

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:

- Sathaye N., Horvath A. and Madanat S., “Unintended impacts of increased truck loads on pavement supply-chain emissions.”

- Transportation Research A*, Vol. 44, pp 1-15, 2010

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:

Geroliminis, N. and C. Daganzo (2005) *A review of green logistics schemes used in cities around the world*. U.C. Berkeley Center for Future Urban Transport, A Volvo Center of Excellence.

Browne, M., M. Sweet, A. Woodburn and J. Allen (2005) *Urban Freight Consolidation Centres Final Report*. Transport Studies Group, University of Westminster.

McKinnon, A. (2003) Logistics and the Environment. *Handbook of Transport and the Environment* (eds. D. A. Hensher and K. J. Button) pp. 665-685 Elsevier.

McKinnon, A. (2005) The economic and environmental benefits of increasing maximum truck weight: the British experience. *Transportation Research Part D*, 10, 77-9

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.

Source: American Association of State Highway and Transportation Officials (1993) *AASHTO Guide for Design of Pavement Structures*.

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:

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

ρ = ESALs to failure

L_1 = standard axle load = 18 kips

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

Source: Madanat, S., J. Prozzi and M. Han (2002) Effect of Performance Model Accuracy on Optimal Pavement Design. *Computer Aided Civil and Infrastructure Engineering*, 17, 22-30.

- 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

Energy (TJ)	6.6
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

Source: Adapted from Horvath, A. (2008) *Pavement Life-Cycle Assessment Tool for Environmental and Economic Effects*.

Tailpipe Emissions

- composite emissions factors based on CARB's EMFAC2007

Source: California Air Resources Board (2006)
EMFAC2007 v2.3.

Main supply-chain emissions contributors:

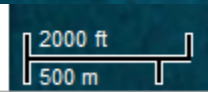
- Aggregate Mines
- Petroleum Refineries
- HMA Plants



