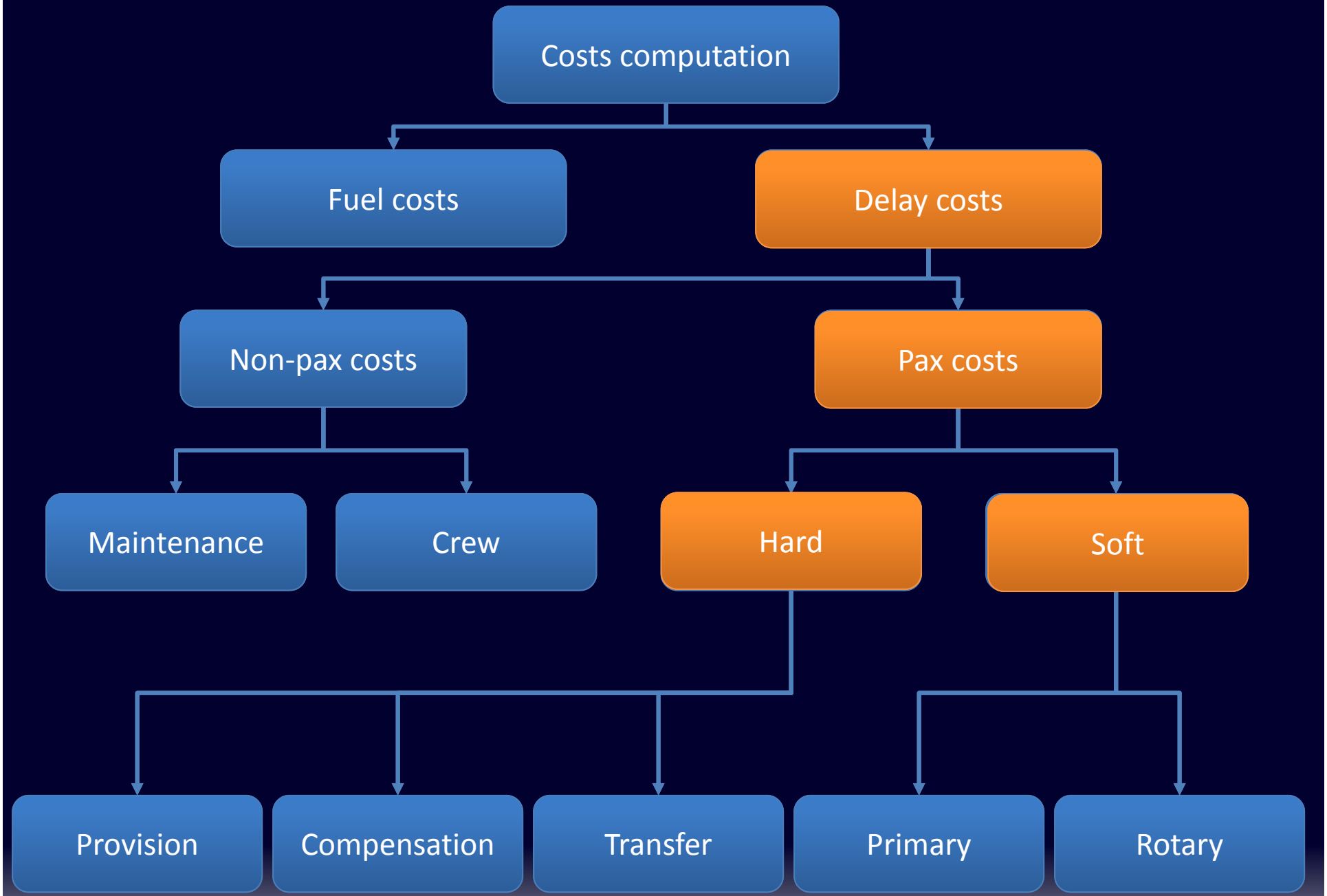






Cost are estimated following a normal probability distribution as a function of MTOW

- Maintenance
  - At gate
  - Taxi
  - En-route
  - Arrival
- Crew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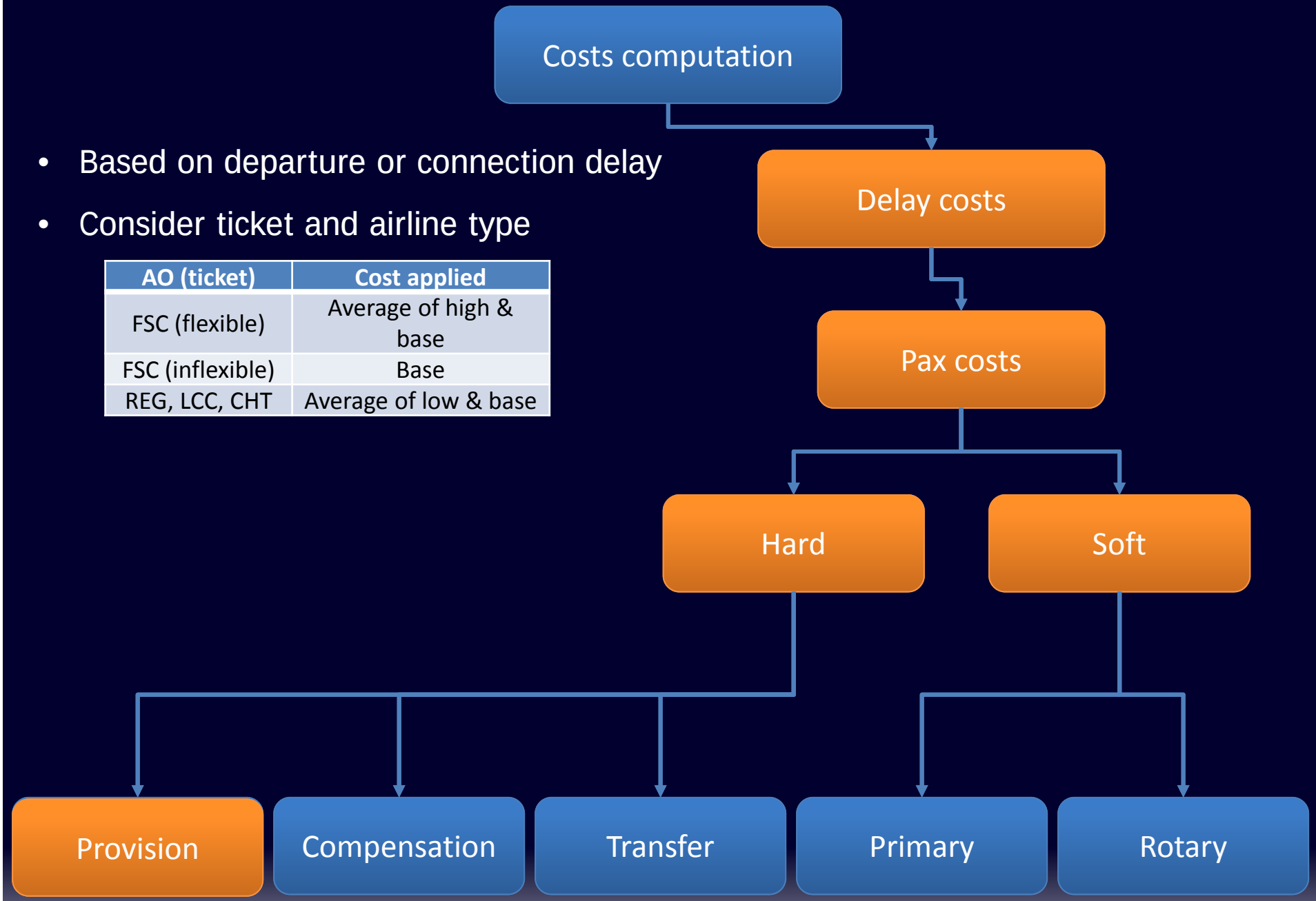
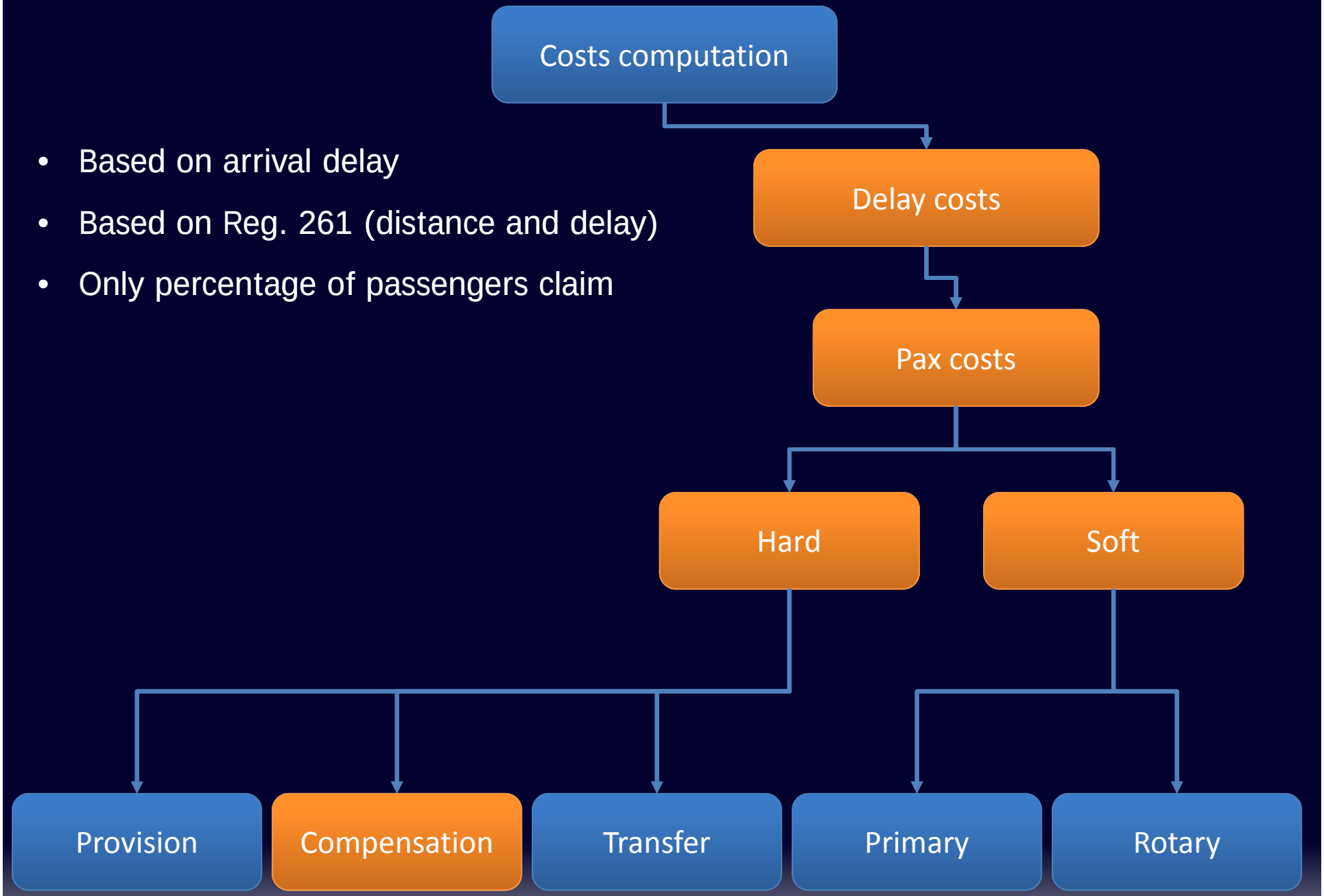
- Based on departure or connection delay
- Consider ticket and airline type

