Policy, Implication, and Application: Unintended Consequences of Load Consolidation in Urban Areas

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Outline

• Truck Load Increases
  – Methodology
    • Transportation Data
    • Environmental Data
  – Results
  – Policy Implications

• Based on paper:
Impacts of Freight Movement

• Freight vehicle emissions impacts on human health in California cost over $500 million per year Source: CARB (2006)

• PM emissions from trucks in California cause about 1500 premature deaths per year Source: CARB (2006)

• PM emissions from trucks in Oakland cause a cancer rate of about 844 per 1 million residents Source: BAAQMD (2008)

• Trucking causes about 14% of GHG emissions in the Bay Area and 6% of global emissions Sources: BAAQMD (2006), IPCC (2007)

• About 1% of GHG emissions can be attributed to the supply-chain for highway maintenance activities in the US
Implementations of Policies to Increase Loads

• Public Freight Consolidation Centers
  – Amsterdam - Tenjin, Japan
  – Heathrow Airport - Kassel, Germany

• Utilization requirements in Copenhagen & Amsterdam

• Individual Companies
  – Tesco Supermarket, UK

• Increased Maximum Weight Limits
  – UK (32.5 to 41 tons since 1980)

Sources:
Equivalent Single Axle Load (ESAL) Per Vehicle Estimation

• The increase in load for a given axle causes exponential pavement damage

• 4th Power Law: The damage caused by a particular load is related to the load by a power of four.

Methodology

• Develop traffic information:
  • Vehicle and cargo weights
  • Equivalent Single Axle Loads per Trip
• Use pavement deterioration model to estimate change in overlay frequency
• Estimate HMA overlay supply-chain emissions
• Estimate tailpipe emissions
• Case examples contrast long-distance and local trucking issues
Pavement Deterioration Modeling

• Use Caltrans Highway Design Manual to get pavement thickness

• Estimate ESALs to failure:

\[ E[\rho] = \exp(12.15 + 6.68 \times \ln(SN + 1) + 2.62 \times \ln(L_2) - 3.03 \times \ln(L_1 + L_2)) \]

\[ \rho = \text{ESALs to failure} \]

\[ L_1 = \text{standard axle load} = 18 \text{ kips} \]

\[ L_2 = \text{dummy variable} = \begin{cases} 
1 & \text{for single axles} \\
2 & \text{for tandem axles} 
\end{cases} \]


• Combine with ESALs/year data to estimate time between overlays
Pavement Overlay
Supply-Chain Emissions

• Two lanes of 1-mile length
• 3-inch thick HMA overlay

Tailpipe Emissions

• composite emissions factors based on CARB’s EMFAC2007
Source: California Air Resources Board (2006) EMFAC2007 v2.3.

Main supply-chain emissions contributors:
• Aggregate Mines
• Petroleum Refineries
• HMA Plants

### Energy (TJ)

<table>
<thead>
<tr>
<th>Energy (TJ)</th>
<th>6.6</th>
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</thead>
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| PM$_{10}$ (kg) | 420 |
| PM$_{2.5}$ (kg) | 140 |
| SO$_{2}$ (kg) | 1000 |
| CO (kg) | 1700 |
| Pb (g) | 110 |
| NO$_{x}$ (kg) | 770 |
| GHG (kg CO$_{2}$ eq.) | 560000 |

Within-Vehicle Class Consolidation on SR-13

**Years between overlays**

- After Shift: 11
- Status Quo: 19

**GHG (10^3 kg CO_2 eq./yr)**

- Status Quo: 140
- After Shift: 30

**SO_2 (kg/yr)**

- Status Quo: 55
- After Shift: 93

**PM_{2.5} (kg/yr)**

- Status Quo: 29
- After Shift: 8
Within-Vehicle Class Consolidation on I-80

- **Years between overlays**
  - Status Quo: 7.9 years
  - After Shift: 4.9 years

- **GHG (10^3 kg CO₂ eq./yr)**
  - Status Quo: 3400
  - After Shift: 2300

- **SO₂ (kg/yr)**
  - Status Quo: 540
  - After Shift: 58

- **PM₂.₅ (kg/yr)**
  - Status Quo: 768
  - After Shift: 36
Consolidation to different truck sizes on SR-13

**Years between overlays**

- Status Quo
- 2 to Large 3-axle
- 2 to 5-axle

**GHG (10^3 kg CO₂ eq./yr)**

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<thead>
<tr>
<th>Status Quo</th>
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<th>2 to 5-axle</th>
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<tbody>
<tr>
<td>140</td>
<td>90</td>
<td>83</td>
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</tbody>
</table>

**SO₂ (kg/yr)**

- Status Quo
- 2 to Large 3-axle
- 2 to 5-axle

**PM₂.₅ (kg/yr)**

- Status Quo
- 2 to Large 3-axle
- 2 to 5-axle

- Overlay
- Tailpipe
Weight Limits and Consolidation on I-80

Years between overlays

- 5 to 6-axle, 90000 pounds: 5.9 years
- 5 to 6-axle, 80000 pounds: 7.1 years
- 5 to 6-axle: 8.8 years
- Status Quo: 7.9 years

GHG (10^3 kg CO₂ eq./yr)

- Status Quo: 140
- 5 to 6-axle, 80000 pounds: 3400
- 5 to 6-axle, 90000 pounds: 3500
- 5 to 6-axle, 80000 pounds: 160
- 5 to 6-axle, 90000 pounds: 190

SO₂ (kg/yr)

- Status Quo: 260
- 5 to 6-axle: 230
- 5 to 6-axle, 80000 pounds: 290
- 5 to 6-axle, 90000 pounds: 350

PM₂.₅ (kg/yr)

- Status Quo: 36
- 5 to 6-axle: 32
- 5 to 6-axle, 80000 pounds: 40
- 5 to 6-axle, 90000 pounds: 49
Impact Considerations

• Criteria pollutants need local intake assessment. EPA’s AIRData cites local industries:
  – Asphalt plant in West Berkeley within 200 meters of residences
  – Refineries in Richmond, aka the “Cancer Belt”
  – Aggregate Mines in Pleasanton
Related Supply-Chain Considerations

• Other types of pavement MR&R activities have different supply-chain emissions
  – e.g. example, steel reinforcement has high associated Pb emissions (EIO-LCA)

• Effects of system boundaries
  – e.g. high SO$_2$, CO and Pb emissions associated with vehicle manufacturing, maintenance and decommissioning

Effects Related to City Logistics Policies

• Indicates possibility of a trade-off between car and truck travel
  – e.g. consolidation of food industry in UK increased car VKT, but reduced truck VKT


• Although there are tailpipe emissions benefits, eliminating empty trips may cause little change to supply-chain emissions

• Circumvention of bans on large trucks causes reversed trade off
  – e.g. Southern California proposed truck bans

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Conclusions

• Increasing loads is beneficial for many pollutants including GHGs, but can increase PM and SO$_2$ emissions
  – Benefits are more likely for long-distance vehicles

• Unintended environmental impacts should be accounted for in future freight policy analyses

• Policy assessments should account for the nuances of both the environment and transportation systems