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State Route 13

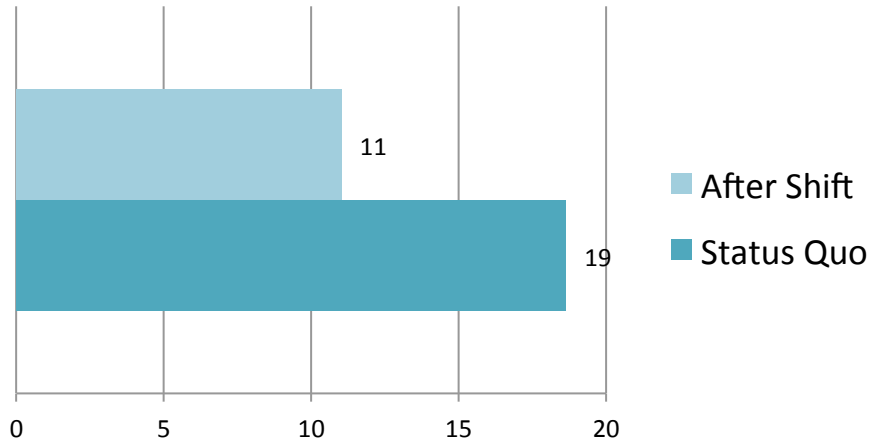
Interstate 80



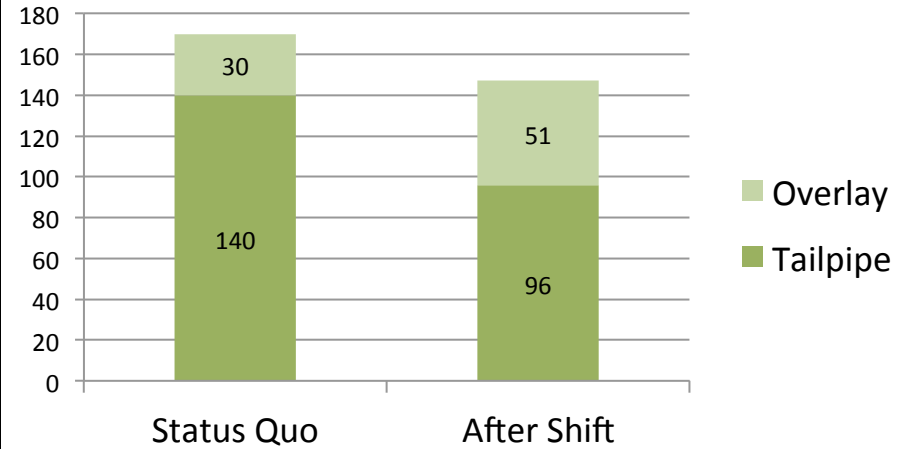
Source: maps.google.com

Within-Vehicle Class Consolidation on SR-13

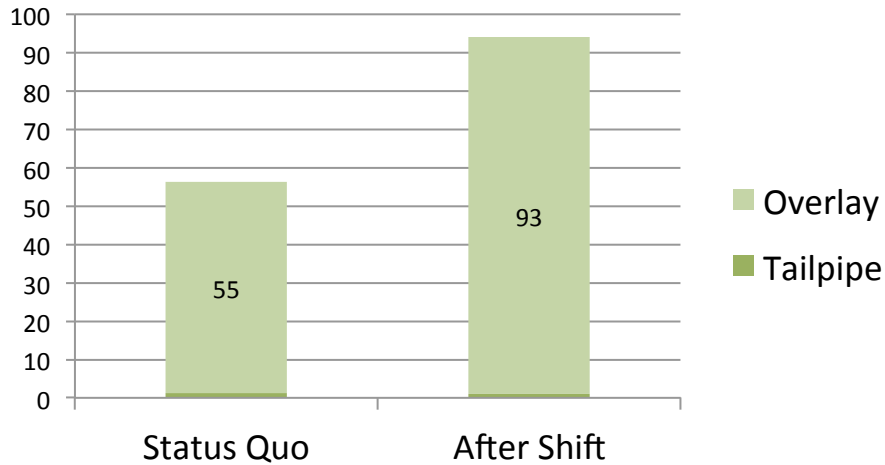
Years between overlays



GHG (10^3 kg CO₂ eq./yr)



SO₂ (kg/yr)

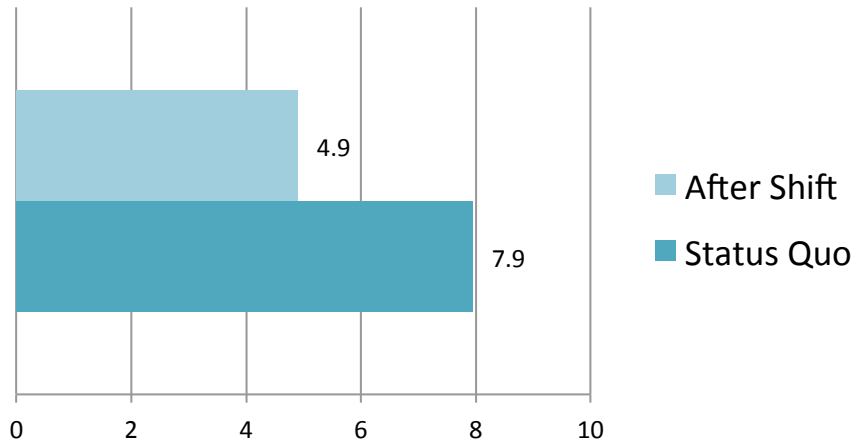


PM_{2.5} (kg/yr)

