Impact of EOBT Uncertainty on Airport Surface Congestion Management

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Motivation

- Airport surface congestion leads to increased taxi time, fuel burn & environmental impacts

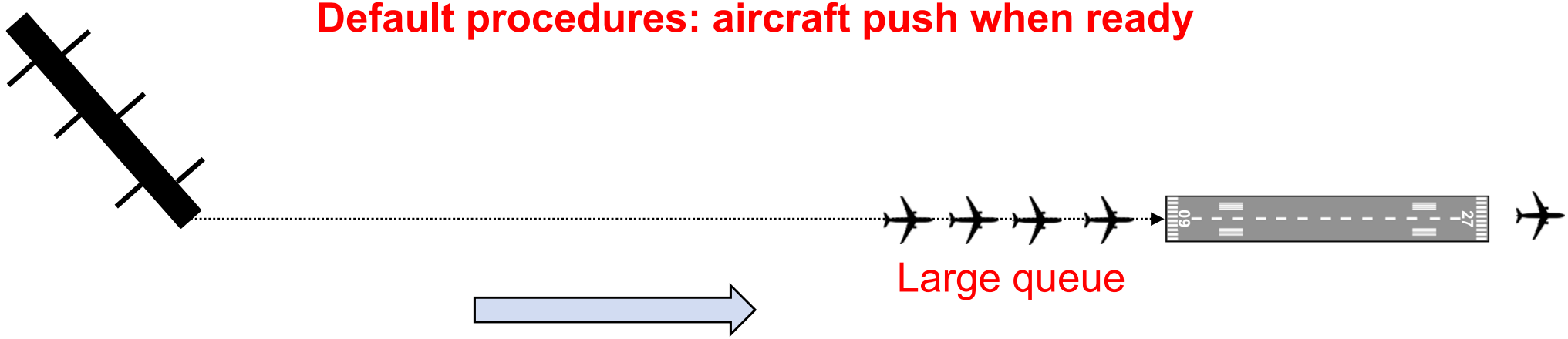
- Advanced automation systems are under development to reduce surface congestion
  - FAA Terminal Flight Data Manager (TFDM)
  - NASA Airspace Technology Demonstrator-2 (ATD-2)

- Effectiveness of systems depend on algorithm design and accuracy of key input data, e.g., Earliest Off-Block Time (EOBT)

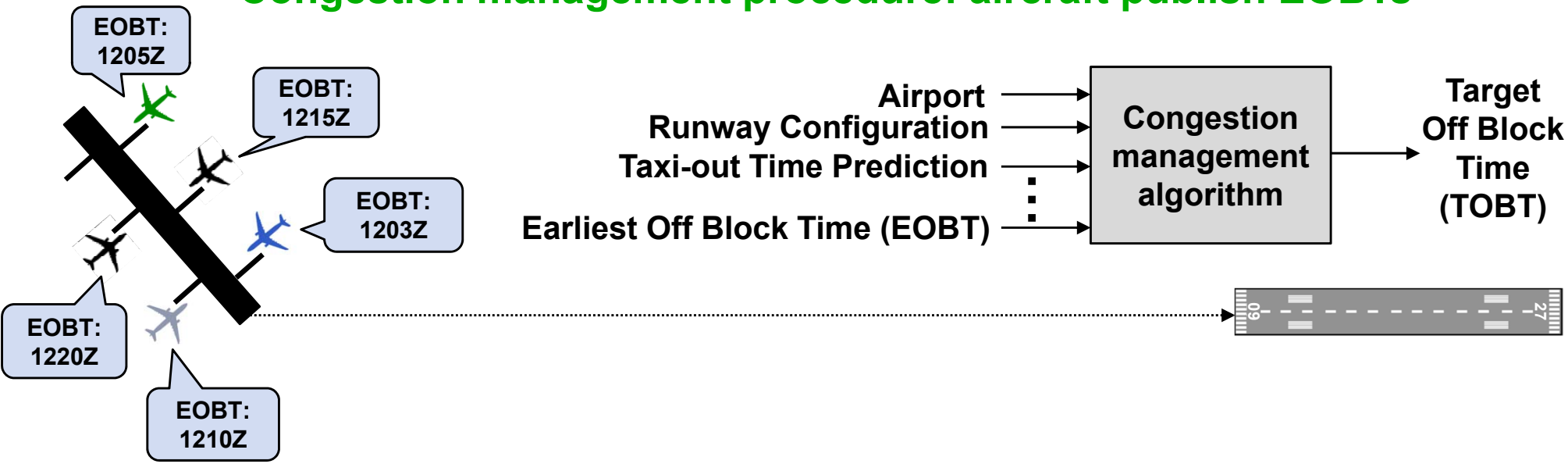
Need for analysis to understand relationship between automation system benefits and EOBT accuracy to inform future algorithm design and airline investments

Motivation

Default procedures: aircraft push when ready



Congestion management procedure: aircraft publish EOBTs



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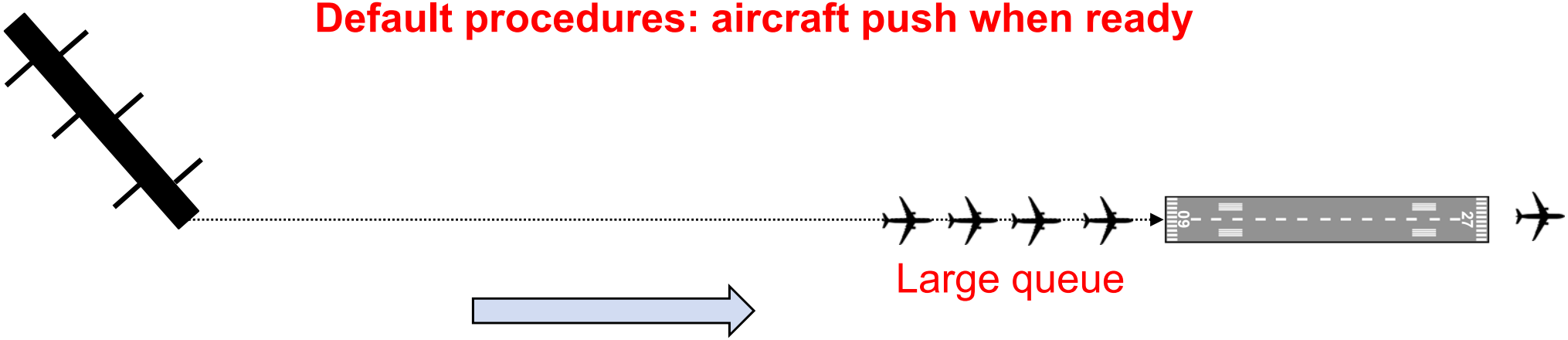

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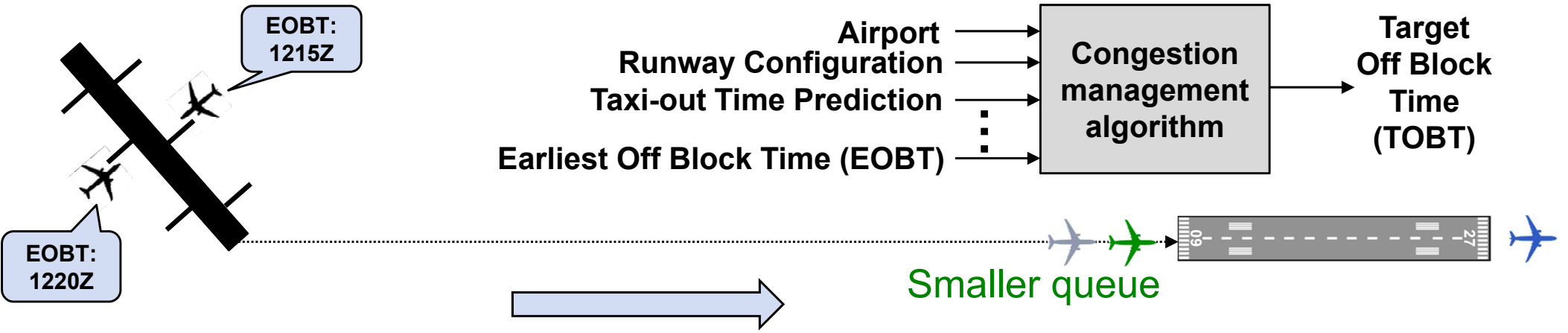

