IMPROVING THE ENERGY EFFICIENCY AND ENVIRONMENTAL PERFORMANCE OF GOODS MOVEMENT: A MULTI-MODAL PERSPECTIVE

James J. Corbett, Ph.D., University of Delaware
Workshop on Transportation Energy Efficiency Improvement Potential in APEC Economies

Overview

- 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 opportunity for mode-shifting in a larger systems context
- Summary: Collaborating to identify opportunities

IPCC 4th Assessment Freight Hypothesis

- BACKGROUND: Freight transport now consumes 35% of all transport energy (WBCSD, 2004b). Freight transport is considerably more conscious of energy efficiency considerations, however this can be offset by pressure to increase speeds and reliability and provide smaller 'just-in-time' shipments.
- GIVEN: The result has been that there has been an ongoing movement to the faster and more energy-intensive modes. Consequently, rail and domestic waterways' shares of total freight movement have been declining, while highway's share has been increasing and air freight, though it remains a small share, has been growing rapidly.
- THEREFORE, PERHAPS: We can solve a large part of the energy and environmental problems of freight transportation by moving goods off of trucks and onto trains and ships.

Overview of Goods Movement

Freight and Environment Overview

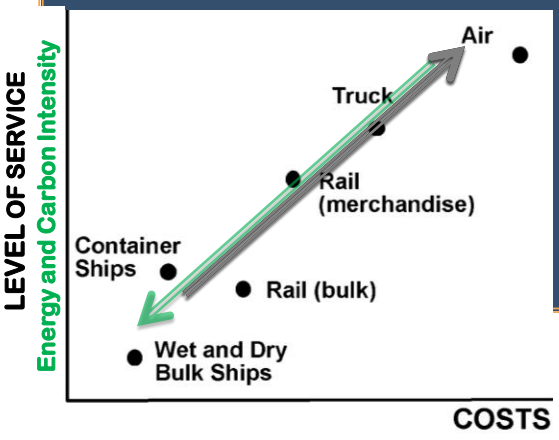
Thinking about **freight transport** requires more

system-thinking than **passenger transport.**

Freight transport is the fastest growing energy sector

Shippers, carriers, consumers can jointly achieve sustainable supply chain systems to

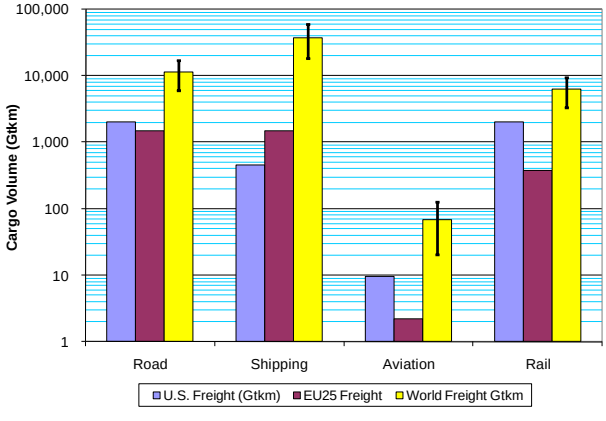
- reduce ***costs***,
- conserve ***energy /environmental resources***,
- protect ***environment & health***.



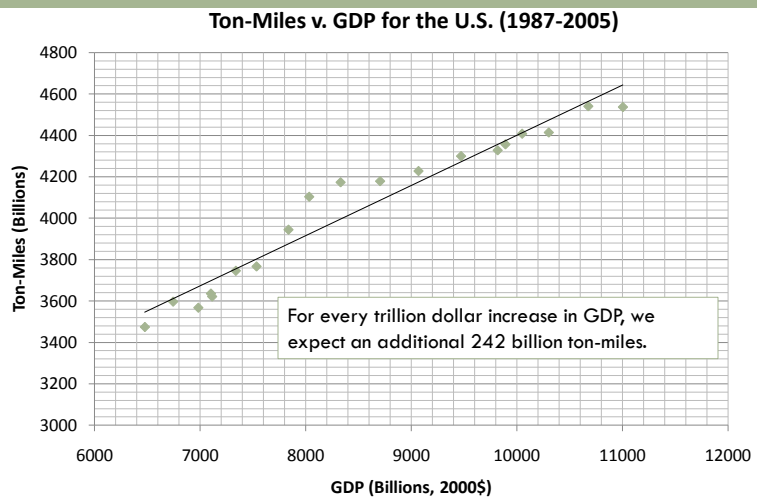
Freight Overview

- Freight movement critical to our national economy and security
- Freight transport is the fastest growing energy sector
- Freight is a major contributor to environmental problems
- Freight overlaps many areas important to our country' : energy use, environmental quality, economic growth, congestion mitigation, and national security

