Implications of Carbon Management on Supply Chain Design Issues

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.

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

Carbon Emission from Supply Chain Activities

<table>
<thead>
<tr>
<th>Factors of Carbon Emission and Energy Consumption</th>
<th>Assumption on Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation: fuel efficiency: Speed (tons/hour), Weight (tons), Transportation mode (Air freight, rail, truck, or ocean freight)</td>
<td>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</td>
</tr>
<tr>
<td>Warehouse Operation: construction material, equipments in the warehouse, size of the warehouse, inventory level, and so on</td>
<td>The inventory in a non-refrigerated warehouse has small effect on energy consumption and is assumed to be ignored. The warehouse operation energy consumption is assumed an exponential function in warehouse size based on regression analysis on data from CBECS 2003.</td>
</tr>
<tr>
<td>Warehouse Construction: construction technology, construction material, size of the warehouse</td>
<td>The energy consumption of construction phase is assumed as concave function of building size.</td>
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Carbon Emission Trade-offs in Logistics

- Action to Reduce Carbon Emission
  - Reduce shipment frequency
  - 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

- Related Issues
  - To maintain the service level, the inventory level has to be increased.
  - Need larger warehouse and keep a single product longer in warehouse.
  - The lead time may be longer due to slower shipment.

3-Tier Supply Chain Structure

Minimize Cost? Or Minimize Carbon Emission?

- How many to ship in each shipment? What transportation mode to use?

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.

<table>
<thead>
<tr>
<th>Action</th>
<th>Min-Cost Solution</th>
<th>Min-Carbon Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Carbon (tons of CO2)</td>
<td>1068.91</td>
<td>732.183 (31% reduction)</td>
</tr>
<tr>
<td>Total Cost (US$)</td>
<td>1,346,530</td>
<td>1,967,670</td>
</tr>
<tr>
<td>Number of Warehouses</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>

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.