MIT International Center for Air Transportation

Potential Approaches to Increase Milestone Prediction Accuracy in NAS Movements

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Presented at NEXTOR/CDM Review Meeting,

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Agenda

- CDM Mission
- Milestones for NAS Movements
- Benefits of Improved Taxi-Out Time Prediction Methods
- Outlook: Using Real-Time Ground Handling Milestones during Turnaround to Improve the Accuracy of Pushback Time Prediction
- Future Research

CDM Mission

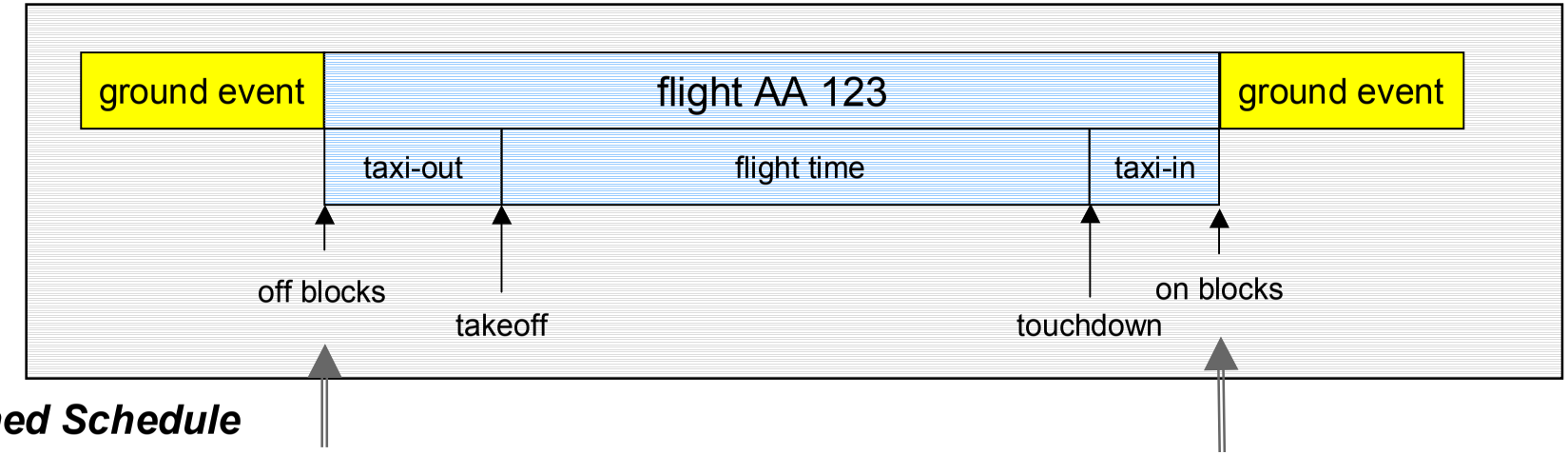
- **"Collaborative Decision Making provides Airline Operations Centers and the FAA with real-time access to National Airspace System status information including weather, equipment, and delays "**
  (FAA website: http://ffp1.faa.gov/tools/tools_cdm.asp)

- **NAS Status Information Dissemination (NASSI)**
  (CDM Summary Report, 01/08/03)

  - ❑ GDP Projected Demand and Capacity
  - ❑ Departure Delays
  - ❑ **Planned and Actual Pushback Times**
  - ❑ Airport Acceptance Rates
  - ❑ Airports Configurations

- **Integrated Arrival and Departure Management**

Milestones for NAS movements – where are we today?



Published Schedule

Agents should predict when they are ready to hand the aircraft over to the next agent ("handoff"):

	Airline	*Tower, TRACON*	*Airline*	*Tower, TRACON*
Estimates	Ready for Pushback	Ready for Takeoff	Ready for Touchdown	Ready for on-blocks
Models		*e.g. Idris, Clarke et al.*	*Airlines (e.g. Lido, proprietary)*	

How do estimates benefit downstream processes?

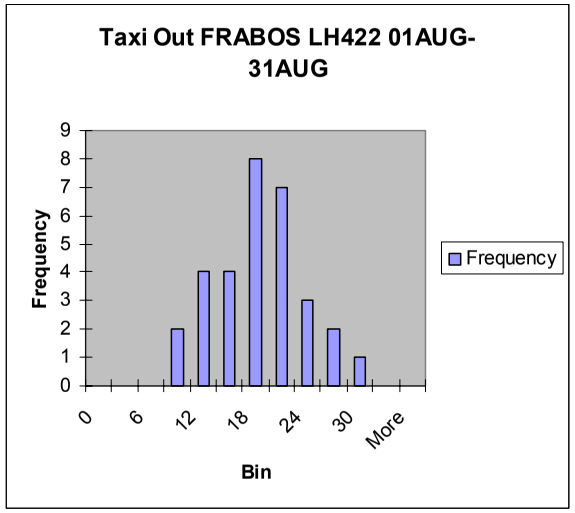
How can we come up with the missing estimates?