Global and US Cargo Flows (Gt-km) by Mode (2005)



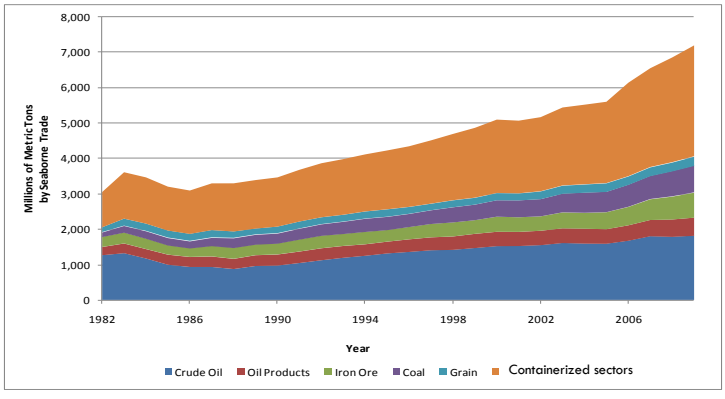
Goods Movement and GDP



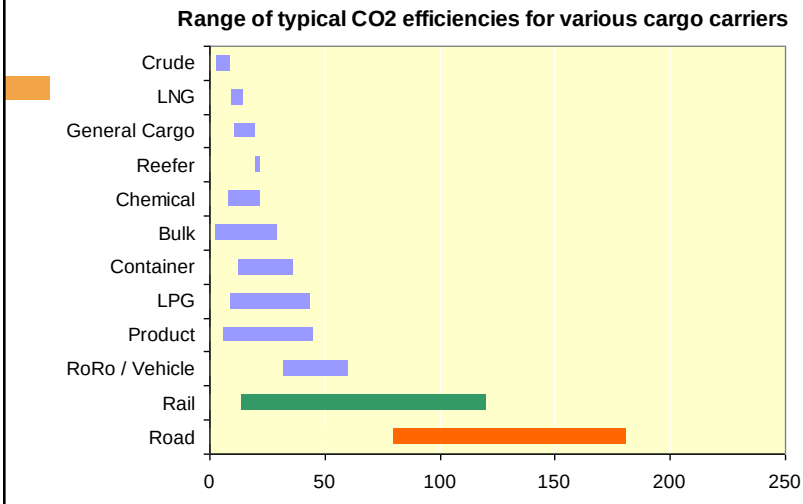
Source: Corbett and Winebrake, 2008.

Maritime transportation has been credited as one of reasons behind the rapid growth in the post-war international trade

8



Source: Institute of Shipping Economics and Logistics



NOTE: Impacts are a function of many factors related to route and modal characteristics.

Source: Buhaug, et al. 2009

Modal Modeling of Possibilities

Calculating Impacts from the Bottom Up

- Use of Emissions Calculator for segments and Transfer Emissions Model for intermodal transfers
- Calculators developed by RIT and the University of Delaware to support research activities under the *Sustainable Intermodal Freight Transportation Research* (SIFTR) program

Geospatial Intermodal Freight Transportation (GIFT) Model

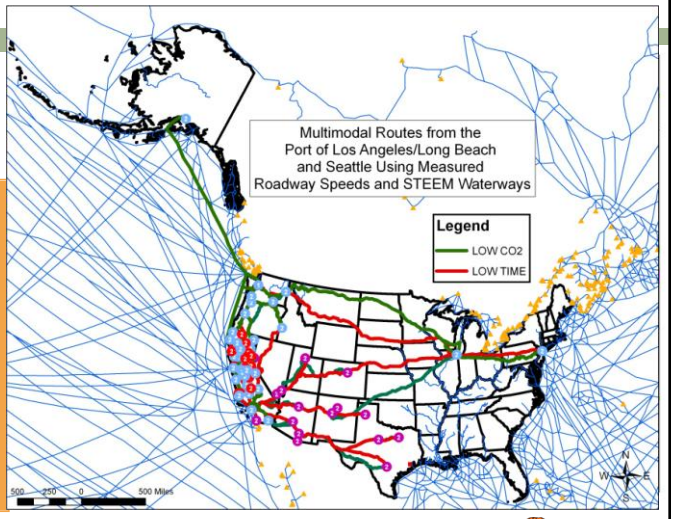
VISUALIZING GOALS
MODELING
ALTERNATIVES

Intermodal freight network optimization model to evaluate objective tradeoffs.

