IMPROVING THE ENERGY EFFICIENCY & ENVIRONMENTAL PERFORMANCE OF GOODS MOVEMENT

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Asllomar 2009 Conference on Transportation and Energy

Acknowledgements

- Although I am presenting today, much of the material was developed jointly with Dr. James J. Corbett, University of Delaware.
- I am indebted to the faculty and students in the Laboratory for Environmental Computing and Decision Making at RIT, including Bryan Comer, Chris Prokop, Dr. Scott Hawker, and Dr. Karl Korfmacher

My Job Today

- Present energy and environmental attributes of goods movement from multiple modes
- Discuss benefits from shifting from high energy-intensity modes to low energy-intensity modes
- Assess overall opportunities for mode-shifting in a larger systems context
- Provoke policy-focused discussion

Working Hypothesis

- We can solve a large part of the energy and environmental problems of freight transportation by moving goods off trucks and onto trains and ships.

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J. Winebrake, Asilomar, 2009.

Overview of Goods Movement

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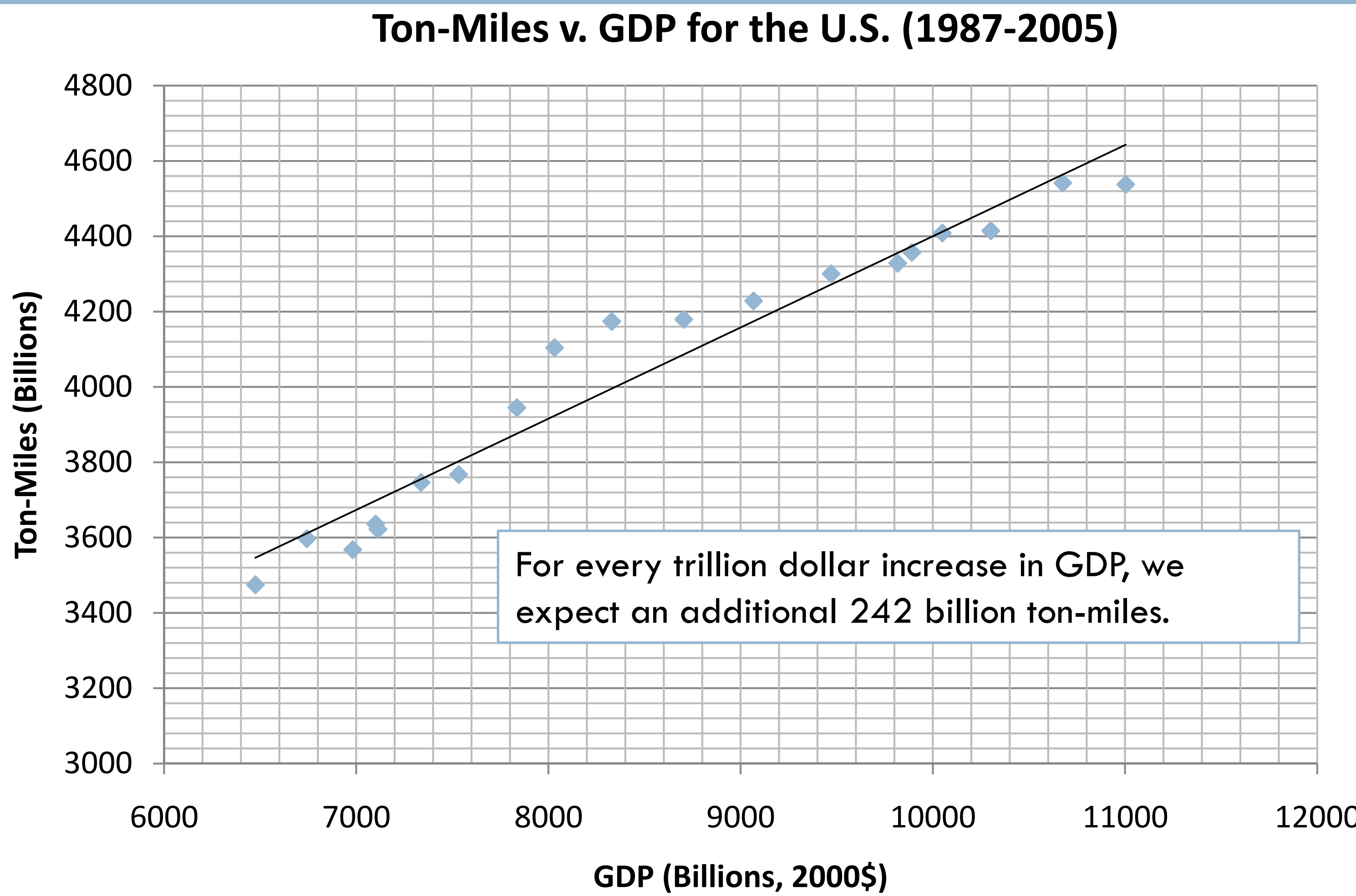
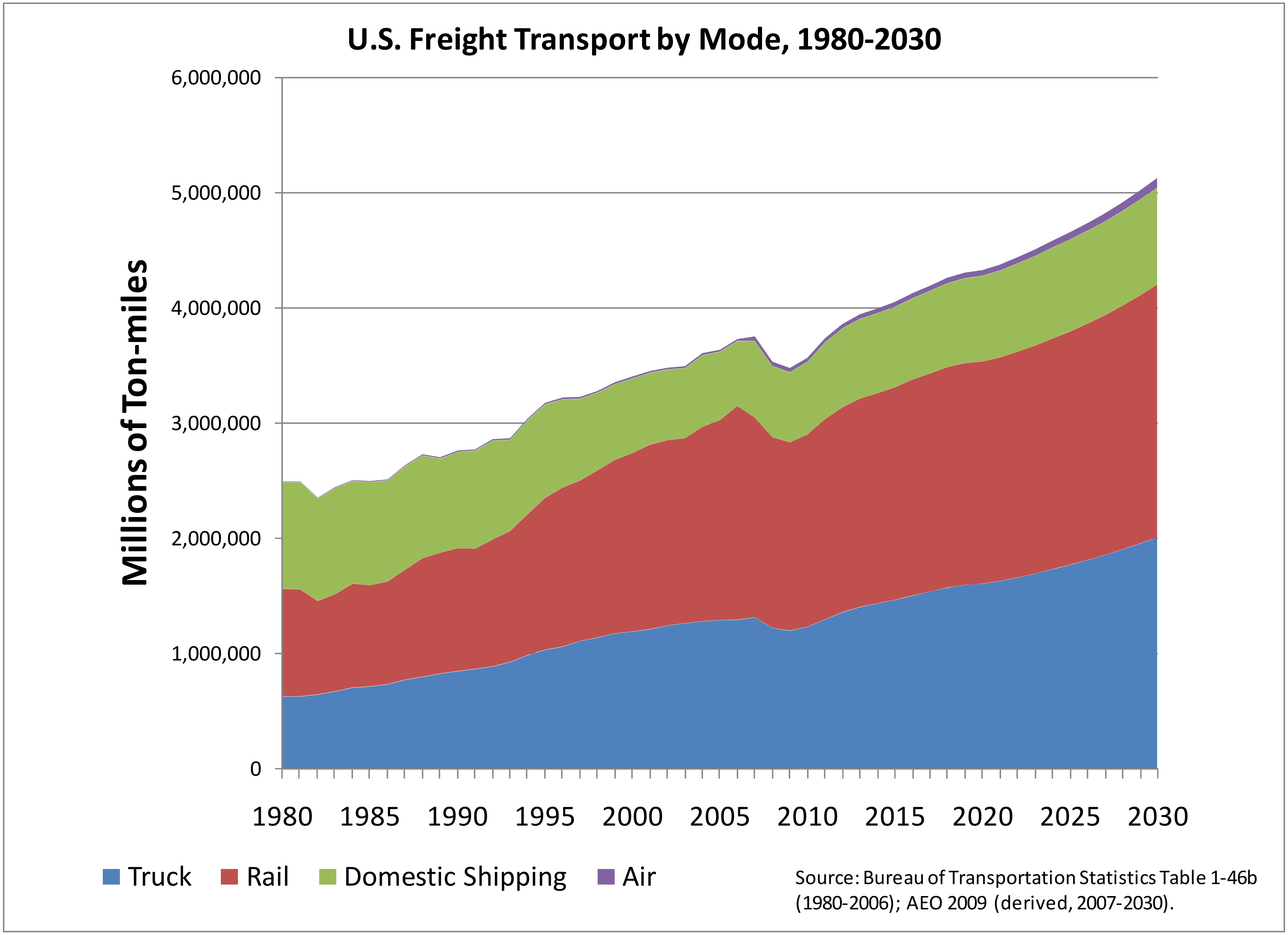
Goods Movement and GDP

