Link-Based Calculation of Motor Vehicle Air Toxin Emissions Using MOBILE6.2

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ABSTRACT

EPA's MOBILE 6.2 model allows transportation planners to respond to community concerns by calculating air toxin emissions from motor vehicles. Metro partnered with EPA, ICF Consulting, and the Oregon Department of Environmental Quality in estimating emissions of 27 hazardous air pollutants at the link and zone level. This presentation describes the emission calculation algorithms that Metro developed for use in EMME/2, MOBILE, Stata, and Oracle.

The chosen approach involved splitting daily vehicle volumes into seven periods to represent congestion at different times of the day. Multiclass assignments were conducted in EMME/2 to track vehicle movements by fleet; the fleets accounted for differences in vehicle age profile by county and in inspection/maintenance program by state. Trips and VMT were then allocated from the seven assignment periods to each hour of the day using factors from Metro's household activity survey.

Separate MOBILE runs were conducted for each combination of the five fleets, two seasons, four link types, and (on freeways and arterials) 14 speed bins. Emission rates for seven of the pollutants of interest were automatically produced by MOBILE 6.2, while most other toxins required the use of Additional HAPS inputs. For each pollutant whose emissions vary by speed, speed curve equations were developed by linear regression to allow the calculation of emissions at any speed.

All the data were exported to an Oracle database. MOBILE's emission rate factors were applied to each link to calculate running emissions at every hour of the day. Emissions from intrazonal travel, as well as all non-running emissions, were calculated then allocated to each trip's origin zone.

Metro plans to use this link-based methodology for future air quality conformity work. The queries and programs developed for this study can also be adapted for use by other agencies with a need for geographically detailed analyses of motor vehicle emissions.

INTRODUCTION

A number of recent studies have shown an association between adverse health effects and elevated roadway air toxics.[1, 2, 3, 4, 5, 6, 7, 8] To identify where these areas of elevated concentrations, or "hot spots," may occur, it is critical to accurately characterize the spatial distribution of highway mobile source emissions. Typically, gridded mobile emissions surrogates are used as input to air quality dispersion models. However, surrogates may not adequately represent the mobile source activity correctly, and distributing mobile source emissions throughout an area may underestimate emission density on transportation features such as major roads. As a result, the air dispersion modeling cannot capture high concentrations that often occur next to roadways and at intersections.

The study described here demonstrates an alternative methodology for developing link-based onroad emissions generated along major highways. Portland Metro partnered with EPA, ICF Consulting, and the Oregon Department of Environmental Quality in estimating emissions of 27 hazardous air pollutants at the link and travel analysis zone (TAZ) level, using EPA's MOBILE6.2 highway vehicle emission factor model in conjunction with link basic traffic data from Portland Metro's travel model. The resulting inventory included emission estimates for seven daily time periods for over 24,000 roadway links.

Sbayti et al. demonstrated that the level of roadway network aggregation can have a significant impact on inventory estimates.[9] The link-based approach presented in this study represents the finest scale currently feasible for building an inventory. A similar approach was recently employed to model the concentration distribution of several pollutants (hydrocarbons, carbon monoxide, and nitrogen oxides) in the urban area of Beijing, China and also to model concentrations of several hazardous air pollutants (HAPs) in Houston, Texas.[10, 11]