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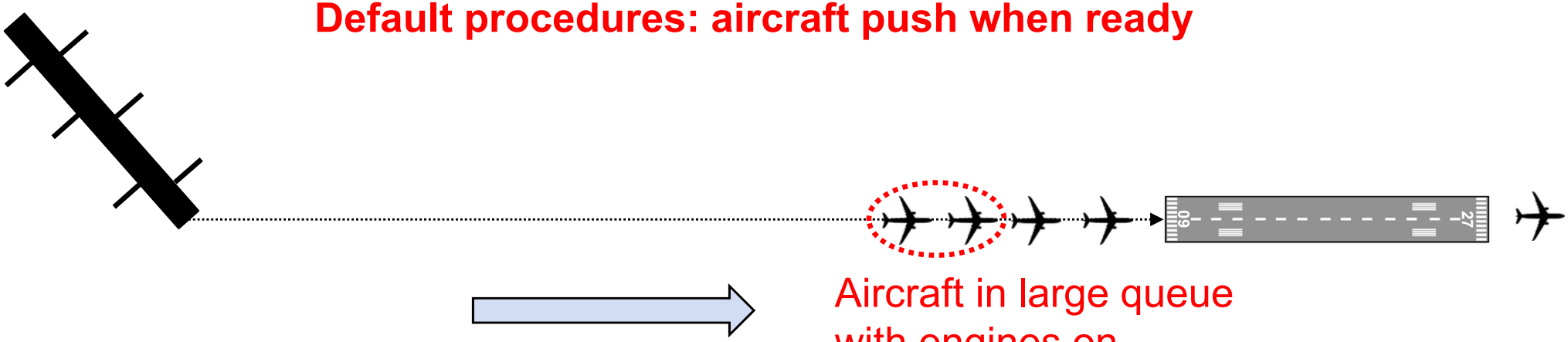
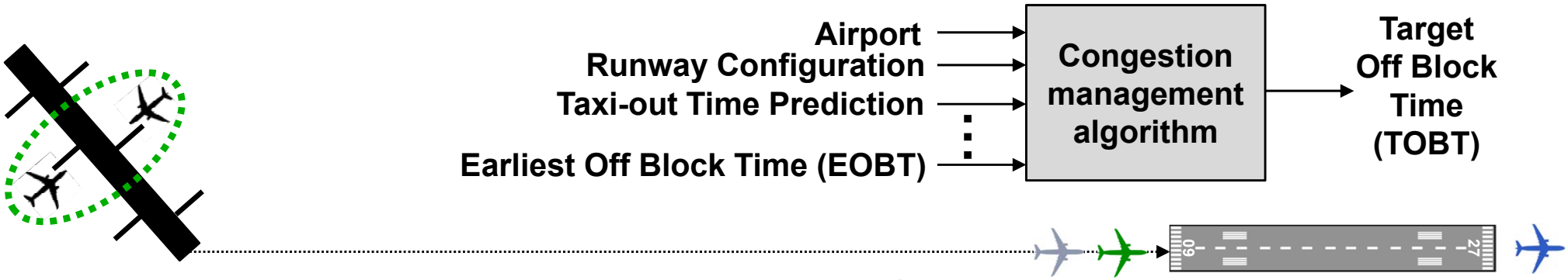


Aircraft in large queue
with engines on

Congestion management procedure: aircraft publish EOBTs



Aircraft held at gate
with engines off

Smaller queue

Outline

Need for analysis to understand relationship between automation system benefits and EOBT accuracy to inform future algorithm design and airline investments

- **Development and validation of queuing network models for surface operations at Charlotte (CLT)**
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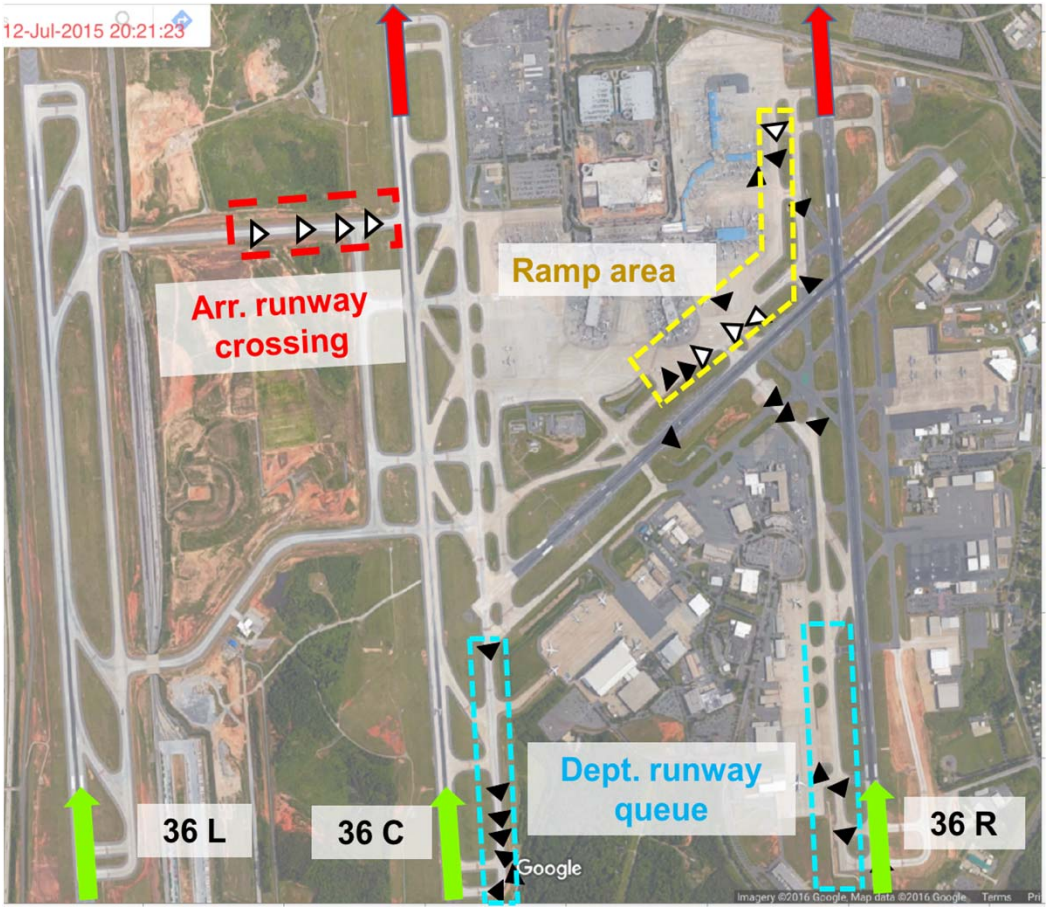
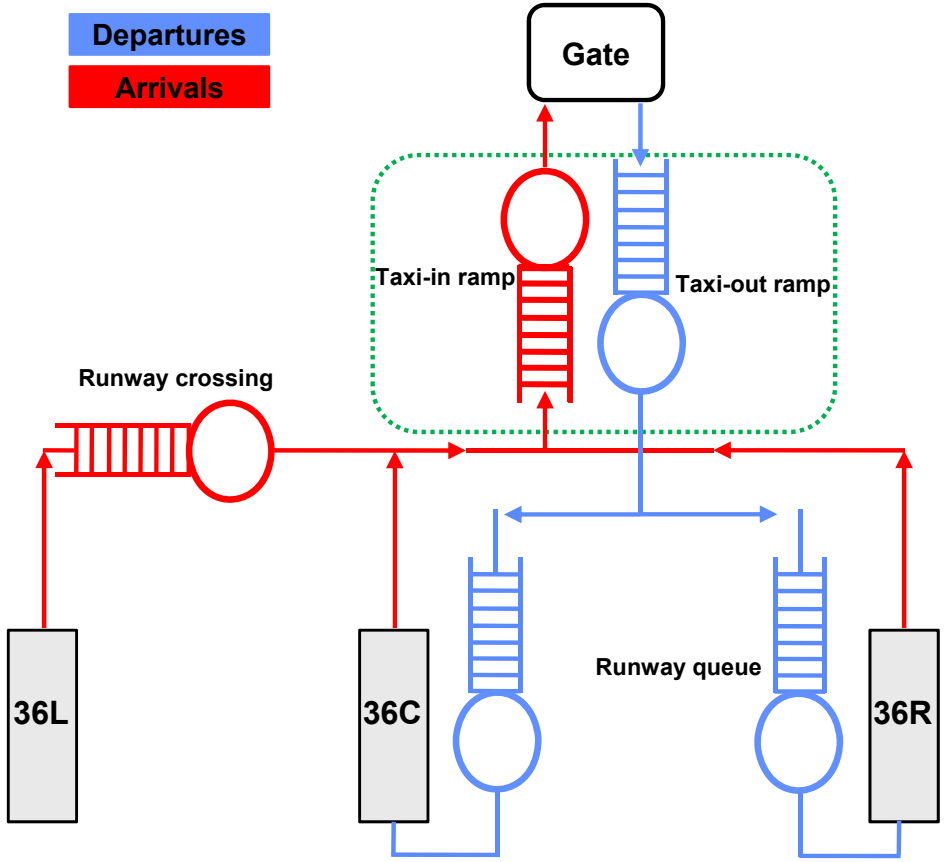
Queuing Network Model of CLT