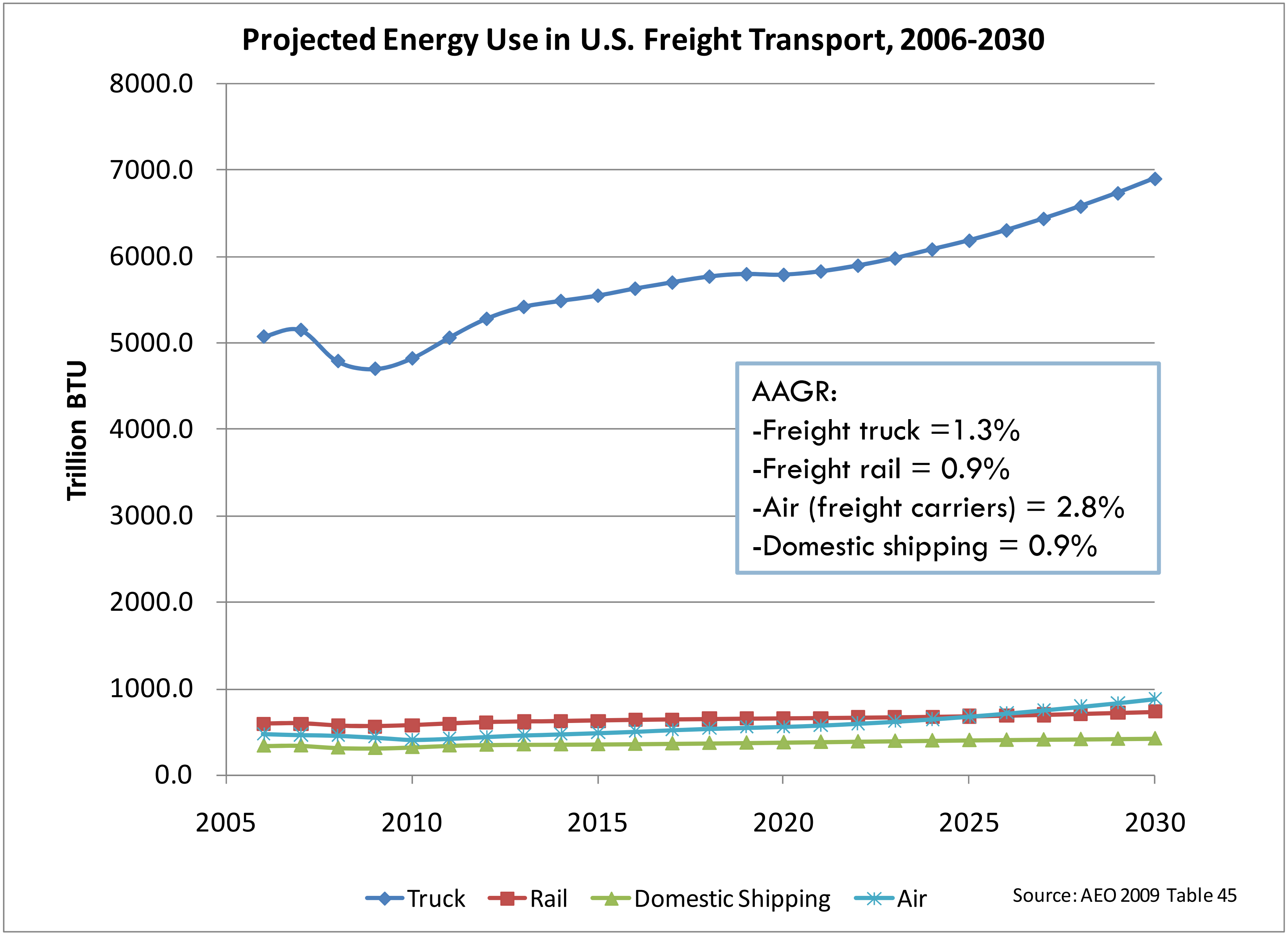


Source: Corbett and Winebrake, 2009.

J. Winebrake, Asilomar, 2009.

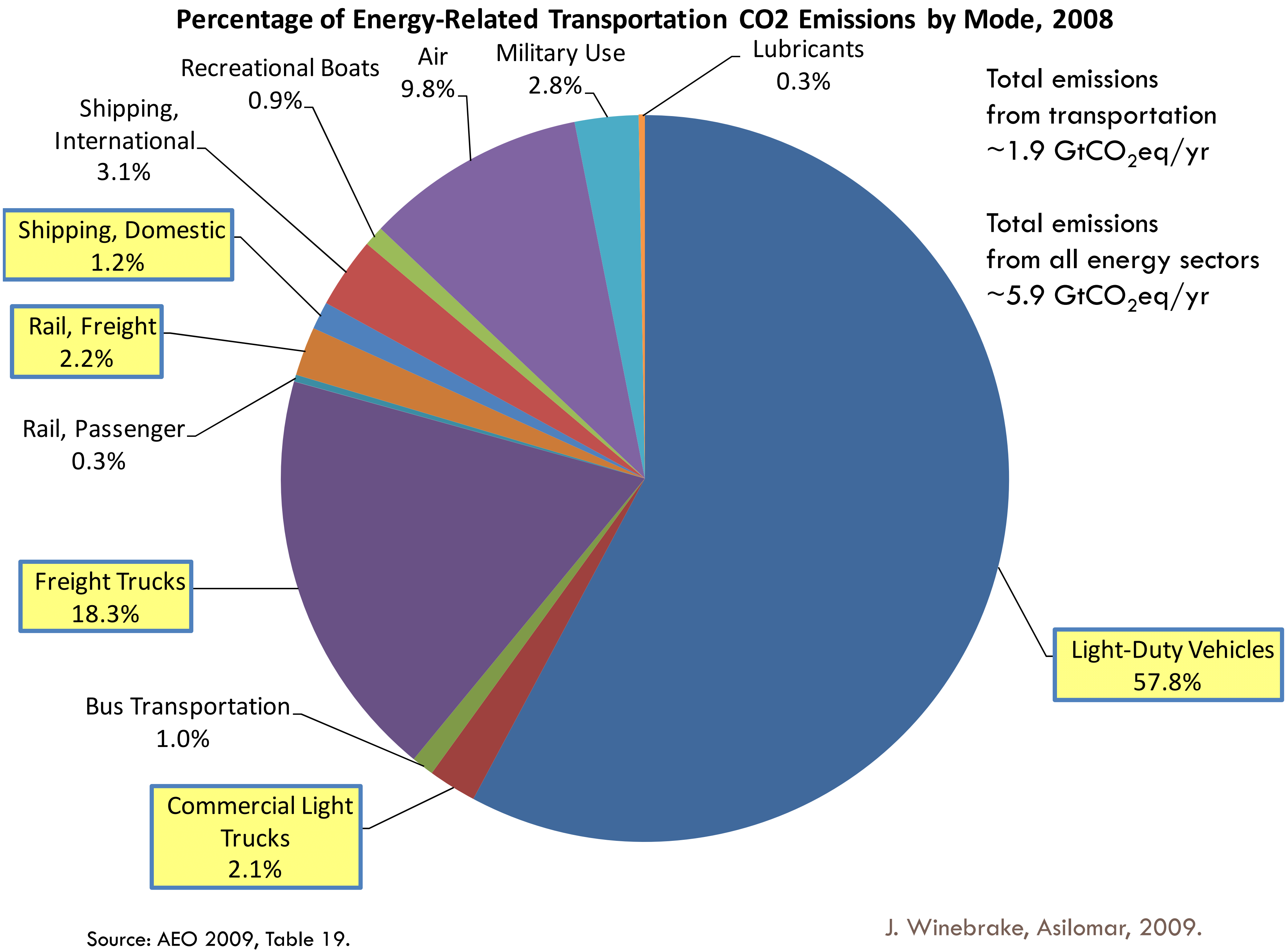


J. Winebrake, Asilomar, 2009.



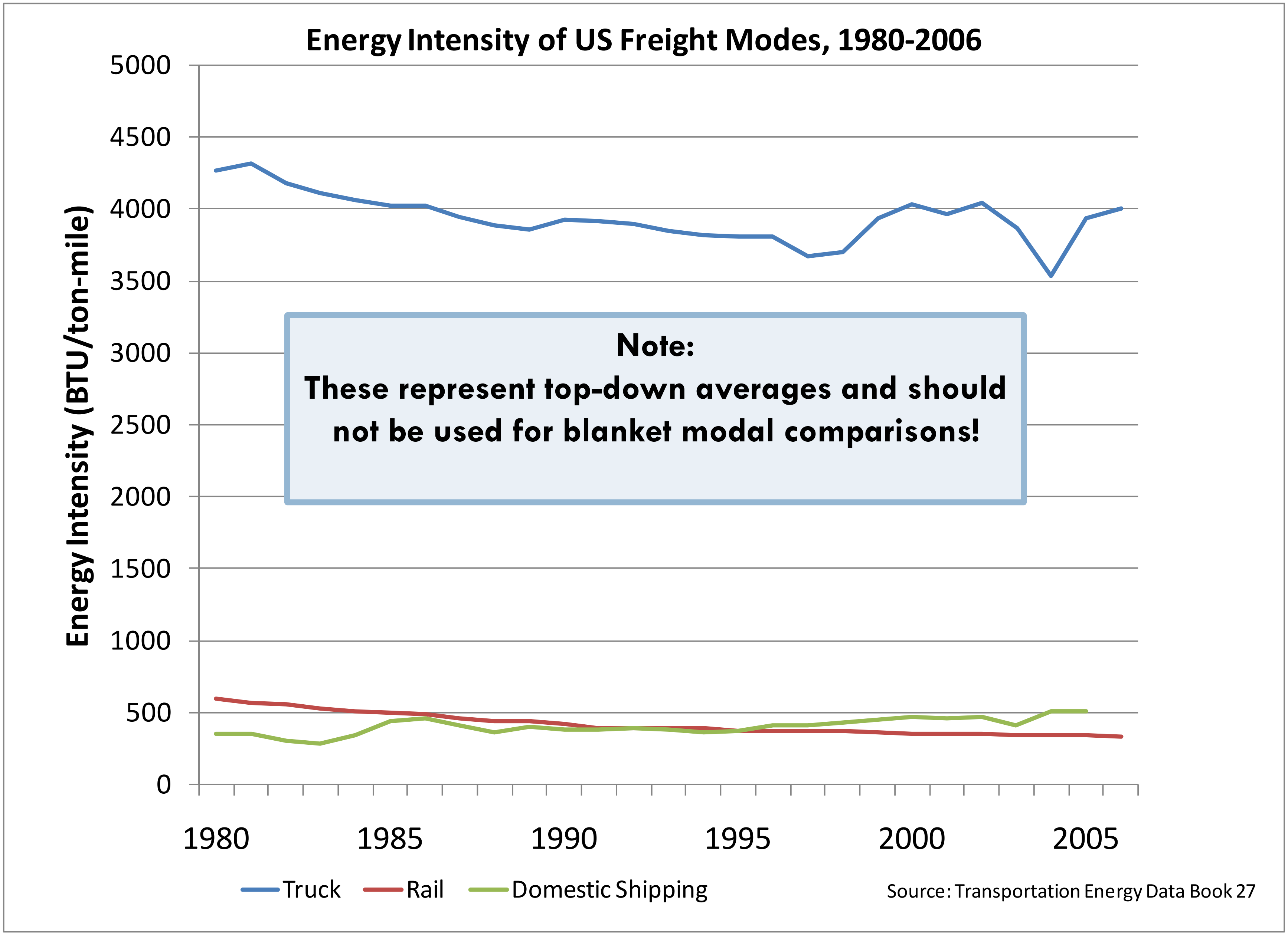
Source: AEO 2009, Table 45.

