The Green Supply Chain
A critical assessment of a multimodal, multinational freight supply chain of a Fortune 50 retailer

Cristiano Façanha, PhD

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Cristiano Façanha, PhD

Program and regional lead
International Council on Clean Transportation
Agenda

- Background and motivation
- Project scope
- Modeling fundamentals
- Results
- Next steps
Background and motivation

The role of freight and supply chain assessment
Freight fuel consumption and GHG emissions are forecasted to grow four-fold through 2050.
Heavy-duty vehicles contribute disproportionally to emissions, thus being an effective target for emissions control

<table>
<thead>
<tr>
<th></th>
<th>Percent of vehicles that are heavy-duty vehicles</th>
<th>Percent of vehicle carbon dioxide emissions that are from heavy-duty vehicles</th>
<th>Percent of vehicle particulate emissions that are from heavy-duty vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>10%</td>
<td>65%</td>
<td>83%</td>
</tr>
<tr>
<td>United States</td>
<td>5%</td>
<td>30%</td>
<td>36%</td>
</tr>
<tr>
<td>European Union</td>
<td>11%</td>
<td>37%</td>
<td>47%</td>
</tr>
<tr>
<td>Japan</td>
<td>19%*</td>
<td>43%</td>
<td>59%</td>
</tr>
<tr>
<td>Brazil</td>
<td>4%</td>
<td>61%</td>
<td>85%</td>
</tr>
<tr>
<td>India</td>
<td>5%</td>
<td>71%</td>
<td>74%</td>
</tr>
<tr>
<td>Russia</td>
<td>14%</td>
<td>54%</td>
<td>81%</td>
</tr>
<tr>
<td>Canada</td>
<td>15%</td>
<td>42%</td>
<td>52%</td>
</tr>
<tr>
<td>Global</td>
<td>11%</td>
<td>46%</td>
<td>71%</td>
</tr>
</tbody>
</table>

*Includes mini commercial vehicles

ICCT (2015): Policies to reduce fuel consumption, air pollution, and carbon emissions from vehicles in G20 nations
What is a supply chain?

- A supply chain involves the upstream and downstream flow of products, services, finances, and/or information from a source to a customer. (Mentzer et al., 2001)

- Procurement
- Manufacturing
- Packaging
- Warehousing
- Transportation
- Retail
- End of life
Project scope | Green Supply Chain Study
Objectives

- Identify and showcase effective technologies and strategies to enhance the energy and environmental performance of global supply chains.
- Assess energy consumption and emissions savings from advanced technologies/strategies along a real-world global supply chain.
- Give visibility of actions already taken by leading shippers while providing benchmark reference for other companies.
- Identify collaboration opportunities for government, industry and other interested stakeholders.
A group of organizations participated in the conception and development of the study.

OTHER STAKEHOLDERS
- Port authorities
- Local environmental agencies
- Shipping lines
- Trucking companies
- Logistics providers

STEEERING COMMITTEE
- ICCT
- United States Environmental Protection Agency
- THE HOME DEPOT
- Smart Freight Centre
- BSR
- Rocky Mountain Institute
THD is the largest home improvement retailer in the U.S. and the 3rd largest container importer.

Thousands of TEU imported in 2017:

- Walmart: 875
- Target: 590
- Home Depot: 388
- Lowe's: 288
- Dole Food: 220
- Samsung America: 185
- Family Dollar Stores/Dollar Tree: 168
- LG Group: 162
- Philips Electronics North America: 143
- IKEA International: 121
- Chiquita Brands International: 118
- Nike: 116
- Newell Brands: 115
- Costco Wholesale: 112
- Sears Holdings: 103
- J.C. Penney: 101
- General Electric: 92
- Ashley Furniture Industries: 86
- Whirlpool: 75
- Heineken USA: 73

Eastbound trade route from Asia to North America had the largest container traffic in 2017

Total millions of TEU in 2017

- *Asia-North America (EB)*: 19
- Asia-North Europe (WB): 10
- Asia-North America (WB): 7
- Asia-Mediterranean (WB): 6
- Asia-North Europe (EB): 5
- North Europe-North America (WB): 3
- Asia-Mediterranean (EB): 2
- North Europe-North America (EB): 2
- Asia-East Coast South America (SB): 1
- North Europe/Mediterranean-East Coast South America (SB): 1
- North Europe/Mediterranean-East Coast South America (NB): 1
- North America-East Coast South America (NB): 1
- Asia-East Coast South America (NB): 1
- North America-East Coast South America (SB): 0

*Analyzed supply chain in this trade route
(WB): West bound
(EB): East bound
(NB): North bound
(SB): South bound
Although the study boundary is limited to transportation, understanding the supply chain is critical to effectively influence the freight sector.

- Basic supply chain:
  - Source components
  - Make product
  - Move product
  - Sell product

<table>
<thead>
<tr>
<th>Flow of products</th>
<th>Flow of cash</th>
<th>Flow of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>Transportation</td>
<td>Customer</td>
</tr>
</tbody>
</table>

Transportation a key component of supply chain management.

Policy Target and Study Boundary
The analysis evaluates each supply chain link based on real-world data.

1. **China drayage**
   Products shipped from supplier’s factories to Shenzhen/Yantian terminals.

