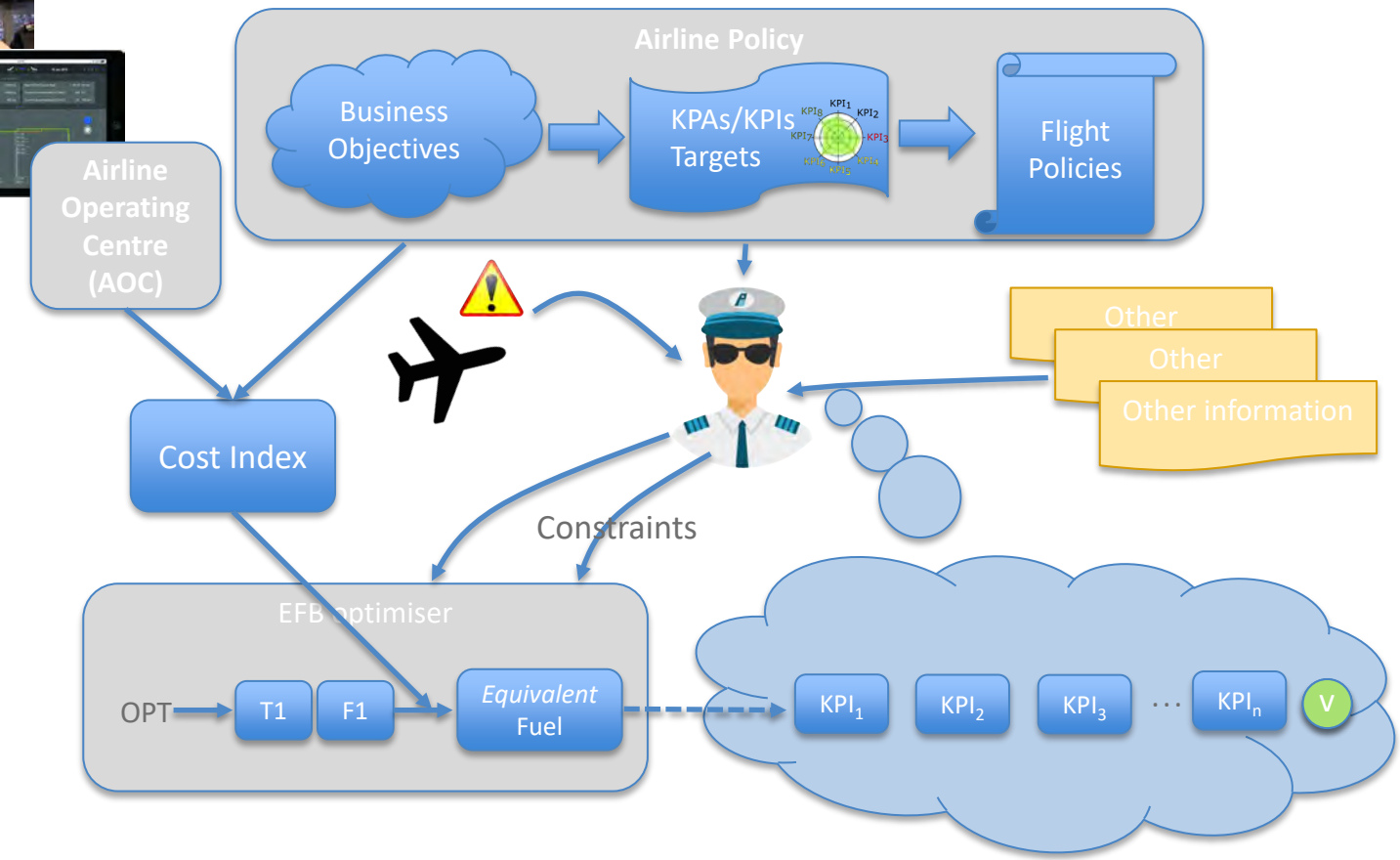
Machine learning to improve tactical flight decision making

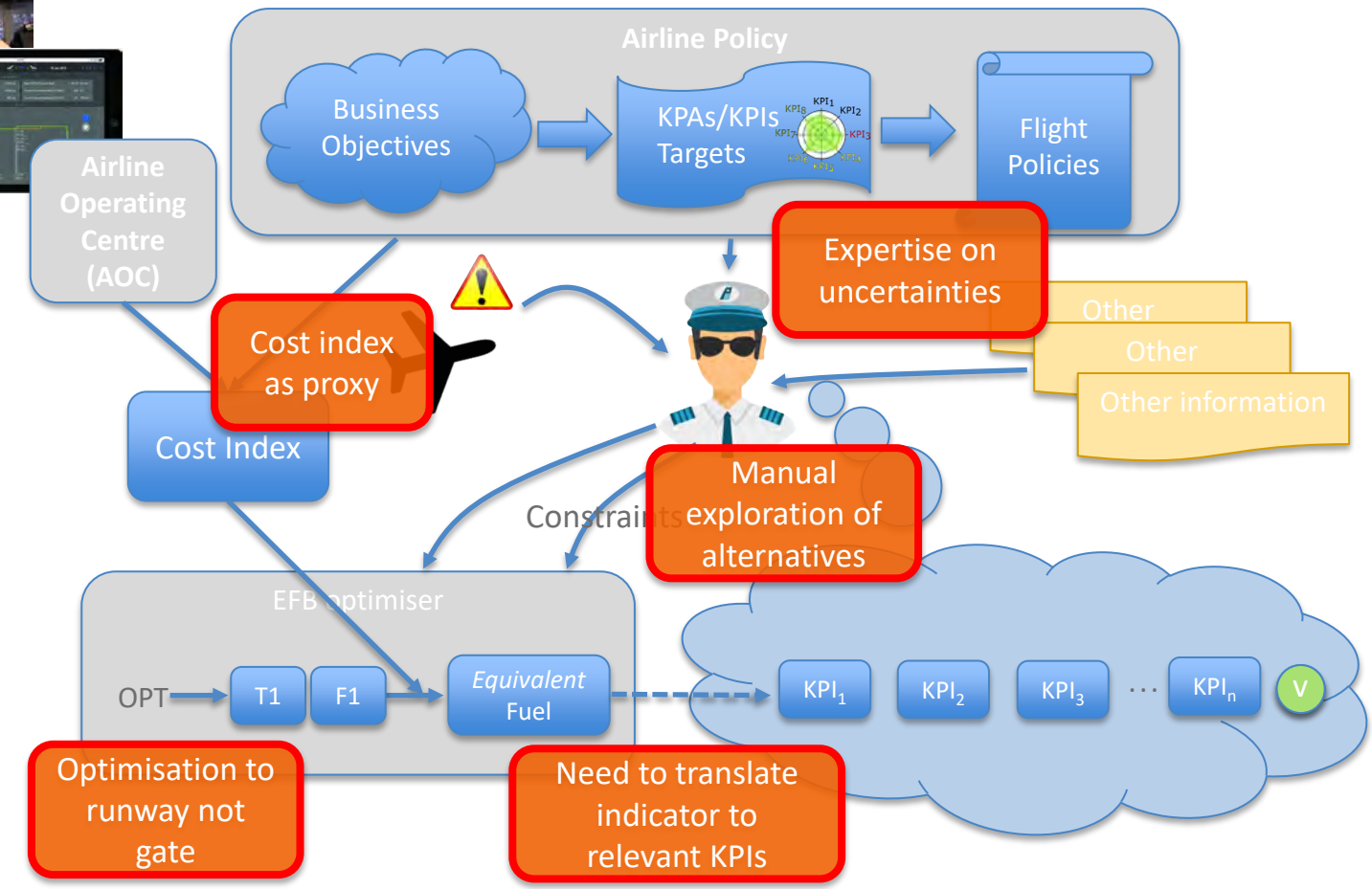
The case of Pilot3

03 September 2021

Pilot3 – What is it about?

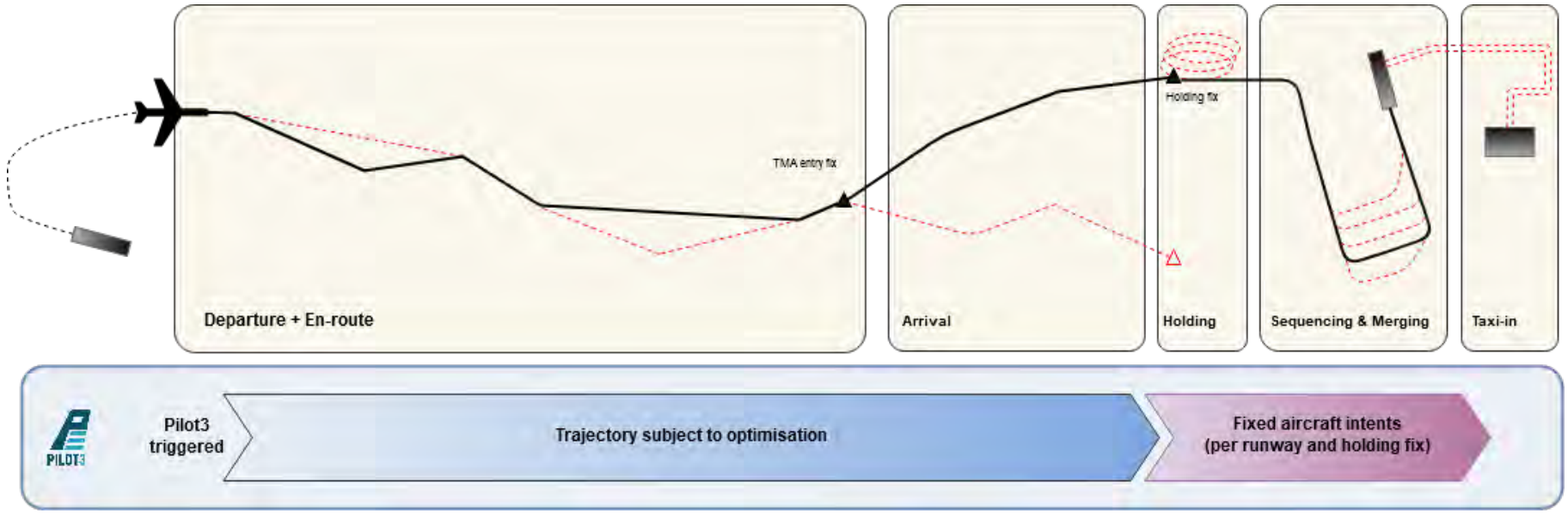


Pilot3 – What is it about?



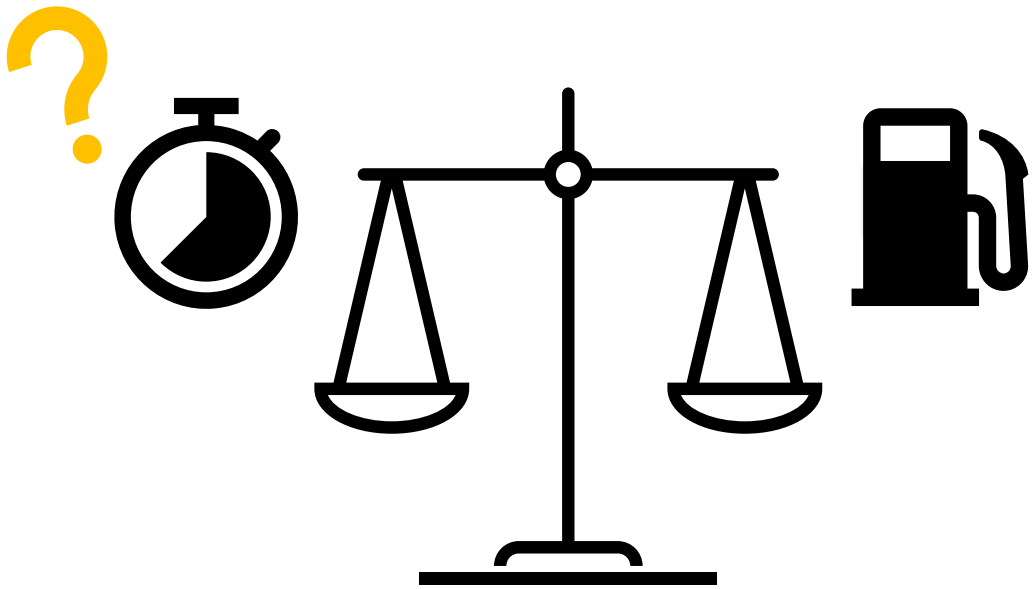
Pilot3 – What is it about?

Pilot3 – Objective function



- Optimisation of vertical profile (from triggering point to FL100)