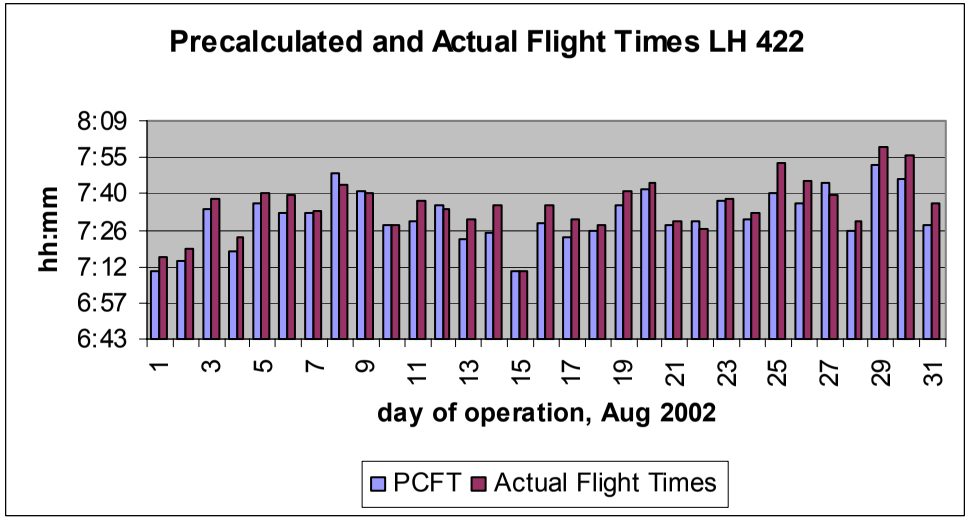
Research Questions

- To what extent does an improved taxi-out time prediction increase the accuracy of touchdown prediction?
- Outlook: How can pushback prediction be improved based on real-time ground handling data?

Available Data

- Flights LH422 FRABOS for August 2002
- Actual taxi-out times
- Pre-calculated flight times at day of operations and actual flight times ("Pre-calculated flight times" are calculated two hours before departure based on planned departure/approach path, winds, etc.)





Two Steps

- **Part A: Prediction of touchdown time based on the available data**
- **Part B: Estimation of average wait times and runway idle time based on touchdown predictions**

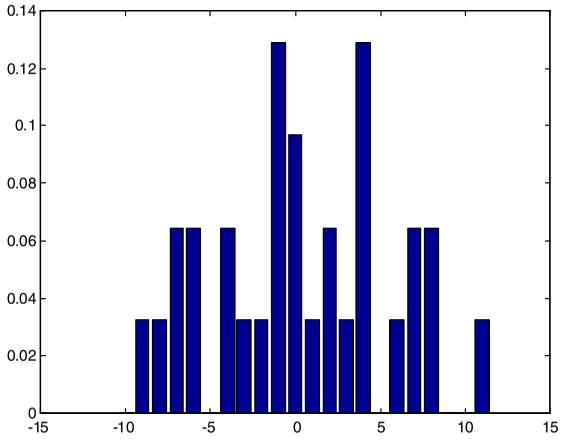
Part A: Methodology

- **Predicting touchdown based on different levels of taxi-out time prediction accuracies**
  - ❑ Base case:
    - o taxi-out prediction: "actual taxi-out time deviation" from taxi-out mean
    - o flight time prediction: "actual flight time deviation" from PCFT
  - ❑ Test case:
    - o *improved* taxi-out prediction:
      50% of "actual taxi-out time deviation" from taxi-out mean
    - o flight time prediction: actual flight time deviation" from PCFT
- **Convolve "taxi out deviation distribution" and "flight time deviation distribution"**
- **Compare standard deviations of touchdown time**

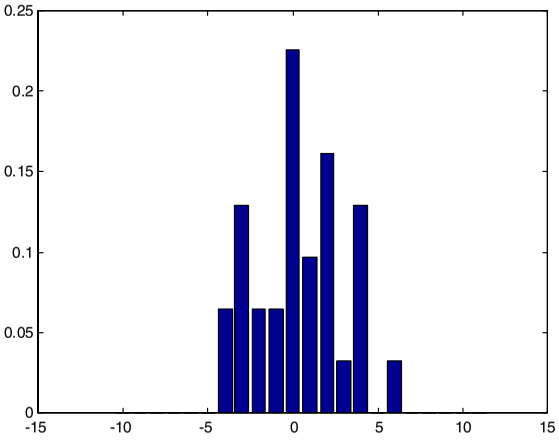
Part A: Methodology

Taxi-out Time Prediction Deviation
(Act. Taxi – Mean Taxi)