J. Winebrake, Asilomar, 2009.

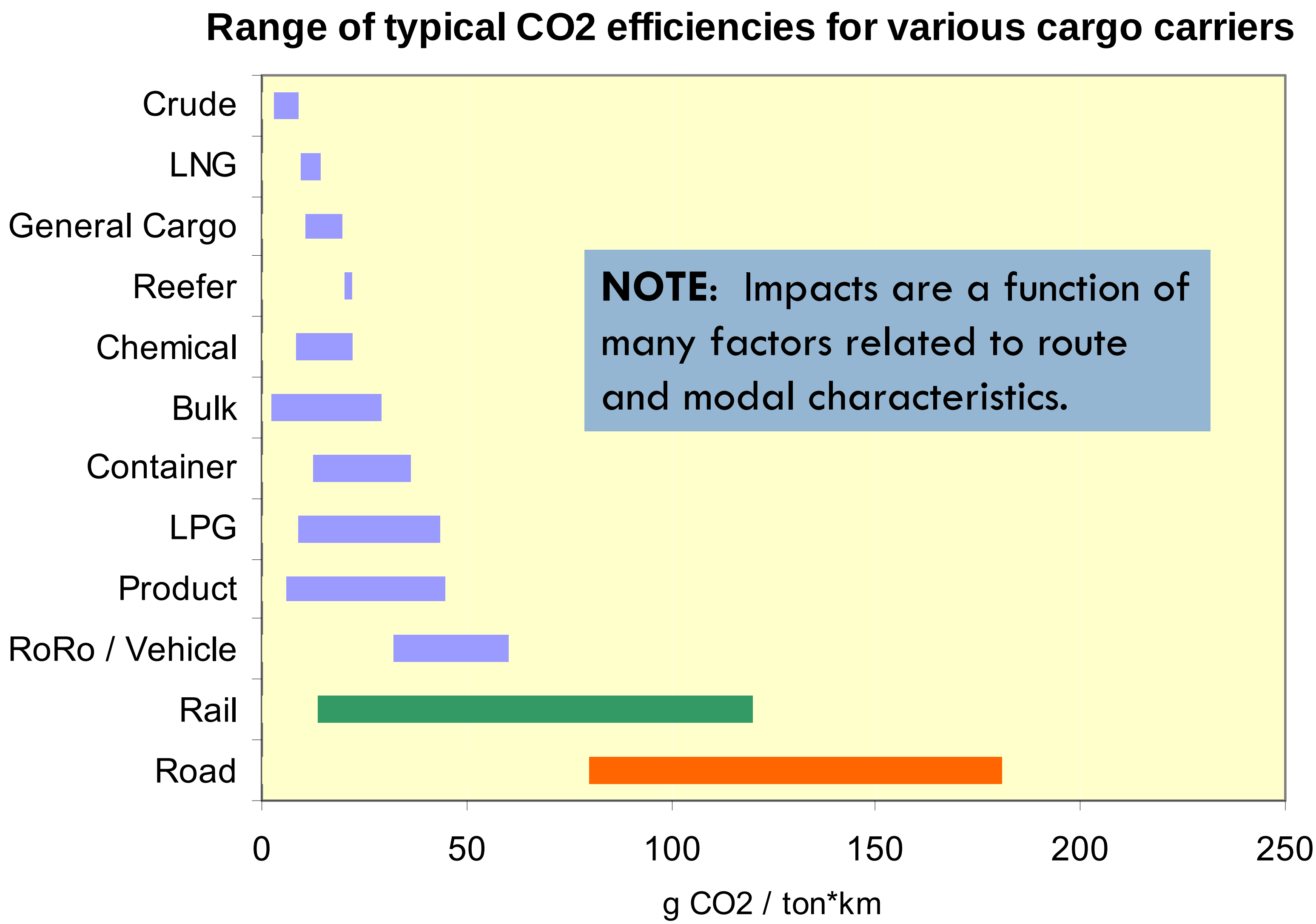

Percentage of Energy-Related Transportation CO2 Emissions by Mode, 2008
Recreational Boats 0.9%
Air 9.8%
Military Use 2.8%
Lubricants 0.3%
Shipping, International 3.1%
Shipping, Domestic 1.2%
Rail, Freight 2.2%
Rail, Passenger 0.3%
Freight Trucks 18.3%
Bus Transportation 1.0%
Commercial Light Trucks 2.1%
Light-Duty Vehicles 57.8%
Total emissions from transportation ~1.9 GtCO2eq/yr
Total emissions from all energy sectors ~5.9 GtCO2eq/yr
Source: AEO 2009, Table 19.
J. Winebrake, Asilomar, 2009.

Modal Comparisons

J. Winebrake, Asilomar, 2009.



J. Winebrake, Asilomar, 2009.



Source: Buhaug, et al. 2009

J. Winebrake, Asilomar, 2009.

Some Examples Using GIFT

The *Geospatial Intermodal Freight Transportation (GIFT)* model is a model jointly developed by the Rochester Institute of Technology and the University of Delaware, with funding support from US DOT/MARAD, Great Lakes Maritime Research Institute, ARB, among others.

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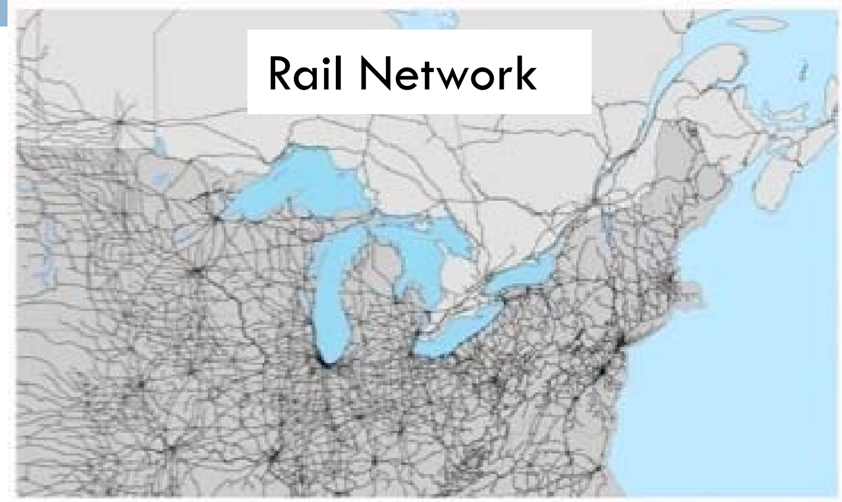
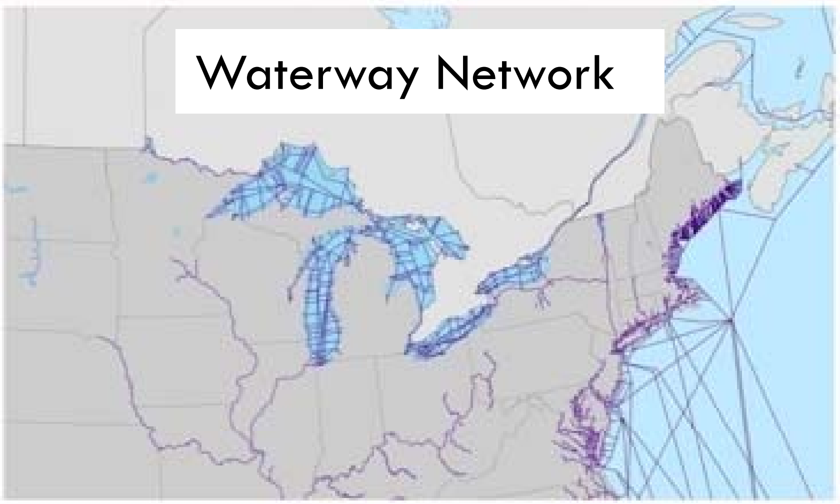
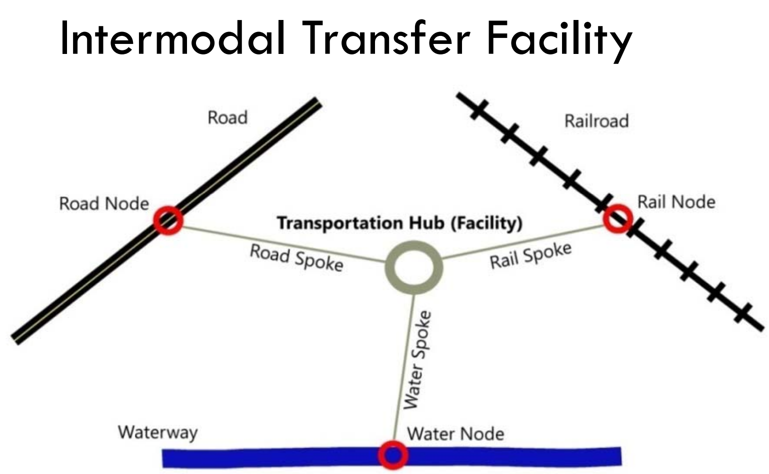
Connect Multiple Transportation Mode Networks at Intermodal Transfer Facilities







