Duty Cycle Analysis & Tools: Maximizing Vehicle Performance

High Efficiency Advanced Trucks Session

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Duty Cycle Affects MPG and Emissions!

Example of HEV improvement in fuel economy over various duty cycles:

Drive Cycle:
- WVUCITY
- CSHVR
- CILCC
- ARTERIAL
- Local
- Transit Bus
- WVUSUB
- COMMUTER
- CBDTRUCK
- WVUINTER

Percent Improvement in Fuel Economy by HEV:
- WVUCITY: 48%
- CSHVR: 45%
- CILCC: 40%
- ARTERIAL: 37%
- Local: 33%
- Transit Bus: 30%
- WVUSUB: 30%
- COMMUTER: 25%
- CBDTRUCK: 19%
- WVUINTER: 15%
It gets more complicated with PHEV’s!

Add in another factor: distance driven on a given drive cycle – MPG is not linear

This transition point varies based on duty cycle

You’ll now need to know:
1) What type of cycle do I have? and
2) How long do I drive on that cycle in order to calculate mpg?
So, Who Should Care and Why?
Top 3 Questions in Each Area

**Fleets:**
- When considering a large purchase of advanced technology vehicles:
  1. What benefit will this technology have in ‘my’ fleet?
  2. What’s the payback?
  3. Where should I place the vehicles in my fleet?

**OEM’s:**
- When designing a system:
  1. What is the range of performance observed for the vehicle type?
  2. What should we target our design for? (component sizing, control, etc)
  3. How should we test the vehicle?

**Regulators/Funding Agencies:**
- When considering funding implementation:
  1. What is ‘real’ benefit in a fleet?
  2. How to assign vehicle HEV credits?
  3. Do we need to target specific locations or routes?
All These Important Questions…

Fleets:
• When considering a large purchase of advanced technology vehicles:
  1. What benefit will this technology have in ‘my’ fleet?
  2. What’s the payback?
  3. Where should I place the vehicles in my fleet?
  4. Will the performance of the vehicle in my fleet match that of others?

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Regulators:
• When considering funding implementation:
  1. What is ‘real’ benefit in a fleet?
  2. Is the benefit claimed legitimate?
  3. Do we need to target specific locations or routes?
All These Important Questions…

**Fleets:**
- When considering a large purchase of advanced technology vehicles:
  
  The answer to all these questions: **It depends on the Duty Cycle**

  1. What is the range of performance observed for the vehicle type?
  2. What should we target our design for? (component sizing, control, etc)
  3. How should we test the vehicle?

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Why is this important to Fleets?

Example: What is the payback?

Typical Example: Purchase a ‘traditional’ truck or an ‘HEV’? The ‘HEV’ costs $25k more. It’s driven 20,000 miles per year and it currently gets 10 mpg. Fuel = $3.00/gal.

(Cost = $6,000/vehicle/yr)

- If the HEV gets a +10% improvement (11 mpg) the payback through fuel reduction is roughly 46 years ($5400/vehicle/year)
- If the HEV gets a +50% improvement (15 mpg) my payback (through fuel reduction) is roughly 12 ½ years ($4000/vehicle/year)

Bottom Line: you’d better know where you’ll fall on fuel economy before you invest!

EPA Window Sticker: ‘Actual mileage may vary’!
Why is this Important to Fleets?

Example: Where should I place the vehicles in my fleet?

Example: One fleet might have a large variation in drive characteristics and it might not make sense to place vehicles on certain routes.
Why is this Important to OEMs?

Example:

1. What is the range of performance observed for the vehicle type?
2. What should we target our design for?
3. How should we test the vehicle?
Why is this important to funding agencies?

**Example:**
- When considering funding implementation:
  1. What is ‘real’ benefit in a fleet?
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**Example:** If you justify based on emissions, consider cost per ton of NOx Reduction:

![Graph](image)
What else can you do with DC info?

If you know a few measured data points, you can now predict % improvement for other routes/duty cycles fall based on a few key metrics: **Be Smart With Your Testing**

- Kinetic Intensity is an attempt to provide a measure of acceleration in cycle
Doesn’t the industry study this already?

Some do - traditional attempts to determine appropriate duty cycle have included:

1) Using previously published data for a vocation (MAN, CILCC, OCTA, etc)
   • Not always accurate for specific location

2) Using limited or basic metrics like ‘stops per mile’ or ‘average speed’ based on overall fleet averages or ‘desired’ routes
   • Not specific to tell you enough

3) Measuring actual vehicles and large numbers or vehicles
   • Takes a long time to design and complete this process without a process or tool
There could be an easier way….

