Reducing Cost and Emissions with Eco-Driving for Transit Vehicles

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A National Center for Sustainable Transportation Webinar
TRANSFORMING THE TRANSPORTATION SYSTEM

RESEARCH — Producing “state of knowledge” white papers and interdisciplinary research projects

EDUCATION — Developing model curricula for graduate programs and advanced training programs

ENGAGEMENT — Informing the policy-making process at the local, state, and federal level
Outline

- Introduction
- Eco-driving algorithm
- Case study
  - Data
  - Method
  - Scenarios
  - Results
- Conclusions
- Ongoing and future efforts
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Introduction

- Transit agencies are always seeking opportunities to conserve fuel to lower operating costs
  - Operating improvement
  - Alternative fuel buses
- Two transit agencies’ fuel and emissions saving results from eco-driving are presented
  - Fuel savings
  - Emission reduction (Greenhouse gases, NOx, PM$_{2.5}$)
Key Findings
Key Findings

Conserves Fuel

Eco-driving can reduce fuel consumption by 5% in local transit service, and 7% in express bus service.
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Works for CNG
Eco-driving would reduce fuel consumption by 5% for a hypothetical all-CNG local fleet, and 10% for an assumed all-CNG express fleet
Key Findings

Conserves Fuel
Eco-driving can reduce fuel consumption by 5% in local transit service, and 7% in express bus service.

Works for CNG
Eco-driving would reduce fuel consumption by 5% for a hypothetical all-CNG local fleet, and 10% for an assumed all-CNG express fleet.

Saves Cost
Savings amount to $1,000/bus/year. No significant capital investment. Many ancillary benefits.
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Eco-Drivering Algorithm

- **Eco-driving training**: a feasible strategy to reduce fuel consumption and emissions of all kinds of vehicle types

- **Eco-driving techniques**
  - Anticipate the traffic
  - **Maintain a steady speed**
  - **Limit engine loads**
  - Limit idling
  - **Limit high speed**
  - Avoid hard accelerations
  - Shift to the highest possible gear with low rpm
  - Check tire pressure regularly
Eco-driving Cycle Modification

- Original Cycle
- Eco Cycle

- Maintaining Status Quo

Start point STP\(\geq STP_L\)

- Speed(eco) = Speed(original)
- Distance(eco) = Distance(original)

- Conservation of Distance (time not in sync)
Avoid High Power Operations

- High power operations
- Large speed and aggressive accelerations involved
- High energy consumption and high emissions involved
Example of Observed and Eco Cycles
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Data

Second-by-second transit operating data
- Local transit: Metropolitan Atlanta Rapid Transit Authority (MARTA)
- Express bus: Georgia Regional Transportation Authority (GRTA)

GIS files
- Road network
- Transit stops

Fleet composition
- National Transit Database (NTD)

Operating schedules
- General Transit Feed Specification (GTFS)
MARTA Operating Data

- Fleet Composition
  - 158 diesel
  - 350 CNG buses
- GPS Loggers
  - 15
- Revenue Routes
  - 224
- Identified Service Runs
  - 5,734
- Operating Distance
  - 65,600 miles
- Operating Duration
  - 6,062 hours

Legend
- Bus Yards
- Bus Routes
- Expressways
- Major Roads
- Fulton and Dekalb Counties

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National Center for Sustainable Transportation
Georgia Tech
College of Engineering
A School of Civil & Environmental Engineering
GRTA Operating Data

- Fleet Composition
  - 166 diesel
- GPS Loggers
  - 14
- Revenue Routes
  - 14
- Identified Service Runs
  - 51
- Operating Distance
  - 5,917 miles
- Operating Duration
  - 104 hours
Method

- Initial GPS Data
  - Kalman Filter: Minimize GPS Errors
  - Spline Process: Interpolate Missing Data
  - GIS Network Mapping: Identify Facility Type
  - Engine-off Identification: Onroad & Offroad Idle
  - Data Gap Treatment: Final Trip Set for Analysis

- Observed Cycles
- MOVES-Matrix
- Age Distribution
- Acceleration & Speed Modification
- Eco cycles
- MOVES-Matrix
- Age Distribution

