Emissions Analysis of Freight Transport Comparing Land-Side and Water-Side Short-Sea Routes: Development and Demonstration of a Decision Modeling Tool

Prepared for:
The United States Department of Transportation
Research and Special Programs Administration
(Under DTRS56-05-BAA-0001 Full Proposal)

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1 Summary Information

1.1 Lead Contact Information

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1.2 Objective and Summary of Work

This study will create a decision tool that can assist in evaluating the economic, environmental, and congestion issues associated with alternative land-side and water-side freight transport routes. The project is aimed at developing the methodology and tools for: (1) quantifying emissions from land-side and water-side freight transport alternatives; (2) evaluating tradeoffs among pollutants, costs, and travel time for moving freight between two points; and, (3) identifying optimal modal combinations within a network of travel paths that would lead to either minimum emissions, minimum costs, or minimum travel time. The decision tool will be able to compare optimal routes for various decision objectives (e.g., minimize emissions, minimize costs, or minimize time) and constraints. For emissions, total fuel cycle emissions of GHGs and other pollutants will be included. We will demonstrate the model through a case study comparing short-sea shipping with other freight modes along the I-95 corridor.[1] This work supports national and international efforts to understand the value and implications of multimodal freight transportation within an integrated analytic framework. Results will enhance efforts to improve freight service and environmental stewardship of multimodal freight transportation.

1.3 List of Participant Organizations

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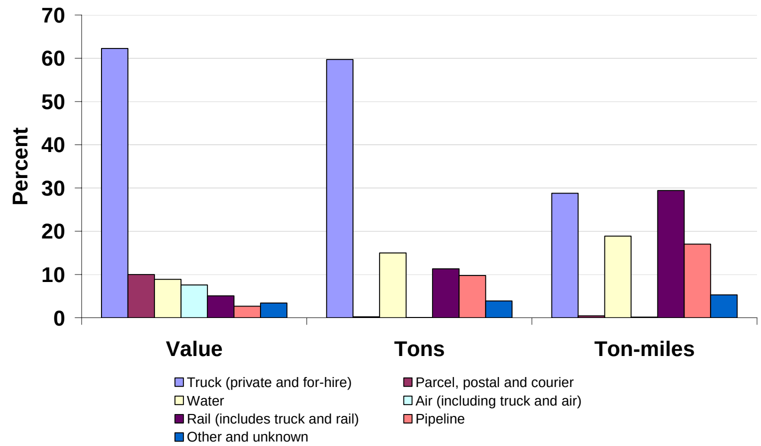
[1] Note that an alternative case study can be defined in coordination with the DOT project manager.

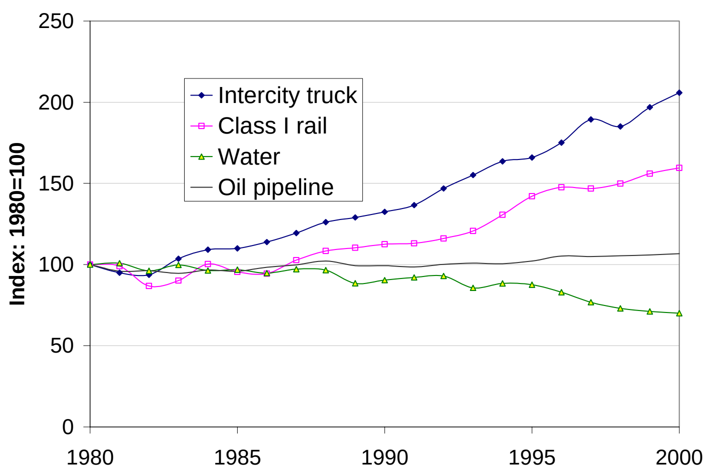
2 Project Overview

2.1 Background

Demand for freight transportation is increasing, but not equally across all modes. According to the Freight Analysis Framework [*Federal Highway Administration and Lambert*, 2002],[2] domestic freight volumes will grow by more than 65 percent from 1998 levels by the year 2020, increasing from 13.5 billion tons (in 1998) to 22.5 billion tons (in 2020). International freight is forecast to grow even faster than domestic trade. However, since 1980 truck freight has doubled (an average annual increase of 3.7%) while domestic waterborne freight has declined by nearly 30% (an average annual decline of 1.8%) [*Bureau of Transportation Statistics*, 2004].[3] Figure 1 illustrates these changes. This translates into significant emissions of greenhouse gases (and other pollutant emissions) for the transportation sector. Trucking alone accounts for nearly 20% of the total CO_2 from transportation; domestic waterborne freight movements accounts for less than 5% [*Davis*, 2003].



a)



b)

Figure 1. a) Modal share in 1997; and b) change since 1980 in domestic ton-miles carried by mode.