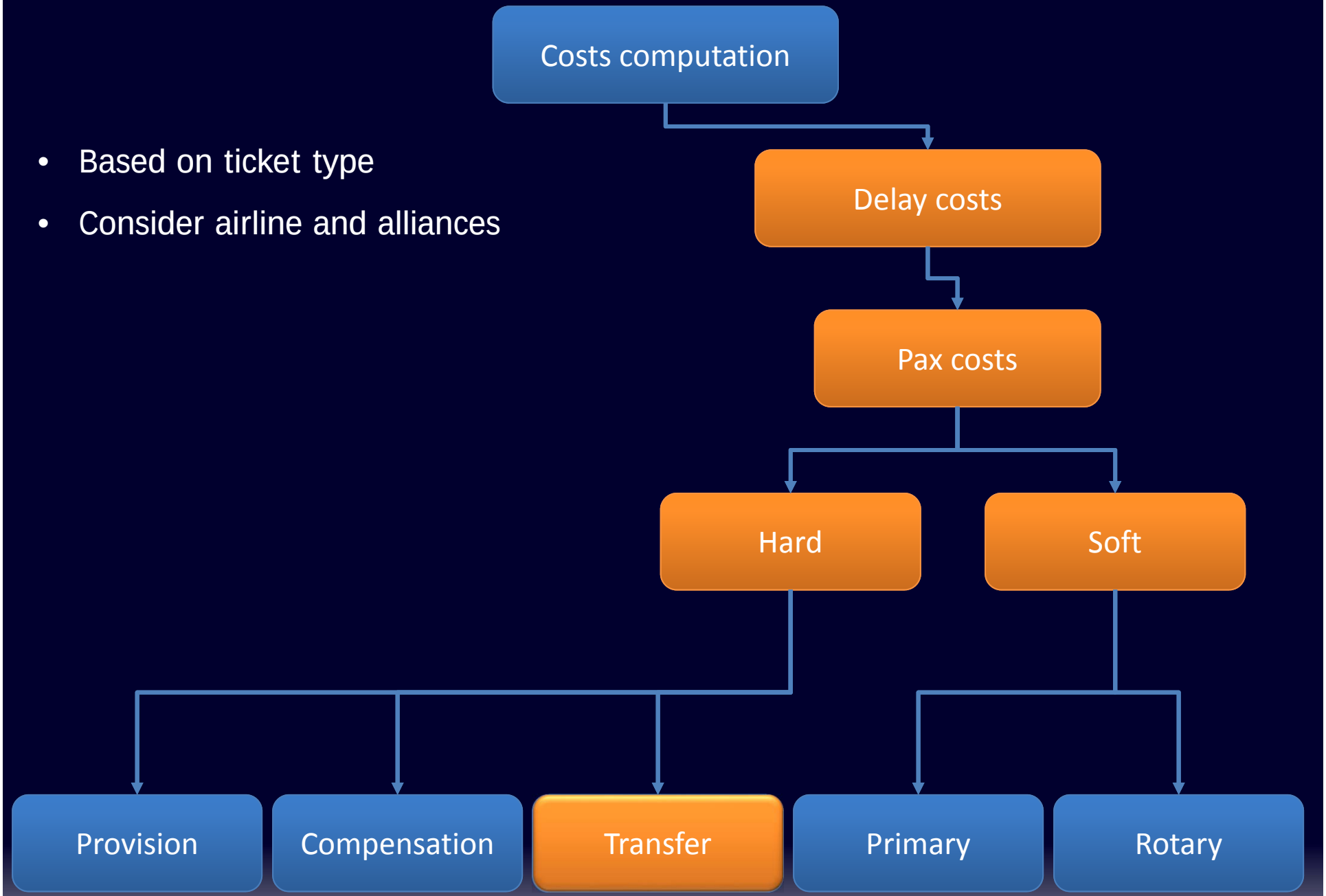
AO (ticket)	Cost applied
FSC (flexible)	Average of high & base
FSC (inflexible)	Base
REG, LCC, CHT	Average of low & base



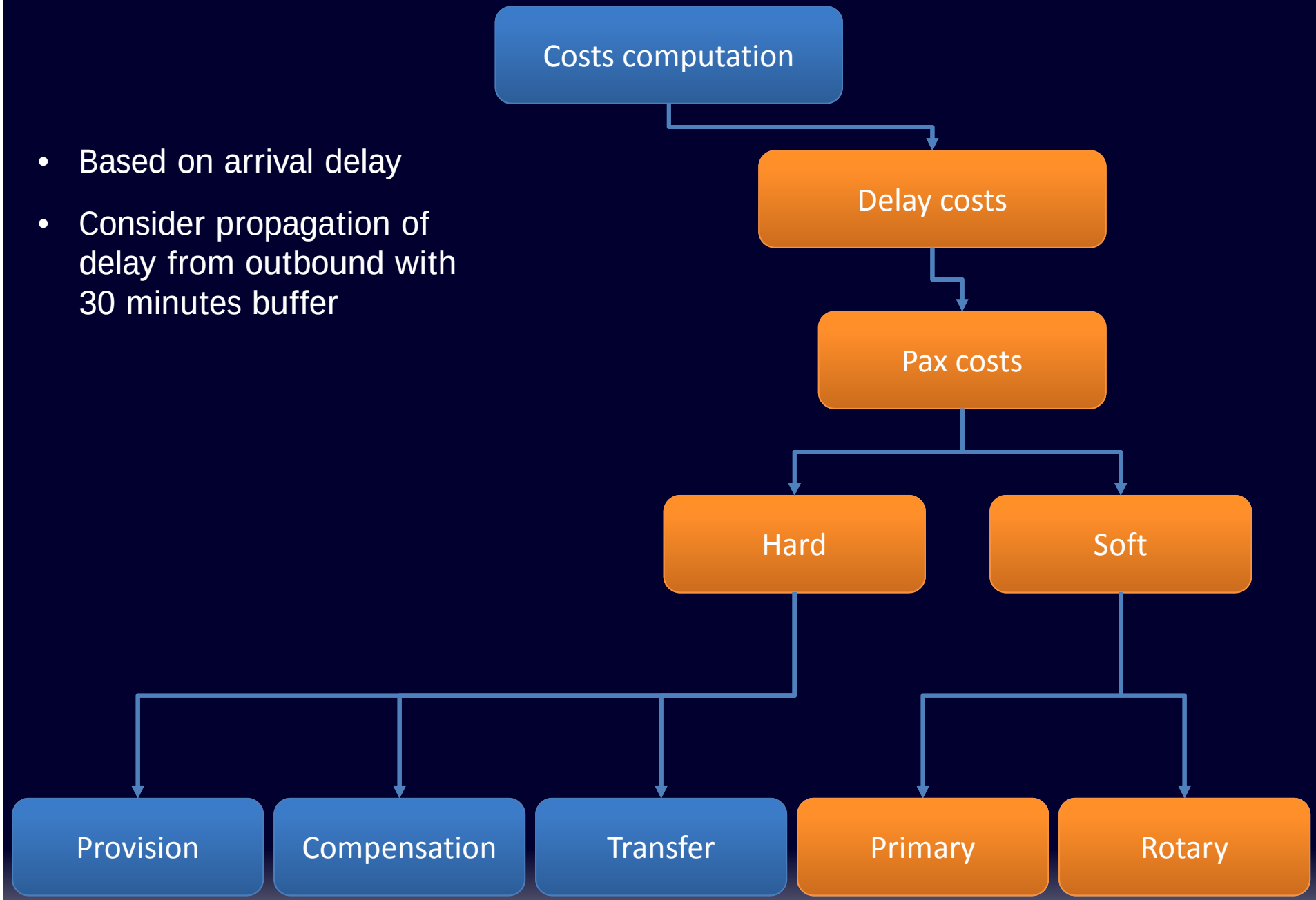
- Based on arrival delay
- Based on Reg. 261 (distance and delay)
- Only percentage of passengers claim