- Second-by-second Operation, Fuel, and Emission Data
- Pump-to-wheel Fuel & Emissions Aggregation
- Well-to-pump Analysis Using GREET
- Pump-to-wheel Fuel & Emissions Aggregation
- Well-to-pump Analysis Using GREET

- Fuel & Emissions Comparison
## Scenarios

<table>
<thead>
<tr>
<th></th>
<th>1. Eco-driving</th>
<th>2. CNG</th>
<th>3. Eco-driving + CNG</th>
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</thead>
<tbody>
<tr>
<td><strong>Operations</strong></td>
<td>Eco cycles</td>
<td>Observed cycles</td>
<td>Eco cycles</td>
</tr>
<tr>
<td><strong>Fleet</strong></td>
<td>Existing fleet</td>
<td>Existing diesel buses</td>
<td>Existing diesel buses</td>
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<tr>
<td></td>
<td></td>
<td>↓ New CNG buses</td>
<td>↓ New CNG buses</td>
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Fuel Consumption Results

<table>
<thead>
<tr>
<th></th>
<th>Local Transit</th>
<th>Express Service</th>
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<tbody>
<tr>
<td>Base</td>
<td>3.6</td>
<td>5.5</td>
</tr>
<tr>
<td>Eco-driving</td>
<td>3.8</td>
<td>5.9</td>
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<tr>
<td>CNG</td>
<td>3.4</td>
<td>5.2</td>
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<tr>
<td>Eco-driving+CNG</td>
<td>3.6</td>
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</table>
## Life-Cycle GHG Results

<table>
<thead>
<tr>
<th></th>
<th>Emission Rate (kg/mile)</th>
<th>Well-to-Pump</th>
<th>Pump-to-Wheel</th>
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</thead>
<tbody>
<tr>
<td>Local Transit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base</td>
<td>2.5</td>
<td>0.7</td>
<td>1.8</td>
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<tr>
<td>Eco-driving</td>
<td>2.4</td>
<td>0.6</td>
<td>1.8</td>
</tr>
<tr>
<td>CNG</td>
<td>2.4</td>
<td>0.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Eco-driving+CNG</td>
<td>2.3</td>
<td>0.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Express Service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base</td>
<td>1.6</td>
<td>0.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Eco-driving</td>
<td>1.5</td>
<td>0.4</td>
<td>1.1</td>
</tr>
<tr>
<td>CNG</td>
<td>1.4</td>
<td>0.5</td>
<td>1.0</td>
</tr>
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<td>Eco-driving+CNG</td>
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<td>0.4</td>
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## NOx Emission Rate Results

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<tr>
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<td>12.7</td>
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<td>Eco-driving</td>
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<td>8.3</td>
<td>1.7</td>
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<td>Eco-driving+CNG</td>
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<td>1.6</td>
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Local Transit

Express Service
Cost Savings

Local service
MARTA, 508 buses
- Fuel consumption reduction: 5%
- 300,000 gallons of diesel fuel equivalent per year
- $720,000 in annual fuel savings, or $1,000/bus/year

Express service
GRTA, 166 buses
- Fuel consumption reduction: 7%
- 55,000 gallons of diesel per year
- $132,000 in annual fuel savings, or $800/bus/year

Implementation cost $650/bus/year
- Includes equipment, real-time communications, driver incentives, and data analysis
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Without significant capital investment, eco-driving

- Can reduce fuel consumption & emissions
- Will provide net cost savings
- Is also effective for CNG fleets
And ancillary benefits if coupled with bus monitoring
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Asset Management
Without significant capital investment, eco-driving

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And ancillary benefits if coupled with bus monitoring

Asset Management  On-time Performance
Without significant capital investment, eco-driving

- Can reduce fuel consumption & emissions
- Will provide net cost savings
- Is also effective for CNG fleets

And ancillary benefits if coupled with bus monitoring

Asset Management  On-time Performance  Driver Safety
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Implementing Eco-Driving for Transit

- Upcoming demo project with MARTA
- Commute Warrior Live Fuel and Emissions
  - The current operating mode is indicated through a dot varying in color
    - Green for low fuel and emissions
    - Yellow for medium fuel and emissions
    - Red for high fuel and emissions
Thank you!

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This presentation is based on the NCST white paper “Eco-driving for Transit”
http://ncst.ucdavis.edu/white-paper/gt-dot-wp1-3c/