[2] See Freight Analysis Framework documents at http://ops.fhwa.dot.gov/freight/freight_analysis/faf/.
[3] BTS Pocket Guide to Transportation 2003, http://www.bts.gov/publications/pocket_guide_to_transportation/2003/.

The publicly available GeoFreight tool projects that regional growth in truck freight traffic (and possibly congestion) will be significantly greater than forecasted growth in waterborne freight [*Department of Transportation et al.*, 2003].[4] For example, along the East Coast (I-95 Corridor) from Maine to Florida, GeoFreight forecasts for 2010 suggest that modal intensity of highway trucking along I-95 is more than 100 times greater than domestic shipping along the same route (with an intensity index of 0.01 for shipping compared to an intensity index of 1.12 for trucking).[5] The I-95 highway corridor also has some of the most congested roads in the nation, which translates into wasted fuel, increased pollution, and more greenhouse gas and criteria pollutant emissions as trucks moving freight are stuck in traffic.

It has been widely acknowledged in the U.S. and in Europe that adjusting the modal share of freight transport can significantly address regional mobility, congestion, and environmental problems [2004; *Donnelly and Mazières*, 1999; *European Commission*, 1999; *Maritime Administration*, 2003; *Yonge*, 2004].[6] Climate change comparisons among modes have also been made [*Skjølsvik et al.*, 2000], but less clearly quantified for U.S. intermodal freight transportation. Current efforts by the U.S. Department of Transportation to investigate and promote short-sea shipping alternatives would benefit from additional focused study comparing the emissions of greenhouse gases and other pollutants among freight modes.

This study will create a decision tool that can assist in evaluating the economic, environmental, and congestion issues associated with alternative land-side and water-side freight transport routes.

2.2 Emissions Analysis and Network Optimization

2.2.1 Problem Statement

Emissions associated with transporting freight can be significant [*Energy Information Administration*, 1998; *OECD and Hecht*, 1997; *Skjølsvik et al.*, 2000]; in fact, U.S. EPA data suggests that heavy duty truck, rail, and water transport together account for more than 50% of CO_2 emissions, about 50% of recent NOx emissions and nearly 40% of the PM emissions from all mobile sources [*Environmental Protection Agency*, 2005a; *Environmental Protection Agency*, 2005b]. Figure 2 shows that recent trends suggest little change in modal contribution to CO_2; longer-term trends show increased NOx emissions until about 2002 (mostly from heavy duty trucks 2002), but significant PM2.5 reductions (mostly a result of heavy-duty trucking emission reductions). As emissions from these alternatives become more important in local pollution and GHG inventories, decision makers will need tools to compare alternative shipping modes, both separately and in combinations serving logistics supply chains. Unfortunately, not enough research has been done directly comparing alternative land-side and water-side shipping options. The PIs comparisons of land-side and water-side commuting alternatives in California and New

[4] See Geofreight information at http://www.fhwa.dot.gov/freightplanning/geofreight.htm
[5] Geofreight's "use intensity index" is a relative number useful for comparisons. Indices less than 1 signify low intensity. Indices above 2 signify high intensity. This may not reflect local intensity at bottlenecks at ports and other intermodal facilities.
[6] Also see U.S. DOT Maritime Administration, http://www.marad.dot.gov/Programs/shortseashipping.html.

York [*Farrell et al.*, 2002b] are among the recently emerging peer-reviewed tools that rigorously analyze the land-side v. water-side modal mix. This work develops the tools needed for the step from passenger transportation comparisons to multimodal freight comparisons that will significantly contribute to the policy analysis and research in this area.

In addition, we believe there are several criteria that should be addressed in the development of decision tools that can analyze water-side v. land-side alternatives. These criteria are:

(1) The tools should be user-friendly and available to a wide-audience. This implies tools and models built on popular software platforms, such as EXCEL.

