# Operational Impact of Alternative Taxiing on Block Time and Relevant Airline Cost

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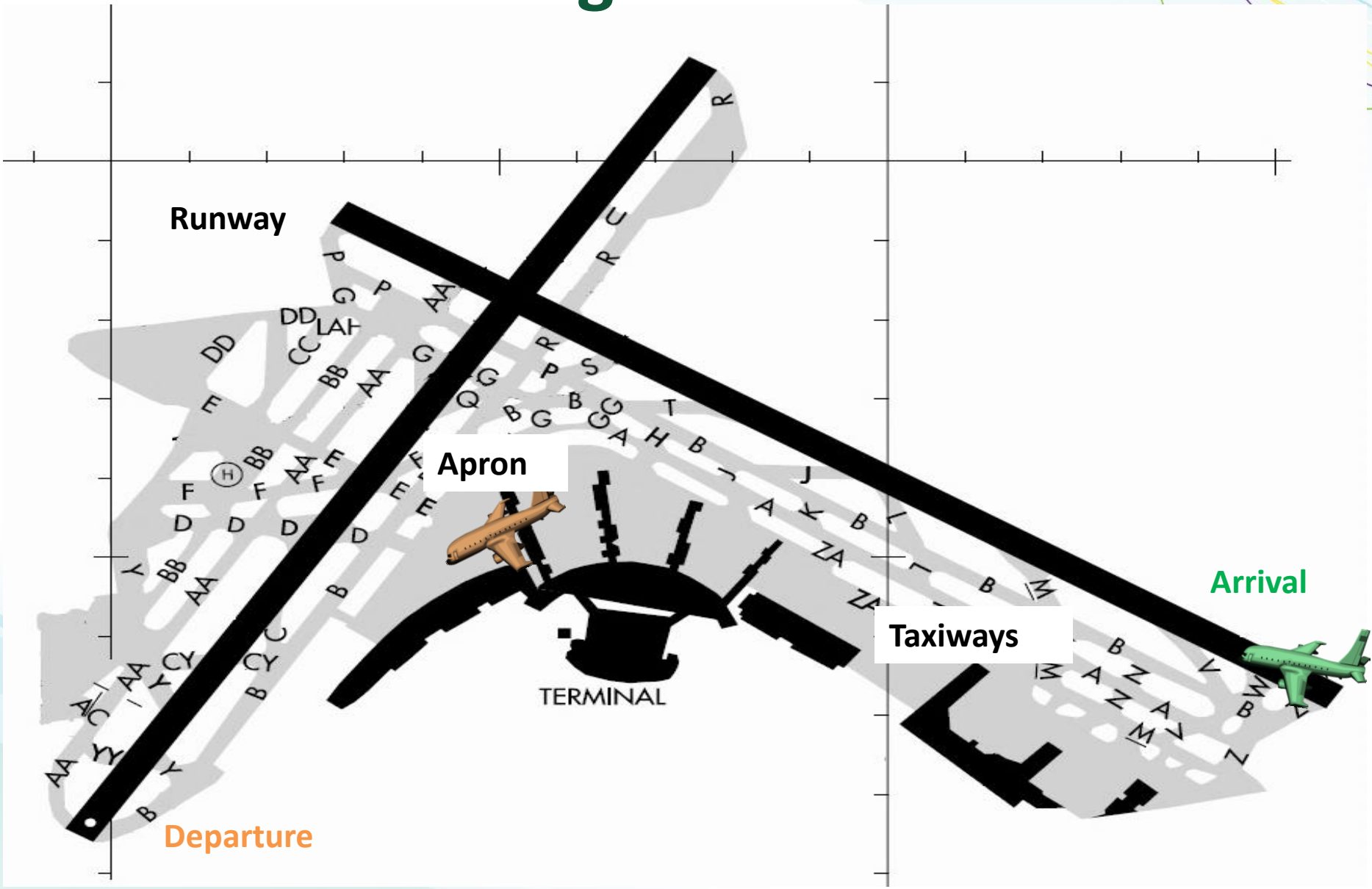
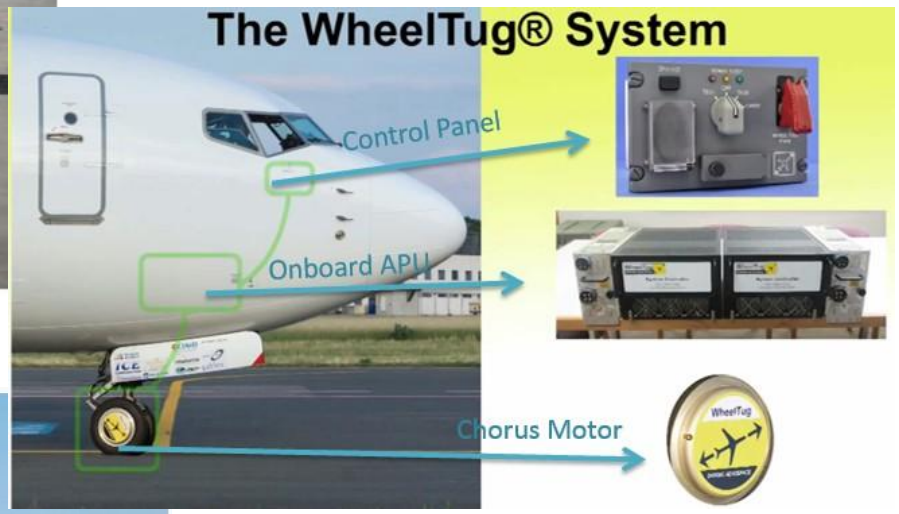
November 5, 2014