Pilot3 – Objective function

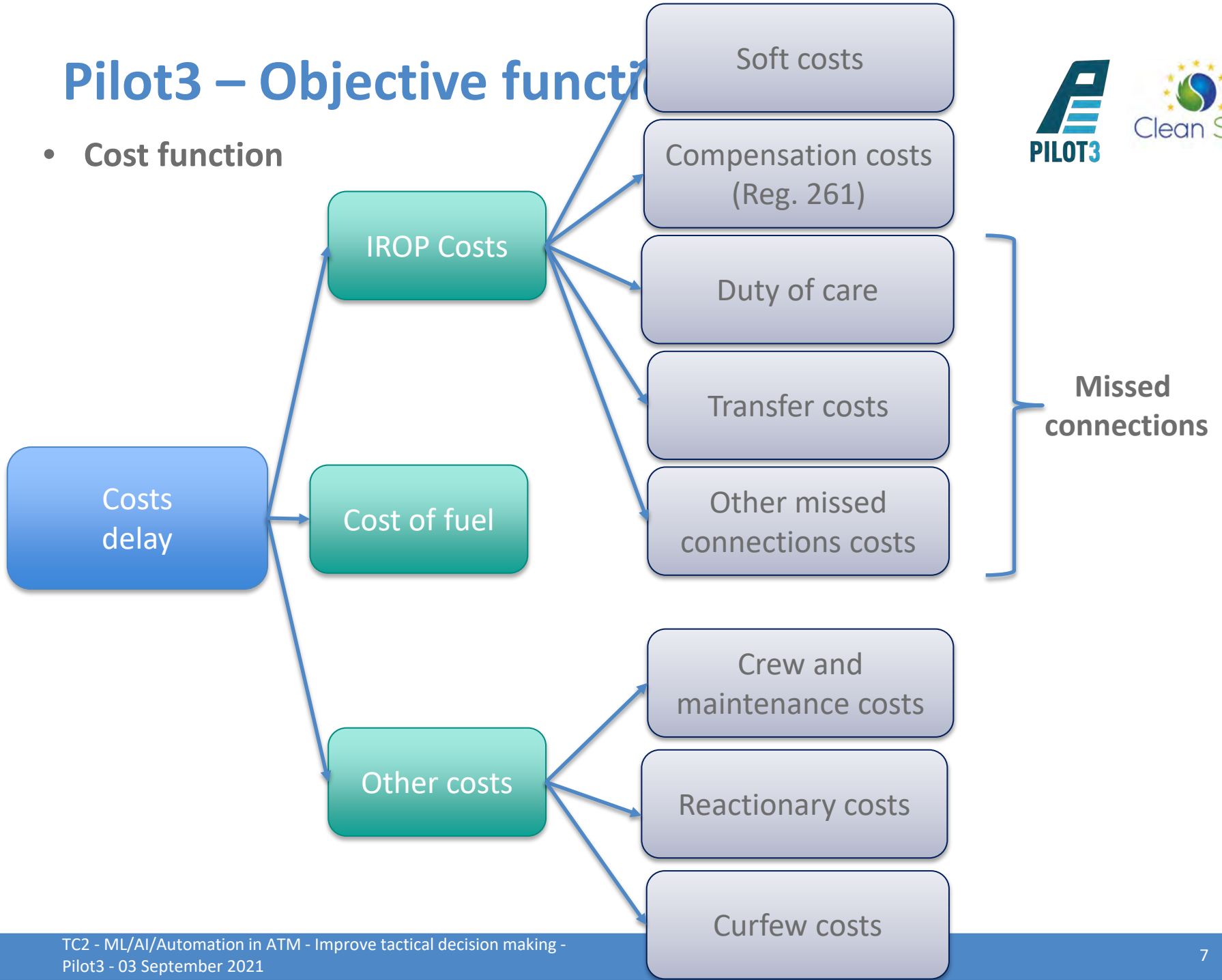


Cost Index

$$\frac{\text{Cost Time}}{\text{Cost Fuel}}$$

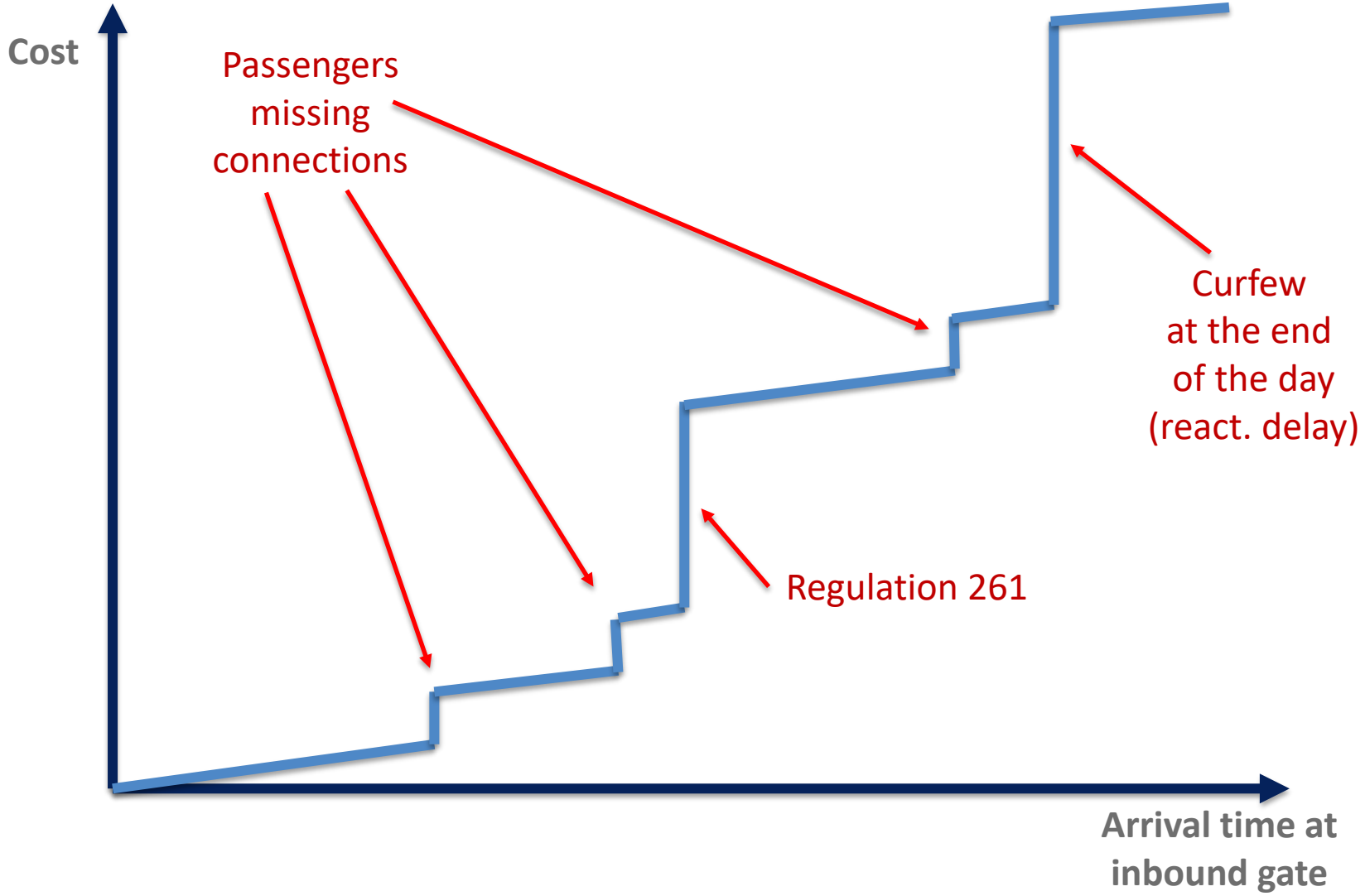
Pilot3 – Objective functi

- **Cost function**



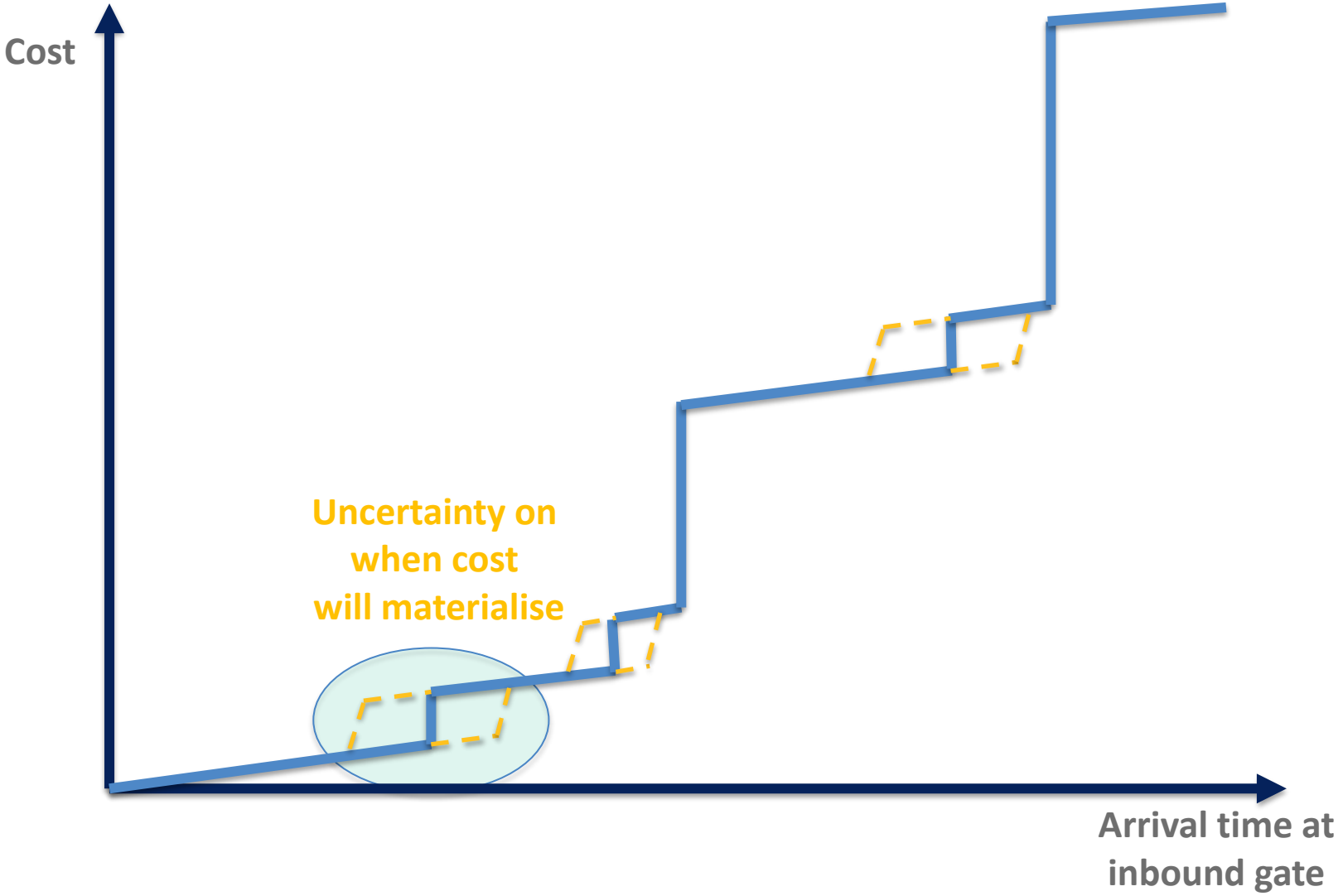
Pilot3 – Objective function

- Cost function



Pilot3 – Objective function

- Cost function

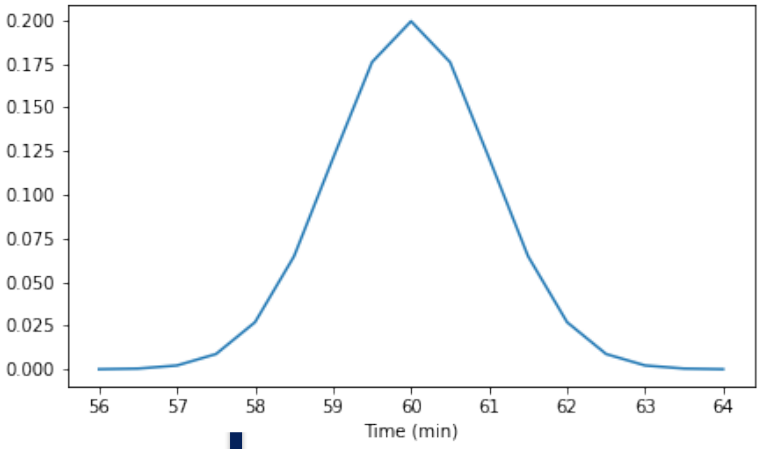


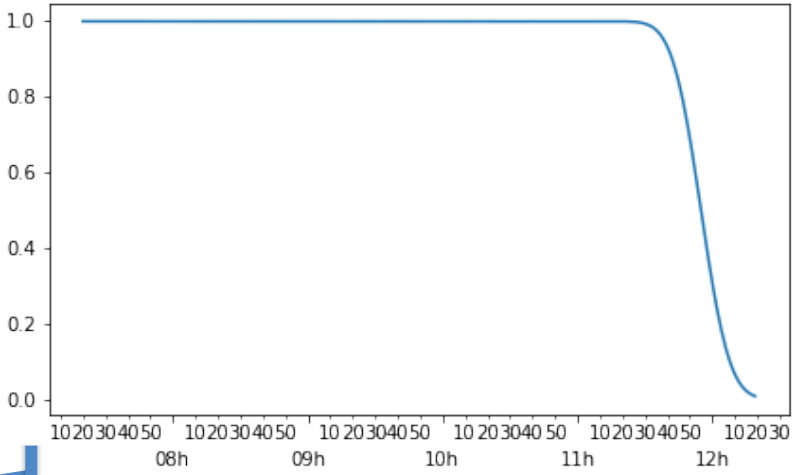
Pilot3 – Objective function

- Cost function

Cost

Opt.	LEMD	EDDF	EDDF	ZBAA	IROP Cost
1	6h35	9h10	11h55	21h15	0
			1		
			1		





Probability flight 1 is there

Connecting time

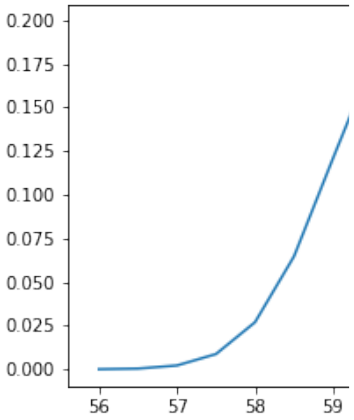
Arrival time at inbound gate

Pilot3 – Objective function

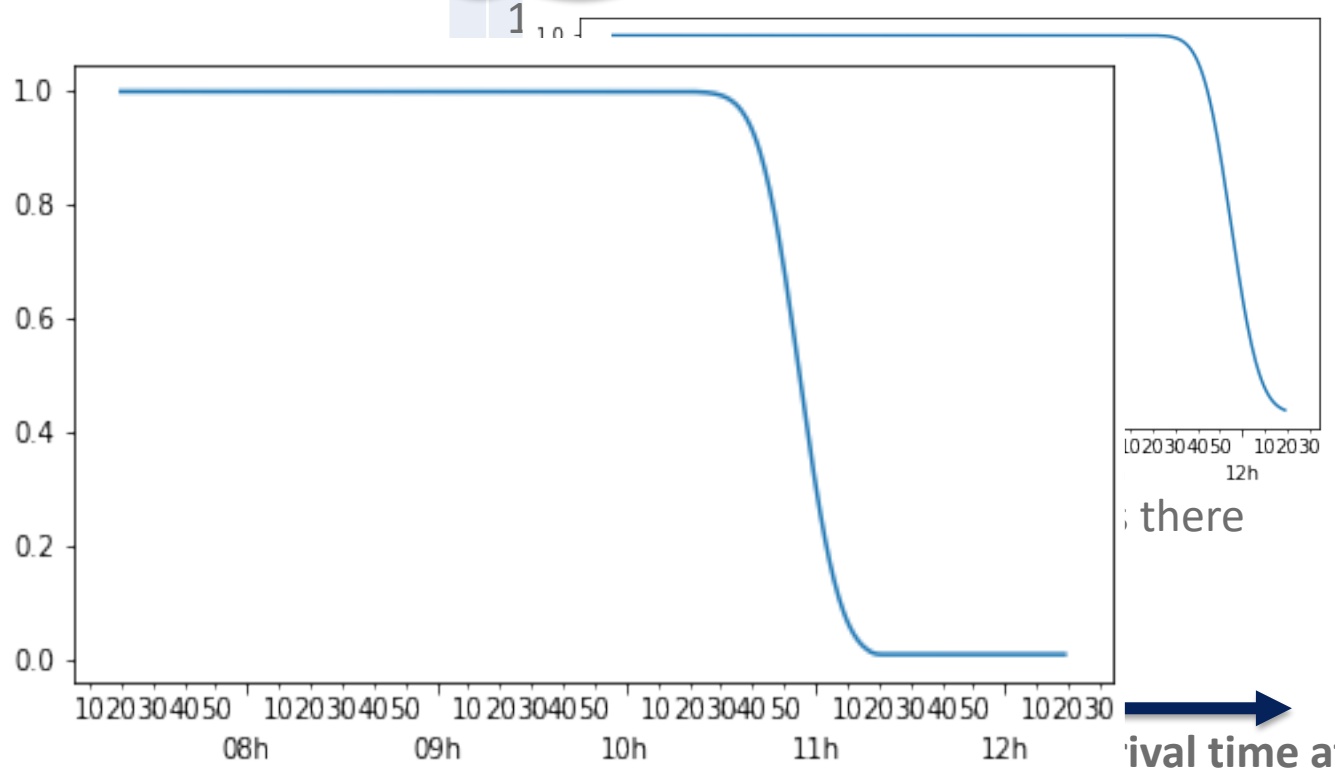
- Cost function

Cost

Opt.	LEMD	EDDF	EDDF	ZBAA	IROP Cost
1	6h35	9h10	11h55	21h15	0



Conn



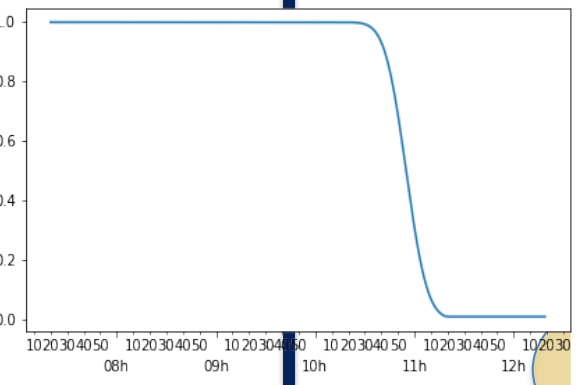
ival time at inbound gate

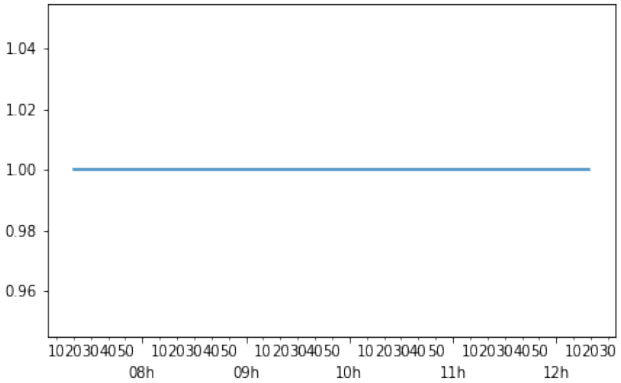
Pilot3 – Objective function

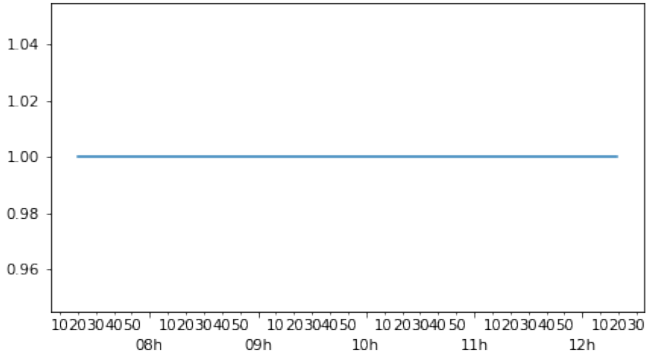
- Cost function

Cost

Opt.	LEMD	EDDF	EDDF	ZBAA	Airline	IROP Cost
1	6h35	9h10	11h55	21h15	CCA	0
2	6h35	9h10	15h15	00h30	DLH	301
3	6h35	9h10	18h15	03h25	CCAA	601