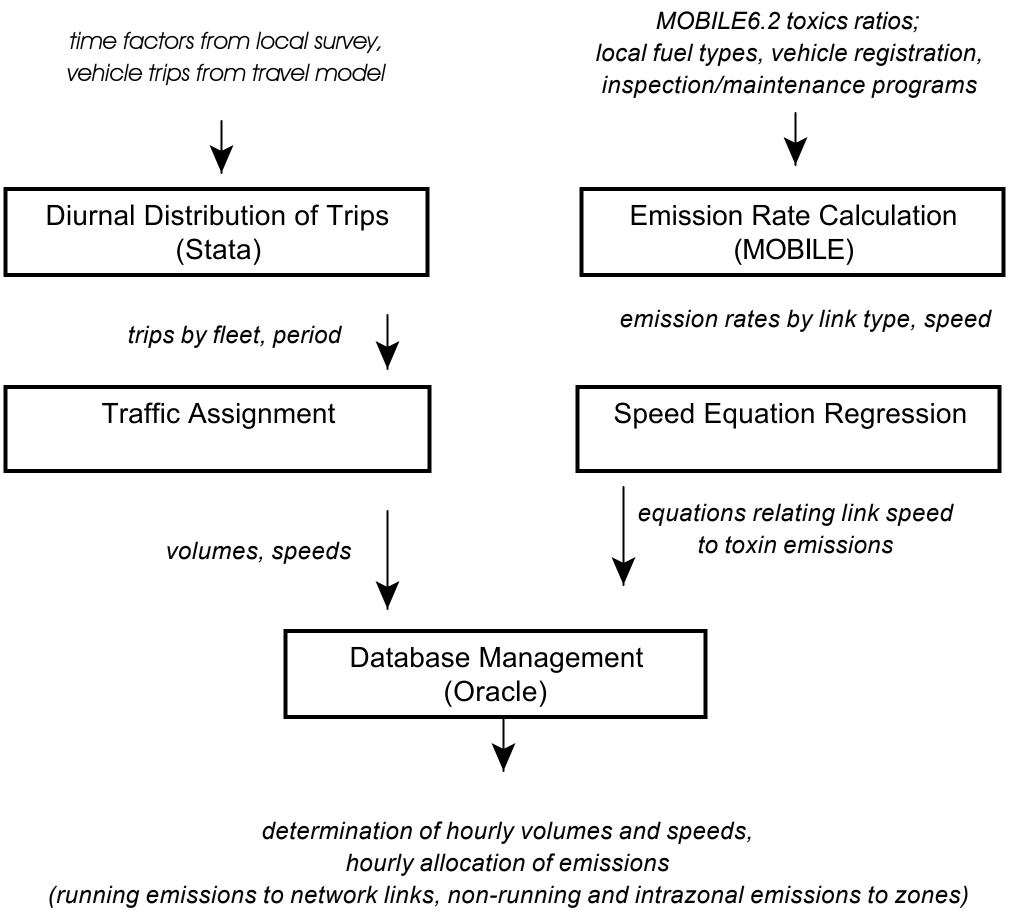
METHODS

Figure 1 outlines the major tasks in developing the link-based inventory, along with their inputs and outputs. Following is a general discussion of these tasks; a detailed discussion of the tasks can be found in a technical document developed by Portland Metro.[12]

Development of Link Volume and Speed Estimates

Data from Portland Metro's travel modeling was used to develop speed and traffic volume data by link for seven time periods. Vehicle trips were assigned to several fleets. The fleets corresponded to individual counties with varying fleet age profiles, and different I/M programs by State. A 1994-1995 household activity survey conducted by Portland Metro was used to assign vehicle trips to the seven time periods. Each hour's proportion of trip starts was used to determine the percentage of assigned traffic volumes to apportion to the seven time periods. Figure 2 shows the distribution of weekday trip starts (Metro does not have a weekend trip model). In addition, all links in Metro's modeling network were assigned to one of five link

Figure 1. Project Flow Diagram



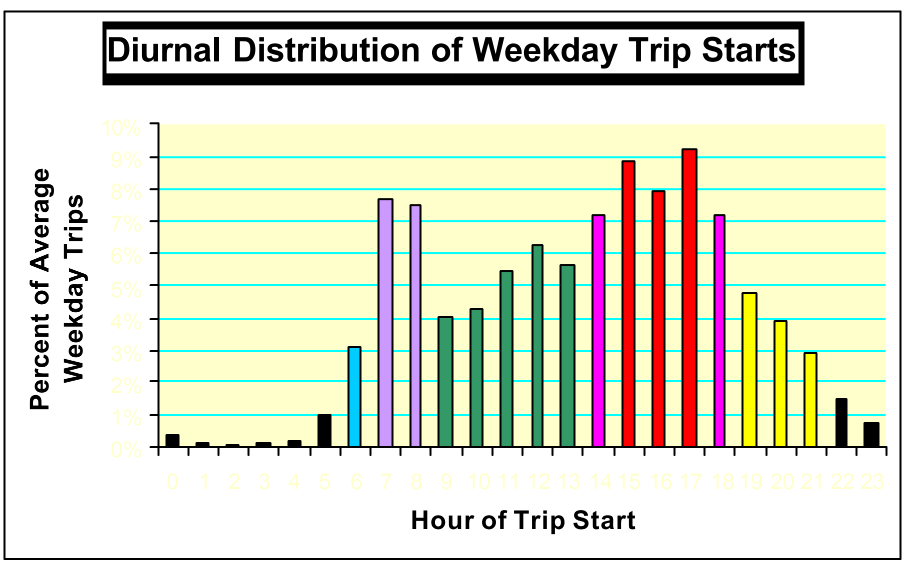


Figure 2. Distribution of Weekday Trip Starts Used to Assign Traffic Volumes to Time Periods

types – freeway, arterial, local roadway, freeway ramp, or non-street link (e.g. walk connector, zero emissions). A travel demand model, EMME/2, was used to develop a database of link speeds and link volumes by fleet type and time period.