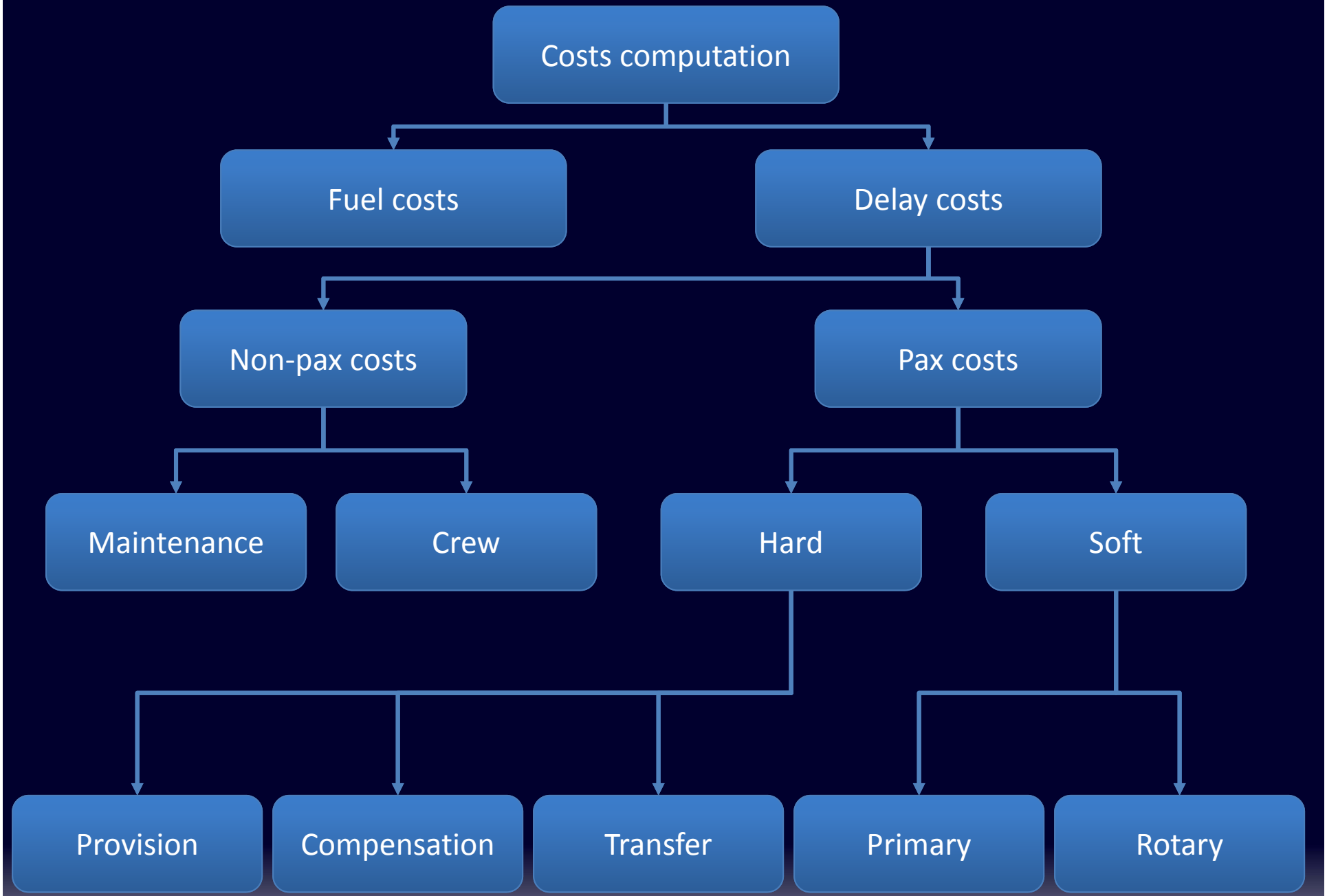


- Based on ticket type
- Consider airline and alliances



- Based on arrival delay
- Consider propagation of delay from outbound with 30 minutes buffer




Costs computation
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Metrics

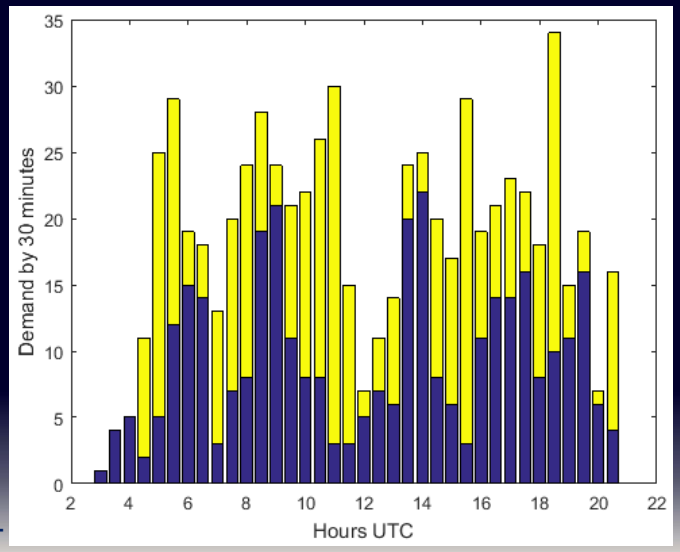
- 140 indicators per flight (e.g. selected speed)
- 22 performance indicators (e.g. flight departure delay)
  - Delay (flight and passenger)
  - Costs
  - Efficiency
- Aggregators (e.g. average, count, percentile 90)
- Restrictors (e.g. all flights, only FSC)
- Total of 381 metrics
- 50 simulations per scenario

Datasets

Datasets

- Traffic data
  - Flight schedules from PRISME
  - Flight trajectory and phases based on so6 data file
  - Nominal speed from BADA (adjusted for short flights)
  - Passenger itineraries from anonymised airport data
  - Taxi time estimations
  - Average ground speed to estimate wind

676 flights
(336 inbound,
340 outbounds)



61,446 pax itineraries
(11,570 connecting
(18.9%))

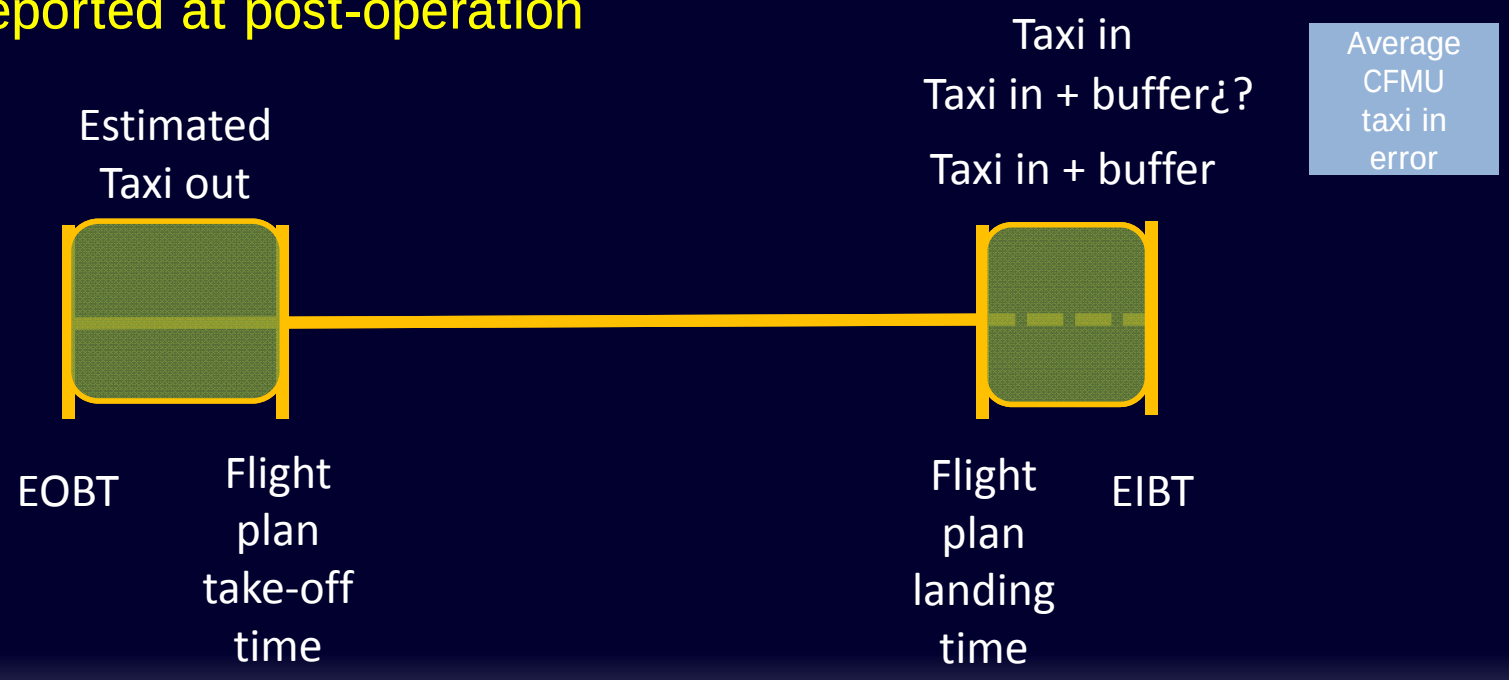
departures and
arrival fixed at
20 acc/30 min

Datasets

- Taxi times estimation
  - Planning stage
  - Execution stage

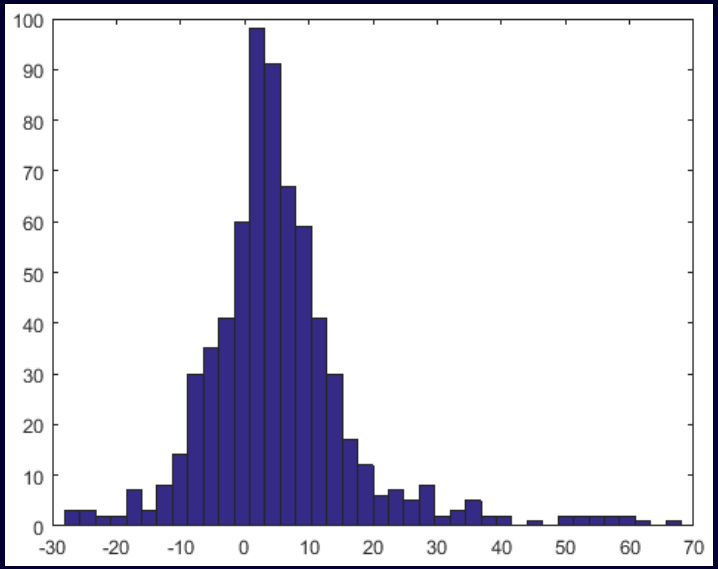
Datasets

- Taxi times estimation
  - CFMU
  - Schedules and planned flight plans
  - Reported at post-operation