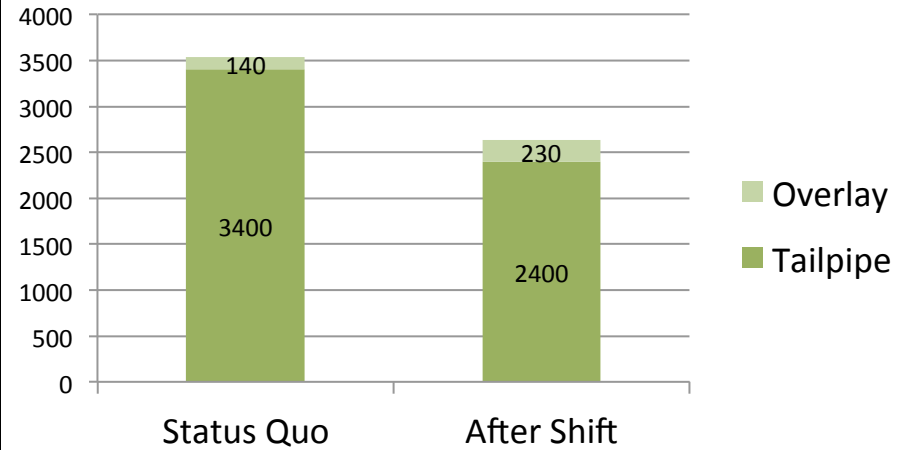


Within-Vehicle Class Consolidation on I-80

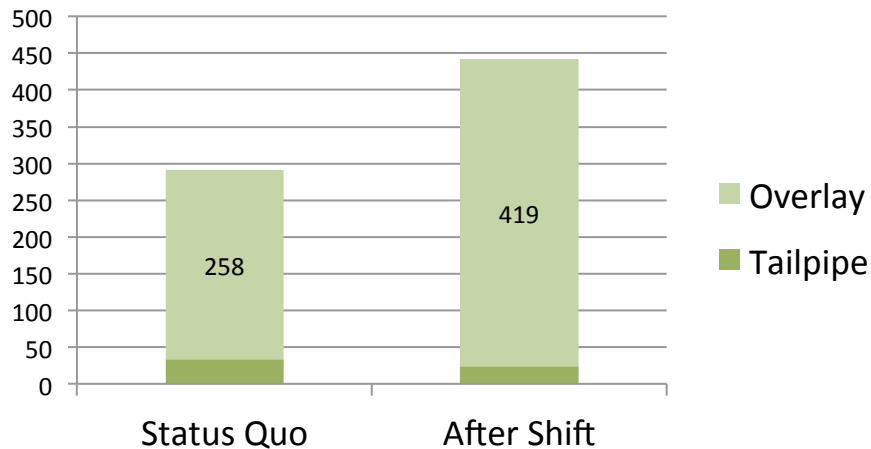
Years between overlays



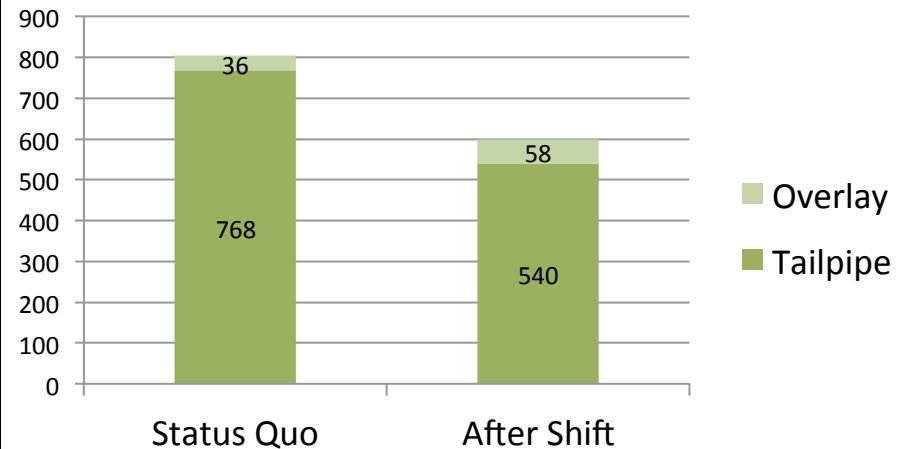
GHG (10^3 kg CO₂ eq./yr)



SO₂ (kg/yr)

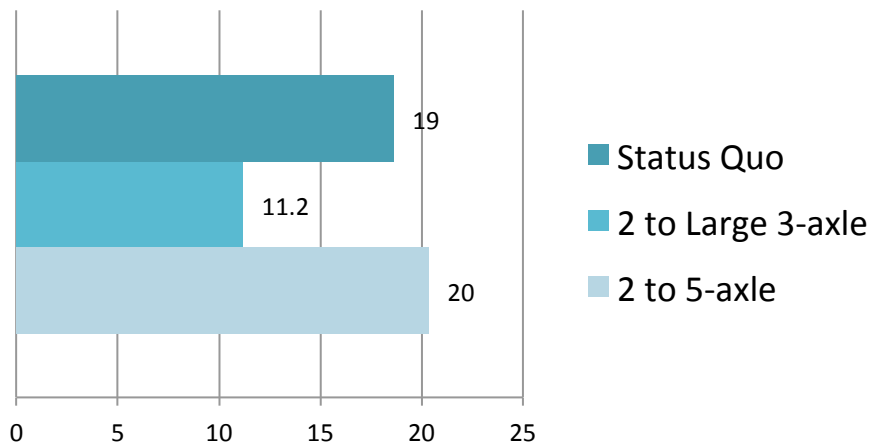


PM_{2.5} (kg/yr)

