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 portable 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

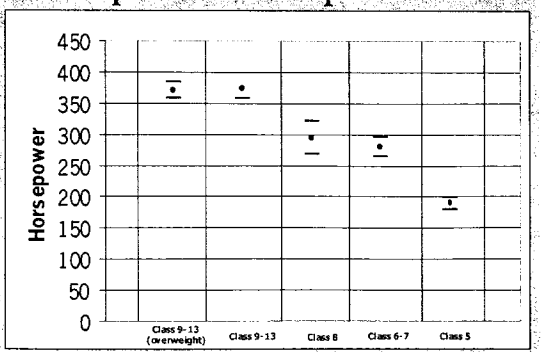
HDV Load-Based Modeling

- 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/monitored data (UTPS and HPMS) to predict link volumes by emission-related vehicle class
- Develop appropriate statistical models for onroad speed /acceleration profiles, and weight and HP distributions
- Estimate HDV onroad operating loads (bhp-hr)
  - Predict and sum inertial, 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:
  - Crosstab analysis between GVW and HP for all trucks
  - Crosstab analysis between GVW and HP for various axle-trailer combinations

Comparison of Horsepower Means

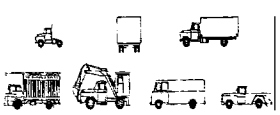


Procedure

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

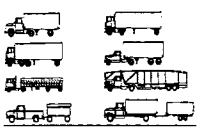
Findings

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

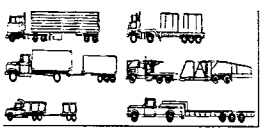


Class 5, 2-axle single-unit trucks

Class 6, 3-axle single-unit trucks



Class 8, 3 or 4-axle single-trailer combination



Class 9, 5-axle single-trailer combination

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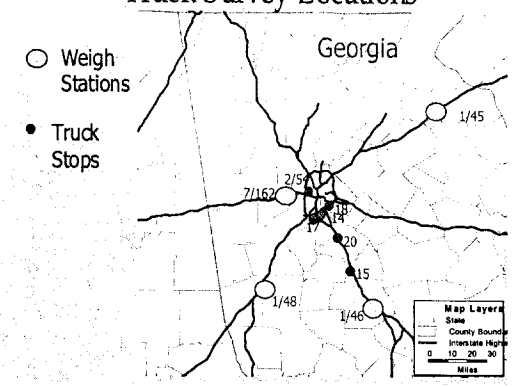
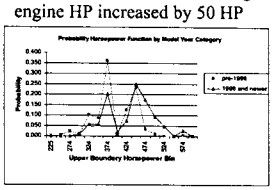
Expanded Truck HP Survey Method

- 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)

Truck Survey Locations



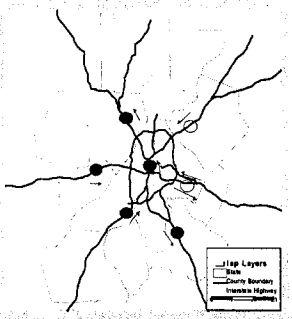
- Statistically significant differences between pre-1996 MY truck HP and newer truck HP (model separately)
- Between 1995 and 1997 average engine HP increased by 50 HP



- 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 weights of 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

WIM Locations

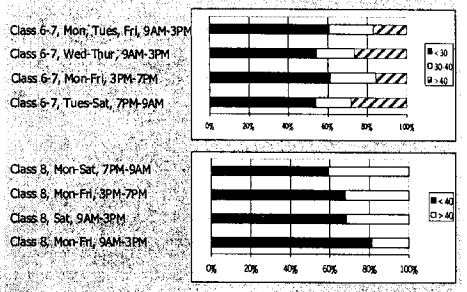
- Successful WIM Locations
- Unsuccessful WIM Locations



Weight Modeling

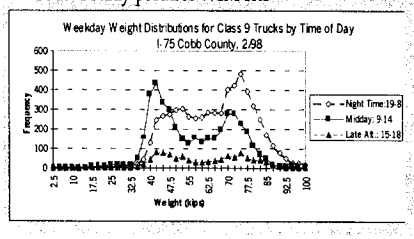
- Selected locations with greatest likelihood of capturing weight differences (limited equipment resources)
- Sampled 75,000+ vehicle weights
- Developed weight distribution models by day of week and time period groupings using chi-square tests (created weight models for day of week groupings without spatial variability, then disaggregated models with spatial variability into shorter time periods)
- χ^2 tests 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

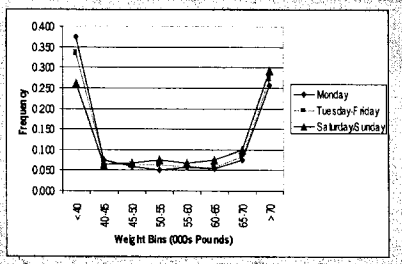


Weight Model Development

- Time periods based on weight data from Cobb County portable WIM site

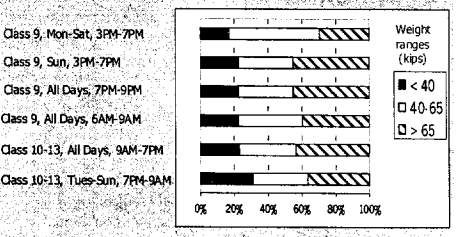


Summary of Weight Models



Graphic Representation of Class 9, Midday Weight Models

Weight Distribution 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 or time periods requires larger samples or more accurate WIM equipment
- Class 5 vehicles could not be reliably measured with WIM equipment. However, weight data for these vehicles appear to be normally distributed (important area of future research).
  - Spatial and temporal models for Class 4 vehicles not yet determined

Conclusions on Weight Models

- Chi-square tests are appropriate for comparing freeway weight distributions
- Classifications based on axle-trailer configuration are efficient for developing HDV weight distributions
- Class 5 vehicle weight distributions not reliably determined
- The weight distribution of Class 6-7 trucks inside the perimeter was statistically different than on Interstate legs (few trucks with weights greater than 40,000 pounds) requiring additional research
- Class 8 vehicles exhibited no spatial differences in weight distributions except near the airport in the afternoon
- Class 9-13 vehicles exhibited no significant spatial variability

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 Commodity Flow Survey data
- Increase data available from the TIUS
  - include horsepower data item
  - use axle-trailer classification in addition to GVWR classification
  - provide data on metropolitan level (aggregate nationally if needed)
- Install additional permanent WIM sites on Interstates in major metropolitan areas
  - site selection based on differences in external spatial weight distributions and and internal land use characteristics

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.)