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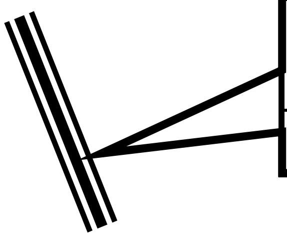
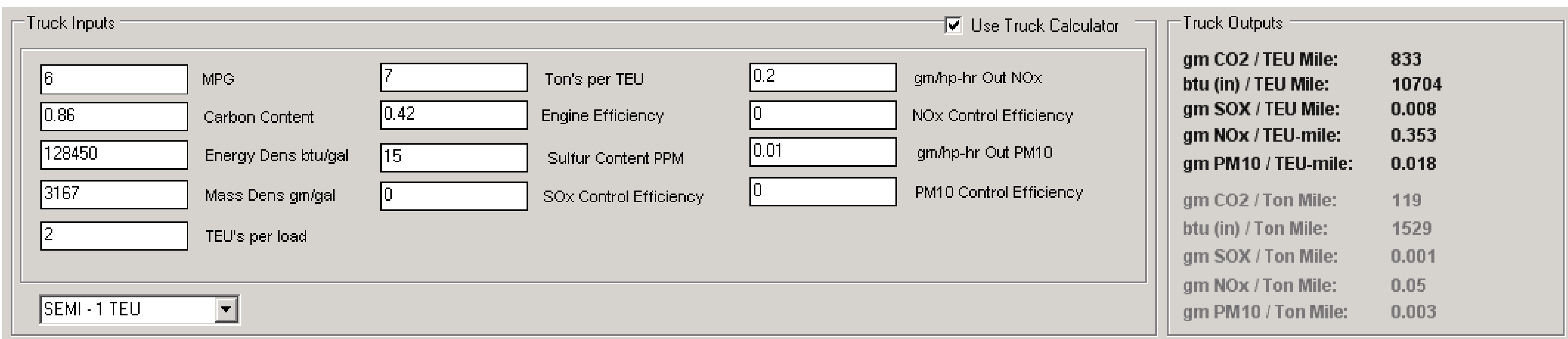
Define Economic, Energy, Time and Environmental Costs of Traversing Each Network Segment and Transfer



Truck Segment "Costs"						
Distance	Time	Operating Cost	Energy	CO_2	NOx	…



ESRI ArcGIS Network Analyst finds "Shortest" (least cost) routes.

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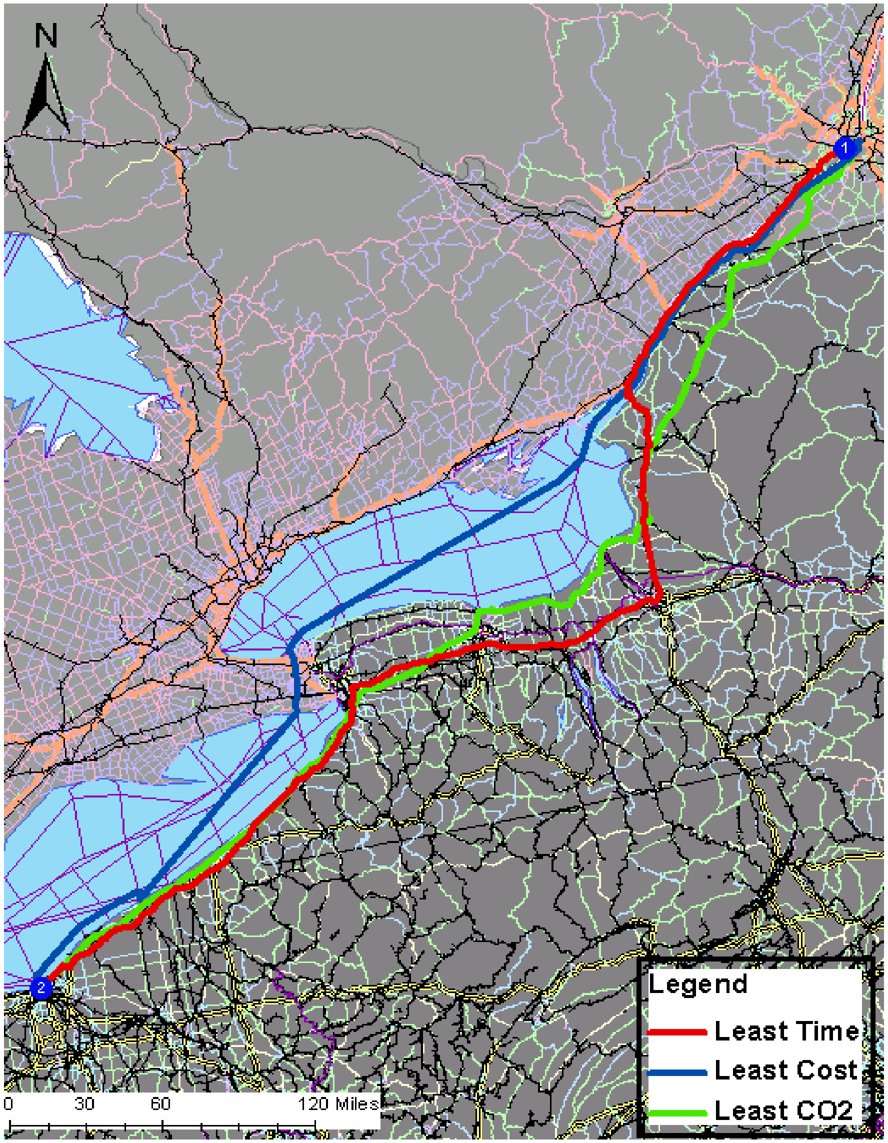
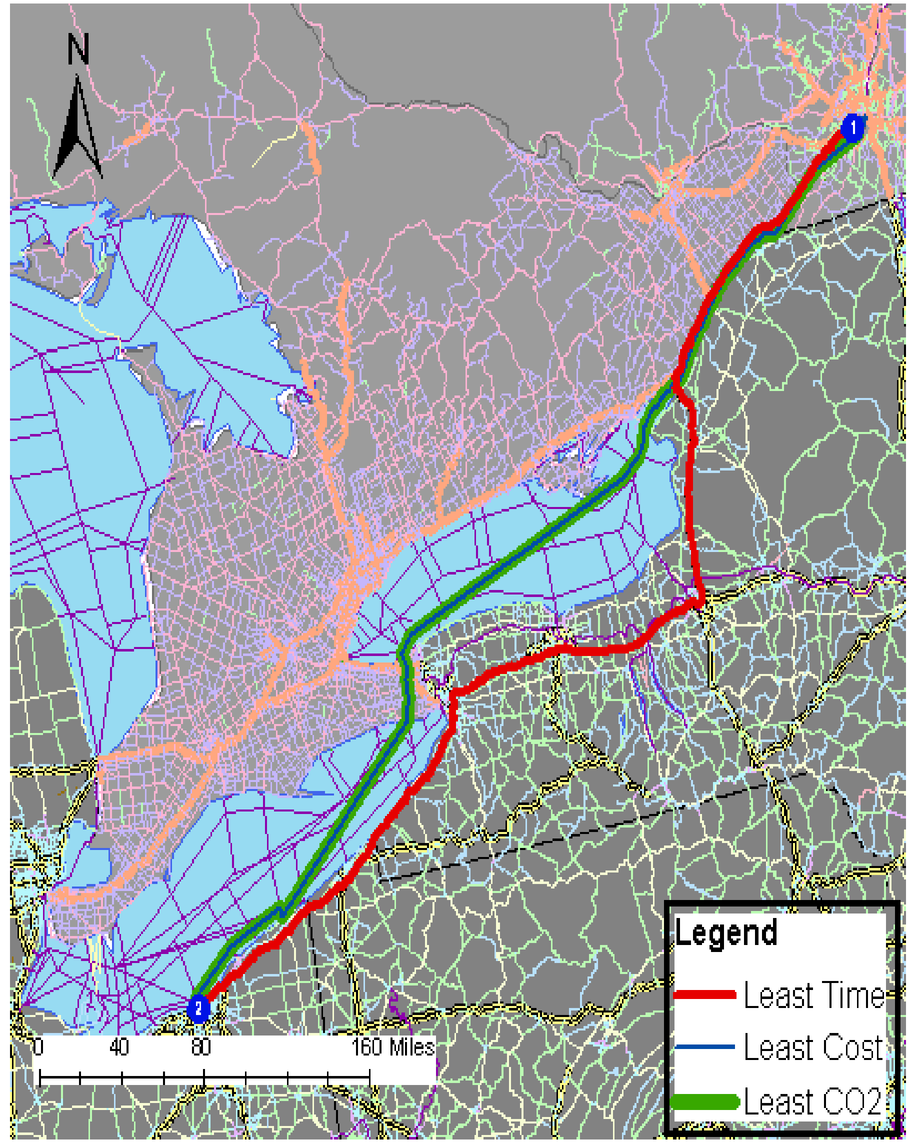