Base Case



Test Case



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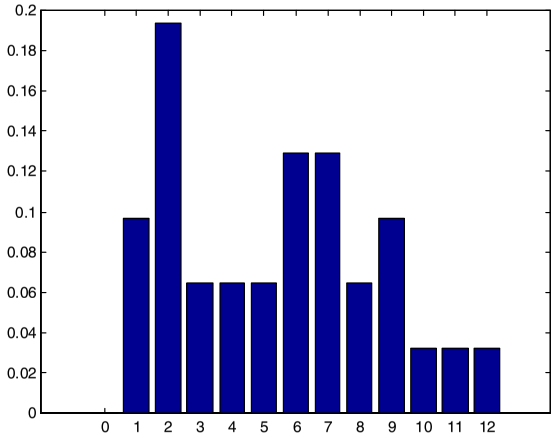
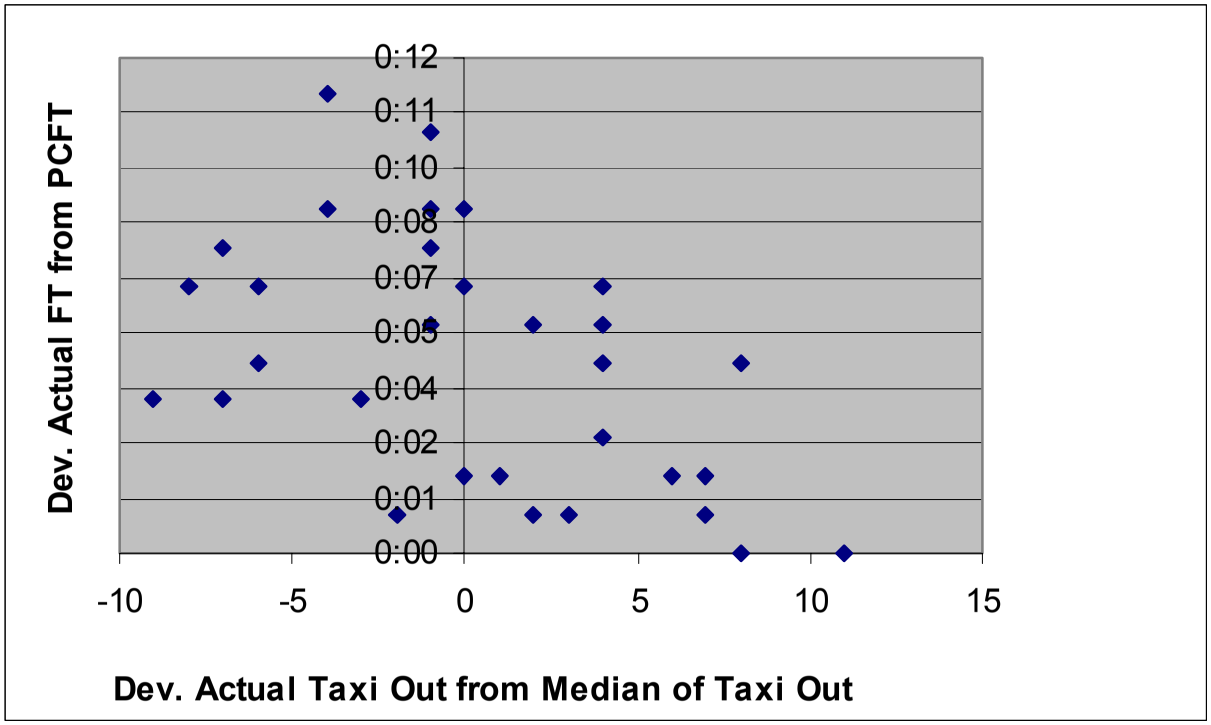
Flight Time Prediction Deviation
(Act. FT – PCFT)



Part A: Calculations

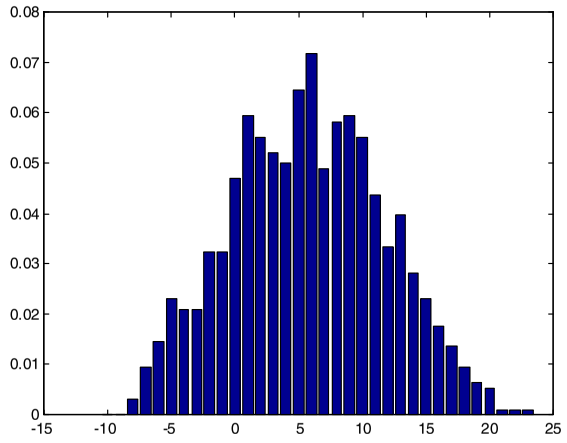
No significant correlation between taxi-out time prediction or flight time prediction



