MIT International Center for Air Transportation

Using Milestone Predictions to Enhance the Efficiency of Ground Operations

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- **Research context: Departure Planner (DP) project in MIT-ICAT**
  - ☐ Goal of DP: Improve departure process at congested airports
  - ☐ Task: Investigate design/implementation of ATC decision-aiding tools
- **Related work: NASA AATT SMS in FAA's FFP2**

  (Advanced Air Transportation Technologies, Surface Management System)
  - ☐ Data integration – traffic demand (pushbacks), runway config, etc.
  - ☐ Predict – queues, delays, congestion
  - ☐ Support/optimize – scheduling, sequencing, coordination, etc.
- **Big blind-spots for surface traffic decision-aids:**
  - ☐ A/C on surface ~ hence multilateration research
  - ☐ Tactical airline plans ~ pushback predictions and dep demand!
- **SMS development has workarounds:**
  - ☐ Uses FAA's SafeFlight 21 surface surveillance prototype
  - ☐ Test-partner with FedEx in Memphis

More about Airlines: Barriers to Dep Demand Updates

- **Principal passenger airline product: LOGISTICS**

  Airlines are *NOT* in the business of flying planes.

  - ☐ "Marketing": Demand analysis and methods to capture market share
  - ☐ "Engineering": Creation of good schedule
  - ☐ "Production": Maintenance of good schedule

- **Strategic decisions are *competitive*.**
  Marketing and scheduling are proprietary business products.

- **Tactical ("Production") decisions are often *collaborative*.**
  BUT… good pushback predictions require investment $$$

  - ☐ Automatic monitoring of turn op's
  - ☐ Optimize business processes
  - ☐ Acceptance in corporate culture
  - ☐ What is the payoff of good dep demand updates?

- **Sometimes good info can have unexpected consequences!**

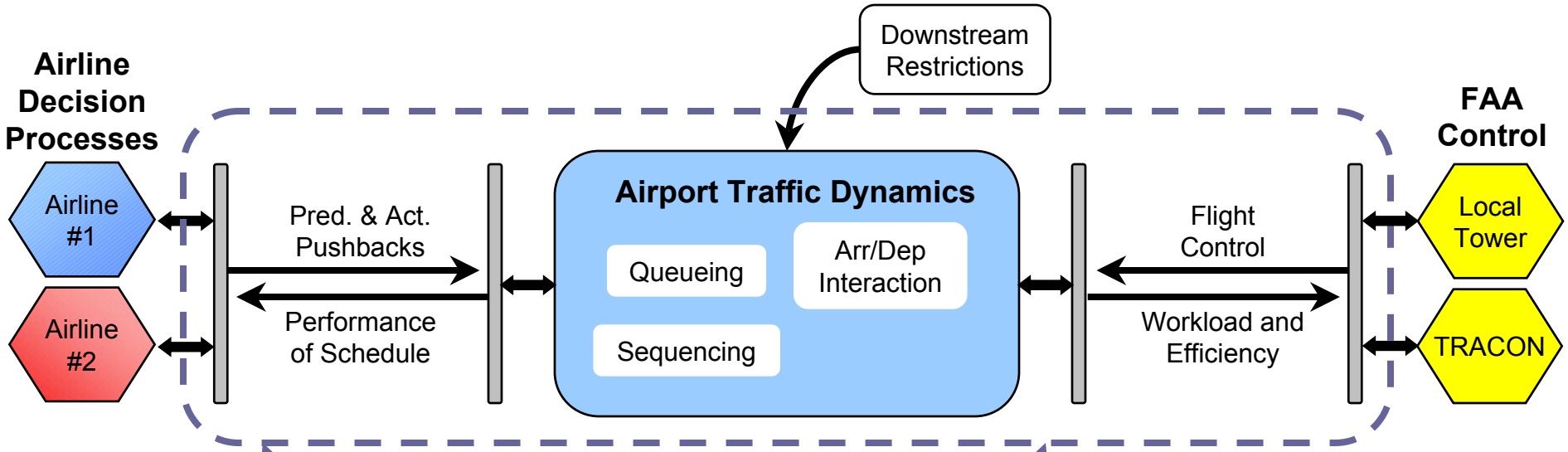
Research Approaches

- **Model the tactical airline decision process(es)?**
  - ☐ Multiple *competing* objectives
    Decrease minimum turn-time. Reliable connections.
    Prioritize "important" flights. Minimize taxi delays. …
  - ☐ Information sources?
    Many sources available to SOC, very few available to automation
  - ☐ Variety of control options
    Cancel. Delay. Swap. Re-route. Re-book. …
- **Develop an interface? Decision-aiding tool ⇔ Airlines**
  - ☐ Structure of interface? (Inputs and outputs)
  - ☐ Coping with uncertainty?
  - ☐ How to measure performance?
  - ☐ Maintain competition, protect business data, AND allow collaboration?
- **Suggestions welcomed during break-period ☺**

Managing Uncertainty In Airport Surface Traffic

How much uncertainty is due to…

Complex dynamics? Mismatched plans (Airline to Airline to FAA)? Murphy's Law?