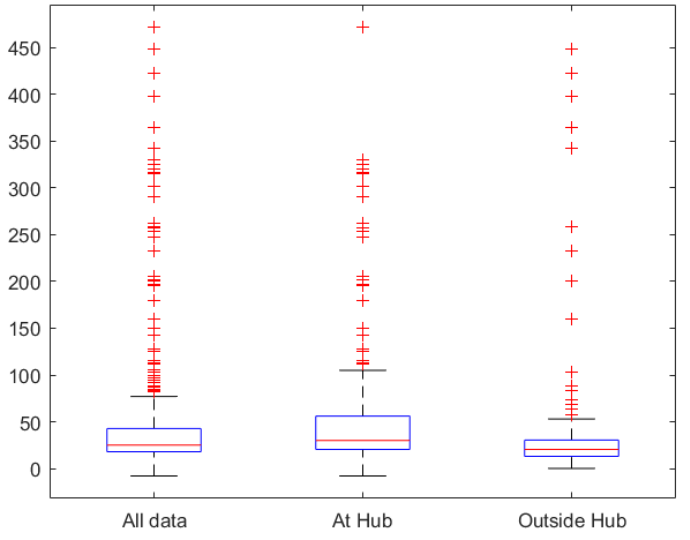


Datasets

- Buffers
  - Schedules
  - Minimum turn around time



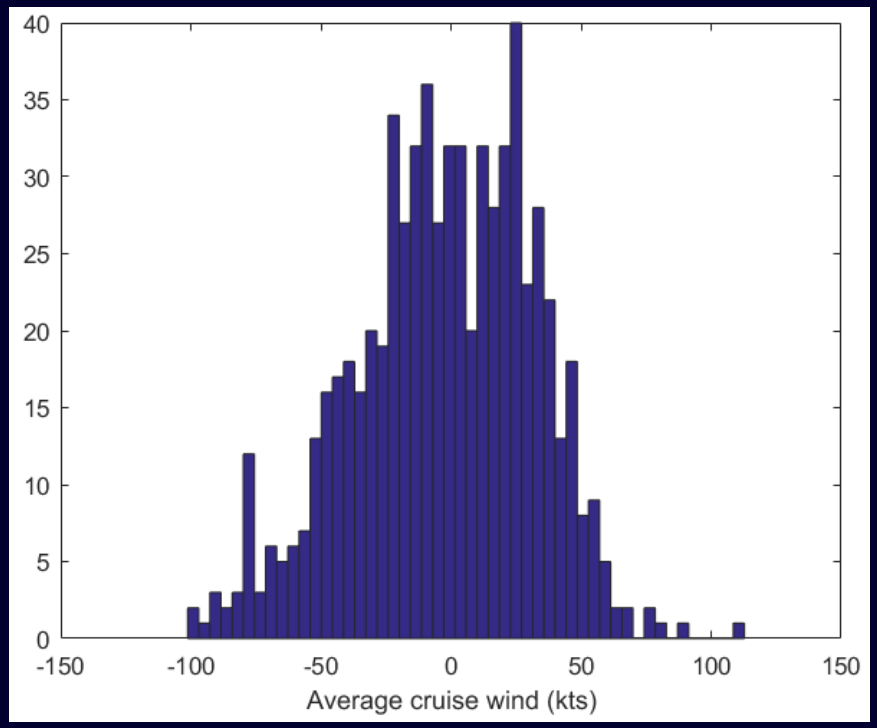
Arrival buffer



Turnaround buffer

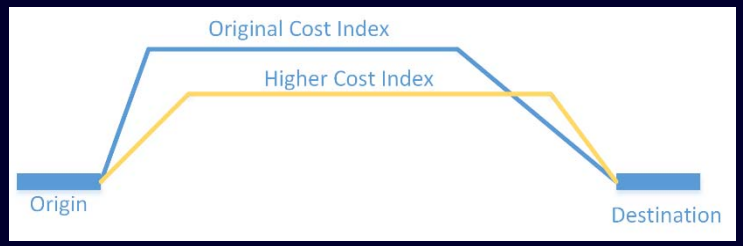
Datasets

- Average cruise wind estimation

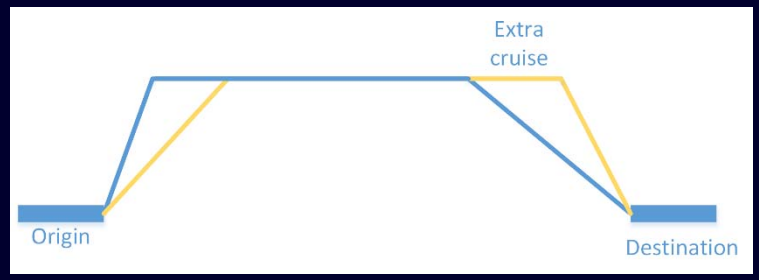


Datasets

- Difference between cruise DCI and speed variation

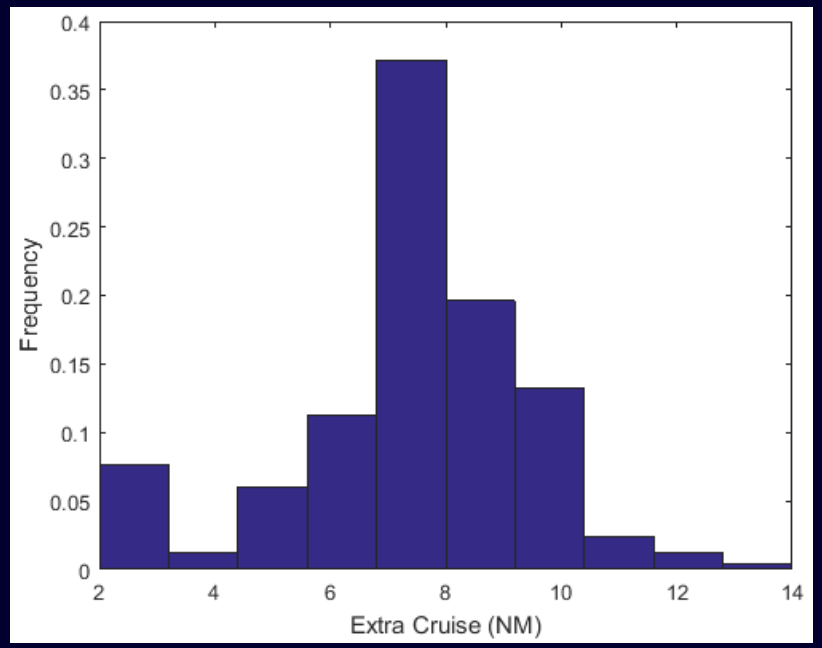


(a) Full trajectory modified



(b) FL maintained

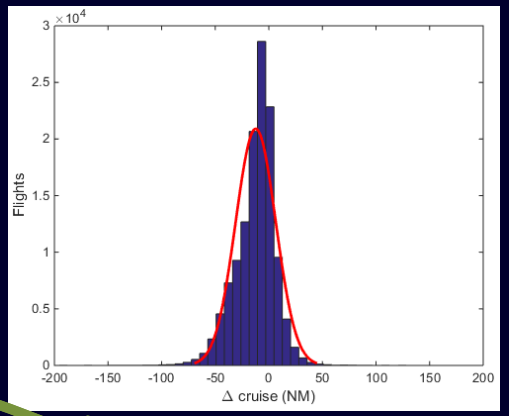
Cost index variation effect



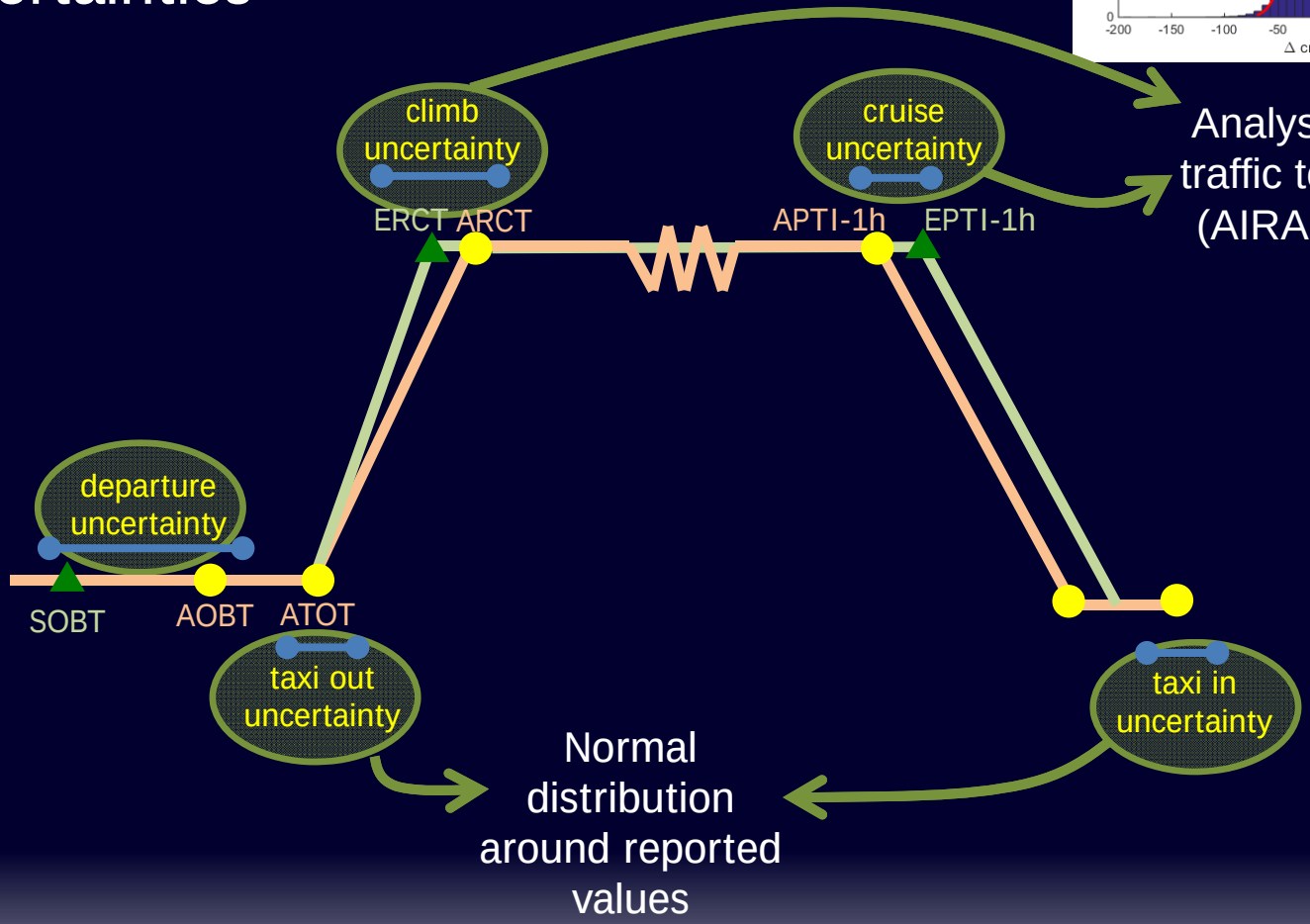
Estimated from Airbus Performance Engineering Program