Montreal to Cleveland (Ship 1)



Montreal to Cleveland (Ship 2)

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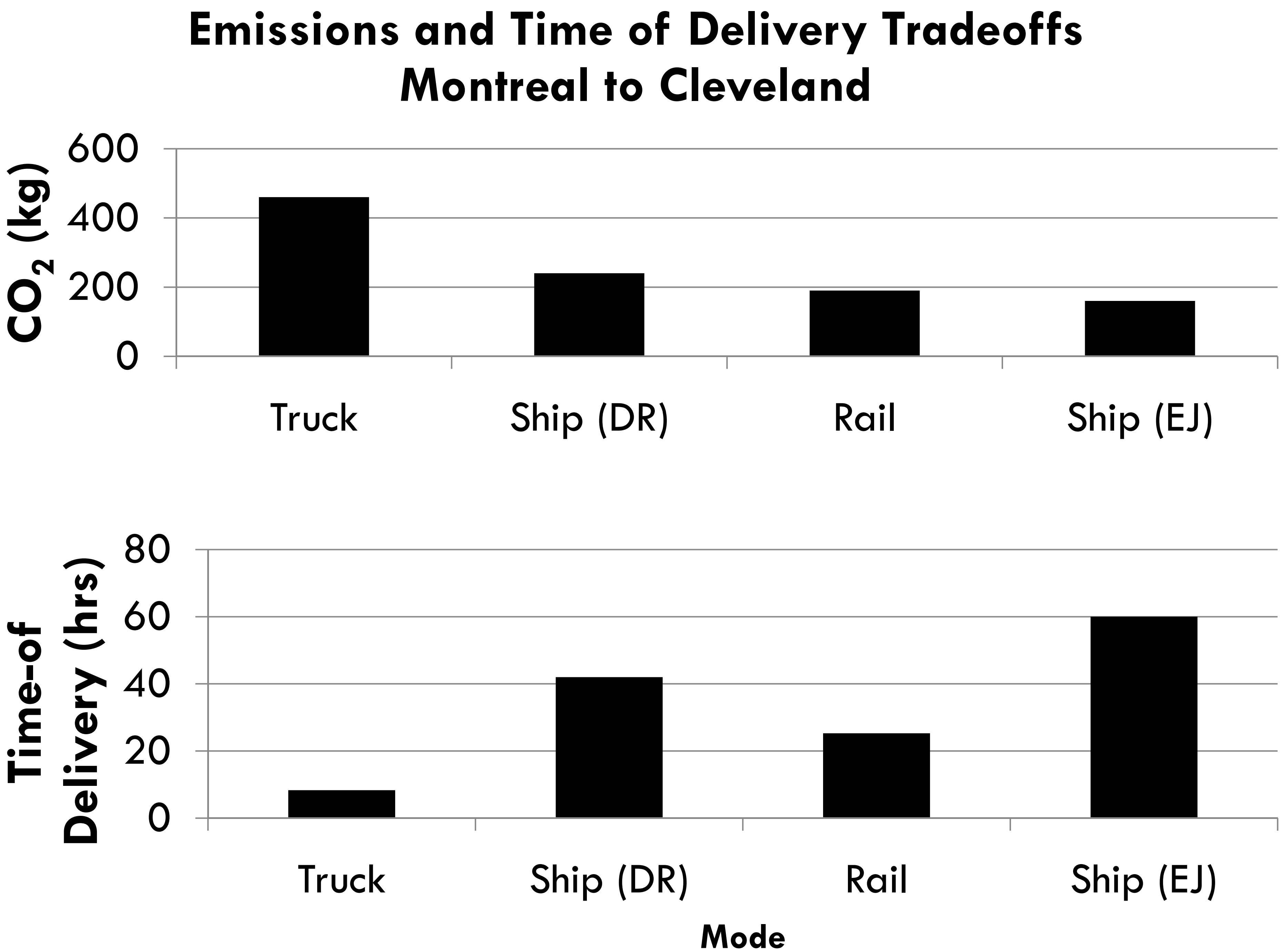
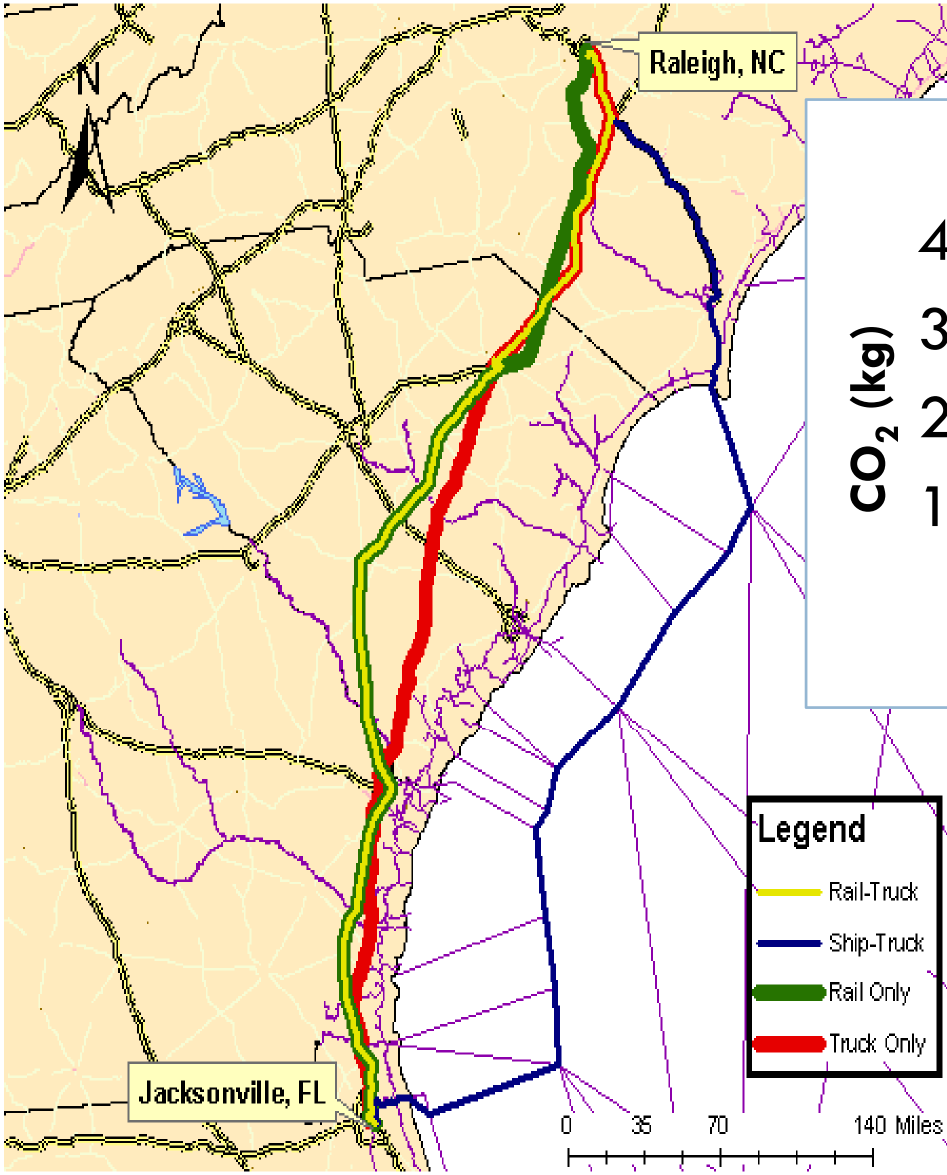
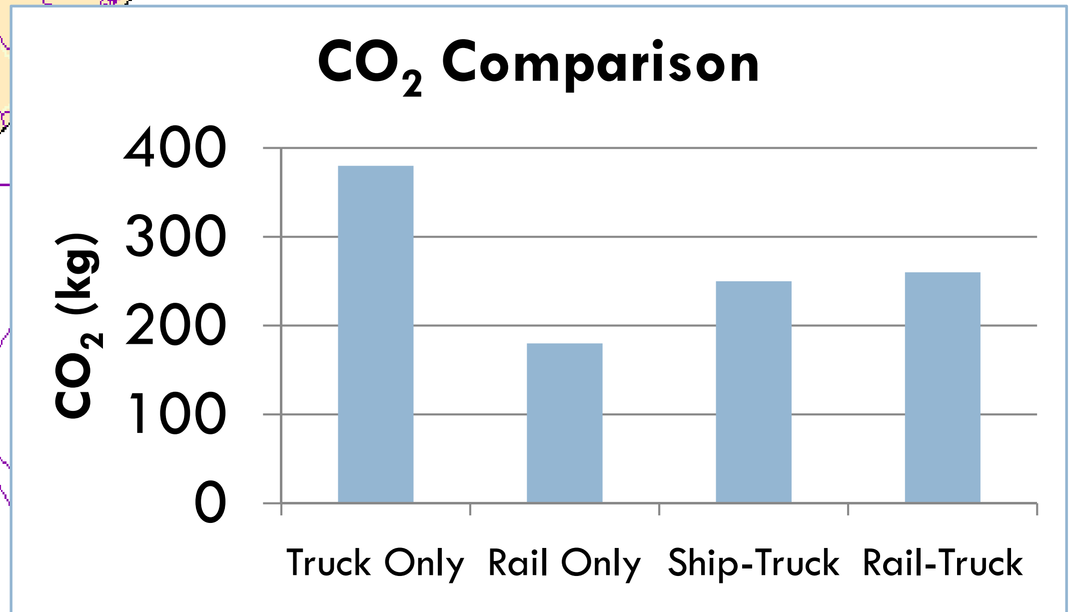
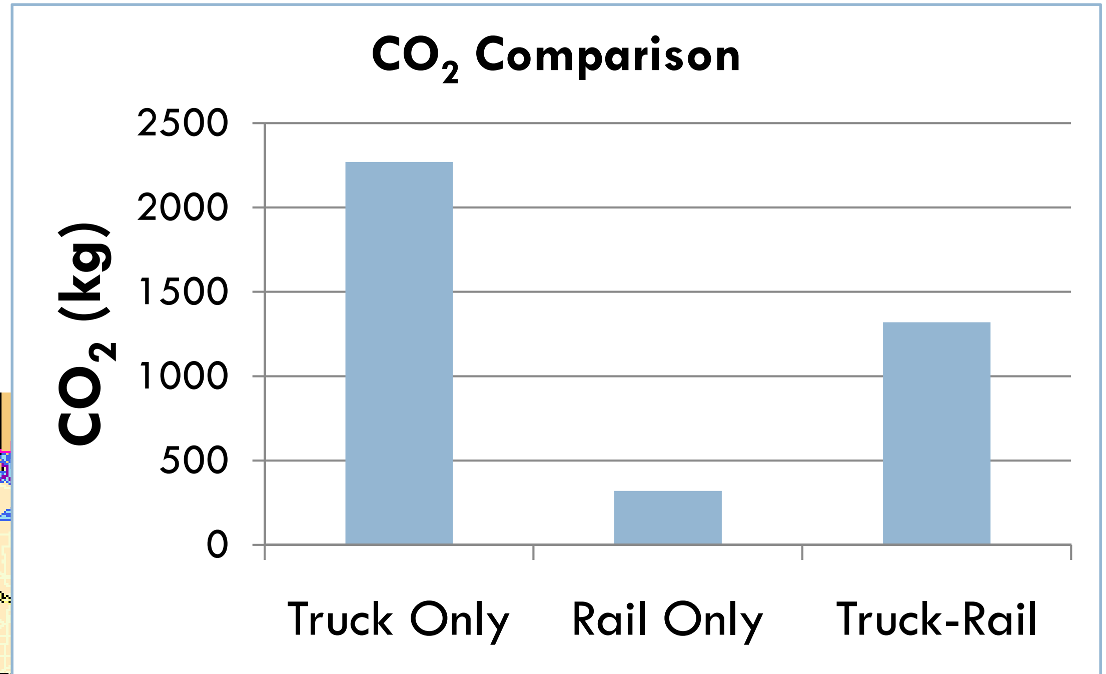