- **Develop** *JOINT FORECASTING CAPABILITY*
  - ☐ All players share plans with a trusted *forecasting service.*
  - ☐ Good plans enable model-based system simulation.
  - ☐ Close the loop: Forecaster shares estimated performance *but not the plans!*
- **Quantify the initial-investment tradeoff:**

  (Costs of high-quality planning) vs. (Benefits of accurate forecasting)

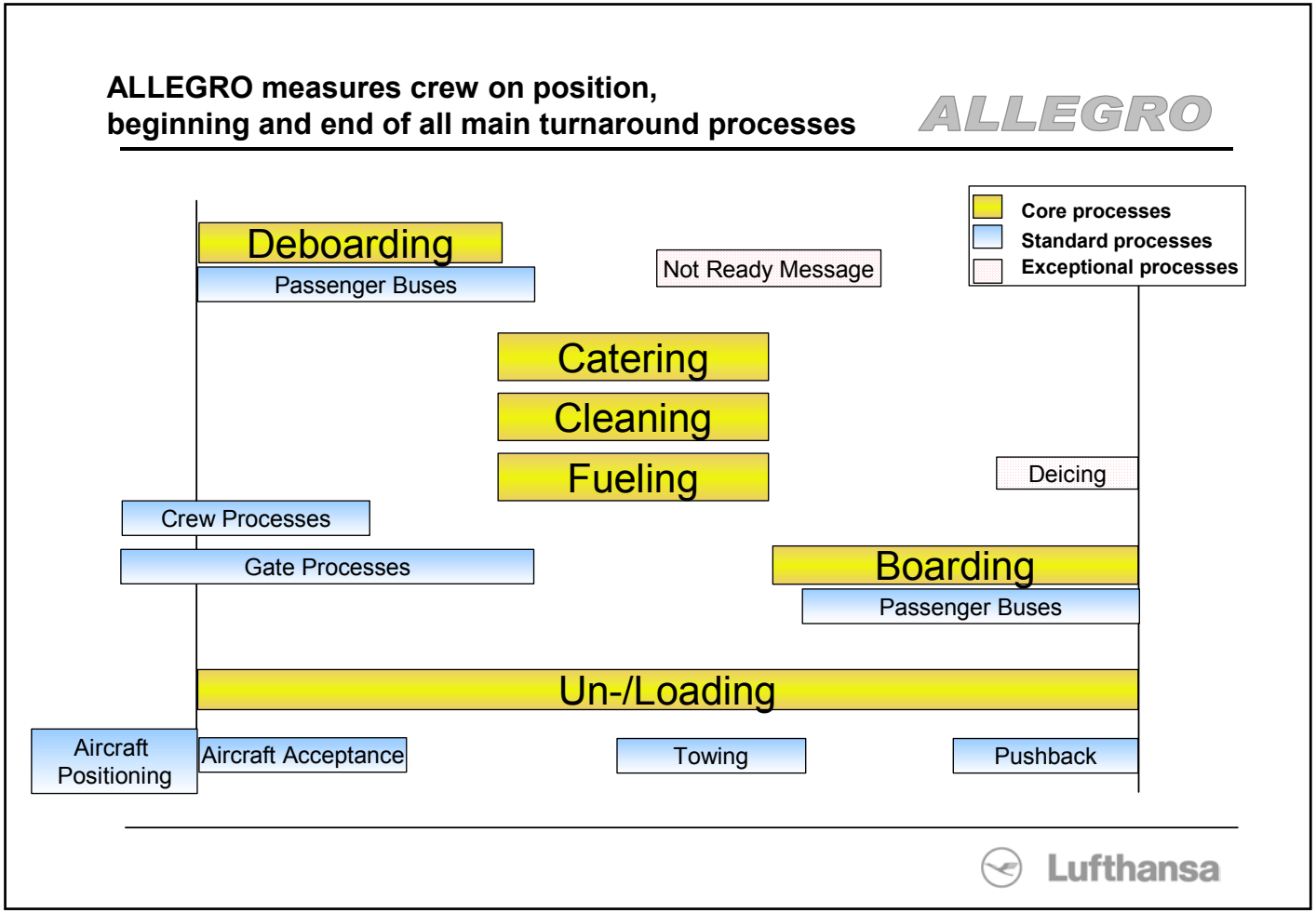
Out in Front:
Lufthansa Airlines and ALLEGRO

- **1999 – Lufthansa Airlines initiates "*Operational Excellence*"**
  Goal: Improved punctuality (dep within 15min of sched)

- **ALLEGRO sub-project focuses on monitoring/scheduling**
  - ☐ Aggregation of turn op's monitoring
    - o Involves airline, service contractors, airport authority, …
  - ☐ Fine-tune business processes
    - o Develop/maintain feasible target-times
    - o Re-negotiate timing/processes with service contractors
  - ☐ Acceptance in corporate culture

- **Continued benefits**
  - ☐ Increased punctuality (70% in 1999 to 85%+ currently – best in Europe)
  - ☐ Improved processes (cost-saving opportunities)
  - ☐ Fewer analysts using better data
  - ☐ Other airlines trying to develop similar programs
  - ☐ … *AMAZING* research opportunity!

Available Data



Source (translated): Theis, G. (2002) Telematik Anwendungen im Luftverkehr, *Internationales Verkehrswesen,* **54**(5), 225-228.