# Taxi Phase of Flights



# Alternative Taxiing Systems


External System--TaxiBot System




On-board System--WheelTug


On-board System—EGTS (*Electric green taxiing system*)



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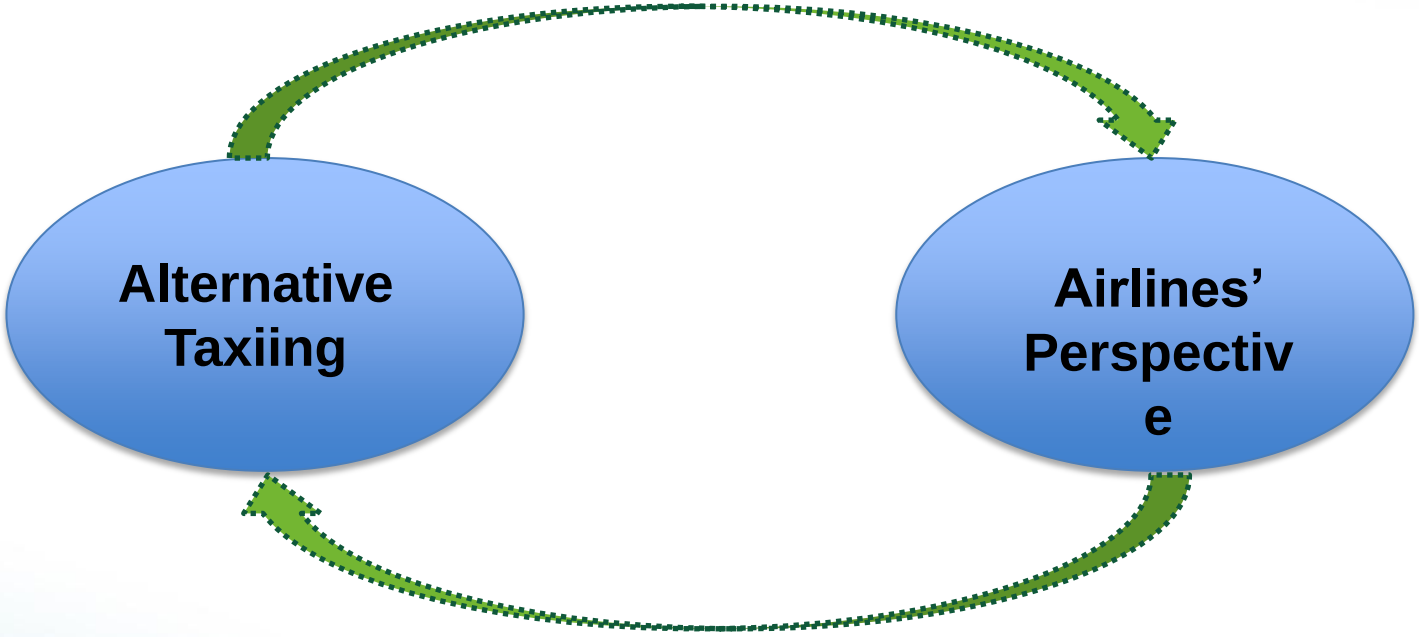
# Alternative Taxiing Systems