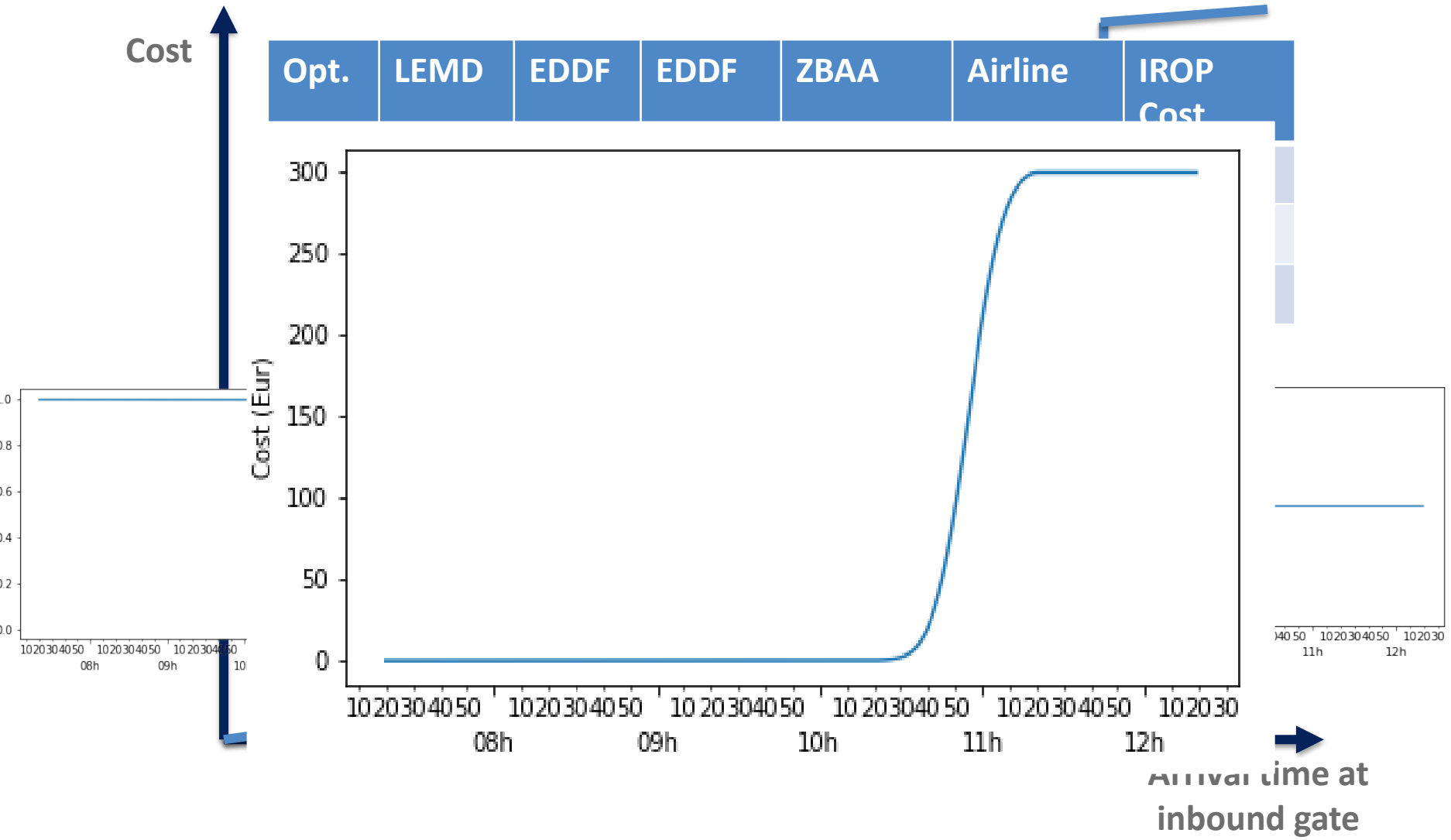




Arrival time at inbound gate

Pilot3 – Objective function

- Cost function



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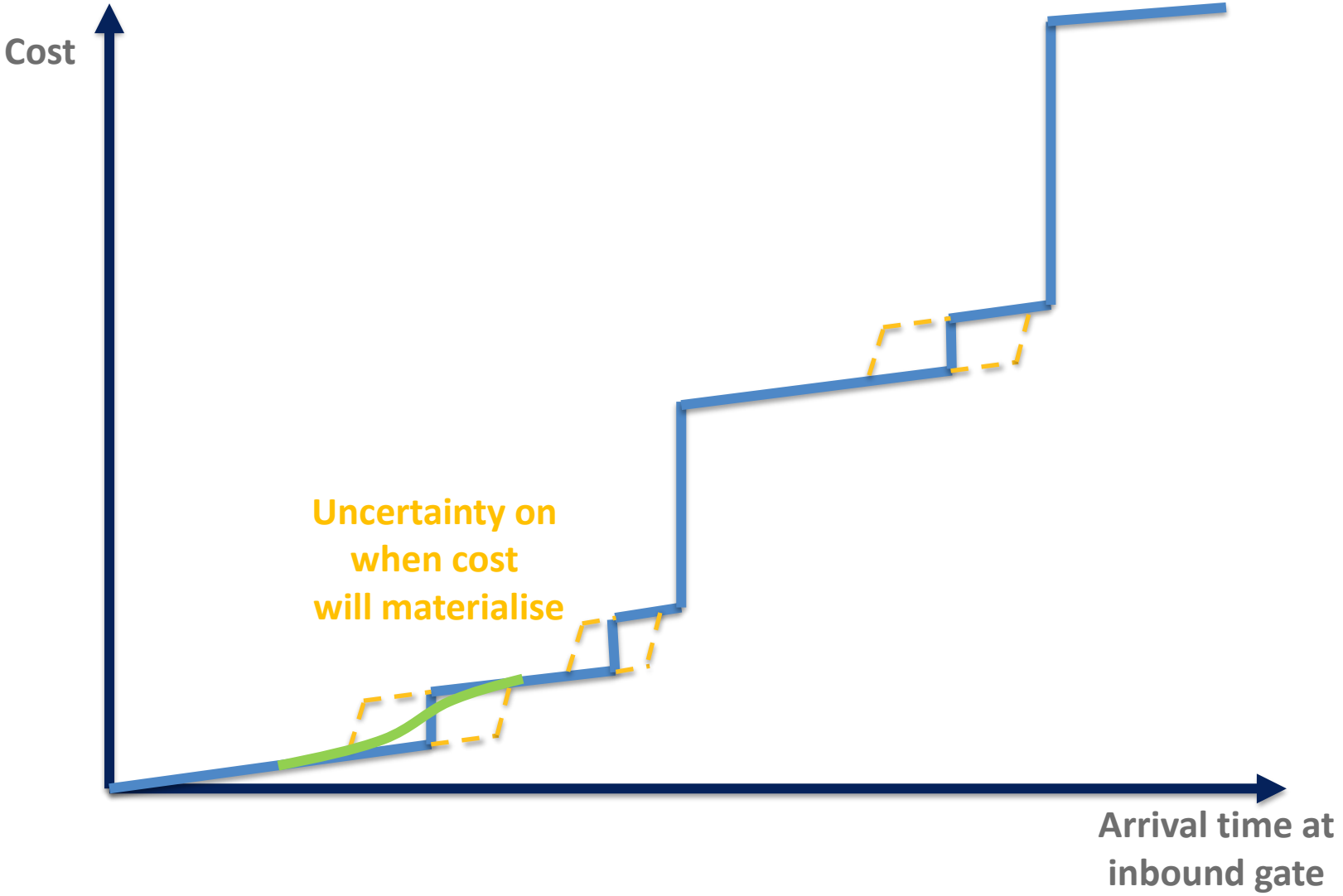

Pilot3 – Objective function

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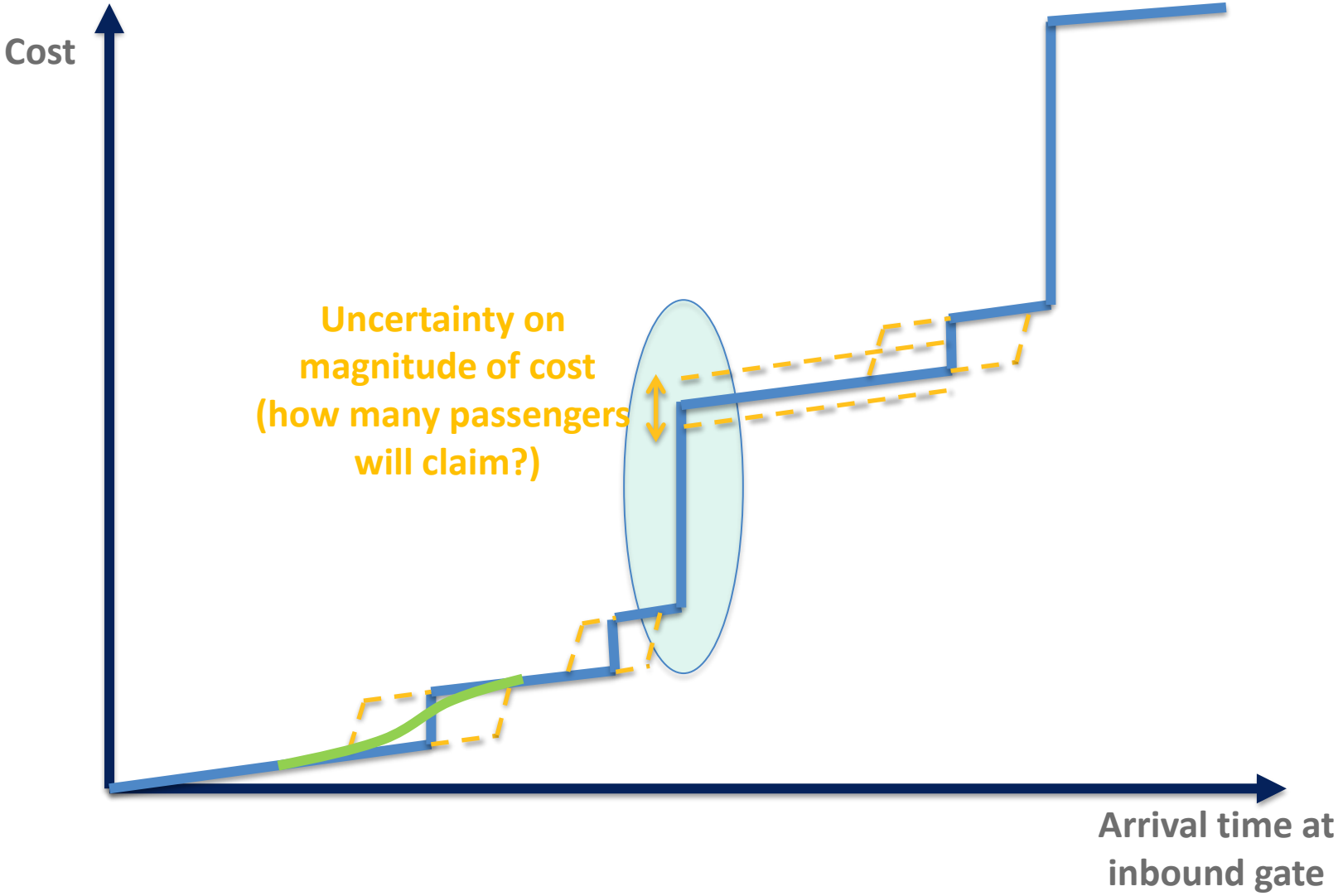

Pilot3 – Objective function

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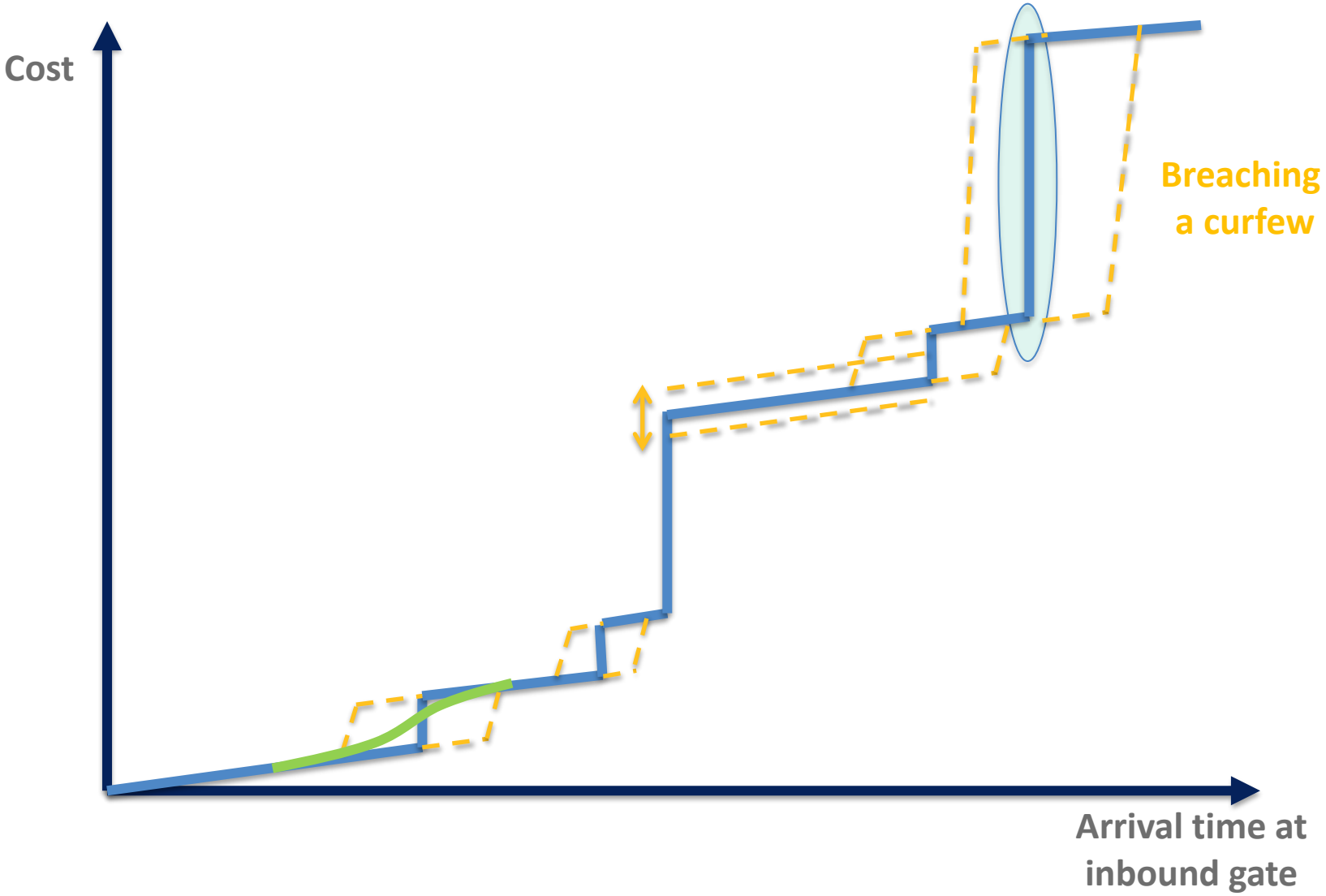
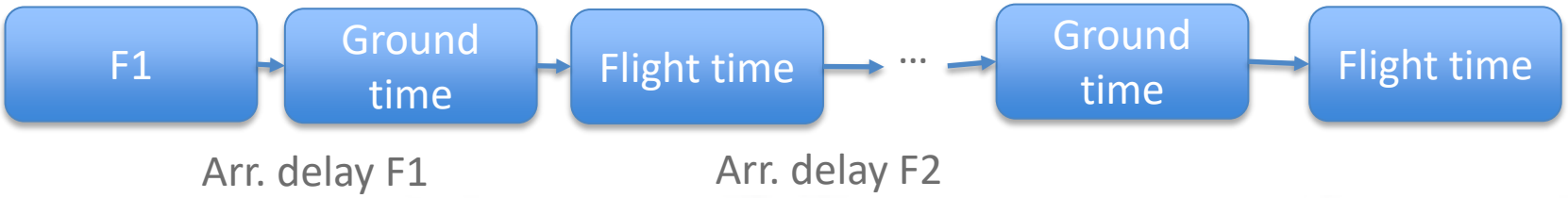
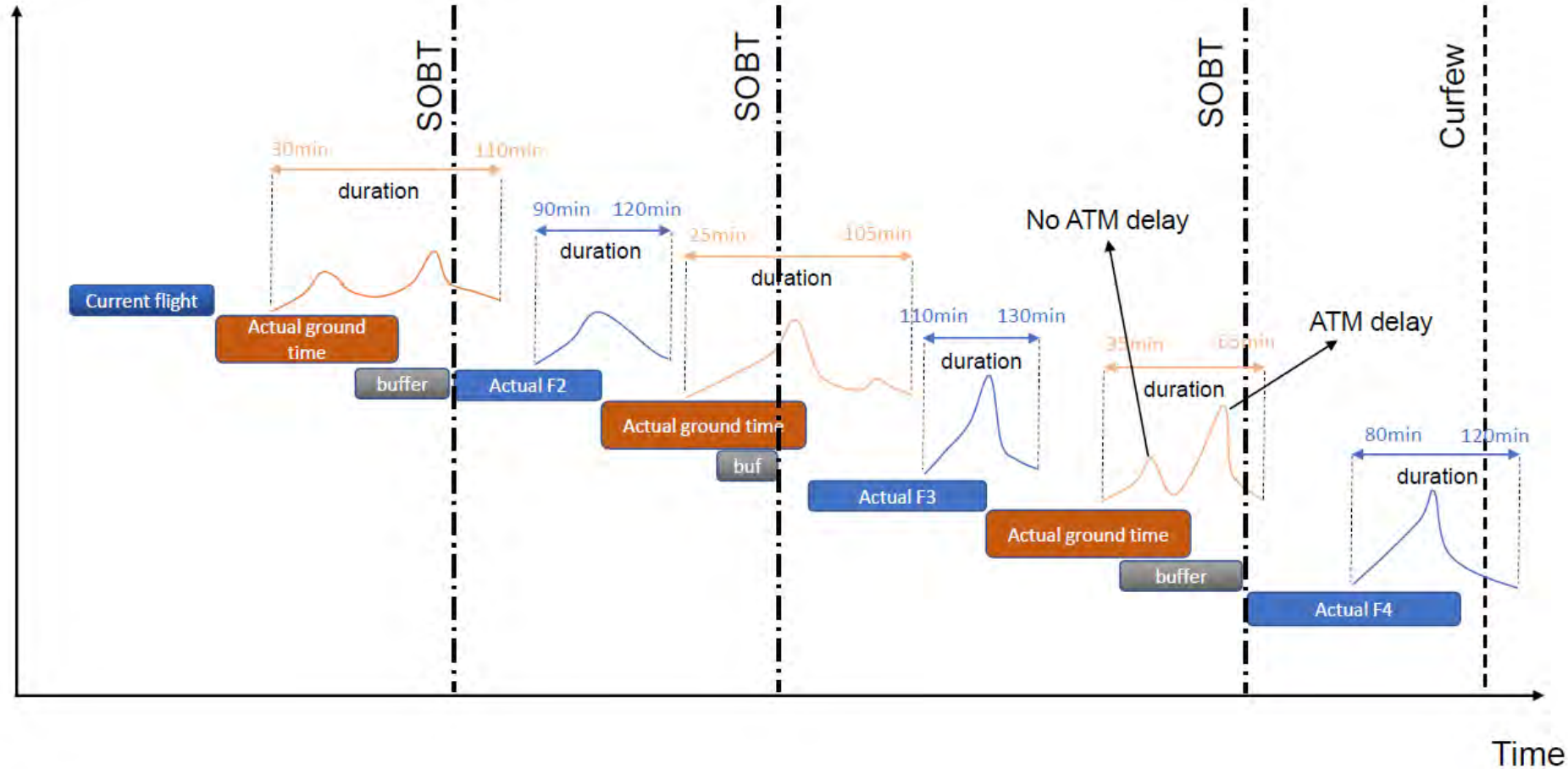