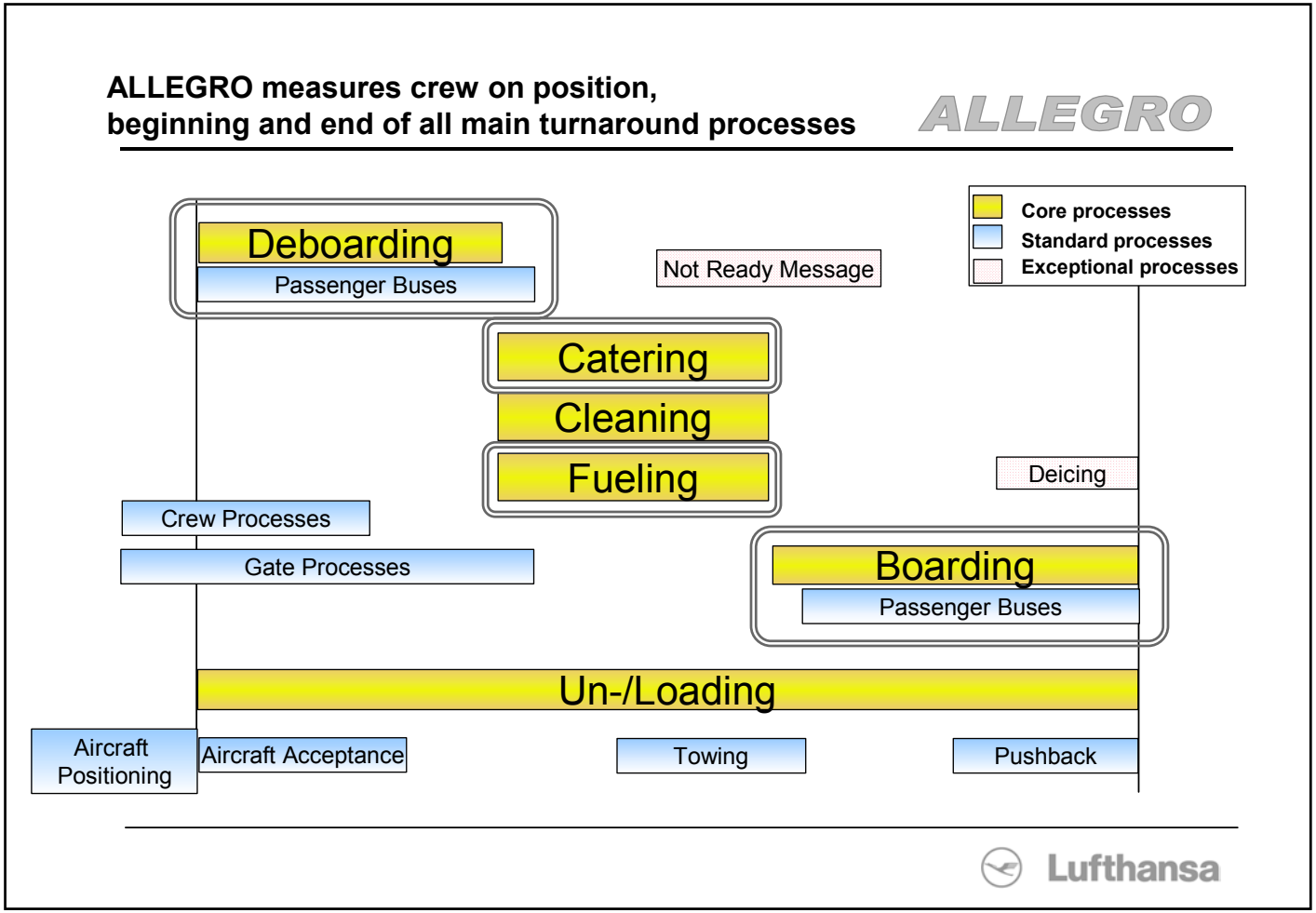
See also: http://www.fraport.com/online/general/en/download/presentation_220802.pdf, 12-13

Preliminary Results

- **Uncertainty in airline turn process has *significant lower bound*.**
  - ☐ Filtered out subset of turns with *minimum* uncertainty:
    - o No towing or delay codes.
    - o Similar aircraft types.
    - o Similar pax-loading equipment.
    - o Minimal ground-time (fast turns are well-controlled).

- **Techniques for *real-time* prediction of offblock (EOFF)**
  - ☐ Stochastic approximation techniques:
    - o Can be calibrated with available data (“curse of dimensionality”)
    - o Give valuable *bounds* (error-bars) on the prediction