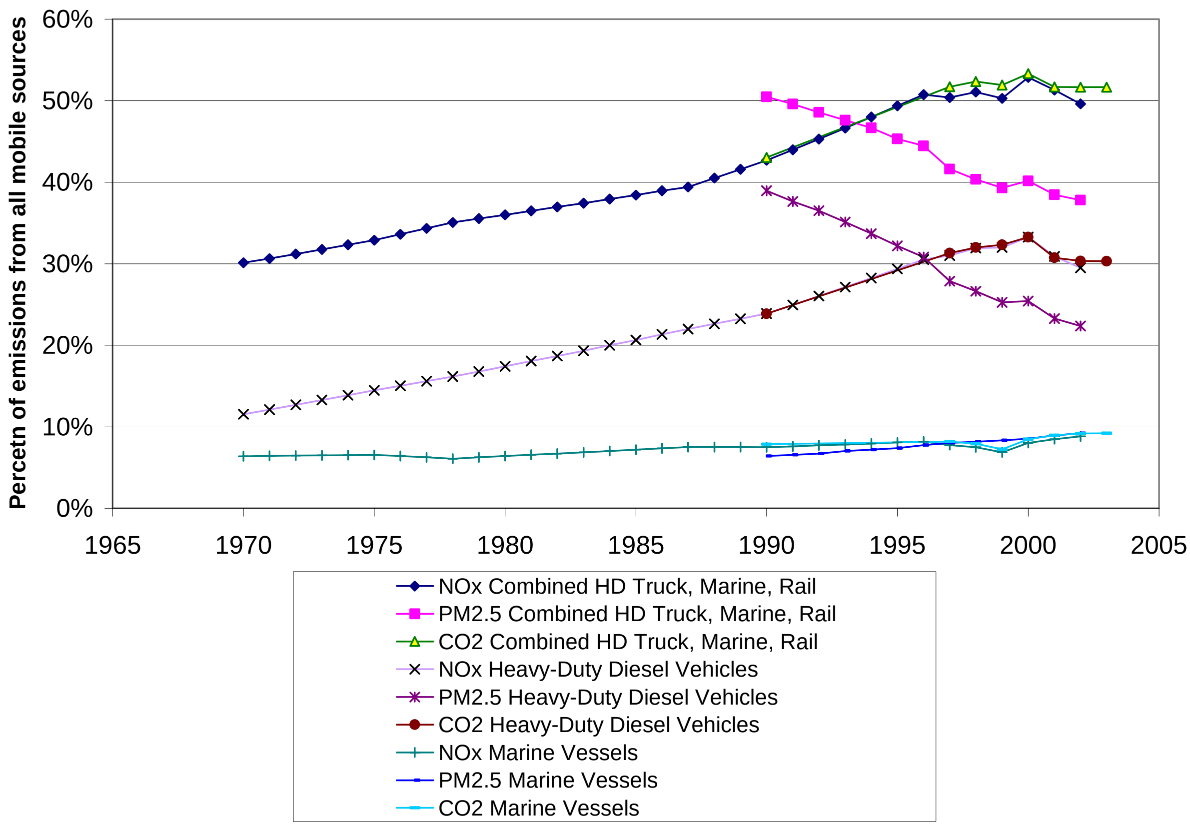


Figure 2. Emissions trends from multimodal freight modes as a percent of total mobile source emissions a) combined truck, marine, and rail; b) for heavy-duty diesel trucks; and c) for marine vessels [*Environmental Protection Agency*, 2005a; *Environmental Protection Agency*, 2005b].

(2) The tools should include *total fuel cycle emissions*. Total fuel-cycle analysis involves consideration of energy use and emissions from the extraction of feedstock (e.g., oil from the well) to the processing of that feedstock into fuel products, to the ultimate use of the fuel in operation. Although recognized as an important analytical approach, EPA (through its MOVES work) has only recently begun to incorporate TFC analyses for *light-duty vehicles* into its modeling

regimen.[7] This project team is currently completing work that will allow total fuel cycle analyses for marine transportation. Those results can be paired with land-side TFC analysis for this project, although some more extensive TFC will need to be conducted for heavy-duty vehicles and locomotives.

(3) The tools should help evaluate a rich array and diversity of decision questions. In particular, we believe analysis tools should include not only parametric analysis, but also ***optimization routines*** that allow decision makers to evaluate optimal decisions under various objectives and constraints.

In this project we propose to build a decision tool that meets all of the above criteria. A final outcome of our work will be a user-friendly EXCEL based model that uses optimization routines to assist decision makers in evaluating the environmental, economic, energy use, and temporal, and other tradeoffs associated with intermodal freight transportation. This work applies our interdisciplinary expertise in engineering, science, and public policy and our extensive prior experience in multimodal analyses of transportation, energy, environment and economics. Details about our research approach are in the next section.

2.2.2 Research Approach

The overall modeling approach demonstrated in Figure 3 and Table 1. We will develop a spreadsheet based model that will accept inputs information on freight and route data, characteristics of land-side and water-side short-sea shipping alternatives, and environmental data (total fuel-cycle emissions factors will be used). This information will be processed and sent through an optimization algorithm. All assumptions for the model will be clearly and explicitly identified in the spreadsheet (as well as a user-guide that accompanies the model). Users will be able to easily modify default assumptions.