- **Need queuing model to allow with/without surface congestion management comparisons**



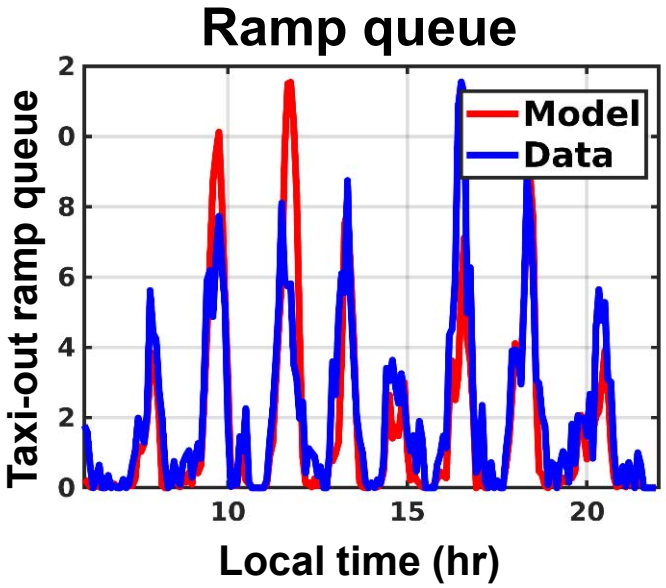
Charlotte airport layout

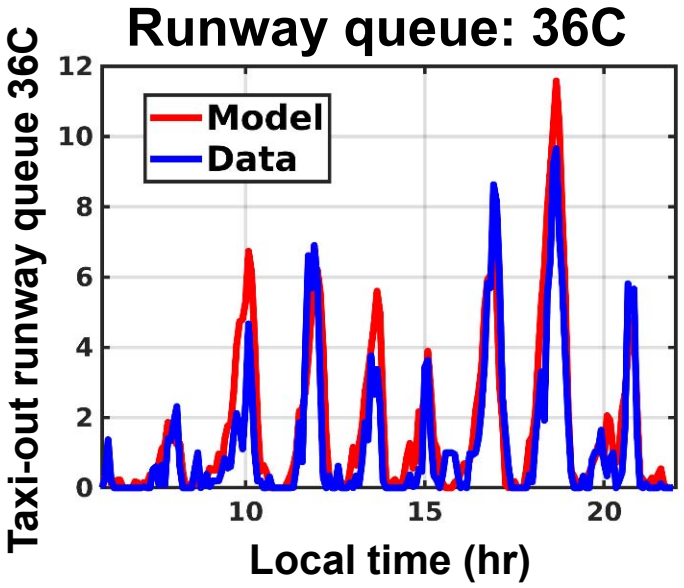


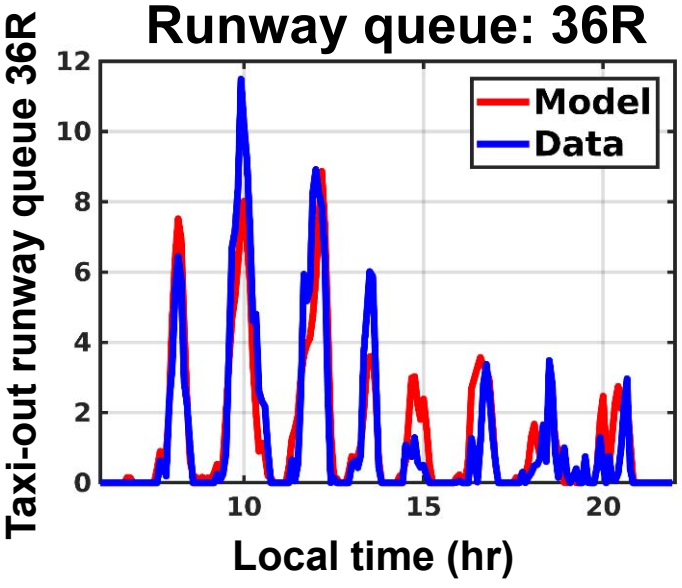
Queuing network representation

Model Validation: Typical Day

- Comparison between the model and data for a typical day (06/25/16)