Available Data



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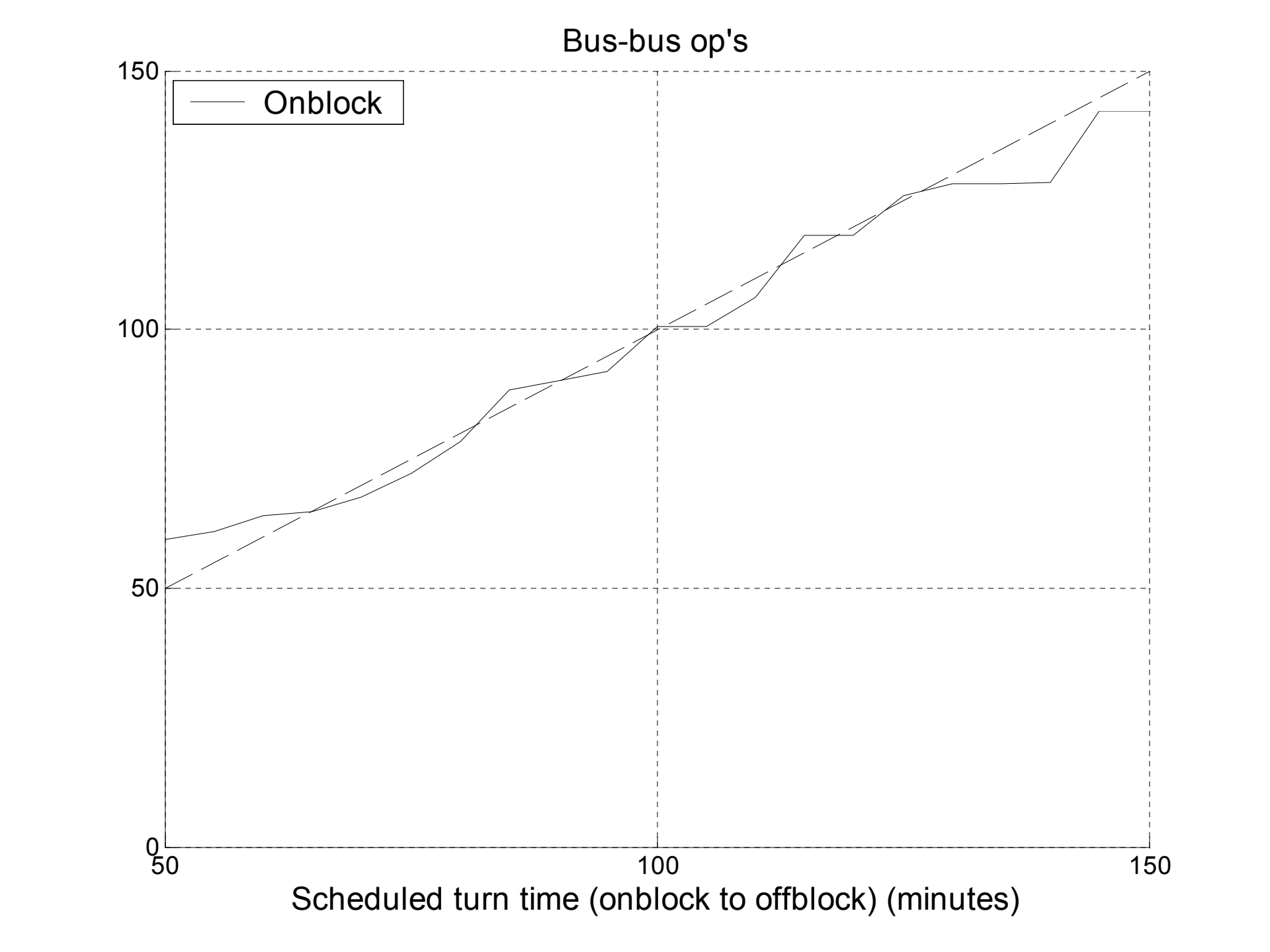