Operational Advantage of Alternative Taxiing:

- Faster push backs
- Greater gate availability
- Greater possibility of postponing the engine start procedure (as well as the warm-up time) into the taxi phase
- Comparable taxiing speeds to the current taxiing

# Alternative Taxiing Systems

Benefits require airline participation…

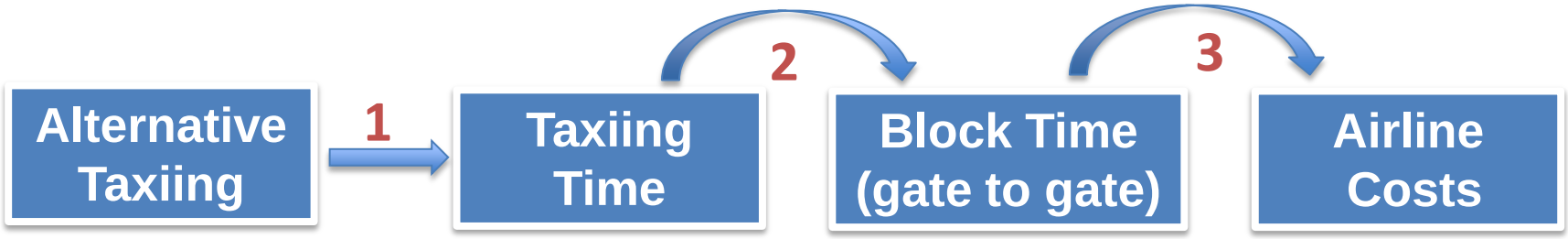



…but airlines won't participate without clear, credible, and relevant benefits!