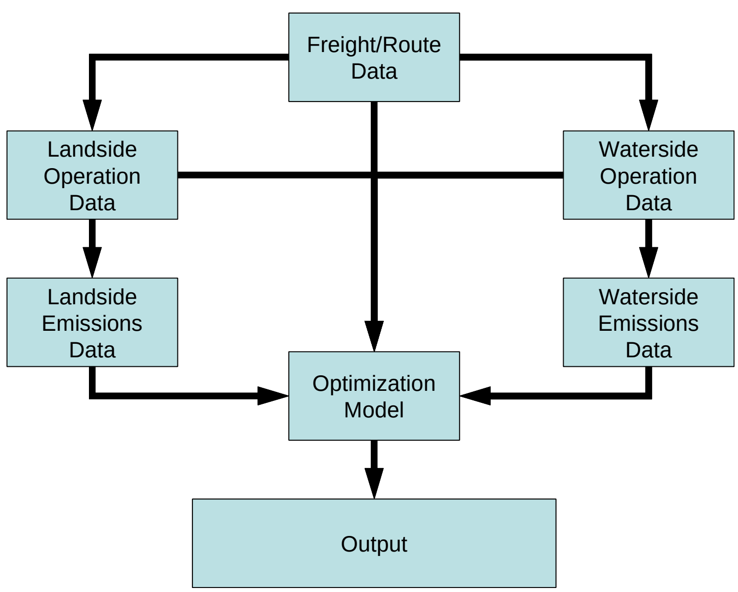


Figure 3. Schematic of the Model

[7] The total fuel cycle analysis approach promoted by EPA is reflected in Argonne National Lab's GREET model for light-duty vehicles.

Estimating emissions for different modal segments can use a common activity-based methodology, or depend upon modal emissions models uniquely developed for each mode. In our work, we propose a common multimodal model using default assumptions representative of current fleets, although the tool will allow users to specify modal inputs for activity, power, and emissions. The PI has used a similar approach without the additional benefits of optimization techniques and a total fuel cycle context for multimodal analyses of freight [*Corbett and Fischbeck*, in preparation 2005; *Skjølsvik et al.*, 2000]. This flexible approach will allow users to update inputs to the tool with their own information or to use insights from other mobile source models such as the federal EPA MOVES model, or California's EMFAC2002 model, both of which we have used in previous multimodal studies [*Farrell et al.*, 2002a; *Farrell et al.*, 2003; *WestStart-CALSTART et al.*, 2001; *Winebrake et al.*, 2005]. We are also familiar with literature that evaluates and produces necessary multimodal data [*Environmental Protection Agency*, 1997; *Sawyer et al.*, 2000; *Yanowitz et al.*, 1999; *Yanowitz et al.*, 2000], and with related modeling efforts in Europe, such as the Swedish Network for Transportation and the Environment (Nätverket för Transporter och Miljön, or NTM).[8]

Table 1. Description of the Model Inputs/Outputs

Freight/Route Data – involves data related to the type of freight, volume/weight considerations, and other characteristics of freight that help dictate the types of land-side or water-side technologies that can be used, as well as the route characteristics and requirements needed to move such freight.
Land-side Factors (Operations and Emissions) – involves data and analysis related to the movement of the freight on land, including mode, fuel type, emissions control technologies, and emissions factors (based on end-use and total fuel cycle emissions).
Water-side Factors (Operations and Emissions) – involves data and analysis related to the movement of the freight on water, particularly short-sea routes. This includes vessel type, fuel type, route characteristics, emissions control technologies, and emissions factors (based on end-use and total fuel cycle emissions)
Land-Side and Water-Side Optimization Model and Output – provides an optimization module that allows decision makers to identify optimal routes, modes, and technologies in order to move freight between two points. The optimization module will allow users to optimize modes/routes based on minimizing costs, minimizing emissions, or minimizing travel time. The results allow for comparative analysis of land-side v. water-side movement of freight under various assumptions, constraints, and optimization objectives.

The optimization aspect of the model is important, and for that reason we discuss it in more detail here. Through the optimization routine, we allow decision makers to consider water-side and land-side shipping alternatives under various objectives and constraints. This research builds on previous work related to travel optimization [*Xu et al.*, 2003a; *Xu et al.*, 2003b]; however, our work includes explicit environmental objectives that address greenhouse gas and pollutant reduction goals. We will model discrete freight volumes that may be transported by different multimodal combinations within an optimization framework that considers emissions,

[8] See http://www.ntm.a.se/

technologies, and costs. This extends optimization modeling for environmental and transportation goals, building on team expertise developed over several multimodal analyses [*Corbett and Chapman*, 2003; *Farrell et al.*, 2003; *Farrell et al.*, 2005; *Skjølsvik et al.*, 2000; *Winebrake et al.*, 2005].

2.2.3 Illustration of Modeling Context

Our proposed work can be illustrated through a simple example. Figure 4 shows a network of alternative pathways to move freight from point A to point B. Freight can move along pathways through each node (shown by the circles). Certain routes (represented by lines connecting the nodes) may be accessible only by truck, or ship, or rail. Some routes may be accessible by multiple modes. Nodes can be associated with metropolitan traffic characteristics, descriptive of congestion delays, engine load and emissions patterns that may differ from open freeway, long-haul rail, and/or intraport segments.