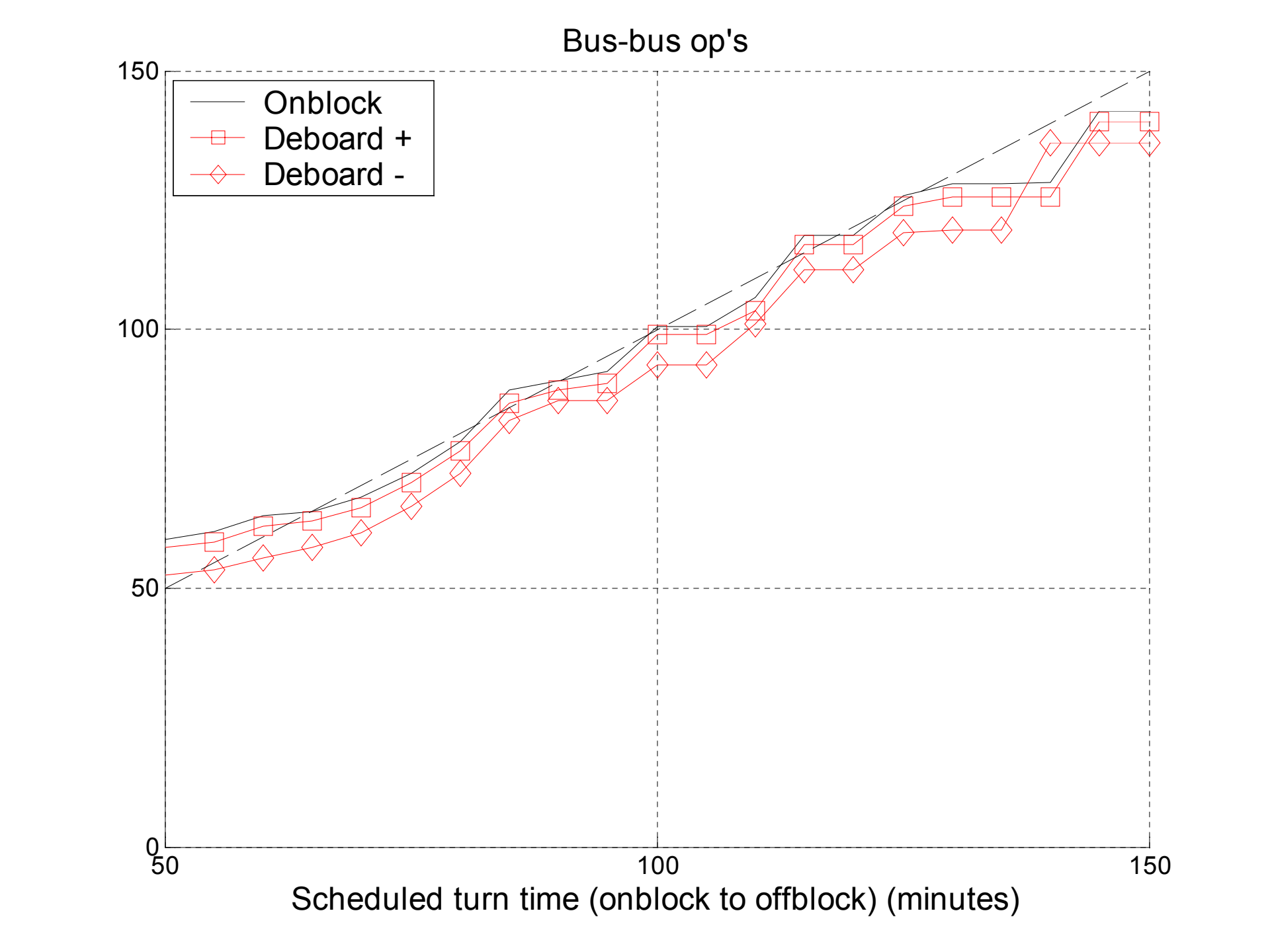
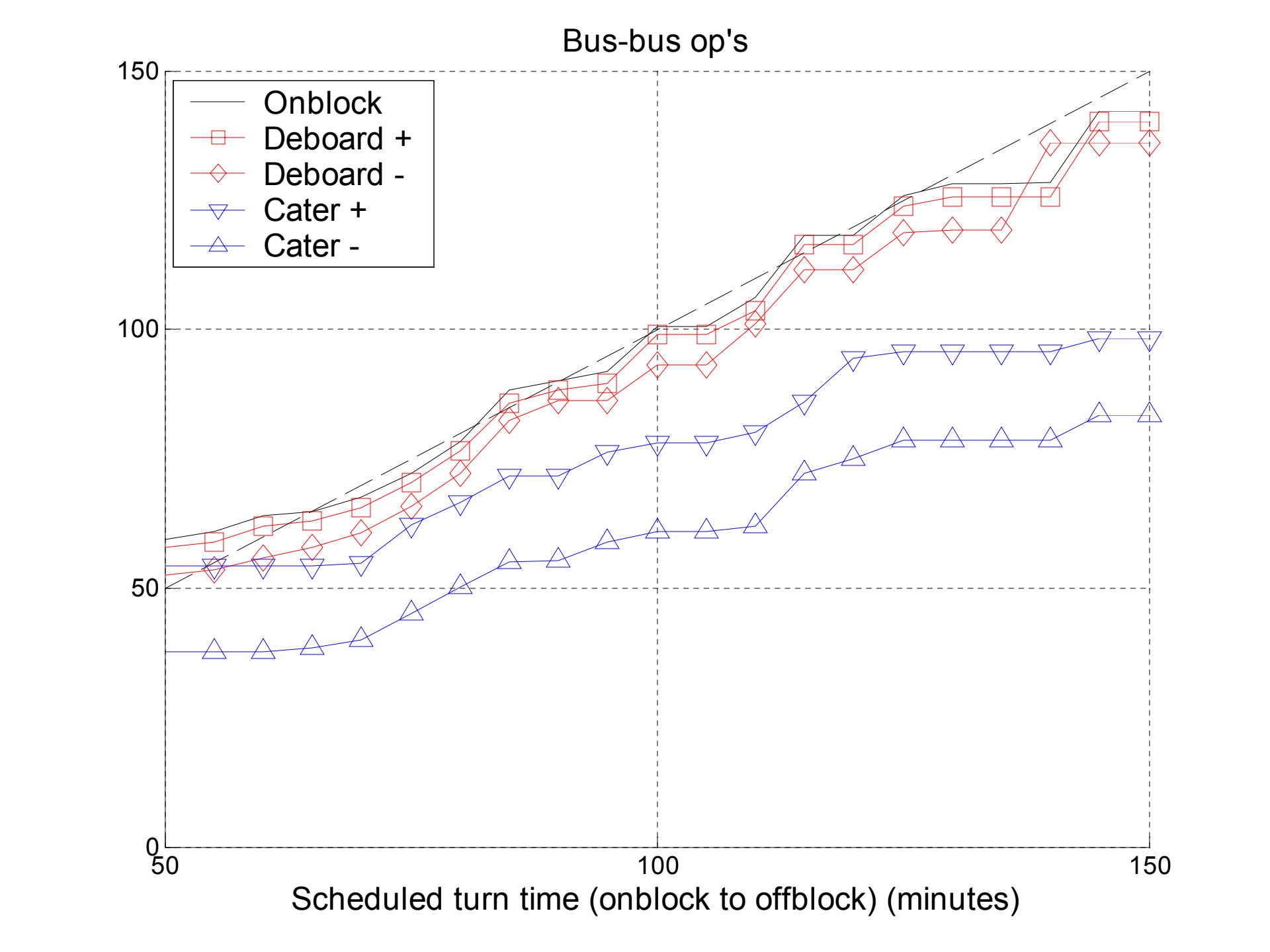