Pilot3 – Objective function

- Dep. delay F2 Dep. delay Fn





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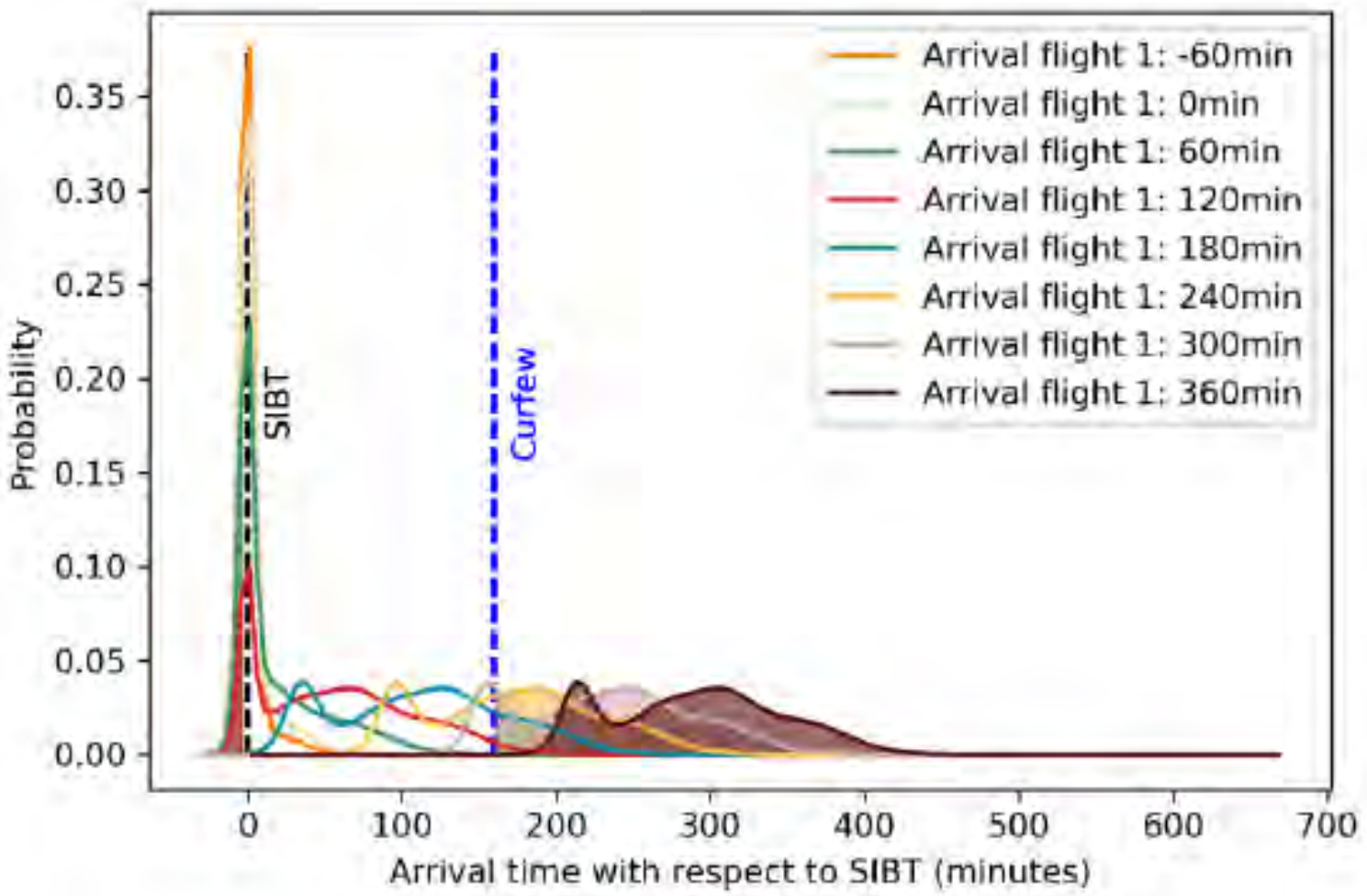

Pilot3 – Objective function

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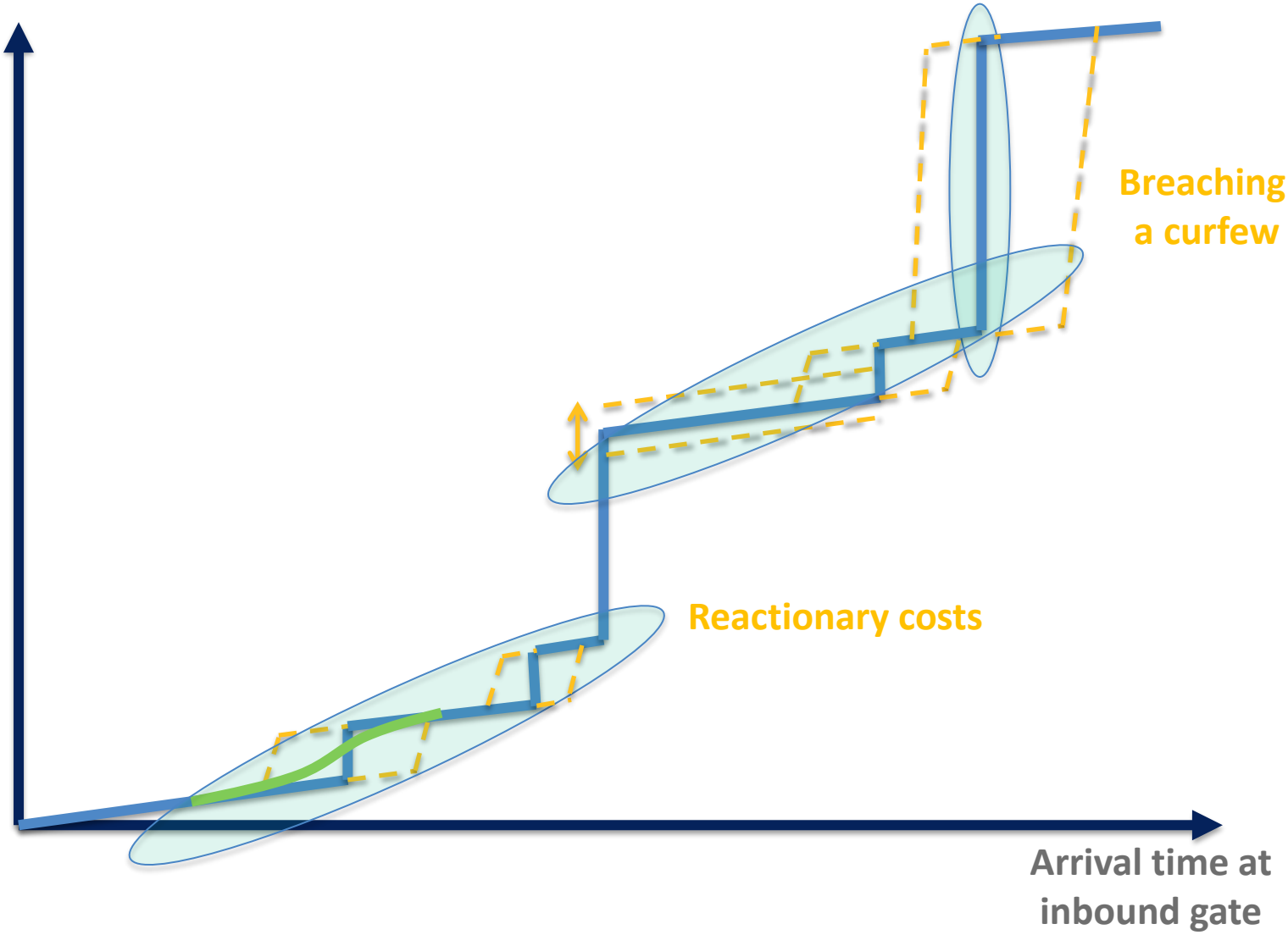

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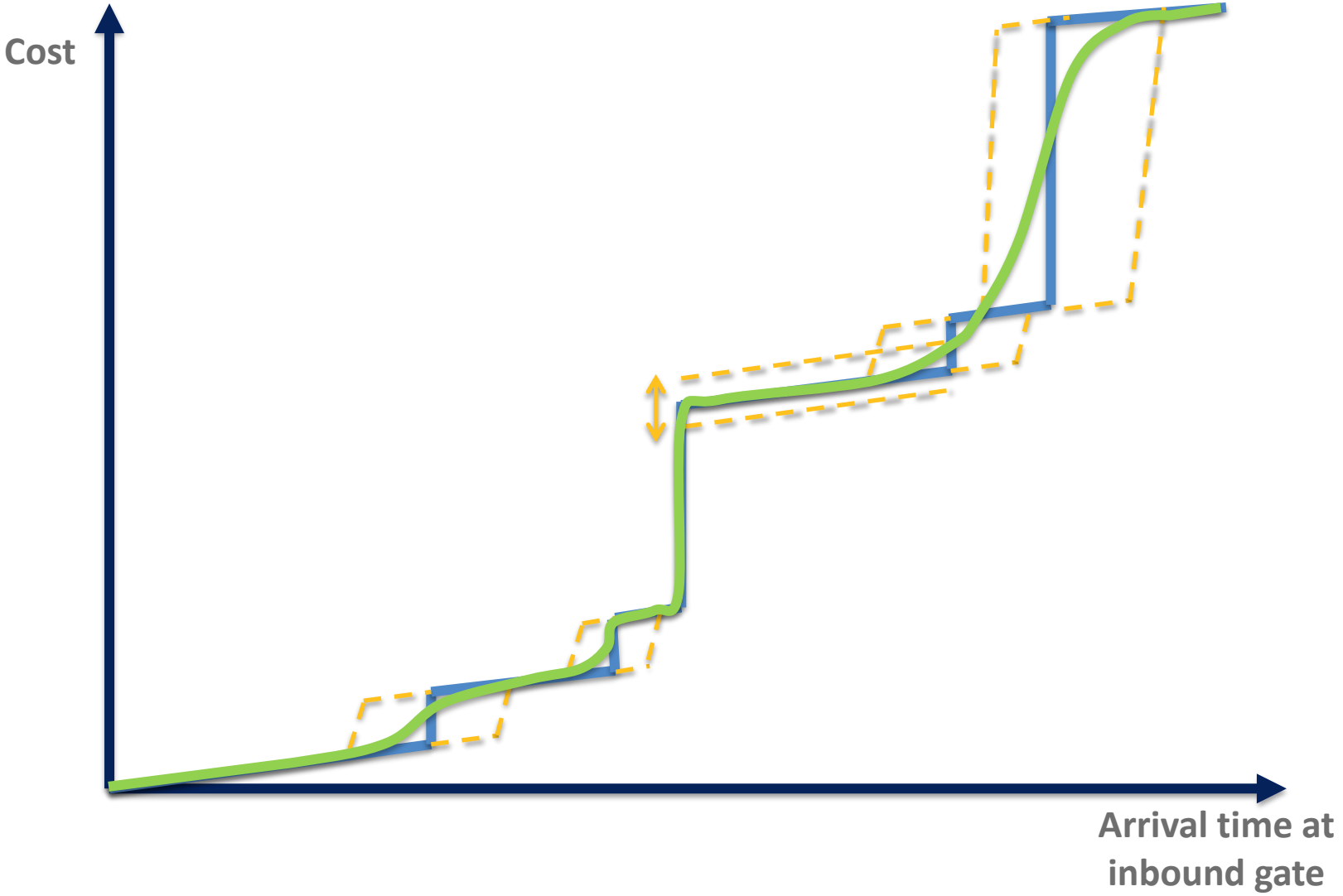
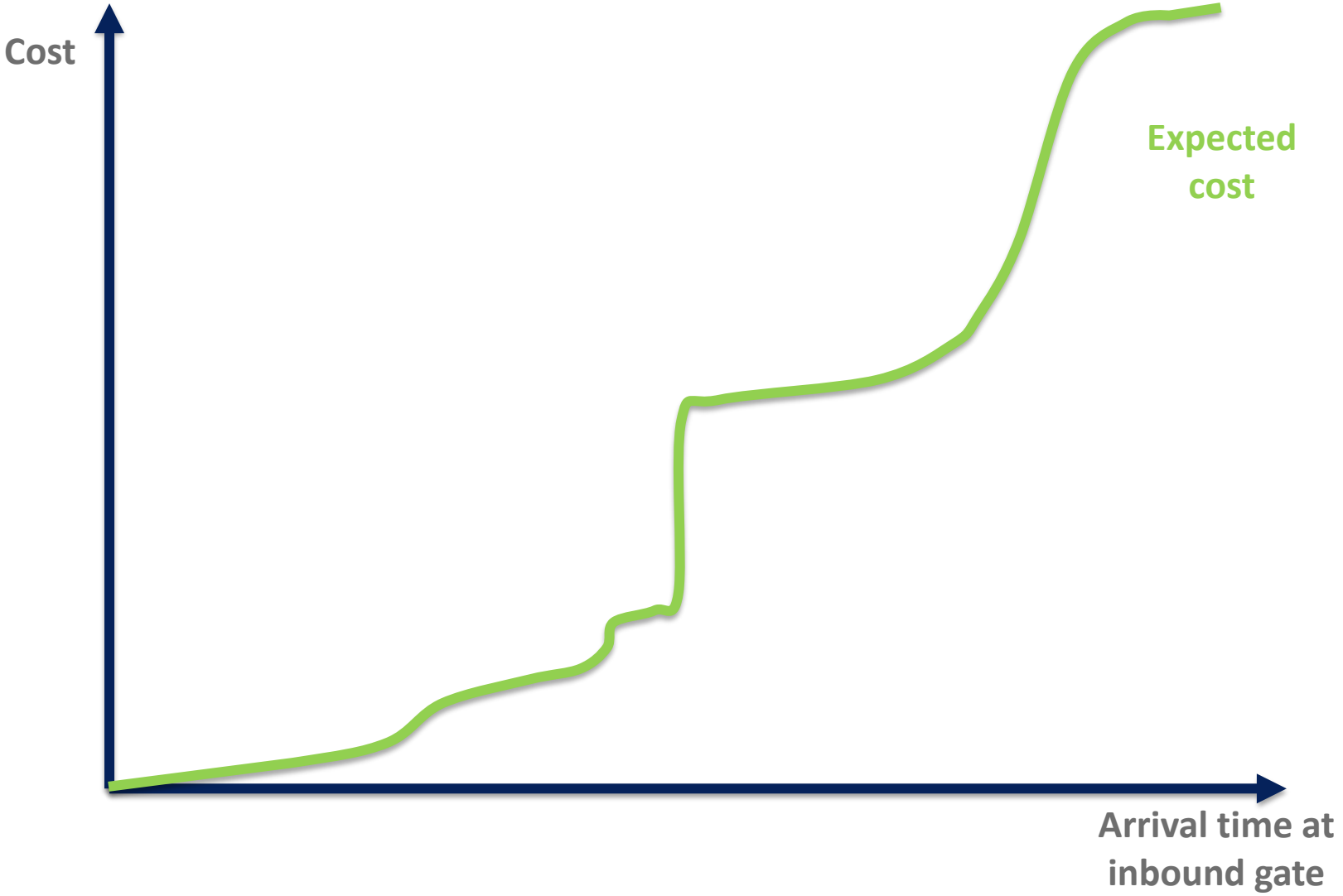