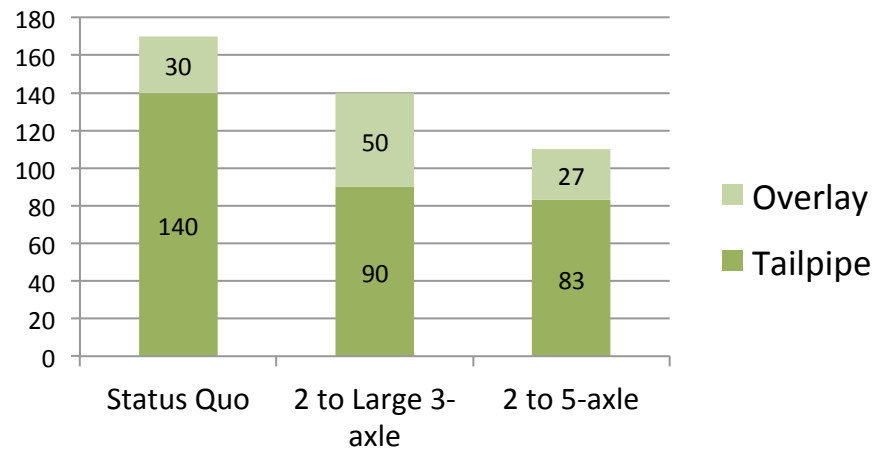


Consolidation to different truck sizes on SR-13

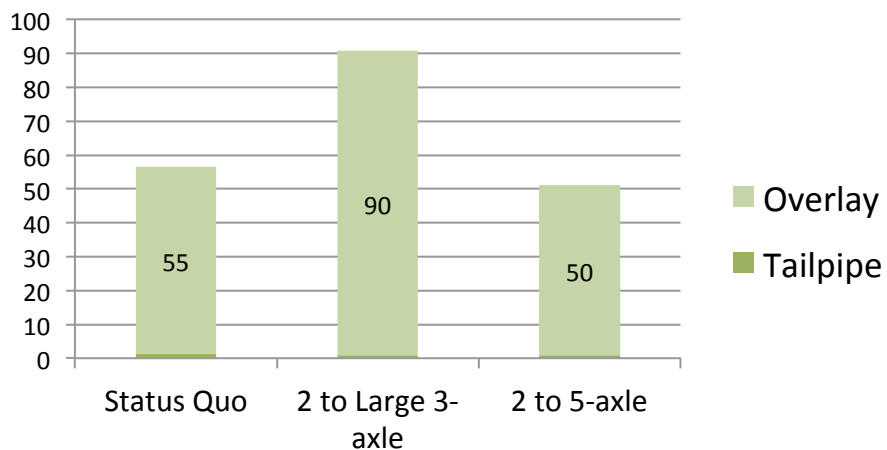
Years between overlays



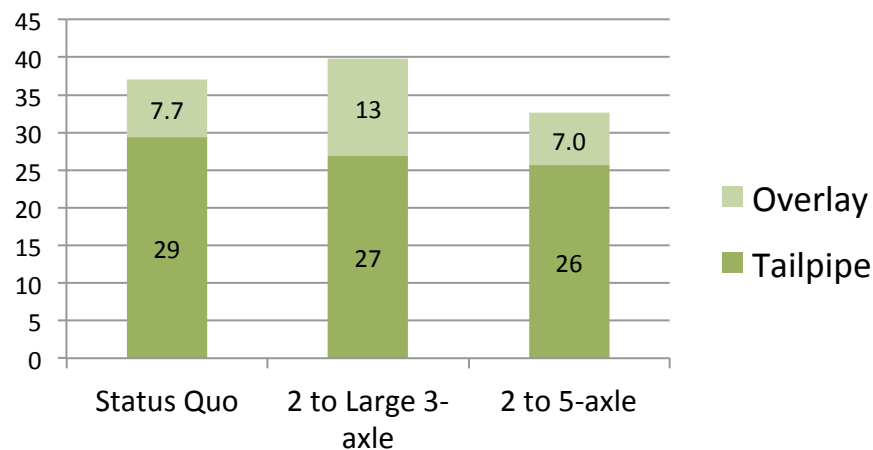
GHG (10^3 kg CO₂ eq./yr)