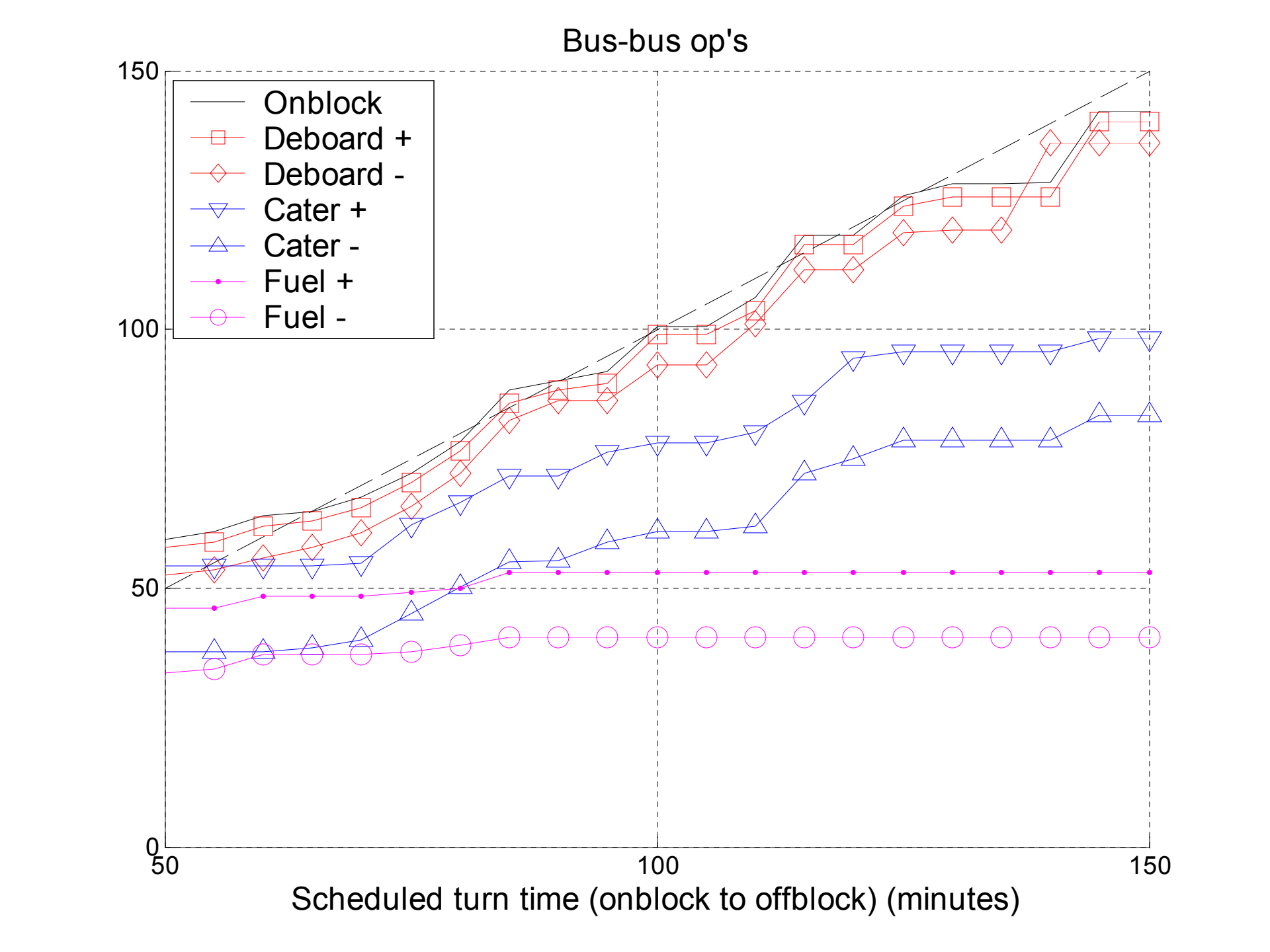
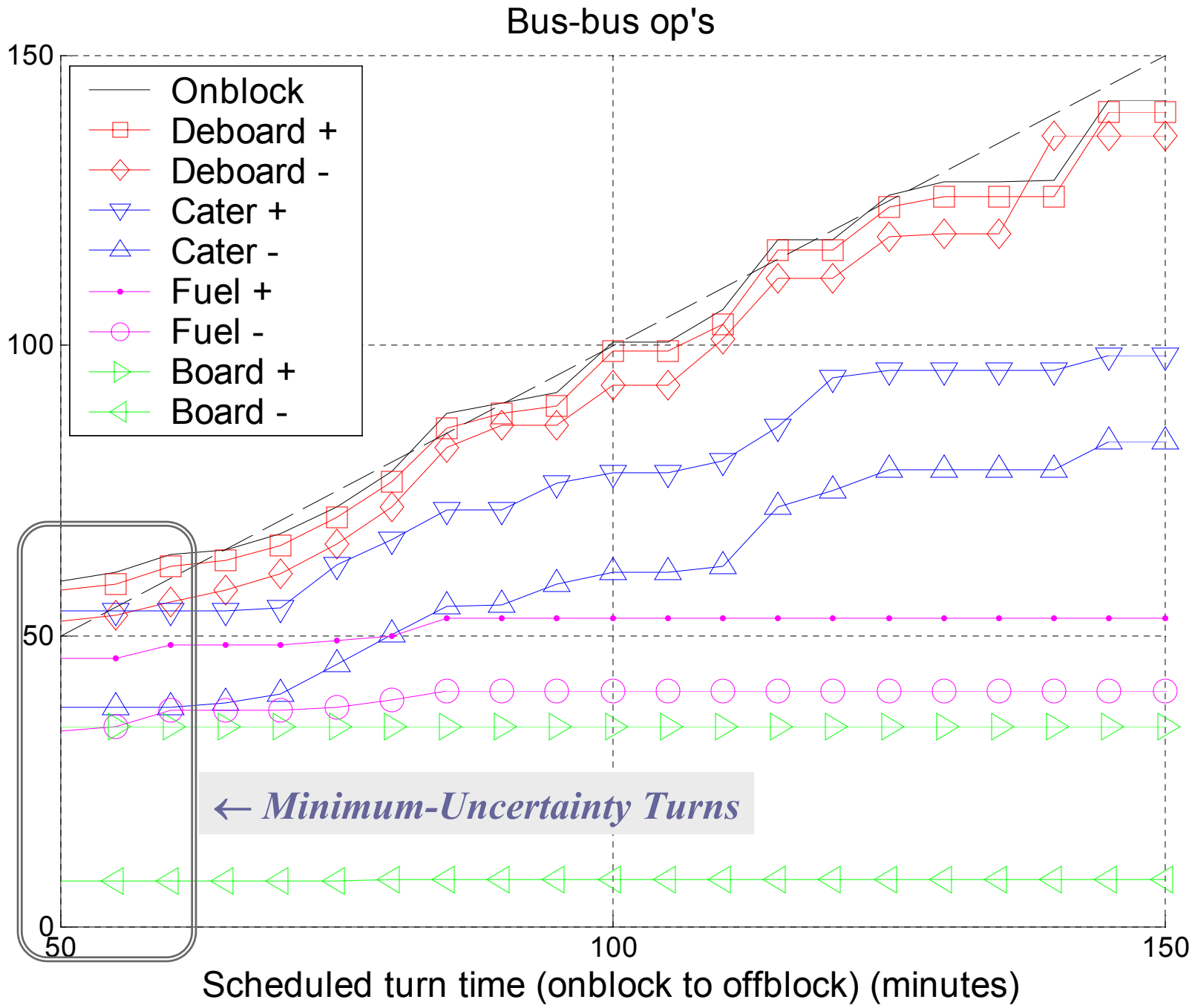