NREL and others have developed ‘tools’ for industry to utilize:

**WVU:** A tool that builds new driving cycles from standard cycles – Emissions Focus

**Oak Ridge National Lab:** A tool that can generate duty cycles based on data collected by ORNL.

**NREL’s Drive Cycle Tool:** Created mainly for fuel economy analysis, it provides a simple, accessible method to help industry users easily capture *their* data, analyze it, create and compare it to fully understand what is happening in their own fleet:

**Tell Me What I Have in My Fleet!**

1. Method to help users generate and better understand *their* specific drive cycle (fleet wide, region or depot/local level)

2. Generate custom test cycles (~30 mins) from *their* large set of on-road experimental data.

3. Compare *their own* user supplied data to known and common industry test cycles – answers the question: what cycle should I use to evaluate this technology?
Specifics – What Does the NREL Tool Do?

1. It Provides for User Directed Analysis of User Supplied Data
   - Extracts:
   - Combines or Splits data:
   - Filters: ~10 filters
   - Calculates all known stats (55 and counting)

User Data: Multiple Days of Route Data (split or combined)
Specifics – What Does the NREL Tool Do?

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   - Extracts:
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Quickly processes and analyzes data in a consistent manner
Specifictions – What Does the NREL Tool Do?

2. **Cycle Generation – matches fuel economy**
   - Crunch any amount of user supplied data and output a user cycle (speed vs. time) for dynamometer testing or modeling based on raw data inputted
   - **Goal** = creates a short, statistically representative cycle (within 5% accuracy statistically and fuel economy) for dyno testing or modeling
   - We’ve validated to show same mpg for short or long cycle within 5%
Specifics – What Does the NREL Tool Do?

3. Compare and Select Best Available Industry Cycle

- Matched based on user selected statistics (mph, stops per mile, kinetic intensity, etc). This will tell the user the best cycle to quantify MPG. Original data vs ‘best selected’ data showed modeled mpg results within 3%
Summary

Simple GPS loggers to acquire data

set of daily GPS route data

Tool filters and sorts data in desired set

Closest ‘Standard’ Cycle Match

cycles with similar mpg

User Specific Test Cycle Generated

Full understanding of supplied data:
daily variation info, stats for original, filtered and shortened data
Future – Tool Moving Forward

1. DOE Clean Cities / NREL will be implement a web based version of tool and make this available to the general public
   • Allow users (fleets or individuals) to upload their own data, generate a custom drive cycle that represents their daily driving habits, and finds ‘best fit’ standard cycle –
   • useful to see if ‘actual’ driving does not match the industry standard test cycle
   • Will be user-friendly and ‘secure’

2. Improve Visualization and interaction capabilities
   • Graphically select individual sections of source data from which to generate test cycles

3. Modify tool to analyze duty cycle characteristics for other parameters (battery duty cycle, temperatures, etc)

4. Tie this tool and others into accessible data bases for industry to utilize
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Thank You!

Take Aways:

1. **Duty Cycle Matters** – has a large effect on fuel economy
2. **Easy to Use, Fleet Focused Tool Now Available For Use to More Fully Understand This**

   - For More Info:
     - **NREL Tool and NREL Fleet Activities:**
       - Kevin Walkowicz – NREL’s Advanced Vehicle Testing Activity
       - [Kevin.walkowicz@nrel.gov](mailto:Kevin.walkowicz@nrel.gov)
       - 303-275-4492

   - Acknowledgements:
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Additional Information

**WVU Tool Info:** An interactive design tool has been developed in Matlab that allows building new driving cycles through the concatenation of individual microtrips obtained by segmentation of second by second measurements from standard cycles. The generated new cycles have prescribed characteristics in terms of relevant parameters such as average speed, stops per mile, percentage idle, speed standard deviation, and kinetic intensity. The selection of microtrips to achieve the desired cycle characteristics is performed using a customized genetic algorithm. The generated cycles are used to increase the available database for regression-based modeling of fuel efficiency and emissions of CO2, CO, NOx, HC, and PM. The validation of the approach is currently in process at WVU.


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**ORNL Tool Info:** The Oak Ridge National Laboratory has developed a Duty Cycle Generation Tool (DCGenT) that can generate duty cycles of user specified duration and user specified characteristics (e.g., metro/urban/rural, good/poor weather conditions, road grade, etc.) based on data collected from real-world driving environments. The data base for Class-8 long-haul operations contains more than 750,000 miles of driving data. Contact Bill Knee 865.946.1300, kneehe@ornl.gov for additional information, and download the Class-8 Final Report that discusses the data collection effort, the collected data and the duty cycle generation tool from: http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008-122.pdf. ORNL is currently engaged in collecting medium truck performance data on two-of four vocations in the Class-6/-7 domain.

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