Development of a Fine-Scale, On-Road, Mobile Source Emissions Inventory for the San Francisco Bay Area

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Outline

• Background
• Emissions Inventory Development
  – Data acquisition and processing
  – Composite emission factors development
  – Emission calculations
• Application: Dispersion Modeling
• Results and Conclusions
• Questions and Discussion
• The San Francisco Bay Area Air Quality Management District (the District) is developing guidance on preparing Community Risk Reduction Plans (CRRPs) for toxic air contaminants (TACs) and fine particulate matter (PM$_{2.5}$)
• These plans will allow for a comprehensive, community-wide approach to reducing local air pollutant emissions and exposures
The District worked with Sonoma Technology, Inc. (STI) to generate the detailed emissions inventories (EI) needed for CRRPs.

- Fine-scale on-road mobile source emissions inventories
  - State highways and major arterials
  - 2012–2082
  - Six communities
EMFAC2007 (EMissions FACtors model 2007): The California Air Resources Board (ARB) model for motor vehicles
Emissions Inventory Development: Data Acquisition and Processing (2 of 4)

- Road network
  - National Highway Planning Network (NHPN) shapefile
  - 2008 TIGER/Line shapefile

- Traffic volumes
  - 2009 annual average daily traffic (AADT) counts from Caltrans
  - Traffic count data from local agencies
  - BAYCAST-90 TDM and SF-CHAMP

**TIGER:** The U.S. Census Bureau’s Topologically Integrated Geographic Encoding and Referencing database

**Caltrans:** California Department of Transportation

**BAYCAST-90 TDM:** Travel Demand Models for the San Francisco Bay Area

**SF-CHAMP:** San Francisco Chained Activity Modeling Process
Emissions Inventory Development: Data Acquisition and Processing (3 of 4)

- **Vehicle speed**
  - BAYCAST-90 TDM and SF-CHAMP

<table>
<thead>
<tr>
<th>Period #</th>
<th>BAYCAST-90</th>
<th>SF-CHAMP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>1</td>
<td>6MOR</td>
<td>Early Morning (0000-0600)</td>
</tr>
<tr>
<td>2</td>
<td>4AMPK</td>
<td>AM Peak (0600-1000)</td>
</tr>
<tr>
<td>3</td>
<td>5MID</td>
<td>Midday (1000-1500)</td>
</tr>
<tr>
<td>4</td>
<td>4PMPK</td>
<td>PM Peak (1500-1900)</td>
</tr>
<tr>
<td>5</td>
<td>5EVE</td>
<td>Evening (1900-2400)</td>
</tr>
</tbody>
</table>

- **Truck volume**
  - Caltrans’ 2009 truck AADT, local truck counts
  - BAYCAST-90 TDM and SF-CHAMP
  - Motor Vehicle Stock Travel and Fuel Forecast (MVSTAFF) report
  - Truck restrictions
• Adjustment factors
  – County specific

• Geospatial processing
  – Traffic activity was associated with road links in roadway networks
  – Road name, start/end nodes, and geographic proximity
Emissions Inventory Development: Composite Emission Factors Development (1 of 5)

• Adopt methodology similar to Caltrans’ CT-EMFAC model
• Based on ARB’s EMFAC2007 model
# Truck/non-truck classification

<table>
<thead>
<tr>
<th>Vehicle Class ID</th>
<th>Vehicle Class</th>
<th>Abbr.</th>
<th>Truck Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Passenger Car</td>
<td>LDA</td>
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</tr>
<tr>
<td>2</td>
<td>Light-Duty Trucks (0-3750 lb)</td>
<td>LDT1</td>
<td>Non-truck</td>
</tr>
<tr>
<td>3</td>
<td>Light-Duty Trucks (3751-5750 lb)</td>
<td>LDT2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Medium-Duty Trucks</td>
<td>MDV</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Light-Heavy-Duty Trucks (8501-10,000 lb)</td>
<td>LHDT1</td>
<td>Truck</td>
</tr>
<tr>
<td>6</td>
<td>Light-Heavy-Duty Trucks (10,000-14,000 lb)</td>
<td>LHDT2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Medium-Heavy-Duty Trucks</td>
<td>MHDT</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Heavy-Heavy-Duty Trucks</td>
<td>HHDT</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Other Buses</td>
<td>OBUS</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Urban Buses</td>
<td>UBUS</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Motorcycles</td>
<td>MCY</td>
<td>Non-truck</td>
</tr>
<tr>
<td>12</td>
<td>School Buses</td>
<td>SBUS</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Motor Homes</td>
<td>MH</td>
<td></td>
</tr>
</tbody>
</table>
Emissions Inventory Development: Composite Emission Factors Development (3 of 5)

- Truck only

\[ EF_{Truck} = \sum_{vec=5}^{8} EF_{vec} \times vmtTF_{vec} \]

\[ vmtTF_{vec} = \frac{relativeVMT_{vec}}{\sum_{vec=5}^{8} relativeVMT_{vec}} \]

where

- \( EF_{Truck} \) = composite truck emission factor for the link average speed
- \( EF_{vec} \) = emission factor by vehicle class
- \( vmtTF_{vec} \) = vehicle class travel fraction relative to all trucks
- \( relativeVMT_{vec} \) = vehicle class travel fraction relative to the whole fleet
- \( vec \) = vehicle class ID, with trucks defined as classes 5-8

