Transportation Fundamentals: Sustainable Freight

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Special Thanks to:
Miguel Jaller Ph.D.
Co-Director – UC Davis Sustainable Freight Center
Who We Are:

Graduate Degree Programs

- Transportation Technology & Policy
- Energy Systems

Research Centers

- Sustainable Transportation Energy Pathways
- Plug-in Hybrid & Electric Vehicle Research Center
- Energy Futures Program
- China Center for Energy and Transportation
- Sustainable Freight Center

Partner Programs

- National Center for Sustainable Transportation (NCST)
- UC Institute of Transportation Studies
- UC Pavement Research Center
- Policy Institute for Energy, Environment and the Economy
- Western Cooling Efficiency Center
- Center on Water-Energy Efficiency
- Program on International Energy Technologies
Numerous Faculty Partners, including:

Professor Dan Sperling, Civil and Environmental Engineering
Professor Jim Bushnell, Economics
Professor Alissa Kendall, Civil and Environmental Engineering
Introduction

• California freight overview
• Environmental impacts
• Sustainable freight
• Automation and e-commerce

Key Term:

**Ton-Mile:** A unit of activity in freight analysis. It represents one ton of goods moved one mile.

If 5 tons of goods were carried 40 miles, that would represent 200 tons of goods movement.

**Mode** – A method of carrying goods. Trucks, rail, ship and air are the most commonly discussed freight modes.

**Intermodal** – Transported on multiple modes
California Freight Overview
Freight is the Physical Expression of the Economy

In California...

**Economy and Employment**
- $650-740 billion
- 32% of the California economy
- ~5 million jobs in freight-related industries
- 33% of California jobs

**Freight Transported**
- 2/3 Within California

**Freight Transport Produced**
- 50% of diesel PM
- 45% of the nitrogen oxide
- 12% of GHGs, 85% of which comes from trucks

**Projections 2025**
- 25% increase in volume
- 70% increase in commodity value

Sources: Freight Analysis Framework Data by U.S. Department of Transportation 2012
EDD, Labor Market Information Division, 2014
California – Domestic Trade

Total Freight By Mode (Billion Ton-miles)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Outbound</th>
<th>Inbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>1.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Water</td>
<td>0.1</td>
<td>0.04</td>
</tr>
<tr>
<td>Truck</td>
<td>125</td>
<td>118</td>
</tr>
<tr>
<td>Rail</td>
<td>21.9</td>
<td>64.4</td>
</tr>
<tr>
<td>Intermodal</td>
<td>12.0</td>
<td>23.5</td>
</tr>
<tr>
<td>Total</td>
<td>160</td>
<td>208</td>
</tr>
</tbody>
</table>

Top Domestic Trading Partners

<table>
<thead>
<tr>
<th>Rank</th>
<th>Outbound</th>
<th>Inbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Texas</td>
<td>Nebraska</td>
</tr>
<tr>
<td>2</td>
<td>Illinois</td>
<td>Texas</td>
</tr>
<tr>
<td>3</td>
<td>New York</td>
<td>Illinois</td>
</tr>
<tr>
<td>4</td>
<td>Florida</td>
<td>Oregon</td>
</tr>
<tr>
<td>5</td>
<td>Pennsylvania</td>
<td>New Jersey</td>
</tr>
</tbody>
</table>

- 718 million tons of shipments originated from California in 2012, total value $1.48 trillion
  - 6.4% of total national tonnage, 10.7% of total value
  - 85% of Truck freight is carried by for-hire trucks – cargo owner does not own the truck

Source: 2012 Commodity Flow Survey
## California – Foreign Trade

### Top Foreign Trade Partners, by Value

<table>
<thead>
<tr>
<th></th>
<th>Exports</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mexico</td>
<td>China</td>
</tr>
<tr>
<td>2</td>
<td>Canada</td>
<td>Mexico</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>Japan</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
<td>Canada</td>
</tr>
<tr>
<td>5</td>
<td>Hong Kong</td>
<td>Malaysia</td>
</tr>
<tr>
<td>6</td>
<td>South Korea</td>
<td>South Korea</td>
</tr>
<tr>
<td>7</td>
<td>Taiwan</td>
<td>Taiwan</td>
</tr>
</tbody>
</table>

### Top Traded Commodities, by Value

<table>
<thead>
<tr>
<th></th>
<th>Exports</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aircraft</td>
<td>Small Cars (gas)</td>
</tr>
<tr>
<td>2</td>
<td>Industrial Equipment</td>
<td>Small Electronics</td>
</tr>
<tr>
<td>3</td>
<td>Cut Diamonds</td>
<td>Cell Phones</td>
</tr>
<tr>
<td>4</td>
<td>Networking Equipment</td>
<td>Petroleum</td>
</tr>
<tr>
<td>5</td>
<td>Integrated Circuits</td>
<td>Large Cars (gas)</td>
</tr>
<tr>
<td>6</td>
<td>Almonds</td>
<td>Networking Equipment</td>
</tr>
<tr>
<td>7</td>
<td>Electric Vehicles</td>
<td>Integrated Circuits</td>
</tr>
</tbody>
</table>

