Development of Detailed Railyard Emissions to Capture Activity, Technology and Operational Changes

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Air Quality Management Consulting
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Overview

• Union Pacific Railroad, the J. R. Davis Yard, and railroad operations in general
• Emission inventory issues for railyards
• Specific activities at the J. R. Davis Yard
• Activity data and emission factors
• Activity and emission trends
• Conclusions
Union Pacific Railroad
The Largest Railroad in North America

23 states
32,615 route miles
7,500 locomotives
J. R. Davis Yard, Roseville, CA

- UP’s largest classification yard in the western U.S.
- 40,000 locomotive arrivals per year
- Subject of a 2004 CARB modeling study
- UP cooperated closely in data collection and analysis for emission inventory
- Methodology extended to assess trends and evaluate emission reduction alternatives
Part of a National Network

Annual Yard Visits by Individual Locomotives

Total Individual Locomotives: ~6000
Average # of Visits/Year = ~7.5

# of Visits

# of Locomotives

0 200 400 600 800 1000 1200 1400 1600 1800

1 2 3 4 5 6-10 11-25 26-50 51-100 >100

Total Individual Locomotives: ~6000
Average # of Visits/Year = ~7.5
Railroad Operations

• Move the freight!
  – Quickly
  – Efficiently
• 1 double stack train = 280 HHDDTs
• 2-4 x more fuel efficient
• 3-4 x cleaner per ton-mile
Railyards

- Strategically located
- Get freight to its destination
  - Break and build trains (classification)
  - Intermodal facilities
  - Ports
- Keep them running
  - Refueling and service
  - Locomotive repair
  - Car repair
Top-Down Rail Emission Inventories

- EPA 1998 Regulatory Support Document
  - Average duty cycles for line-haul and switching
  - Emission factors in g/bhp-hr by model and duty cycle
  - Fuel consumption estimated and converted to bhp-hrs
  - Emissions = (bhp-hrs) x (g/bhp-hr)

<table>
<thead>
<tr>
<th>Duty Cycle</th>
<th>Throttle Position (Percent Time in Notch)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D.B.</td>
</tr>
<tr>
<td>Line-Haul</td>
<td>12.5</td>
</tr>
<tr>
<td>Switch</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Problems with Top Down Approach

• Impossible to spatially disaggregate
  – Roseville arrivals likely to have been last fueled in Utah or Oregon
  – Duty cycles are not representative of activity within railyards
• Bottom-up inventory approaches are required
Q: What Goes on in Railyards?

A: It depends on the yard

• J. R. Davis Yard
  – “Hump” yard for classification
  – Locomotive fueling and service
  – Locomotive repair and testing
  – Local train operations
  – Track “maintenance of way” trains
Q: What’s a Hump?

A: Gravity-powered classification

• Incoming trains pushed over a hump
• Cars are automatically uncoupled at the hump and directed into “bowl” tracks with computer switching and braking to build new train segments
• Switchers ("trim sets") pull out new train segments and push to departure tracks
The J. R. Davis Yard
Yard Schematic

- Departure Yard
- Hump Operations Area
- Bowl
- Hump
- Trim Operations Area
- City Yard (Local Trains)
- Receiving Yard

(Not to scale)
What Happens at J. R. Davis Yard

- Through trains pass on the Northside track
- In-bound line-haul and locals go to the Receiving Yard
  - Consists (groups of locomotives) disconnect and are sent to the Service Track or to out-bound trains
  - Cars are sent to classification (hump)
- Service Track washes, fuels, oils, and sands out-bound consists, and does minor repairs
What Happens at J. R. Davis (cont.)