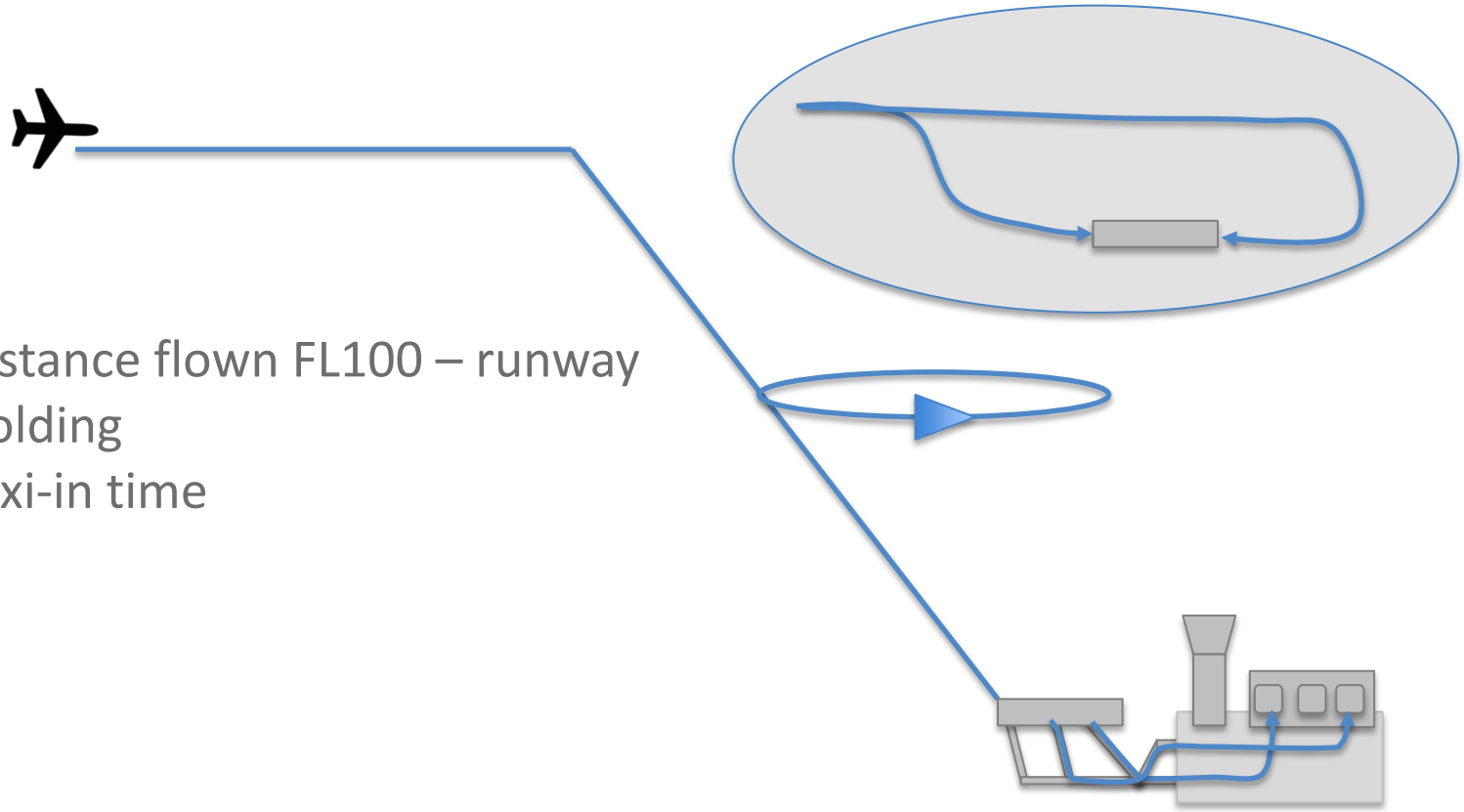
Pilot3 – Objective function

- Cost function



Pilot3 – Objective function

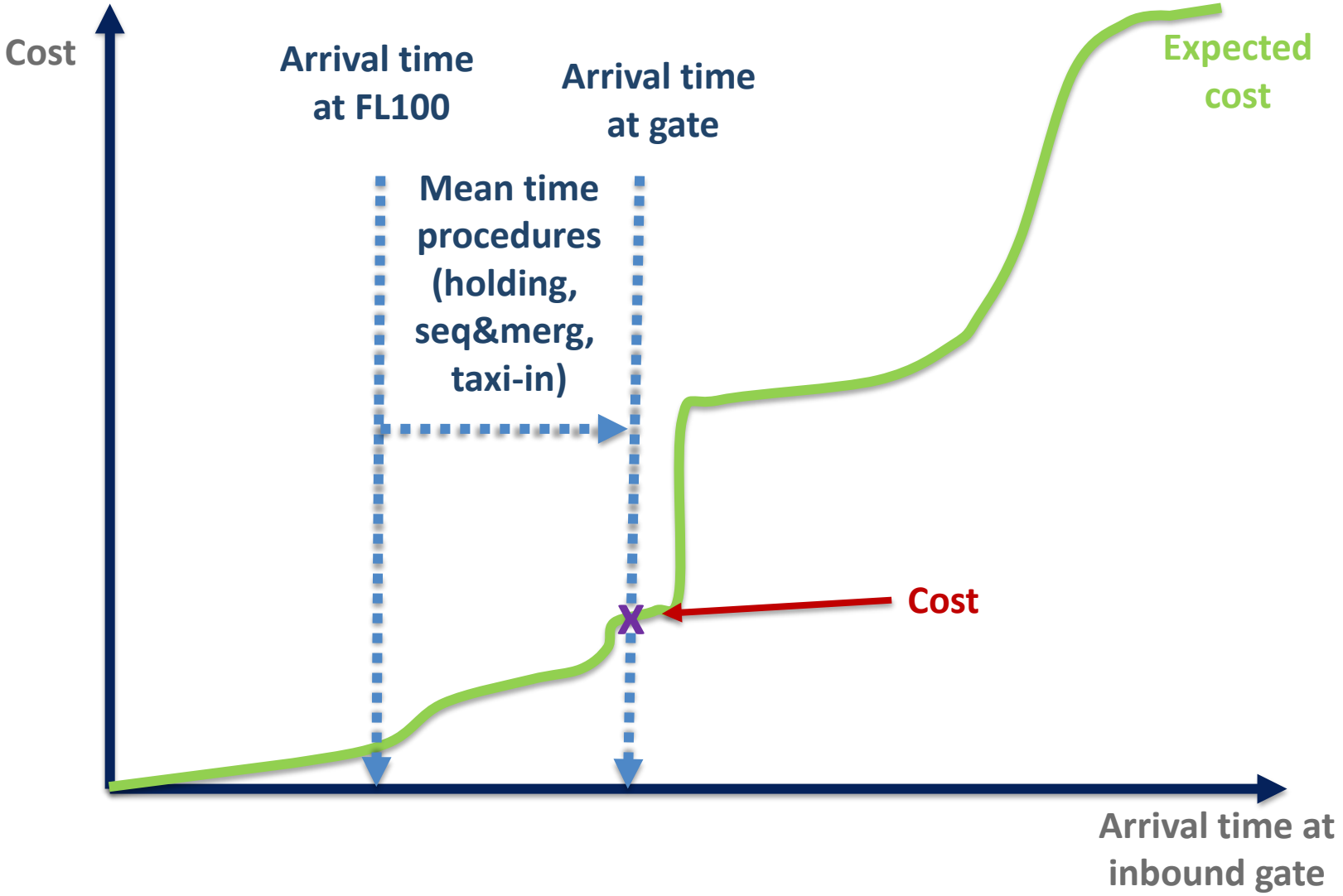
- **Cost function**



- Distance flown FL100 – runway
- Holding
- Taxi-in time

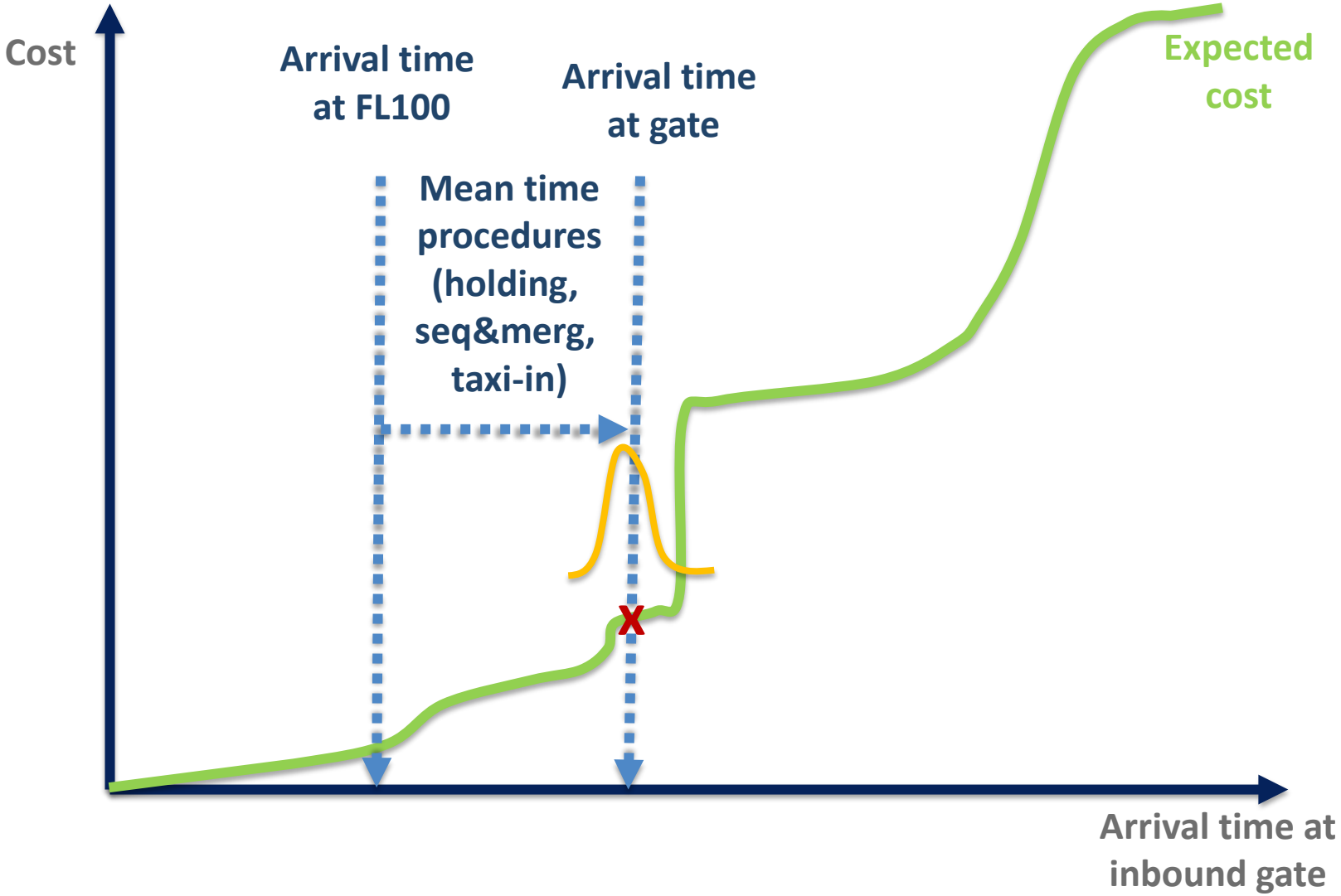
Pilot3 – Machine learning models

- Cost function



Pilot3 – Machine learning models

- Cost function



Pilot3 – Machine learning m

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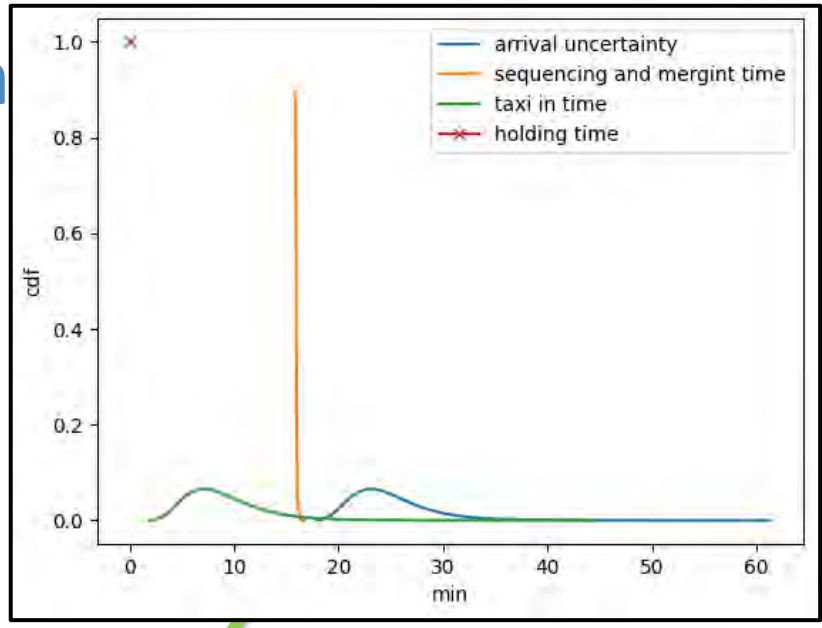
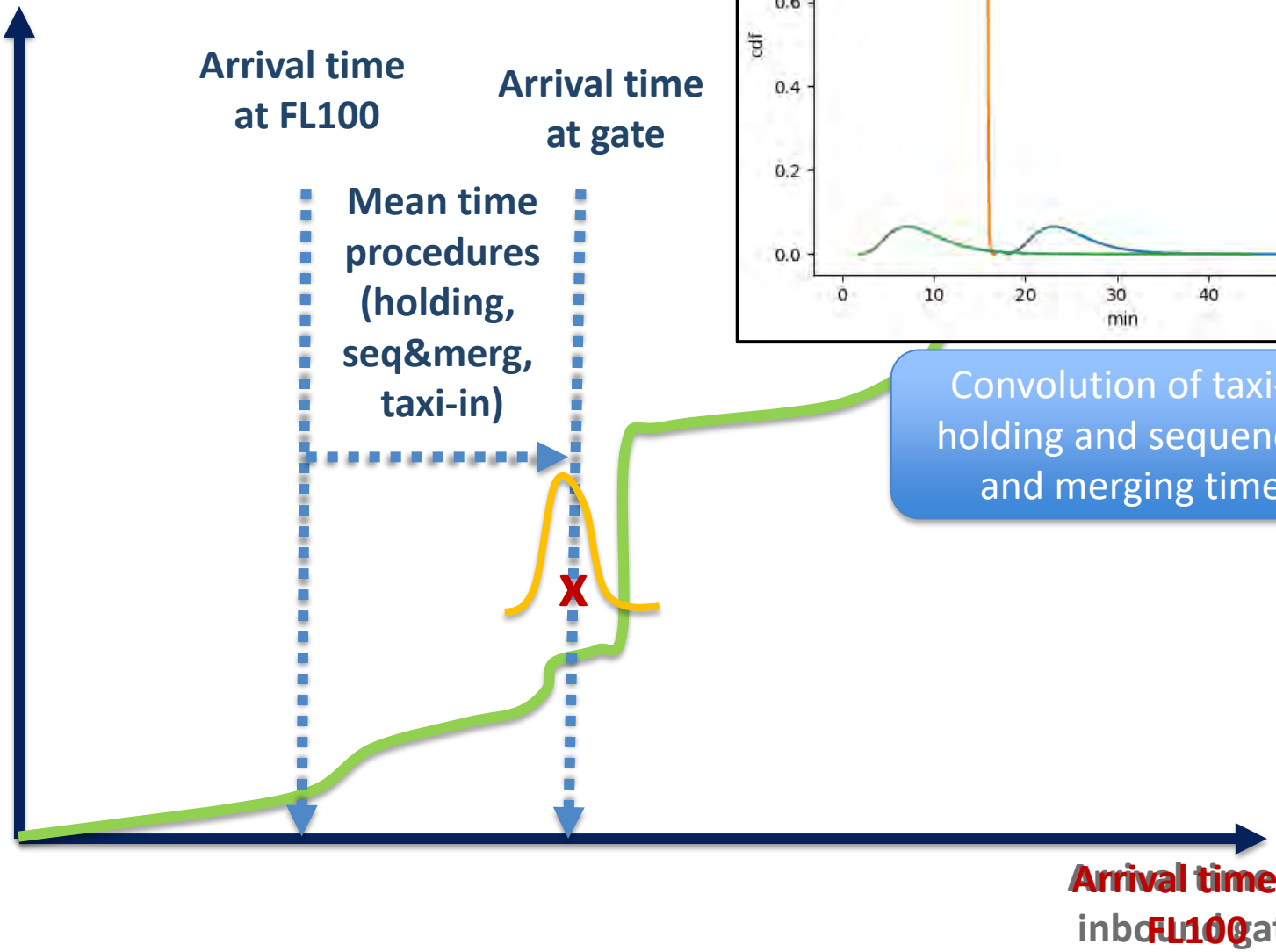
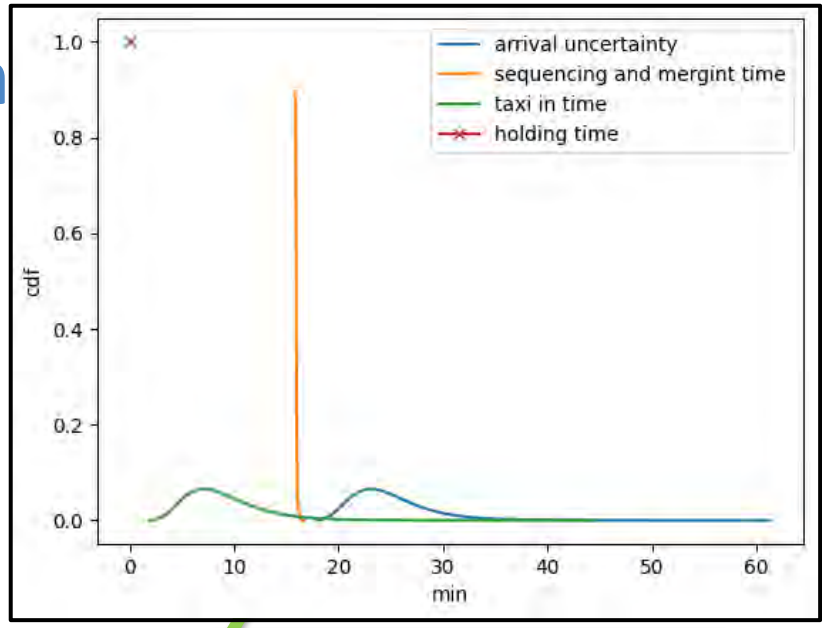




Pilot3 – Machine learning m

- Cost function



Cost

Arrival time at FL100

Arrival time at gate

Mean time procedures (holding, seq&merg, taxi-in)

X

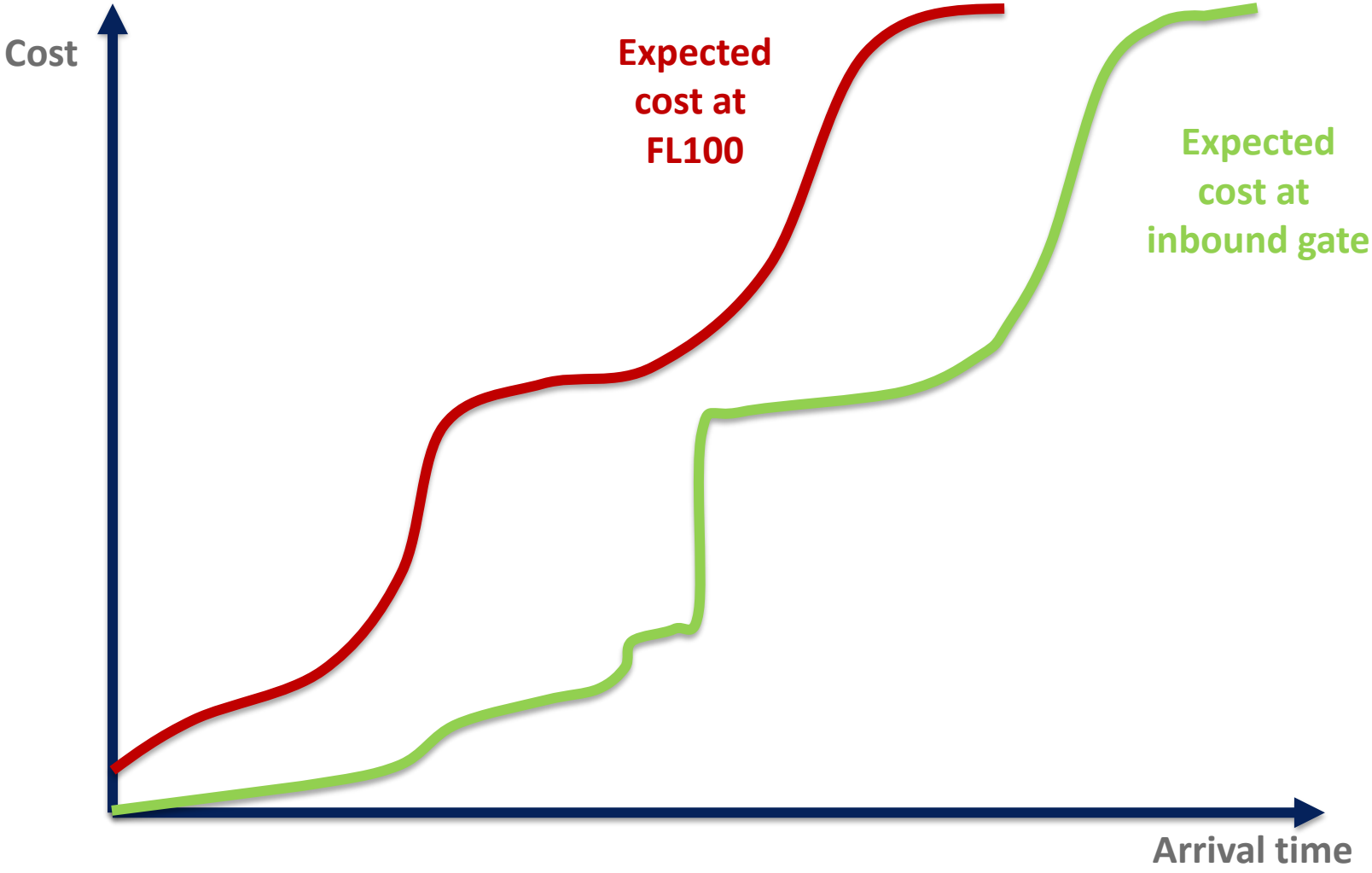
Convolution of taxi-in, holding and sequencing and merging times