Emissions and Time of Delivery Tradeoffs
Montreal to Cleveland
CO2 (kg)
600
400
200
0
Truck
Ship (DR)
Rail
Ship (EJ)
Time-of Delivery (hrs)
80
60
40
20
0
Truck
Ship (DR)
Rail
Ship (EJ)
Mode





J. Winebrake, Asilomar, 2009.



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Opportunities for Mode Shifting

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The IF-TOLD Mitigation Framework: A Context for Mode Shifting Discussions

- The IF-TOLD "six-legged cow":
  - ***I*****ntermodalism/mode-shifting** – use of efficient modes
  - ***F*****uels** – use of low carbon fuels
  - ***T*****echnology** – application of efficient technologies
  - ***O*****perations** – best practices in operator behavior
  - ***L*****ogistics** – improve supply chain management
  - ***D*****emand** – reduce how much STUFF we consume

Even a six-legged cow can move all legs – dynamic, balancing!

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Opportunities for Mode-Shifting

$$\Delta E_{ij} = \sum_k \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$

ΔE_{ij} = *energy savings due to modal shift from i to j*
W_{ik} = *work done by mode i for commodity k (ton-miles)*
$\boldsymbol{c_{ijk}}$ = *shipment* ***<u>compatibility fraction</u>*** *of i to j for k (cargo)*
$\boldsymbol{f_{ijk}}$ = *shipment* ***<u>feasibility fraction</u>*** *of i to j for k (infrastructure)*
$\boldsymbol{p_{ijk}}$ = *shipment* ***<u>practicality fraction</u>*** *of i to j for k (economic)*
E_i = *energy intensity factor for i (Btu/ton-mile)*
E_j = *energy intensity factor for j (Btu/ton-mile)*

Also need to account for intermodal transfer penalties.

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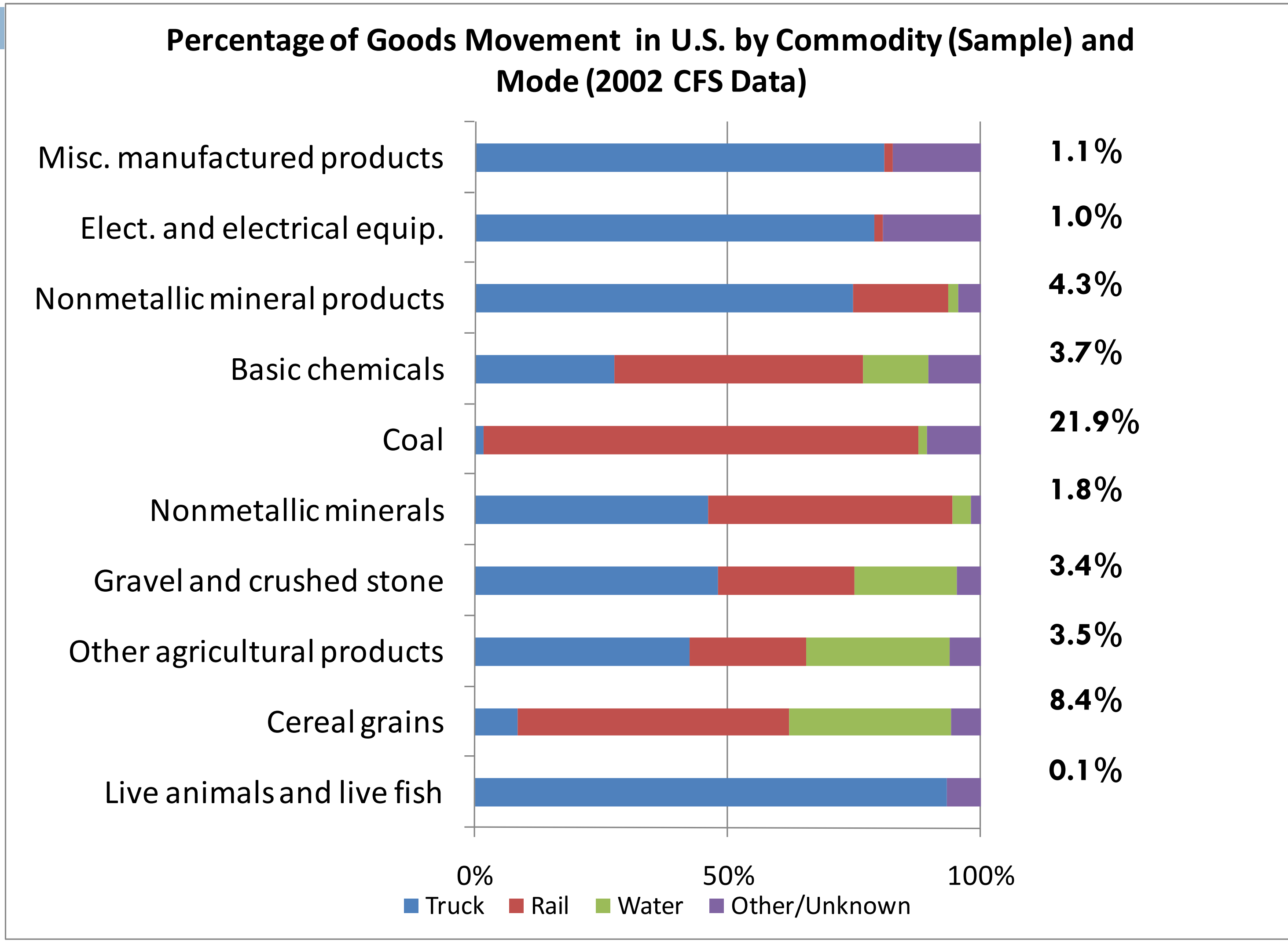
Insights into c_{ijk} – Cargo Characteristics