SO₂ (kg/yr)

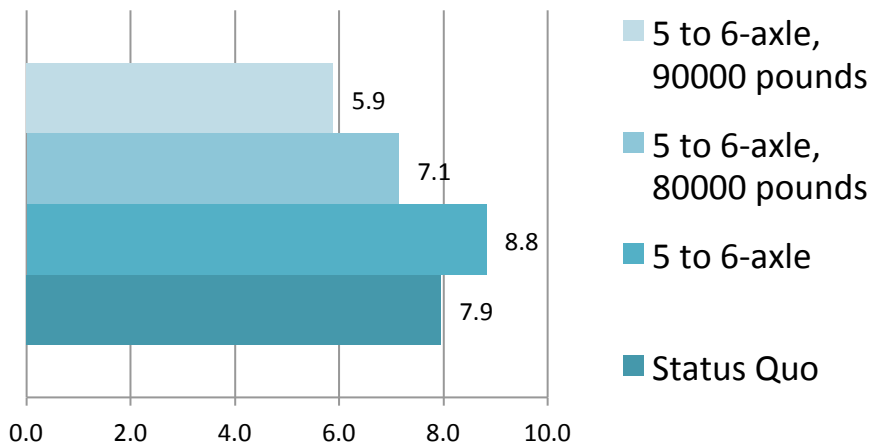


PM_{2.5} (kg/yr)