Arrival time at FL100

Arrival time at inbound gate

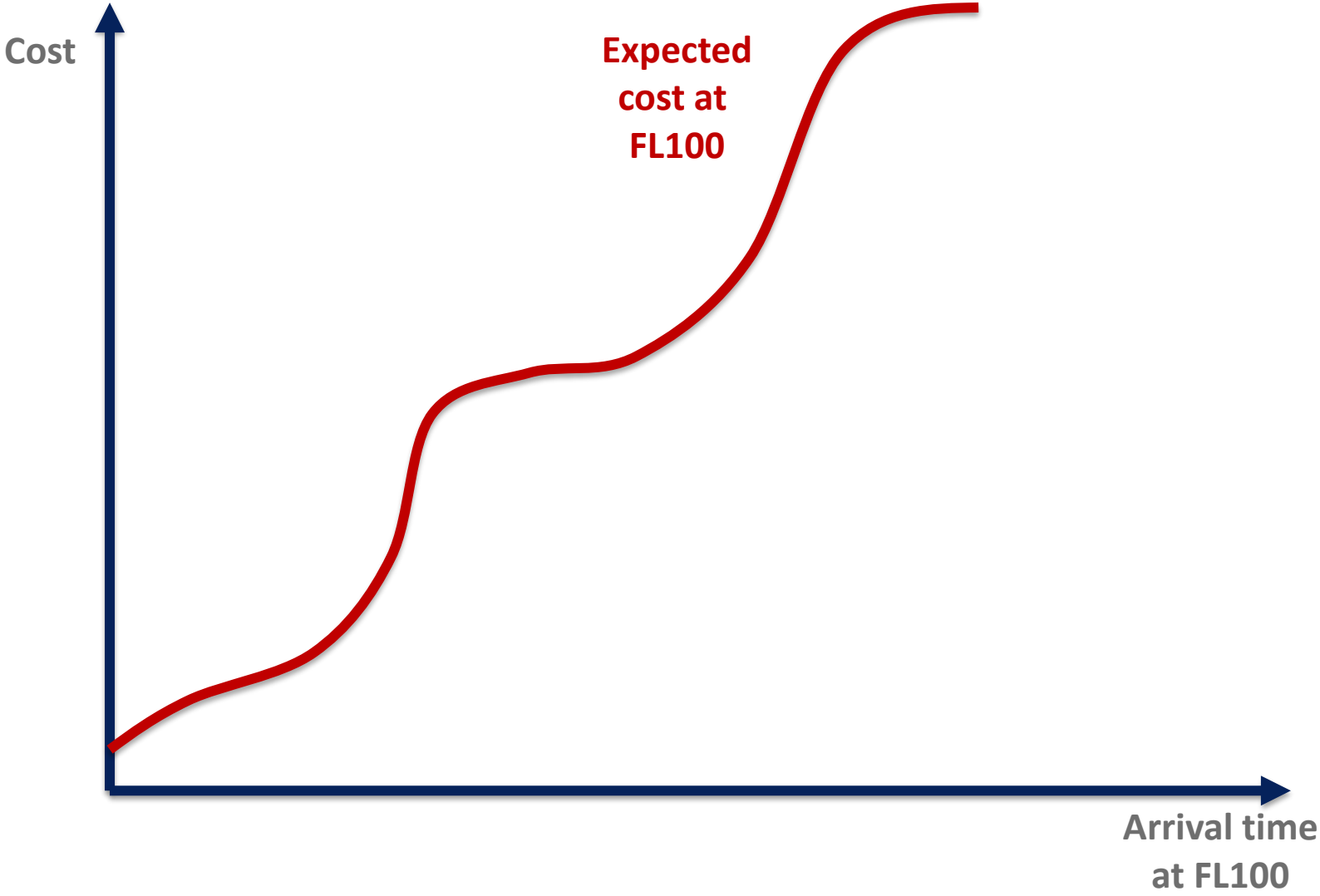
Pilot3 – Objective function

- Cost function

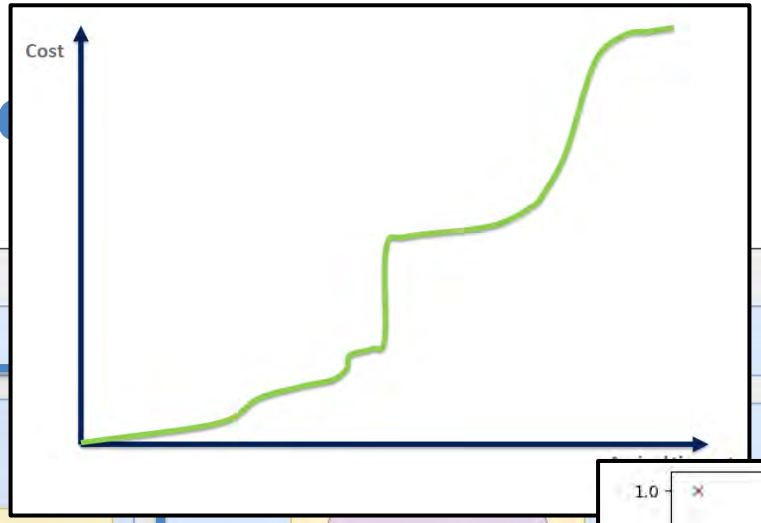


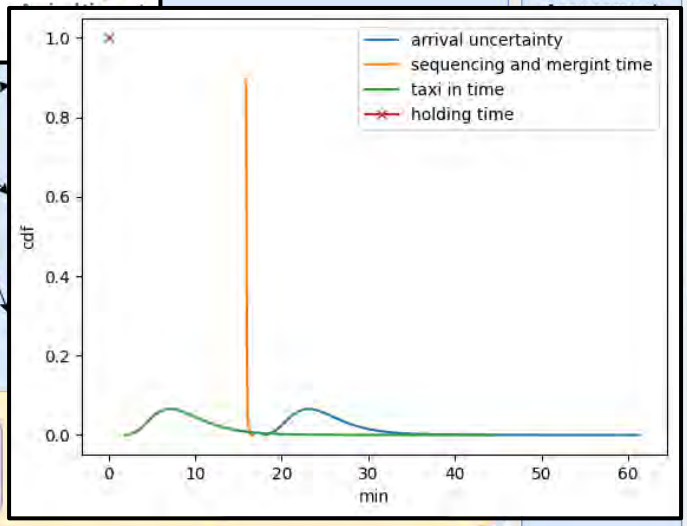
Pilot3 – Objective function

- Cost function



Pilot3 – Compe





Performance Indicators Estimator

Soft Costs Estimator

Compensation Costs Estimator

Duty of Care Costs Estimator

Transfer Costs Estimator

Minimum Connecting Time Estimator

Departure Time Estimator

Non-passenger Costs Estimator

Gate-to-gate Time Estimator

Ground Time Estimator

Non-connecting passengers costs estimation

Connecting passengers costs estimation

Reactionary Delay Estimator

Reactionary Costs Estimator

Cost Fuel Estimator

IROP Cost Estimator

Other Costs Estimator

IROP Cost at arrival gate

Other Costs at arrival gate

Integrate uncertainty

Holding time dist. Holding fuel dist.

Seq.&merg. time dist. Seq.&merg. fuel dist.

Taxi-in time dist. Taxi-in fuel dist.

Trajectory Predictor FL100 - runway

Holding Time Estimator

Sequencing and merging distance Estimator

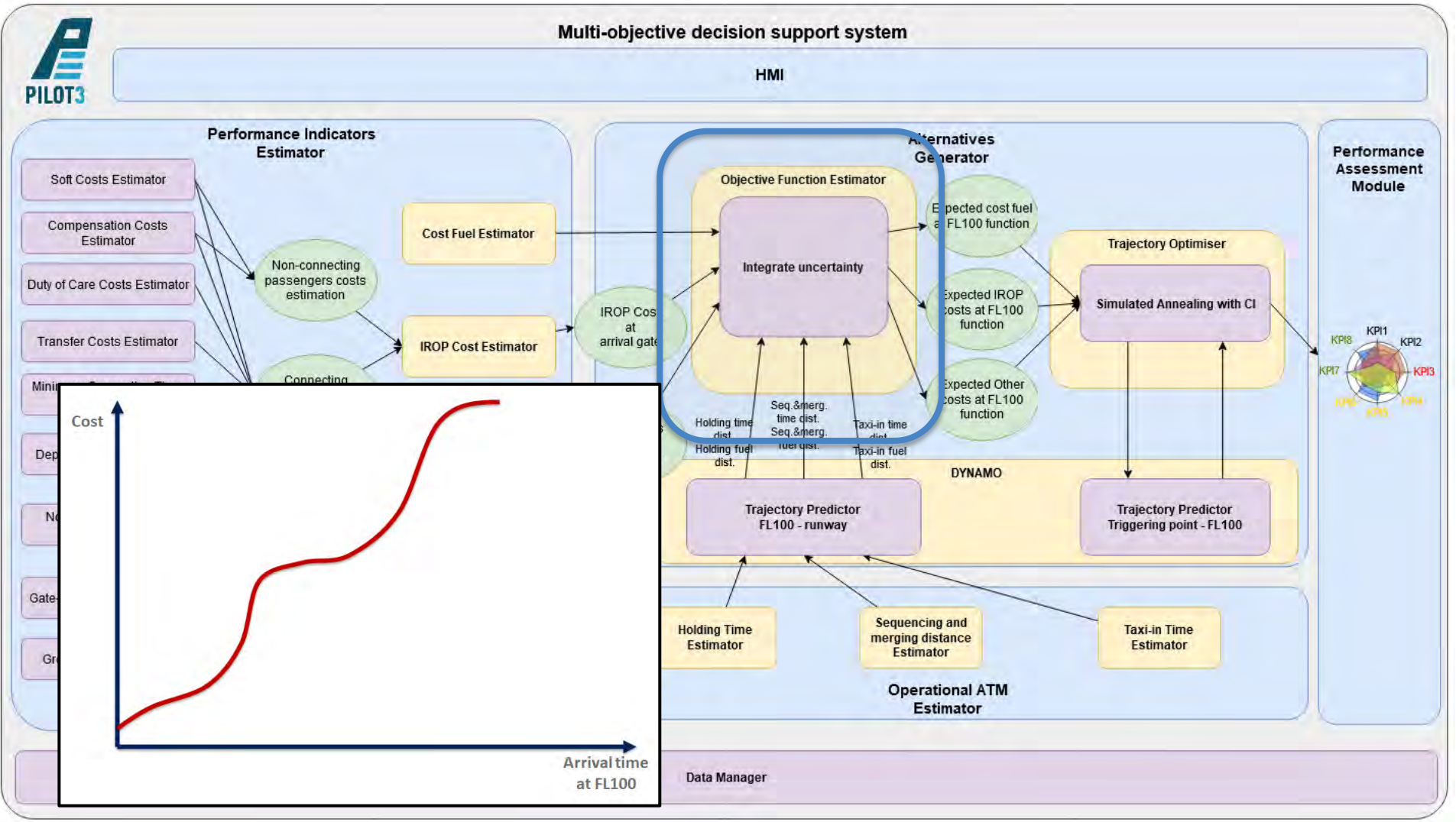
Taxi-in Time Estimator

Operational ATM Estimator

Performance

Data Manager

Pilot3 – Components



Pilot3 – Machine learning models

For cost function generation

- Reactionary delay estimation
    - Ground time
    - Gate-to-gate time
- Missed connections
    - Connecting time
    - Departure of possible connecting flights

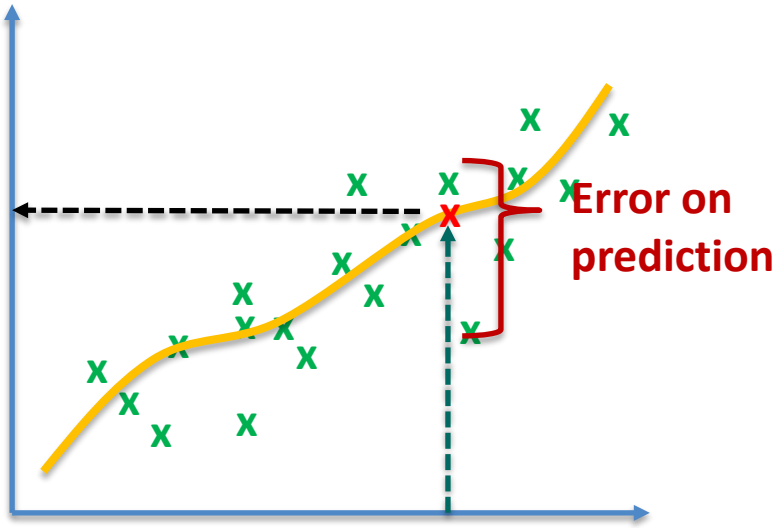
For uncertainties in model

- Holding at arrival (minutes)
- Flight distance from FL100 to runway (NM)
- Taxi-in time (minutes)

Pilot3 – Machine learning models

Challenges

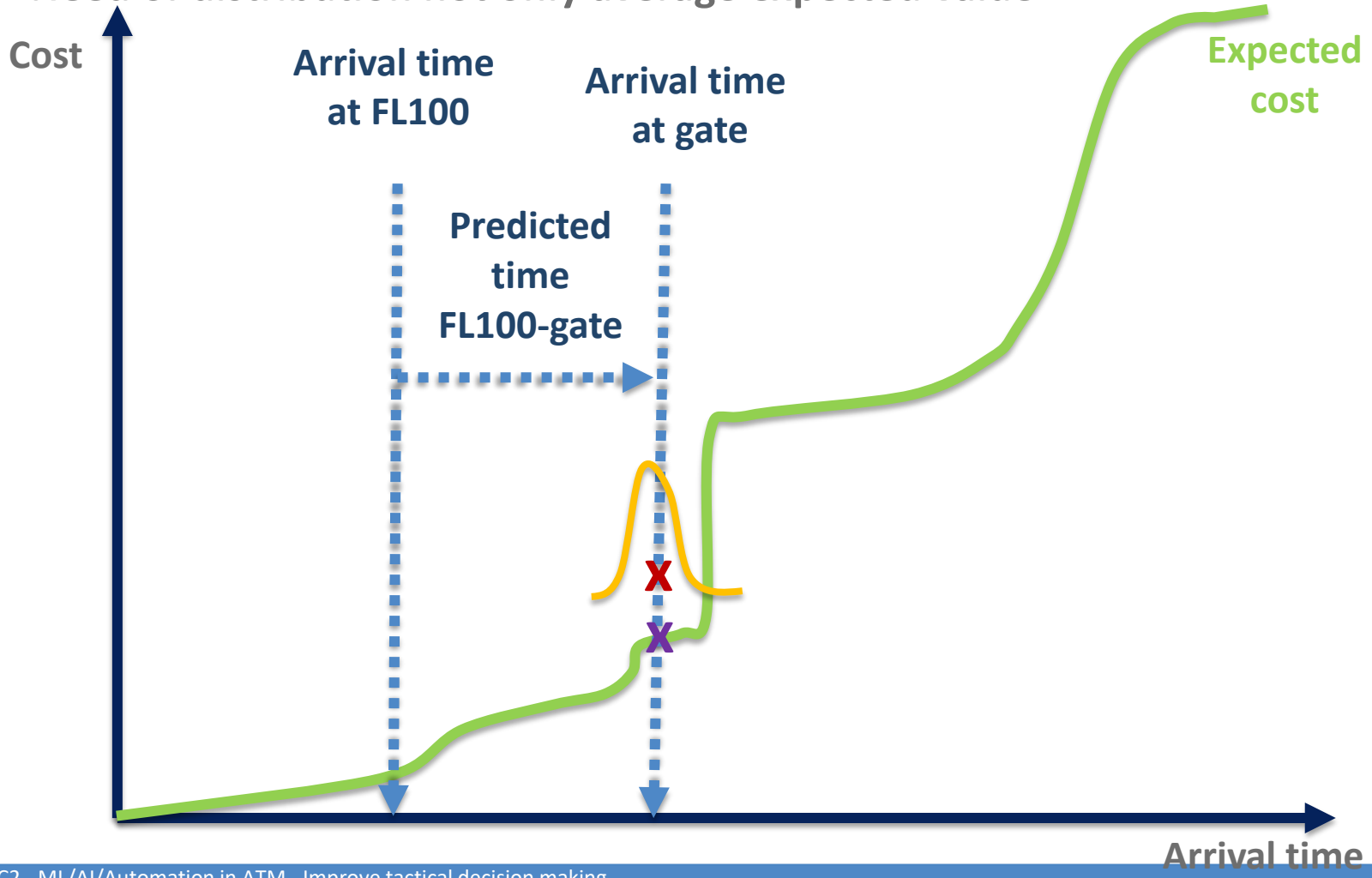
1. Need of distribution not only average expected value



Pilot3 – Machine learning models

Challenges

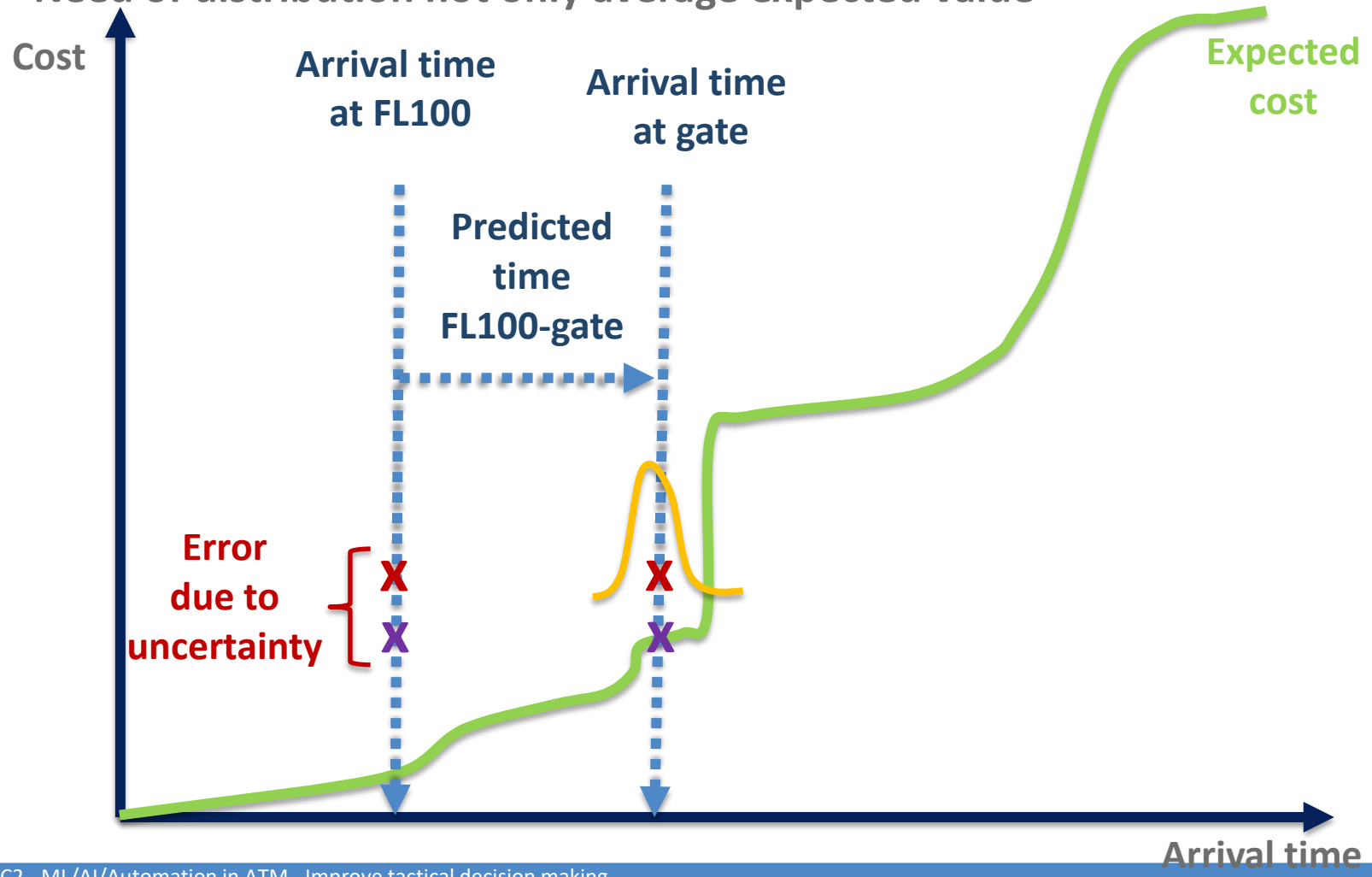
1. Need of distribution not only average expected value