Source: 2017 U.S. Census Bureau Data
The Ports Dominate Freight

Port Growth ➔ Warehouse & Logistics Growth
Intermodal Freight is Complex
Western U.S. Freight is Largely Moving CA Port Traffic
Lots of Rail Traffic Leaves L.A.
But Lots of Truck Traffic, Too
Environmental Impacts of Freight
Carbon Emissions – Trucks are Less Efficient

From Buhaug, et al. (2008), GHG Emissions from Ships
Goods Movement Has Real Health Harms

TABLE G-2: Statewide Health Effects and Valuation (2013 $) Associated with Freight Emissions Contributing to PM2.5—Midpoint Projections

<table>
<thead>
<tr>
<th>PM2.5 and NOx</th>
<th>2012</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>2,200</td>
<td>980</td>
<td>1,100</td>
</tr>
<tr>
<td>Hospitalizations*</td>
<td>330</td>
<td>150</td>
<td>160</td>
</tr>
<tr>
<td>ER Visits†</td>
<td>950</td>
<td>420</td>
<td>450</td>
</tr>
<tr>
<td>Valuation (billions)</td>
<td>$20</td>
<td>$9</td>
<td>$10</td>
</tr>
</tbody>
</table>

* Includes respiratory and cardiovascular hospitalizations.
† Includes asthma and cardiovascular emergency room visits.

Source: Sustainable Freight Action Plan, Appendix G
Freight is a major source of pollution
Maps of the Los Angeles area suggest the correlation of air pollution (diesel particulate matter in this example) to income and race.

Notes: “Minority population” refers to the fraction of California’s population that is all but non-Hispanic white. “Diesel particulate matter” represents the amount of this pollution in a given area relative to other areas in California. “Low income population” refers to the percent of Californians whose household income was less than two times the poverty level in the past 12 months. Percentiles are as follows: yellow: 80–90 percent; orange: 90–95 percent; red: 95–100 percent. Percentiles are relative to California’s population.

SOURCE: EPA 2016B.

http://www.ucsusa.org/clean-vehicles/electric-vehicles/freight-electrification
Emissions Reducing

Significant Progress Has Been Made!
• CARB 2006 Truck & Bus Rule (PM & NOx)
• Federal Heavy-Duty Fuel Economy Standards (GHGs, PM)
• Ultra-low sulfur diesel (PM, SOx)
• HVIP, Carl Moyer, AB 118 clean vehicle incentives
• Low-Carbon Fuel Standard

Source:
Sustainable Freight
Sustainable Freight Action Plan – 2030 Statewide Targets

**System Efficiency Target**

Improve freight system efficiency by 25 percent

Metric compares the value of goods and services produced from the freight sector, i.e., California freight transportation sector (NAICS 48-49, minus passenger components) gross domestic product, relative to the amount of carbon that it produces.

Base year 2014: $1,550 of economic output per ton of carbon dioxide eq.

($43.9 billion GDP; 28.35 million metric tons of carbon dioxide emissions equivalent)

**Transition to Zero Emission Technology Target**

Deploy over 100,000 freight vehicles and equipment capable of zero emission operation; and

Maximize near-zero emission freight vehicles and equipment powered by renewable energy

**Increased Competitiveness and Economic Growth Targets**

Foster future economic growth within the freight and goods movement industry
Lots of Tools to Choose From

Reducing Truck Impacts
Aerodynamics
Low Rolling Resistance Tires
Alternative fuels
Increase truck size
Limiting truck speed
Idle reduction
Reduce empty mileage
Pooling urban delivery
Efficient land use
Some Alternative Fuels in the Freight Space

**Electricity**
- 70-99% less carbon than diesel
- Zero Pollutant Emissions from Tailpipe
- Electric vehicles 3-5x more efficient
- Batteries expensive, but getting cheaper
- Cold weather can be a problem
- Recharge time slower than fueling
- Charging can help or hurt local grid

**Renewable Diesel**
- 40-65% less carbon than diesel
- Lower PM & NOx
- Made from things like vegetable oil, used cooking oil or food processing waste
- Runs in conventional diesel engines
- Supply may be limited by feedstock availability and land use change issues

**Renewable Natural Gas**
- 50% to 300% less carbon than diesel
- Lower PM & NOx
- Requires natural gas vehicles and fueling infrastructure
- Limited number of engines at present.
- Helps solve organic & animal waste disposal problems
- Supply may be limited by amount of waste

**Biodiesel**
- 30-50% less carbon than diesel
- Lower PM, slightly lower NOx
- Same feedstocks as Renewable Diesel, simpler lower-energy process to make
- Requires engine modification to burn more than 20% blend; 5-10% blends common
- Has challenges in cold weather
Batteries are getting rapidly cheaper

Source: Bloomberg New Energy Finance
Zero-Emission Freight is Getting Cheaper

Source: Miller & Fulton (2017)
Investments in ZEV are Likely to Pay Off

Truck Cost Difference (ZEV - BAU)

Cost Difference (million $)

Source: Miller & Fulton (2017)
Last mile deliveries ready for electrification...