Bus-bus op's
Onblock
150
100
50
0
50
100
150
Scheduled turn time (onblock to offblock) (minutes)

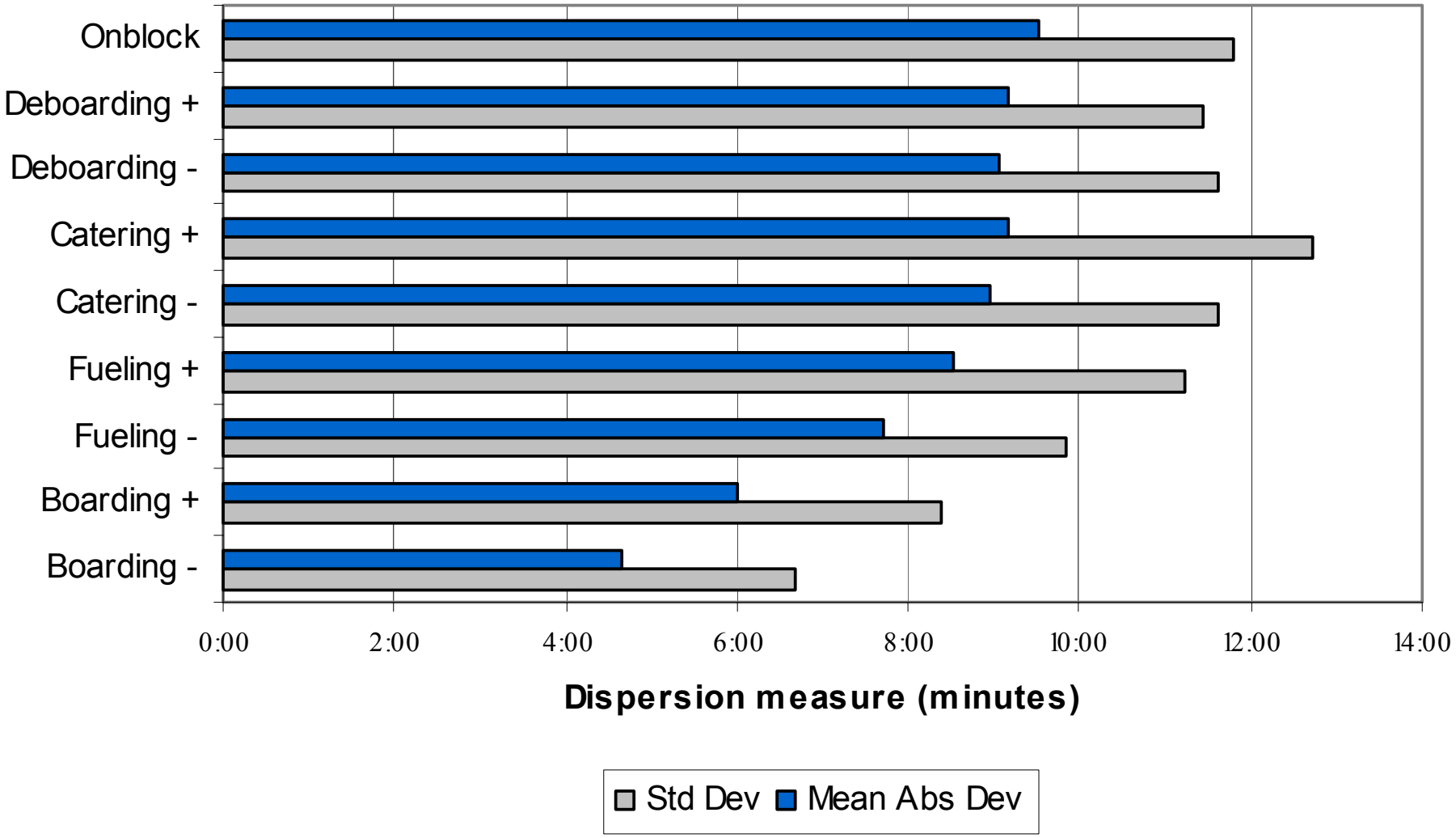

Bus-bus op's
Onblock
Deboard +
Deboard -
150
100
50
0
50
100
150
Scheduled turn time (onblock to offblock) (minutes)