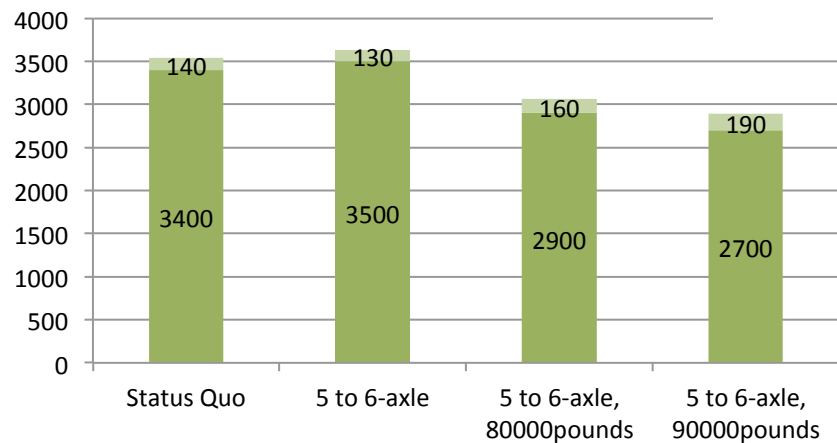


Weight Limits and Consolidation on I-80

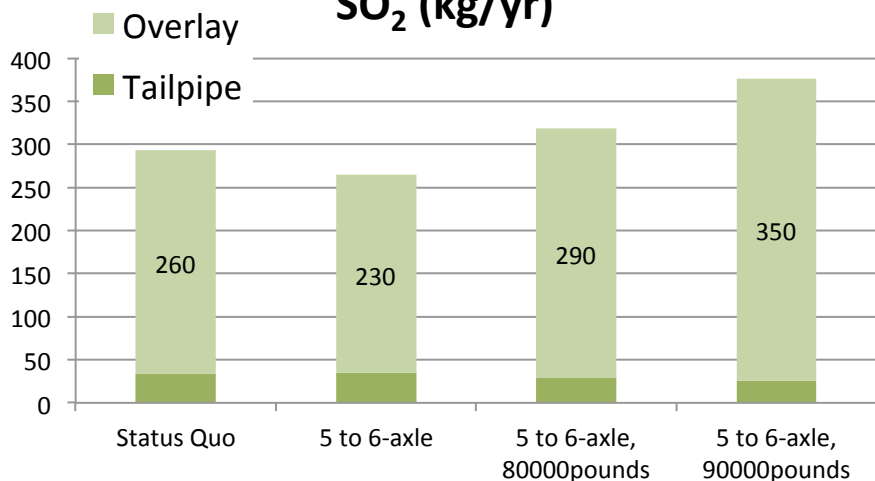
Years between overlays



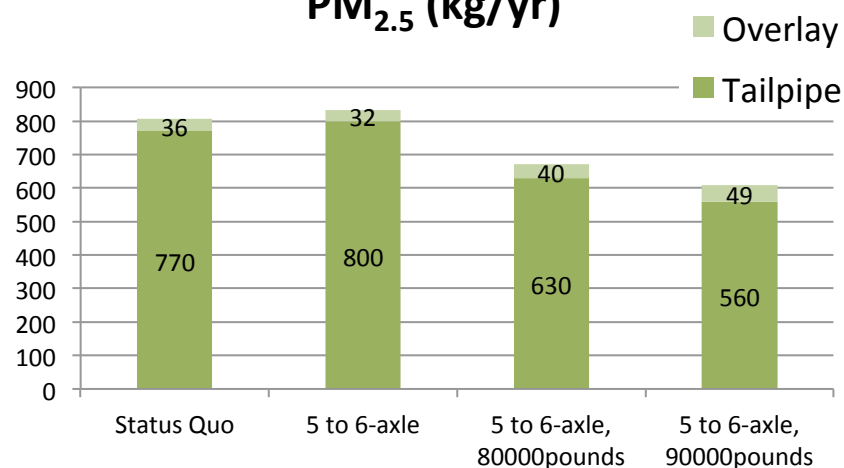
GHG (10^3 kg CO₂ eq./yr)



SO₂ (kg/yr)



PM_{2.5} (kg/yr)



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 SO₂, CO and Pb emissions associated with vehicle manufacturing, maintenance and decommissioning

Source: Facanha, C. (2006) *Life-cycle Air Emissions Inventory of Freight Transportation in the United States*. Doctoral Dissertation, Department of Civil and Environmental Engineering, UC Berkeley.

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

Source: McKinnon, A. and A. Woodburn (1994) The Consolidation of Retail Deliveries: Its Effect On CO2 Emissions. *Transport Policy*, 1, 125-136.

- 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

Source: Campbell, J. (1995) Using Small Trucks to Circumvent Large Truck Restrictions: Impacts on Truck Emissions and Performance Measures. *Transportation Research Part A*, 29, 445-458.

Introducing PaLATE-Web

The screenshot displays the PaLATE-Web application interface. The browser's address bar shows the URL `127.0.0.1:64505/sb-admin/index.html`. The application title is "PaLATE - Greenhouse Gas Estimation Tool for Pavements".

The interface includes a dark sidebar on the left with the following navigation items:

