HEAVY-DUTY VEHICLE WEIGHT AND HORSEPOWER DISTRIBUTIONS:
MEASUREMENT OF CLASS-SPECIFIC TEMPORAL AND SPATIAL VARIABILITY

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Abstract

Heavy-duty vehicle emissions are highly correlated with engine load, which in turn is a function of vehicle weight, road grade, and onroad vehicle operations. The USEPA and West Virginia University are currently developing load-based emission rate models for various classes of heavy-duty vehicle engine technology. However, current onroad data for engine technology class and heavy-duty vehicle weights are usually inadequate to link with these new models (due to non-representative samples included in truck surveys and the predominance of data available from non-urban weigh-in-motion sites).

Over a two-year period, Georgia Tech researchers collected heavy-duty vehicle classification and weight data from: 1) State of Georgia weigh stations, and 2) onroad weigh-in-motion equipment in the greater Atlanta area. Additional weight, horsepower, and truck classification data were collected through roadside truck surveys. Analysis of these data identified significant relationships between heavy-duty vehicle class, onroad weight, and horsepower distributions. The application of these relationships in emissions modeling routines has the potential to significantly improve heavy-duty emission models by temporally and spatially disaggregated heavy-duty vehicle data and linking these load-related data with more accurate heavy-duty load-based modal emissions rates.

Background

MOBILE5a Modeling Inaccuracies

• Vehicle registration data are not representative of the onroad HDV fleet due to large variability in onroad operations
• Current GVWR classes are not matched with engine, activity, and load categories
• Activity and emission factor estimates are averaged across engine classifications
• Light-duty vehicle traffic counts are often used as a surrogate to spatially and temporally allocate estimated regional heavy-duty traffic

Study Objectives

• Develop a heavy-duty vehicle classification system for on-road HDV weight and horsepower data collection
• Determine if on-road heavy-duty vehicle weight and horsepower distributions can be predicted based on classification and temporal characteristics for the Interstate System

HDV Load-Based Modeling

⇒ Develop load-related HDV emission rates (g/bhp-hr) by engine HP class (and other technology variables)
⇒ Create a compatible HDV classification system
⇒ Engine class, truck class, and cargo weight distributions
⇒ Use modeled or monitored data (UTPS and HPMS) to predict link volumes by emission-related vehicle class
⇒ Develop appropriate statistical models for beyond speed acceleration profiles, and weight and HP distributions
⇒ Estimate HDV onroad operating loads (bhp-hr)
⇒ Predict and can initial rolling resistance, drag, grade, and accessory loads as a function of onroad operations
⇒ Estimate emissions using HDV load model
⇒ Multiply engine load activity by load-based emission rates

Preliminary Truck Surveys

⇒ Purpose
  • Develop HDV classification scheme
  • Determine relationship between GVW and HP
⇒ Data Collected
  • Axle-trailer configuration
  • VIN (used to determine HP)
  • Gross vehicle weight from static scale
⇒ Statistical Analysis
  • Cross-tab analysis between GVW and HP for all trucks
  • Cross-tab analysis between GVW and HP for various axle-trailer combinations

Comparison of Horsepower Means

![Comparison of Horsepower Means](image)

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<th>Horsepower</th>
<th>Class 5 &amp; 6 (combined)</th>
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Procedure

• Surveys conducted at the Douglas County weigh station
• Vehicles selected at random from traffic stream
• Weighed on static scale
• Engine survey in parking lot

Findings

• Four-vehicle classification system sufficient to classify HP differences
• Horsepower ratings within each truck classification independent of weight
• Separate models for HP and GVW
Expanded Truck HP Survey Method

- Variables considered:
  - Trip type - external trips may use lower HP engines to increase vehicle reliability and driveability
  - Truck company type - large for-hire companies may use higher HP engines to fulfill the wide range of service requirements (requires additional data)
  - Trailer body type - vehicles hauling flatbeds may haul heavy machinery requiring higher HP engines
  - Survey locations - internal trips from truck stops and external trips from weigh stations
  - Additional data collected from 453 HDVs: VIN, weight, and HP (based on driver ID)

- Disaggregation of vehicles into 4 classifications is sufficient to explain the horsepower-weight relationship for all heavy-duty trucks
- Truck surveys conducted at weigh stations and truck stops are sufficient for estimating HP of HDVs with 5 or more axles
- Chi-square tests indicate that there is no statistically significant relationship between HP and GVW for Class 9 vehicles (70-90% of Interstate traffic)
- Trucking companies do not appear to match engine horsepower to the loads for Class 9-13 trucks
- No significant differences across sites (more data needed to verify the independence of HP and spatial location by trip type)
- Can use HP distributions in 50 HP bins, by truck class, in emissions modeling

**Weight Modeling**

- Selected locations with greatest likelihood of capturing weight differences (limited equipment resources)
- Sampled 76,000+ vehicle weights
- Developed weight distribution models by day of week and time period groupings using chi-square tests (created weight models for day of week groupings without spatial variability, then disaggregated models with spatial variability into shorter time periods)
- Test show 3 day of week categories that are statistically significantly with weight distributions independent of WIM site location for Class 9 vehicles 9AM-3PM

**Weight Distribution Models**

Class 9, Mon-Sat, 9AM-3PM
Class 9, Mon-Sat, 3PM-7PM
Class 9, Mon-Sat, 7PM-9AM
Class 9, Mon-Sat, 9AM-7PM
Class 9, Mon-Sat, 3PM-7PM
Class 9, Mon-Sat, 7PM-3PM

**Summary of Weight Models**

Graphic Representation of Class 9, Midday Weight Models

**Conclusions and Recommendations**

**Conclusions on Portable WIM Data Collection**

- Portable WIM equipment, with post-processing (manual peak shifting methods were not discussed in this poster due to space constraints), is sufficient for collecting most classes of HDV weight data on Interstates
- Further disaggregation of weight data to refine weight bins in time period requires larger samples or more accurate WIM equipment
- Class 5 vehicles could be reliably measured with WIM equipment. However, weight data for these vehicles appear to be normally distributed (important concerns for future research).
- Spatial and temporal models for Class 4 vehicles not yet determined

**Conclusions on Weight Models**

- Chi-square tests are appropriate for comparing frequency weight distributions
- Classifications based on axle-tailer configuration are efficient for developing HDW weight distributions
- Class 5 vehicle weight distributions not reliably determined
- The weight distribution of Class 5-7 trucks inside the perimeter was statistically different than an interstate leg (fewer trucks with weights greater than 65,000 pounds) requiring additional research
- Class 9 vehicles exhibited no spatial differences in weight distributions except near the airport in the afternoon
- Class 9-13 vehicles exhibited no significant spatial variability

**Future Research**

- Validate weight and horsepower distributions through additional data collection
- Check for spatial and temporal variability on local roads and proximal land use characteristics
- Incorporate other vehicle characteristics with weight distributions (vehicle length, axle spacing, etc.)

**Policy Recommendations**

- Develop national HDV registration database that links registrations to VIN and engine characteristics
- Incorporate HDV truck class and engine technology data items in commercial vehicle surveys
- Enhance Bureau of Census Community Flow survey data
- Increase data available from the TRU
- Provide additional equipment data (e.g., axle-tailer classification in addition to tractor trailer classification or provide data on metropolitan level (aggregation normally needed))
- Install additional permanent WIM sites on Interstate in major metropolitan areas
- Site selection based on differences in external spatial weight distributions and multilevel use classification