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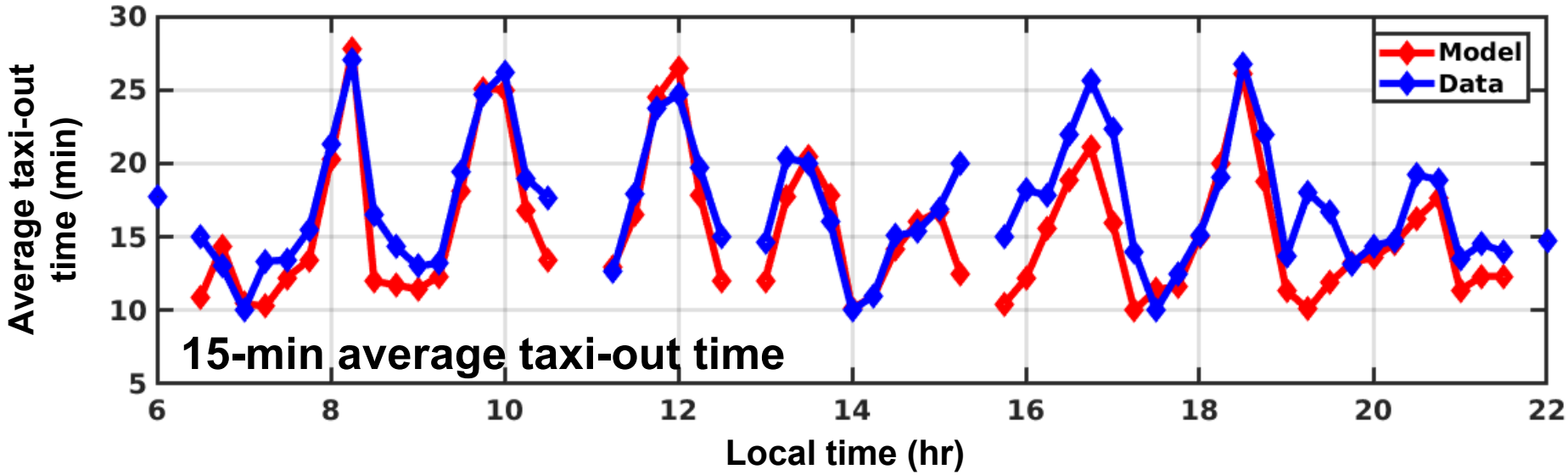
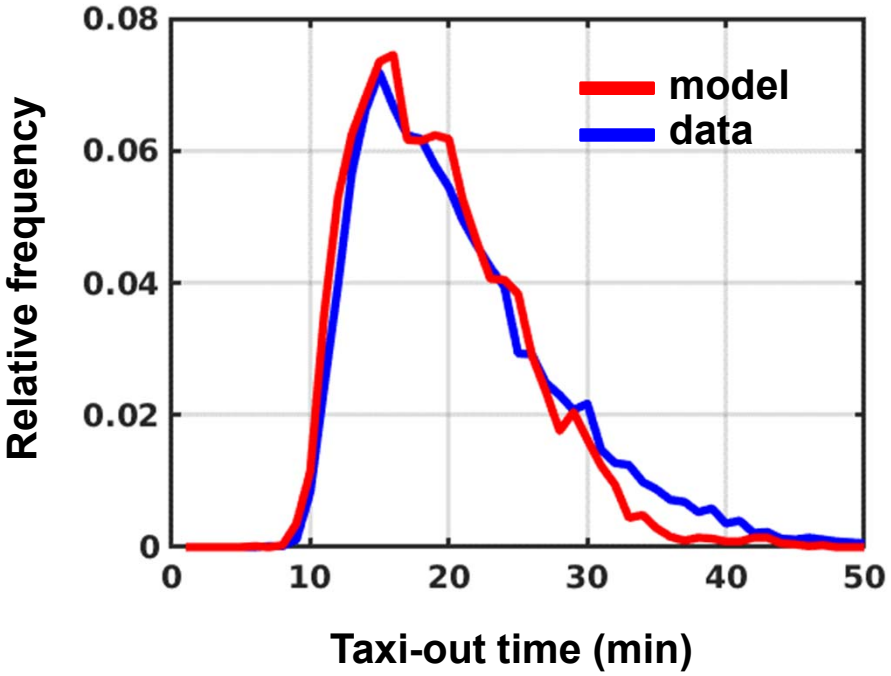


Model Validation: Aggregate Statistics

- **Error statistics on an independent test set: 7,484 departures, May/June 2016, CLT northflow**



Statistics (min)	Gate to spot	Spot to runway	Taxi-out
Mean values	9.68	10.40	20.09
Mean error	-0.87	-0.58	-1.45
Mean |error|	3.08	2.7	4.35
% flights with |error| < 5 mins	82%	86%	69%

- **Queuing network model can be adapted to other airports**
  - **Extended to DFW and EWR for this phase of the analysis**

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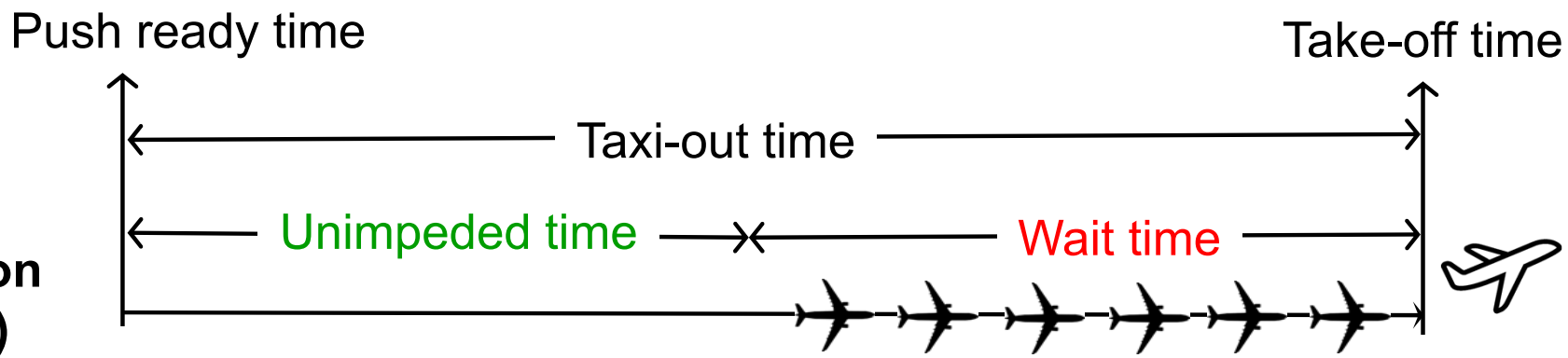
Congestion Management Algorithm: Ideal Case

(a) Default scenario (no congestion management)