Datasets

- Uncertainties

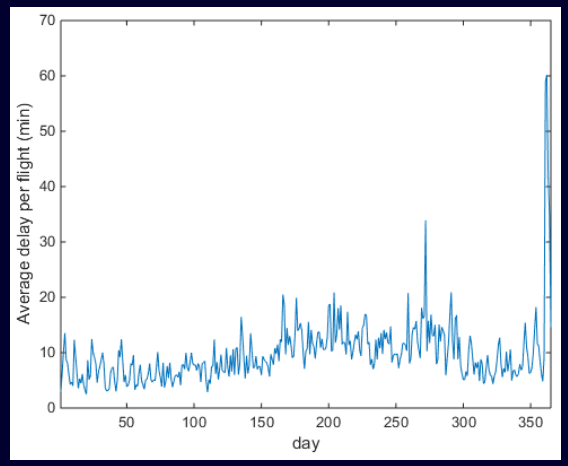


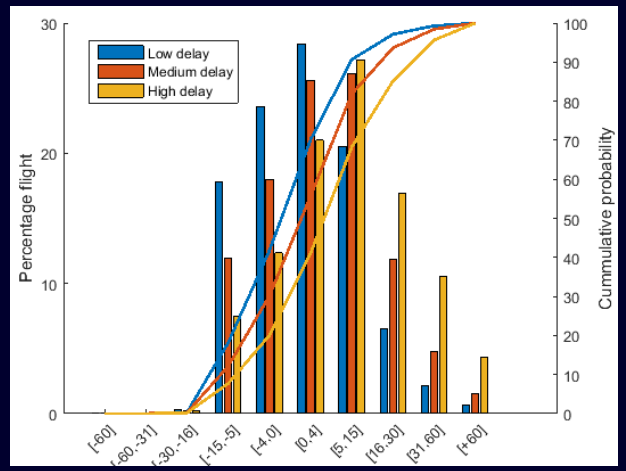
Analysis of a year of traffic to-from the hub (AIRAC 1313-1413)

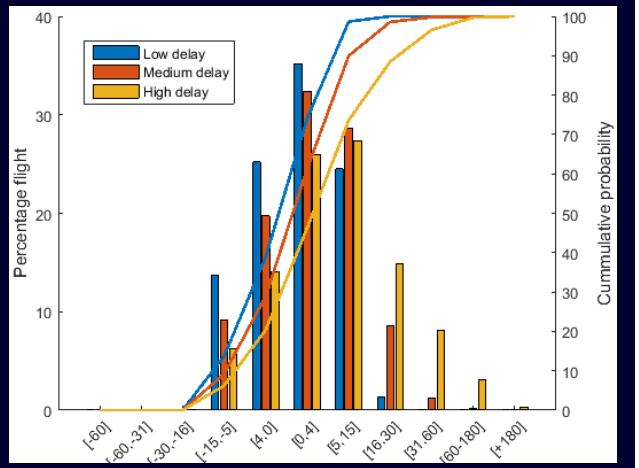


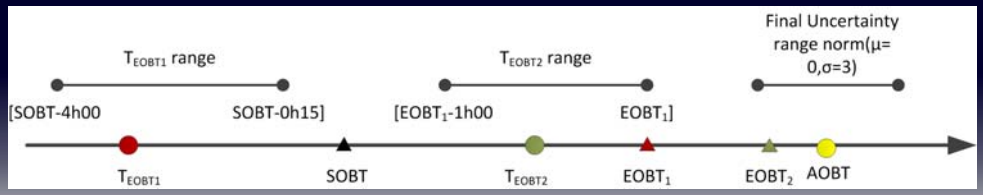
Datasets

- Delay
  - CODA data
  - Select 25 and 75 quartile to define low, medium and high delay days
  - Outbound flights delay reduced considering reactionary delay (codes 91-96)
  - Consider release of delay information to AOC









Burr distribution fitting

Case of study

Case of study

- Strategies
  - Baseline
    - Flights with delay > 15 minutes → 10% probability recover up to remaining 5 minutes
    - Outbound → wait-for-passengers if inbound recovering and waiting time required < 20 minutes
  - Optimised
    - Delay recovered and wait-for-passenger based on estimated cost

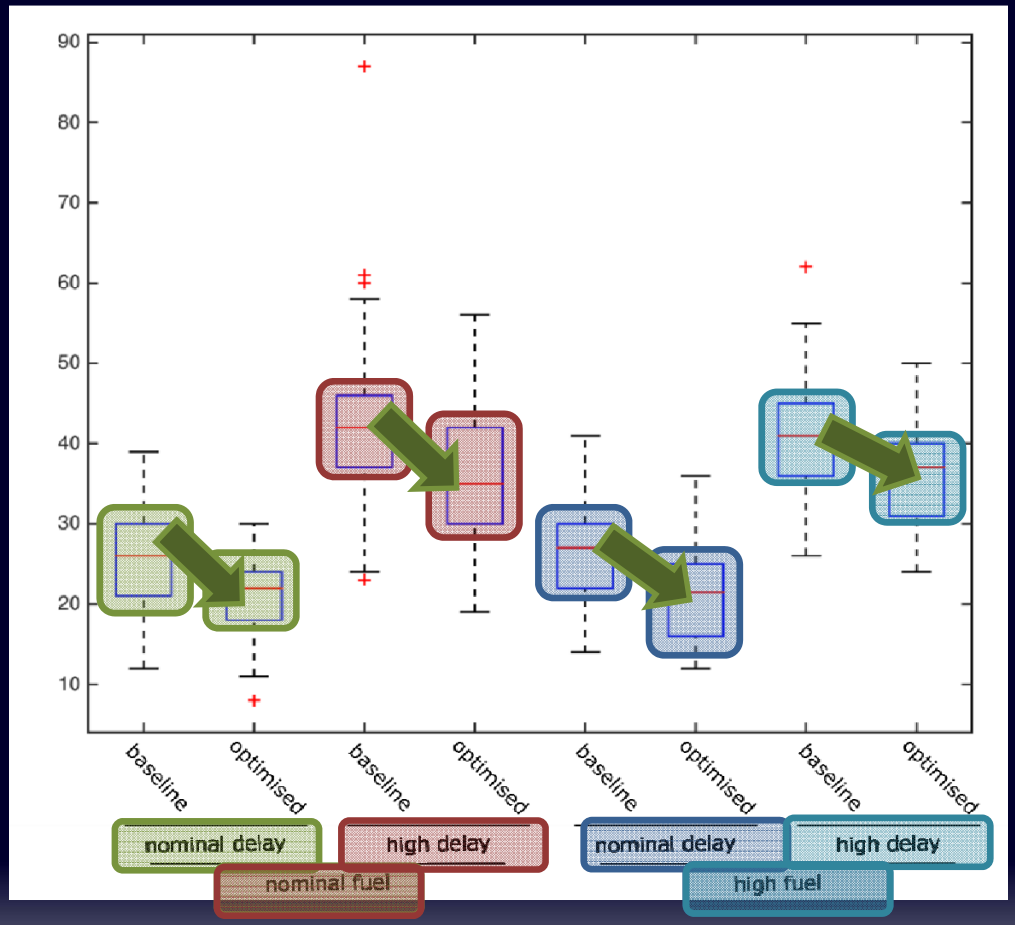
Case of study

- Parameters
  - Delay
    - Nominal
    - High
  - Fuel
    - Nominal (0.5 EUR/kg)
    - High (0.8 EUR/kg)
  - Passenger compensation uptake
    - Nominal (11%)
    - High (50%)

Results

Results

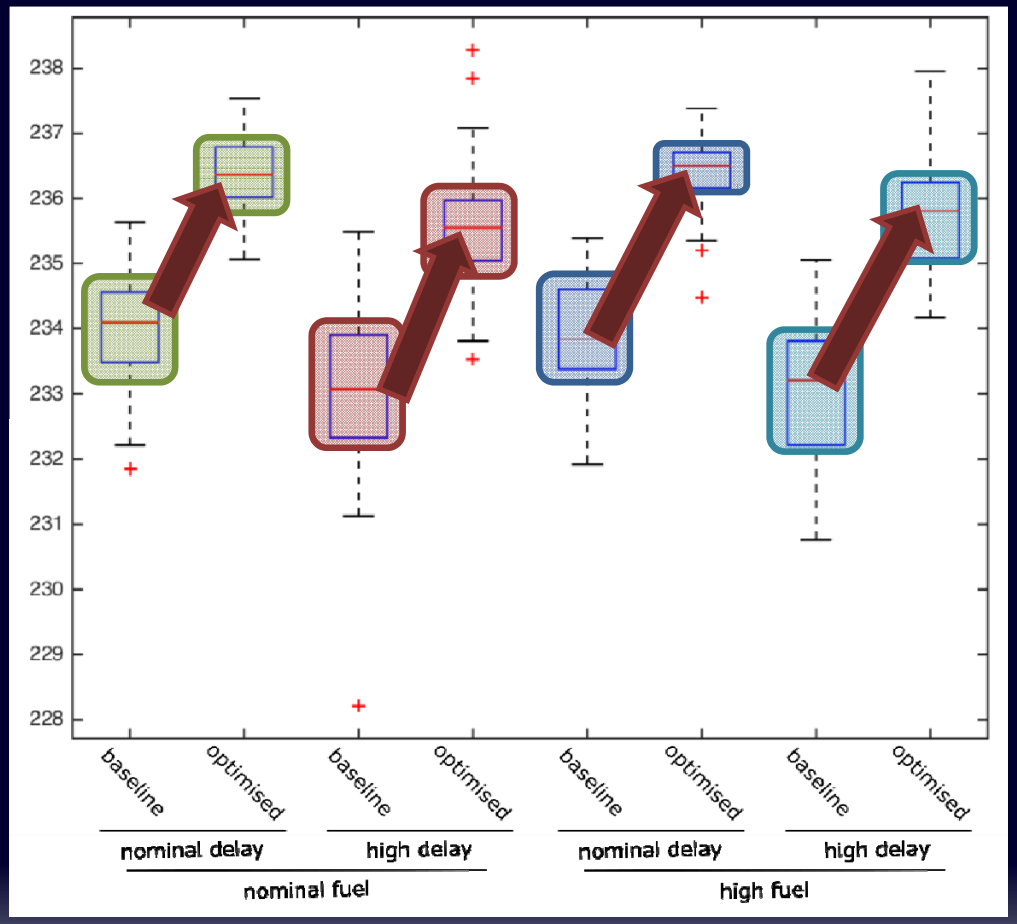
- Number of missed connections at the hub