• Locomotive repairs and testing handled at the locomotive shop
• Maintenance of way and out-bound local trains handled at the Rockpile and City Yard
• Out-bound line-haul trains are mated with consists in the Departure Yard
What Happens at Other Yards

• J. R. Davis is a hump classification yard with maintenance facilities
• Other yards differ
  – Flat switching classification yards
  – Intermodal terminals
  – Ports and car loading
  – Service and maintenance
  – Geographic layout and types of freight handled
Emission Inventory Needs

• Activity
  – Number, model and location of consists
  – Paths through the yard
  – Duration of operations and throttle settings
  – Hump set operations
  – Trim set operations
## Train Data (~70,000 Records)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Identification of Train Events</th>
<th>Location in Railyard</th>
<th>Consist Composition</th>
<th>Temporal Profile</th>
<th>Train Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Symbol</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Train Section</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train Date</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrival or Departure</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Originating or Terminating</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direction</td>
<td></td>
<td></td>
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<td>X</td>
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<tr>
<td>Crew Change?</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Arrival &amp; Departure Times</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td># of Locomotives</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td># of Working Locomotives</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Trailing Tons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Locomotive ID #</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Locomotive Model</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Hump and Trim

• Dedicated units (sort of)
  – Hump: Specially modified GP-38s with variable throttle
  – Trim: GP-38 or switchers that may be traded out
  – Most equipped with ZTR SmartStart
  – 24/7 operations with fixed number of units

<table>
<thead>
<tr>
<th>Duty Cycle</th>
<th>D.B.</th>
<th>Idle</th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>N5</th>
<th>N6</th>
<th>N7</th>
<th>N8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trim Operations</td>
<td>0.0</td>
<td>44.2</td>
<td>5.0</td>
<td>25.0</td>
<td>2.3</td>
<td>21.5</td>
<td>1.5</td>
<td>0.6</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Hump Pull-Back</td>
<td>0.0</td>
<td>60.4</td>
<td>12.5</td>
<td>12.4</td>
<td>5.9</td>
<td>3.6</td>
<td>3.6</td>
<td>1.5</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Hump Push</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>100</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Movement, Service, Repair and Testing

- Consist movements avoid bowl and hump, typically with all but one unit shut down
- Service volume and model distribution data
  - Service codes by locomotive ID give location
  - Maintenance codes identify load tests

<table>
<thead>
<tr>
<th>Duty Cycle</th>
<th>D.B.</th>
<th>Idle</th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>N5</th>
<th>N6</th>
<th>N7</th>
<th>N8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consist Movement</td>
<td>0.0</td>
<td>0.0</td>
<td>50.0</td>
<td>50.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Load Tests:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-Minute</td>
<td>0.0</td>
<td>20.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>80.0</td>
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<tr>
<td>15-Minute</td>
<td>0.0</td>
<td>33.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>66.7</td>
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<tr>
<td>30-Minute</td>
<td>0.0</td>
<td>33.3</td>
<td>33.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>33.3</td>
</tr>
</tbody>
</table>
Emission Factors

- > 50 locomotive submodels in common use
- Differences may be negligible between models, and in-use emissions data are not available for every model
- 11 model groups were selected based on common engine families
## Locomotive Model Groups

<table>
<thead>
<tr>
<th>Model Group</th>
<th>Engine Family</th>
<th>Representative Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switchers</td>
<td>EMD 12-645E</td>
<td>GP-15, SW1500</td>
</tr>
<tr>
<td>GP-3x</td>
<td>EMD 16-645E</td>
<td>GP-30, GP-38</td>
</tr>
<tr>
<td>GP-4x</td>
<td>EMD 16-645E3B</td>
<td>GP-40, SD-40-2, SD-45-2</td>
</tr>
<tr>
<td>GP-50</td>
<td>EMD 16-645F3B</td>
<td>GP-50, SD-50M</td>
</tr>
<tr>
<td>GP-60</td>
<td>EMD 16-710G3A</td>
<td>GP-60, SD-60M</td>
</tr>
<tr>
<td>SD-7x</td>
<td>EMD 16-710G3B</td>
<td>SD-70MAC, SD-75</td>
</tr>
<tr>
<td>SD-90</td>
<td>EMD 16V265H</td>
<td>SD-90AC, SD-90-43AC</td>
</tr>
<tr>
<td>Dash-7</td>
<td>GE7FDL (12 cyl)</td>
<td>B23-7, B30-7, C36-7</td>
</tr>
<tr>
<td>Dash-8</td>
<td>GE7FDL (12 or 16 cyl)</td>
<td>B39-8, B40-8, C41-8</td>
</tr>
<tr>
<td>Dash-9</td>
<td>GE7FDL (16 cyl)</td>
<td>C44-9, C44AC</td>
</tr>
<tr>
<td>C60-A</td>
<td>GE7HDL</td>
<td>C60AC</td>
</tr>
</tbody>
</table>
Emission Factors (PM, g/hr)