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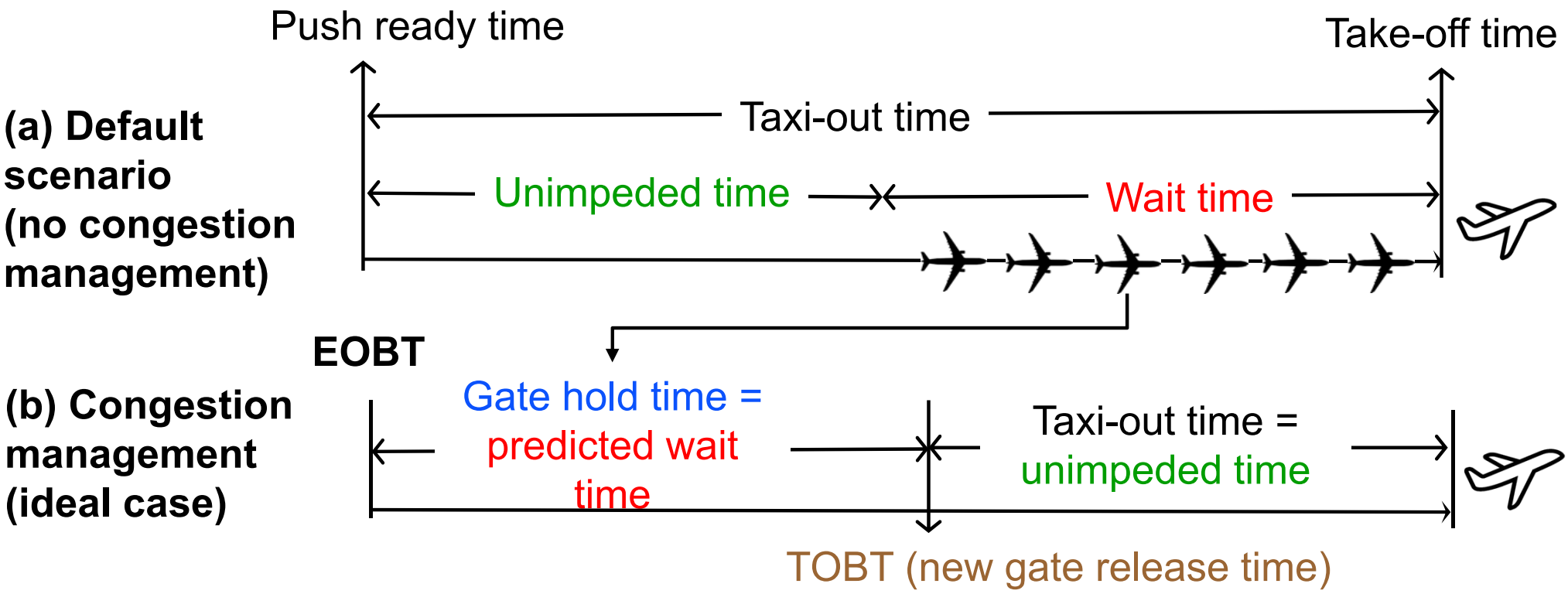
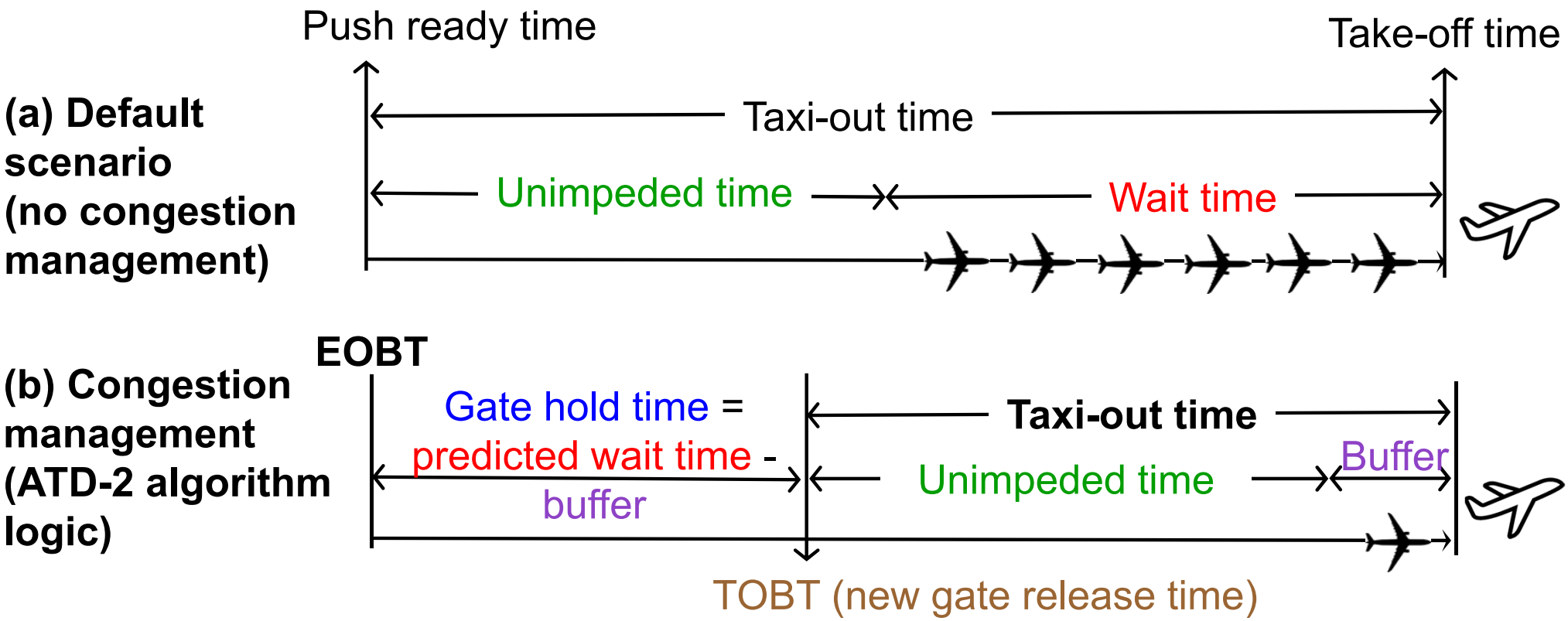


TOBT = Target Off Block Time

Congestion Management Algorithm: ATD-2 logic



- **Buffer parameter accounts for errors in taxi-out time prediction, EOBT and other sources, in order to avoid losing runway utilization**
- **ATD-2 logic: TOBT = EOBT + max(0, Predicted wait time – Buffer)**

EOBT = Earliest Off Block Time
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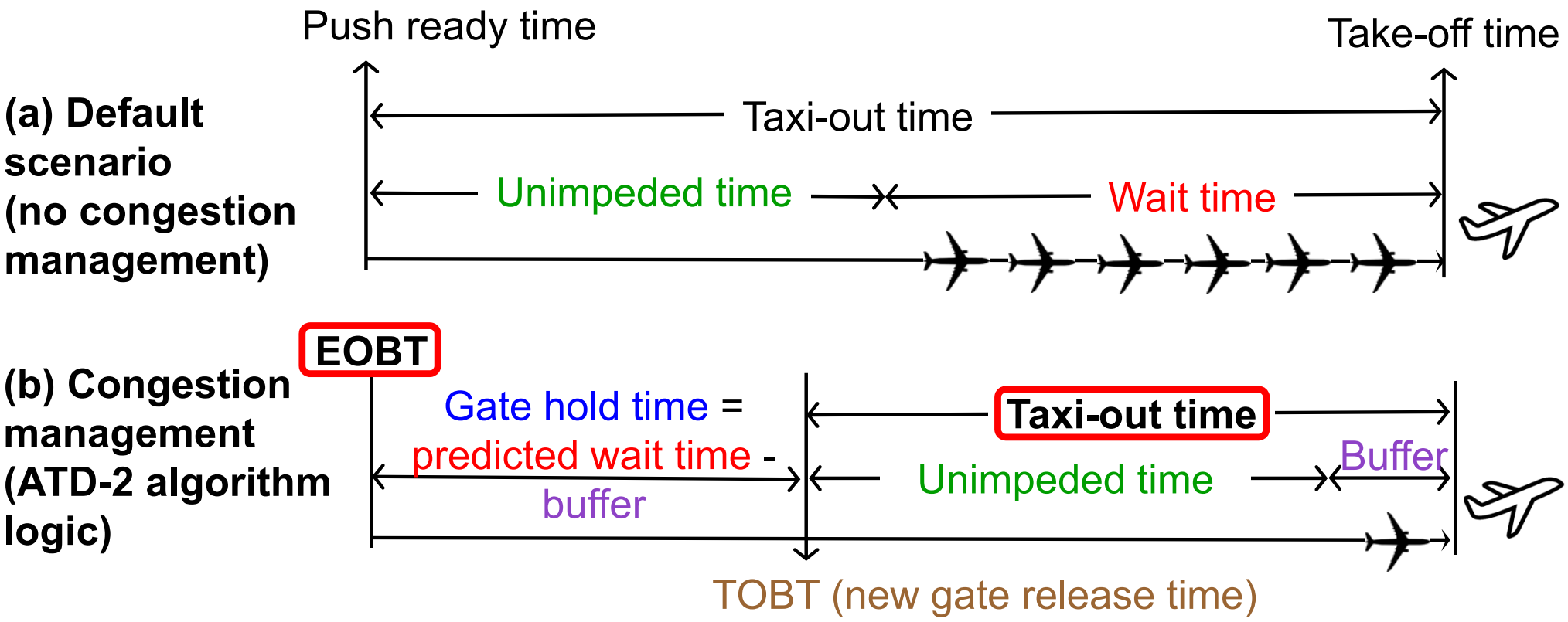
Congestion Management Algorithm: ATD-2 logic