**Airlines have looked into the fuel cost saving but no other indirect saving**

# Operational Impact of Alternative Taxiing




1. Create scenarios of possible changes on taxi times

2. Identify the relationship between taxi times and block time

3. Quantify the consequent indirect cost changes for air carriers

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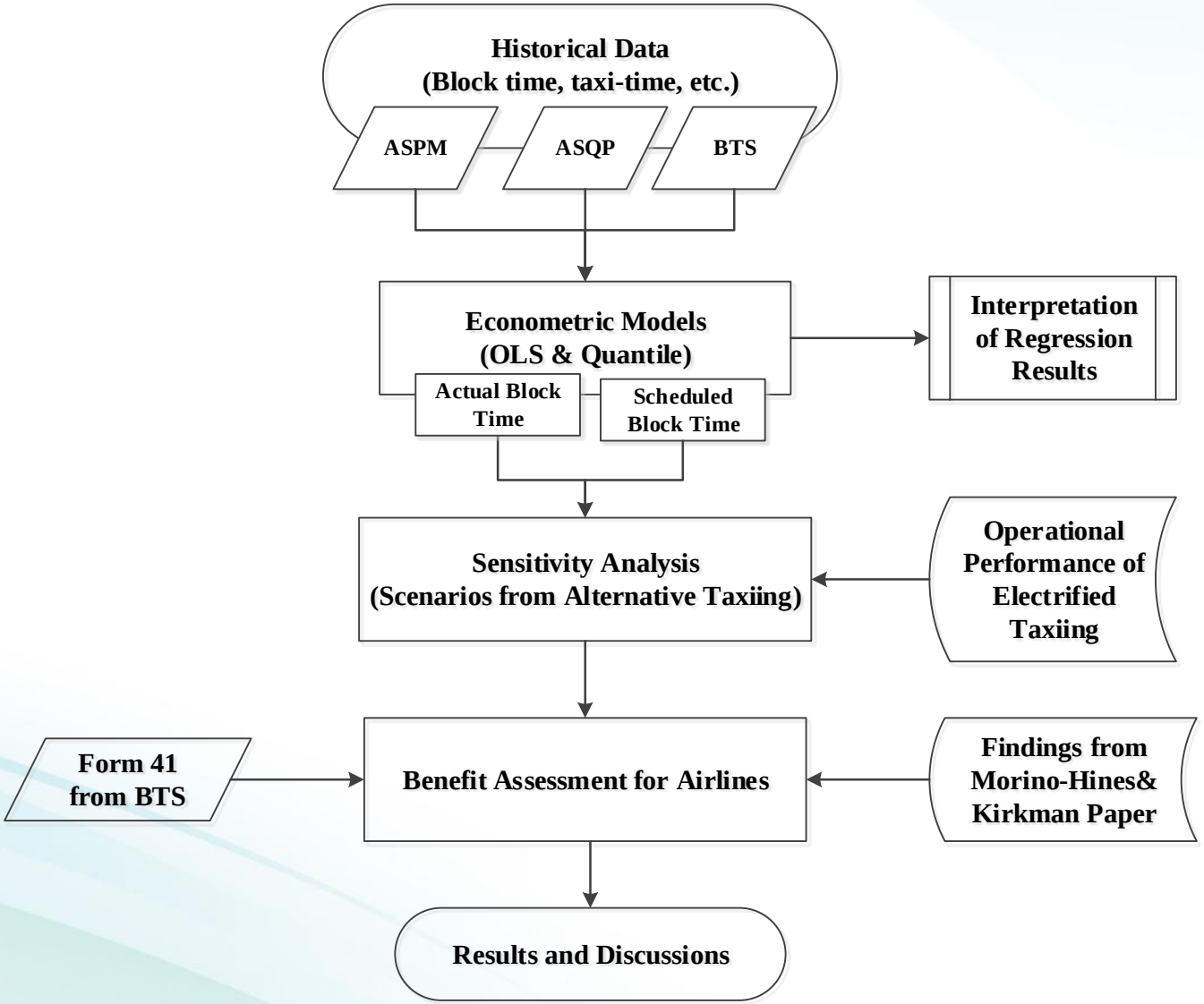
# Literature Review

| | Alternative Taxiing | Block Time and Airline Cost | |
|---|---|---|---|
| | | Block Time Prediction | Scheduled Block Time |
| **Representative references** | Mainly focused on the economic (e.g., fuel saving when taxiing) and environmental impact analysis of alternative taxiing (Guo, Zhang, Wang, 2014; Vaishnav, 2014) | (Coy,2006)-A global model for estimating the block time;<br>(Tony,2012)- Predicting block time using quantile regression;<br>(Vinayak, 2012)- Impact of flight schedules on delays | 2013ATM (Hao & Hansen)-How airlines set scheduled block times;<br>2013ATM (Moreno-Hines &Kirkman)-Assessing the NextGen avionics business case |
| **Comments** | Operational assessment from airlines perspective has not been deliberated | Prediction models emphasized the flight delays;<br>their models are referred when choosing variables in our study. | Their research priority was given to predictability and airlines' responses to general changes;<br>some of their results can be used in our study. |

# Methodology



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# Data Sources

- Aviation System Performance Metrics (ASPM) Individual Flights Database
- Airline Service Quality Performance System (ASQP) City Pair: Causal Detail Report
- The T-100 D Database from the BTS
- Form 41 Database from the BTS

Data matching: according to flight number for an airport-pair on each date (Month/Day/Year) of an airline (e.g., JBU647-JFK-SFO-07/01/2012)

# Econometric Models

**Quantile Regression:**

$$y_i = x_i'\beta_q + e_i$$

where $\beta_q$ is the vector of unknown parameters associated with the $q^{th}$ quantile.