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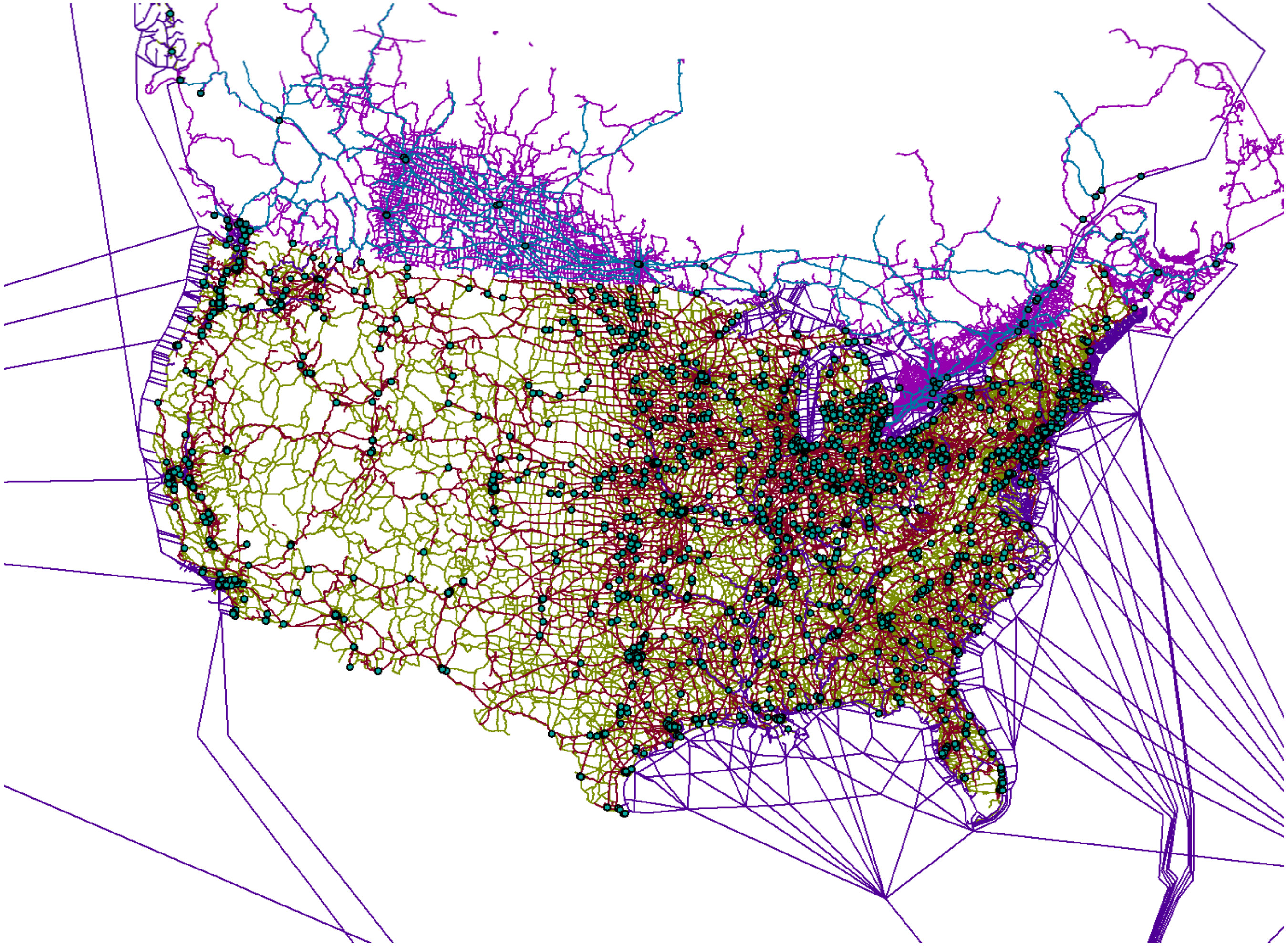
Source: CFS 2002, Ton-Miles by Commodity and Mode

Insights into f_{ijk} – U.S. Intermodal Infrastructure



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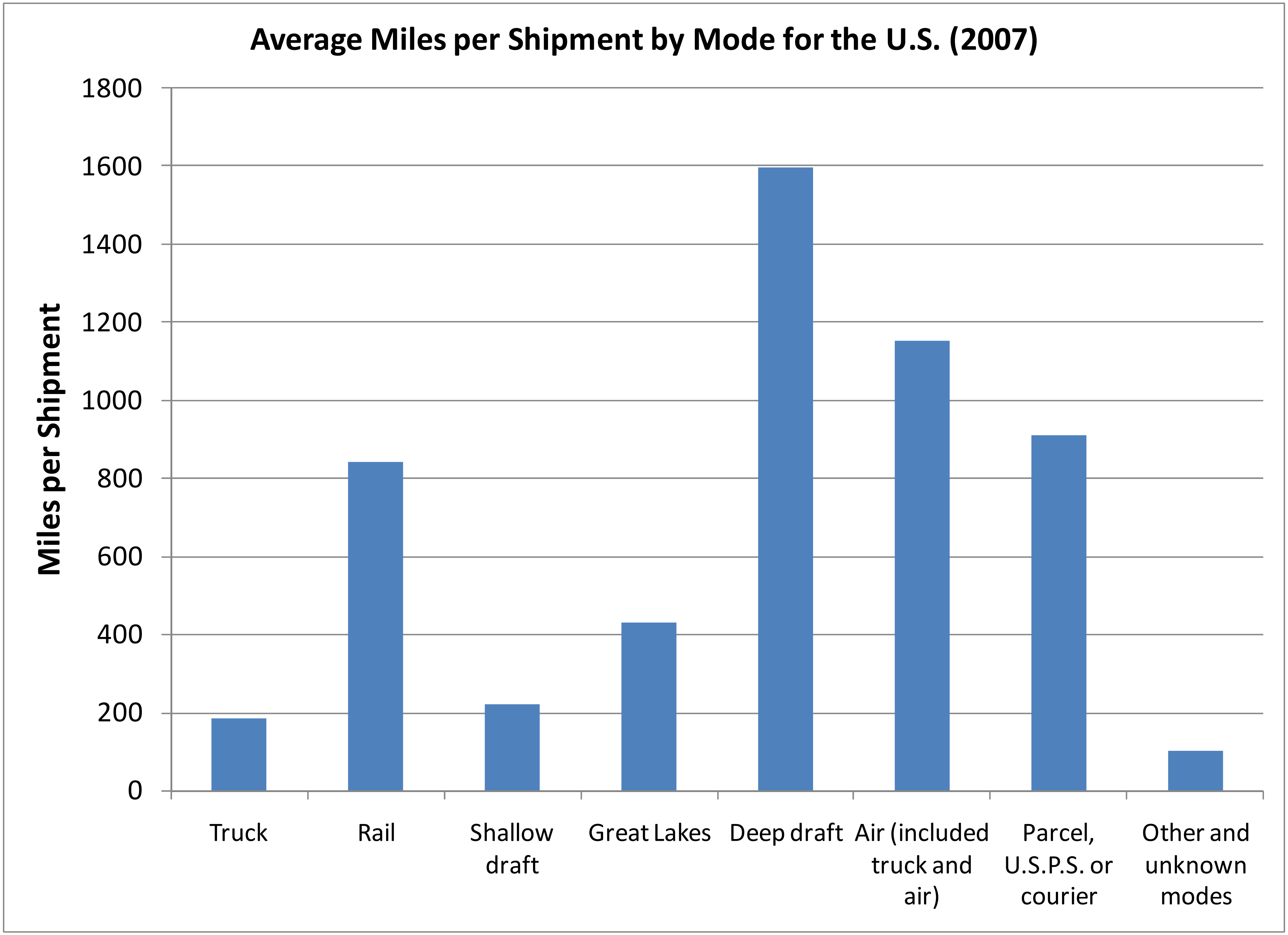

Source: CFS 2007.

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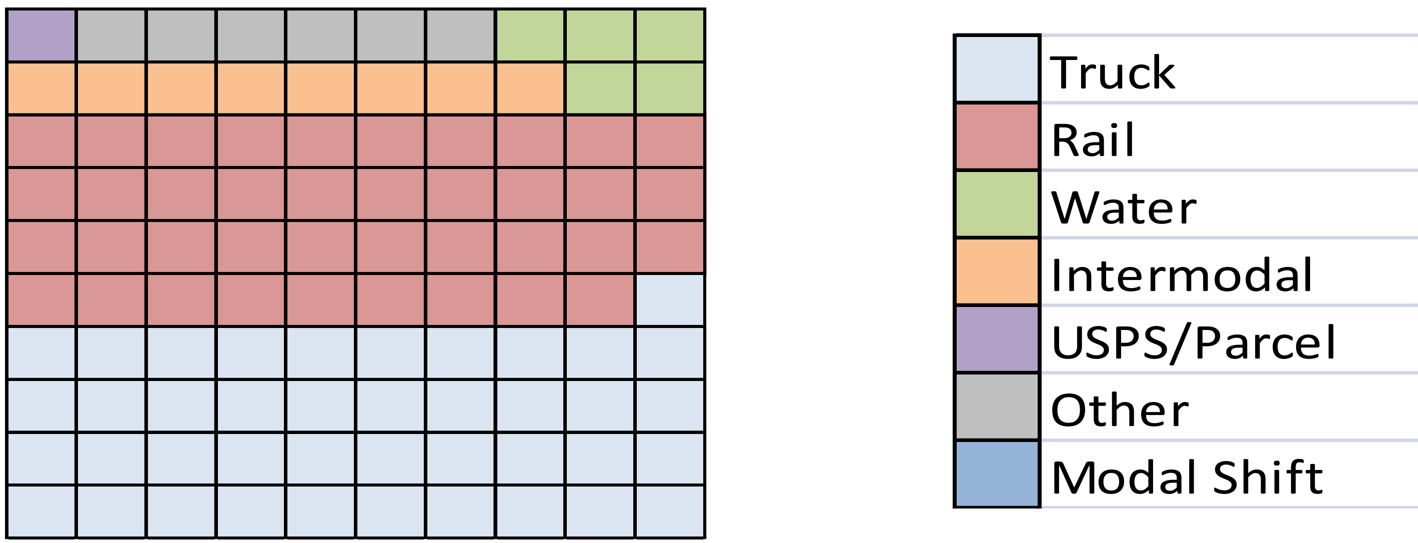
Estimating Mode Shifting Potential

$$\Delta E_{ij} = \sum_{k} \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$



Consider total ton-miles as a gridded box, where each cell is equivalent to 1%.