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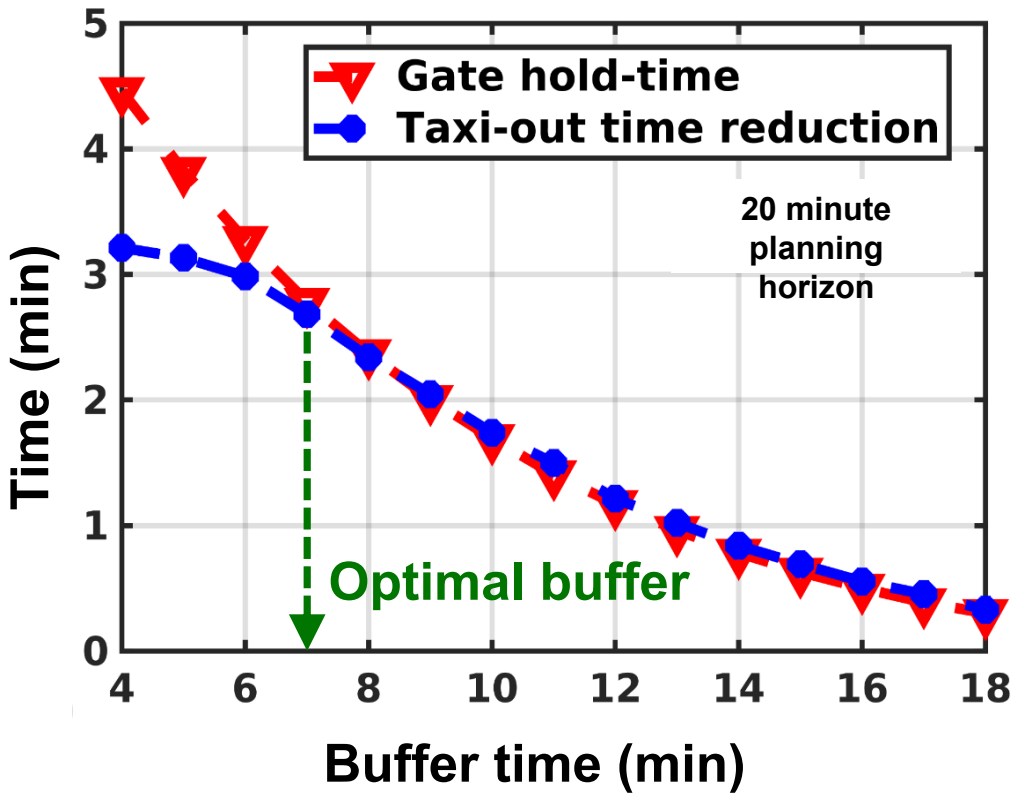
Congestion Management: Perfect EOBT information

- Departure metering logic tested using stochastic simulations
  - 6,447 departures over 15 day period at CLT
- Taxi-out time reduction depends on the choice of excess queue buffer (larger the buffer, lower the benefits)
- Optimal buffer is lowest value that ensures no loss in runway utilization
- Results with a planning horizon of 20 min



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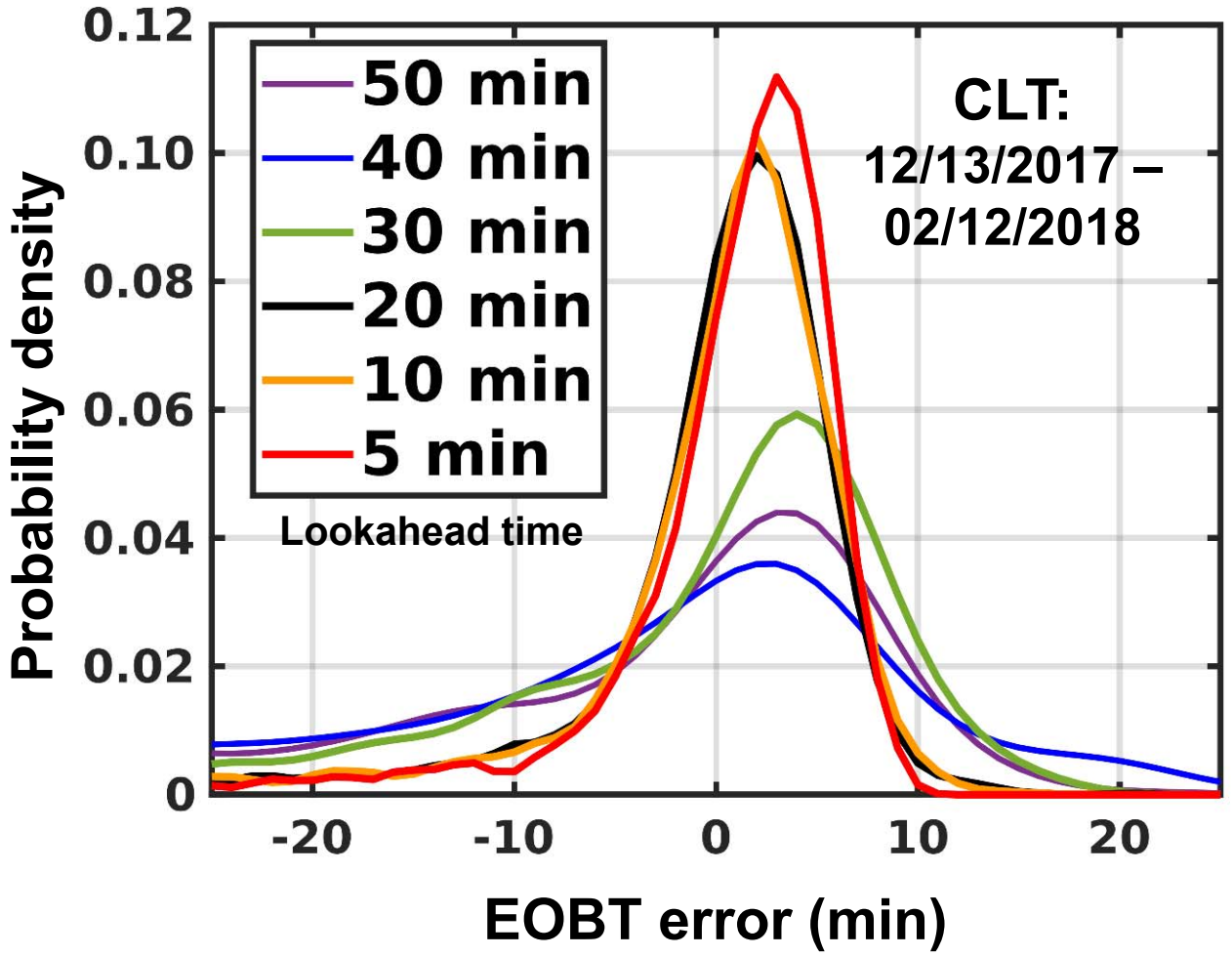
Evaluation of Empirical EOBT Uncertainty

- Many airlines publish EOBT data through TFMS feed
  - EOBT messages from a major airline shown here
- EOBT error(t) = EOBT(t) – AOBT
- EOBT error varies for different look-ahead times