Reduction between 14.4% and 17.5%

Results

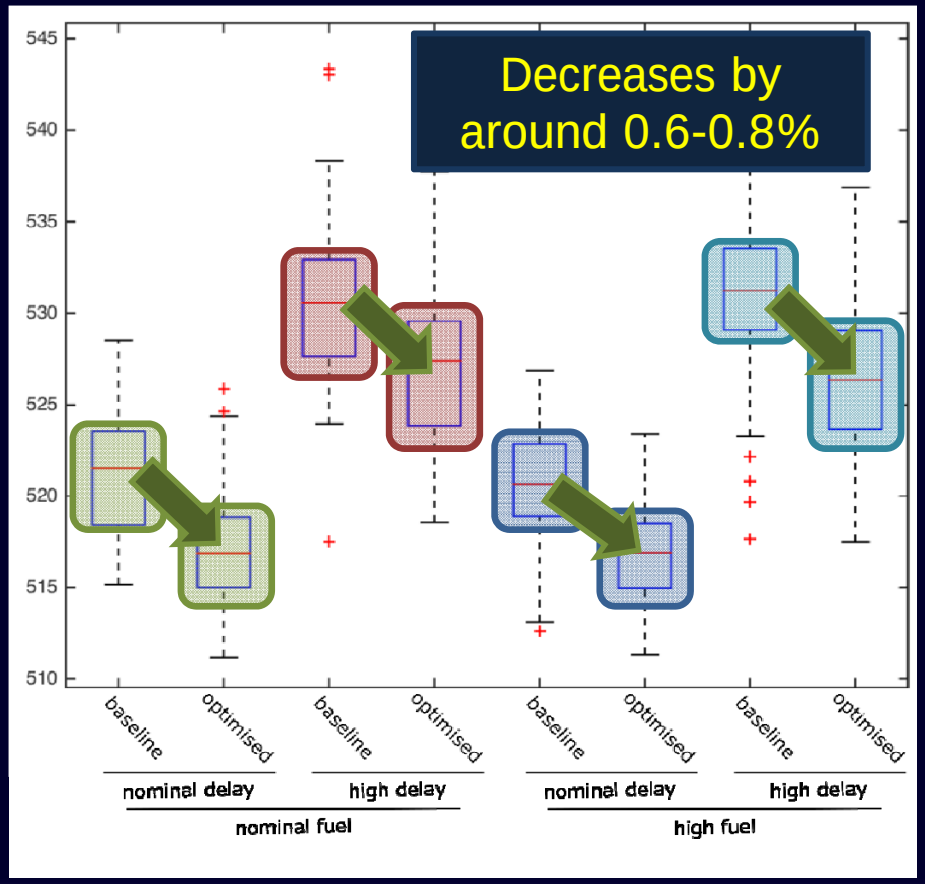
- Gate-to-gate trip time (min)



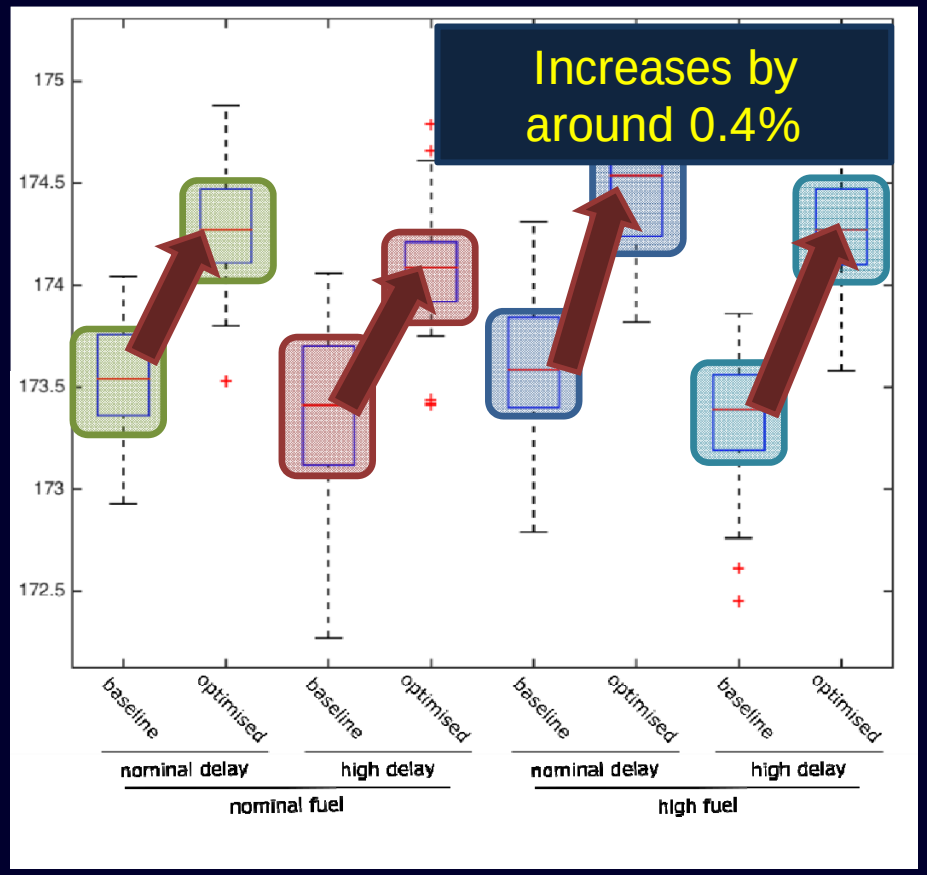
Increases by around 1.1%

Results

- Gate-to-gate trip time (min)