- Home
- Use the Tool
- FAQ
- Forum

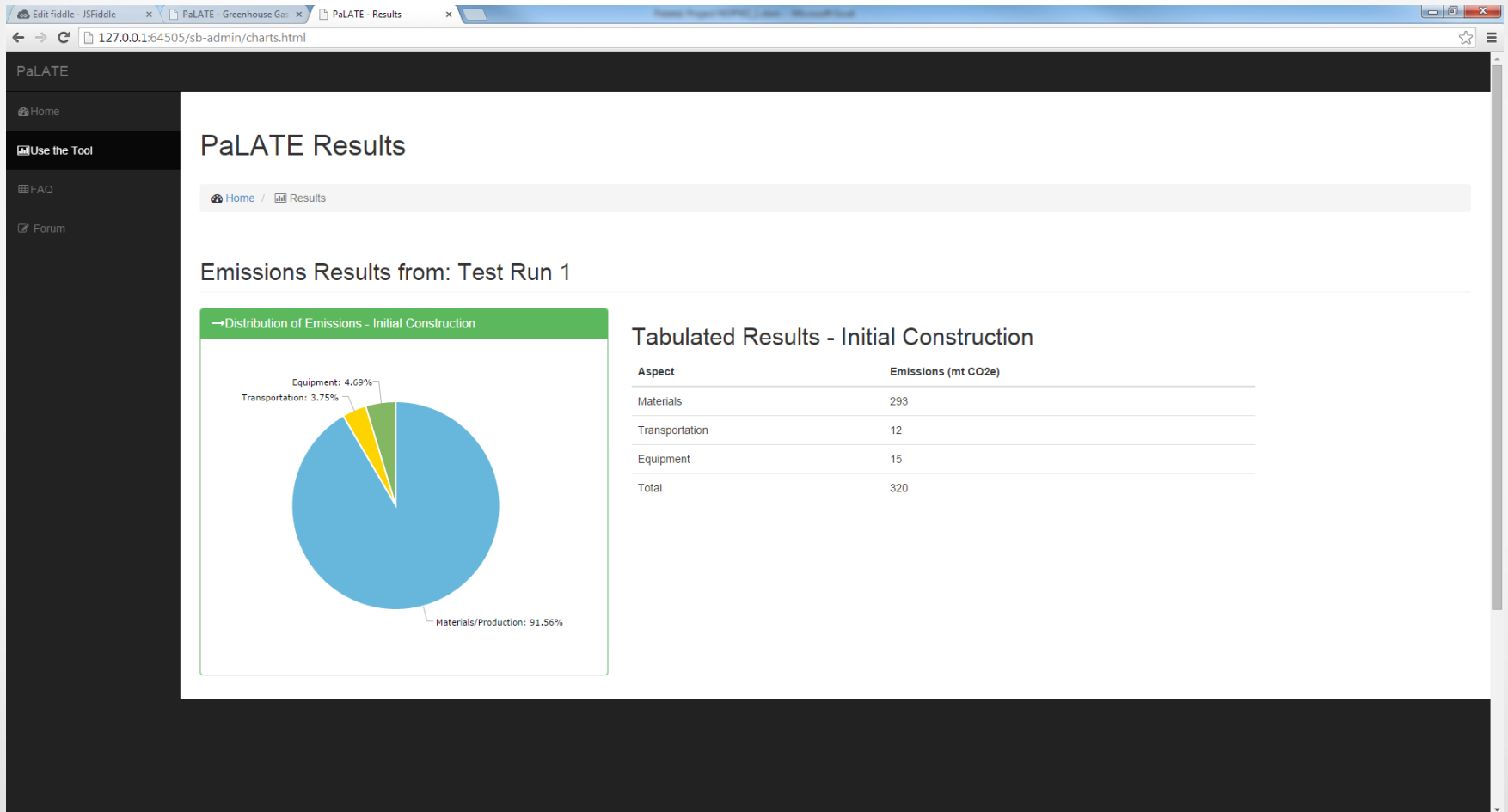
The main content area features a "Home" link and a light blue notification box that reads: "Please see the FAQ for a tutorial on how to use the new PaLATE". Below this, there is a dropdown menu labeled "Select the Number of Layers/Wearing Courses" with the value "1" selected.

The "Layer 1" section contains a table with the following columns: Material, Source, Number of Cubic Yards, Density, Asphalt/Concrete/Neither, Transportation Type, and Distance. The table contains one row of data:

Material	Source	Number of Cubic Yards	Density	Asphalt/Concrete/Neither	Transportation Type	Distance
Virgin Aggregate (Land Won)	EIO-LCA 2002	<input type="text" value="Cubic Yards"/>	<input type="text" value="Density (tons/cubic yard)"/>	<input type="text" value="Asphalt"/>	<input type="text" value="Class 8 Truck"/>	<input type="text" value="Miles"/>

Below the table is a blue button labeled "Add Another Material".

New Web-Tool Design



Keep PaLATE-Web Up to Date

The screenshot shows a web browser window with the URL `127.0.0.1:64505/sb-admin/blank-page.html`. The page title is 'PaLATE'. A dark sidebar on the left contains navigation links: Home, Use the Tool, FAQ, and Forum. The main content area is titled 'Improve PaLATE' and includes a breadcrumb trail 'Home / Forum'. There are two main sections: 'Materials Suggestions' and 'Equipment Suggestions'. Each section has a form with 'URL' and 'Material Type' (or 'Equipment Type') input fields and a 'Submit' button. Below each form is a table of suggestions.

URL	Material Type
http://www.eurobitume.eu/publications	Asphalt Binder
http://ascellibrary.org/doi/abs/10.1061/(ASCE)IS.1943-555X.0000148	Fine Aggregates

URL	Equipment Type
http://www.cedarapids.com/paver/mat.htm	MTV
http://www.wirtgenamerica.com/cold.html	Milling Machine

Conclusions

- Increasing loads is beneficial for many pollutants including GHGs, but can increase PM and SO₂ 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