Part A: Convolution Results

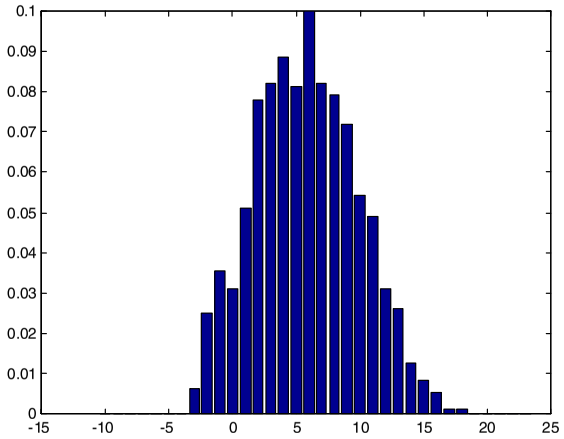
Deviation from touchdown prediction

Base Case



σ= 6.03 min

Test Case



σ= 4.05 min

Discussion Part A

- In this example, an improvement of taxi-out time prediction by 50% leads to an improvement of touchdown prediction by approx. 33%
- More accurate taxi-out time prediction has a considerable effect on the accuracy of touchdown predictions

Part B: How does improved touchdown prediction change wait times and runway idle time?

- **Analyze average wait time and average runway idle time for different touchdown prediction accuracies at constant expected arrival headways**
- **Assumptions:**
  - ❑ Runway only used for landings
  - ❑ Service Time 1.5 min, i.e. capacity of 40 aircraft/hour
  - ❑ Expected headway of landing aircraft 1.5 min. with different standard deviations for base and test case
  - ❑ 16 hour operation
  - ❑ First come first serve
- **Simulation: 25 Runs**

Part B: Methodology

- **E(Touchdown)=**

  [Median Taxi-Out + Mean (Deviation$_{\text{Median vs. Actual}}$ Taxi Out)]

  + [PCFT + Mean (Deviation$_{\text{PCFT vs. Actual}}$ Flight Time)

