NYC Taxi Drive Cycle Development and Simulation Study

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VSS073
Overview

- **Timeline**
  - Project start date: Nov. 2011
  - Project end date: May 2012
  - 95% complete

- **Barriers**
  - Unique vehicle mission, drive cycle
  - Limited data availability (HVAC)
  - Charging infrastructure
  - Vehicle readiness

- **Budget**
  - New project, FY12 funding
  - FY12 funding: $ 100 k
  - Field Data Provided (Ricardo)
  - FY13 (current) funding: $0k project completed

- **Partners**
  - Oak Ridge National Laboratory
  - NYC Taxi and Limousine Commission
  - Ricardo
  - INL, ANL, NREL
Objectives

- Obtain “in-use” HEV Taxi cab field data (Ricardo - Escape HEV Taxi Deployment)

- Develop appropriate drive cycles using ORNL’s DC_Gen Tool

- Construct basic Nissan Leaf™ simulation model in Autonomie

- Simulate and project vehicle performance using ORNL developed drive cycles.
Vehicle Technology Program (VTP) - Relevance

- **VTP Multi-Year Program Plan (2 key goals from VSST Subprogram)**
  - Demonstrate market readiness of grid-connected vehicle technologies by 2015.
  - Support the laboratory and field evaluations of large-scale demonstration fleets of advanced commercial and passenger PHEVs and EVs.

- **Barriers**
  - Public acceptance of electric drive as central vehicle choice
  - Battery cost and durability
    - Though not directly evaluated in this program, right sizing components for mission design is critical – consumer behavior and understanding of expectations (HVAC)
Background NYC Taxi Fleet - Relevance

- Largest taxi fleet in the United States
- The New York City Taxi and Limousine Commission (TLC) was established in 1971 with jurisdiction over the city's medallion (yellow) taxicabs and “for hire” service vehicles
- 48,000 cabbies in New York & 13,000+ licensed “Medallion” taxicabs*
- Huge fleet operation costs/logistics

HEV fuel use in 2010 – Operators noted a reduction of nearly $20/day

Ford used HEV Taxi’s from west coast to evaluate battery performance**

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**http://wardsauto.com/news-amp-analysis/hybrid-battery-durability-stuns-ford
Leaf Taxi Pilot Project - Relevance

- New York City Taxi & Limousine Commission
- Opportunity to Green the NYC Fleet
- 4 Vehicles in pilot program – DC “Fast Chargers” located around city
- Reduce operational cost (current Crown Victoria avg < 12 mpg)
- Idaho National Laboratory (INL)
  - PI - Jim Francfort
  - Field data collection and analysis
- Nissan NV200 – Taxi of the Future, proposed all EV driveline 2016-17 (Prototype is currently being tested by FedEx® in Europe)
Approach

- Obtain Ford Escape HEV NYC field use data
  - Ricardo FTP Site access and data format help
  - Utilizing ORNL’s DC_Gen tool develop “NYC TAXI” drive cycles based on field data; High load & nominal cycles
    - HVAC load estimates and projected impacts

- Develop ‘Autonomie’ base Nissan Leaf model
  - Battery Mule calibration and estimation work overlap
  - ANL test runs on 2011 Leaf utilized for model validation

- Conduct simulations in Autonomie

- Project performance of EV in taxi service
  - Future analysis of field usage data, adjust drive cycles as needed
Milestones Status

• Milestone #1, January 2012:
  – Data received in usable format from Ricardo
  – Histogram generation and analysis
  – Baseline Nissan Leaf Autonomie model created

• Milestone #2, February 2012:
  – Drive cycle modules created from ORNL DCgen Tool
  – Full drive cycles developed and simulations performed using Leaf model in Autonomie

• Milestone #3, March 2012:
  – VSATT presentation
  – Presentation to NYC Taxi and Limousine Commission

AOP Project Objective:
The purpose of this task is to create a representative drive cycle for simulation and performance projections of all electric vehicles placed into taxi cab service in New York City.
Project Focus Area – Taxi Drive Cycle Creation