Calculation of Emission Rates

MOBILE6.2 was used to calculate toxic emission rates. Using toxic emissions data and algorithms from EPA's Complex Model for Reformulated Gasoline, MOBILE6.2 estimated emission factors for five gaseous HAPs -- benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein.[13,14] MOBILE6.2 also has the capability to model particulate matter emissions and was used to estimate diesel PM and elemental carbon. The algorithms used for the gaseous HAPs require a number of fuel parameter inputs which are not required for the estimation of criteria pollutants, such as benzene content, aromatics content, and olefin content. For Portland, these fuel parameters were obtained from data collected in surveys of service stations by TRW. The surveys are conducted twice a year, once in summer and once in winter. The same fuel parameters were used in the draft 1999 National Emissions Inventory (NEI) for HAPs, version 3.[15] MOBILE6.2 also has an ADDITIONAL HAPS command which allows the user to estimate emission factors for additional hazardous air pollutants not explictly included in the model by providing data on basic emission rates, air toxic to TOG ratios, or air toxic to PM ratios. The ADDITIONAL HAPS command was used to estimate emissions of other HAPs included in the Portland study -- chromium (hexavalent and trivalent), nickel, arsenic and 16 polycyclic aromatic hydrcarbons. The inputs used in conjunction with this command were the same as those used in the draft 1999 NEI for HAPs, version 3. These ADDITIONAL HAPS inputs were included in the recent release of updated MOBILE6.2, and are available at www.epa.gov/otaq/m6.htm.

For freeways and arterials, the MOBILE6.2 AVERAGE SPEED command was used to calculate emission rates for 14 average speed bins, which are centered on 2.5 mph and each 5 mph increment between 5 mph and 65 mph. For local roadways and freeway ramps, MOBILE calculates emission rates based on a fixed speed, regardless of the speeds produced by the traffic assignment. The assumed speed is 12.9 mph for local roadways and 34.6 mph for freeway ramps. For each season (summer and winter) and the five fleets, MOBILE was run 30 times: at the 14 average speed bins for freeways and arterials and once each for local roadways and freeway ramps (see Figure 3) The MOBILE default vehicle type distributions were used for all link types. MOBILE's composite ("All Veh") emission rates were used for all pollutants except diesel particulate matter.

Since most HAPs estimated by MOBILE6.2 vary by speed, speed-emission curve equations were developed by linear regression using the emission rates for each speed bin. Stata software was used to perform these regressions. For each season-fleet-link type-toxin combination, speed-emission curve equations were developed by linear regression using the 13 records for average speeds between 5 and 65 mph. A fifth order polynomial equation form was used as it produced the best fitting curve:

- Dependent variable: MOBILE emission rate
- Independent variables: Speed, $Speed^2$, $Speed^3$, $Speed^4$, $Speed^5$

An example curve, for running benzene emissions on arterial roads in Multnomah County, Oregon, is provided in Figure 3.