  -> set E(Touchdown Deviation)=0

- **Standard Deviation as calculated in Part A**

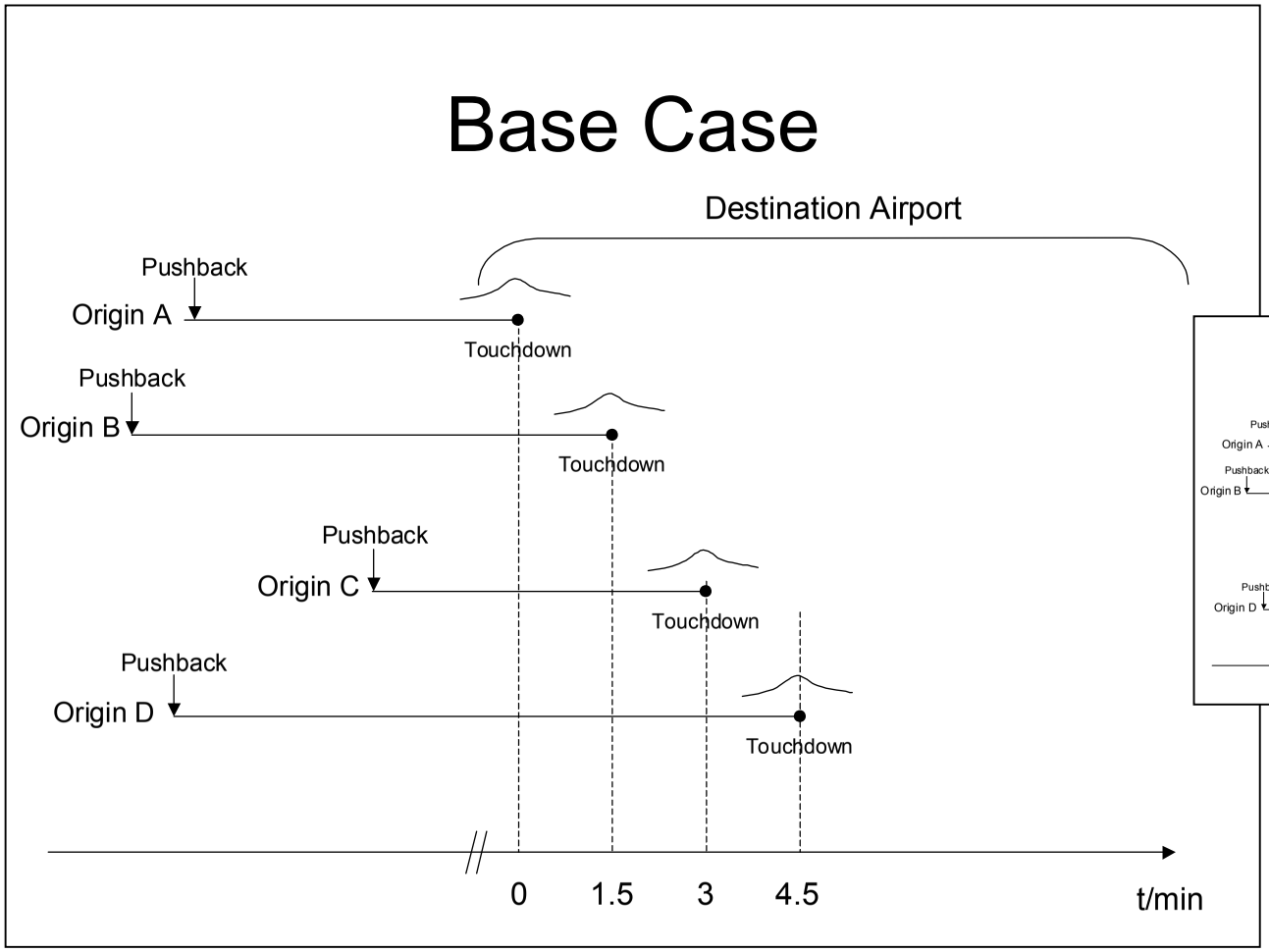
- **Wait time per aircraft:**

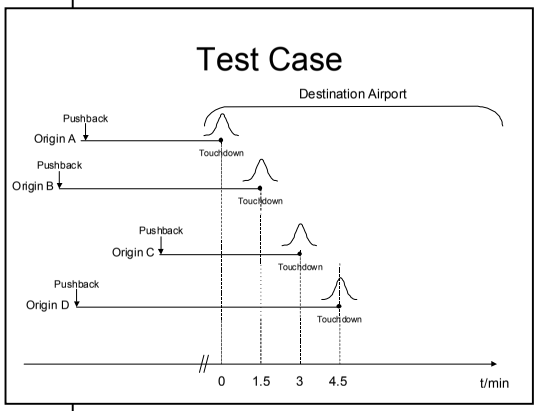
  Departure Time – Service Time – Arrival Time

- **Runway Idle Time:**

  Time when no aircraft is serviced (because no aircraft is available in queue)