- 1 month of single vehicle data
- Around 3000 trips
- Daily Range 252-360 miles per day (mpd)
- Average range 270 mpd

### NYC HEV Taxi field data

<table>
<thead>
<tr>
<th>Speed Ranges [km/h]</th>
<th># Trips</th>
<th>% Total Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0-5)</td>
<td>168</td>
<td>5.52%</td>
</tr>
<tr>
<td>(5-10)</td>
<td>301</td>
<td>9.89%</td>
</tr>
<tr>
<td>(10-15)</td>
<td>601</td>
<td>19.74%</td>
</tr>
<tr>
<td>(15-20)</td>
<td>711</td>
<td>23.35%</td>
</tr>
<tr>
<td>(20-25)</td>
<td>523</td>
<td>17.18%</td>
</tr>
<tr>
<td>(25-30)</td>
<td>294</td>
<td>9.66%</td>
</tr>
<tr>
<td>(30-35)</td>
<td>185</td>
<td>6.08%</td>
</tr>
<tr>
<td>(35-40)</td>
<td>86</td>
<td>2.82%</td>
</tr>
<tr>
<td>(40-45)</td>
<td>57</td>
<td>1.87%</td>
</tr>
<tr>
<td>(45-50)</td>
<td>50</td>
<td>1.64%</td>
</tr>
<tr>
<td>(50-55)</td>
<td>24</td>
<td>0.79%</td>
</tr>
<tr>
<td>(55-60)</td>
<td>16</td>
<td>0.53%</td>
</tr>
<tr>
<td>(60-65)</td>
<td>17</td>
<td>0.56%</td>
</tr>
<tr>
<td>&gt;=65</td>
<td>12</td>
<td>0.39%</td>
</tr>
</tbody>
</table>

Total: 3045
Drive Cycle Development – Module Category Determination

NYC HEV Taxi field data
Test Drive Cycle Development - Low Speed (LS) Synthesis

15% of all trips

ORNL DC Gen Tool Histogram
Test Drive Cycle Development - Approach

- Medium speed band

60% of all trips
Test Drive Cycle Development - Approach

- Medium high speed band

15% of all trips
Drive Cycle Development – Low Speed (LS) module

- Drive cycle modules created for four speed ranges (final speed bins)
  Influenced by maximum trip lengths and existing drive cycles - approx. 1800 sec
- Synthetic cycles appear aggressive when compared to historical drive cycles
Drive Cycle Development – High Speed (HS) module

- Synthetic cycles have similar traits when compared to updated drive cycles
Drive Cycle Development - Synthesis

- Synthetic cycles show characteristics of field data when overlaid.
Drive Cycle Development - Synthesis

Module Plug and Play Method

- Operator shift based drive cycle length
  
  Early simulation results deemed 8 hour cycle would result in low SOC

- SOC limits for “24/7” operation – fast charge limitations for SOC (80%)

- ‘High Load’ versus ‘Nominal’ drive cycles vary use of modules

<table>
<thead>
<tr>
<th>Drive Cycle</th>
<th>Module Type and Number</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>LS</td>
</tr>
<tr>
<td>Nominal</td>
<td>1</td>
</tr>
<tr>
<td>High Load</td>
<td>1</td>
</tr>
</tbody>
</table>

* Varied modules  ** All from high speed bin
Assumptions - HVAC Load Impact on EV Operating Range

- Previous electric vehicles research for vehicle preconditioning*
  - This analysis shows that typical climate control loads can reduce CD range up to 35% for heating loads.

- Due to the unique HVAC loads of a taxi cab (due to constant ingress and egress) the 2kW estimated typical load for cabin conditioning was not deemed sufficient
  - For these simulations non-drive loads ranged from 0.5kW (assuming little to no HVAC use) to 3.5kW, these estimates will be updated once testing on the Nissan Leaf is completed later this year.

