Implications of Carbon Management on Supply Chain Design Issues

LMAS

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Yi-Fen. Chen © 2011 LMAS contact email: yifenchen@berkeley.edu

Green Supply Chain Focus in Practice

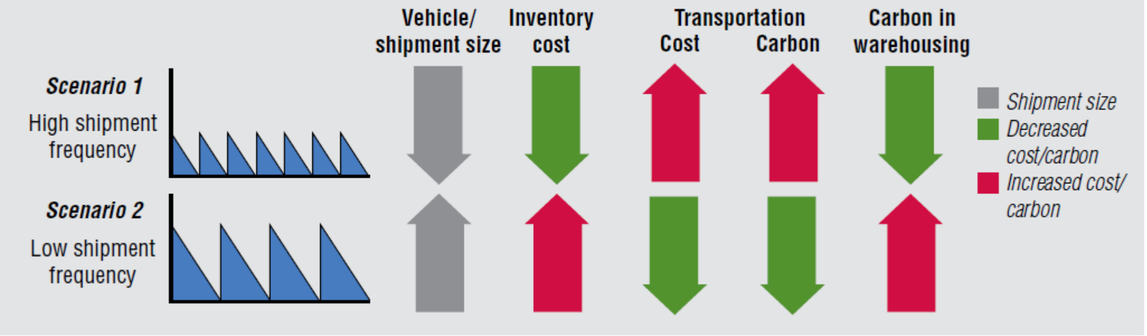
- The transportation is usually the focus of company to reduce their carbon emission because it is implementable in a short period.
  - Honda use marine or railway transportation to save energy, change the import seaport in Japan to reduce mileage on land.
  - Toyota worked with their partner to restructure routes and increase load density
- Norris et al. (2002) and Weber et al. (2007) suggested that carbon emission from international transportation and wholesaling/retailing are significant.

- ***A long-term strategy may make more impact on the whole supply chain.***

Carbon Emission Trade-offs in Logistics

Action to Reduce Carbon Emission	Related Issues
Reduce shipment frequency	To maintain the service level, the inventory level has to be increased. ➔ Need larger warehouse and keep a single product longer in warehouse
Increase the lot size so that the products can be shipped by larger trucks and the carbon emission per product will be reduced	
Change to a low-carbon transportation mode	The lead time may be longer due to slower shipment

Carbon's impact on shipment scenarios.



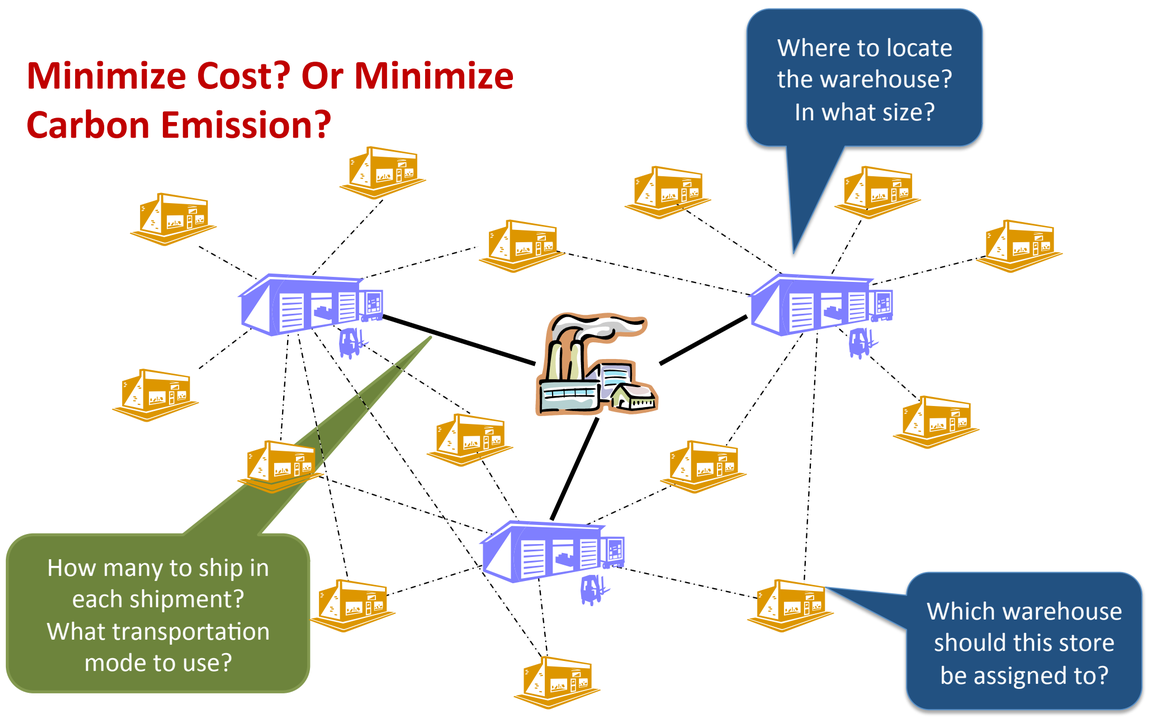
Source: Butner et al. (2008)

Research Questions

- What are the trade-offs between reducing transportation emission and other supply chain activities?
  - Some actions that reduce the emission from transportation will increase the inventory level in the warehouse.
- Is bigger warehouse better as traditional supply chain literature review suggested?
- How the relationship between cost and carbon emission affects the optimal supply chain design?