The quantile regression minimizes $\sum_i q|e_i| + \sum_i (1-q)|e_i|$, a sum that gives the asymmetric penalties $q|e_i|$ for underprediction and $(1-q)|e_i|$ for overprediction

- ✓ Flexibility for modeling data with heterogeneous conditional distributions
- ✓ A more complete model than OLS (ordinary-least squares) regression
- ✓ Richer characterization and description of the data

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# Variables

**Dependent variable**: actual block time

**Independent variables**:

- Taxiing time characteristics:
  - Fixed: unimpeded taxi time
  - Stochastic: NAS delay
- Airborne time (~flight distance)
- Competitiveness of the OD pair: HHI
- Airport characteristics: OEP 35 airports
- Others: gate delay, block buffer

# Case Study and Results

**Regression Results for AAL and JBU_2012Q3**

| ACTBLOCK | Air Carriers | OLS (Adj. $R^2$=0.98) | τ=0.25 | τ=0.50 | τ=0.75 | τ=0.95 |
|---|---|---|---|---|---|---|
| **NOMTO** | AAL | **1.054*** | **0.761*+** | **1.029*** | **1.321*+** | **1.600*+** |
| | JBU | **0.870*** | **0.544*+** | **0.768*+** | **0.980*+** | **1.252*+** |
| FPETE | AAL | 0.998* | 0.996*+ | 1.000*+ | 1.004*+ | 1.006*+ |
| | JBU | 0.997* | 0.995*+ | 0.999*+ | 1.003*+ | 1.007*+ |
| **NOMTI** | AAL | **1.010*** | **0.753*+** | **0.888*+** | **1.043*** | **1.293*+** |
| | JBU | **0.826*** | **0.859*** | **0.877*** | **0.878*** | **0.745*** |

*: Significantly different regression coefficient from zero at the 5% significance level;

+: Significantly different quantile regression coefficients from OLS coefficients at the 5% level;

Number of observations: 115817 for AAL and 52216 for JBU;

All VIF<4, meaning no strong correlation between independent variables;

Tests for heteroskedasticity show Prob>chi2=0.0000 for both airlines.

# Sensitivity Analysis for Alternative Taxiing

To reflect the possible changes (time savings) in taxi time, nine scenarios are created by assuming the reasonable ranges of taxi-time changes

| Scenario | Taxi-out (min) | Taxi-in (min) |
|---|---|---|
| 1 | -2.5 | -1.0 |
| 2 | -2.5 | -0.5 |
| 3 | -2.0 | -1.0 |
| 4 | -2.0 | -0.5 |
| 5 | -1.5 | -1.0 |
| 6 | -1.5 | -0.5 |
| 7 | -1.0 | -1.0 |
| 8 | -1.0 | -0.5 |
| 9 | -0.5 | -0.5 |

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# Benefit Assessment for Airlines

<table>
<tr><th>Pilots</th><th>Purchased Goods</th><th>Maintenance</th><th>Aircraft Ownership</th><th>Other</th></tr>
<tr><td>Salaries and Wages</td><td>Fuel/Oil</td><td>Labor</td><td>Rentals</td><td rowspan="5">Delay cost</td></tr>
<tr><td>Pilot Training</td><td>Insurance</td><td>Materials</td><td rowspan="4">Depreciation and Amortization</td></tr>
<tr><td rowspan="2">Benefits and Payroll Taxes</td><td rowspan="3">Other (inc. Tax)</td><td>Third Party</td></tr>
<tr><td>Total Direct</td></tr>
<tr><td>Per Diem/Personnel</td><td>Burden</td></tr>
</table>

- Direct Saving: fuel burn on surface movement (our previous study)
- Indirect Saving: labor cost and aircraft cost through block time

# Case Study and Results

The impacts of alternative taxiing on airline costs:

- For AAL, the quarterly **saving in labor cost** is in the range of $1.6 million to $12 million with alternative taxiing
- For AAL, the quarterly **saving in aircraft cost** is in the range of $1.4 million to $10 million
- For JBU, the quarterly **saving in labor cost** is in the range of $0.4 million to $2.2 million

*The magnitudes of the airline cost savings are the same as those in the study by Hao et al (2014), where the benefits of general ATM improvements were estimated.*

# Conclusions

- The impacts of NOMTO and NOMTI are higher for AAL than for JBU, except for 25% quantile regression;
- For AAL, the impacts of taxi time increases with higher block times (higher quantiles); For JBU, the impact of NOMTI does not significantly vary across the quantiles;
- This study quantifies the impact of alternative taxiing on airline operational and financial performance (decision support);

# Thank you!

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# Benefit Assessment for Airlines