Developing resources for "table-top" exercises with industry and agencies.

Evaluates performance against *benchmarks* and optimizes with respect to possible ***targets***

Web-version in development.



R·I·T University of Delaware

Comer, B.; Corbett, J. J.; Hawker, J. S.; Korfmacher, K.; Lee, E. E.; Prokop, C.; Winebrake, J. J., Marine Vessels as Substitutes for Heavy-1 Duty Trucks in Great Lakes Freight Transportation. *Journal of Air and Waste Management* ***2010, forthcoming.***

How are we using GIFT?

- Table-top exercises with leaders in transportation
  - Modal experts and industry decision makers
  - Public infrastructure planners at regional and national levels
  - Environmental, energy interests in public and private sectors

- Choose origin-destination pairs given current or new ***infrastructure***
- Consider current or future ***fuels***
- Pick average, emerging, or best ***technologies***
- Input parameters for current or best practice ***operations***
- Interact with the model results to visualize supply chain ***logistics***
- Respond to environmental needs, energy targets and economic ***demand***

Opportunities for Mode Shifting

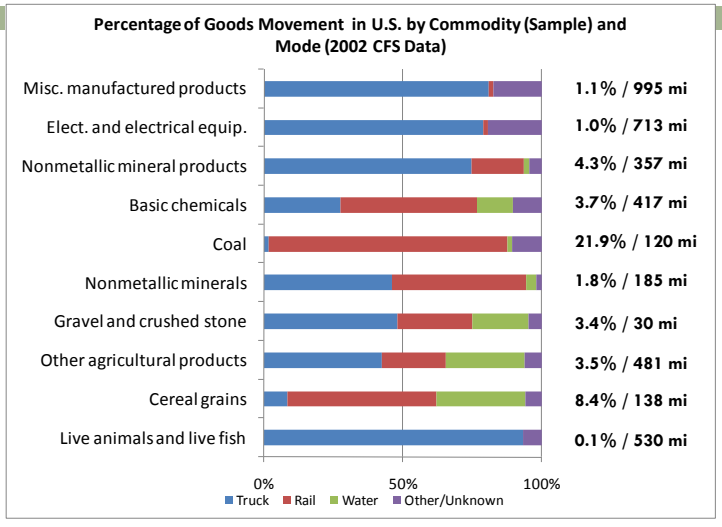
Opportunities for Mode-Shifting

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

ΔE_{ij} = *energy savings due to modal shift from i to j*
W_{ik} = *work done by mode i for commodity k (ton-miles)*
c_{ijk} = *shipment compatibility fraction of i to j for k (cargo)*
f_{ijk} = *shipment feasibility fraction of i to j for k (infrastructure)*
p_{ijk} = *shipment practicality fraction 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)*

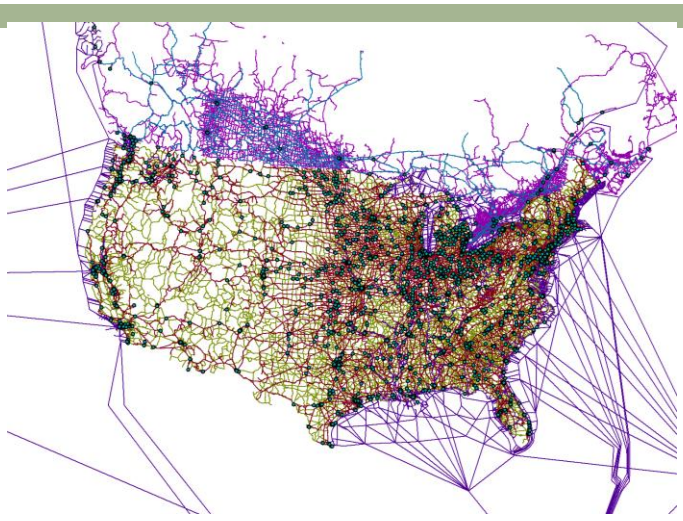
Also need to account for intermodal transfer penalties.