Pilot3 – Machine learning models

Challenges

1. Need of distribution not only average expected value

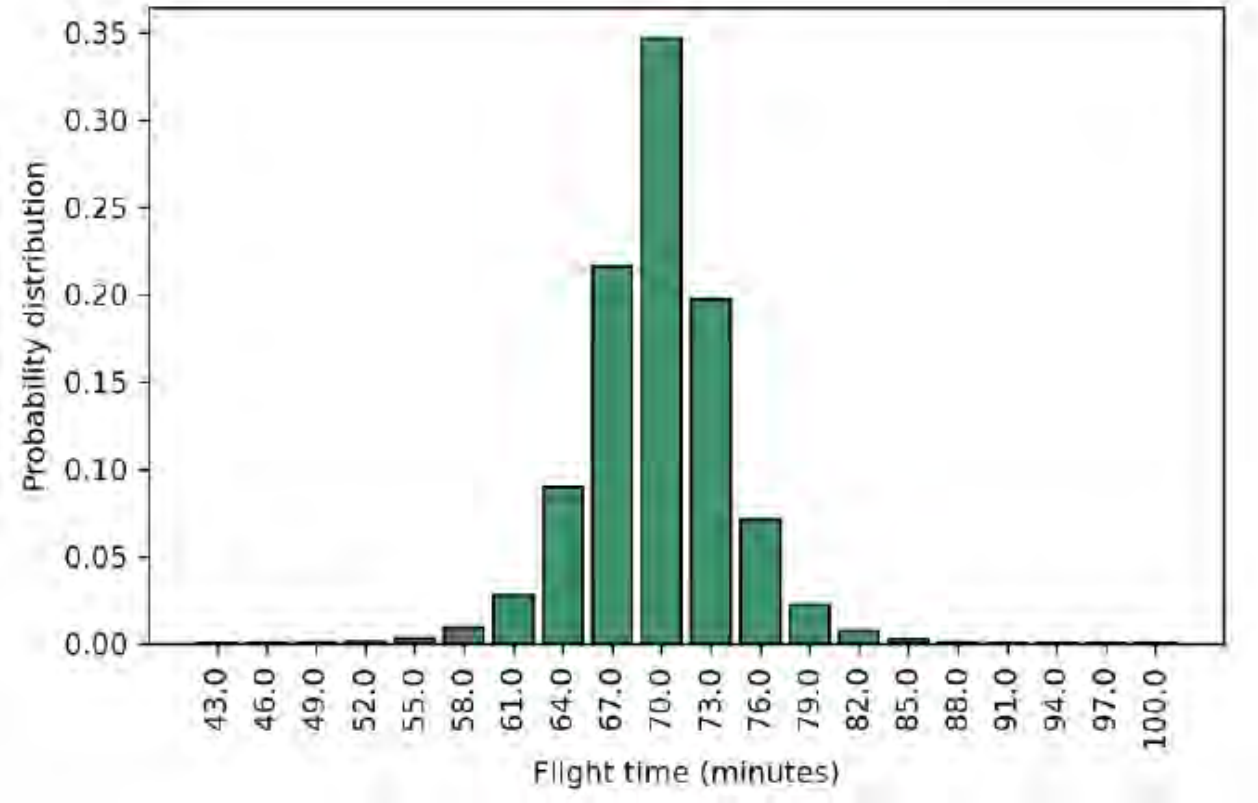


Pilot3 – Machine learning models

Challenges

1. Need of distribution not only average expected value

Simple (or not) regression model → **Computation of error** → **Classifier to characterise error**