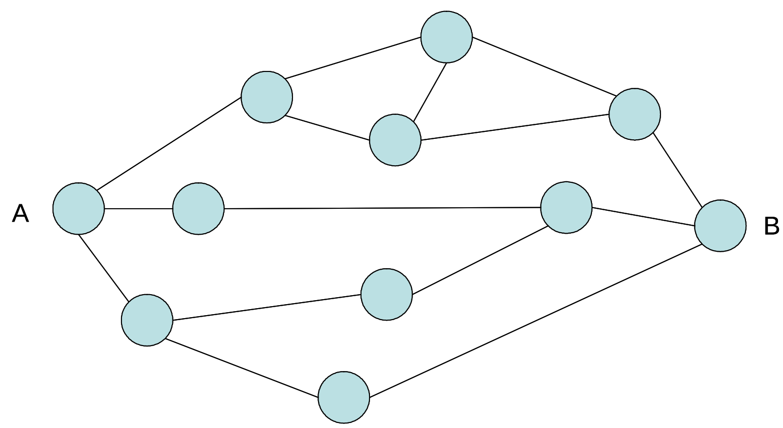


Figure 4. Network Nodes and Routes for Transporting Freight from "A" to "B"

The decision maker may wish to analyze alternative pathways from A to B under various assumptions, constraints, and objectives. For example, one may want to know what pathway leads to the *least cost* transport of freight from A to B, a traditional context for the application of optimization routines. To analyze this, each route from node *i* to node *j* must include a dataset that helps characterize that route. That dataset would include information about mode accessibility, costs, average speed, distance, emissions, among others. For a *least cost* example, we can set up a network optimization model of the form:

$$\min \sum_{ijk} C_{ijk} \cdot X_{ijk}$$

where C_{ijk} is the cost of moving freight from node *i* to node *j* using mode *k*; and X_{ij} is a binary variable that takes on a value of "1" if mode *k* is used to move freight from *i* to *j*, and "0" otherwise. (We have simplified this example for this proposal; we recognize that costs components would be calculated in the model based on variable, fixed, and other components that affect cost—formulating those cost functions will be part of the scope of work under this project). This model is controlled through constraints (not included here for brevity) that ensure that freight leaves A and gets to B. Other constraints (for example, not allowing certain modes to operate between certain nodes) would also be included in the model design.

In this work, we can model this network system with other optimization objectives. For example, the user may want to explore the pathway (again, characterized by routes and modes) that minimizes emissions of greenhouse gases (or other pollutants). The user then would use a model with the following objective:

$$\min \sum_{ijk} E_{ijk} \cdot X_{ijk}$$

Where now E_{ijk} is the emissions associated with moving freight from node *i* to node *j* using mode *k*. (Again, for simplicity we don't show all the equations associated with calculating the emissions; but they will be calculated within the model based on emissions factors and other variables).

Other objectives that our model will allow are energy consumption and travel time. The beauty of the model is that it will allow users to choose among traditional objectives of cost and time or environmental and energy objectives—that is, there will be a user-friendly interface that will easily allow the user to select different objectives and compare results. This aspect of our research extends significantly beyond prior multimodal analyses and case studies that are primarily descriptive [*Corbett and Fischbeck*, in preparation 2005; *OECD and Hecht*, 1997; *Schipper and Marie-Lilliu*, 1999; *Schipper et al.*, 1997; *Skjølsvik et al.*, 2000].

One could use the model for numerous types of decision analysis. For example, the user could simply use it to identify optimal routes to meet a particular objective under varying constraints and assumptions. Users could also use it to explore tradeoff curves, an example of which is shown in Figure 5. This curve demonstrates the tradeoff between costs and GHG emissions. Along the curve are representative "optimal solutions"; these solutions correspond to a particular pathway (routes, mode, technologies) for moving freight from A to B. We anticipate building into the model a routine that will develop automatically output tradeoff curves for two objectives. Finally, users can explore the impact of alternative technologies on identical routes—e.g., one could run one route analysis using diesel fuel and then run the identical route using biodiesel to compare emissions impacts.

This makes the tool useful for evaluating/forecasting the performance of alternative mitigation measures, and by including TFC detail the insights comparing onboard technologies with fuel-based options may be particularly useful to policy makers. All this will be captured in a decision tool that can be used in MS Excel to maximize potential use. We will demonstrate the model and its many uses through a case study; we anticipate using data for the I-95 corridor, because it has been the subject of recent study vis-à-vis shortsea shipping, which suggests the data may be current and available. Our model can define specific metropolitan traffic characteristics along route segments, using average comparative values available from existing sources (e.g., data for the EPA MOVES model). To demonstrate how the modeling tool may be used, we will adopt available data related to modal cost comparisons, emissions rates, and travel time. Users will be able to modify cost and other inputs with data specific to their needs.