Aircraft have an expected arrival every 1.5 minutes





Case: $\mu=0$, $\sigma=4.05$

Base Case: $\mu=0$, $\sigma=6.03$

Results

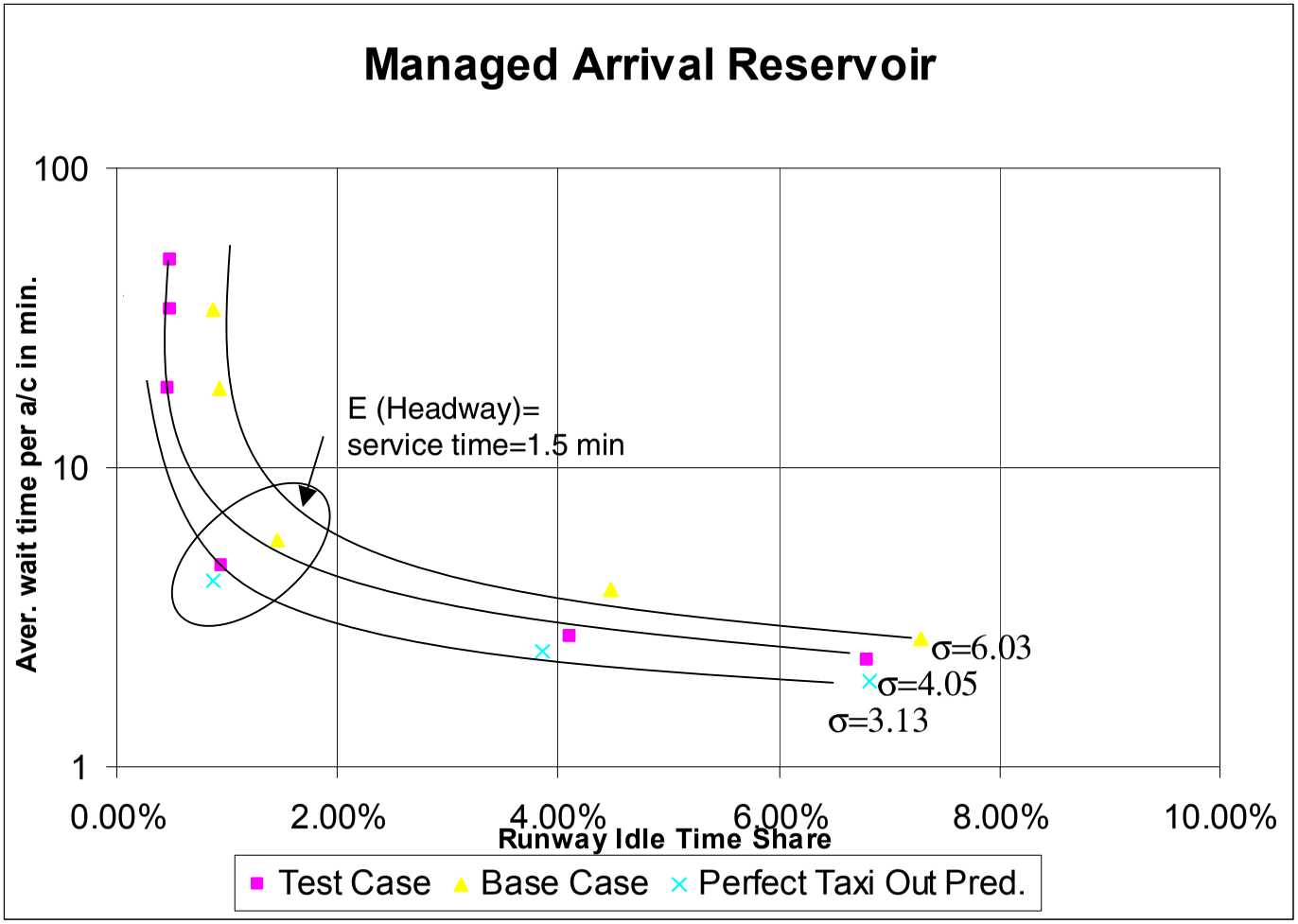
- **Wait times can be reduced by approximately one minute by using improved taxi-out time prediction**
- **Idle times can be reduced by 34%**

	6.03 (base case)		4.05 (Test Case)	
Headway	Idle Time	Aver. Wait	Idle Time	Aver. Wait
1.5	1.45%	5.72 min	0.95%	4.68 min

Changing the headway gives consistent results

	6.03 (base case)		4.05 (Test Case)		3.13 (perfect taxi)	
Headway	Idle Time	Wait Time	Idle Time	Wait Time	Idle Time	Wait Time
1.4	0.87%	33.68	**0.48%**	33.66499	0.51%	32.88
1.45	0.93%	18.44	**0.46%**	18.33	0.48%	17.65
1.5	1.45%	5.72	**0.95%**	4.68	0.87%	4.16
1.55	4.48%	3.9	**4.10%**	2.74	3.86%	2.44
1.6	7.29%	2.7	**6.80%**	2.26	6.83%	1.94

Results


Managed Arrival Reservoir
100
10
1
Aver. wait time per a/c in min.
E (Headway)=
service time=1.5 min
σ=6.03
σ=4.05
σ=3.13
0.00%
2.00%
4.00%
6.00%
8.00%
10.00%
Runway Idle Time Share
Test Case
Base Case
Perfect Taxi Out Pred.

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Implications

- **More accurate taxi-out time can improve the prediction accuracy of touchdown**
- **Wait times in holding patterns can be reduced and runway utilization rates improved**
- **Reduction in holding patterns:**
  - ❑ At $3000/block hour, reduction of $ Mio 11.7 p.a.
    - o 40aircraft/hour*1min*16 hours=10.7 delay hours/day
    - o 10.7 delay hours/day*365 days*$3000=$ Mio 11.7 p.a.
- **Passenger delay costs:**
  - ❑ At a value of 30$ per hour and 100 pax/aircraft, reduction of another $11.7 Mio p.a.
    - o 10.7 delay hours/day*30*100=$32100/day
    - o $32100*365 days= $11.7 Mio p.a.