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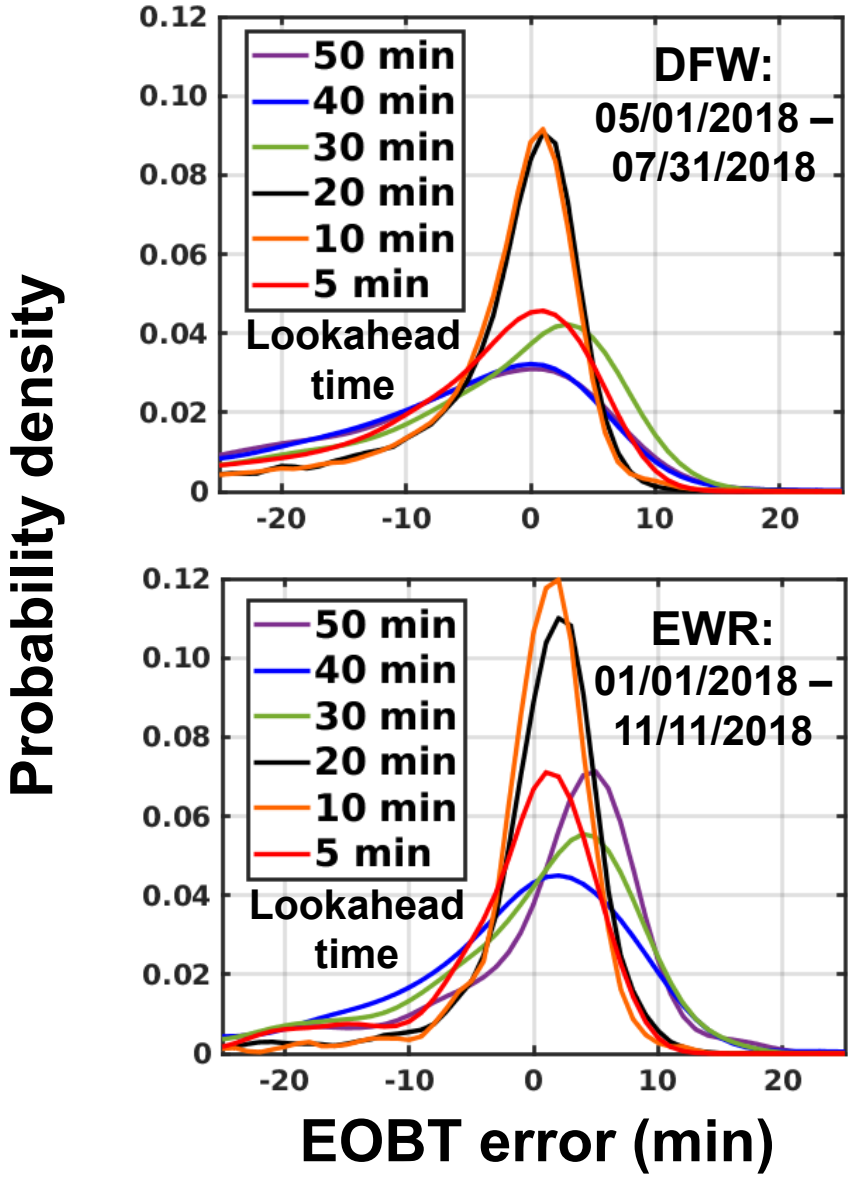

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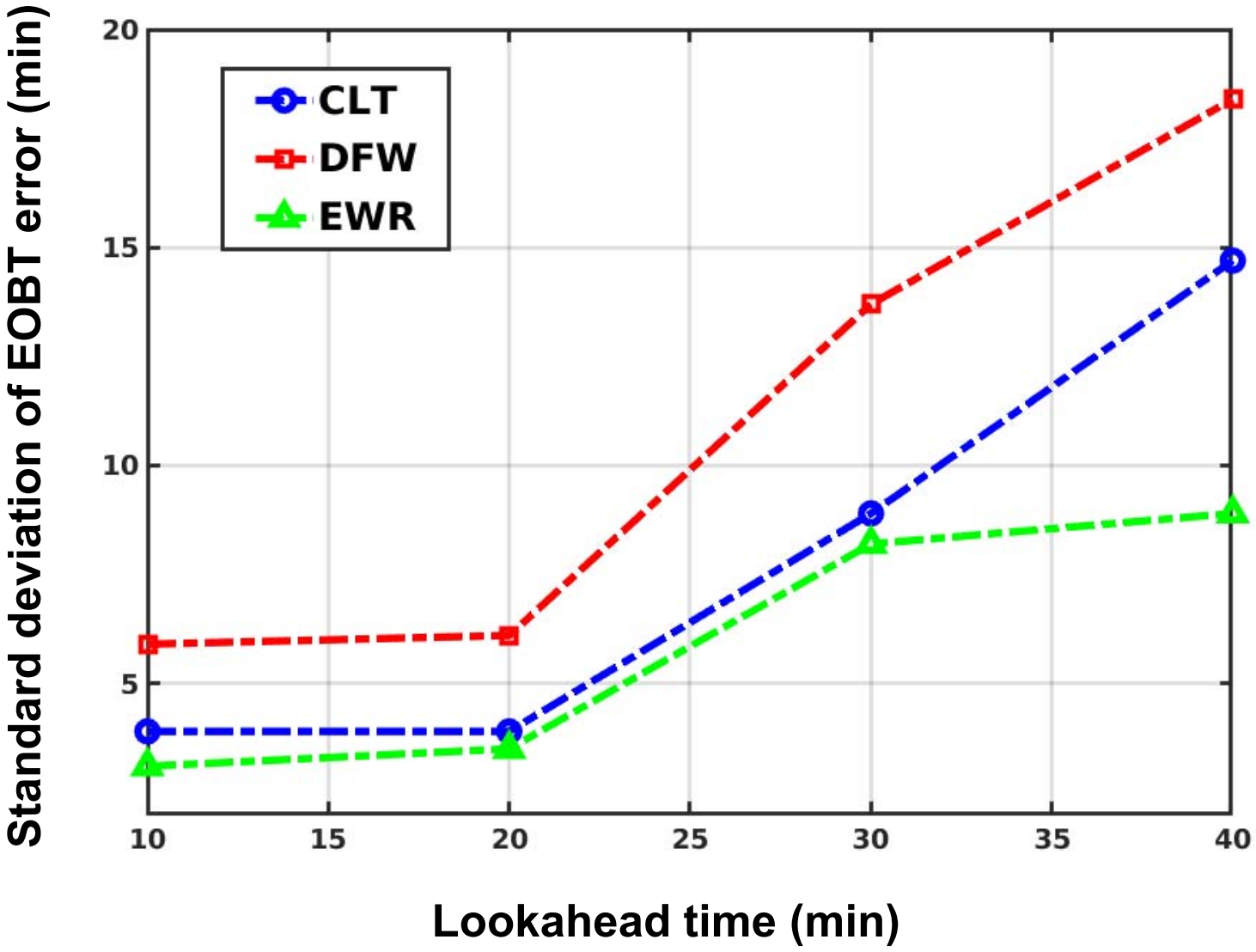
Evaluation of EOBT Uncertainty Summary Results