A study that consider the *cost* and *carbon emission* of *inventory and transportation* is needed to understand the above questions

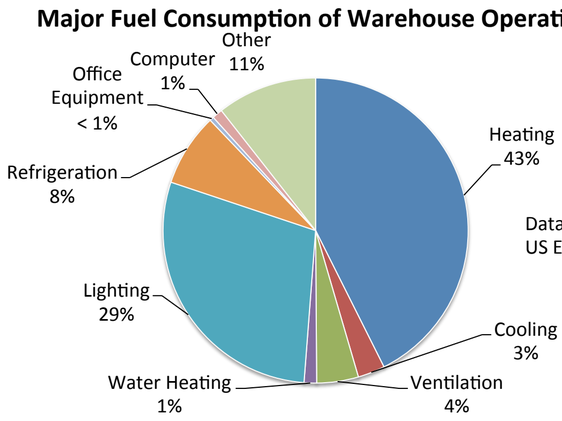
3-Tier Supply Chain Structure



Carbon Emission from Supply Chain Activities

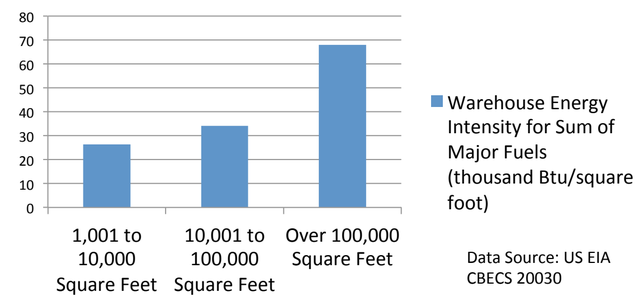
	Factors of Carbon Emission and Energy Consumption	Assumption on Estimation
Transportation	**fuel efficiency:** Speed Weight Transportation mode (Air freight, rail, truck, or ocean freight)	**Outbound logistics:** (carbon emission factors) * (travel distance) * (total weight of loading products) **Inbound logistics:** Fixed carbon emission per shipment + variable carbon emission per unit product per distance
Warehouse Operation	construction material, equipments in the warehouse, **size of the warehouse**, **inventory level**, and so on	The **inventory** in a non-refrigerated warehouse has small effect on energy consumption and is assumed can be ignored. The warehouse operation energy consumption is assumed **an exponential function** in warehouse size based on regression analysis on data from CBECS 2003.
Warehouse Construction	construction technology, construction material, **size of the warehouse**	The energy consumption of construction phase is assumed as concave function of building size.

Major Fuel Consumption of Warehouse Operation



Data source: US EIA CBECS 200

Warehouse Energy Intensity for Sum of Major Fuels (thousand Btu/square foot)



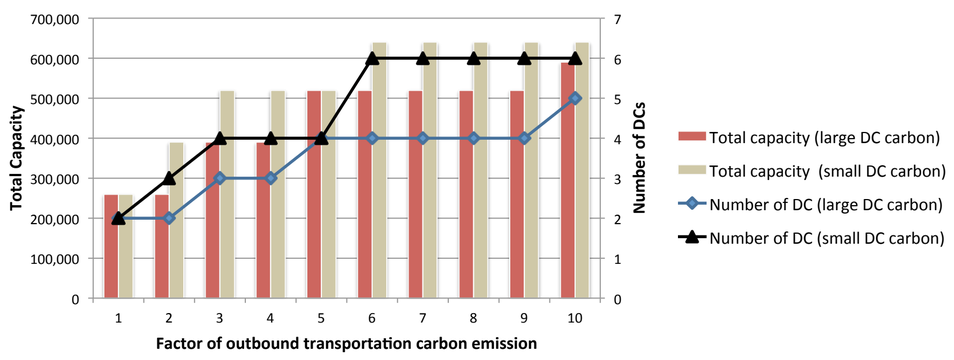
Data Source: US EIA CBECS 20030

Conclusion and Future Work

- Two models that minimize cost and minimize carbon emission are constructed.
- Results from numerical analysis
  - Improvement in carbon emission rate on transportation, warehouse operation affects the optimal supply chain design.
  - The Min-Carbon solution can reduce 31% carbon emission comparing with the Min-Cost solution. However, it also increases the total cost.

	Min-Cost Solution	Min-Carbon Solution
Total Carbon (tons of CO_2)	1068.91	732.103 (31% reduction)
Total Cost (US $)	1,346,530	1,967,670
Number of Warehouses	8	3

Optimal Number of DCs and Total Capacity in Min-Carbon Problem



Future Work

- Analyze the Pareto frontier from the multi-objective problem to find a balance between cost and carbon emission.

- Extend the model to include multiple trucks during the batch shipment.

- Extend the model to upper stream and lower stream of supply chains.

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