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Improving estimates of transportation emissions: Modeling hourly truck traffic using period-based car volume data

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ABSTRACT

We estimate hourly truck traffic using period-based car volumes that are usually available from travel demand models. Due to the lack of local or regional data, default vehicle-miles traveled mix by vehicle class in mobile emission inventory models is usually used in transportation emissions inventory estimates. Results from such practice, however, are often far from accurate. Heavy-duty trucks generate orders of magnitudes higher emission rates than light duty vehicles. Vehicle classification data collected from weigh-in-motion stations in California are used to examine the performance of various forms of the method across days of week and geographic areas. We find that the models identified provide satisfactory and statistically robust estimates of truck traffic.

1. Introduction

Under policies and regulations like the Clean Air Act Amendments of 1990, the Intermodal Surface Transportation Efficiency Act of 1991, and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005, US states are required to meet the National Ambient Air Quality Standards by coordinating transportation and air quality planning to reduce emissions from transportation sources.

Within this regime, accurate emissions inventory estimation is the basis for transportation conformity analysis that helps to gauge whether a transportation plan is in compliance with the air quality improvement goals of a State Implementation Plan (SIP). Further, mobile emissions inventories representative of the reality at various temporal and spatial scales are necessary inputs for, among other things, air quality modeling, exposure assessment, and environment justice studies.

Mobile emission inventory models require transportation activity inputs such as traffic volume, vehicle-miles traveled (vmt), travel speed and so on by vehicle class (e.g., light-duty auto, heavy-duty truck) to estimate running exhaust emissions, since emission rates (grams/mile) vary dramatically across vehicle classes (Jackson, 2001). In particular, advanced air quality simulation and exposure assessment models require the emissions inventory and transportation activity data to be computed at fine temporal (e.g., hourly) and spatial, 4 by 4 km grid, resolution. Therefore, accuracy of the results from this whole chain of models is heavily dependent on the accuracy of transportation activity inputs, of which truck transportation data is the focus of this study.

In practice transportation activity data of light-duty vehicles (e.g., passenger cars) are available, to certain degree of accuracy, in period-based outputs from travel demand models or from highway performance monitoring data. To meet the temporal and spatial resolution needs of air quality modeling, Lin and Niemeier (2001) developed empirical techniques to convert the period-based traffic volumes into hourly volumes. Then emission tools such as the California Department of

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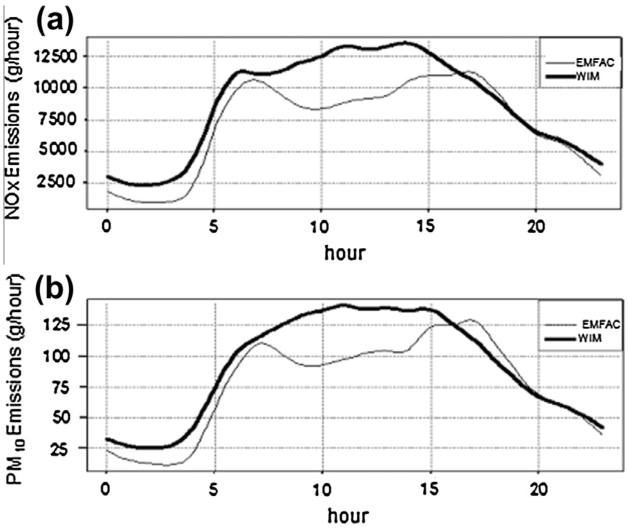

Fig. 1. Emissions from a one-mile road segment in Los Angeles County (estimated from EMFAC and WIM vehicle mixtures): (a) NO and (b) PM10.

Transportation's (CALTRANS') Direct Travel Impact Model (DTIM4) can be used to combine transportation activity data and the corresponding emission factors from EMFAC models to estimate hourly grid-based transportation emissions inventories.

The models built in previous studies are calibrated and proved to work well for light-duty vehicles or night traffic volume, but traffic on roads consists of a mix of classes of vehicles, which produce different levels of emissions per mile driven. Vehicle mix is therefore important for accurate emissions estimation. Existing emission models such as EMFAC and MOVES provide users with options to use locally or regionally vehicle mixes, but actual vehicle mix/classification data is hard to obtain especially if fine spatial and temporal resolution is desired. Often the default values in emission models are unrepresentative of a particular area (Bhat and Nair, 2000). In the current EMFAC model, for instance, default vehicle mix assumes a fixed truck fraction over large areas across hours of a day, which in many cases is far from representative, especially for project-level microenvironment assessment.

Trucks, especially heavy duty-diesel trucks account for 60% NOx and 40% of PM in their emissions, with emissions factors tens of times higher than those for passenger cars. If the default vehicle-mix in an emission model under-estimates the proportion of truck traffic, adoption of the model default will lead to under-estimation of emissions. Fig. 1a and b exhibits the hourly NOx and PM_{10} emissions from a one-mile freeway segment in Los Angeles, calculated using the EMFAC default vehicle mix for Los Angeles and the vehicle mix from weigh-in-motion (WIM) vehicle classification data. As shown, results from using the EMFAC default vehicle mix, compared to using WIM vehicle mix data, underestimate NOx and PM10 emissions by as much as 30% during the off-peak hours. Further, while the EMFAC curves echo the standard double peak distribution of traffic, the WIM results depict a more accurate picture of the NOx and PM emission patterns, reflecting impacts of the unimodal truck traffic distribution (a single mode during the mid-day) (Hallenbeck et al., 1997).

Here we develop a method to improve estimation of truck traffic for emissions modeling. An extensive vehicle classification database obtained from the WIM stations in the metropolitan areas of Los Angeles, Sacramento and San Diego in California for 2000 is used to demonstrate the methodology and evaluate model performance for calculating hourly truck traffic.

2. Data

The data was collected from WIM traffic monitoring sites by the California Department of Transportation and provides information of individual trucks.[1] The data is continuously collected as a truck passes over the magnetic loops and axle sensors embedded in the pavement (Hajek et al., 1994). The truck event data from WIM systems is aggregated into hourly traffic units, and includes, truck volumes, car volumes, average gross truck weights, average truck lengths and average truck speeds. The data of interest are hourly truck volumes, hourly truck fractions (truck ratios) and period car volumes. The use of truck volumes as a response variable is an obvious choice, but truck ratios may better account for the dynamic variability of truck volumes in relation to car traffic. Twenty-four hourly traffic volumes from each WIM station represent one data point, giving, Los Angeles approximately 800 points, San Diego, 750 and Sacramento 500.

Period-based car volumes are the predictor variables; i.e. the hourly car volumes in a period divided by the number of hours in the period. Two types of period definitions are used. The first includes three-period car volumes that are typical

[1] In the Los Angeles area, the data was collected from WIM stations 8, 9, 12, 13, 47, 48, 59, 60, 79, 80, 82, and 83. In the San Diego area, the data was available from WIM stations 14, 22, 23, 84, 85, 87, 88, 89, 90, 91, and 92. In the Sacramento area, data from WIM stations 3, 4, 29 and 46 was available.