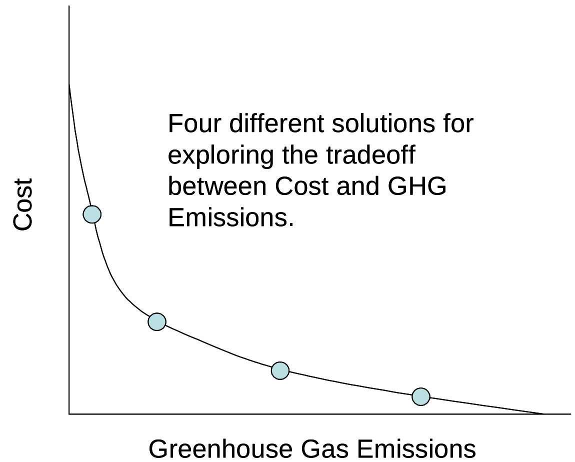


Figure 5. Exploring Tradeoffs for Different Objectives

2.3 Importance of Project

This project advances the knowledge available to policy makers and analysts by integrating environmental elements with other important freight logistics objectives, such as time and cost. The results of our project will provide decision makers an integrated spreadsheet tool to evaluate multiple freight modes, alternative route logistics, and possible control technologies to mitigate emissions impacts of moving freight from source to destination. The model can be used to quantify where improved environmental performance may be necessary to facilitate the mode combinations that minimize emissions of greenhouse gases and pollution at least cost.

This research develops the integrated tools to evaluate where marine mode contributes best to improved environmental performance in domestic (and international) multimodal freight transportation. This transitional research bridges the gap between current single mode comparisons and emerging detailed analysis of logistics alternatives to achieve emissions reductions in an optimization framework, as we have done for passenger ferries [*Winebrake et al.*, 2005].

The final deliverables of this project will be extremely helpful to policy makers, planners, federal agencies, states, and the private sector. The model will

1. Compare greenhouse gases and criteria pollutant emissions among freight modes.
2. Allow optimization analysis of multi-modal logistics chains with various decision objectives (e.g., minimize emissions, cost, and/or travel time).
3. Estimate in-use and total fuel cycle emissions.
4. Incorporate into the optimization analysis a limited number of mitigation technologies, including emission control and alternative fuels.
5. Provide an avenue for integrating some of the modeling modules developed here into the EPA MOVES work.

In addition, the case study will

1. Apply the model to likely cargoes that may be shipped in a short-sea context.
2. Produce a baseline comparison of different logistic chains (e.g., “bulk” cargo v. containerized cargo).

3. Compare typical costs for alternative logistics (e.g., short-sea) and/or mitigating technologies.
4. Provide a clear example on how EPA may use this work to integrate marine TFC emissions into their MOVES program.

2.4 Longer Term Goals and Plans for Future Work

The long term goal of this project is to develop a modeling tool that will be used by decision-makers in evaluating land-side v. water-side transportation alternatives under various decision objectives. Our goal is to develop a tool that can be fully integrated into much of the current and expected modeling activities of EPA, DOT, and DOE. We also can see our model being incorporated into state and local government decision-making. Future work could involve conducting a set of case studies that apply the model for important US and international transportation routes, technologies, and logistics.

We have spent the past several years conducting analyses that compare and investigate modal trade-offs, as part of a larger research community effort to understand the energy and environmental impacts of freight transportation. Decision maker can access information currently only through summary reports of specific case-studies, or by asking modelers to rerun their complex models under alternative assumptions. Our goals for this work include providing an accessible spreadsheet platform that can be more directly used by decision makers at agencies like DOT to get a clear sense of the potential for multimodal tradeoffs when considering environmental performance in different context. The value of this tool can be analogous to other widely used spreadsheet tools such as GREET, and may help inform emerging multimodal models for use by researchers and policy makers.

Our own plans for future work will include this model, as we work to illustrate, evaluate, and recommend feasible alternatives to improve the multimodal freight system, especially where inclusion of nonroad elements may assist in sustainable transportation for the nation. We would also work to make this model more compatible with spatial depictions of routes so that it could better complement GIS techniques.

3 Detailed Statement of Work

3.1 Period of Performance

Phase I of this project (data collection, model development, and testing) will be complete one year after time of award. Phase II of the project (case study evaluation, reporting) will be complete within 18 months of the time of award.