**Regression Coefficients for Benefits Analysis***

| in Dependent Variable | in Explanatory Variable | Legacy Airline | Low Cost Airline |
|---|---|---|---|
| Average Scheduled Block Time | Average Actual Block Time | 0.75 | 0.9 |
| Average Daily Flights per Aircraft | Average Scheduled Block Time | -0.02 | / |
| Average Pilot Salary per Available Seat-mile | Average Scheduled Block Time | 6.4E-5 | 6.7E-5 |

**Source: Moreno-Hines and Kirkman (2013). All time variables in minutes.*

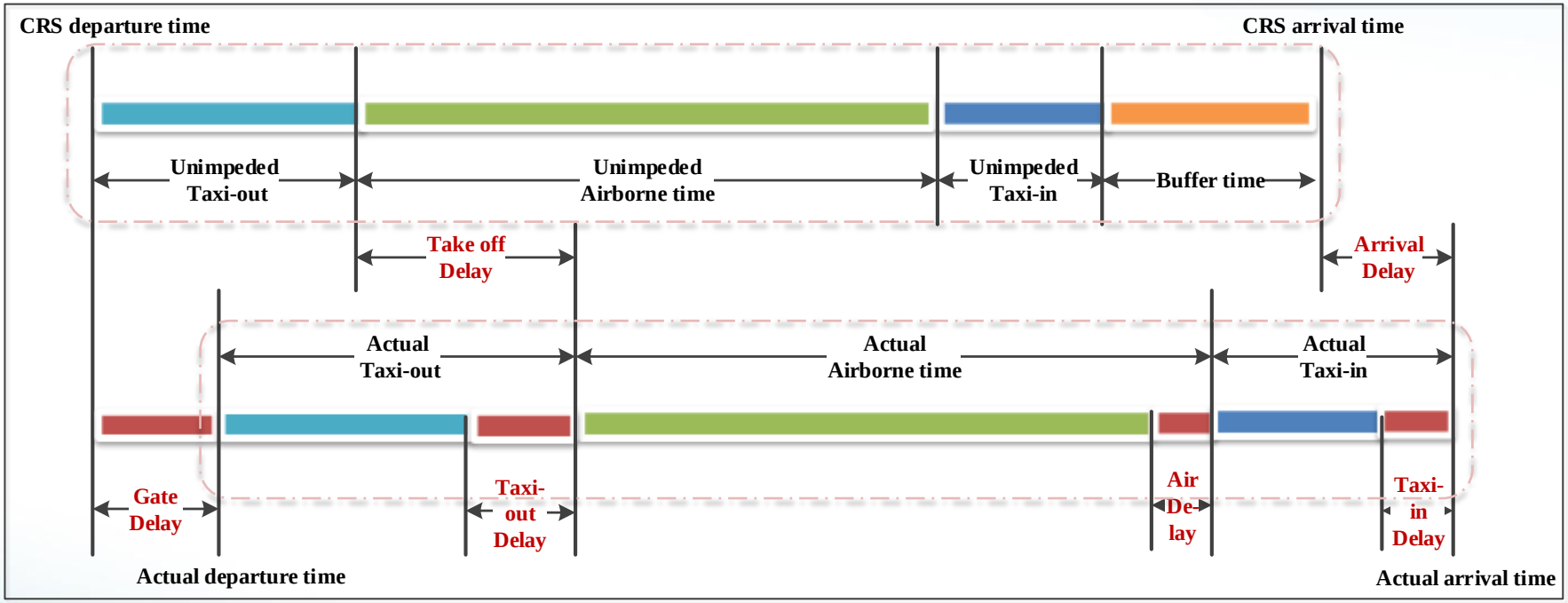
# Case Study and Results

**Descriptive Statistics for AAL and JBU Airlines_2012Q3**

| | American Airlines | | | | JetBlue Airways | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Min | Max | Mean | Std. Dev. | Min | Max |
| ACTBLOCK | 170.81 | 73.84 | 39 | 591 | 176.37 | 83.78 | 47 | 505 |
| NOMTO | 11.76 | 1.72 | 8.9 | 19.8 | 13.22 | 2.14 | 9 | 17.9 |
| FPETE | 145.41 | 71.20 | 4 | 528 | 151.38 | 81.06 | 7 | 382 |
| NOMTI | 5.48 | 1.11 | 2.8 | 8.7 | 4.63 | 1.11 | 2.1 | 6.6 |
| NAS_WX | 0.06 | 0.24 | 0 | 1 | 0.05 | 0.23 | 0 | 1 |
| NAS_EQ | 0.00 | 0.04 | 0 | 1 | 0.00 | 0.01 | 0 | 1 |
| NAS_VOL | 0.03 | 0.17 | 0 | 1 | 0.02 | 0.14 | 0 | 1 |
| NAS_RW | 0.01 | 0.09 | 0 | 1 | 0.01 | 0.08 | 0 | 1 |
| NAS_OT | 0.00 | 0.06 | 0 | 1 | 0.00 | 0.05 | 0 | 1 |
| NAS_NM | 0.07 | 0.26 | 0 | 1 | 0.04 | 0.20 | 0 | 1 |
| HHI | 0.67 | 0.27 | 0.147 | 0.67 | 0.60 | 0.25 | 0.206 | 1 |
| OEP_DEP | 0.87 | 0.34 | 0 | 1 | 0.73 | 0.44 | 0 | 1 |
| OEP_ARR | 0.87 | 0.34 | 0 | 1 | 0.73 | 0.44 | 0 | 1 |
| GATE_DEL | 16.14 | 41.16 | 0 | 1070 | 15.89 | 42.39 | 0 | 593 |
| BUFFER | 9.85 | 8.38 | -96.6 | 104.3 | 10.62 | 9.93 | -77.2 | 104.2 |