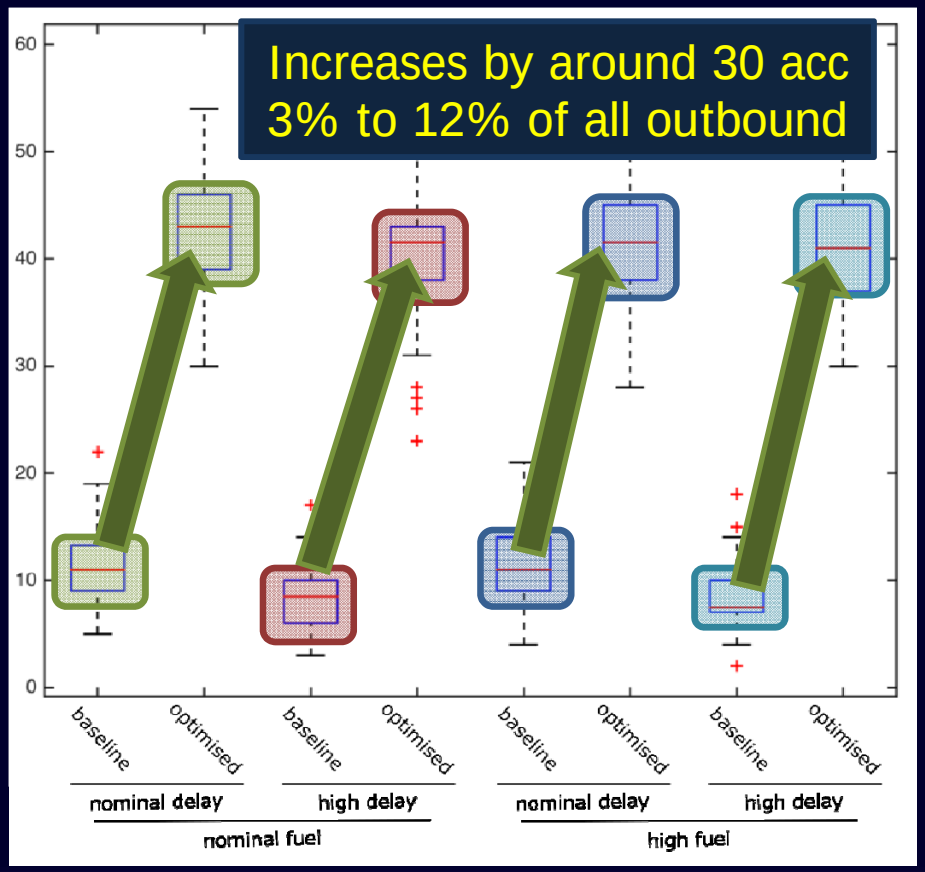
Connecting passengers



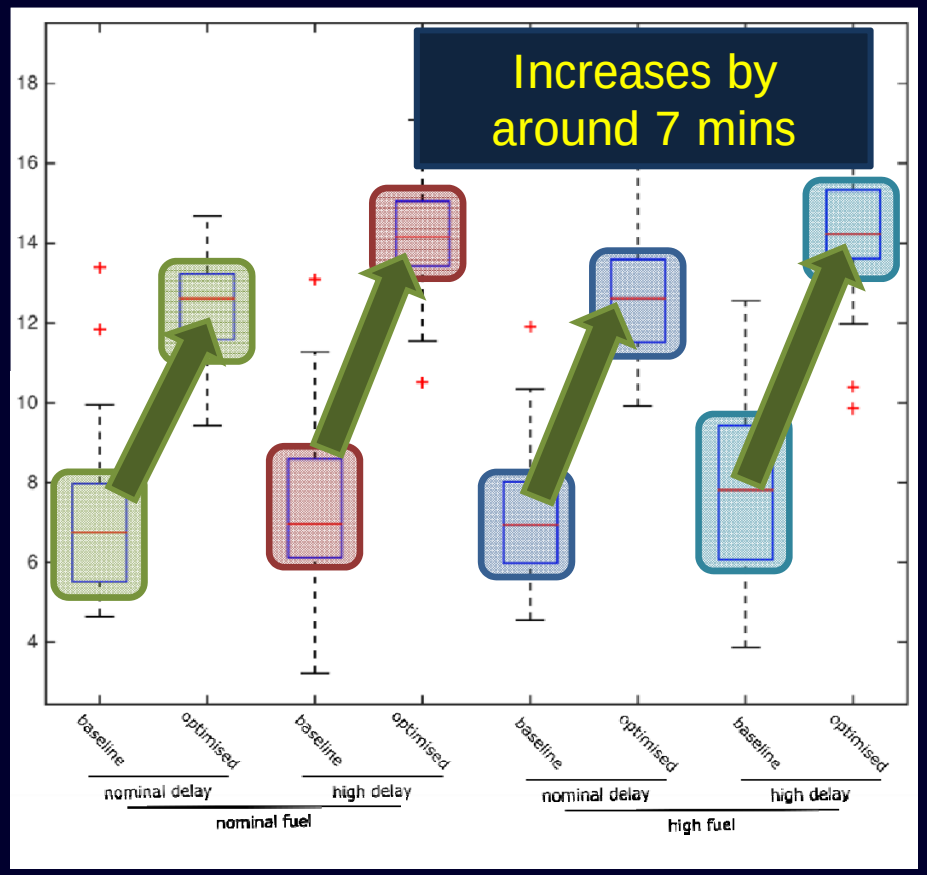
Non-connecting passengers

Results

- Wait for passengers performances



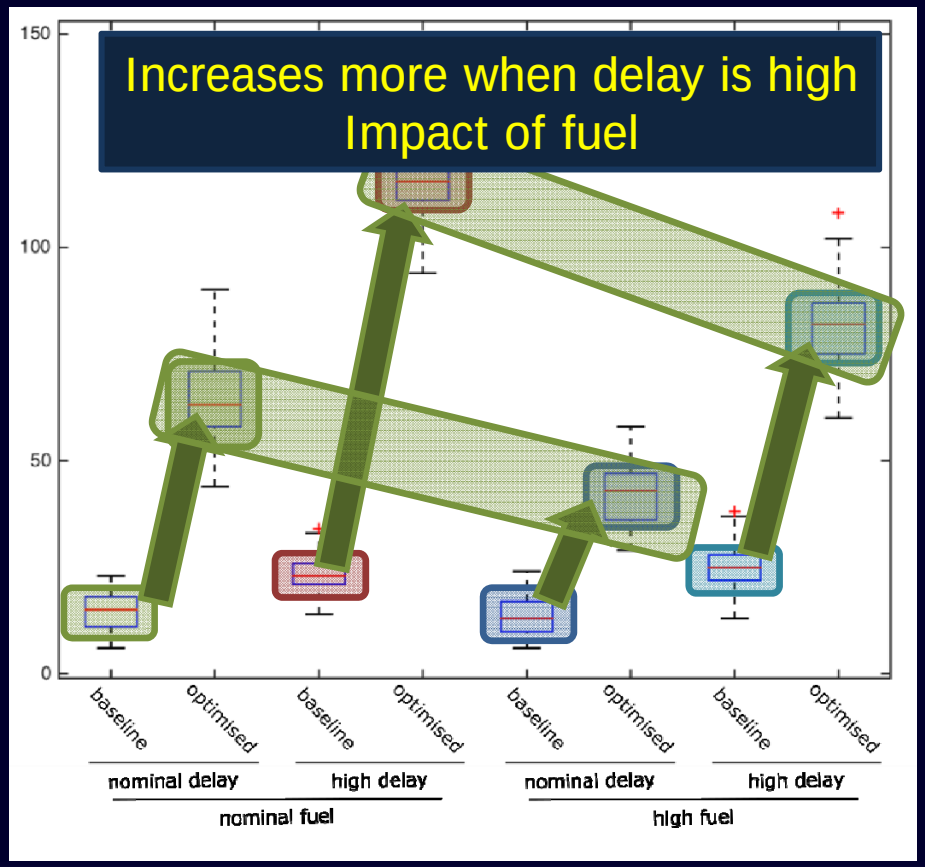
Number of flights waiting



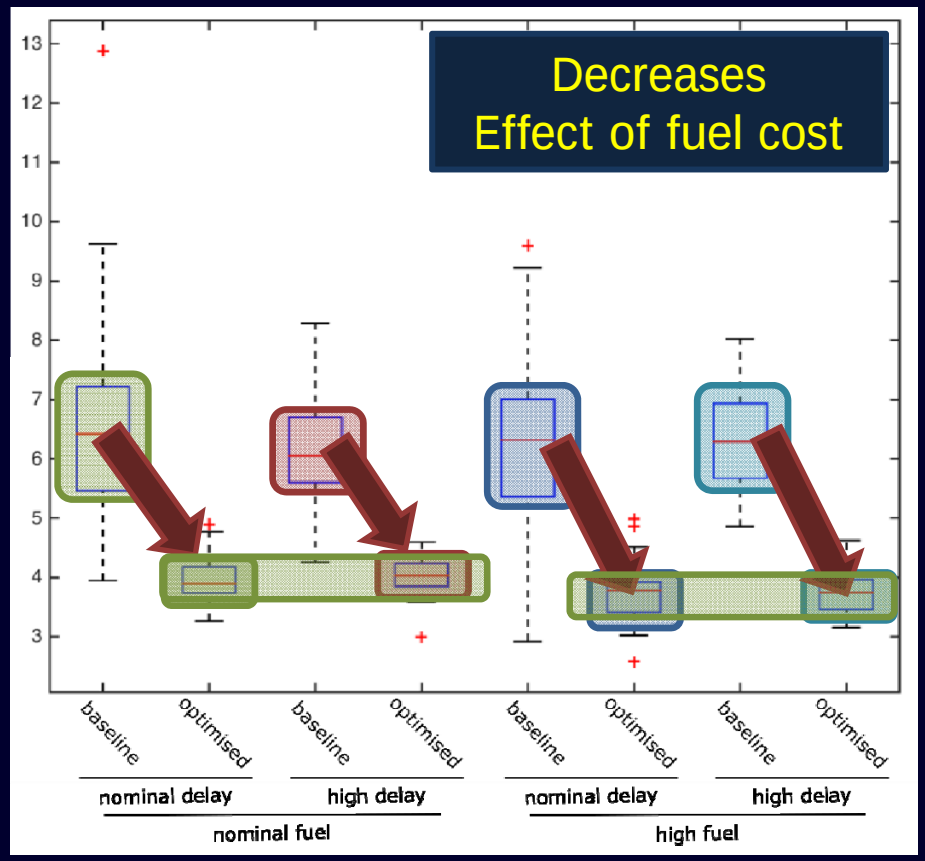
Average waiting time (min)

Results

- DCI performances at TOC



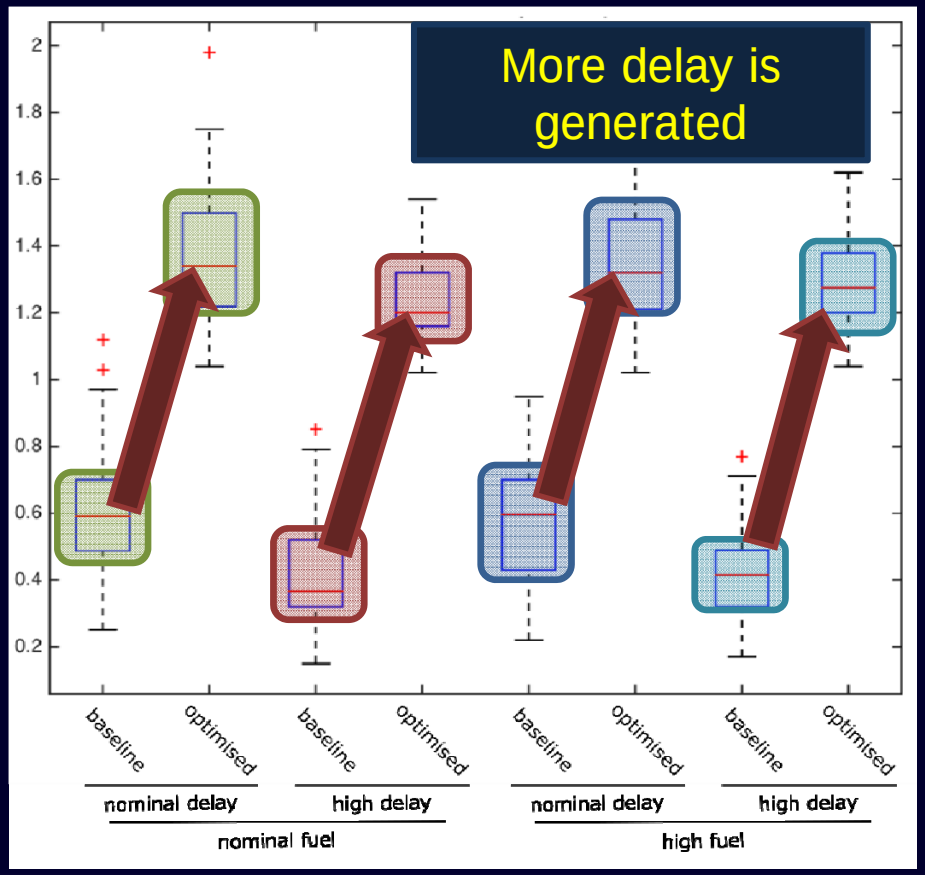
Number of flights performing speed variations