Insights into c_{ijk} – Cargo Characteristics



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

Insights into f_{ijk} – a Nation's Intermodal Infrastructure



Insights into p_{ijk} – Economic Practicality

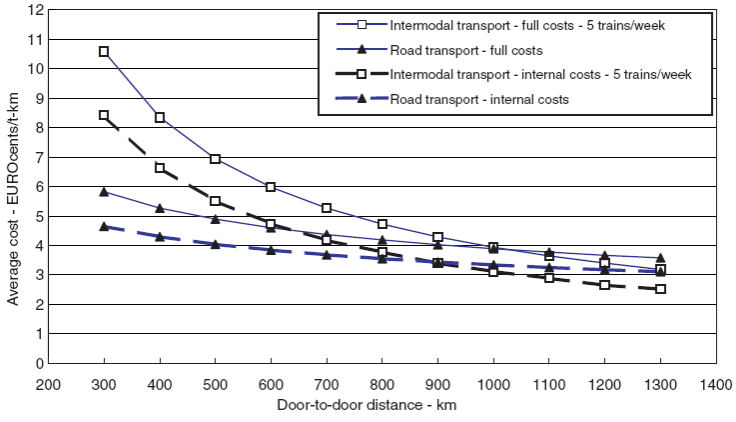
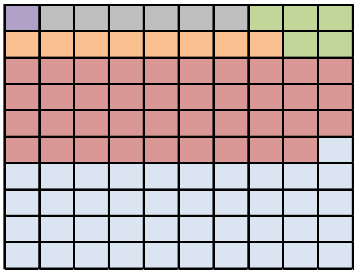


Fig. 3. Dependence of the average external, internal and full costs of given intermodal and road transport network on the door-to-door distance.

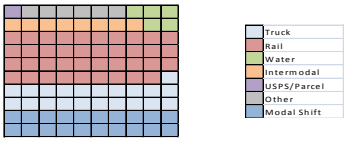
Source: Janic (2007).

Estimating Mode Shifting Potential



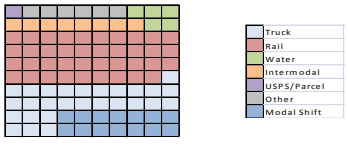
Consider total ton-miles as a gridded box, where each cell is equivalent to 1%.

Estimating Mode Shifting Potential



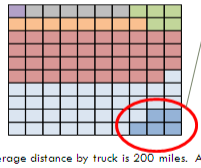
Assume that about 50% of the cargo currently moved by truck is compatible with rail or ship movement due to physical properties, safety issues, loading logistics, etc. [c_{ijk} ~ 0.50]

Estimating Mode Shifting Potential



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]

Estimating Mode Shifting Potential



Under these assumptions, there is potential to move ~ 5% of the 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 by truck are > 200 miles and that 25% are > 500 miles. Assume economic possibility exists for mode shifting for 35% of these trips. [p_{ijk} ~ 0.35].

Special Aside on Service

- We also must consider service constraints
  - Slower service with a constant demand means that capacity must be increased (ton-miles moved) through
    - Larger vessels or trains
    - Greater population of vessels or trains
- This is not accounted for in the simplified equation
- A 10% decrease in service speed implies ~10% increase needed in trip frequency (at full capacity, *ceteris paribus*)

Conclusion

- Modal shifts present large side-by-side benefits
- These benefits vary greatly depending on vessel, vehicle, or locomotive characteristics and route characteristics
- True comparative analyses must be done from a bottom up framework
- System benefits are constrained by compatibility, feasibility, and practicality
- Because modal choice is distance dependent, will greater localization help or hurt emissions?
- Overall effects are promising, but limited; more research needed to determine the overall opportunities for mode-shifting (in particular, quantifying c_{ijk}, f_{ijk}, and p_{ijk}).

Acknowledgements

- Much of the material was developed jointly with Dr. James J. Winebrake, Rochester Institute of Technology; Dr. Winebrake co-directs a series of efforts under the joint Sustainable Intermodal Freight Transportation Research program.
- I am also indebted to faculty and students in the Laboratory for Environmental Computing and Decision Making at RIT; and to faculty and students at University of Delaware.
- These issues are also discussed in several publications, including Winebrake, J. J.; Corbett, J. J., Chapter 13: Improving the Energy Efficiency and Environmental Performance of Goods Movement In *Climate and Transportation Solutions: Findings from the 2009 Asilomar Conference on Transportation and Energy Policy, Sperling, D.; Cannon, J., Eds. Institute of Transportation Studies, University of California, Davis: Sacramento, CA, 2010.*

Thank you

James J. Corbett

jcorbett@udel.edu