Limitations/Next Steps

- **Limitations**
  - Small sample
  - Assumption was made that pushback at origin can be moved arbitrarily to assure an arrival at a specific expected time
  - Assumption that pushback time setting has no effect on taxi/flight time or en-route constraints
  - Headway is fixed

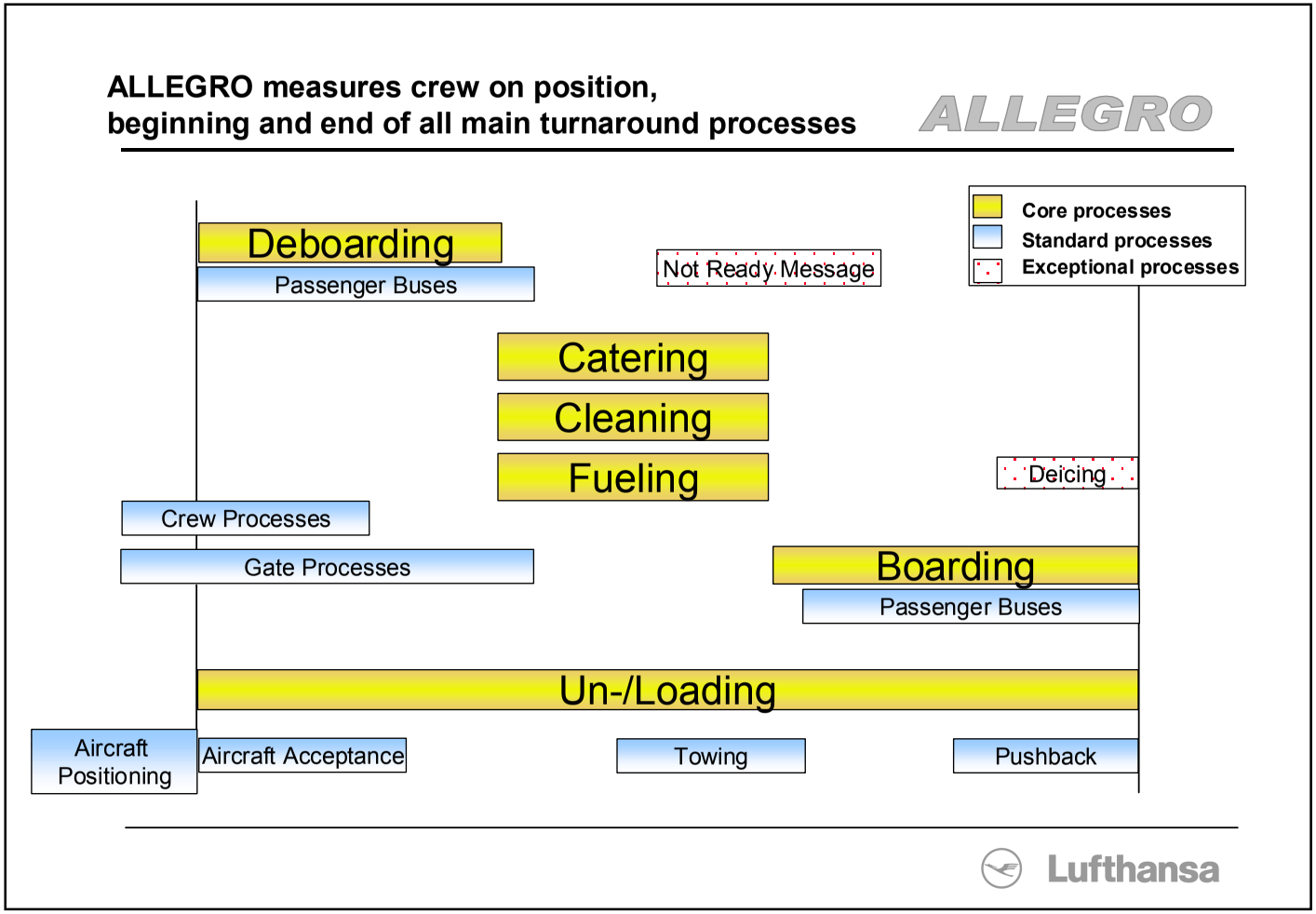
- **Possible Next Steps**
  - Verify results with larger sample and more simulation runs
  - Allow for dual use runway and different aircraft sizes
  - Allow changes in headway over time

Outlook: How can ground handling data be used to improve the accuracy of pushback time prediction?

- Improved Taxi-Out Time Prediction only helps after Pushback
- Controllers need to know how many aircraft are about to push
- How can we already predict the downstream touchdown during turnaround?