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Estimating Mode Shifting Potential

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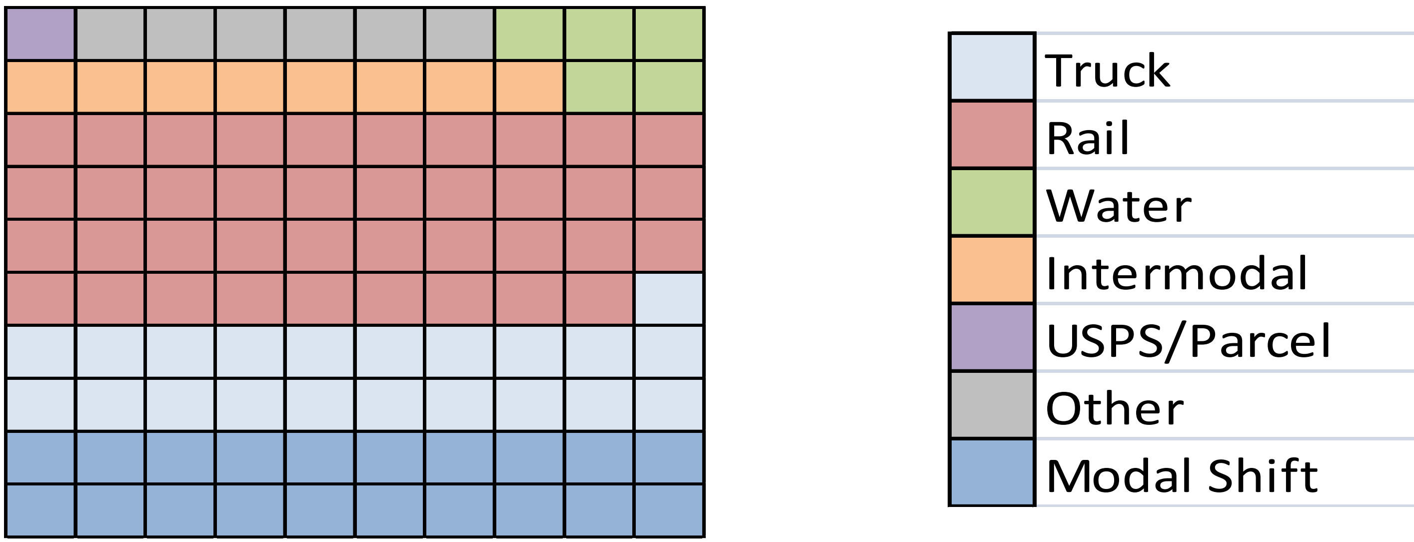

Assume that about 50% of the cargo currently moved by truck is compatible with rail or ship due to physical properties, safety, loading logistics, etc. [$c_{ijk} \sim 0.50$]

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Estimating Mode Shifting Potential

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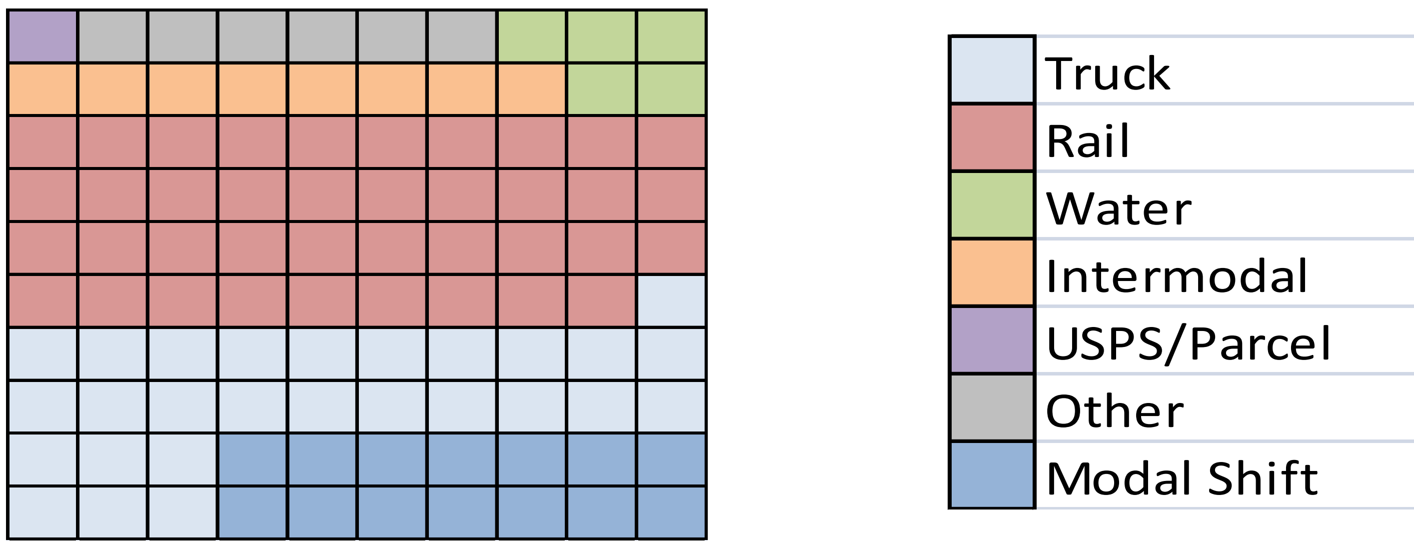

Assume that of the cargo that is compatible, infrastructure can only serve 70% of the ton-miles in the short term [f_{ijk} ~0.70]

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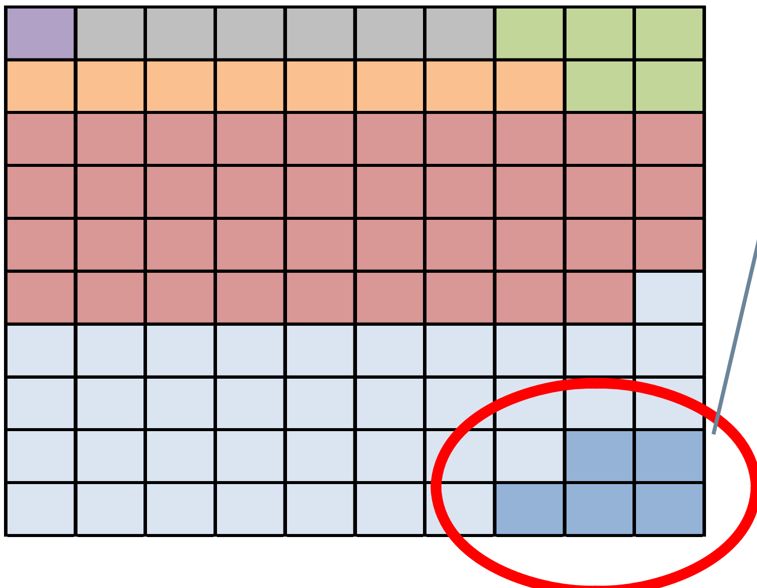
Estimating Mode Shifting Potential

$$\Delta E_{ij} = \sum_k \left[W_{ik} \cdot c_{ijk} \cdot f_{ijk} \cdot p_{ijk} \left(E_i - E_j \right) \right]$$



Under these assumptions, there is potential to move ~ 5% of the total ton-miles (~12% of truck ton-miles) from truck to rail/ship. If truck is ~5 times more energy intense than rail/ship, then this implies ~8% reduction in energy consumption.

Average distance by truck is 200 miles. Assume that ~50% of the ton-miles shipped > 200 miles and 25% are > 500 miles. Assume economic possibility exists for mode shifting for 35% of total truck trips. [p_{ijk} ~ 0.35].

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Policies for Promoting Efficiency

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Policy Options

Policy Options	Intermodalism I	Fuel F	Technology T	Operations O	Logistics L	Demand D
Efficiency standards	•		•		•	
Taxes	•	•	•	•	•	•
Subsidies	•	•	•			
Technology mandates			•			
Infrastructure investment	•				•	
R&D investment		•	•			
Alternative/LC fuels		•	•			
Size/weight restrictions	•			•	•	
Demand management						•

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Conclusion

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Conclusion

- Modal shifts offer large side-by-side benefits
- System benefits vary depending on vessel, vehicle, locomotive, and route characteristics and are constrained by compatibility, feasibility, and practicality – research needed here
- Suite of policy options should be considered recognizing freight sector as a <u>system</u>
- Wedge analysis needed for freight sector that looks at potential for the IF-TOLD set of elements

Citations

- Corbett, J. J.; Winebrake, J.J.; "The impact of globalisation on international maritime transport activity: Past trends and future perspectives," in *Globalisation, Transport, and Environment*, edited by N. A. Braathen, Organisation for Economic Cooperation and Development (OECD), Paris, forthcoming.
- Buhaug, Ø.; Corbett, J. J.; Endresen, Ø.; Eyring, V.; Faber, J.; Hanayama, S.; Lee, D. S.; Lee, D.; Lindstad, H.; Mjelde, A.; Pålsson, C.; Wanquing, W.; Winebrake, J. J.; Yoshida, K. *Updated Study on Greenhouse Gas Emissions from Ships*; International Maritime Organization (IMO) London, UK, 2009.
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