- DVMT – Daily Vehicle Miles Traveled
- Most urban “last mile” delivery vehicles drive less than 200 miles per day
- Stop-and-go driving is a great match for electric vehicles
**Significant Financial Resources Available**

**Table II-2. MD/HD Proposed Fiscal Year 2017-2018 Funding for Clean Transportation Initiatives**

<table>
<thead>
<tr>
<th>Project</th>
<th>Low Carbon Transportation</th>
<th>AQIP</th>
<th>Warehouse Program</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural School Bus Pilot</td>
<td>$10M</td>
<td></td>
<td></td>
<td>$10M</td>
</tr>
<tr>
<td>Zero- and Near Zero-Emission Freight Facilities (including warehouses)</td>
<td>$100M</td>
<td>$50M</td>
<td></td>
<td>$150M</td>
</tr>
<tr>
<td>Zero-Emission Off-Road Freight Voucher Incentive Project</td>
<td>$40M</td>
<td></td>
<td></td>
<td>$40M</td>
</tr>
<tr>
<td>Clean Truck and Bus Vouchers (HVIP + Low NOx Engine Incentives)</td>
<td>$180</td>
<td>$8M</td>
<td></td>
<td>$188M</td>
</tr>
<tr>
<td>Truck Loan Assistance Program</td>
<td></td>
<td>$20M</td>
<td>$50M</td>
<td>$20M</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$330M</strong></td>
<td><strong>$28M</strong></td>
<td><strong>$50M</strong></td>
<td><strong>$408M</strong></td>
</tr>
</tbody>
</table>

Source: ICF Task 1 Report
Benefits of Intermodal Freight

Truck and rail platform comparisons

<table>
<thead>
<tr>
<th>MODE</th>
<th>FUEL CONSUMPTION</th>
<th>INFRASTRUCTURE CAPACITY</th>
<th>COST (TO USERS)</th>
<th>SAFETY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railroad</td>
<td>455 ton-miles per gallon</td>
<td>216 million annual tons per mainline</td>
<td>2.7 cents per ton-mile</td>
<td>0.6 fatalities per billion ton-miles</td>
</tr>
<tr>
<td>Truck</td>
<td>105 ton-miles per gallon</td>
<td>37.8 million tons per lane</td>
<td>5 cents per ton-mile</td>
<td>1.5 fatalities per billion ton-miles</td>
</tr>
</tbody>
</table>

Fuel savings potential of substituting trucks with rail intermodal

Source: Rocky Mountain Institute
Automation, E-Commerce and the Future of Freight
Autonomous and Connected Vehicles

Uber’s self-driving truck delivered 50,000 cans of Budweiser

By Andreas Polonoswski

On Oct. 24, Uber, Otto, and Collins, a company, delivered 50,000 cans of beer by truck.

If you drink a cold beer in Colorado Springs, you may have a Otto to thank.

That’s where a big rig tricked out with self-driving tech delivered 50,000 cans of Budweiser.

Otto

6-truck makers to participate in European platooning challenge

March 12, 2016

Six European truck makers are participating in next month’s European Truck Platooning Challenge, a project initiated by the Dutch government to promote platooning by bringing truck convoys to public roads.

Volvo Group started its participation in the European Truck Platooning Challenge on March 18, sending a group of semi-automated trucks out from the city of Gothenburg,
E-commerce is Changing How People Shop

Source: Jaller with data from U.S. Census Bureau (2017)
Many Different Relationships and Models

• E-Commerce is not just simple 1:1 substitution of clicking for personal trips.
• Numerous combinations of virtual and in-person shopping
• Returns and exchanges are becoming a big factor.
Rush Deliveries: Great for Consumer, Not so Great for the Environment

% change in negative externalities

Change

Stops per tour
Automated Delivery Options Are Coming!

JD.com launches robot delivery service at Chinese universities
We Are Happy to Answer Questions!

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The Policy Institute now offers rapid response policy analysis – contact kelfleming@ucdavis.edu

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Sources

BTS Port of Entry Map
https://maps.bts.dot.gov/arcgis/sharing/rest/content/items/a7bebeb5690e40b5ab48efd4bf3b4c3c/data?token=


Rocky Mountain Institute http://www.rmi.org/RGraph-Fuel_savings_potential_trucks_rail_intermodal