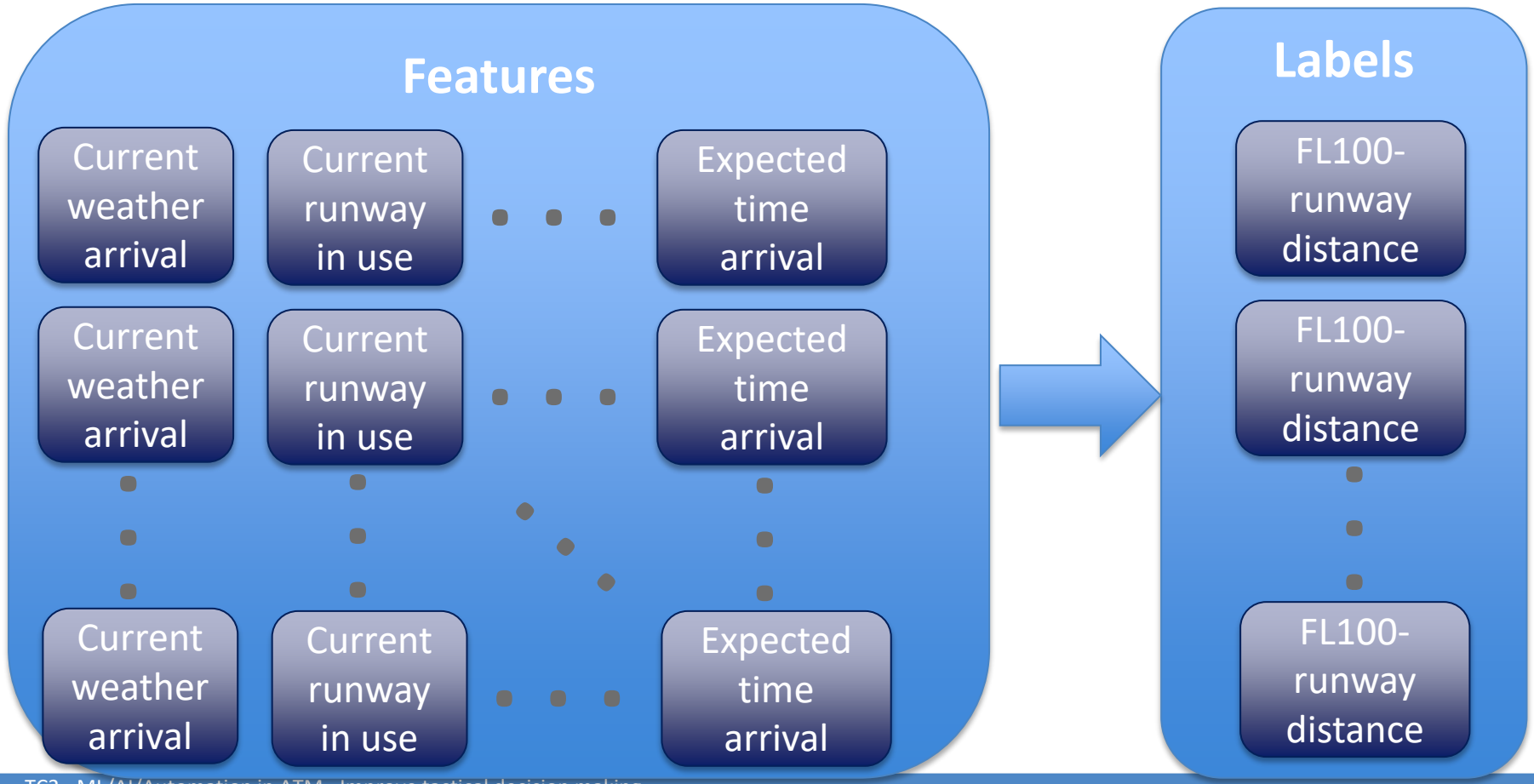


Pilot3 – Machine learning models

Challenges

2. Prediction-horizon

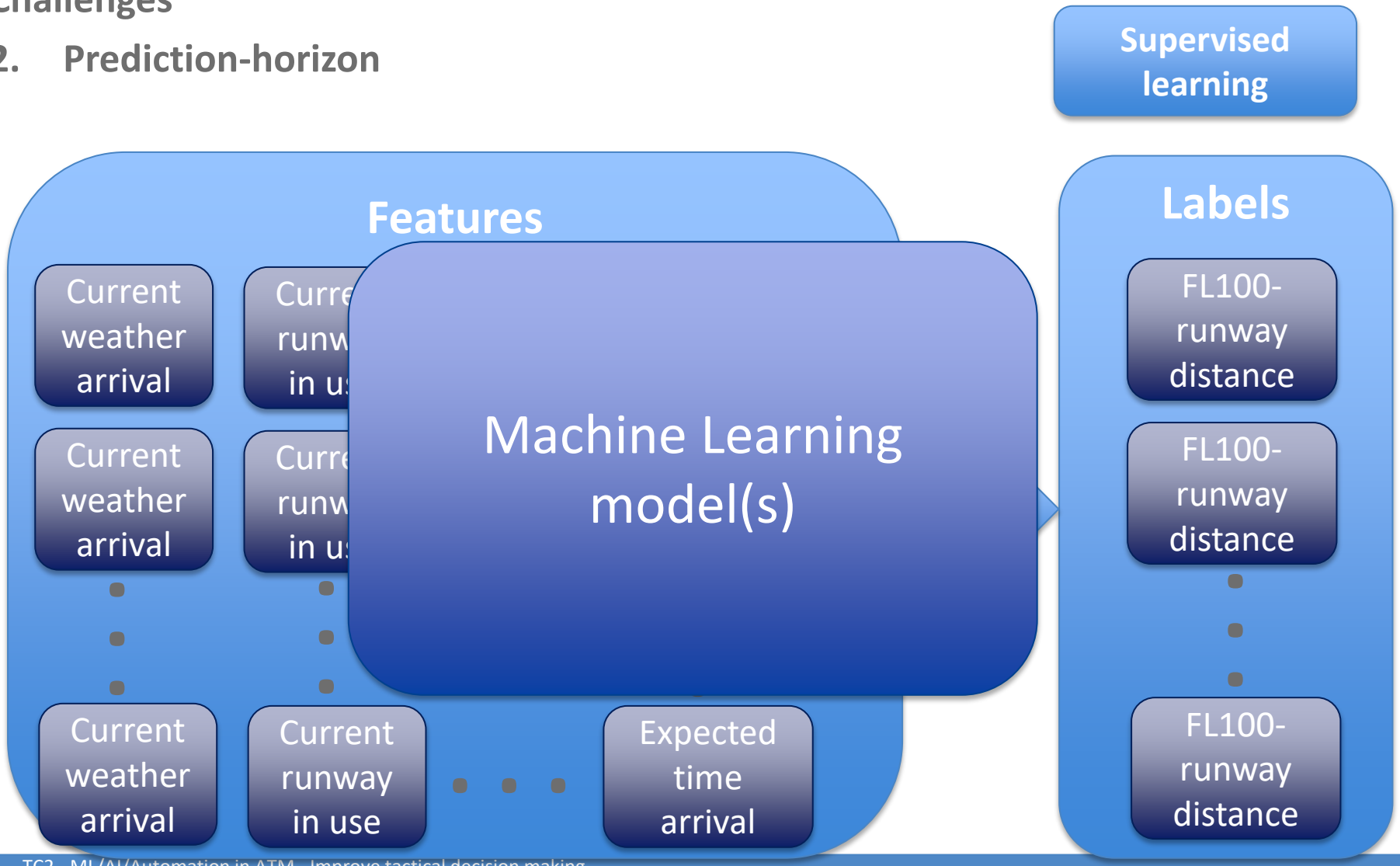
Supervised learning



Pilot3 – Machine learning models

Challenges

2. Prediction-horizon

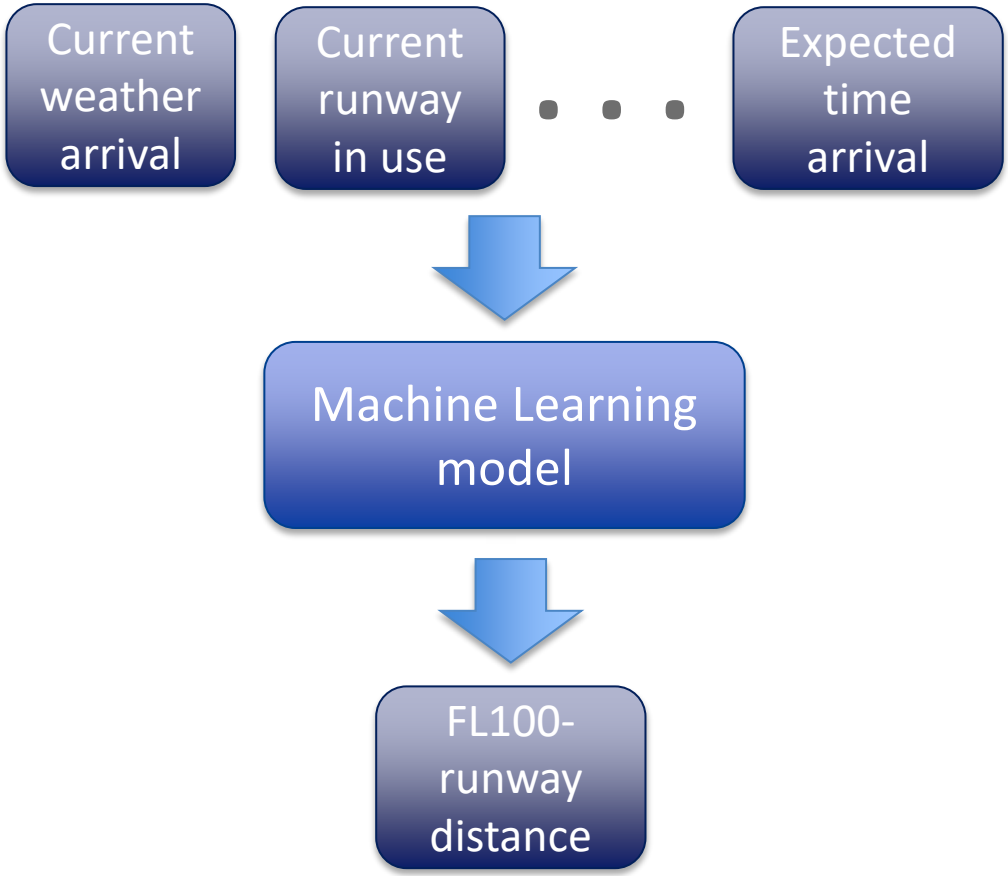


Pilot3 – Machine learning models

Challenges

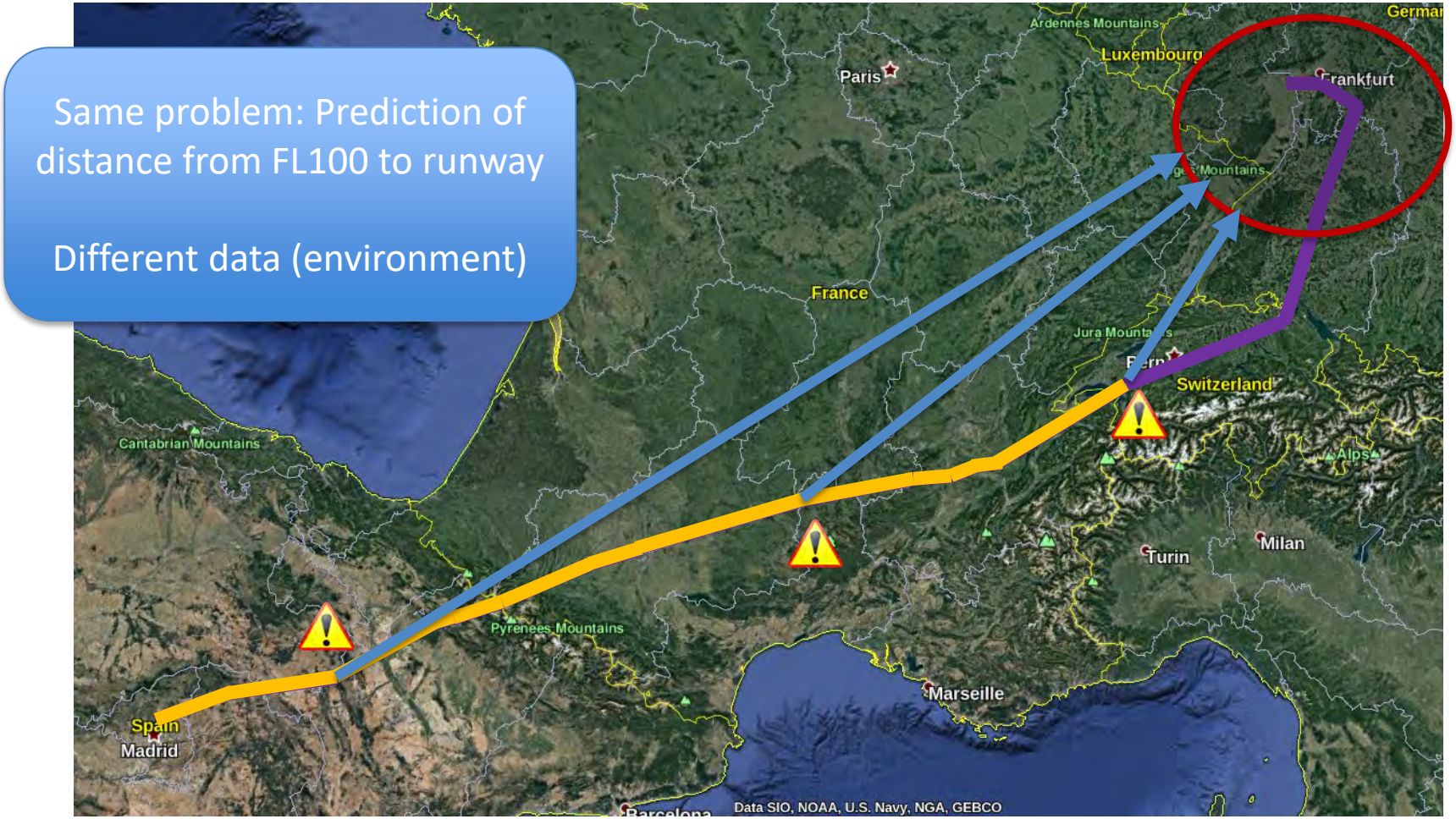
2. **Prediction-horizon**

Supervised learning



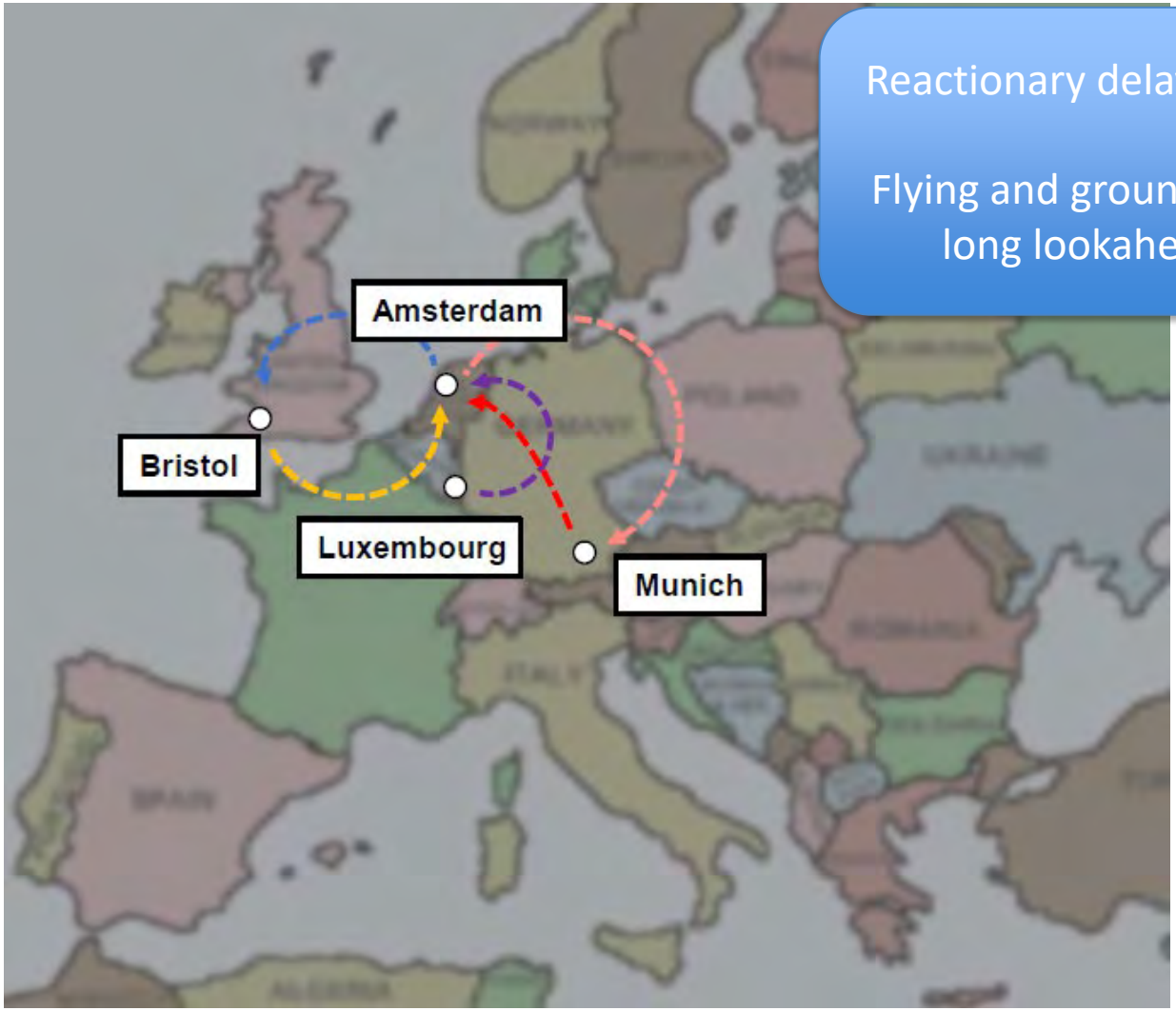
Pilot3 – Machine learning models

Challenges



Pilot3 – Machine learning models

Challenges



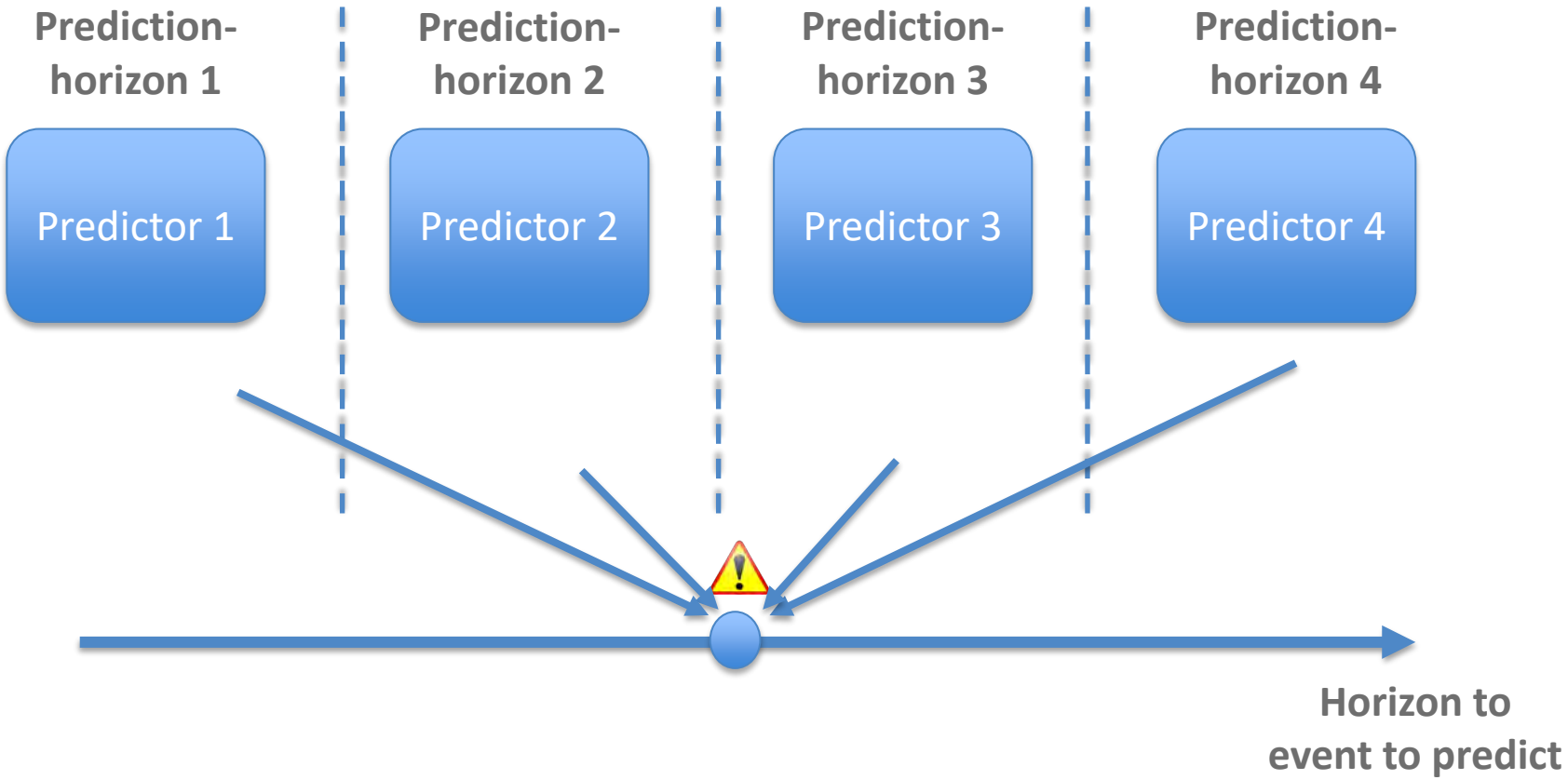
Reactionary delay estimation:

Flying and ground times with long lookahead times

Pilot3 – Machine learning models

Challenges

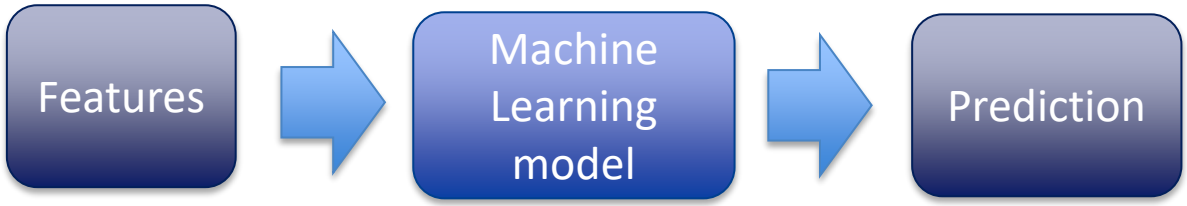
2. Prediction-horizon

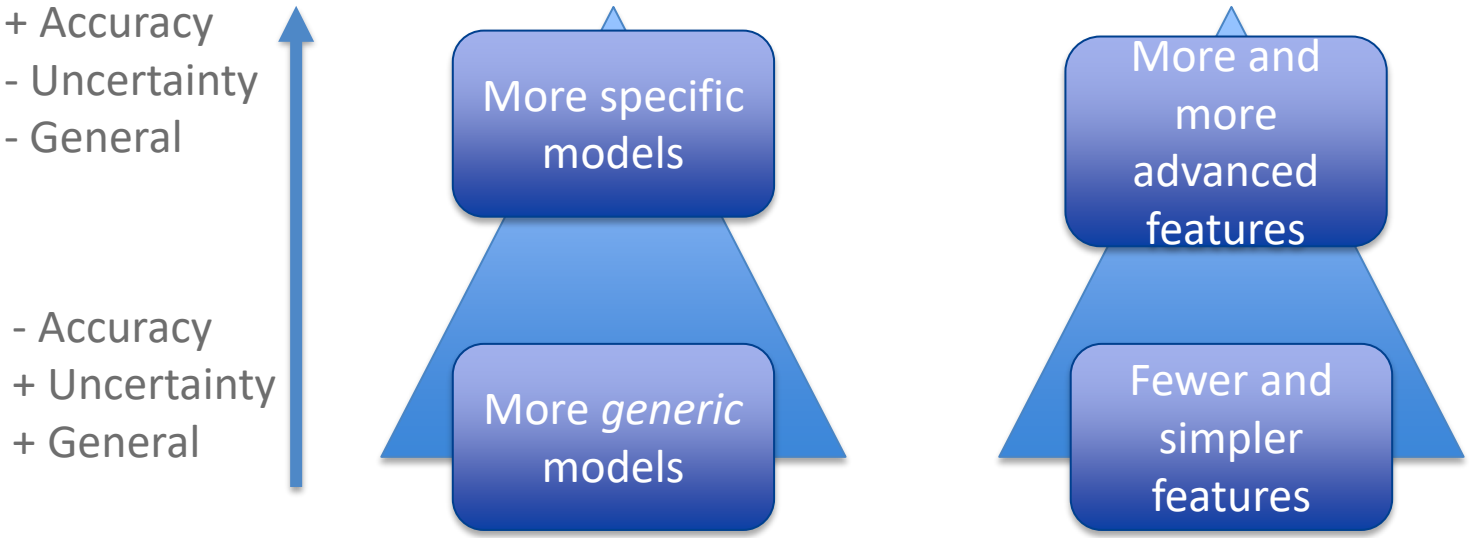


Pilot3 – Machine learning models

Challenges

3. Multi-model approach





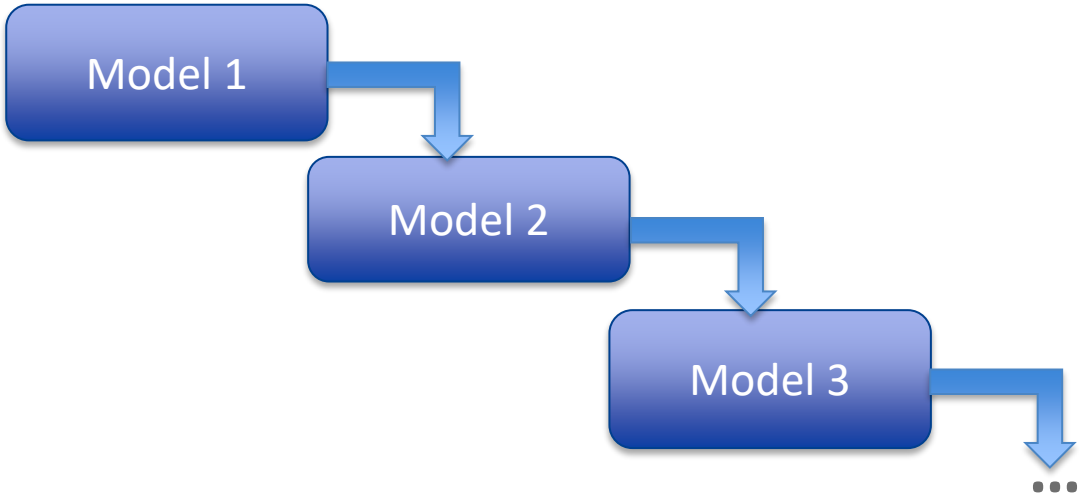
Pilot3 – Machine learning models

Challenges

3. Multi-model approach

Specific
More advanced features
Ground-updated data

Which model to use for a given prediction: trade-off accuracy/uncertainty/ genericity



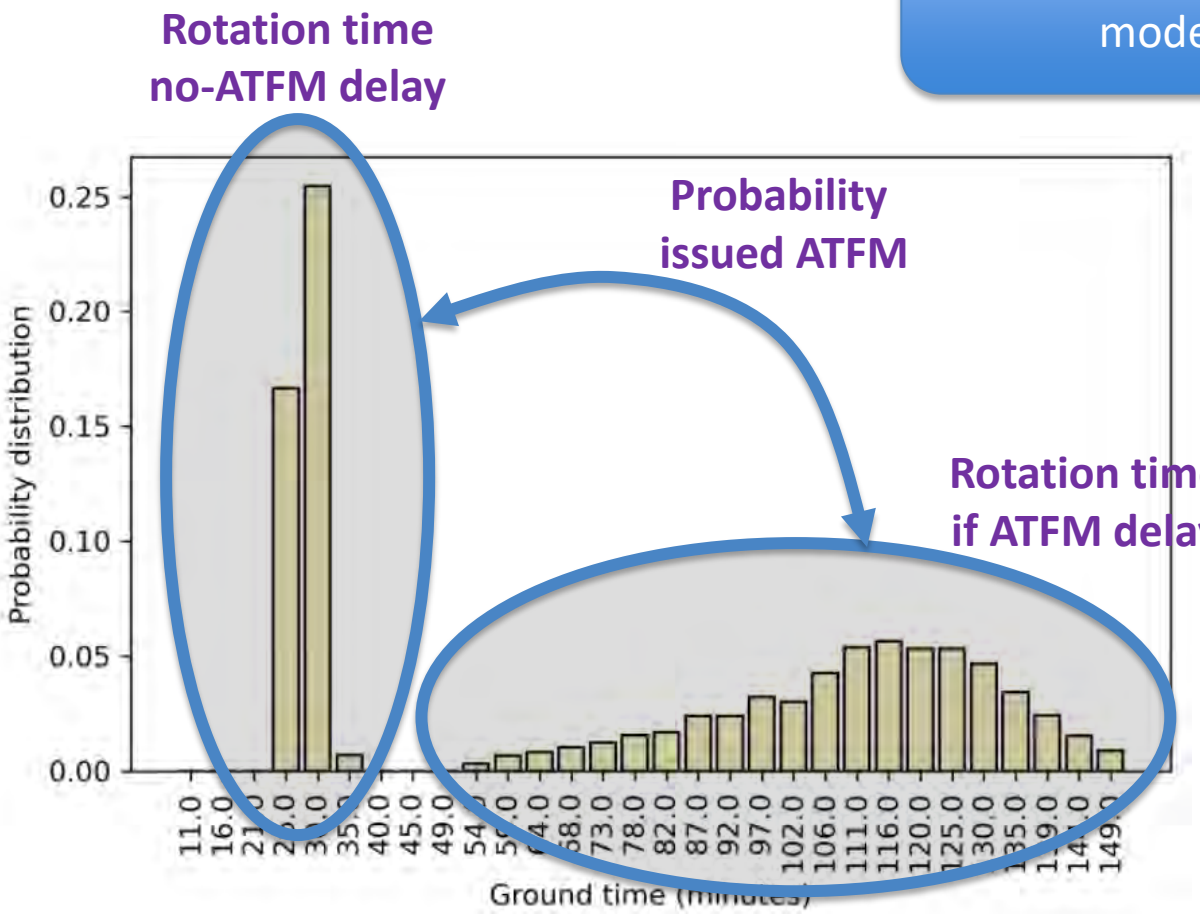
Generic
Fewer features
Air-available data

Pilot3 – Machine learning models

Challenges

3. Multi-model approach

Estimation of complex interactions integrating models



Propagation of errors across models?

Pilot3 – Machine learning models

Challenges

4. Visualisation – interpretability

Using predictions with uncertainties → How to present the information to users?

Pilot3 – Machine learning models

Challenges

5. Data!

Historical data at different prediction-horizons by different users?

How to extract information from data (features computation)?

Pilot3 – Conclusions

- Machine learning models in Pilot3
  - Used to compute cost function components
  - Used to estimate uncertainties that affect operations

- Challenges (most of them applicable to ATM in general)
  1. Need of distribution not only average expected value
  2. Prediction-horizon
  3. Multi-model approach
  4. Visualisation – interpretability
  5. Data!