# Literature Review

**Block time:** the elapsed time between departure and arrival gates




**Main segments of scheduled and actual block times**

**Computer Reservation System (CRS)*



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# Case Study and Results

**Airline Specific Data for Benefits Analysis (Domestic, Quarter 3 in 2012)**

| Airlines (2012 Q3) | Available Seat Miles | Departures per quarter | Quarterly Average Wage for Pilots | Quarterly Average Wage for Flight Attendants | Quarterly Total Operating Fleet | Quarterly Ownership Cost per Aircraft |
|---|---|---|---|---|---|---|
| AAL | 22,685 millions | 115,817 | $35,787 | $12,240 | 597 | $441,623 |
| JBU | 8,919 millions | 52,216 | $34,896 | $9,702 | (174) | $433,860 |

*Source: US DOT Form 41 via BTS, schedule T2, P6, P10 &P-5.2.*

# Case Study and Results

**Impacts with Alternative Taxiing on Actual Block Time**

| Changes in ACTBLOCK | Airlines | Sce1 | Sce2 | Sce3 | Sce4 | Sce5 | Sce6 | Sce7 | Sce8 | Sce9 |
|---|---|---|---|---|---|---|---|---|---|---|
| OLS | AAL | -3.69 | -3.18 | -3.16 | -2.64 | -2.63 | -2.11 | -2.10 | -1.58 | -1.05 |
| | JBU | -2.99 | -2.59 | -2.55 | -2.15 | -2.12 | -1.71 | -1.68 | -1.28 | -0.84 |
| =0.25 | AAL | -2.67 | -2.30 | -2.29 | -1.91 | -1.90 | -1.53 | -1.51 | -1.14 | -0.76 |
| | JBU | -2.22 | -1.79 | -1.94 | -1.52 | -1.67 | -1.24 | -1.40 | -0.97 | **-0.70** |
| =0.50 | AAL | -3.46 | -3.02 | -2.95 | -2.50 | -2.43 | -1.99 | -1.92 | -1.47 | -0.96 |
| | JBU | -2.77 | -2.35 | -2.39 | -1.96 | -2.01 | -1.58 | -1.62 | -1.19 | -0.81 |
| =0.75 | AAL | -4.36 | -3.83 | -3.70 | -3.17 | -3.03 | -2.51 | -2.37 | -1.85 | -1.19 |
| | JBU | -3.40 | -2.92 | -2.91 | -2.43 | -2.42 | -1.94 | -1.94 | -1.46 | -0.97 |
| =0.95 | AAL | **-5.44** | -4.74 | -4.63 | -3.93 | -3.82 | -3.12 | -3.02 | -2.32 | -1.51 |
| | JBU | -3.92 | -3.47 | -3.32 | -2.87 | -2.72 | -2.26 | -2.11 | -1.66 | -1.06 |