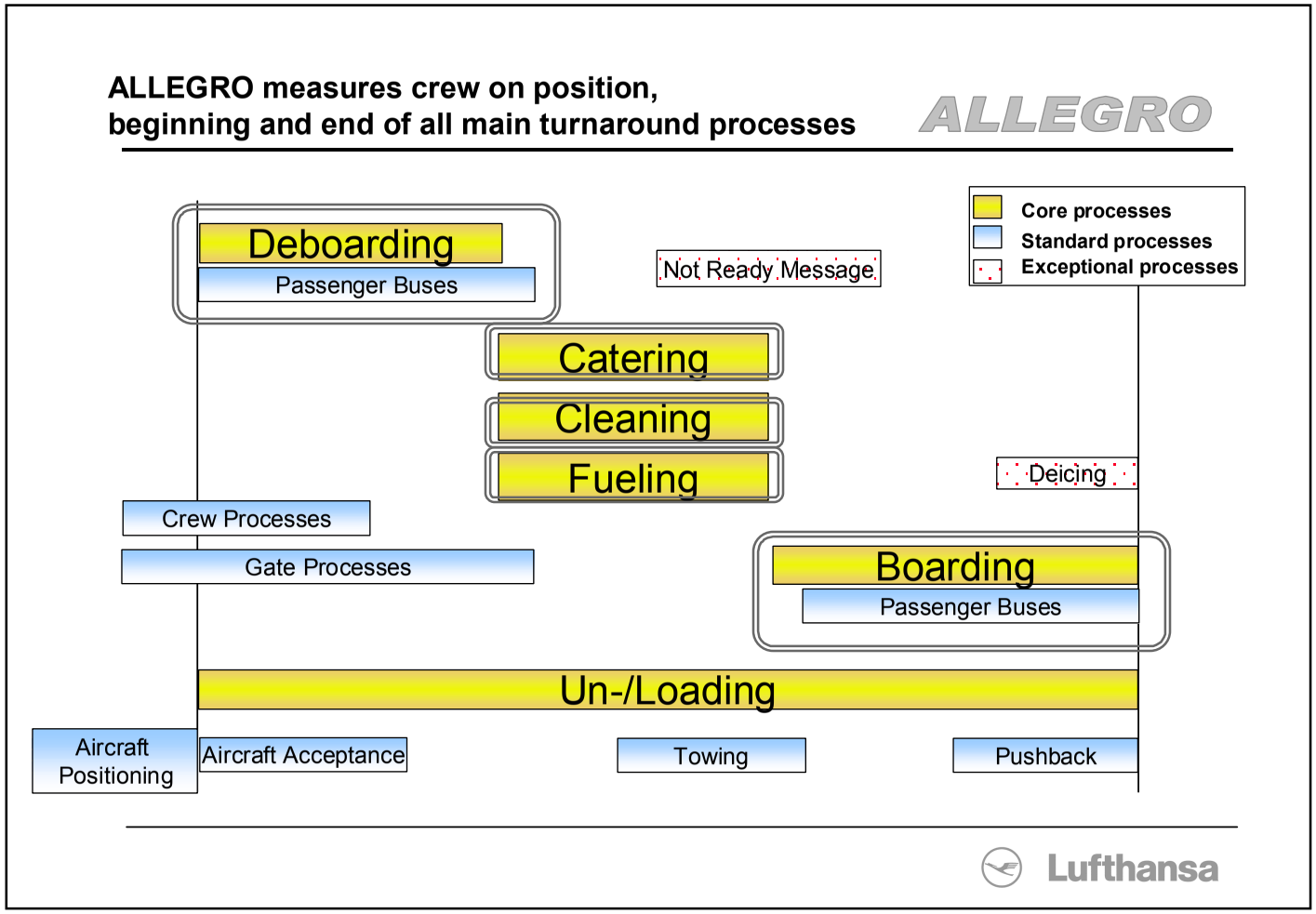
-> We need an accurate pushback time prediction: Ongoing Research of Francis Carr/Georg Theis/Professors Clarke, Feron

Ground Handling Data to our knowledge currently only available to Lufthansa Airlines



- For all processes, beginning and end are reported real-time
- For every involved vehicle, the system gets the messages “at aircraft”, “begin service”, “end service”

Used 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

Methodology

- **Filtered out exogenous influences**
  - GDP
  - Technical Failure
  - Weather
- **With these causes being eliminated, "ready for pushback = actual pushback" from a ground handling perspective**
- **Different methods**
  - "On block based":
    Sched.TDep= max (Sched.TDep, (on block + Minimum Ground Time))
  - Age based: use elapsed ground time to improve updates
  - Status based: update pushback prediction after end of major processes

Preliminary Results

- **Status based predictions improve the quality of pushback estimates**
- **However, uncertainty in airline turn process has *significant lower bound***
  - ❏ Subsequent processes catch up for late previous processes, i.e. basing the prediction on planned process times reduces the estimate's quality
  - ❏ Decision Support Tools for ground-air handoffs will have to take into account intrinsic stochasticity of pushback estimates

Future Research

- **Check what data sources are available to use for**
  - ❏ Taxi Out Time Model (Idris, Clarke, et al.)
  - ❏ Pushback Time Prediction Model
- **Make Models Responsive to Dynamic Stream of Data Updates**
- **Estimate Potential Benefits**