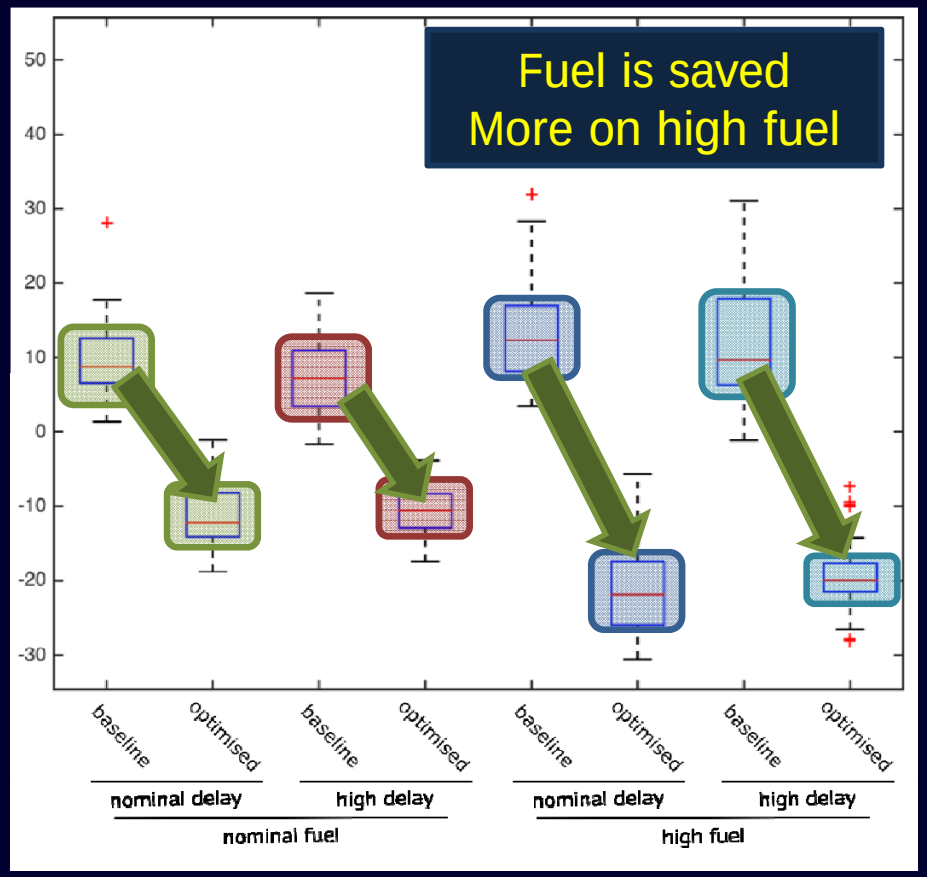
Average variation (%)

Results

- AMAN performances



Average delay (min)



Average extra fuel consumption (kg)

Conclusions

Conclusions

- Hub operations modelled considering
  - Dynamic cost indexing
  - Wait-for-passengers rules
  - E-AMAN with collaborative decision making to select slots
  - Passengers' gate-to-gate times
  - Costs: fuel, delay, passengers (hard and soft)
- Collaborative strategy computation
- Passenger-centric metrics

Conclusions

- Dynamic cost indexing
  - High number of flights decide to apply speed variations
  - Increment in speed is small (around 4%)
  - Sensitive to fuel cost
    - Higher fuel cost reduces flights increasing speed by 30-35% and selected speed by 5-7%
  - Delay recovered is small and adsorbed by E-AMAN
- Wait-for-passengers
  - Number of flights waiting increases from around 10 to around 45
  - Average waiting time increases from around 7 min to 13-14 min

Conclusions

- E-AMAN
  - Trade delay for fuel: consideration of connections at that point
  - Higher fuel cost leads to more delay and more fuel saving
    - Voluntary selection of later slot
  - Sensitive to original delay

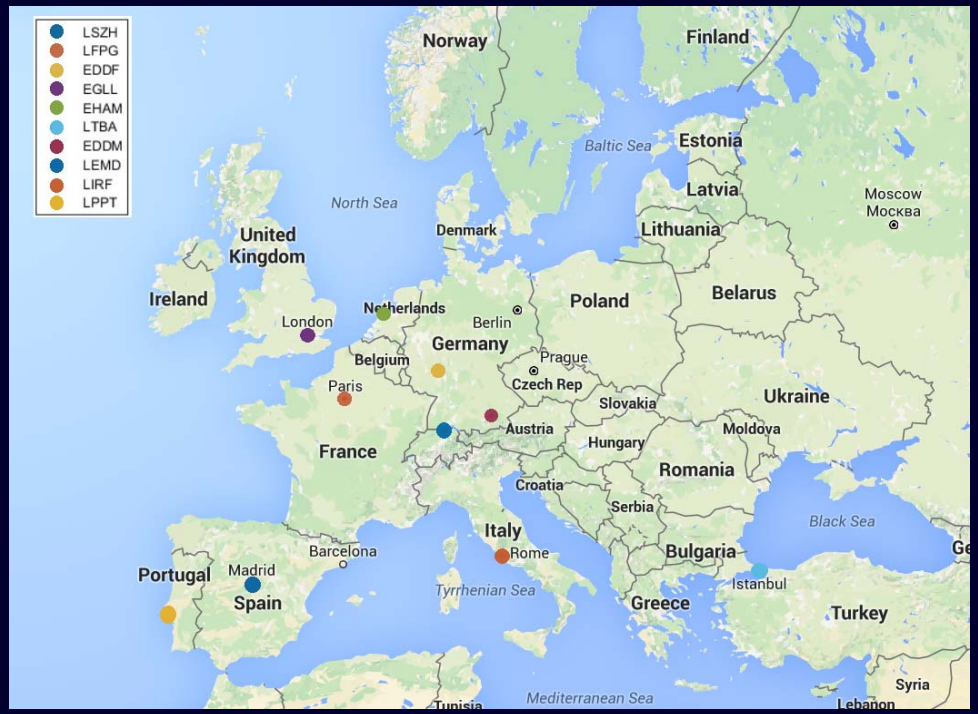
Conclusions

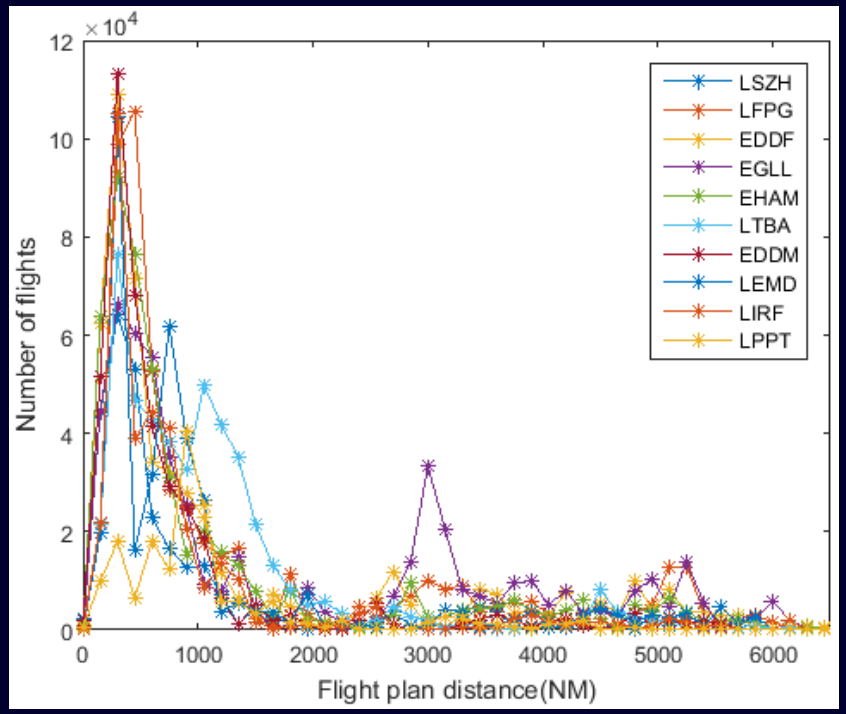
- Costs
  - Airline costs reduced by around 0.7%
- Delay
  - Gate-to-gate time increased by around 1.1%
  - Tradeoff between type of passengers
  - Reduction of missed connections (14.4-17.5%)
  - Waiting time for passengers at airport decreases (around 1.6%)
  - Sensitive to passenger claiming ratio (missed connections reduced by 8.5-15%)

Next steps

Next steps

- Airport selection

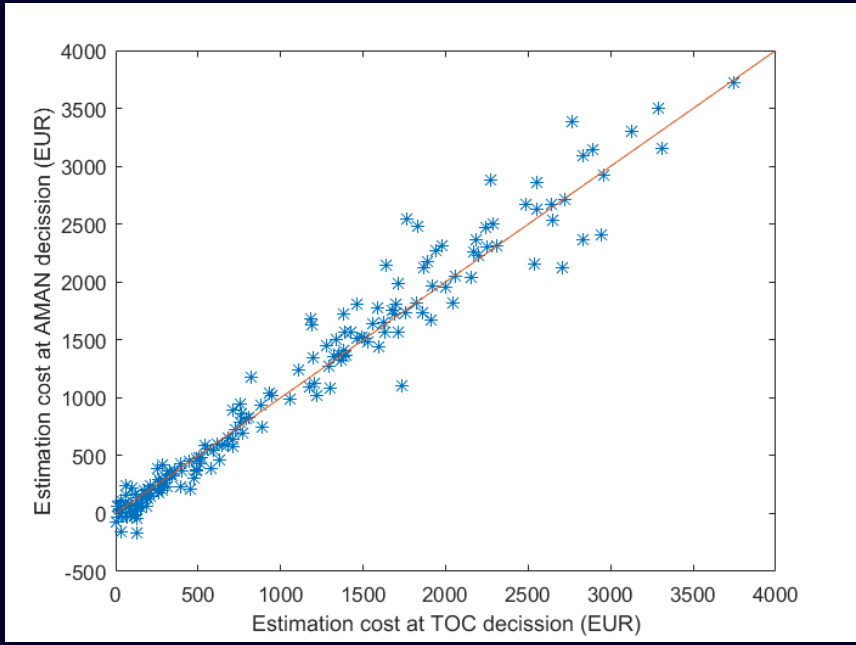




AIRAC 1313 to AIRAC 1413

Next steps

- Airport selection
- Analysis expected and actual costs



Next steps

- Airport selection
- Analysis expected and actual costs
- Sensitivity and stability go the solutions to input variables
- E-AMAN radius
- Feedback to inbound flights when outbound are modified
- Differentiation of airline behaviours
- Learning techniques

Thank you