- CLT: 12/13/2017 – 02/12/2018
- DFW: 05/01/2018 – 07/31/2018
- EWR: 01/01/2018 – 11/11/2018

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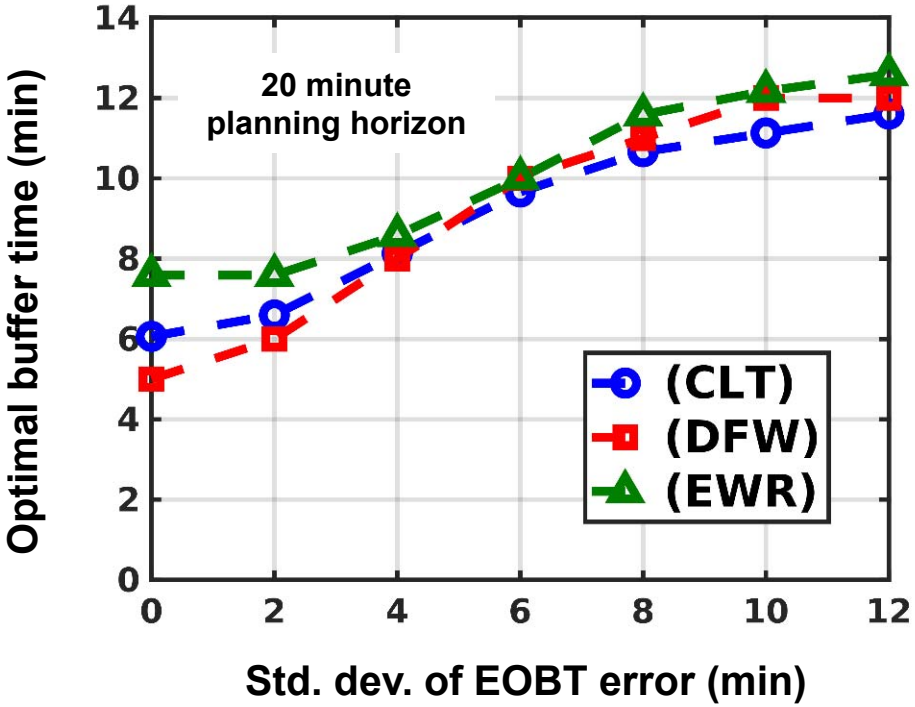
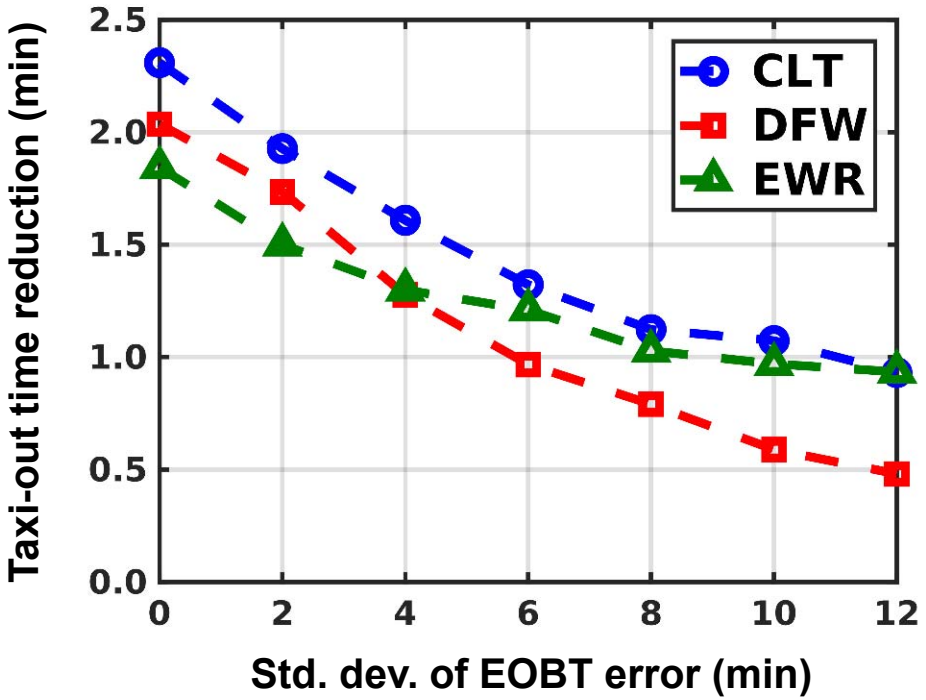
Congestion Management in the Presence of EOBT Uncertainty

- EOBT uncertainty impacts congestion management because of
  - Reduced prediction accuracy of taxi-out times
  - Non-conformance to the target pushback time
- Need to increase excess queue buffer parameter to account for uncertainties and to maintain runway utilization





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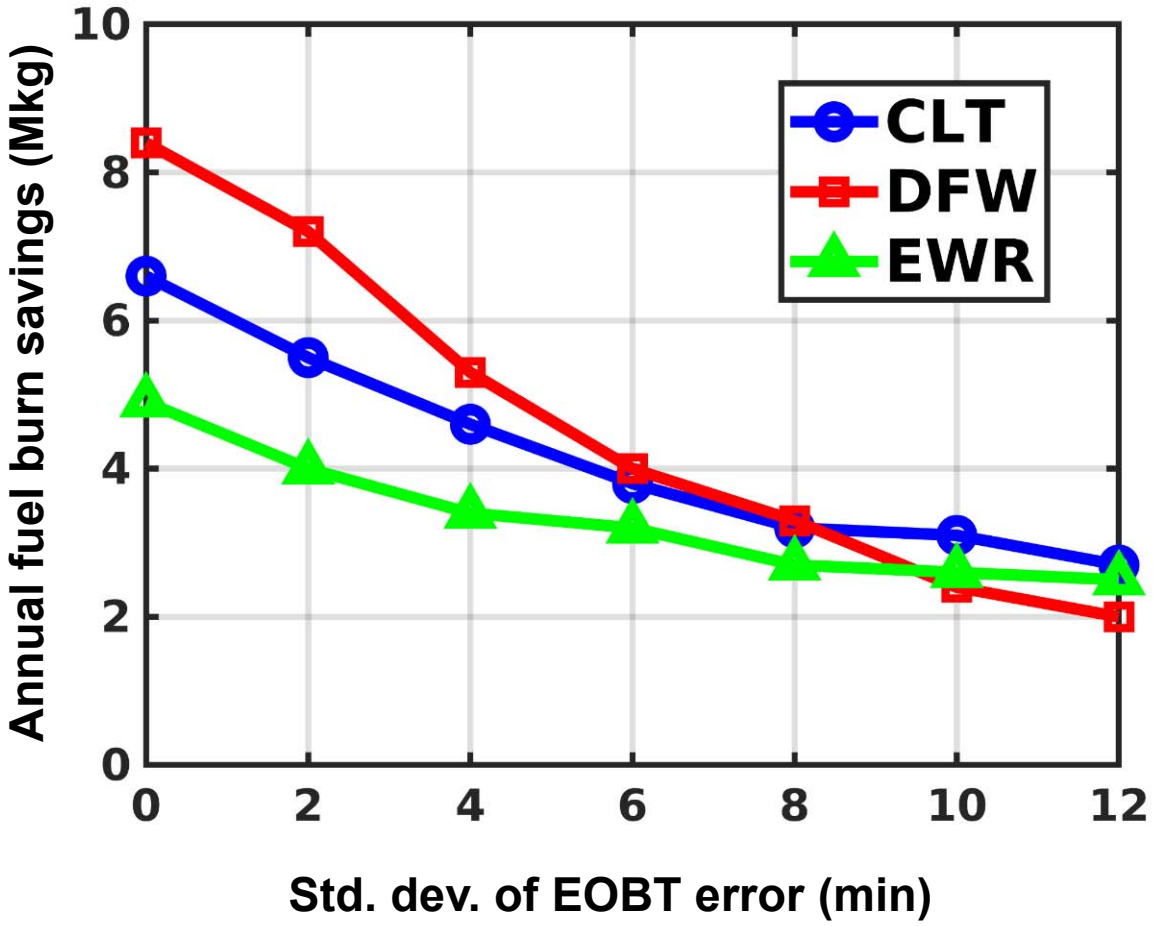

Taxi-out time & fuel benefits decrease as EOBT error increases

Summary

- Surface congestion management automation systems will enable fuel and emissions reductions
- Analysis presented to understand relationship between automation system benefits and input data (esp. EOBT) accuracy
- Informs future algorithm design and airline investment decisions

- Recommended next steps
  - Extend analysis to broader range of airports and operating conditions
  - Analyze incentives for airlines to improve the accuracy of EOBT data
  - Develop and evaluate surface congestion algorithms that can
    - Explicitly handle uncertainties
    - Account for uncertainties in arrival times, in addition to EOBT uncertainties

Disclaimer