3.2 Tasks and Milestones

Tasks include data collection for both model and case-study efforts (Tasks 1 and 4); these tasks are related and will be focused on gathering representative data that may suggest default model values, and specific regional data for the case study assumptions. Tasks 2 and 3 will develop the model and necessary documentation to describe it for prospective users. Tasks 5 and 6 will produce the case study and related documentation of assumptions, results, and sensitivity analysis. A milestone and task effort chart is below:

Milestone Chart of Tasks

Task	***End (after TOA)***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***
1. Collect data for model	6 months																		
2. Program and test model performance	10 months																		
3. Provide model and report (***milestone***)	12 months												**X**						
4. Collect data for case study	13 months																		
5. Conduct case study analysis	16 months																		
6. Provide report on case study (***milestone***)	18 months																		**X**

*TOA = Time of Award

3.3 Deliverables

The primary deliverable on this project is a model or set of models that can be used by decision makers to conduct a comparative analysis of land-side v. water-side short-sea shipping alternatives for moving freight. Secondary deliverables include a report that describes the model and the types of analyses that can be conducted by the model; a report that applies the model to a case study of the I-95 corridor (or alternative proposed by DOT); and, a presentation on the use of the model for transportation planners (anticipated to coincide with a conference presentation at an upcoming Transportation Research Board Annual Meeting).

3.4 Costs

The total DOT cost for this project is $155,441 over eighteen months. The cost for Year 1 (months 1-12) is $105,175; the cost for the next six months (12-18) is $50,266. In addition, we have provided $35,984 in cost-shared contributions. With cost-share, the value of this project is $191,425.

The project budget changed in response to valuable comments from the pre-proposal review. Funds requested from DOT increased approximately 11% to cover additional model functionality related to optimization and uncertainty and to consider potential routing and/or fleet changes caused by modal shifts. This increased effort related to both model development and case-study application. In response, we increased our leveraged cost-share support by about 44%, through tuition assistance for graduate research assistants. A task-based breakdown is shown in Table 2.

Table 2. Budget Allocation by Task

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Total	Cost Share
RIT Budget	$15,702	$16,537	$12,657	$4,477	$4,477	$5,970	**$59,820**	$12,500
UD Budget	$21,082	$22,203	$16,994	$10,603	$10,603	$14,136	**$95,621**	$23,484
TOTAL Budget	$36,784	$38,740	$29,651	$15,080	$15,080	$20,106	**$155,441**	$35,984

3.4.1 Budget Justification

Principal Investigator salary and associated fringe costs:

Funds are requested for the Principle Investigator James Corbett to cover 1 month of University of Delaware salary in year one and 0.5 months of salary in year two. Associated fringe benefits are calculated for the principal investigator at the approved University of Delaware's faculty/professional rate of 30%.

Graduate Research Assistantship costs:

Funds are requested to support a research assistant stipend at the University of Delaware for 9 months in year one and for 6 months in year two. Associated fringe benefits are calculated for the principal investigator at the approved University of Delaware's rate of 3%.

Travel:

Travel costs for both University of Delaware (UD) and Rochester Institute of Technology (RIT) are covered out of UD budgets to keep indirect costs down. Funds requested include transportation for the Co-PIs and one student (standard mileage and tolls, rail fare, economy airfare, and meals) from our institutions (University of Delaware and Rochester Institute of Technology) to Washington, D.C. associated with two one-day meetings at DOT headquarters in year one, and travel expense (standard mileage and tolls, rail fare, economy airfare, lodging and meals) for one meeting associated with the Transportation Research Board Annual Meeting in January. Based on actual travel costs to meet with DOT staff for a current research project (Contract #DTRS56-04-P-70123), we have budgeted $1400 for two meetings during year one. A budget of $5500 is associated with the January 2007 meeting with DOT staff, to include attendance (and likely presentation) at TRB during the second six months.

Materials and Supplies:

Funds are requested to cover expendable equipment and supplies, including copying, telephone, and other materials including necessary upgrades to standard software. The budgeted amount of $1000 is consistent with past expenses for project of similar size and scope.

Subcontract:

We are subcontracting participation with Rochester Institute of Technology (RIT) to support collaboration with co-investigators. RIT funds will support 1.5 months of salary and fringe for Professor James Winebrake, stipend and half tuition for a research assistant, and associated fringe and indirect charges. Professor Alex Farrell's time and expenses will be paid from the RIT subcontract through a direct consulting agreement.

Indirect costs:

These costs represent the latest University of Delaware's Facilities and Administrative Cost and Fringe Benefit Rates agreement. University of Delaware indirect costs are assigned only to the first $25,000 of subcontracts.

4 Description of Past Performance

4.1 Lead and Contributing Authors

This project will be carried out by a team of experts in the energy, environmental, and marine transportation fields. They are: Dr. James J. Corbett (University of Delaware); Dr. James J. Winebrake (Rochester Institute of Technology); and Dr. Alex E. Farrell (University of California—Berkeley). The team lead for the project is Dr. Corbett. More on each team member is found below.