Throttle Position

- Idle
- N1
- N2
- N3
- N4

Switchers
GP-4x
SD-7x
Dash-9

PM (g/hr)
Factors Affecting Emission Trends

- Fleet modernization
  - 1900 new units since January 2000
  - Higher horsepower, Tier 0, 1 and (soon) 2
  - Decrease in GP-4x, GP-50, GP-60, Dash 7 & 8
  - Lower idle emission rates
  - 1800 units now have auto start/stop technology
  - Decrease in maintenance and load testing

- Increased freight volume and operational changes
  - Little change in number of trains
  - Decrease in fraction of trains handled in the yard
Locomotive Model Trends

Fraction

C60-A
Dash-9
Dash-8
Dash-7
SD-90
SD-7X
GP-60
GP-50
GP-4X
GP-3X
Switchers

0% 10% 20% 30% 40% 50%

Yard Activity Trends

Trains, Locomotives and Freight

<table>
<thead>
<tr>
<th></th>
<th>Trains</th>
<th>Locomotives</th>
<th>Trailing Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrivals</td>
<td>-5.2%</td>
<td>-3.5%</td>
<td>--</td>
</tr>
<tr>
<td>Departures</td>
<td>-7.0%</td>
<td>-7.3%</td>
<td>--</td>
</tr>
<tr>
<td>Throughs (Bypassing the yard)</td>
<td>8.0%</td>
<td>6.8%</td>
<td>--</td>
</tr>
<tr>
<td>Total Arrivals and Departures</td>
<td>-0.3%</td>
<td>-0.9%</td>
<td>15.1%</td>
</tr>
</tbody>
</table>

Load Testing (scheduled and unscheduled maintenance)

<table>
<thead>
<tr>
<th>Test Type</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10-Minute Tests</td>
<td>-18.9%</td>
</tr>
<tr>
<td>15-Minute Tests</td>
<td>14.6%</td>
</tr>
<tr>
<td>30-Minute Tests</td>
<td>-43.2%</td>
</tr>
<tr>
<td>Total Tests</td>
<td>-12.3%</td>
</tr>
<tr>
<td>Idling Hours</td>
<td>-20.6%</td>
</tr>
<tr>
<td>Notch 1 Hours</td>
<td>-43.2%</td>
</tr>
<tr>
<td>Notch 8 Hours</td>
<td>-12.0%</td>
</tr>
</tbody>
</table>
### Emission Trends

<table>
<thead>
<tr>
<th></th>
<th>Estimated Emissions (tons per year)</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idling and Movement of Trains</td>
<td>5.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Idling and Movement of Consists</td>
<td>8.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Testing</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Hump and Trim</td>
<td>7.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Total</td>
<td>22.3</td>
<td>18.9</td>
</tr>
</tbody>
</table>
Conclusions

• Each railyard is unique w.r.t. activities, layout, types of freight, and role in the national network
• Top-down methods don’t apply
• Total activity (trains, tons, locomotives, and models) can be well characterized
• Details of in-yard operations less available, and require expert input
Conclusions (cont.)

- Disaggregate (bottom-up) data provide verifiable trends and the opportunity to evaluate emission reductions from operational changes and new technologies
- Yards are part of a national network and can’t be treated in isolation
- Yard operations and emissions will reflect the effects of national network changes