Bus-bus op's
Onblock
Deboard +
Deboard -
Cater +
Cater -
150
100
50
0
50
100
150
Scheduled turn time (onblock to offblock) (minutes)


Bus-bus op's
Onblock
Deboard +
Deboard -
Cater +
Cater -
Fuel +
Fuel -
150
100
50
0
50
100
150
Scheduled turn time (onblock to offblock) (minutes)


Bus-bus op's
Onblock
Deboard +
Deboard -
Cater +
Cater -
Fuel +
Fuel -
Board +
Board -
150
100
50
0
50
100
150
← Minimum-Uncertainty Turns
Scheduled turn time (onblock to offblock) (minutes)

Inherent Uncertainty



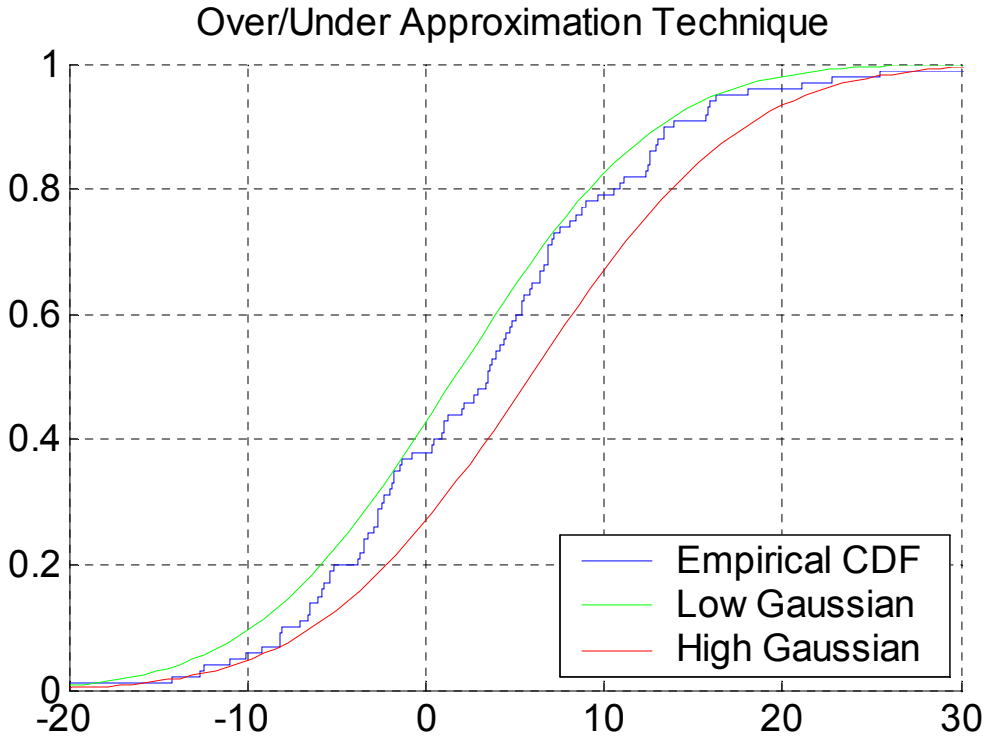
Pushback Prediction

- **Question:**
  Can EOFF be estimated (with uncertainty bounds!) from real-time process observations?

- **Problems:**
  - ☐ Stochastic dependencies
    - o Correlation of (start-delay) and (end-delay)
    - o Correlation between scheduled and actual duration
  - ☐ High dimensionality
    Even with simplified status for each epoch ("EARLY/GOOD/LATE"), 9 variables still gives $3^9 = 19683$ states… *months* of traffic data req'd!
  - ☐ Non-standard observations
    Rather than "epoch = t", we observe "epoch $\geq$ t"
    Lacking standard closed-form results (e.g. Bayesian est. or whatnot)

Proposed Technique

- **Normalize out schedule effects.**
  - ☐ "Delay flow": differential startup delay,
    (start-delay of leading activity) – (start-delay of following activity)
  - ☐ "Soak": differential duration, (planned – actual)
- **Use *pair* of Gaussian approximations:**



"Low" normal approx:
***Stochastically* smaller**
"High" normal approx:
***Stochastically* larger**
Proper scaling:
Identical *correlation*

Allows smaller datasets,
"easy" integrals.
Work-in-progress,
but looks promising.

Preliminary Conclusions

- **Minimum uncertainty in airline turn process**
  - ☐ Decision-aiding tools must be robust to these uncertainties.
  - ☐ Communication/coordination benefits are easiest to gain, since the human decision-maker provides robustness.
- **Prediction of offblock (EOFF)**
  - ☐ Flights have established handoff procedures between zones of control.
  - ☐ Ground op's lack standardized transition! (Or even std. terminology)
  - ☐ Proposed "handoff" procedures:
    - o ATC should predict wheels-on (with error estimate).
    - o Airline should predict EOFF (with error estimate)
    - o Added functionality? Airline "priorities" (if can be determined).
  - ☐ Suggested benefits:
    - o NASA SMA at ATL saved airlines $10M's yearly (anecdotal)
    - o Eurocontrol CDM reports congestion & coordination benefits
    - o "It doesn't hurt to run a tight ship" (The competition may benefit, but not as much.)

Acknowledgements

The data on ground-event timing are remarkable, and present a first-rate opportunity for systematic analyses of the turn process using accurate observations over a long period of time.

We are indebted to Lufthansa Airlines for this opportunity, and sincerely hope for a good working relationship between our research group and the Traffic Flow Management Department at Lufthansa.