2. **Marine**
   Containers with products shipped across Pacific Ocean to Los Angeles port.

3. **U.S. Drayage**
   Containers transported from Los Angeles port to transload facility or closest distribution center.

4. **U.S. in-land**
   Aggregated products at transload facility sent to distribution centers.

5/6. **SDC/RDC to Stores**
   Final delivery from distribution centers to stores.

Distances:
- Shenzhen to Los Angeles: 7456mi
- Los Angeles to stores: 840mi
- Distribution centers: 35mi
- Stores: 173mi
The analysis considers three scenarios to evaluate emission reduction strategies

- **Conventional Scenario**: Basic supply chain without strategies considered in the green scenario, instead those strategies are replaced by basic technology and operational practices.

- **Green Scenario**: Current supply chain considering improvements already adopted (green strategies).

- **Green Plus Scenario**: Future supply chain with additional improvements to those already implemented in the green scenario. To consider implementation timeframe, we divide this scenario into:
  - Short-term (2020)
  - Medium-term (2025)
  - Long-term (2030)
Modeling fundamentals

Data, scenarios, strategies and modeling approach
We first developed a detailed model of the considered supply chain...
... and parametrized it based on a network of links and nodes

![Diagram of a network of nodes and links](image)
We used detailed 2017 data on purchase orders from three suppliers

Item 1 (42’’ ceiling fan)
- Quantity
- Volume
- Weight
- Factory of origin
- Port terminal of origin
- Port terminal of destination
- Inbound/Outbound Distribution center
- Final store destination
- Size of container
- Marine vessel
- Trucking carrier
- …

Item 2 (50’’ ceiling fan)

Item 3 (60’’ ceiling fan)
Basic modeling approach: aggregate PO data into shipments and characterize that shipment

- **PO**
- **CO₂, NOₓ, PM, BC, SO₂**
- **Calculate this for all shipments**

**Distribution Center** (Origin) → Distance traveled → **Store** (Destination)

- Specific carriers performance (U.S. EPA SmartWay Data)

- Freight of analyzed suppliers
- Total freight
The study categorize strategies in three groups:

- **Clean & Efficient Logistics**: Strategies to improve supply chain efficiency through reduction of vehicle activity.
- **Clean & Efficient Modes**: Strategies to leverage the use of the cleanest and most energy efficient modes.
- **Clean & Efficient Equipment**: Strategies to improve truck/rail/vessel efficiency through technologies or eco-driving.
We evaluated a number of strategies applied to specific segments under different scenarios.

<table>
<thead>
<tr>
<th>Strategy Type</th>
<th>Strategy</th>
<th>Supply chain Link</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>China drayage</td>
</tr>
<tr>
<td><strong>Clean and efficient logistics</strong></td>
<td>Cargo consolidation (Consolidated Freight Station)</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Cube optimization</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Transloading (network reconfiguration)</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Floor loading</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Direct routing + Short sea shipping</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Schedule optimization (port and ship)</td>
<td>●</td>
</tr>
<tr>
<td><strong>Clean and efficient modes</strong></td>
<td>Truck to rail</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Transloading (container switch)</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Move to larger ships (Tripple E etc.)</td>
<td>●</td>
</tr>
<tr>
<td><strong>Clean and efficient equipment</strong></td>
<td>Shore power</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Slow steaming</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Vessel technology</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Vessel operations</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Truck technology</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Truck electrification</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Rail technology</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Driver training</td>
<td>●</td>
</tr>
</tbody>
</table>

- ● Strategy applied to Green scenario
- ● Strategy applied to Green plus scenario
Results
Overview of supply chain emissions

180 million ton-km

1,500 metric tons

8.4 gCO₂/km
Current available technologies and strategies reduced CO₂ emissions by almost 30% with respect to the conventional supply chain. Adopting advanced strategies can further reduce CO₂ by roughly 35%.
For land-based segments, adopting logistic and mode shift strategies have shown reductions as large as vehicle technology improvements.

Land-based CO₂ savings by strategy

Clean Equipment
Clean Modes
Clean Logistics

> CFS  ■  Cube opt  ■  Floor loading  ■  TSLD  ■  TSLD  ■  Shift to rail  ■  Rail tech  ■  Driver training  ■  Truck tech  ■  Truck ZE
Most certain path to reduce emissions further is to promote vehicle technology not only on ICE trucks, but also zero-emission trucks and low-carbon rail technologies.
Given long distances traveled by marine vessels, technology and ship size provide the largest opportunities for supply chain decarbonization.
Insights on health-related results

- Study evaluated supply chain emissions of NO$_x$, PM, black carbon, and SO$_2$.
- Marine emissions account for the lion’s share of local air pollutant supply chain emissions.
- Technology plays an important role in the reduction of local air pollutants.
  - For marine, technology strategies in the Green scenario have reduced air pollutants by over 20%. Future technologies could reduce air pollution by over 50% from current levels.
  - For land-based links, cleaner vehicles reduced local air pollutants by over half. Moving towards soot-free HDVs and cleaner locomotives will virtually eliminate these emissions.
Next steps

- Review process
- Publication and outreach
- Future research
  - Well-to-wheels emissions
  - Follow-up on key strategies to develop cost-benefit analysis
  - Expand the future analysis to include more complex solutions (mode and logistics)
  - Evaluate other industries and trade routes