- Regional temperature data is not enough
  - Taxi cab use is linked directly to local ambient conditions – not just temperature. Driving characteristics as well as customer usage traits change with precipitation as well. Number of trips per hour – indicator of number of door openings per hour. What are the customers expectations - responses to interior temperature of vehicle

* Analysis of Off-Board Powered Thermal Preconditioning in Electric Drive Vehicles
Robb A. Barnitt, Aaron D. Brooker, Laurie Ramroth, John Rugh, and Kandler A. Smith
National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401, U.S.A
Drive Cycle Development - Summary

- Utilization of field data
  - Limited to a summer month of operation for one vehicle
  - Averaged 21 hours/day operation (only 5 days operated less than 20 hours)
  - No limitations to service routes
  - Typical daily mileage exceeds any current EV range (recharging required)

- NYC Taxi drive cycle overviews
  - Based on field data developed modules

<table>
<thead>
<tr>
<th>Drive Cycle</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (hours)</td>
</tr>
<tr>
<td>Nominal</td>
<td>4</td>
</tr>
<tr>
<td>High Load</td>
<td>4</td>
</tr>
</tbody>
</table>
## Vehicle Simulation Results

<table>
<thead>
<tr>
<th>Vehicle Configuration</th>
<th>Nominal cycle</th>
<th>High Load</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Vehicle</td>
<td>238 wh/mi</td>
<td>231 wh/mi</td>
<td>0.5kW, 80% SOC</td>
</tr>
<tr>
<td>Base Veh w/ Htr</td>
<td>584 wh/mi</td>
<td>553 wh/mi</td>
<td>3.5kW heater load, 80% SOC</td>
</tr>
<tr>
<td></td>
<td>39.1 / 56.0mi</td>
<td>42.8 / 69.4 mi</td>
<td></td>
</tr>
</tbody>
</table>

Yellow highlighted areas indicate vehicle does not complete 4 hour drive cycle.
Drive Cycle Development – Simulation Result
Electric Taxi Performance Projection Summary

- Expected operational time with no HVAC loads is above 4 hours for Nominal drive cycle only
  - Recharging locations critical to reduce “lost fairs” and route restrictions may be needed to avoid issues

- Additional HVAC load data required for accurate estimations as well as impact of changes with 2012 Leaf cold package.
  - Based on field data developed modules
  - ANL is collecting data as part of cold ambient Leaf testing

- ‘High Load’ drive cycle placed vehicle in more efficient range of operation
  - Key for future vehicle design parameter generation, NV200 is larger, 99 mph top speed not required.
Accomplishments – Model, Drive Cycle and Data Sharing

- Creation of new project specific drive cycles and vehicle model

- Simulated initial vehicle performance using new drive cycles and ORNL developed model of vehicle

- Summarized vehicle information for field data comparison and future test procedure modifications
Collaboration and Coordination with Other Institutions

- Ricardo - Vehicle data transfer
- Taxi & Limousine Commission

National Laboratory information sharing (ANL, NREL, INL)
- Preliminary Leaf Test Results
- HVAC load estimations
- Future field data
Future Work

- Obtain in-use EV Taxi field and charging data
  - Validate ORNL developed drive cycle and simulation model

- Opportunity for regenerative breaking algorithm modifications in simulation.

- HVAC Load information for various temperatures in high duty cycle use (multiple ingress and egress - door openings)

- Opportunity charging route analysis
Overall Project Summary

- NYC Taxi Driving Cycles were developed using Ricardo gathered field data from a Hybrid Ford Escape operating in NYC
  - High load and Nominal load driving cycles were developed and compared to historical cycles and field data.

- A baseline Autonomie model of the Nissan Leaf was created to predict performance of this vehicle used as a NYC taxi cab

- Considerations for impact of HVAC loads were incorporated into the simulation as well as DC “Fast Charge” SOC boundaries
  - Typical cab ‘24/7’ availability may require route restrictions and recharging process standards to ensure maximum hours of operation.
Acknowledgements and Contacts

DOE Vehicle Technologies Program:
- Lee Slezak, Vehicle Systems Manager

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- Oscar Franzese – franzeseo@ornl.gov
- Adam Siekmann
Thank You
Technical Backup Slides
Drive Cycle Development - Synthesis

Characteristics of synthetic modules when over laid. (first 100 sec)