- Non-truck: same method
Emissions Inventory Development: Composite Emission Factors Development (4 of 5)

- Diesel truck emission factors

\[ EF_{DSL\text{Truck}} = \sum_{vec=5}^{8} EF_{vec,DSL} \times vmtTF_{vec,DSL} \]

\[ vmtTF_{vec,DSL} = \frac{relativeVMT_{vec,DSL}}{\sum_{vec=5}^{8} relativeVMT_{vec,DSL}} \]

where

- \( EF_{DSL\text{Truck}} \): composite diesel truck emission factor for the link average speed
- \( EF_{vec,DSL} \): emission factor by diesel vehicle class
- \( vmtTF_{vec,DSL} \): vehicle class travel fraction relative to all diesel trucks
- \( relativeVMT_{vec,DSL} \): vehicle class travel fraction relative to the whole fleet
- \( vec \): vehicle class ID, with trucks defined as the diesel-fueled portion of classes 5 to 8

- Diesel non-truck: same method
Emissions Inventory Development: Composite Emission Factors Development (5 of 5)

- All-vehicle emission factors

\[ EF_{fleet} = EF_{Truck} \times TruckPect + EF_{NonTruck} \times NonTruckPect \]

where

- \( EF_{fleet} \) = fleet-average composite emission factor for the link average speed
- \( TruckPect \) = link-specific truck percentage
- \( NonTruckPect \) = link-specific non-truck percentage
- \( EF_{Truck} \) = composite truck emission factor for the link average speed
- \( EF_{NonTruck} \) = composite non-truck emission factor for the link average speed

- Diesel vehicle only: same method
Emissions Inventory Development: Emission Calculations

\[ Emis = EF_{fleet} \times VMT \]
\[ TREmis = EF_{truck} \times VMT \times TruckPect \]

where

\( Emis \) = emissions in grams per day from all vehicles traveling on the road link
\( TREmis \) = emissions in grams per day from all trucks traveling on the road link
\( VMT \) = daily vehicle miles traveled on the road link, the product of traffic volume and length of the link

Diesel vehicles only: same method
Application: Dispersion Modeling

The fine-scale on-road mobile source emissions inventory was then used to model pollutant concentrations from vehicles:

- State highways
  - Rcaline (v0.95)
  - Meteorology
  - Keyhole Markup Language (KML) format

- Major arterials
  - AERMOD
  - Meteorology, dimension, and heights
Results and Conclusions (1 of 5)

Emissions inventory

- Average day
- Link specific
- All-vehicle and truck-only
- 2012–2082
- Microsoft Access database
- Quality assurance: compared with ARB’s statewide EI and UC Berkeley’s fuel-based EI

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>All Vehicles (Tons/day)</th>
<th>Trucks (Tons/day)</th>
<th>Truck Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>252.52</td>
<td>13.30</td>
<td>5%</td>
</tr>
<tr>
<td>CO2</td>
<td>44,006</td>
<td>5,737</td>
<td>13%</td>
</tr>
<tr>
<td>DEOG</td>
<td>1.74</td>
<td>1.51</td>
<td>87%</td>
</tr>
<tr>
<td>DPM$_{10}$</td>
<td>1.13</td>
<td>1.01</td>
<td>89%</td>
</tr>
<tr>
<td>DPM$_{2.5}$</td>
<td>1.04</td>
<td>0.93</td>
<td>89%</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>70.59</td>
<td>33.28</td>
<td>47%</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>2.29</td>
<td>1.02</td>
<td>45%</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>2.11</td>
<td>0.94</td>
<td>45%</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>0.43</td>
<td>0.05</td>
<td>13%</td>
</tr>
<tr>
<td>TOG</td>
<td>19.15</td>
<td>1.94</td>
<td>10%</td>
</tr>
</tbody>
</table>

**DEOG**: diesel organic gases
**DPM**: diesel particulate matter
Results and Conclusions (2 of 5)
Dispersion modeling: Rcaline

- Near-road PM$_{2.5}$ concentrations, cancer risk, chronic/acute hazard index
- On both sides of each link at distances of 10, 25, 50, 75, 100, 200, 300, 400, 500, 750, and 1,000 ft.

Results and Conclusions (4 of 5)

Dispersion modeling: AERMOD

Direct contribution of on-road mobile PM$_{2.5}$ concentration and cancer risk on a dense network of receptor locations
Results and Conclusions (5 of 5)

Fine-scale emission inventories become increasingly important

- Input to city-level air pollution dispersion modeling
- Fine-scale spatial mapping, detailed activity data and composite emission factors, plus compilation into modern database structures accessible to automated programming tools are key to generating detailed maps of air quality risk at the city scale
- Detailed air pollution maps help health and planning agencies identify areas with high risk and the sources that contribute to them to protect public health from exposure to local air pollution sources
Questions and Discussion

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