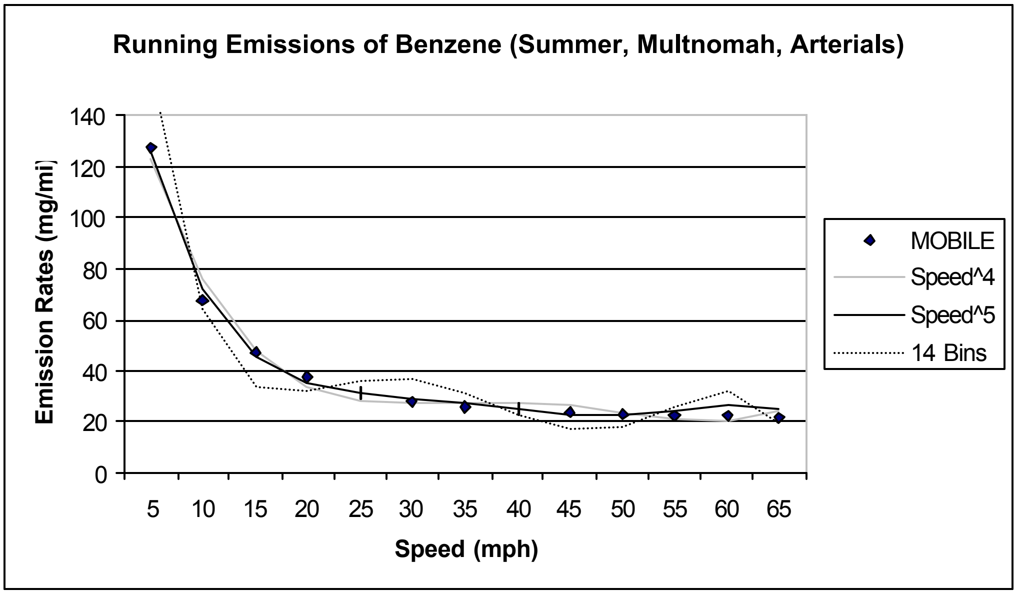


Figure 3. Example Speed-Emissions Curve

Calculation of Emissions

Due to the large amount of data required to generate the link based inventory, and the complexity of the needed calculation, the data on traffic volumes, speeds, and emission rates were transferred to Oracle. The project eventually required 10 gigabytes of Oracle tablespace. MOBILE6.2 emission factors were applied to each link to calculate running emissions at every hour of the day.

All emissions of diesel particulate matter, elemental carbon, formaldehyde, acetaldehyde, acrolein, chromium, nickel, arsenic, and PAHs were assumed to be running emissions and associated with roadway links. The only exception to this were emissions from trips which begin and end in the same TAZ. The emissions from these trips were assigned to the TAZ where the trip originated. These intrazonal trips accounted for only 1% of the total VMT. Start and evaporative emissions of benzene and 1,3-butadiene were treated differently from these pollutants.[a] These were the only two modeled pollutants with evaporative emissions, and also have substantial cold start emissions. These start and evaporative emissions were assigned to travel analysis zones based on where trips originate (See Figure 4).

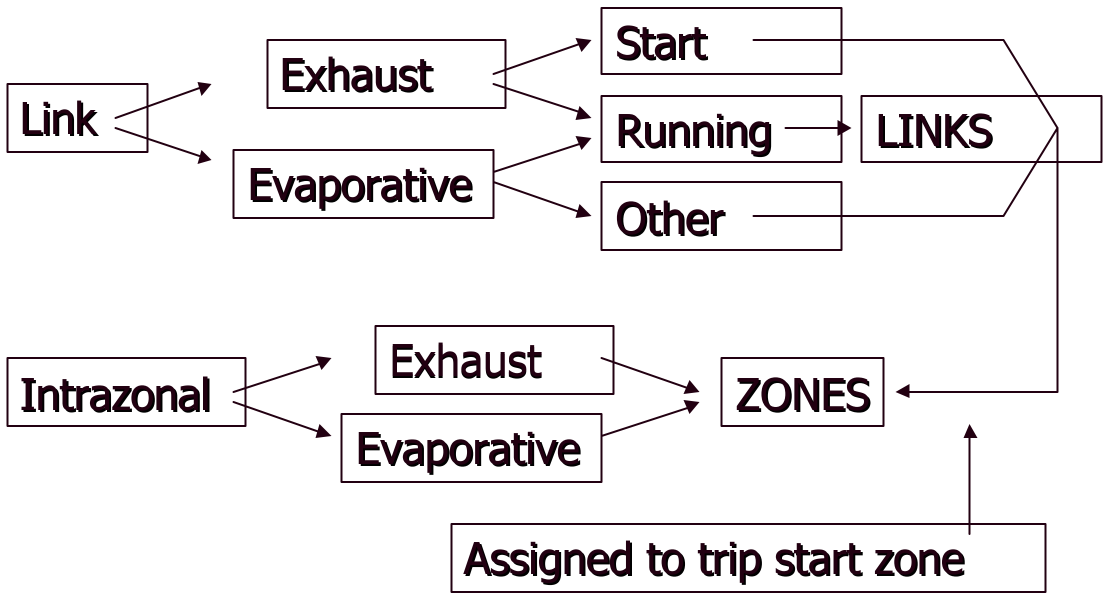


Figure 4. Allocation of Emissions of Benzene and 1,3-Butadiene.

Conclusions

Metro plans to use this link-based methodology for future air quality conformity work. The queries and programs developed for this study can also be adapted for use by other agencies with a need for geographically detailed analyses of motor vehicle emissions. This approach is useful in identifying potential highway mobile source emission "hotspots" for further study, and when used in dispersion modeling, may help better characterize the spatial distributions of concentrations of HAPs, particularly in urban centers where major roadways are located. In should be noted that the approach used here was computationally intensive, and fewer time periods and fleets may produce similar results.

[a]MOBILE6.2 does not output start emissions for air toxins. Thus, the ratio of start to running emissions for benzene and 1,3-butadiene was assumed to be proportional to the ratio VOC start and running emissions.

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Key Words

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