Dr. Corbett is an Assistant Professor in the Marine Policy Program of the College of Marine Studies. His research has focused on transportation and environment, specifically air emissions from maritime transport and an engineering assessment of technological control strategies. The work includes both theoretical and empirical research areas, which inform important decisions in environmental, maritime, and technology policy. He is a coauthor of the 2000 IMO Study on Greenhouse Gases from Ships. Dr. Corbett is a licensed professional engineer who holds a B.S. in Marine Engineering from the California Maritime Academy, M.S. degrees in Mechanical Engineering and in Engineering and Public Policy, and a Ph.D. in Engineering and Public Policy from Carnegie Mellon University. He is currently developing multimodal models of freight transportation that are used by industry to consider greenhouse gas and air pollution impacts of logistics alternatives [*Corbett and Fischbeck*, 2004].

Dr. Winebrake is currently Professor and Chair of the STS/Public Policy Department at RIT and Director of the Center for Energy Analysis. He publishes in the area of technology policy generally, and environmental and transportation policy more specifically. Dr. Winebrake worked closely with researchers at Argonne National Lab in the development GREET-TOX, which was the first total fuel cycle model to include air toxics for alternative fuel vehicles (see section 5 for publications related to this work). He is also the lead-PI (working with Drs. Corbett and Farrell) for the DOT project to develop a total fuel cycle analysis model for marine transportation. Dr. Winebrake holds a B.S. in Physics from Lafayette College, a M.S. in Technology and Policy from M.I.T., and a Ph.D. in Energy Management and Policy from the University of Pennsylvania.

Dr. Farrell is an Assistant Professor in the Energy Resources Group at the University of California, Berkeley. Dr. Farrell's research is on energy and environmental technology, economics, and policy. More specifically, he is interested in the use of technical (i.e. scientific and engineering) information in policy-making, the environmental impacts of energy, security in energy systems, and alternative transportation fuels. Dr. Farrell has a B.S. in Systems Engineering from the U.S. Naval Academy and a Ph.D. in Energy Management and Policy from the University of Pennsylvania. His prior experience has been with Carnegie Mellon University, Harvard University, the American Association for the Advancement of Science, Air Products and Chemicals, and the U.S. Navy.

4.2 Demonstration of successful completion of past work

Our team is currently engaged is a number of other research projects, one funded by the Deparment of Transportation (Principal Investigator Professor James Winebrake). That work under Contract #DTRS56-04-P-70123 entitled *Total Fuel Cycle Emissions for Marine Transportation: Development of a "Well-to-Hull" Modeling Tool*, is on schedule. We presented a draft version of the model at a meeting at DOT on March 29, 2005. Throughout April we have modified the model to incorporate auxiliary engines. This has been successful, and users can now run the model with one type of fuel being used for main engines (e.g., biodiesel) and another type for auxiliary engines (e.g., conventional diesel). We also improved some of the default data values and the results section of the model. We are now undergoing model validation, which should be complete by mid-May. Case study analyses for that project will commence at that time.

The team worked on a project that produced a WestStart report funded by the DOT Global Climte Change Task Force, Brookhaven National Laboratory and The Gas Technology Institute.[9] Professors Corbett and Winebrake worked on a project funded by the Federal Transit Administration (FTA) to evaluate public-private incentives to reduce emissions from regional ferries that resulted in several deliverables and significant coordination with related FTA projects; while only recently completed, this work already has yielded a journal publication [Winebrake, 2005 #988].

[9] http://www.marad.dot.gov/nmrec/energy_technologies/images/Final%20Report%202.pdf

Professor James Corbett (PI for this proposal) has conducted several projects on behalf of DOT through subcontracts. He produced a Vessel Operator Engine Emissions Measurement Guide for the Maritime Administration (MARAD) and coauthored a conference paper with MARAD staff.[10] He also produced a report to assist with technology evaluation for marine engine control technologies.[11]

In addition to project deliverables within the scope of our funded research, work products are generally substantial and important enough to publish in peer-reviewed archival literature and to present at various conferences, including national and international meetings sponsored or attended by DOT. The list of articles below is only a sampling of those that pertain directly to the work proposed here.

1. Wang, C., and J.J. Corbett, Geographical Characterization of Ship Traffic and Emissions, *Transportation Research Record*, *in press*, 2005.
2. Corbett, J.J. and P.S. Fischbeck, *A Supply Chain Emissions Model (SCEM) For Evaluating Freight Logistics.* Journal of Environmental Management, *in preparation*, 2005.
3. Winebrake, J.J., et al., *Optimizing Emissions Reductions for Passenger Ferries in the New York-New Jersey Harbor.* Journal of Air and Waste Management, 2005. **55**(4): p. 458–466.
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[10] http://www.marad.dot.gov/nmrec/energy_technologies/images/Final%20Report%207.pdf
[11] http://www.marad.dot.gov/nmrec/energy_technologies/images/Decision%20Framework%20for%20Technology%20Selection.pdf

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